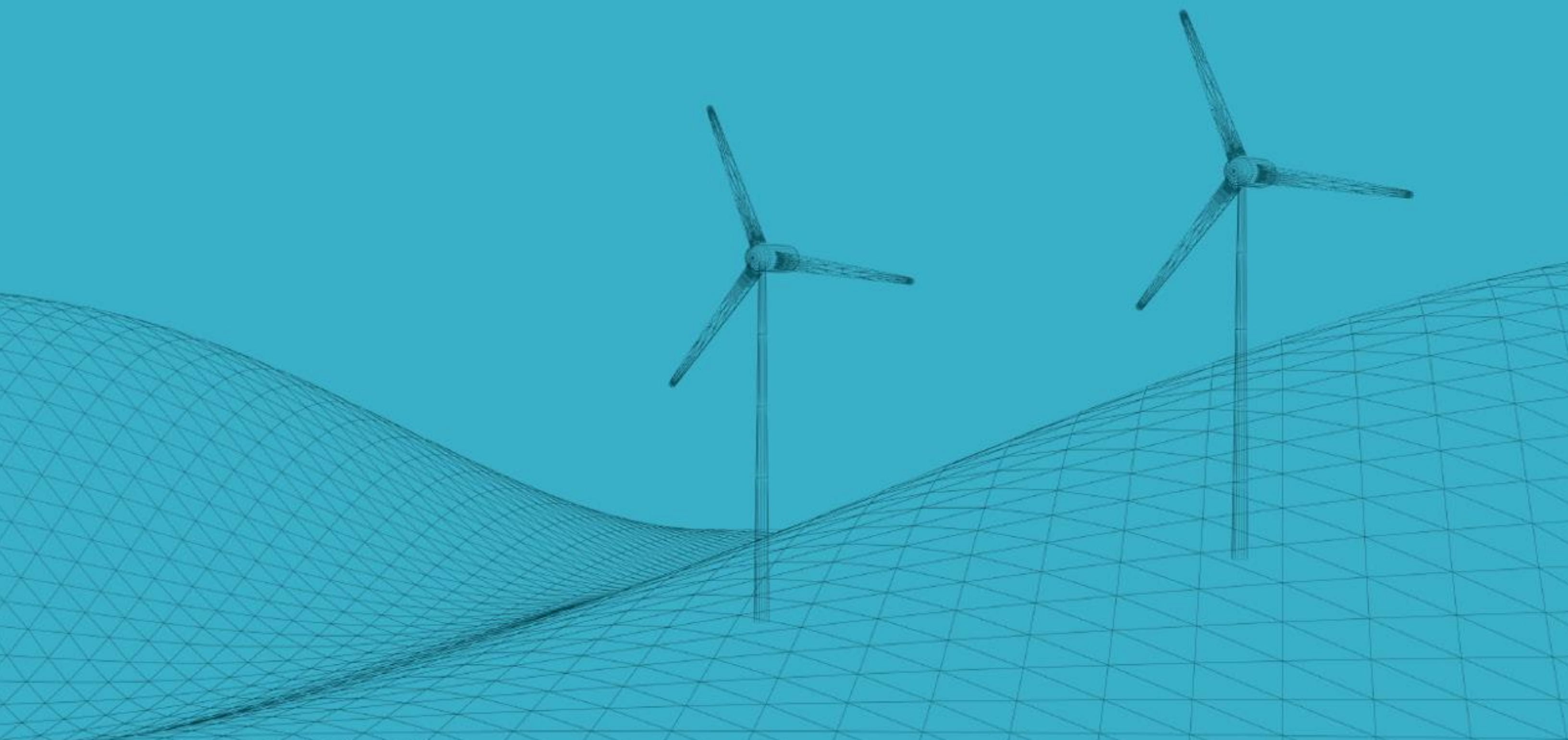
COLLEGIATE
WIND COMPETITION
U.S. DEPARTMENT OF ENERGY



U.S. Department of Energy 2017 Collegiate Wind Competition

TECHNICAL CHALLENGE

Revision 1: 10/13/2016

Preface

The U.S. Department of Energy 2017 Collegiate Wind Competition Technical Challenge will be governed and adjudicated by this rules and requirements manual, which is intended to establish fair contest rules. The organizers reserve the right to change contest criteria, rules, and measurable outcomes as needed. In the case of a discrepancy between information in this manual and any other material related to the contest, the information in the most recent version of this manual will take precedence.

In addition, we encourage the teams to bring to our attention rules that are unclear, misguided, or in need of improvement. We will seriously consider suggestions that are feasible and within our constraints and are intended to improve the competition, its rules, measurable outcomes, fairness, and precision.

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Revision History

This document is the original version for the 2017 event. If revised, revisions will be detailed in this section.

- Version 1: Original document issued 10/13/2016.

1 Background

The United States will have more than 75 gigawatts of wind installed by the beginning of 2017, enough to power 20 million homes. The Department of Energy's *Wind Vision* report says wind generation could double by 2020 and double again by 2030.[1] As more wind energy is incorporated into the United States' power generation mix, qualified workers are needed to fill related jobs at all levels.

To help facilitate this process, the U.S. Department of Energy (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 directly aligns with DOE's overall goals: to catalyze the timely, material, and efficient transformation of the nation's energy system, secure the United States' leadership in clean energy technologies, and maintain a vibrant domestic effort in science and engineering as a cornerstone of economic prosperity. Specifically, its 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, business and sales forces, and many others. Wind-energy-specific advanced degrees are not required for many of these jobs, but having wind-related experience is considered to be highly valuable.

[1] Source: http://www.energy.gov/eere/wind/maps/wind-vision; accessed 9/20/16.

2 General

2.1 Overview

The 2017 Collegiate Wind Competition Technical Challenge is an opportunity for the 12 institutions that participated in the May 2016 Collegiate Wind Competition to capture the spirit of team collaboration and apply the acquired skills and knowledge to the 2017 challenge. Additionally, while structured as a competition, this event will include an emphasis on wind energy education for all teams and information sharing for prospective teams.

The competition challenges interdisciplinary teams of undergraduate students from a variety of academic programs to offer unique solutions to complex wind-energy-related problems. To fulfill the requirements, each team must perform the following multifaceted tasks:

- Design, build, and present a unique, wind-driven power system
- Document the design of the turbine and load in a technical report
- Present on the design and report to a panel of judges
- Participate in a bonus, educationally focused siting challenge.

The 2017 Collegiate Wind Competition Technical Challenge focuses on testing a small-scale wind turbine in a wind tunnel. This year's competition adds the challenge of testing a turbine in yawed inflow. It simplifies the contest from the 2016 competition by removing the link to a market turbine and eliminates the business plan and deployment strategy. Specifically, for testing in the wind tunnel, competition participants will need to design and build:

- A turbine that is able to yaw, to address changing wind directions; that is safe, reliable, and effective; using sound electrical, mechanical, and aerodynamic practices
- A load system that can match the power being generated. Students are encouraged, but not required, to make the load visually stimulating by indicating the power being generated in an interesting and creative way.

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

2.2 Roles and Responsibilities

Table 1 describes the competition roles, who performs each role, and what the role entails.

Table 1. Roles and Responsibilities

Role	Individual 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/advisors. There is no limit to team size. However, the number of students that teams may bring to competition may be limited based on space requirements. Interdisciplinary teams are encouraged in the following areas of study: engineering, business, marketing, 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 also 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 primary contacts for the team but, in this case, one 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 Google Group that is discussed later in this manual) during the event.
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 Managers	Maggie Yancey, DOE Amber Passmore, DOE	Represents the U.S. Department of Energy and has the final decision-making authority in all aspects of the competition.

Role	Individual Assigned	Definition
Competition Operations Manager and Operational Point of Contact	Elise DeGeorge, NREL	Leads correspondence with the collegiate teams regarding contracts, contest questions, and team expectations. During the competition event, the Operations Manager is the primary point of contact for questions related to engagement with the judges, logistics, individual competition contests, and protocol. Tasks include, but are not limited to, developing team schedules and coordinating/collating scores and team feedback from the contests in time for the awards ceremony; and supporting the testing team, collegiate teams, judges, Competition Manager, and Head Rules Official. Reports to the Competition Managers.
Competition Safety Point of Contact	Ian Baring-Gould, NREL	Point of contact for questions or issues related to safety.
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 as to the wording or intent of these rules, the decision of the Rules Panel shall prevail.
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 of whether a turbine can be tested or not in the tunnel due to safety concerns.
Communications and Outreach Point of Contact	Kelly Yaker, NREL	Coordinates all aspects of media representation, website management, publications, signage and outreach.
Additional Organizers	Mike Arquin, KidWind Lee Jay Fingersh, NREL Heidi Tinnesand, NREL Suzanne Tegen, NREL	Perform 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 prior to the competition	Conduct and evaluate each individual contest at the competition.

2.3 Safety and Conduct

The competition is a forum for students with an interest in wind energy to showcase their innovative ideas and demonstrate their knowledge of the wind industry. The event is designed to be safe, fair, and competitive as well as a fun learning experience and a professional growth opportunity. Each team is responsible for the safety of its operations in accordance with the requirements identified in their contract with NREL (subcontract agreement). Each team member shall work in a safe manner at all times during the competition. Participants are expected to conduct themselves in the spirit of the competition by being team players—within their own teams and with competitor teams. DOE and NREL maintain a professional and safety-focused culture. Participants are expected to conduct themselves in a way that is consistent with that culture regarding every aspect of the competition. NREL also maintains a drug-, alcohol-, and firearms-free campus.

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. Competition organizers will provide hard hats. Teams are expected to bring the following appropriate protective equipment for use during wind tunnel testing and other potentially hazardous activities at the competition:

- Safety glasses
- Electrical personal protective equipment, if electrical voltage demands it
- Hearing protection for use in areas that are in close proximity to the wind tunnel during operation
- Steel-toed boots, if expecting to handle heavy loads.

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.

There will be standard 110 volts of alternating current (VAC) electrical outlets available in the bullpen area to allow students to operate tools, test equipment, or use computers.

As part of DOE 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, re-using packaging materials that were used in transporting items to the competition, and eliminating the use of nonrecyclable 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 in this regard is encouraged.

Student participants will be required to sign a code of conduct prior to participating in the event.

2.4 Dispute Resolution

All disputes must be submitted to the Competition Operations Manager in writing and include the name and signature of the collegiate team PI, the date of the protest submission, and a clear description of the action being protested. Once submitted, the Competition Manager will meet with the Head Rules Official to determine whether a dispute is considered minor or major. The Head Rules Official will then make a determination in consultation with competition staff. The Head Rules Official is the only person who can make a final ruling.

Major disputes will be discussed with at least three judges and/or competition organizers who will gather appropriate information through interviews or other means. A final ruling will be issued by the Head Rules Official. 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. Minor rule decisions during the competition event will be made jointly by at least two judges.

After the Head Rules Official makes a decision that may directly or indirectly affect the strategies of some or all of the teams, he will record the decision on the Google Group site (discussed further in Appendix C).

In all cases, the Head Rules Official has the final say in disputes.

3 Competition, Contests, Products, and Awards

The 2017 Collegiate Wind Competition Technical Challenge includes the subcontract project agreement between the competitively selected collegiate teams and NREL as well as the contests, products, and event.

Teams compete in two contests and an unscored bonus challenge. Products receive points toward winning a contest. An overview of which product contributes to the scoring of each of the contests is detailed in Table 2. The amount of points a product contributes to the overall score is covered in Appendix B.

Table 2. Contests and Products Overview

	Products			
Competition Contests	**Written Report**	**Public Presentation**	**Turbine**	**Load System**
Technical Design	✓	✓	-	-
Turbine Testing	-	-	✓	✓
Bonus Siting Challenge	-	-	-	-

This manual includes product descriptions and contest descriptions. Products include the written report, on-site oral presentation, and the wind turbine and load system for testing. The bonus challenge does not contribute to the teams' overall score, but provides the teams with an opportunity to learn about the unique challenges of siting wind turbines in a fun way.

While teams work on these products, principal investigators, co-principal investigators, supporting faculty, 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 certification of concept.

Awards will be provided for, but not necessarily be limited to, the following:

- Overall winner: the team that earns the highest combined score
- Second-place winner: the team that earns the second-highest combined score
- Third-place winner: the team that earns the third-highest combined score
- Technical design contest winner: the team that earns the highest combined score from the written report and presentation
- Turbine testing contest winner: the team that earns the highest combined score from all of the tunnel testing tasks
- Bonus challenge winner: the team that earns the highest score on the bonus challenge criteria.

Refer to each product section and Appendix D for specific deadlines and format requirements. Information on penalties can be found in Appendix B. Teams are encouraged to allow time for technical difficulties or unforeseen circumstances and submit early. See Appendix D for more information on submission.

Judges will review the written report ahead of time then refine their reviews as the products are presented at competition. At the competition venue, judges will verify that the wind turbine is accurately represented in the report.

4 Turbine and Load Design Requirements

Each turbine prototype must be designed for testing inside the Collegiate Wind Competition wind tunnel, described in detail on the website. 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. A safety inspection of the wind turbine and load system will be performed by the judges and must be passed before the wind turbine and load system are installed in the wind tunnel. The Turbine Safety Official will make the final and official determination about whether a turbine may be tested in the wind tunnel.

For the testing contest:

- The turbine must be designed to withstand continuous winds of up to 18 meters per second (m/s).
- The minimum turbine output must be 10 watts (W) continuous for at least one wind speed from 5 to 11 m/s.
- New for this year, the tunnel base flange, where the turbine mounts, will be subjected to yaw rates of up to 180° per second with a maximum of 2 full rotations from the initially installed position.

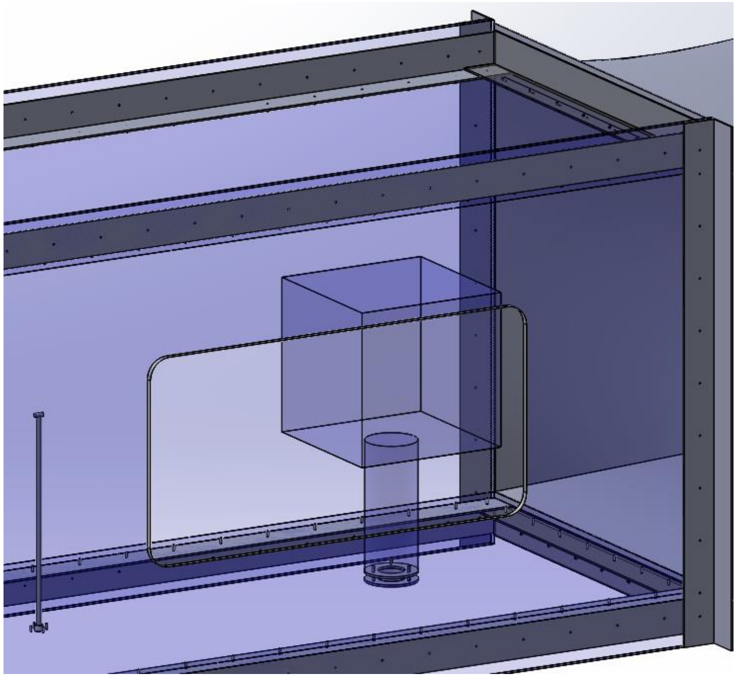

Figure 1. Allowable turbine volume

- For turbine sizing, the entire turbine must fit within the volume specified below and shown in Figure 1.
  - A 45 cm x 45 cm x 45 cm cube centered horizontally on the flange axis and vertically centered within 2.54 cm of the longitudinal center line of the wind tunnel can contain both rotor and non-rotor turbine parts.
  - New for this year, a 15 cm diameter cylinder around the vertical centerline of 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.
  - Other electronic components may also be located outside the tunnel. Within practical limits, there is no size restriction for these components.
  - All turbines must fit through the turbine door in one assembly with no additional assembly occurring inside the tunnel other than attachment to the base flange and connection to external electrical components.

- The wind turbine system must be mountable on the test stand at the specified location within the wind tunnel:
  - The turbine base plate must be constructed of material no thicker than a half inch to fit the tunnel base flange and to fit over three ¼-inch diameter studs where it will be secured to the tunnel base flange with nuts. Refer to the tunnel specifications on the website for the bolt pattern and sizing of this flange.
  - New for this year, the tunnel base flange incorporates a turntable to generate yawed flow. The flange height, stud pattern, and external dimensions will be identical to previous years and have a 3.5 cm diameter vertical hole through the center.
  - Teams are free to apply their engineering judgment to their own base plate design, keeping in mind that the turbine base must be designed with adequate tolerances such that it can be attached safely to the base flange in the wind tunnel and be able to withstand the tension of the mounting studs when torqued to approximately 10 Newton-meters (N-m).
  - The turbine base plate will 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.

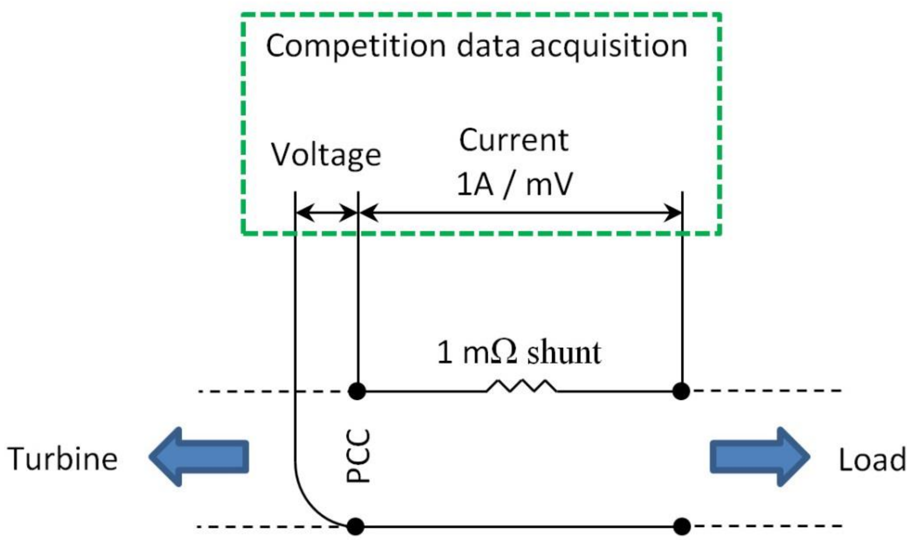

Figure 2. Load, turbine, and point of common coupling arrangement

- Wires should exit the tunnel at the turbine base through the center of the turntable. From this point, each team must provide a length of wire approximately 1 meter in length to reach the point of common coupling (PCC) on the judge's side of the tunnel where they will join with the load connectors from the team-provided loading system. This connection will be split and the competition instrumentation will be inserted at this point (Figure 2). A table will be provided to display the load on the opposite side of the tunnel from the judges and the PCC. Teams should provide adequate lengths of wire to run from the PCC to the load to accommodate their desired load display arrangement on the table.

- Voltage must be direct current (DC) at the PCC and is required to be at or below 48 volts of direct current (VDC). 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.
    - Additionally, for the turbine side of the PCC:
        - No batteries of any type or excessively large capacitors[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.
        - Verification of zero energy at the start of the test will be accomplished by the use of 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 through the use of a multimeter or similar before the testing begins.
        - Teams must show that all components utilized to control the turbine reside on the turbine side of the PCC. During the safety inspection, students must adequately demonstrate to the judges through verbal explanation, wiring diagrams, software architecture, and similar tools that the load is not controlling the turbine. Teams must show that any connection external of the PCC, either wired or wireless, is being used for monitoring or logging only—not active command and control. Wired connections between the turbine and load external of the PCC are allowed, but must be optically isolated.
    - For the load side of the PCC:
        - Bulk energy storage is allowed provided it is utilized in a safe and reliable manner
        - 120 VAC will be provided to run the load, if desired.
- 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). Teams are expected to provide their own Powerpole connectors of appropriate size: 15A, 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.

[2] No single capacitor (or electrical combination thereof) can have a storage capability of greater than 1 Joule, calculated as $^{1}/_{2}CV^{2}$, where C is capacitance in farads and V is the rated voltage of the capacitor.

- Turbines must be capable of shutting down on command as well as when electrically disconnected from the load. During the contest:
    - The judges will initiate an electrical shutdown by disconnecting the load connection to the PCC.
    - Manual shutdown will be triggered by a competition-provided, normally closed switch that is typical of industrial emergency stop circuits and will be located outside the tunnel. Judges will initiate a manual shutdown by depressing the switch and opening the circuit. To connect to this circuit:
        - Each team must provide two wires (22–28 AWG) that are at least 2 meters in length exiting the tunnel at the base flange to reach this switch. These wires should be terminated, prior to the competition, with a standard JST RCY female receptacle housing (Manuf. P/N: SYR-02T housing using SYM-001T-P0.6(N) for the corresponding male pin contacts).[3]
        - 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).[3]

5 Written Report

Each team must compile a single written report covering the technical design. The report is due on April 5, 2017, by 11:59 p.m. Mountain Daylight Time.

The following format requirements apply to the written report:

- Length must not exceed 25 pages (single-sided, including the cover and appendices). The paper should be 8.5 x 11 inches, paginated, and with 1-inch margins. Content should be single-spaced, using 11-point Calibri font. Reports not formatted to these requirements will be returned within 24 hours and late penalties applied (see Appendix B). Any pages beyond the page limit will not be reviewed.
- Captions for figures and tables must be numbered for easy navigation.
- The final document must be packaged into a single PDF file (see Appendix D) with bookmarks created using the document's table of contents.

[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.

The written report is the primary means for a team to provide detailed information about its project to the judges, given that the judges have a limited opportunity at the competition event to evaluate the wind turbine design specifications. Cohesiveness of the report will be evaluated in the final score. The report must include the following sections (at a minimum):

- Cover sheet
- Table of contents
- Executive summary
- Technical design.

5.1 Cover and Executive Summary

Teams should begin the report with a one-page cover page that includes their affiliation and contact information. Provide the names, roles, and majors of primary team members and PIs. Also include approximately how many additional students, faculty, and others (e.g., sponsors, volunteers, and family members) are involved in the project.

The executive summary discusses components from all sections of the report and includes a short description of the team project. The information in the executive summary is important to many communications-related aspects of the competition and should:

- Provide essential content for the organizers to use while developing various event materials (e.g., the website, event program, media kit, and signage)
- Prepare teams to answer questions from visitors at the competition event
- Help organizers and teams respond effectively to media inquiries.

The executive summary must not exceed three pages (including figures). It is recommended to write this section last to best capture the distinct and unique factors of the written report.

5.2 Technical Design

The technical design section of the written report explains the turbine concept development process from an engineering perspective. Teams are encouraged to detail their entire design process here as they see fit. However, the technical design section of the written report must provide detail that is adequate enough 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
- A description and analysis of the turbine's yaw system

- An analysis of the expected mechanical loads and associated safety factors within the design
- An electrical analysis comprised of the generator model, power electronics (e.g., canonical model), electrical load model, and operating voltage
- 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
- Results of laboratory and/or field testing of turbine prototypes
- Engineering diagrams with at least a basic mechanical drawing of all components and an electrical one-line diagram.

6 Public Presentation

In addition to the written report, each team will present its technical design to a panel of judges via a live, oral evaluation in a public forum. This presentation should convey the most important details of the technical design and overall approach. It is highly recommended that the team's presentation participants represent the interdisciplinary nature of the teams.

Presentations are limited to 15 minutes, followed by 5 minutes of questioning from the audience. Students will then have 10 minutes to interact with the judges in a private setting to answer questions from the judges and get feedback on their work. Presenters should showcase their turbine prototype and may use posters, charts, PowerPoint slides, or other visual aids to engage the audience. A laptop computer running Windows 7 will be provided for digital presentations. Please bring necessary files on a USB drive. If an application is embedded in the presentation that requires unique software, teams may use their own computers to ensure the presentation functions the way it is intended.

7 Turbine Testing Contest

The turbine-testing contest consists of a number of 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 B.

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 turbine safety.

7.1 Testing Procedure

All teams will follow the same prescribed schedule for testing in the wind tunnel. Only one team's turbine will be tested at a time. Each team will have 30 minutes of tunnel time—25 minutes to install the turbine and complete all testing, and 5 minutes to remove the turbine. 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 not be allowed to touch their turbines or controls during the test. 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.

If a team wants to retest their turbine for any reason, team members may request a single retest during the 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. Retesting will be conducted on a first-come, first-served basis. Teams will have an opportunity to sign up on the retest request list that will be maintained at the tunnel by the Tunnel Operator throughout the competition during or following their initial test—but not before.

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 the turbine configuration throughout the entire competition must 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.

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

7.3 Control of Rated Power and Rotor Speed Task

Wind turbines have to 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 wind speeds of 12 m/s and 13 m/s and compared to a rated wind speed of 11 m/s. 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.

7.4 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 (A) average over a 5-s interval at a steady wind speed.

7.5 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 the maximum continuous wind speed specified in Section 4 over a 5-minute test period. Yawed flow will be achieved using the tunnel's turntable governed by the limits set in Section 4. This test helps verify that the turbine can function under a wide range of operating conditions.

7.6 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 fail-safe shutdown capability. Turbines must shut down when disconnected from the grid as well as manually upon command, as described in Section 4. 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 wind speed specified in Section 4. For each turbine, the shutdown process will be initiated once "on command" and separately by electrical disconnect. The turbine must be capable of restarting between tasks 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-s bin average rpm achieved during the power performance testing. This reduction in rpm must occur within 10 s and remain below the limit indefinitely.

8 Bonus Siting Challenge

Preparation for this activity is not necessary, but some basic understanding of siting elements would be beneficial. This could include: understanding wind resource data, factors that affect economics, building setbacks, terrain effects, permitting requirements, and turbine/tower technology. The emphasis of this bonus challenge will be around student education. Feedback will be shared during a joint session with teams and wind siting experts.

Glossary

Competition	The competition is all aspects and activities leading up to, through, and following the event. It is the subcontract project agreement between the competitively selected collegiate teams and NREL, the contests, products, and event, collectively referred to as the U.S. Department of Energy Collegiate Wind Competition Technical Challenge 2017.
Contest	The competition consists of four contests with multiple products.
Products	Products are what the team builds, writes, submits, and brings to compete in the competition.
Event	The event is when and where the teams compete in the contests.
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.
Tasks	The individual achievement goals of the test turbine that will be scored during the wind tunnel testing period.
PCC	Point of common coupling. The point at which the students interface to the wind tunnel instrumentation with their turbine and load systems.
R&R	Rules and requirements. The overarching document that defines how the contest will be run and how student teams will be scored against one another.

Appendix A. Timeline and Schedule

Competition Timeline

The 2017 competition timeline is shown in Table A-1.

Table A-1. 2017 Competition Timeline and Related Activities

Month/Year	Competition Activity
Fall 2016	Release of competition rules and requirements
Fall 2016	Concept development
Spring 2017	Product development and testing
April 2017	Competition takes place
June 2017	The winning wind turbine is put on display at the U.S. Department of Energy headquarters in Washington, D.C. A review meeting/conference call is held to review the competition and make recommendations for the next event.

Preliminary Event Schedule (timeframe is fixed though contents are subject to change)

Thursday, April 20, 2017

<table>
<tr><td>9 am – 12 pm</td><td colspan="2">NREL Golden Main Campus Presentation and Tour (optional)</td></tr>
<tr><td>1 pm – 5 pm</td><td>Optional Tunnel Practice for Returning Teams</td><td>Information Sharing Session between Returning and Prospecting Teams</td></tr>
<tr><td>5 pm — 7 pm</td><td colspan="2">CWC Welcome Reception (tbd)</td></tr>
</table>

Friday, April 21, 2017

<table>
<tr><td>8 am — 8:45 am</td><td colspan="4">Continental Breakfast</td></tr>
<tr><td>8:45 am — 9 am</td><td colspan="4">Announcements</td></tr>
<tr><td>9 am - 10:30 am</td><td rowspan="4">Colorado KidWind Challenge</td><td colspan="3">Educational Sessions</td></tr>
<tr><td>10:30 am – 1 pm</td><td rowspan="3">Turbine Testing Contest</td><td>Technical Design Presentation</td><td>Siting Challenge</td></tr>
<tr><td>1 pm — 2 pm</td><td colspan="2">Lunch (NWTC)</td></tr>
<tr><td>2 pm - 5 pm</td><td colspan="2">Presentations and NWTC Tours
(in partnership with DOE Race to Zero Competition Participants)</td></tr>
<tr><td>5 pm — 7 pm</td><td colspan="4">Event (tbd)</td></tr>
</table>

Saturday, April 22, 2017

<table>
<tr><td>8 am—8:45 am</td><td colspan="4">Continental Breakfast and Announcements</td></tr>
<tr><td>9 am—1 pm</td><td>Educational Sessions</td><td>Turbine Testing Makeup</td><td>Technical Design Presentation</td><td>Siting Challenge</td></tr>
<tr><td>1 pm – 2 pm</td><td colspan="4">Lunch and Earth Day Keynote</td></tr>
<tr><td>2 pm – 3 pm</td><td colspan="4">Award Ceremony</td></tr>
<tr><td>3 pm – 5 pm</td><td>Optional Tunnel Time</td><td>View Race to Zero Event</td><td>Industry Tours (tbd)</td><td>Travel</td></tr>
</table>

Judged Contests
Educational Activities
General activities with all participants

Figure A-1. 2017 Technical Challenge Event Schedule

The Technical Challenge event will be held in accordance with the schedule provided in Figure A-1; however, times and content are subject to change any time up to the event. A final, more detailed schedule will be provided to the teams before and at the competition, including a team-specific customized schedule highlighting where each team needs to be and when throughout the event.

Appendix B. Rubrics

Products

Table B-1. Scoring Summary for the Competition Products (1,000 Points Total)

Competition Contests	Total Scores	Products		
		Written Report (400)	Public Presentation (150)	Turbine and Load System (450)
Technical Design	550	400	150	-
Turbine Testing	450	-	-	450
Bonus Challenge	Separate from overall score	-	-	-

Written Report

Table B-2. Scoring Rubric for the Written Report (400 Points Total)*, **

Description	Possible Points	Score
Executive Summary (100 points)		
Provides a well written, concise, and comprehensive summary of the report	100	
Subtotal		
Technical Design (300 points)		
Design objective and technical specifications description	45	
Static performance and aerodynamics analysis	30	
Mechanical load analysis and associated safety factors	30	
Electrical analysis	30	
Controls analysis and software documentation	30	
Design for varying wind direction	25	
Results from laboratory and/or field testing	40	
Engineering diagrams, including mechanical and electrical drawings	25	
Cohesiveness, clarity, and presentation	45	
Subtotal		
Total		

* 5% of total allowable points, distributed evenly across each contest section, will be deducted for each day the presentation is late.
**Reports that do not meet formatting requirements will be returned to the team within 24 hours of submission for correction. As a result, the penalty for late submission will apply.

Public Presentation

Table B-3. Scoring Rubric for the Presentation (150 Points Total)

Description	Possible Points	Score
Design objective and technical specifications description (include varying wind direction)	30	
Static performance and aerodynamic analysis	15	
Mechanical load analysis and associated safety factors	15	
Electrical analysis	15	
Controls analysis and software description	15	
Results from laboratory and/or field testing	15	
Unique elements of the team's story, including challenges overcome	25	
Cohesiveness, clarity, and presentation	20	
	Subtotal	
	Total	

Turbine Performance Testing

Table B-4. Scoring Rubric for Turbine Performance Testing (450 points total)

Description	Possible Points	Score
Power curve performance task	125	
Control of rated power	40	
Control of rated speed	40	
Cut-in wind speed task	75	
Durability task	70	
Safety task	100	
	Subtotal	
	Total	

Scoring algorithms for each testing task are described below.

Power Curve Performance Task

If the turbine does not meet the minimum continuous power output specified in the turbine design requirements for at least one wind speed from 5 m/s to 11 m/s, the score for the power performance task will be zero. A total score for this task will be calculated according to Table B-5 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.

Table B-5. Weighting for the Power Curve Performance Task

Wind Speed (m/s)	Factor
5	1.7
6	2.0
7	2.0
8	1.7
9	1.1
10	0.7
11	0.3

Control of Rated Power and Rotor Speed Task

Scores for power will be calculated according to the following formulas:

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

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

In Figure B-1, a ratio, r_p, of 1.000 represents perfect power control at exactly the same value as was measured in the 11-m/s bin. The weighting shown will be multiplied by 20 for the 12-m/s and 13-m/s bins to obtain scores for each bin.

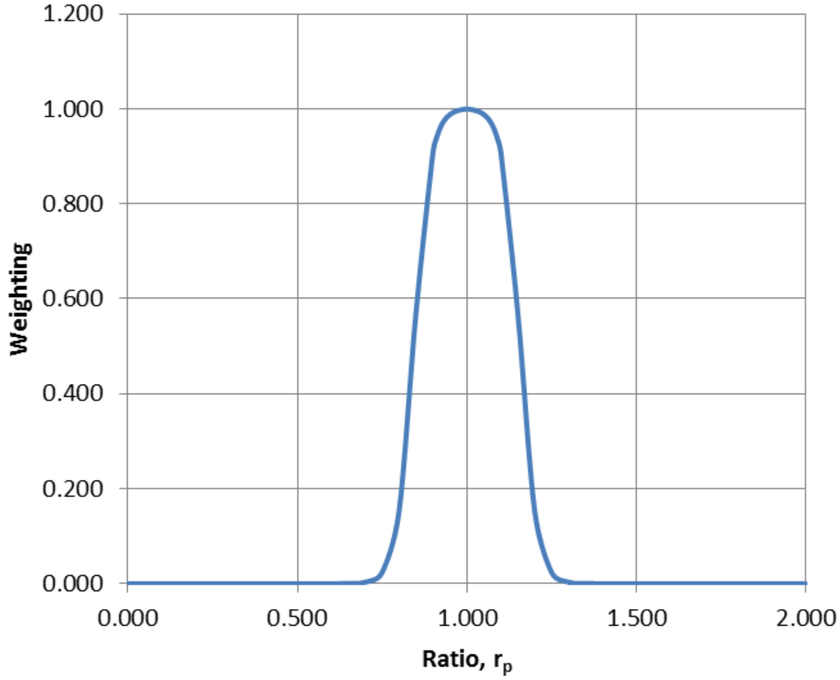

Figure B-1. Score weighting based on power ratio for control of rated power task

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

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

$$0 < r_s < 1.03 \rightarrow Bin\ Score = 20$$

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

In Figure B-2, a ratio, r_s, of 1.000 represents the perfect rotor speed control at exactly 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 20 for the 12-m/s and 13-m/s bins to obtain scores for each bin.

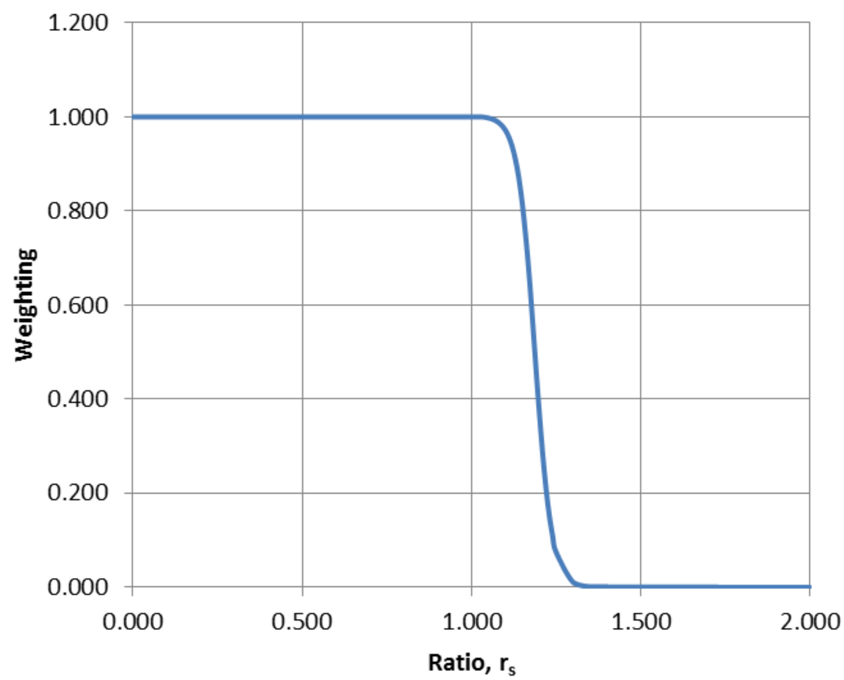

Figure B-2. Score weighting based on rpm ratio for control of rated rotor speed task

Cut-In Wind Speed Task

A team will earn 15 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 7.4), up to the maximum score of 75 points for this task. The team receives one score based on its cut-in wind speed.

Durability Task

This portion of the turbine performance testing contest is scored on a pass/fail basis. If the turbine can produce power at both the beginning and end of the task, and not stop producing power for more than 10 continuous seconds at any time during the task, the team will receive 70 points. If the turbine experiences any faults or is not able to produce power for more than 10 continuous seconds during the 5-minute duration period, the team will receive zero points. This includes faults that are visually observed during operation that do not cause a detected fault or a loss of ability to produce power, such as high vibration, cracks, loss of parts or pieces of parts, or other problems.

Safety Tasks

If the turbine fails to produce positive power during at least one wind speed of the power performance task, the score for the entire safety task will be zero. 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 7.6). If the turbine achieves a successful shutdown and subsequent restart upon manual initiation, the team will receive 50 points. If the turbine achieves a successful shutdown when disconnected from the load system and subsequent restart when reconnected, the team will receive an additional 50 points.

Appendix C. Communications and Business Operations

External Communications

The website will showcase the various elements of the competition, ongoing collegiate team engagement, and information about how to participate in future competitions. The website will also feature important documents such as this manual and the Collegiate Wind Competition identity guidelines. The identity guidelines provide information about how the competition name, logo, and visual identity can be used.

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:

- **Google Group**. Official communications suitable for viewing by all team members and organizers will be posted on the Google Group message board. Instructions for joining Google Group will be provided by NREL to the teams following each team's commitment to participate.
- **Dropbox**. 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 Google Group 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 Google Group has been established; then provided via the Google Group thereafter.
- **Meetings during event**. Meetings will be held daily throughout the event.
- **Email**. For expediency, and to protect confidentiality, the organizers may choose to communicate with teams via team members' email addresses as listed in the Google Group database; however, most official communications occur via the Google Group message board.

Branding

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

Content and images (graphics and photos), and any publications in which the content and images appear, may be viewable 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 credit. To ensure proper usage of, and credit for, images, teams should submit photos and graphics by uploading them to the Dropbox.

Teams are encouraged to develop branding for their turbines and teams. This branding, including web pages, Facebook or other social media, outreach material, and team T-shirts, are welcomed during the competition. The use of the Competition logo or name as part of individual school/team branding is covered by the identity guidelines provided. Examples of good team branding will be provided prior to the competition; however, all branding should conform to the Safety and Conduct provisions described in Section 2.3.

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. In addition, 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.

Judging and Scoring

Panels of judges are responsible for scoring team performance in each contest (i.e., technical design, turbine testing, and bonus siting challenge). 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 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 2017 Collegiate Wind Competition Technical Challenge.

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 Head Rules Official for official 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 also receive a short narrative that is derived from the judges' deliberations after each team's presentation. Teams will also receive copies of notes judges may have written on the individual rubric forms.

Appendix D. Product Submission Instructions

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 (see each product section) and submitted to organizers packaged as a single .zip file.

Submission Locations

Products must be delivered to the competition Dropbox.

PDF Requirements

PDFs must meet the following criteria:

- Embedded fonts
- A minimum resolution of 300 dpi.

If a software application does not support a direct-to-PDF function, create a postscript file by printing to a postscript printer with the "print to file" option selected. Use this postscript (.ps or .prn) file to create a PDF using Acrobat Distiller's high-resolution job settings. Points to remember include:

- Creating 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 is not acceptable
- All-raster PDFs are large files at 300 dpi but are of unacceptable quality at lower resolutions and are not scalable without degradation.

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

Example: A report submitted by the University of Alaska Fairbanks on April 5, 2017, would have the following file name: UAF_Report_2017-04-05.PDF.

Table D-1. Team Names and Abbreviations

Team Name	Team Abbreviation
Boise State University	BSU
California Maritime Academy	CAL_MARITIME
California State University, Chico	CHICO_STATE
Kansas State University	KSU
Northern Arizona University	NAU
Pennsylvania State University	PSU
Universidad del Turabo	TURABO
University of Alaska Fairbanks	UAF
University of Maryland	UMD
University of Massachusetts Amherst	UMA
University of Massachusetts Lowell	UML
University of Wisconsin-Madison	UWM

Table D-2. Product Names and Abbreviations

Product Name	Product Abbreviation
Written report	REPORT
Public presentation or poster	PRESENTATION
Product zip before competition	PORTFOLIO