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# Small wind industry, stakeholder, and site analysis in support of the small wind training and testing facility at James Madison University

Curt Louis Dvonch  
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Small Wind Industry, Stakeholder, and Site Analysis in  
Support of the Small Wind Training and Testing Facility  
at James Madison University

Curt Louis Dvonch

Master of Science in Sustainable Environmental Resource Management  
/ Master of Science in Integrated Science & Technology

University of Malta / James Madison University

2010

Small Wind Industry, Stakeholder, and Site Analysis in Support of the Small Wind Training and Testing Facility at James Madison University

A dissertation presented in part fulfillment of the requirements for the Degree of Master of Science in Sustainable Environmental Resource Management / Master of Science in Integrated Science & Technology

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## ABSTRACT

Curt Dvonch

Small Wind Industry, Stakeholder, and Site Analysis in Support of the Small Wind Training and Testing Facility at James Madison University

This work is in support of the development of the Small Wind Training and Testing Facility at James Madison University. The facility is intended to provide small wind training and testing capabilities that are tailored to the needs of small wind energy stakeholders in the Commonwealth of Virginia and across the greater mid-Atlantic Region of the United States. This work focuses on the development of testing capabilities by analyzing the state of the small wind industry in the region, by surveying a sample of small wind stakeholders in the region, and by tailoring the development of the facility to meet the identified needs. The results of the small wind industry analysis include an interactive geographic information system tool which contains relevant stakeholder information. The results of the stakeholder surveys are analyzed and have yielded multiple recommendations for the further development of the test facility. The development of capabilities to meet stakeholder small wind turbine testing needs includes an analysis of a prospective site location for the facility, the specification of instrumentation packages to equip the facility, and the creation of tools to help facilitate the continued development and eventual operation of the facility.

**KEYWORDS: SMALL WIND ENERGY, SMALL WIND TURBINE TESTING, MID-ATLANTIC SMALL WIND TURBINE INDUSTRY**

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November 2010

## **Dedication**

This work is dedicated to the memory of Benjamin Curry Stassen.

## **Acknowledgements**

Thank you to my family for their love and support throughout this endeavor. I give many thanks to Dr. Jonathan Miles, Dr. James Ridings, Dr. Tonio Sant, and Ms. Remy Luerssen, for their sage advice and support. I would also like to thank my classmates, both those in America and those in Malta.

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## **List of Acronyms**

AWEA – American Wind Energy Association

DAQ – data acquisition system

IEC – International Electrotechnical Commission

JMU – James Madison University

NABCEP – North American Board of Certified Energy Practitioners

NREL – National Renewable Energy Laboratory

NWTC – National Wind Technology Center

SWCC – Small Wind Certification Council

SWTTF – Small Wind Testing and Training Facility

VCWE – Virginia Center for Wind Energy

## **1. Introduction**

This work describes a comprehensive effort designed to advance the development of the *Small Wind Training and Testing Facility* (SWTTF) at James Madison University. As its name suggests, the SWTTF will serve two roles: *Training* and *Testing*. Development of the testing capabilities is the focus of this thesis.

The SWTTF will be the first testing facility dedicated to small and intermediate wind systems in Virginia and the surrounding mid-Atlantic region, and will provide capabilities that are tailored to the wind resource and industry requirements of the region. The testing capabilities provided by the facility may include small wind turbine testing for certification to American Wind Energy Association standards, shakedown testing of prototype designs, and experimental research projects. This work focuses on the identification of appropriate testing capabilities and development of these testing capabilities in seven (7) chapters.

The testing and training capabilities will complement each other in the operations of the facility. Regional small wind stakeholders are likely to utilize both capabilities and the equipment and hardware will be available for both training and testing purposes. While it is not the focus of this work, the training capabilities are an important part of the facility and are discussed in the following section.

### **1.1. Small Wind Training**

The Small Wind Training and Testing Facility will collaborate with other educational institutions in Virginia to provide a curriculum that addresses a variety of topics that relate to small wind energy development. These include safety, site assessment, installation, and troubleshooting. (Miles, 2010)

The safety curriculum will include a two-day unit that will address the safety related issues that pertain to the construction, erection, and maintenance of small wind turbine systems. The course will provide instruction on the proper techniques for tower climbing, which is an important component of tower construction and turbine maintenance. The course will provide an introduction to and instruction in the use of safety equipment such as harnesses, personal anchoring devices, and other personal protective equipment. The teamwork that is required for safe erection of small wind turbines and towers will be addressed, as will general safe practices that pertain to small wind systems. This unit will prepare students in identification of both electrical and mechanical safety concerns that may endanger both workers and members of the public. Finally, this unit will address environmental

concerns including bird and bat populations as well as viewshed impacts. Mitigation strategies will be addressed. (Miles, 2010)

The site assessment curriculum will cover the characterization of potential wind development sites. Site energy load estimation and wind resource assessment will be addressed. These characteristics help inform system sizing, which is also covered in this curriculum. Other topics of instruction will include the identification of potential locations and determination of the optimal location with consideration for obstructions, required tower heights, types, and other infrastructure issues such as wire runs. The course will also address the system power output characterization by providing instruction in calculating wind power, monthly and yearly energy, incentives, and payback periods. (Miles, 2010)

Planning and procedures for small wind installations will be covered in the Small Wind Installation unit. Schematics and written turbine and tower installation instructions will be utilized to calculate parameters associated with wire runs, foundation and footer locations and characteristics, and tower and guy wire placement. Hands-on instruction will include raising and lowering systems, guy wire tensioning, checking erected towers for plumb, and bolt tensioning. Installation of electrical components will be demonstrated and post-installation mechanical and electrical inspections will be performed by the students. (Miles, 2010)

The final course to be offered will cover small wind troubleshooting. This course will cover all wind turbine system components including blades, generators, towers, inverters/controllers, wire runs, and monitoring systems. Input from experts in the small wind industry will provide knowledge gained from experience in troubleshooting problems, including procedures for diagnosing problems and the likelihood of various problem scenarios. (Miles, 2010)

## **1.2. Previous Work**

Previous work titled *Regional Small Wind Turbine Test Facility on JMU/CISAT Campus* by Caspar introduced the concept of developing a test facility at JMU and addressed a number of important concepts related to the project. The concepts covered in depth include the history of wind energy, the current state of wind energy including the technology and a market analysis, the mechanics of wind power, the existing turbine test facilities, and the mechanics of tower construction and installation.

This previous work lightly addressed the testing of wind turbines for reliability, the necessity of small wind turbine testing, and the steps required for the development of a regional small wind test facility.

Acquisition of turbines for testing, performance and acoustic tests, and as the duration of tests and the role of student technicians in performing these tests are addressed. The procedures of installing a small wind turbine, including site planning, the safety issues involved with small wind turbine testing, tower construction and other infrastructure as it relates to small wind turbine testing, were addressed in this work. (Caspar, 2008)

The most useful aspects of the previous work include the identification of existing facilities to use as models. The Appalachian State University Small Wind Research and Demonstration site was visited during the course of both Caspar's research and the research that is described herein. (Caspar, 2008)

The work presented herein builds on the previous work, particularly with regard to the development of a regional small wind test facility, with an investigation into and characterization of the small wind energy industry within the mid-Atlantic region, and include an assessment of stakeholders within the region, and concludes with in-depth research into the technical requirements for developing the Small Wind Training and Testing Facility. Each chapter of this thesis is introduced individually in the remaining sections of this chapter.

### **1.3.Small Wind Energy Industry Characterization**

James Madison University is located near the geographic center of the mid-Atlantic Region of the United States. The University has attracted talented individuals with an interest in wind energy and serves as a hub for small wind energy activities in the Commonwealth of Virginia and the region. The Virginia Center for Wind Energy (VCWE) at James Madison University serves as an administrative center of wind energy activities within the state through administration of various wind energy related programs, some of which are discussed in this chapter, and provides valuable stakeholder data which is utilized to characterize the industry. The mission of the VCWE is to

*provide wind related services to local governments, state agencies, landowners, academia, non-governmental organizations, and businesses. These services include wind resource measurements, economic modeling, education & outreach, energy policy analysis, assessment of technical specifications, Geographic Information Systems analysis, and the strategic deployment of wind power within the Commonwealth and beyond. (Virginia Center for Wind Energy, 2010)*

Three programs are described in this chapter. They are the Virginia State-Based Anemometer Loan Program (SBALP), the Virginia Small Wind Incentives Program (VSWIP), and the Residential and Commercial Solar and Wind Incentive Program (RCSWIP). Each of these programs provides, or has provided in the past, support to land owners who wish to develop their wind resource. The support

includes grants, rebates, equipment loans, and expert advice and analysis. The forms of support vary between the programs.

Stakeholder data are associated with each program and with a list of small wind installation companies that is maintained by the VCWE. These data includes names and addresses of land owners who have applied to the various programs and names, addresses, and contact information of each installation company. The addresses were converted into latitude and longitude and were plotted in Google Earth.

A visual, geographic presentation of the stakeholder data is used to characterize the small wind energy industry in the mid-Atlantic region. Interactive maps allow for identification of relationships within the small wind industry. Relationships between the state's wind resource, terrain, location of small wind industrial services, and location of land owners who have shown an interest in developing small wind energy projects have been identified with the goal of informing the development of the SWTTF and characterizing the small wind industry in the region. These relationships are discussed in Chapter 3. The geographic information system and the analysis herein have been delivered to the Virginia Center for Wind Energy to be used to enhance the Center's capabilities and understanding of the region. The VCWE may utilize the tool as a method for quick identification of stakeholders within a region as well as for identifying relationships between the geographic locations of stakeholders in the region and other parameters. For example, the tool might be used to identify relationships between small wind stakeholder locations and elevation, which may be interesting because higher elevation is correlated to higher wind resource. As it becomes available, new data may be added to the tool, enhancing the ability to identify interesting relationships and to analyze new problems that stand in the way of further development of the wind resource in Virginia.

#### **1.4.Mid-Atlantic Stakeholder Survey Response and Analysis**

As a complement to the geographical characterization of the stakeholders within the Mid-Atlantic region, direct interaction with stakeholders through the use of a survey instrument was conducted and analysis of responses was performed. This work is presented in Chapter 3. The stakeholders were identified from a variety of sources including the list of small wind installation companies maintained by the VCWE, through personal contacts, and through web searches. The survey was created using an online survey tool which enabled tracking and presentation of results as well as ensuring anonymity for the respondents. The decision to use this tool was reached after consultation with the Institutional Review Board (IRB) at James Madison University, which is responsible for overseeing all human subject research at the University.

The survey questions were tailored to apply to the development of small wind turbine testing capabilities at the SWTTF. Many questions were intentionally open-ended to encourage diverse responses. A 2006 National Renewable Energy Laboratory small wind stakeholder survey served as a model for the creation of this.

Chapter 3 begins with a presentation of each question and a discussion of the justification and purpose for asking each question. The intended results of each question are identified along with background that pertains to each.

Forty nine (49) stakeholders were identified and eleven (11) responded. The analysis of these responses yields insights into what testing and training capabilities members of the regional small wind industry need or would find useful. These responses and insights are discussed in the last section of Chapter 3. The survey was also useful for gaining insight into other aspects of the small wind industry such as the perceived role of testing facilities in turbine certification and the perceived role of the Small Wind Certification Council. Additionally, the survey was found to be useful for connecting with industry stakeholders such as small wind turbine manufacturers. These connections may serve as the basis for long-lasting relationships that mutually benefit both the stakeholders and the SWTTF.

### **1.5. Proposed Site Analysis**

Having gained an understanding of the region's small wind industry and the stakeholders' small wind testing needs, the proposed SWTTF site is analyzed for its potential to meet those needs in Chapter 4. The proposed site is located on the east campus of James Madison University between the East Campus Library and Interstate 81, as shown in Figure 1. This site has been approved; however the final design is still in development.

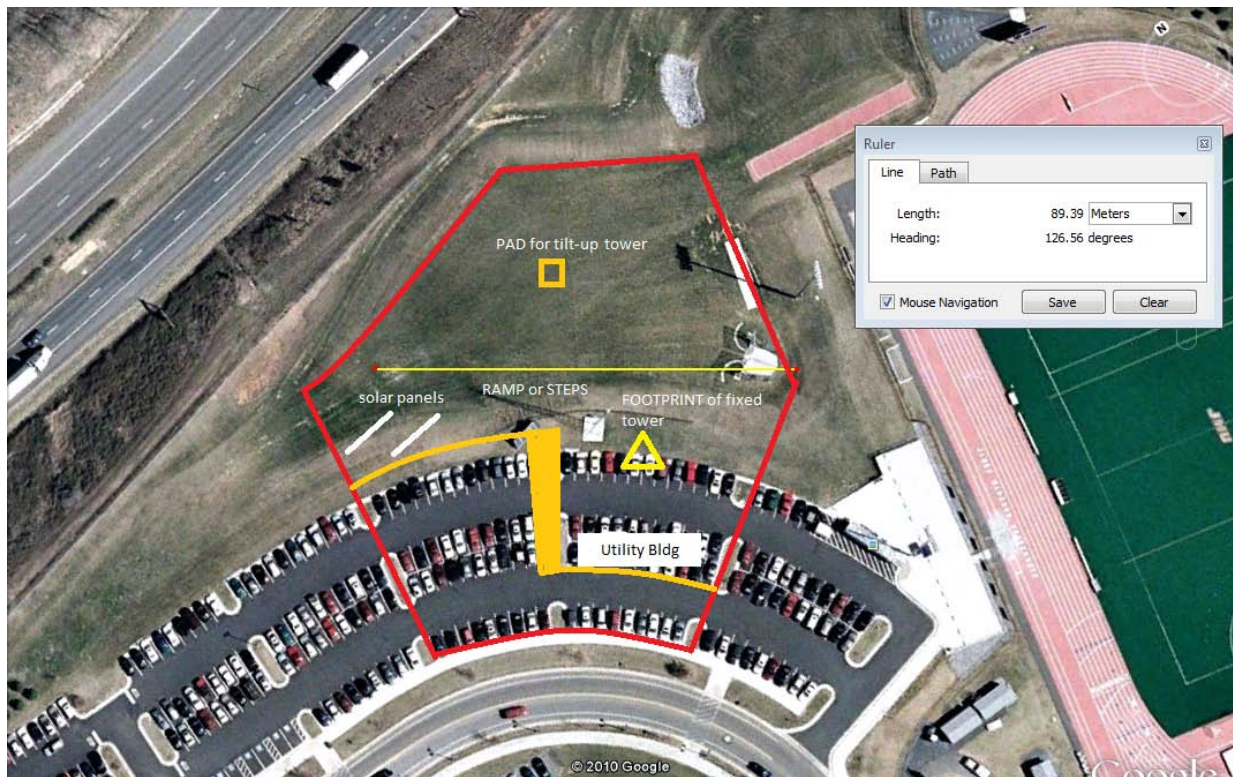


Figure 1. Proposed SWTTF site location

The site's location and other characteristics are examined with the aid of guidelines provided by Joe Smith, a wind turbine testing expert at the National Renewable Energy Laboratory who has helped develop small wind turbine testing within the United States. This examination and analysis covers the area of the proposed site, the wind resource, the accessibility and terrain, issues with local laws and the existing and potential infrastructure at the site.

The wind resource at the site was estimated through analysis of available wind speed and direction data from the site supplemented with data from a local airport. The analysis was performed using Windographer wind data analysis software. The primary results include statistical wind speed data as well as prevailing wind direction data. The wind class at the site was estimated. The results of this analysis will inform decisions regarding which type of testing and training capabilities the facility may provide. Other aspects of the site were analyzed in as much as was possible in accordance with the guidelines provided by Joe Smith.

## 1.6. Site Development

Steps toward informing critical decisions regarding the development of the SWTTF at JMU are presented in Chapter 6. Information gathered during a visit to Appalachian State University's Small



Wind Research and Demonstration (SWRD) site at Beech Mountain is discussed and provides a basis for the development work presented in this chapter. The SWRD site visit included discussions with three SWRD technicians and investigation that focused on the instrumentation utilized at the facility, small wind turbine testing operations, turbines, towers, wire runs, and outbuilding infrastructure.

A thorough examination of available instrumentation options has been completed and two instrumentation packages, basic and advanced, are outlined. The basic instrumentation package is designed for long-term, stable turbine performance measurements. These measurements are likely to be used for certification of small wind turbines to AWEA standards. The advanced instrumentation package is designed to support short term, experimental research projects. These projects may cover a very wide variety of topics including turbulence characterization, wind prediction and modeling, and turbine behavior studies.

Topics pertaining to student exposure to the SWTTF and experimentation within the SWTTF, as well as facility stability and reliability, are discussed. The main focus of these discussions involves maintaining the reliability and stability of the basic instrumentation package and long term measurements for certification. The creation of a robust documentation repository and requirements for the creation of a data repository as a method of preventing reliability problems was undertaken is presented in this chapter.

## **1.7. Conclusion**

Throughout each chapter, this work has generated a number of recommendations for future development of the SWTTF. These recommendations are gathered together in a tabular format and further discussed in the conclusion. These recommendations are wide ranging and are intended to inform the future development of the facility by presenting a variety of options available to the staff of the SWTTF.

## 2. Background

### 2.1. Wind Energy

Harvesting the wind is an ancient method of obtaining free energy that has become a mainstream source of electrical energy in modern times. The technologies used to harvest this energy and transform it into electricity are many; however they can generally be categorized according to size.

Classes of wind turbines can be described using the rotor diameter, where medium and large commercial wind turbines generally range from 20 to 100 m and small wind turbines range from 0.5 to 20 m. (Gipe, 2009) Large wind turbine output can reach 7.5 MW, (Enercon GMBH) while small wind turbines generally reach a capacity of less than 100 kW.

The different classes of turbines tend to be used in differing ways. The medium class turbines are generally used for applications such as farms, factories, businesses and small wind farms. The large class turbines can be found singly or in clusters and are power plant scale electricity generators.

The complexity of wind turbines tends to increase as with the size of the turbine. However, all sizes have blades, rotors, towers, and generators. Figure 2 depicts many of the major components that make up medium and large wind turbines. (Energy Efficiency and Renewable Energy Program, 2010)

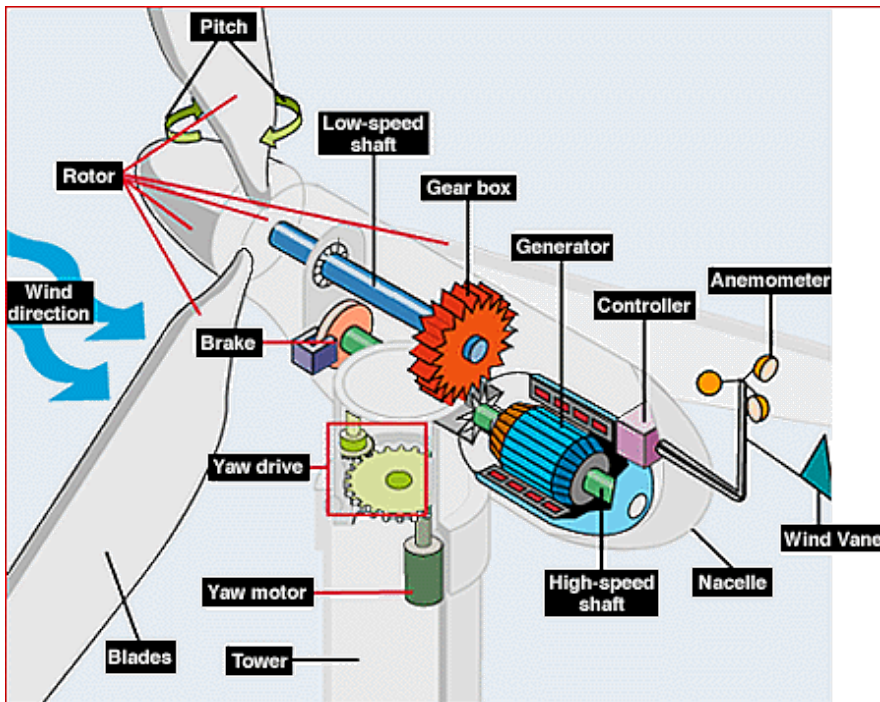


Figure 2. Components of medium and large turbines (Energy Efficiency and Renewable Energy Program, 2010)

## 2.2. Small Wind Energy

This work focuses on producing energy with small wind turbines with capacities of less than 100 kW. The power generated by these turbines may be fed into the electrical grid, used to power a battery bank, or used to pump water either mechanically or electrically. For the purposes of this thesis only, electrical applications are considered. Small wind turbines are often found operating in conjunction with solar photovoltaic panels as demonstrated in Figure 3. The two technologies within this hybrid system complement each other in that wind turbines maximize power output during the winter season when winds are strong, and photovoltaic panels maximize power output during the long sunny days in summer. This hybrid system contains smaller components as compared to a similarly performing wind only or photovoltaic system. (Gipe, Wind Power: renewable energy for home, farm, and business, 2004)



Figure 3. Hybrid system featuring small wind turbine and solar photovoltaics at James Madison University.(Armstrong, 2009)

Small wind energy systems provide to homeowners, farmers, small business owners, and other consumers reliable, sustainable, and clean electricity that they generate themselves. Most consumers opt to sell excess electricity generated by their system to the grid. This process, known as net metering, allows residential and other electricity generating systems to credit excess generation to their bill at a pre-determined rate. (Database of State Incentives for Renewables & Efficiency, 2010). In Virginia, net metering is regulated and is an important incentive to small wind power developers. (Virginia Department of Mines, Minerals and Energy, 2006) Other consumers store excess energy in battery banks to enable operation that is independent from the grid and for protection against grid failure.

### **2.3.Small Wind Turbine Testing**

Testing provides information about system performance, safety, and reliability by ensuring that both the companies that install small wind systems and the turbines themselves meet minimum performance standards. This information is necessary for consumers to make an informed investment decision in a small wind energy system. Four categories of testing have been identified: testing for certification, power performance verification, prototype testing, and research and development (R&D) testing. These are listed roughly in order from the most to the least rigorous, however this is not always the case as certain prototype and R&D testing may be highly rigorous.

Research and development testing will often focus on a single turbine subsystem such as drivetrains, blades, or control schemes and mechanisms. These tests are usually performed in laboratory settings using specialized research turbines, dynamometers, and other equipment. (Wind Research, 2010)

Prototype testing involves determining the performance, reliability, and durability of working prototypes by exposing them to real world conditions. Small wind turbine manufacturers may develop and test many working prototypes before sending a model into production. Once a model is ready for production, it will usually undergo power performance verification to determine or verify the rated capacity of the turbine and to produce a power curve, which is a plot of power output versus wind speed. (Danish Wind Industry Association, 2003) Testing for certification is a rigorous procedure which entails testing to determine annual energy output, rated power output, rated sound output, durability and safety. Testing for certification is usually performed in accordance to a set of standards that detail the testing procedures and minimum or maximum thresholds that must be met to pass certification. (National Renewable Energy Laboratory, 2011)

## **2.4.Small Wind Turbine Testing Standards**

Until recently, the small wind energy industry has been self-regulated. (AWEA Small Wind Turbine Global Market Study, 2009) This situation has begun to change with the American Wind Energy Association's introduction of a comprehensive *Small Wind Turbine Performance and Safety Standard*, which is included in Appendix A. (AWEA Small Wind Turbine Performance and Safety Standard, 2009) The 2009 adoption of these standards and the beginning of third-party certification to these standards has signaled major changes in the small wind industry.

This Standard is based on and is nearly identical to standards created by the International Electrotechnical Commission. The Standard itself explains that it "is derived largely from existing international wind turbine standards developed under the auspices of the International Electrotechnical Commission." (AWEA Small Wind Turbine Performance and Safety Standard, 2009) The IEC has created standards for all types and classes of wind turbines, including large scale and offshore. However, the AWEA Small Wind Turbine Performance and Safety Standard of 2009 is based only on three sections of the IEC wind turbine standards: section 61400-2 for small wind turbines, section 61400-11 for acoustic noise measurement techniques, and section 61500-12-1 for power performance measurements of electricity producing wind turbines.

## **2.5. Small Wind Certification Council**

The Small Wind Certification Council (SWCC) was established in 2008 to act as an independent certification body which audits testing organizations, including their facilities and procedures, to certify that small wind turbines meet or exceed the AWEA *Small Wind Turbine Performance and Safety Standard* (Small Wind Certification Council, 2010). Given how recently the SWCC was established, no turbines have yet been certified to the AWEA standards. However, as of March 2011, twenty five (25) small wind turbines have begun the certification process under the auspices of the SWCC, as indicated in Table 1. (Certified Turbines, 2010) Once these turbines are certified, they will be the first turbines on the market to be tested to the AWEA standards and vetted by a third-party certification body.

Table 1. Small wind turbines that are currently undergoing the SWCC certification process

<b>Date*</b>	<b>Applicant</b>	<b>Turbine</b>
5/20/10	American Zephyr Corporation	Airdolphin GTO
5/27/10	Bergey Windpower Co.	Bergey 5kW
6/15/10	Bergey Windpower Co.	Bergey Excel-S
1/31/11	BRI Energy Solutions, LTD	Vbine 10-05
6/7/10	Endurance Wind Power Inc.	Endurance S-343
9/27/10	Enertech, Inc.	Enertech E13
8/13/10	E Vance Wind Turbines Ltd.	E Vance R9000
6/18/10	Eveready Diversified Products (Pty) Ltd.	Kestrel e400i 3kW 250V
6/18/10	Eveready Diversified Products (Pty) Ltd.	Kestrel e400i 3kW 48Vdc
2/4/11	Evoco Energy	Evoco 10kW
12/20/10	Gaia Wind Ltd.	GW 133 - 11kW
10/15/10	Polaris America LLC	P15-50
11/19/10	Polaris America LLC	P10-20
9/23/10	Potencia Industrial S.A.	10kW Hummingbird
5/25/10	Renewegy, LLC	Renewegy VP-20
6/16/10	Seaforth Energy	AOC 15/50
6/7/10	Southwest Windpower	Skystream 3.7
10/20/10	Taisei Techno Co.	TTK-10kW
2/08/11	Talk, Inc.	Suelflow 100
11/30/10	Urban Green Energy	UGE-1K
11/30/10	Urban Green Energy	UGE-4K
6/15/10	UrWind Inc.	UrWind O <sub>2</sub>
6/11/10	Ventura Energy Corporation	Ventura VT10
6/4/10	Windspire Energy	Windspire - 800040
6/3/10	Xzeres Wind Corporation	ARE442

\*Date: date of execution of the Certification Agreement between the Applicant and the SWCC. For turbines that have been or will be certified by another certification body, this is the date of the Notice of Intent.

## 2.6. Testing Organizations

Small wind turbine testing organizations generally fall within three categories: Accredited, NREL Regional Test Centers, and Non-Accredited. (Test Organizations for Small Wind Turbines, 2010) Their geographic locations are shown in Figures 4 and 5. Three North American organizations are accredited by third-party accreditation bodies that have signed the International Accreditation Cooperation Arrangement, which was established with the intention of “developing international cooperation for facilitating trade by promotion of the acceptance of accredited test and calibration results”. (ILAC, 2011) The National Renewable Energy Laboratory’s (NREL) National Wind Technology Center is one of these three. NREL established four regional small wind turbine test centers which are indicated with red place marks in Figures 4 and 5. These organizations are non-accredited and operate independent

of NREL, but receive support in the form of funding and technical assistance from NREL. The majority of small wind test centers are non-accredited and are not part of the regional test center program. As of July 2010, the SWCC identified seventeen (17) non-accredited test centers. (Test Organizations for Small Wind Turbines, 2010) The details are provided in Appendix B.

All test centers are eligible to work with the SWCC in order to document compliance with the AWEA/IEC standard for small wind turbine testing. However, SWCC oversight is minimal when tests are performed by accredited test organizations (FAQs for Manufacturers, 2010).

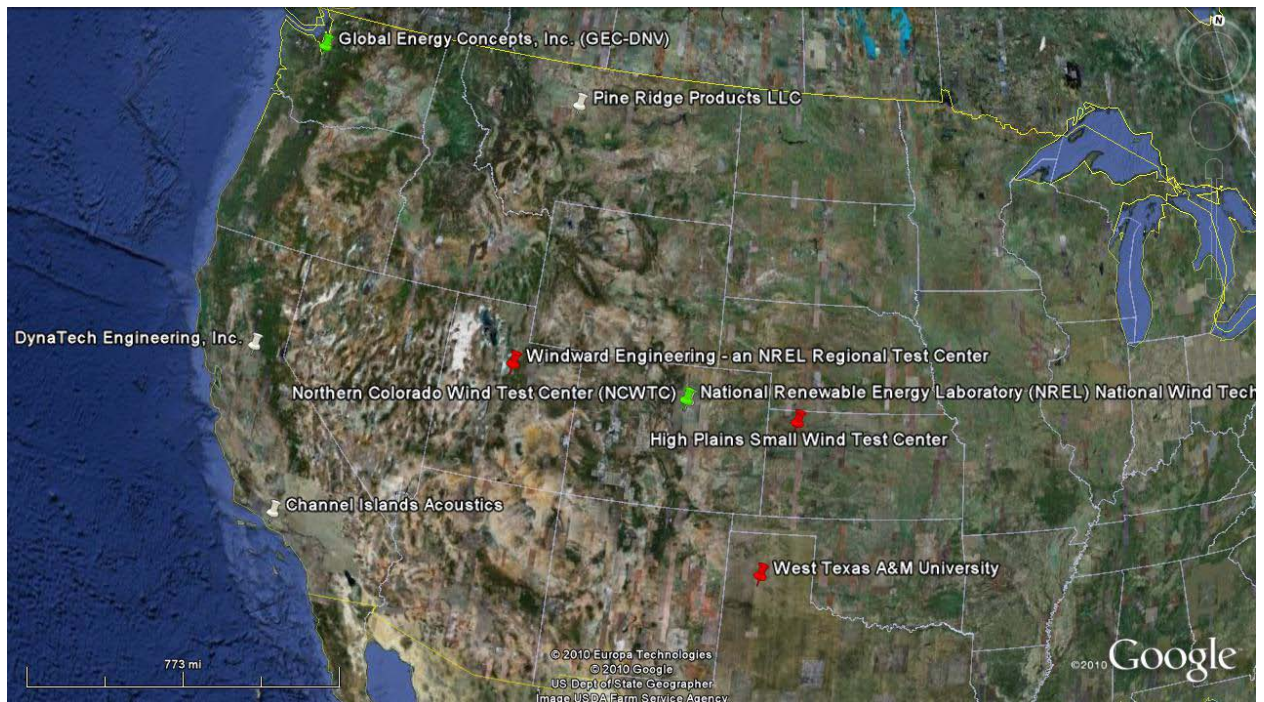


Figure 4. Test organizations in the West. Accredited are in white, regional in red, and non-accredited are in green.



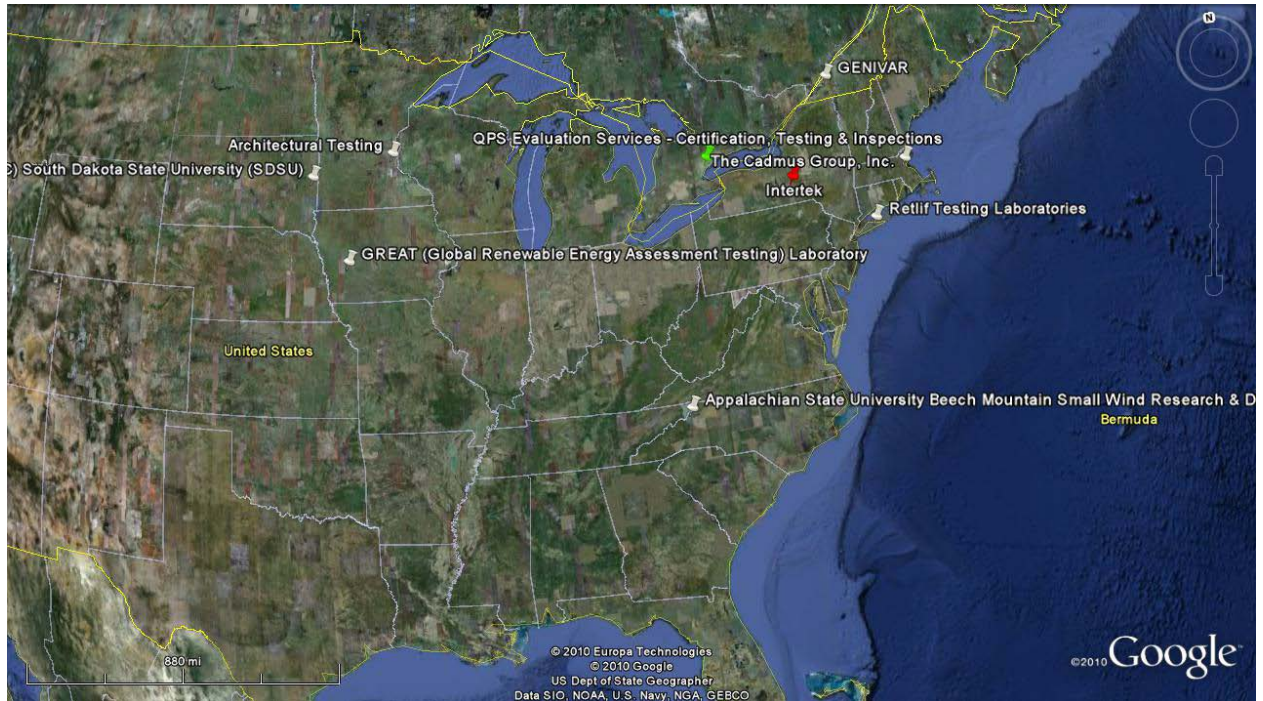


Figure 5. Test organizations in the East. Accredited are in white, regional in red, and non-accredited are in green.

The existing standards address issues of reliability, durability, and longevity, but only during the course of the test period, which may be as short as six months. (FAQ for Consumers & Policy Makers, 2010) Because the payback period of a small wind energy system in Virginia might reach 15 years (Virginia Wind Power Rebate Program, 2010) or even longer, long-term reliability is an essential component to the economic feasibility of such a system. The 2002 U.S. Small Wind Turbine Industry Roadmap published by AWEA (American Wind Energy Association, 2002) discusses the necessity for effective duplication of real-world wear and tear during turbine development, which is not fully addressed within the AWEA standard.

## 2.7. Small Wind Training and Testing Facility at JMU

The Virginia Center for Wind Energy at James Madison University (JMU) was awarded a grant in the amount of \$800,000 by the Commonwealth of Virginia in June 2010 to develop the Small Wind Training and Testing Facility (SWTTF) at JMU. The award was announced by Virginia Lieutenant Governor Bill Bolling during his keynote address at the 2010 Virginia Wind Energy Symposium (James Madison University Public Affairs, 2010). The training component of the facility will provide a variety of courses in subjects relevant to small wind. The testing component will provide an independent testing and certification capability to the mid-Atlantic region. The funding is divided nearly equally between



the two endeavors, with some funding dedicated to the purchase of new turbines which will assist in both testing and training.

A training curriculum that addresses topics including small wind safety, site assessment, installation, and troubleshooting is important to advancing the workforce that will support the deployment of small and intermediate wind power systems. The training programs will be targeted at developers and installers of small wind power projects and experts in trades that support such projects. In addition, the SWTTF will provide training and testing opportunities to two-year institutions which have implemented or are developing wind technical training programs. It will also support K-12 education through the *Wind For Schools* program (Virginia Wind For Schools Program Overview, 2009) recently established at JMU with support from the U.S. Department of Energy (DOE).

The Small Wind Training and Testing Facility is currently under development in partnership between the Department of Integrated Science and Technology, Facilities Management, and private consulting firms. The SWTTF is a landmark endeavor by the university with support from the state and funding from the American Recovery and Reinvestment Act of 2009. It is intended to advance a burgeoning sector within the wind industry, that which emphasizes small, intermediate, and community-scale wind projects, and to provide the necessary resources to build a future workforce to serve this area.

### 3. Mid-Atlantic Small Wind Energy Industry Characterization

The Virginia Center for Wind Energy (VCWE) is a hub of small wind activities in the State of Virginia. In the process of administering a variety of small wind energy related programs, the VCWE has amassed a large amount of data from land owners and others who are interested in developing small wind energy projects. As a part of the characterization of the mid-Atlantic small wind energy industry, these data were analyzed with Google Earth, a geographic visualization tool, to develop a visual representation of the mid-Atlantic Region's small wind industry.

Data from four sources (see Table 2) were used to develop the small wind energy stakeholder maps that are presented in this chapter. Applications for three government-funded programs administered by the VCWE contain stakeholder location data. These three programs were designed to help spur the industry by encouraging investment in small wind energy through rebates and grants and by allowing land owners to assess the wind resource at a proposed site. The land owners who have submitted applications to these programs are considered to be small wind stakeholders because they have shown interest in developing a small wind energy system on their property. The fourth source is a list of small wind installation businesses in the region that is maintained by the VCWE. A free, online batch address locator tool was used to convert addresses into GPS coordinates that were then used as input into Google Earth. (Schneider)

Table 2. Wind stakeholder data sources.

Program	Effective dates	Notes
Virginia State-Based Anemometer Loan Program (SBALP)	August 2001 – Present	SBALP allows land owners who are interested in developing their small wind resource to obtain the necessary data to characterize that resource.
Virginia Small Wind Initiatives Program (VSWIP)	2005 - 2006	VSWIP distributed grants to support the purchase and installation of small wind turbines.
Residential and Commercial Solar and Wind Incentive Program (RCSWIP)	2009	RCSWIP provided the residents of Virginia with assistance in small wind energy projects, including \$15 million in rebates and assistance in ensuring that the projects are feasible and safely installed.
Commercial Small Wind Installers	Ongoing	The VCWE maintains a list of active commercial small wind installers in the region.

### **3.1. Virginia State-Based Anemometer Loan Program (SBALP)**

The SBALP has allowed land owners who are interested in developing their small wind resource to obtain the necessary data to characterize that resource since 2001. JMU administers the program within the framework of the U.S. Department of Energy Wind Powering America Initiative with the help of a grant from the Virginia Department of Mines, Minerals and Energy, along with assistance from the National Renewable Energy Laboratory. (Howell K. R., 2010) The program has successfully installed and outfitted towers with anemometers in forty one different locations throughout the state.

Four (4) anemometers, each on 50 meters towers and outfitted with a data logger, are available for loan to Virginians at no cost to the applicants. The recipients of the anemometers assume little responsibility beyond replacing the data plug and batteries in the data logger and in general safeguarding the unit. The data collected by these anemometers is used by the land owners to determine the feasibility of deploying a small wind turbine and in sizing a small wind energy system, and by members of the Virginia Center for Wind Energy to build their wind resource database and to ground-truth wind resource maps.(Howell K. , Frequently Asked Questions, 2010)

Current anemometer installations include: a deployment at Port Isobel on Tangier Island in conjunction with the Chesapeake Bay Foundation, an anemometer in Quinby in conjunction with Mid Atlantic Aquatic Technologies, a deployment to the CSDA Dam Neck in Virginia Beach, which is in the process of being decommissioned, and one at the Augusta County Landfill in conjunction with the Augusta County Service Authority. This final project is in the planning stages. (Howell K. , Wind Analyst, 2011)

Figure 6 shows a satellite image of the Mid-Atlantic Region with the geographic locations of Virginia State-Based Anemometer Loan Program applicants overlaid in yellow. This figure allows for observation of the dispersion and concentration of applicants across the state.

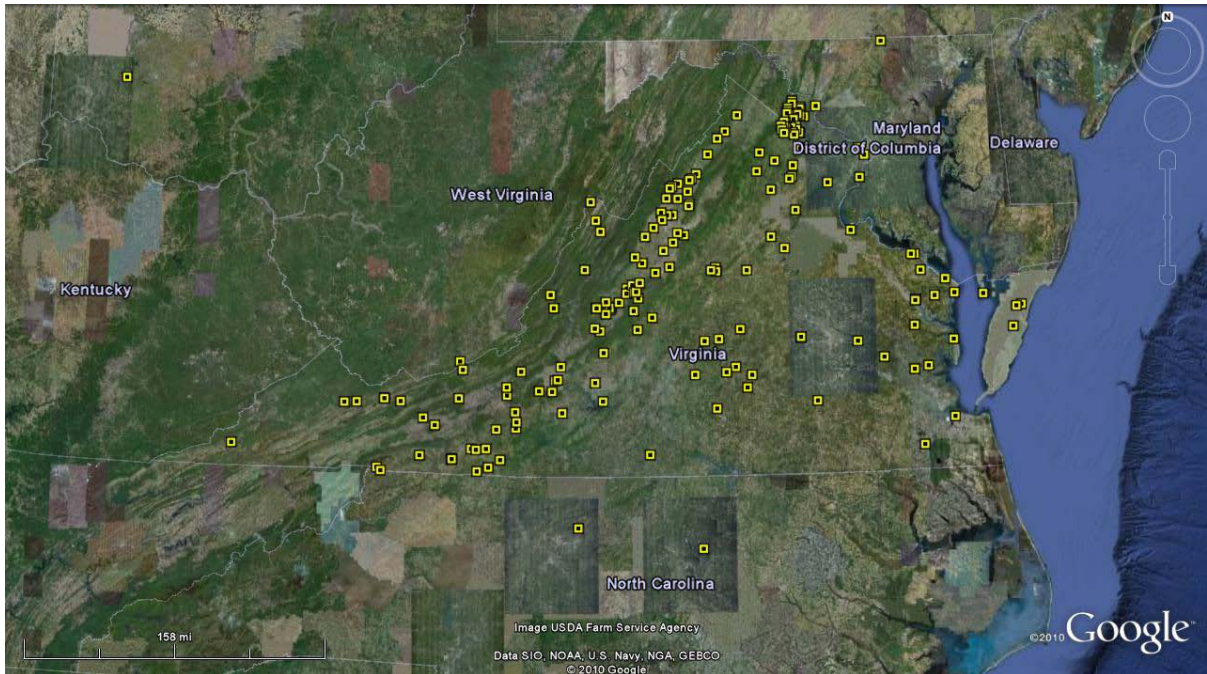


Figure 6. Virginia State-Based Anemometer Loan Program Applicants

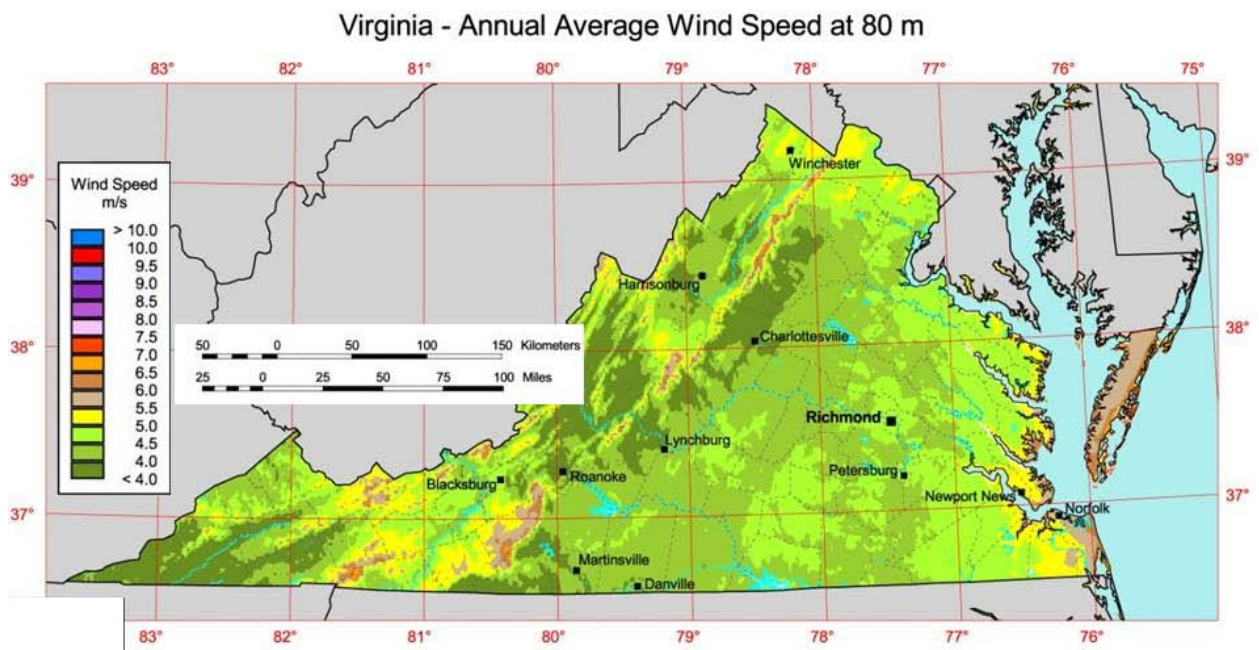


Figure 7. 50m wind resource map. (Virginia Center For Wind Energy, 2010)

The map shows the distribution of land owners interested in measuring their wind resource. The majority lies in the western and southwestern portions of the state. These regions correspond to high wind resource areas as shown in Figure 7. This is an interesting correlation that is obvious when a



visual approach is taken towards characterizing the small wind industry in Virginia. An interesting anomaly exists in Loudoun County, which lies approximately 30 miles northwest of the District of Columbia. Large concentrations of land owners who have applied for an anemometer loan reside in this county when compared with other counties in the state, as shown in Figure 9. The reason for this anomaly is not entirely understood, but may be a result of the combination of factors such as the high average income level in the county, as shown in Figure 8, the relatively high wind resource, as shown in Figure 7, and perhaps an effective outreach programs or a champion of wind energy technology in that area.

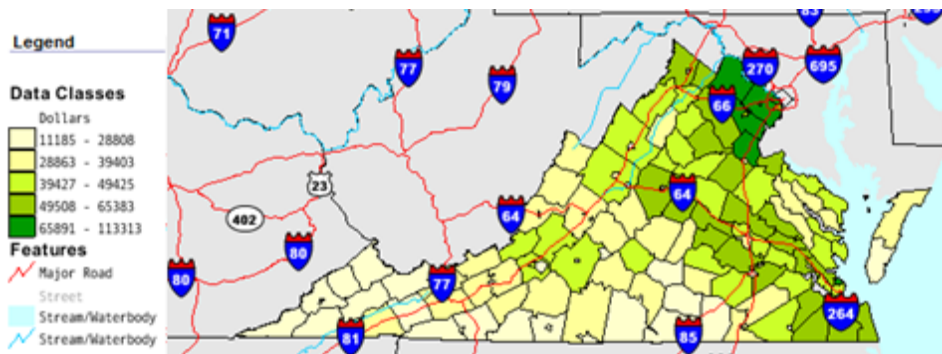


Figure 8. Virginia income by county(U.S. Census Bureau, 2009)

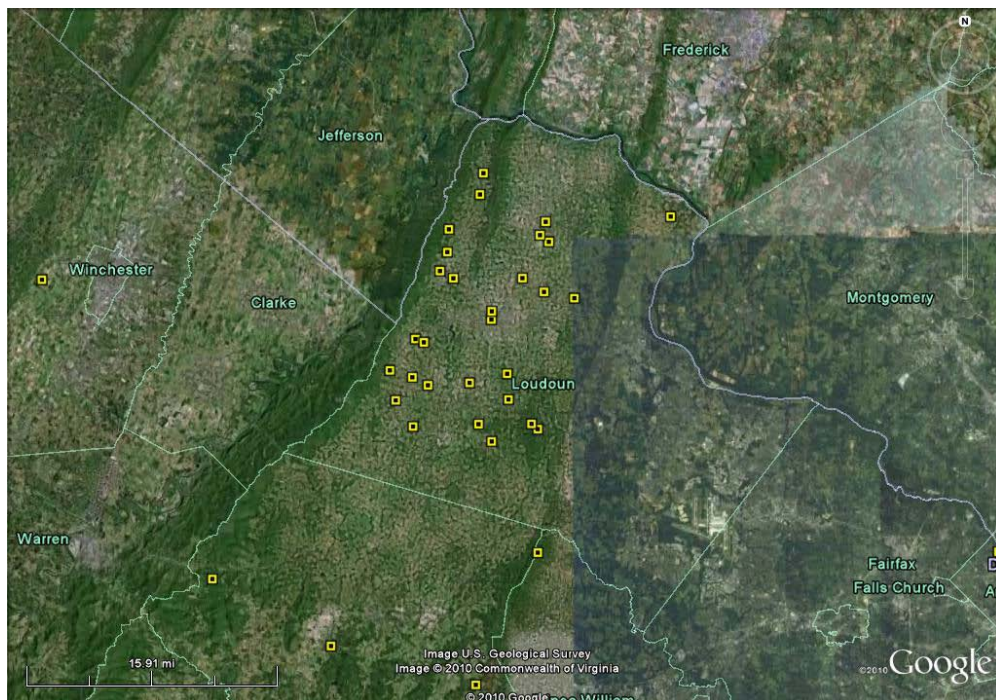


Figure 9. Loudoun County SBALP applicants.

### 3.1. Virginia Small Wind Incentives Program (VSWIP)

The VSWIP was a grant program which was intended to “provide the stimulus needed in Virginia to spur consumer confidence in wind energy.” (Virginia Wind Energy Collaborative) The main function of the program was to distribute grants to support the purchase and installation of small wind turbines. The grants covered 33% of the total cost for purchase and installation of a turbine up to \$10,000. This program is an extension of the Next Step Initiative, a program intended to “provide tools to ... landowners across Virginia who wish to exploit their wind resource for clean electrical power generation.”

The program ran a three-year course between 2004 and 2006, resulting in funding of twelve new small wind turbine installations which were chosen from a pool of sixty-three (63) applications. (Virginia Wind Energy Collaborative, 2006) The selection process was rigorous, and included an analysis of the quality of the applicants’ wind resource and site, their financial means and commitment, and their willingness to act as champions for the technology within their community. The call for applicants yielded forty-two (42) applications. The locations of the applicants are shown in Figure 10. These applicants were primarily located in Virginia. However, one application was received from West Virginia, and another from Tennessee.

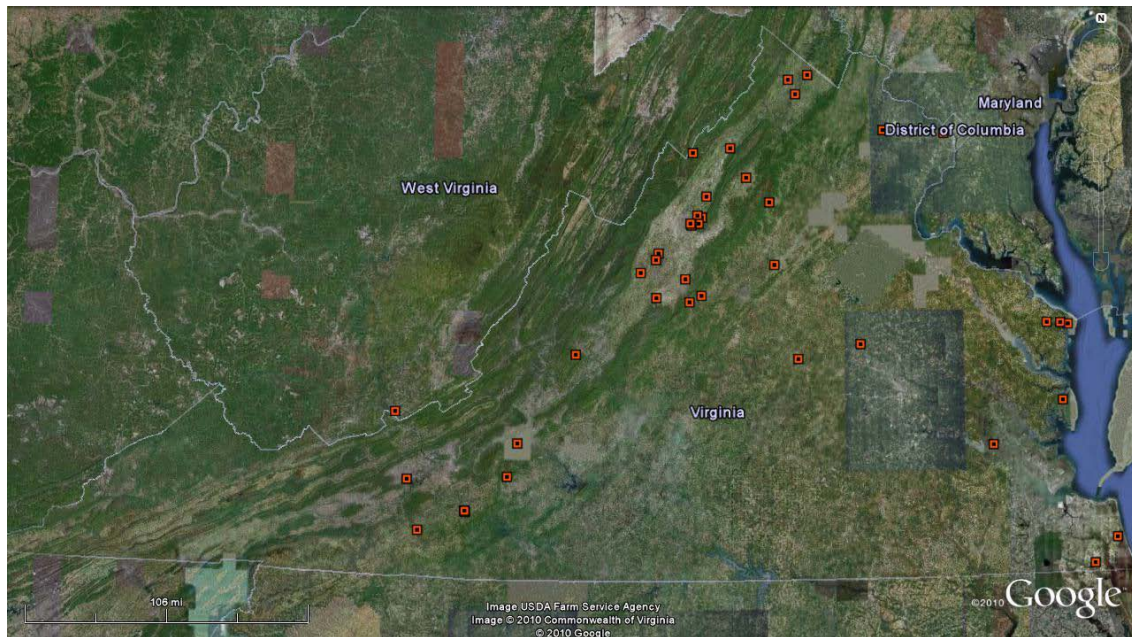


Figure 10. VSWIP applicant locations.



These applicants are fewer in number when compared to the SBALP applicants. Figure 11 shows that the geographical distribution of applicants is similar between the two programs, with the majority of applicants in the Shenandoah Valley and others spread throughout the southwestern, central, and eastern parts of the state.

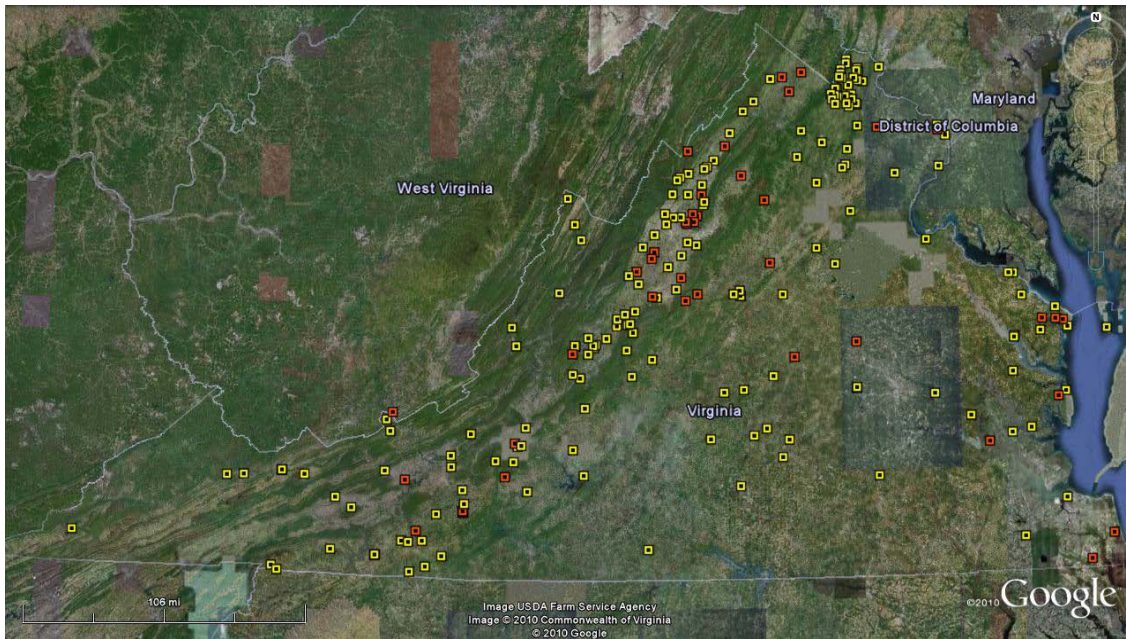


Figure 11. VSWIP applicant locations in red and SBALP applicant locations in yellow

### **3.2. Residential and Commercial Solar and Wind Incentive Program**

The Residential Commercial Solar and Wind Incentive Program provides the residents of Virginia with assistance in small wind energy projects, including up to \$15 million in rebates and assistance in ensuring that the projects are feasible and safely installed. This program covers both solar, including photovoltaic and solar thermal, and wind energy projects. (Virginia Department of Mines, Minerals, and Energy, 2010) The eligible applicants are awarded a rebate of \$1,500 per installed kW of solar or small wind capacity with a maximum of 10 kW for residential and 500 kW for commercial. Initially the program received seventy-five (75) applications with a combined reservation total of \$1,258,350. There are currently twenty-five (25) active projects at various stages of development and six (6) additional projects have received funding. Applications for additional rebates continue to be accepted.

These applicants may opt to install a solar only system, and therefore, the applicants shown in Figure 12 are not necessarily interested in developing a small wind energy system. However, the map is informative in that it shows a distribution pattern that is very similar to those seen in Figure 6 and

Figure 10, and includes an unusual concentration of applicants in Loudoun County, as is the case with the SBALP and discussed in section 3.1.

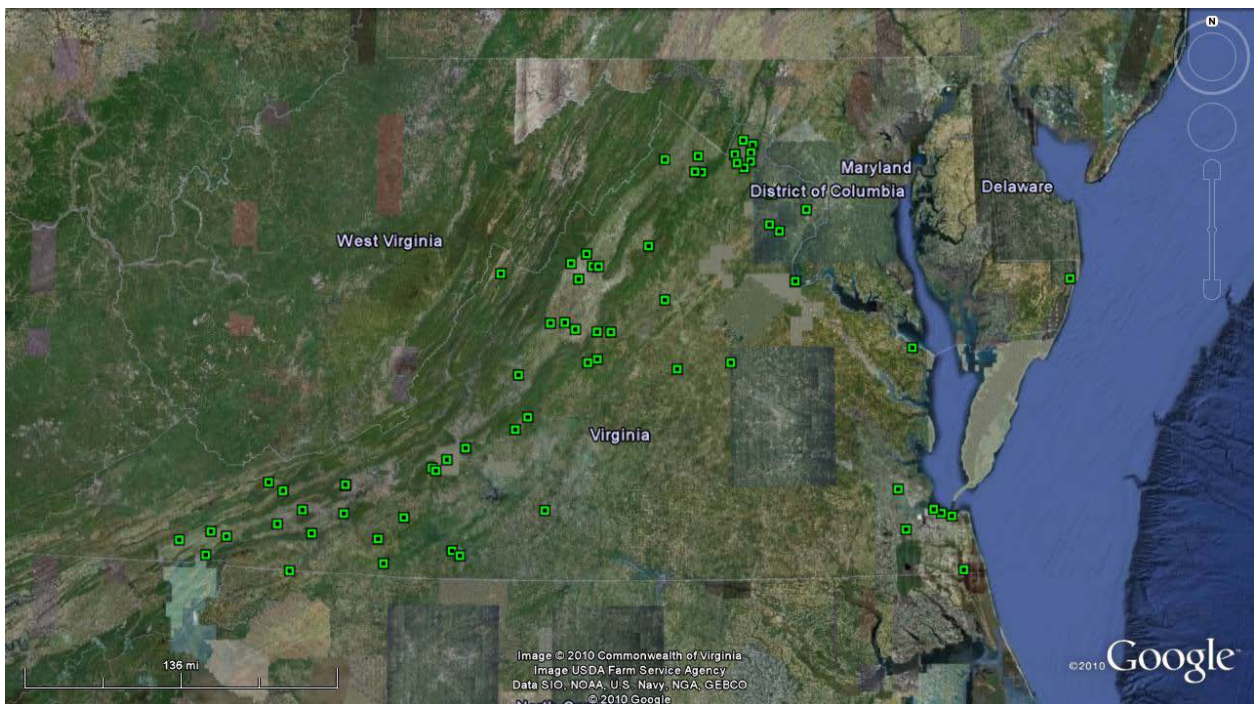


Figure 12. Virginia Residential and Commercial Solar and Wind Incentive Program applicant locations

### 3.3. Small Wind Installation Companies

In addition to land owners with an interest in developing small wind energy projects, small wind energy installation companies are an important part of the region's small wind energy industry. A list of twenty four (24) businesses that provide small wind installation services to the region was provided by the VCWE. These business locations were plotted in the Google Earth geographic visualization system. Sixteen (16) businesses are located in Virginia, three (3) each in West Virginia and North Carolina, and two (2) in Maryland, as shown in Figure 13.

As discussed in Section 4.4, these small wind installation companies provide a variety of services to the small wind industry in the Mid-Atlantic Region. Retail in particular is a very common function that these companies perform. In addition to identifying relationships between installers and landowners, this plot allows users to easily identify the installers within each region of the state. This capability is a useful to landowners with an interest in developing their wind resource because it allows them to identify the installers in their area.



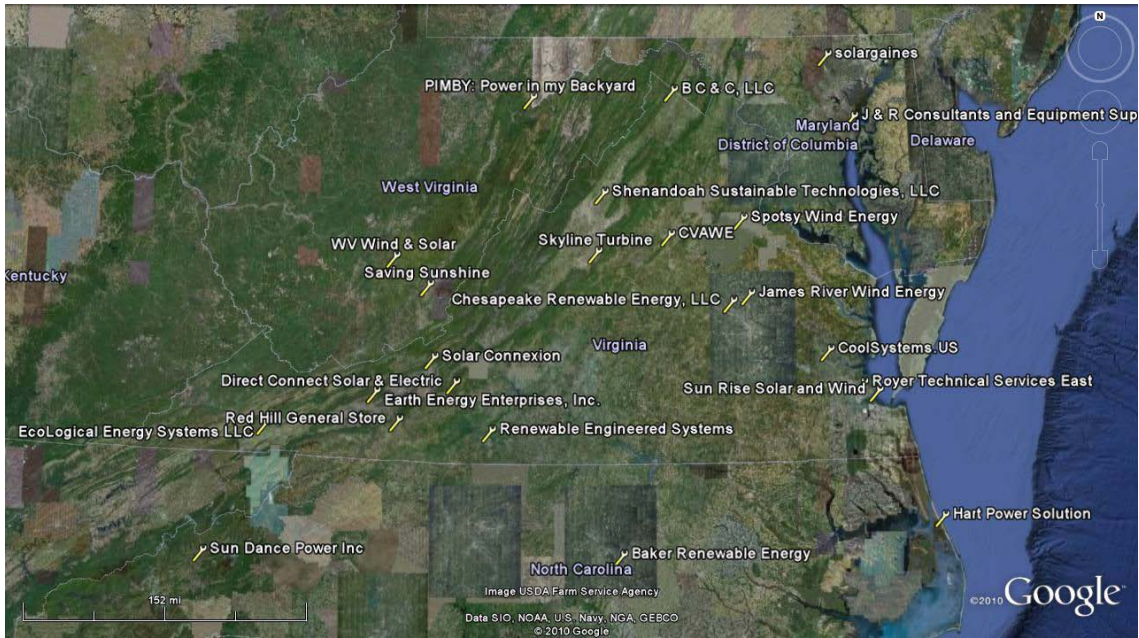


Figure 13. Mid-Atlantic Region Small Wind Installers

The wrench icon is used to symbolize the geographic location of each business, and the business name accompanies each icon. Combining the business locations in Figure 13 with the applicant locations in Figure 6, Figure 10, and Figure 12 yields Figure 14: the geographic distribution of all identified Mid-Atlantic stakeholders.

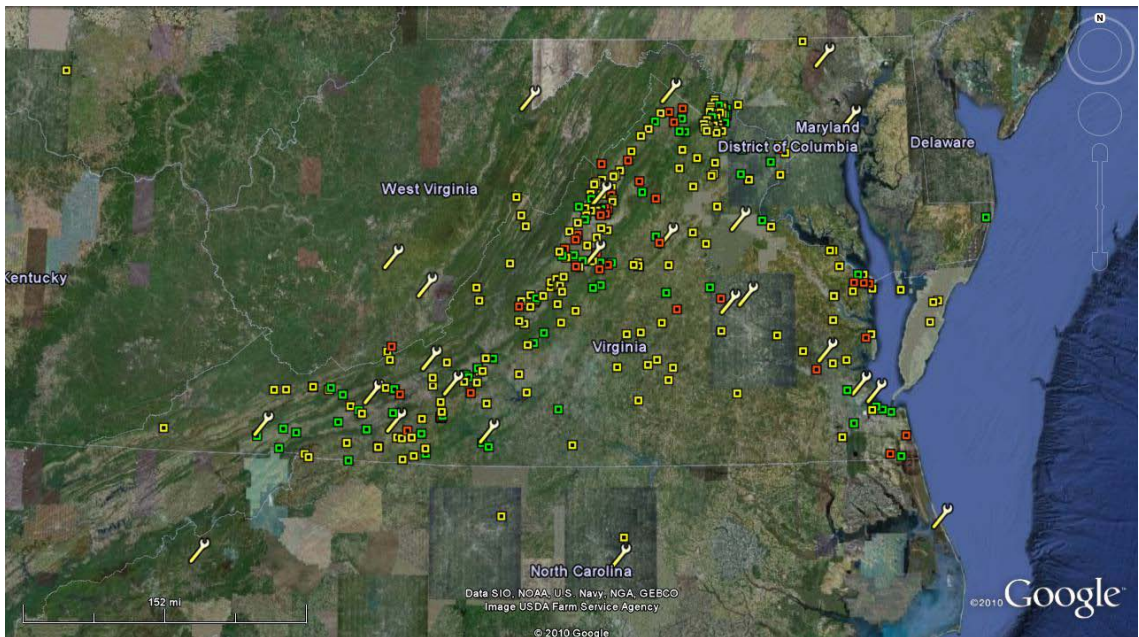


Figure 14. Mid-Atlantic stakeholders

### 3.4. Using the Maps

The Google Earth-based interactive mapping visualization is a powerful tool for understanding relationships between the wind resource, geography, terrain, and location of small wind energy stakeholders within the region as has been demonstrated in the previous sections. The ability to quickly enable and disable datasets and to view the plots at various scales allows users to tease out these relationships.

The tool also contains relevant information for each stakeholder embedded into the tool. This information includes name, address, and contact information, as shown in Figure 15. This method of organizing stakeholder data makes for easy identification of important stakeholder information, allowing users to efficiently obtain stakeholder data that they are searching for.

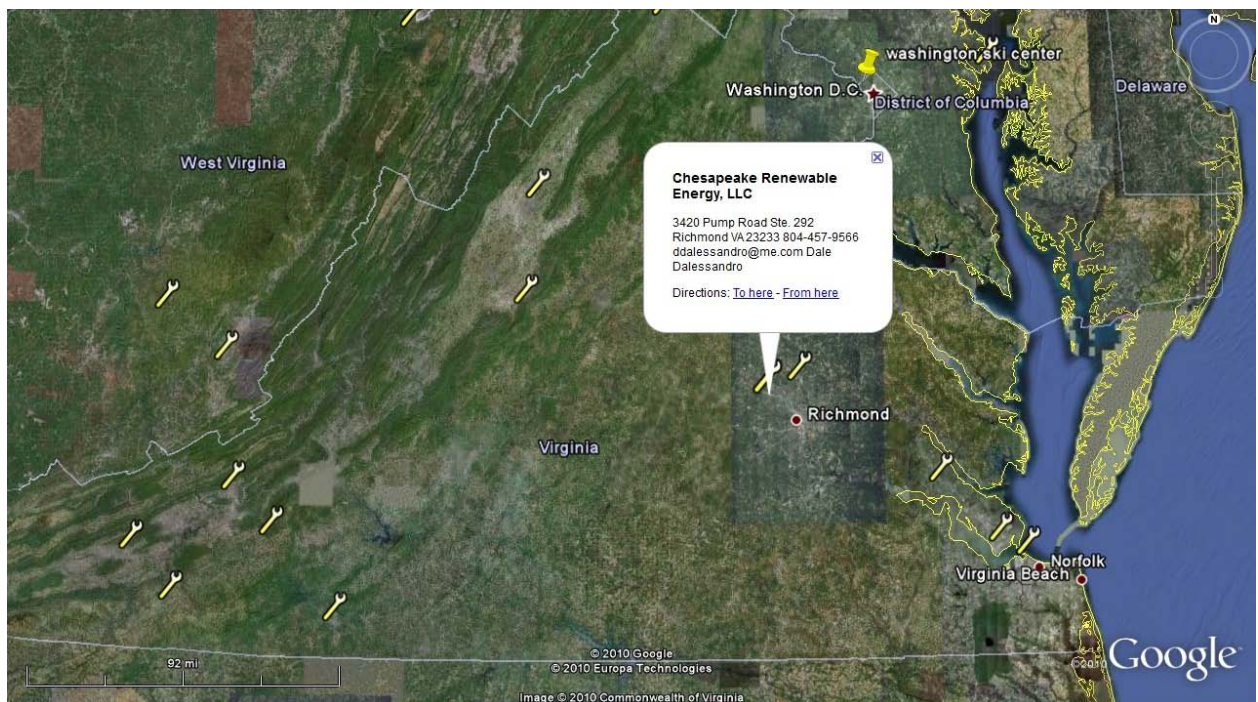


Figure 15. Example of information embedded within the geographic visualization tool.

This tool has been provided to members of the Virginia Center for Wind Energy and is included in the SWTTF note repository as discussed in Section 6.5.1. It is recommended that the map and corresponding spreadsheet continue to be used for storing and viewing stakeholder information and that they are continually updated to maintain their accuracy and relevance.



## **4. Mid-Atlantic Small Wind Energy Stakeholder Analysis**

The Small Wind Training and Testing Facility at James Madison University is meant to serve small wind stakeholders in the Mid-Atlantic region of the United States, particularly the stakeholders within the Commonwealth of Virginia. In order to tailor the development of the facility to best serve stakeholders in the region, their small wind turbine testing needs were identified with the use of a survey that was distributed to small wind stakeholders in Virginia, Maryland, West Virginia, and North Carolina. The responses to the survey have given insight into both the small wind testing needs of the region and the state of the region's wind industry as a whole. This insight has led to recommendations which will help direct the development of the facility, especially in terms of creating a testing strategy and making investments in turbines, towers, instrumentation, and other equipment.

The survey was designed to determine how to best develop testing services for existing and future companies within the small wind industry. It was modeled after a 2006 small wind stakeholders survey produced and distributed by the National Renewable Energy Laboratory (NREL) National Wind Technology Center (NWTC). (National Renewable Energy Laboratory, 2009) This national survey concerned the development of small wind certification testing and helped lead to the creation of the Small Wind Certification Council and the AWEA standards for small wind turbines. Though modeled after the 2006 NREL survey, the SWTTF stakeholder survey was customized to the task of producing information which will aid in SWTTF development.

The survey was distributed via email to forty nine (49) email addresses. Twenty five (25) of these belonged to small wind installers in Virginia and were provided by the Virginia Center for Wind Energy, which maintains a list of companies that provide installation services. The remaining addresses were obtained from internet searches for Mid-Atlantic small wind energy related organizations, including government, education, non-profit, and for-profit organizations in Virginia, Maryland, West Virginia, and North Carolina.

### **4.1. Human Subject Research**

The James Madison University Institutional Review Board is responsible for overseeing all human subject research at the University, and the Institutional Review Board falls under the auspices of the Office of Sponsored Programs at JMU. (University Policy Committee, 2010) Because the research presented herein requires interaction with human subjects, a process to determine whether this survey and the resulting analysis and reporting are considered human subject research was

undertaken with the assistance of the Office of Sponsored Programs. In the course of this process, a human subject research training course provided by the Collaborative Institutional Training Initiative was completed by the author. This training provides the following conditions which must be met in order for a research project to qualify as human subject research. First, the activity must be “a systematic investigation including research development, testing and evaluation, designed to develop or contribute to generalizable knowledge.” (Hicks, 2010) Second, the research must deal with a “living individual about whom an investigator (whether professional or student) conducting research obtains: 1. Data through intervention with the individual, or 2. Identifiable private information.” (Hicks, 2010)

In the case of the proposed survey, the activity is considered research, therefore the first condition is met. However the second condition is not met because, although it involves interaction with living individuals, and it does obtain data through intervention with the individuals, it does not obtain data *about* the individuals. The training course clarifies this type of interaction with the following:

Some research that involves interactions with people does not meet the regulatory definition of research with human subjects because the focus of the investigation is not the opinions, characteristics, or behavior of the individual. In other words, the information being elicited is not about the individual (“whom”), but rather is about “what”.(Hicks, 2010)

The subjects of the survey are asked questions about small wind turbine testing, not about themselves. Therefore, this survey does not require Institutional Review Board approval. However, as an extra measure of protection for the survey respondents, Qualtrics, an online surveying tool, was used to allow for anonymous responses from respondents.

## **4.2. Small Wind Stakeholder Survey**

The survey was comprised of an introduction and seven questions. See Appendix C for the full text of the survey. The number of questions was restricted to as few as necessary while still ensuring the ability to collect the desired information. Because the responses provided were entirely voluntary, the survey was designed to minimize the amount of time required of the respondents to complete and submit it in order to obtain a significant number of responses.

The survey introduction describes the purpose of the survey and why it might be in the interest of the recipient to respond. It explains that the survey is focused on identifying small wind turbine testing services that their organization may find useful. The introduction also encourages respondents to respond with as much or as little detail as they deem necessary, assures them that their responses will

be anonymous and will not be published and that general conclusions will be published. It asks those who receive the survey to forward it on to other small wind stakeholders in the Mid-Atlantic Region or to more appropriate members of their organization, and gives them a deadline for submission, along with contact information.

### **4.3. Survey Questions**

This section describes each question statement and explains the rationale for asking each question. The answers are discussed in the next section.

#### ***Question 1: Please identify your organization's functions in the small wind industry.***

The first question asked the respondents to identify how their organization functions within the small wind energy industry. The purpose of asking this question is to gain an understanding of the level of specialization within the region's small wind industry and allow responses to other questions to be parsed according to the function(s) of the respondent.

#### ***Question 2: What small wind testing services would your organization benefit from if available at JMU? Please consider all testing services that are applicable to the small wind industry. Please comment on the importance to your organization of the services that you list.***

The second question gets at the heart of the matter by asking respondents to list the small wind testing services that their organizations would benefit from if the services were available at JMU. The purpose of asking this question is twofold: first, to identify the most important testing services for small wind stakeholders in our area. This information would inform the development of small wind turbine testing capabilities at the SWTTF. Second, the question was asked to help identify the whole range of testing capabilities in the industry.

#### ***Question 3: Does your organization currently certify the small wind turbines that it manufactures, sells, installs, or uses? If yes, how does it certify and to what standards?***

The third question asks the respondent if their organization certifies the small wind turbines that it manufactures, sells, installs, or uses, and which standards the turbines are certified to. Although the AWEA standards (AWEA Small Wind Turbine Performance and Safety Standard, 2009) are becoming the industry standard, other standards and other standards and certification bodies do exist and have existed in the past. The answers to this question will indicate what role certification plays in the Mid-

Atlantic small wind industry, and which standards are relevant to the region. Because certification is a major function of many small wind testing facilities, the responses will inform the decisions regarding the importance and appropriateness of developing a small wind certification program at SWTTF.

***Question 4: Would your organization benefit from third party small wind certification at JMU? Would it benefit from shakedown or long-term testing at JMU? Which ratings - e.g. sound, annual energy output, rated power, durability – are most important to your organization? Please comment on the time frame for shakedown and long-term testing.***

The fourth question asks whether the respondent's organization would benefit from the availability of third-party small wind certification, shakedown testing, and long-term testing at JMU. Additionally, the question asks respondents to identify which performance ratings are the most important to their organization, suggesting sound level, annual energy output, rated power, and durability as examples. Question four also asks the respondents to comment on the time frame for shakedown and long-term testing that their organization would find acceptable. This question was designed to obtain responses which will help determine the demand for third-party certification. The responses will help determine the necessity and demand for shakedown testing, which is field testing of working prototypes and is generally a less intensive and detailed type of test. The responses will also provide information regarding long-term (more than one year) testing.

***Question 5: What experience does your organization have with small wind testing, certification, and labeling programs?***

Question five attempts to draw wisdom from stakeholder's previous experiences with small wind testing, certification and labeling programs. This will allow us to obtain an understanding of what has worked for small wind energy stakeholders in the Mid-Atlantic in the past.

***Question 6: How might your organization utilize both training and testing services that are offered by a single facility at JMU?***

One of the advantages of a small wind test facility at JMU is that the testing capabilities can be combined with extensive training and educational capabilities at a single location. Question six asks stakeholders to identify ways in which their organizations might leverage such a combination. The responses may guide the facility to develop in a way that helps stakeholders to take full advantage of the training and testing capabilities offered at the SWTTF.

***Question 7: Any additional feedback?***

The final question simply asks for any additional feedback in an attempt to capture respondent's thoughts about small wind testing which were not directly addressed in previous questions.

**4.4. Survey Responses**

The survey was distributed to forty nine (49) email addresses which represent both individuals and small businesses involved with small wind energy in the Mid-Atlantic region. Eleven responses were returned, providing a response rate of 22%. The responses were wide ranging, with some directly responding to the questions, some discussing their businesses, and some providing examples of testing and research facilities which they recommend we model the SWTTF after. This wide range of responses has proven useful for harvesting ideas and was exactly the kind of response the survey was intended to provoke.

***Question 1: Please identify your organization's functions in the small wind industry.***

Results to the first question indicate that individual organizations often perform multiple functions. Over half of the respondents indicated that they both act as installers and retailers. One respondent indicated that his or her organization performs all of the functions listed. Manufacturing and research were the least common function, with only two responses indicated that their organizations operate in these capacities. Three responses indicated education as a function, six indicated retail as a function, and ten indicated installation as a function.

These results suggest that the organizations within the small wind industry in the Mid-Atlantic Region operate in multiple roles and capacities, performing many functions within the region. The lack of specialization may indicate an industry which has not reached maturity. The results also suggest that the ratio of manufacturers to installers in the region is small. This is expected because installation services tend to operate locally whereas manufacturers may operate globally and ship their product. However, the numbers may be a result of the survey distribution methodology in that a comprehensive list of installers was used in the distribution but not a comprehensive list of manufacturers.

Two manufacturers were identified in the region. They are likely to have the most potential for utilizing a test facility for traditional turbine testing. These respondents provided the name of their

companies and, in one case, a link to their website. I recommend building partnerships with both known and any other regional manufacturers that are identified as the SWTTF develops.

The respondents who indicated “education” as a function of their organizations also noted a variety of other functions such as installation and retail. This indicates that installers and retailers have an interest in providing education in small wind energy. However, it also suggests that no responses were submitted from educational organizations such as trade schools, community colleges, or universities. These educational institutions with an interest in small wind energy are known to exist in the region and have been present at regional small wind energy conferences. It is recommended that the SWTTF develop relationships with other educational institutions through outreach efforts.

Finally, the first question asks respondents to indicate additional small wind energy functions that their organizations provide to the region. Four respondents indicated that their organization performed a task that other than the ones listed. These tasks were solar installation, system design, energy auditing, and site evaluation. It is reasonable to assume that solar power and energy auditing companies would be interested in small wind energy, and that small wind energy companies would be interested in solar and energy auditing, because the three technologies complement each other and share a customer base. It is recommended that the SWTTF keep this relationship in mind by considering the development and implementation of solar systems and solar system testing capabilities. These dual capabilities could provide empirical evidence of hybrid solar and wind system capabilities.

***Question 2: What small wind testing services would your organization benefit from if available at JMU? Please consider all testing services that are applicable to the small wind industry. Please comment on the importance to your organization of the services that you list.***

The second question asks respondents which small wind turbine testing capabilities their organizations would benefit from if the services were offered at the SWTTF. Only one response indicated traditional small wind testing services such as reliability testing and testing to turbine performance standards such as the AWEA standards. Perhaps the other responses did not include these traditional testing services because the survey asks what services the organizations would benefit from directly, and the majority of respondents are installers and retailers who do not directly benefit from traditional testing services the way that manufacturers might.



Two responses mention the Small Wind Certification Council (SWCC), which operates as a third party certification body and utilizes the AWEA standards as discussed in section 2.5. This is the first of many mentions of the SWCC within the responses and indicates that there is knowledge of the SWCC in the region. The responses to this question mention that testing at JMU is redundant due to the existence of the SWCC. This is not the case because the SWCC relies on tests performed at test facilities such as the SWTTF, and does not perform any tests itself. (FAQs for Manufacturers, 2010) It is recommended that the SWTTF work to educate the region's small wind stakeholders about the complementary role that test centers such as the SWTTF and the SWCC play in certifying small wind turbines.

Three responses list small wind related services which do not fall into the testing category. These are wind mapping, permitting services, and the need for better organized website for Virginia small wind data, resources, and information. One respondent points to the Maryland Energy Administration website, which contains well organized information regarding programs and resources for all major energy sources, including wind. It is recommended that the SWTTF, in collaboration with the Virginia Center for Wind Energy, the Virginia Wind Energy Collaborative, the Virginia Department of Mines, Minerals, and Energy, and other energy organizations develop and maintain a similarly comprehensive, umbrella website. This will help promote the SWTTF and act as a vehicle to bring in stakeholders who might benefit from testing and training services provided by the SWTTF.

Two responses to the second question mention services directly related to vertical axis wind turbines, showing significant interest in this branch of small wind turbine technology. One response suggests the SWTTF perform fundamental vertical axis turbine research and points to this type of research which is taking place at California Institute of Technology (Caltech), and the other mentions possible manufacturing of vertical axis wind turbines in the region. It is recommended that the SWTTF investigate the special requirements for vertical axis wind turbine testing and consider tailoring the facility to those needs in order to serve regional vertical axis wind turbine development.

***Question 3: Does your organization currently certify the small wind turbines that it manufactures, sells, installs, or uses? If yes, how does it certify and to what standards?***

Three responses to this question indicated that they do not certify the small wind turbines that they use. Two sets of state standards (New York and California) were identified by one installer/retailer as requirements for the turbines they sell. This respondent indicated that these state standards must be met in order for their customers' purchases to be eligible for state grant money. Tests performed at national labs such as NREL's National Wind Technology Center, and tests performed at Windward

Engineering of Spanish Fork, Utah were cited by two responses from installers as important to their organizations. Another installer/retailer mentioned warranties, but did not specify if those were manufacturer warranties for the turbines or warranties on the installation work that his or her organization performs. Two respondents mention the SWCC, and none mention the AWEA standards that the SWCC certifies to, indicating that the role of the SWCC and AWEA standards might need clarification to stakeholders in the region.

***Question 4: Would your organization benefit from third party small wind certification at JMU? Would it benefit from shakedown or long-term testing at JMU? Which ratings - e.g. sound, annual energy output, rated power, durability – are most important to your organization? Please comment on the time frame for shakedown and long-term testing.***

Five responses indicated that their organizations would benefit from third party certification at JMU. One respondent mentioned shakedown testing as beneficial for companies that have viable but unproven turbine designs. The same respondent explains that rated power is a poor performance indicator because it is a measure of maximum output, which is rarely achieved in actual conditions. This suggests a need for the development of an actual output performance rating, which may be difficult to develop due to the extreme variability between small wind turbine installations. Another response indicated that such third-party certification would help the respondent's organization decide which turbine models to purchase and resell. Another cites turbine dependability as important because of the long payback period on small wind turbine investments, implying the need for long term testing for dependability.

Two responses mention SWCC requirements, or AWEA standards, but the respondents do not expand on how their organizations might benefit from SWTTF certification to the SWCC requirements. One response indicated that his or her organization would not benefit from such testing at JMU because turbines in production are required to meet standards and that manufacturers have reputations that help guide his or her organization's choice in where and what to resell. Resistance to third-party certification is likely due to the perceived costs of testing and compliance.

Although the SWCC has potential to become the primary third-party certification body in the industry, only 20% of respondents that mentioned the SWCC. The region's exposure to the SWCC is likely to increase significantly when the first turbines are certified, as is discussed in section 2.5.

***Question 5: What experience does your organization have with small wind testing, certification, and labeling programs?***

None of the responses indicated any experience with small wind testing, certification, or labeling programs, which indicate the lack of other standards or certifying bodies in the region, both presently and in the past.

***Question 6: How might your organization utilize both training and testing services that are offered by a single facility at JMU?***

Two responses from stakeholders who indicate manufacturing as a function of their organization showed the desire to utilize a JMU based test facility for their turbines. This strengthens the recommendation that the SWTTF works to identify and build partnerships with manufacturers in the region. One installer/retailer answers that their organization would utilize the test facility to test their turbines to New York State standards. It is recommended that the SWTTF look into these standards as an alternative or compliment to the AWEA standards. Another respondent cites cost and availability as important factors for SWTTF utilization.

***Question 7: Any additional feedback?***

This open ended question provided interesting responses and comments. One response asserts that the short term future of small wind energy in the region will rely on industrial and community users as opposed to individual land owners. Another response mentions that the cost of certifying wind turbines is nearly the same regardless of the size of the turbine, but the small companies that manufacture small turbines do not have the funds for certification that large companies have. One of the most beneficial responses suggests that an installer certification program for small wind installation companies may be useful. The North American Board of Certified Energy Practitioners (NABCEP) currently provides small wind certification for installation of systems under 100kW. As a response to this comment, it is recommended that the SWTTF consider providing certification for installers and consider joining the NABCEP in the effort.

## 5. Proposed Site Analysis

The IEC Standards for Small Wind Turbine Testing (IEC 61400-12-1) provides an appendix which details the guidelines and requirements for small wind certification facilities. (Smith, 2008) It is recommended that these standards be one of the first purchases made by the SWTTF at a cost of approximately \$3,100 dollars. These requirements should be consulted frequently throughout the development of the facility. Adhering to these standards is essential to allow the SWTTF to test small wind turbines for certification to AWEA standards.

In the absence of the IEC Standards for Small Wind Turbines, a PowerPoint presentation authored by Joe Smith of NREL's National Wind Technology Center was used to provide basic guidelines for development of a small wind test facility. This presentation, titled *Guidelines for SWT (small wind turbine) Test Site* (Smith, 2008), addresses small wind testing facility site analysis, and was presented at a small wind testing workshop in 2008. The presentation explains that the IEC standards are the proper guidelines and requirements for small wind test facilities to follow. However, the presentation provides guidelines for new facilities that do not want to start with the rigor of the IEC standards. Smith suggests that, until small wind turbine testing facilities are able to meet the IEC standards, all exceptions to the IEC standards should be noted on test results. (Smith, 2008)

### 5.1. Land Area

The first parameter to consider is the land area of the proposed wind testing site. According to Joe Smith, general rule of thumb is that the facility should be 20 times the diameter of the rotors to be tested. (Smith, 2008) Therefore, the size of the site is dependent upon the size of the turbines to be tested.

In the case of the proposed SWTTF site shown in Figure 16, a Bergey xl1 turbine has been installed at the site since October 2004 (Chesapeake Renewable Energy, LLC, 2008). Assuming that the existing Bergey xl1 is representative of size of turbines to be tested at the proposed site, the length of the site should be 50m, which is twenty (20) times 2.5m, the rotor diameter of the Bergey xl1. Therefore, the site's 100 m length is twice the recommended 50 m length, and the area of the site is more than enough.



Figure 16. The proposed SWTTF site location lies between the East Campus Library and Interstate 81. The yellow line indicates the length of the proposed site at its widest, approximately 100 m, and is close to perpendicular to the prevailing wind direction, which is discussed in section 5.2.3.

## 5.2. Wind Resource

Another significant set of parameters is the average annual wind speed and other wind characteristics which will strongly affect the testing capabilities of a wind test facility. A resource between Class 2 and 3 is ideal according to information gathered during a visit to Appalachian State University's Small Wind Research and Demonstration Site as discussed in the section 6.1. Lower class winds will not provide enough data throughout a wide range of wind speeds, and higher classes may subject the turbines to forces beyond their designed threshold, resulting in component and turbine failure. The proposed SWTTF site appears to experience Class 1 winds, as is discussed in the next section of this chapter. However, more wind analysis is necessary to fully characterize the site's wind resource.

### 5.2.1. Wind Resource Assessment

Approximately six months of wind speed and direction data from the anemometer and wind vane located at the existing JMU small wind turbine site was obtained and analyzed. This data set begins near the end of July 2003 and ends near the end of March 2004, with a break between mid-November 2003 and mid-January 2004. The data from this site is especially pertinent because it is sourced from the exact location of the proposed small wind turbine test site. Unfortunately, six months of data is not enough to make solid conclusions regarding the wind resource at any site. However, some

interesting information has been gleaned from this small data set using Windographer software for analysis and two years of data from Shenandoah Regional Airport was obtained and analyzed to provide wind speed trends for the site. The histogram depicted in Figure 17 was created from the proposed site indicates that, when the wind is blowing, the average speed is between 3 and 4 m/s at an approximate height of 27 m. Additionally, the histogram shows that the wind is not blowing approximately 30% of the time.

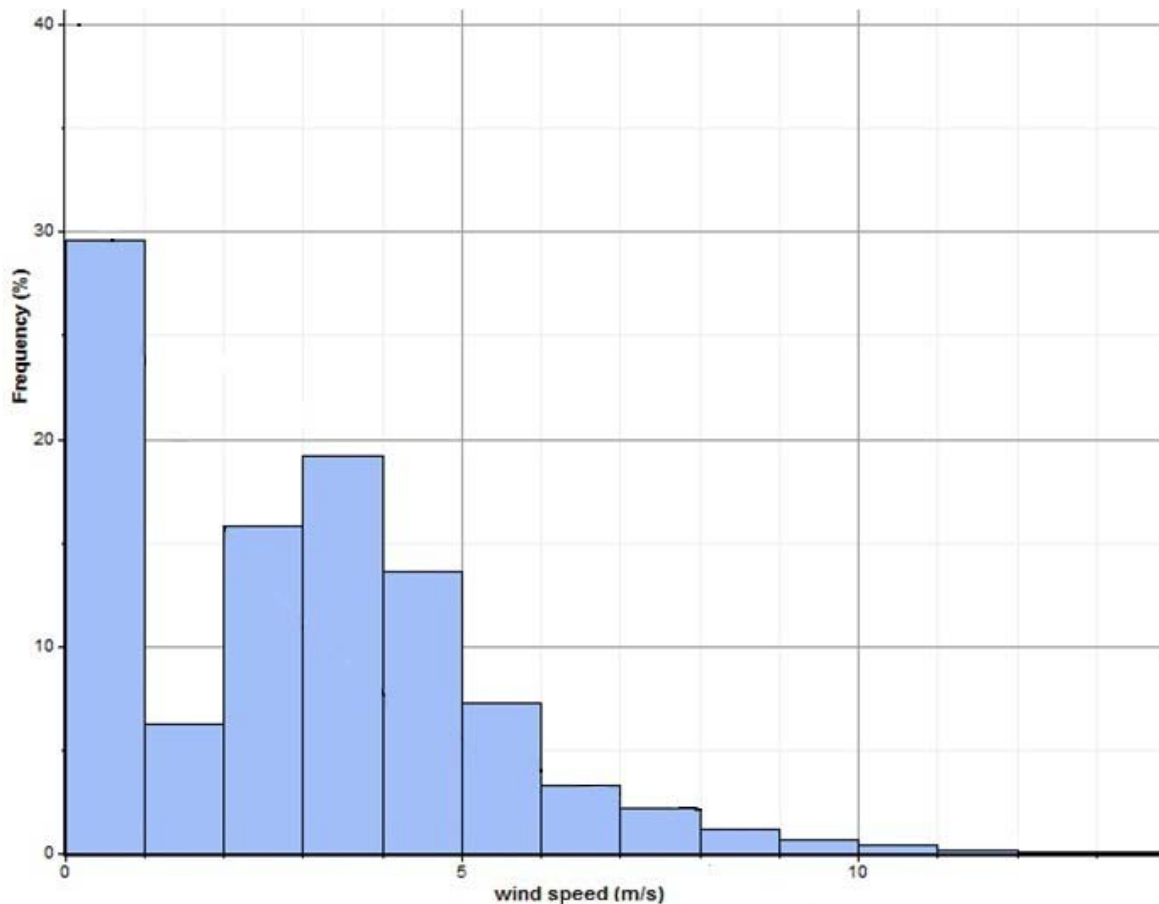


Figure 17. SWTTF proposed site wind speed histogram



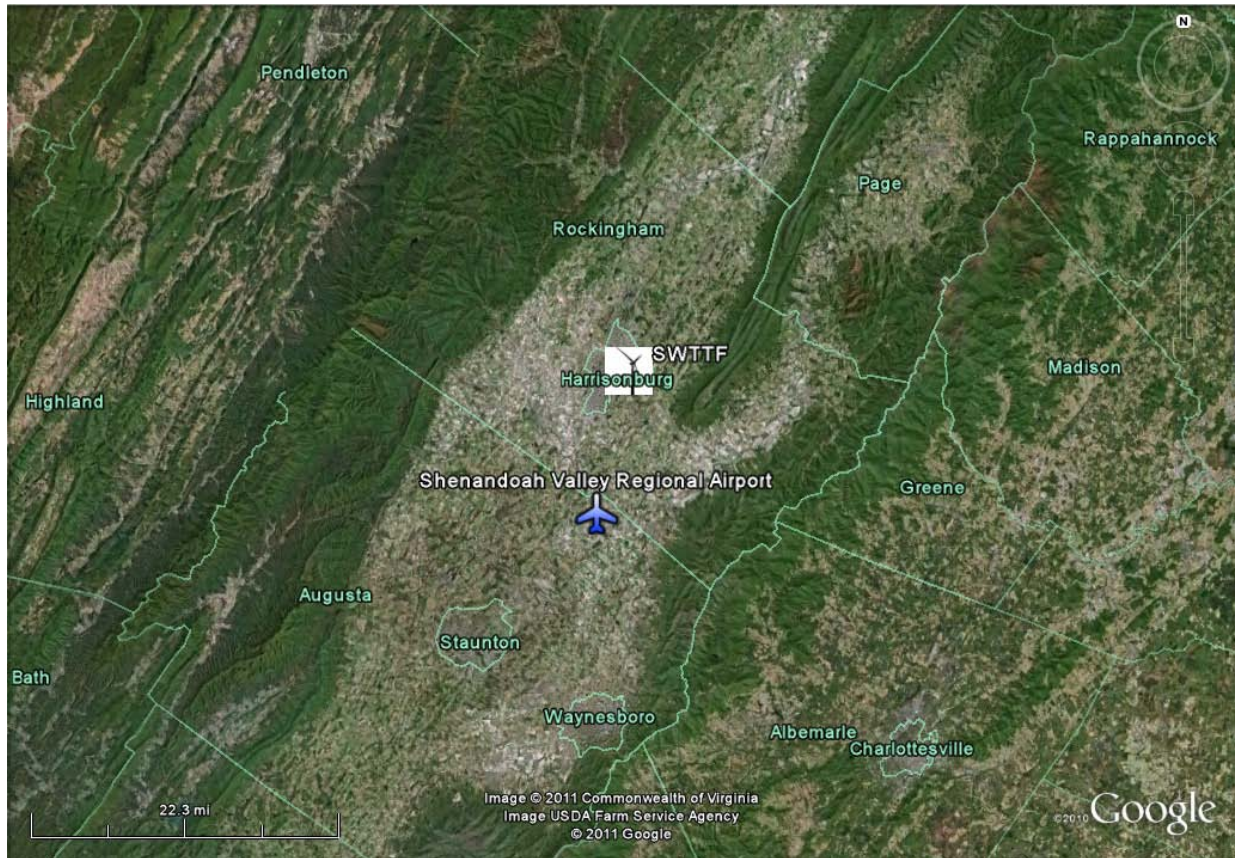


Figure 18. Geographic locations of Shenandoah Valley Regional Airport and the proposed SWTTF site

Data from Shenandoah Valley Regional Airport was acquired and analyzed to determine a quantitative trend of wind speeds in the region. The airport is approximately 18 kilometers south of the proposed SWTTF site. Both sites are located in regions of similar terrain within the Shenandoah Valley.

Two years of data (2003 and 2004) was obtained from the National Oceanographic and Atmospheric Administration. (National Oceanic and Atmospheric Administration, 2011) The monthly averages of this data were calculated and plotted as seen in Figure 19. This plot provides an annual mean and a predictable trend of wind speed behavior at the airport.

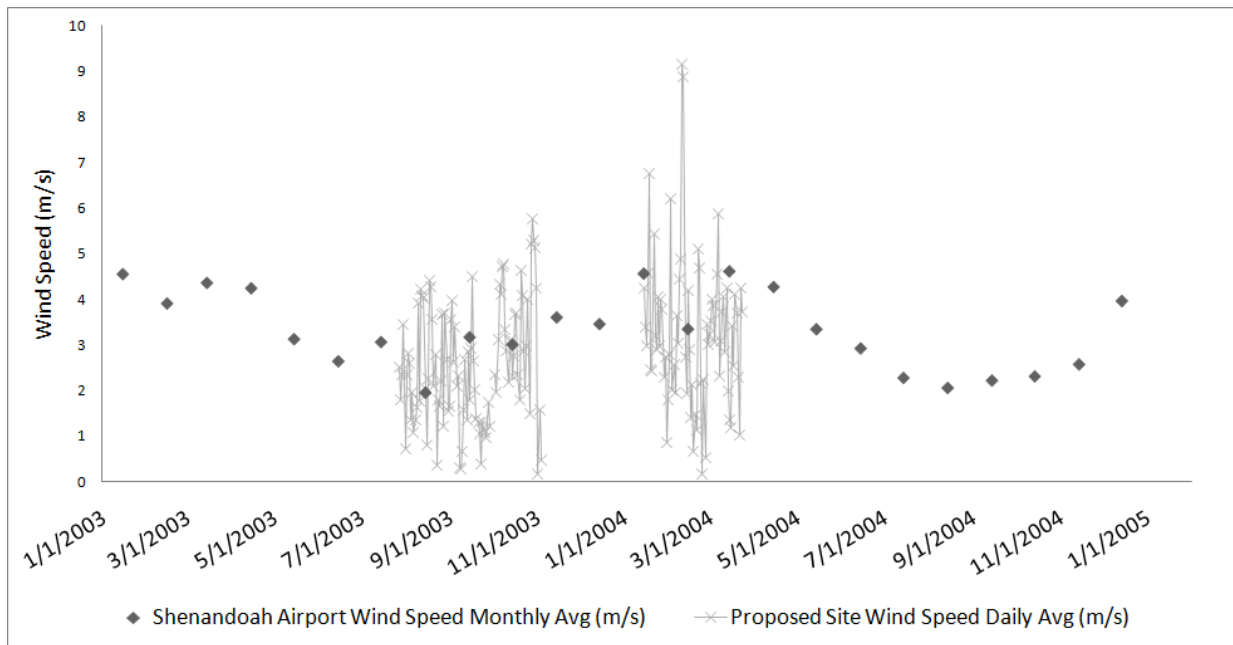


Figure 19. Time series data from the proposed site and Shenandoah Regional Airport

In addition to the Shenandoah Airport data, daily averages from the proposed site were calculated and plotted on top of the monthly airport data. The overlying plots allow for a qualitative assessment of the relationship between the wind speed at Shenandoah Regional Airport and at the proposed site. The daily averages appear to trend lower than the monthly averages, but otherwise the two sets show similar behavior. This qualitative assessment helps to better quantify the incomplete data set for the proposed site.

### 5.2.2. Wind Power Class

The wind power class is determined by measuring or calculating annual average wind speeds at either 10 m or 50 m. Figure 20 depicts the industry accepted wind power class breakdown for both heights. The anemometer at the proposed SWTTF site provided this data for a height of approximately 27 m. (Chesapeake Renewable Energy, LLC, 2008) Without data from a second height available, it is not possible to calculate the average wind speed at either 10 m or 50 m. However, comparison with the wind class definition for 10 m shows that the proposed site most likely experiences Class 1 winds because the overall mean wind speed for the entire 6 month data set is 2.4 m/s at 27 m. The threshold for Class 2 starts at 4.4 m/s at 10 m, and increases as height increases. Therefore, based on the six month data set that was available for this analysis, it is determined that the proposed SWTTF site experiences Class 1 winds.



It is highly recommend that, if possible, additional analysis be carried out with a minimum of 1 year of data taken at multiple heights. It is expected that the East Campus Library building, which was completed in the summer of 2008, will have significant effects on the site wind characteristics. These effects can be determined through the analysis of data taken both before and after the building construction. This analysis would provide solid basis for wind power class site characterization.

<b>Classes of Wind Power Density at 10 m and 50 m<sup>(a)</sup></b>				
<b>10 m (33 ft)</b>			<b>50 m (164 ft)</b>	
<b>Wind Power Class</b>	<b>Wind Power Density (W/m<sup>2</sup>)</b>	<b>Speed<sup>(b)</sup> m/s (mph)</b>	<b>Wind Power Density (W/m<sup>2</sup>)</b>	<b>Speed<sup>(b)</sup> m/s (mph)</b>
<b>1</b>	<100	<4.4 (9.8)	<200	<5.6 (12.5)
<b>2</b>	100 - 150	4.4 (9.8)/5.1 (11.5)	200 - 300	5.6 (12.5)/6.4 (14.3)
<b>3</b>	150 - 200	5.1 (11.5)/5.6 (12.5)	300 - 400	6.4 (14.3)/7.0 (15.7)
<b>4</b>	200 - 250	5.6 (12.5)/6.0 (13.4)	400 - 500	7.0 (15.7)/7.5 (16.8)
<b>5</b>	250 - 300	6.0 (13.4)/6.4 (14.3)	500 - 600	7.5 (16.8)/8.0 (17.9)
<b>6</b>	300 - 400	6.4 (14.3)/7.0 (15.7)	600 - 800	8.0 (17.9)/8.8 (19.7)
<b>7</b>	>400	>7.0 (15.7)	>800	>8.8 (19.7)

(a) Vertical extrapolation of wind speed based on the 1/7 power law

(b) Mean wind speed is based on the Rayleigh speed distribution of equivalent wind power density. Wind speed is for standard sea-level conditions. To maintain the same power density, speed increases 3%/1000 m (5%/5000 ft) of elevation.  
(from the Battelle Wind Energy Resource Atlas)

Figure 20. Wind class chart (Guey-Lee, 2008)

### 5.2.3. Prevailing wind direction

A sense of wind direction can be obtained from a wind rose/satellite image overlay as seen in Figure 21. The wind is most frequent from the south-southwest direction. However, this data was taken before the East Campus Library was built. It is reasonable to assume that the construction of the East Campus Library has had an effect on the prevailing wind direction, especially because the prevailing

wind comes from the direction of the Library. I recommend that further research into the effect of the East Campus Library on wind speeds and direction be performed as the SWTTF project moves forward.



Figure 21. Wind rose overlay

#### 5.2.4. Turbulence

Another consideration related to annual wind speed is the amount of turbulence that the turbines are subjected to. Excessive turbulence may subject the turbines to stresses beyond their designed threshold. Although measuring of turbulence is not addressed in the presentation slides, one method of quantifying turbulence involves the use of a three dimensional sonic anemometer, as discussed in section 6.3.1.

### 5.3. Accessibility and Terrain

Another aspect that is discussed in the *Guidelines for SWT test sites* presentation involves assessing the accessibility of the site. (Smith, 2008) In the case of the proposed SWTTF site, accessibility is excellent, and is one of the most appealing characteristics of the site. It is located in a highly developed

region of the Shenandoah Valley. Paved roads provide easy access for vehicles. The on campus location will allow technicians to operate at the site on a daily basis, whereas a mountaintop location is not conducive to daily access. This should decrease the amount of instrument and turbine downtime that is required to troubleshoot problems, perform inspections, and carry out repairs.

The test location terrain, especially upwind, is an important factor to consider. Major obstructions in the immediate vicinity will increase turbulence and decrease average wind speed. The southwest edge of the proposed SWTTF site is located a mere 30 m from the northwest edge of the East Campus Library (ECL). Wind direction data collected before the construction of the East Campus Library indicates that the prevailing wind passed through the proposed SWTTF site from a south-southeast direction (as discussed in the Prevailing Wind Direction section of this chapter), which is exactly where the ECL now sits. Thus, the proposed SWTTF site may have major upwind obstructions to contend with.

#### **5.4. Local Laws**

Consideration of the legal and ownership issues regarding the site location is important. The land is owned by JMU and thus should not pose a problem as long as the university is willing to make a long term commitment to the SWTTF. The local zoning and height ordinances must be taken into account. The presence of the existing turbine indicates that these ordinances do allow for wind turbines, but the particulars were not investigated for this thesis.

#### **5.5. Infrastructure**

Space and infrastructure for an outbuilding are available at the proposed site (see section 6.4 for more detail regarding the outbuilding). Electrical power, telephone with long distance service, and wired internet are necessary for operating wind tests. The communication infrastructure allows technicians to contact each other and technical support when instrumentation and turbine problems arise, and allow for autonomous data transmission to a central server through the internet.

## **6. Site Development**

This chapter builds on the undergraduate thesis entitled *Regional Small Wind Turbine Test Facility on JMU/CISAT Campus* authored by Denise Caspar. (Caspar, 2008) Caspar's thesis describes model facilities for a small wind test facility at JMU. The facilities described are the National Wind Technology Center at the National Renewable Energy Laboratory in Boulder, Colorado, and the Appalachian State University Small Wind Research and Demonstration Site. The thesis also describes requirements for the erection of small turbines and meteorological towers, including legal restrictions, tower location, cable runs, anchors, and other construction topics.

This work's focus is on the instrumentation necessary to run tests on small wind turbines and on the development of a data and note repository system for the facility that will withstand years of development and use by temporary researcher assistants. This research draws from the author's previous experience in working with university research institutions, previous work with metrological towers and instrumentation, a visit to the Appalachian State University Small wind Research and Demonstration Site, and interactions with small wind application engineers at Campbell Scientific, Inc.

### **6.1. Appalachian State University Small Wind Research and Demonstration (SWRD) Site Visit**

A meeting with three SWRD technicians was held on September 24, 2010 at Appalachian State University's Small Wind Research and Demonstration Site at Beech Mountain. The visit was coordinated through the site faculty advisor, Dr. Dennis Scanlin of the Department of Technology in the College of Fine and Applied Arts. The goal of the meeting was to gain an understanding of the physical site, including the turbines, towers, wire runs, instrumentation, and outbuilding. Additionally, the author assisted in his hosts' work activities. These included assessing the condition of various towers and components and planning for the installation of new towers.

#### **6.1.1. Small Wind Research and Demonstration Site**

The mountaintop site is located on a south facing slope and includes a telecommunication tower and outbuilding in addition to the small wind test facility. The facility is currently composed of six turbines and towers and one outbuilding. The two buildings, a generator, and other electrical infrastructure are enclosed by a chain link fence in the northern portion of the site (see Figure 22). The northern end is a densely forested area and the southern portion is grassy with a downward slope. The turbines and towers reside outside the fence in the downward sloping southern portion of the site (see Figure 23).

A short, unpaved road connects to a nearby paved road and provides access to the site from the southwest. The turbine testing facility shares the mountaintop with a number of resort condominiums.



Figure 22. Appalachian State Wind Test Center north facing view of outbuilding and telecommunication tower.



Figure 23. View of three towers from the outbuildings facing south.

Guyed, freestanding lattice and monopole towers have been used at the site. The guy wires attach to either buried or poured concrete anchor points. Tilt-up towers are preferred for most test applications because of the ease in which they can be lowered and erected, providing easy maintenance and replacement of turbines, anemometers, and other components.



### 6.1.2. Instrumentation

All power produced by the turbines is fed into the outbuilding where it is either used to charge a battery bank or converted to AC and fed into the grid. All power data is measured with the use of power transducers made by Ohio Semitronics, as shown in Figure 24. (Summerville, 2005)

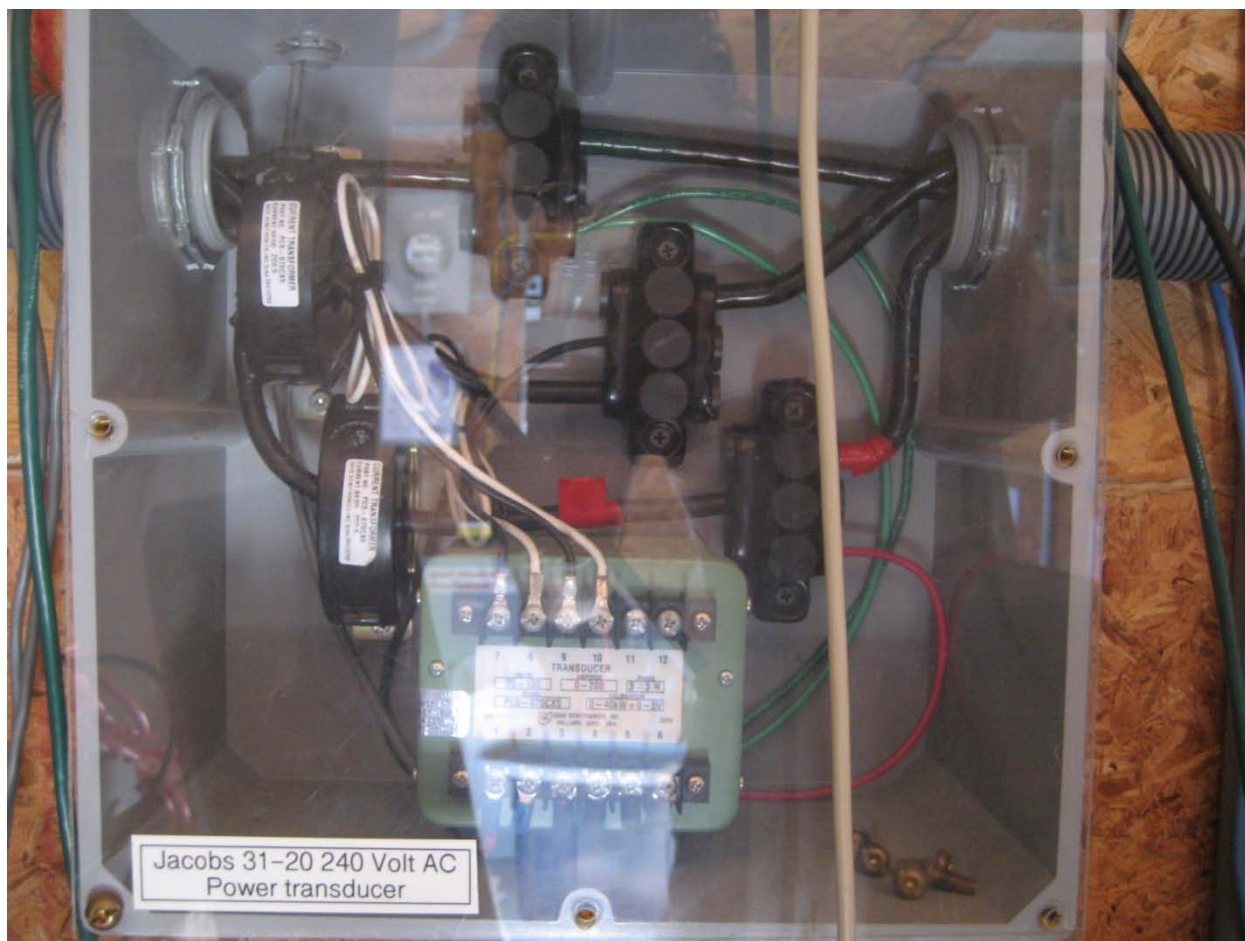


Figure 24. All power data is measured with the use of power transducers. Each transducer is housed in an enclosure.

The data from the power transducers, anemometers, wind vanes, thermocouples, and barometric pressure sensors was taken with a CR-1000 datalogger made by Campbell Scientific, Inc. This datalogger interfaces with a desktop computer running LoggerNet software. The datalogger can be programmed by technicians with a BASIC-like programming language to interact with a large variety and number of sensors and other instruments. Data processing and analysis routines can be executed

as data is being taken, reducing the need for post-processing. (CR1000, 2010)

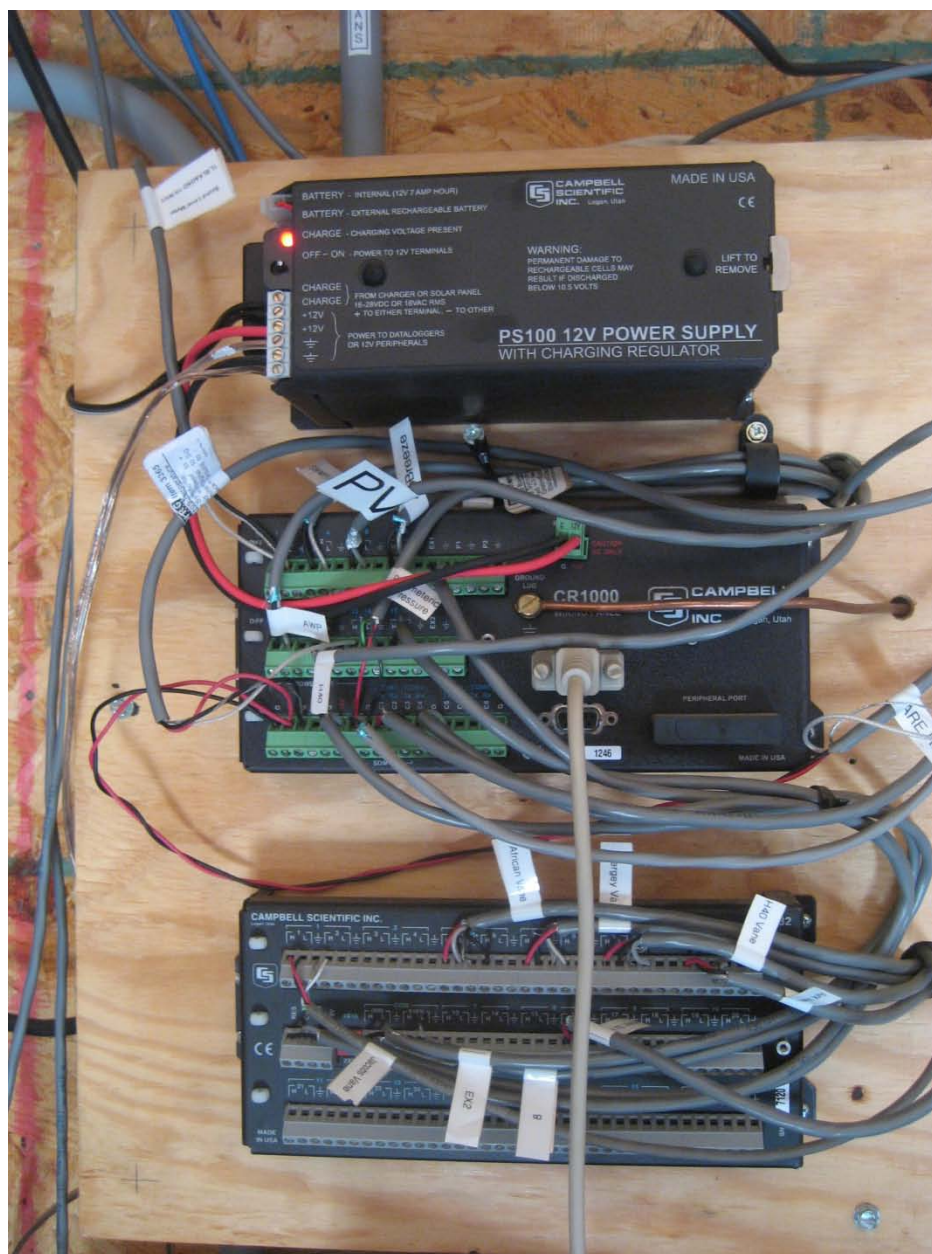


Figure 25. CR1000 datalogger with PS100 power supply and AM16/32B multiplexer

The CR1000 contains eight (8) differential analog input channels which measure voltage. These channels are used with thermocouples, power transducers, wind vanes, some anemometers, and other sensors. The Small Wind Research and Demonstration center requires more than eight analog inputs because of the large number of sensors that the center is using. In order to expand the CR1000 analog inputs, a AM16/32B multiplexer is used. This device provides an additional 16 differential analog inputs and interfaces with the CR1000. (AM16/32B, 2010)

The two pulse counting channels in the CR1000 were expanded with the use of two SDM-INT8 measurement modules (see Figure 26). Like the AM32B multiplexer, these modules interface with the CR1000 and expand the two pulse counting channels by providing an additional eight pulse counting channels each. These channels are necessary for anemometers that output pulses where each pulse represents one revolution. The SDM-INT8 converts pulses into binary data which is outputted to the CR1000 digital I/O ports. (SDM-INT8, 2010)



Figure 26. Two SDM-INT8 measurement modules provide an additional eight pulse counting channels each.

The data from all instruments is stored onsite using the desktop computer. The data is also uploaded to the university web servers once per day. This setup allows for access to the data without requiring technicians to physically be on site. The system as a whole is illustrated in Figure 27, which is sourced from Brent Summerville's *Report from the Small Wind Research and Demonstration Facility Beech Mountain, NC*. (Caspar, 2008)



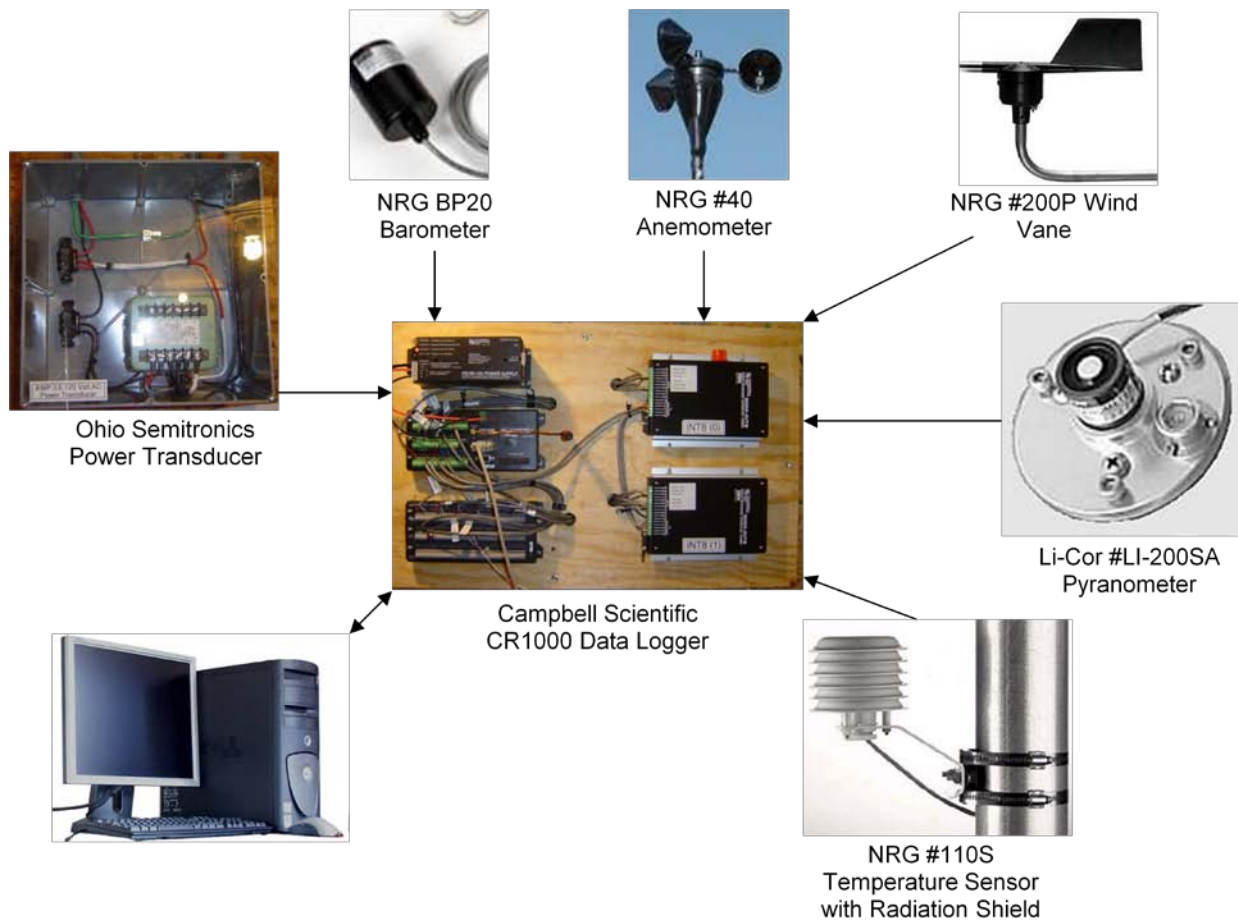


Figure 27. Instrumentation overview as illustrated by Brent Summerville in his *Report from the Small Wind Research and Demonstration Facility Beech Mountain, NC.* (Caspar, 2008)

## 6.2. SWTTF Instrumentation Package

The SWTTF will require a significant investment in instrumentation in order to begin testing small turbines. This basic instrumentation package, including installation, must fit within the \$125,000 budgeted for instrumentation. (Miles, 2010)

A comprehensive list of major instrumentation components has been assembled in order to begin the process of instrumenting the facility. The list does not include the turbines themselves or components related to the turbines, including towers, anchors, wire runs, and underground conduits. This list draws heavily from the document entitled *Automated Data Acquisition Systems for Small Wind Turbine Performance Monitoring* published by Campbell Scientific, Inc. (SWP-Series, 2010), as well as from knowledge gained during the Appalachian State University Small Wind Research and Demonstration site visit.

### **6.2.1. Basic Instrumentation Package**

The basic instrumentation package described herein will provide the facility with the ability to carry out power performance tests, shakedown tests, and long term tests. The package will provide the majority of instruments and sensors needed for SWCC certification testing except for the sound components of those tests. Additional information about SWCC certification testing is located in section 2.5.

### **6.2.2. System Computer and Software**

The data acquisition system (DAQ) requires an always on, internet connected, dedicated master computer. This computer system need not be an especially powerful machine as it will primarily run LoggerNet datalogger support software, which is not resource intensive. LoggerNet will not work with 64 bit processors. (LoggerNet Compatability, 2010) A low-end Dell manufactured desktop computer purchased through James Madison University's acquisition system would be adequate. The desktop form factor, as opposed to a laptop form factor, allows individual components to be added and replaced easily, extending the life of the system. Windows 7 Professional 32 bit operating system is recommended because of its stability and, unlike Windows XP, Windows 7 will continue to be supported by Microsoft for years to come. The system should contain at least one serial port adapter, providing two (2) serial ports. Additional built in serial ports are often helpful in connecting with various instruments. A built in card reader will add convenience for SWTTF technicians.

### **6.2.3. Datalogger**

The datalogger is the heart of the instrumentation system. Like most of the instrumentation described in this chapter, the recommended datalogger is made by Campbell Scientific, Inc. CS data acquisition equipment is widely used across meteorological, agricultural, and industrial fields, including the wind energy industry. A variety of Campbell Scientific dataloggers would work in the SWTTF, however, based on information gathered from wind energy application engineers at CS, I recommend the CS1000. (Smart, 2010) The CS1000 provides eight (8) differential (sixteen single-ended) analog channels, three (3) switched excitation channels, two (2) pulse counters, and eight (8) control ports. Onboard computing allows for complex data acquisition and basic data processing routines. (CR1000, 2010)

The system computer will interface with the datalogger via a TCP/IP connection and an NL-120 Ethernet interface. The NL-120 converts the 40-pin peripheral port output on the CR1000 datalogger

into a TCP/IP signal. (NL120 Ethernet Interface, 2010) A network switch can be used to network the datalogger output, an internet connection, and any other TCI/IP devices.

#### **6.2.4. Sensors and Transducers**

One power transducer is required to measure the power output of each turbine. The standard transducers are produced by Ohio Semitronic, Inc. A less costly alternative is produced by Veris Industries, Inc., although this is a new product and the reliability is not known. The price list at the end of this chapter includes three (3) power transducers. However, one will be needed with the addition of each wind turbine.

At least one cup anemometer and wind vane are required for wind speed and direction measurements. However, in order to fully characterize the wind, multiple wind speed and direction measurements are desirable. One anemometer and wind vane are already operating at the site, and other anemometers may be obtained through the anemometer loan program, which is discussed in section 3.1. Therefore, only one additional anemometer is recommended. A two dimensional sonic anemometer made by Gill Instruments Ltd. provides high accuracy ( $\pm 3^\circ$  for wind direction,  $\pm 2\%$  of wind speed reading), high output frequency (40Hz averaged to 1Hz output), and does not contain moving parts.

Barometric pressure, air temperature, and relative humidity are the final three essential measurements for a small wind turbine test facility such as the SWTTF. These measurements can be acquired from a CS106 pressure sensor manufactured by Vaisala and a CS215-L RH and temperature sensor, both sensors are distributed by Campbell Scientific, Inc. The relative humidity and temperature sensor requires a solar radiation shield, also obtainable from Campbell Scientific, Inc.

These basic components to the instrumentation package are tabulated in Table 3. The prices and part numbers are sourced from Campbell Scientific, Inc. *2010 Price List*. (2010 U.S. Price List, 2010) Minor components such as wiring, housings, and fittings are not included in this table.

Table 3. Basic instrumentation package price list

Instrumentation package component	Quantity	Part Number	Cost (\$)	Note
System computer	1	OptiPlex 980 MT	1153	Low end Dell desktop with serial port adapter from JMU procurement
Operating system	1	Windows 7 Professional Upgrade	70	Purchase online or from JMU bookstore
Datalogger	1	CR1000	1440	
Rechargeable power supply	1	PS100	240	May be trickle charged from grid, wind turbine, or solar panel
Wall charger	1	9591		
Wind speed	1	Windsonic 1-l	1080	2D sonic anemometer
Barometric pressure	1	Cs106	660	Vaisala ptb110 barometer
Temp/rh	1	Cs215	325	Temp and rh probe
shield	1	41303-5A	120	6 plate solar radiation shield
AC Power Transducer	3	Ohio semitronics	1500	dmt multifunction transducer or dwv ac watt/var transducer
Communications	1	NL120	220	Ethernet interface requires cr1000
Software	1	Loggernet	599	Advanced datalogger support software
Total Cost			10,407	Includes 4% educational discount from Campbell Scientific, Inc.

The approximate total cost of this basic package is less than 10% of the total amount budgeted for instrumentation. The remaining 90% of the budget may be put towards duplicating parts of the basic instrumentation package to expand capacity, setting up and configuring the package, and towards purchasing advanced instrumentation options. These are discussed in section 6.3.1.

### **6.3. DAQ Stability and Reliability**

All efforts should be made to ensure that the DAQ system remain stable and reliable because long term, uninterrupted measurements are required for wind turbine tests. One of the first efforts that will need to be made is to reformat the system computer immediately after it has been delivered. This will provide the computer with a clean installation of Windows 7 which will eliminate unnecessary software that will come bundled with the computer. This bundled software is often the cause of reliability problems. Another important and ongoing requirement is that the master computer be dedicated solely to monitoring the DAQ through LoggerNet software. Additional software should not be installed on this computer without significant consideration of the effect that it will have on the stability of the system.

These restrictions are necessary for reliable measurements. However, they severely restrict the possibility for experimentation. The SWTTF can and should serve as a laboratory for students and professors with an interest in instrumentation and measurement to learn how to operate dataloggers and to execute experimental projects. However, experimental development projects, especially those executed by students, are often temporary in nature, and are often developed using nonstandard practices without proper documentation. If these projects affect the basic DAQ system and master computer, the effects can far outlast the length of the student project, causing major difficulty when the facility needs to quickly come online and operate at full utilization. Therefore, it is strongly recommended that students and professors strongly resist the temptation to develop LabVIEW, Matlab, and other software programs for system control, data acquisition, data processing, and data analysis using the basic instrumentation and master computer.

Instead, experimental projects should take place on a separate, secondary computer system that is designated for experimental use and should not interfere with the communication or setup of the primary DAQ and master computer system in any way. Therefore, it is recommended that a secondary, advanced instrumentation package be purchased and installed to support experimental projects which do not directly relate to the primary training and testing functions of the facility.

### 6.3.1. Advanced Instrumentation Package

This package will duplicate certain components of the primary package, namely the datalogger and the system computer. Many other components, such as temperature sensors, can be shared between systems as long as the advanced system can not affect the basic system through the shared component. The other pieces of instrumentation in this package are recommended because they can provide students and faculty with extensive research capabilities that extend well beyond wind turbine testing into related research fields such as weather prediction and turbulent air flow modeling.

The first advanced piece of instrumentation to be considered for research purposes is the three dimensional sonic anemometer. This device provides both the horizontal and vertical components of wind flow. This three dimensional data allows researchers to study turbulent air flows, which can play an important role in wear and tear on small wind turbines. Additionally, the three dimensional sonic anemometers can provide insight into the furling behavior of small wind turbines, as described in a 2005 technical report published by NREL and illustrated in Figure 28. (Meadors, 2005)



Figure 28. Three dimensional sonic anemometer taking data for furling research at NREL National Wind Technology Center(Meadors, 2005)

Acquiring three dimensional wind data is also possible through the use of SODAR and LIDAR based measurements. The combination of sonic anemometer, SODAR, and LIDAR measurements has the



potential to yield unique and significant observations, leading to a greater understanding of how wind moves through the boundary layer of the atmosphere.

Turbine imaging provides a vast array of possibilities for advanced turbine testing and experimentation. A digital video camera proves useful for general monitoring as well as recording events such as bird strikes, lightening hits, icing, and component failures. High speed imaging and photogrammetry may aid in operation, vibration, and furling studies during proof of concept and shakedown tests for small wind turbine prototypes. Infrared imaging is already a highly developed capability with the program of Integratd Science and Technology at JMU. This capability may provide the opportunity to collect thermal cycling data to aid in wear and tear assessments as well as to provide health monitoring.

Vibration, strain, and furling behavior may also be studied with the use of strain gages and other direct contact sensors. The number of sensors may outnumber the channels available on the experimental CR1000 datalogger. In this case, multiplexers may be employed to expand the available channels without purchasing a new data logger. The type of multiplexer depends on the type of sensors being used. For example, a SDM-INT8 may be used for interval timing, and the AM16/32B increases the number of analog inputs.

Sound measurements are important for certification but will be difficult due to the proposed site's proximity to vehicular traffic. Nonetheless, developing sound measurement capability is a sound investment for the SWTTF.

Table 4 is an indication of the costs associated with an advanced instrumentation package. The recommended system computer is a Dell Latitude E6510 high end laptop. The mobility provided by a laptop will provide for easier troubleshooting and configuring in the field. Additional research is required for specification of high speed imagers, SODAR, LIDAR, strain, and sound measurements.

Table 4. Advanced instrumentation package price list

Instrumentation package component	Quantity	Part Number	Cost (\$)	Note
System computer	1	Latitude E6510	1396	High end Dell laptop with Windows 7 Professional, extra memory (4GB) and 9-cell battery from JMU procurement
Serial to USB adapter	1	USB2-8COM-M	170	Industrial 8 port serial to USB adapter allows eight RS-232 compatible instruments to interface with system laptop
Datalogger	1	CR1000	1440	
Rechargeable power supply	1	PS100	240	May be trickle charged from grid, wind turbine, or solar panel
Wall charger	1	9591		
Wind speed and direction	1	CSAT3	7700	3D sonic anemometer
CSAT3 carrying case	1	16764	360	Hard case with foam protection
Communications	1	NL120	220	Ethernet interface requires cr1000
Software	1	Loggernet	599	Advanced datalogger support software

## 6.4. Outbuilding

An outbuilding is a major acquisition necessary for development of the SWTTF. Keeping in line with the ideal for job creation and retention in Virginia, two capable Virginia builders have been identified through web searches. These are: Easi-Set© Industries in Midland, Virginia and VFP, Inc. in Roanoke, Virginia. Both companies provide telecommunication style outbuildings which would fit the needs of the SWTTF.

The building must provide weather-proof shelter for instrumentation and electrical systems. It should be adequate in size to contain a workbench, desk, tool chest, storage for turbine parts and other materials. The building must provide conduits to allow power and signal wires to pass from the outside to the inside. The building should be connected to both the electrical grid and the internet. Heating and air conditioning should be considered, but are not absolutely necessary.

## **6.5. Data and Documentation Repository**

It is expected that many people will have a hand in the setup, operation, and execution of tests and experiments in the SWTTF. The nature of this type of operation requires that all participants be meticulous in documenting, cataloging, and storing their work. A major step towards making this happen is the creation of a central repository for all data and documentation. As long as all students, faculty, and staff who become involved in the facility are briefed regarding the existence of the repository and how it is used, important data and documentation of changes should be available when needed.

### **6.5.1. Documentation Repository**

A documentation repository has been created and currently serves as a record of all notes, pictures, and documents that were collected during the work leading up to and including the writing of this thesis. Microsoft OneNote is the medium in which this documentation repository exists. This productivity software is bundled with most versions of Microsoft Office, and suits the needs of a documentation repository. The user interface is designed to mimic a paper notebook by organizing notes into notebooks, where each notebook contains multiple tabs, and each tab contains multiple pages.

All major issues which are ongoing throughout the facility's lifetime receive their own notebook to contain documentation regarding that issue. These include the physical site itself, the basic instrumentation and DAQ system, and the data collected. Within each notebook, the issues are broken down into major components with the use of tabs, and then again with the use of pages, which is where the raw notes are located. For example, the Data notebook has a tab dedicated to each major data collection test or experiment, as seen near the top of Figure 29. The first page in each tab contains an overview of that data set, including a screenshot of the data, the date and time of collection, what was collected, and any errors observed. Subsequent pages detail how and when this data was processed, and document the location of the processed data.

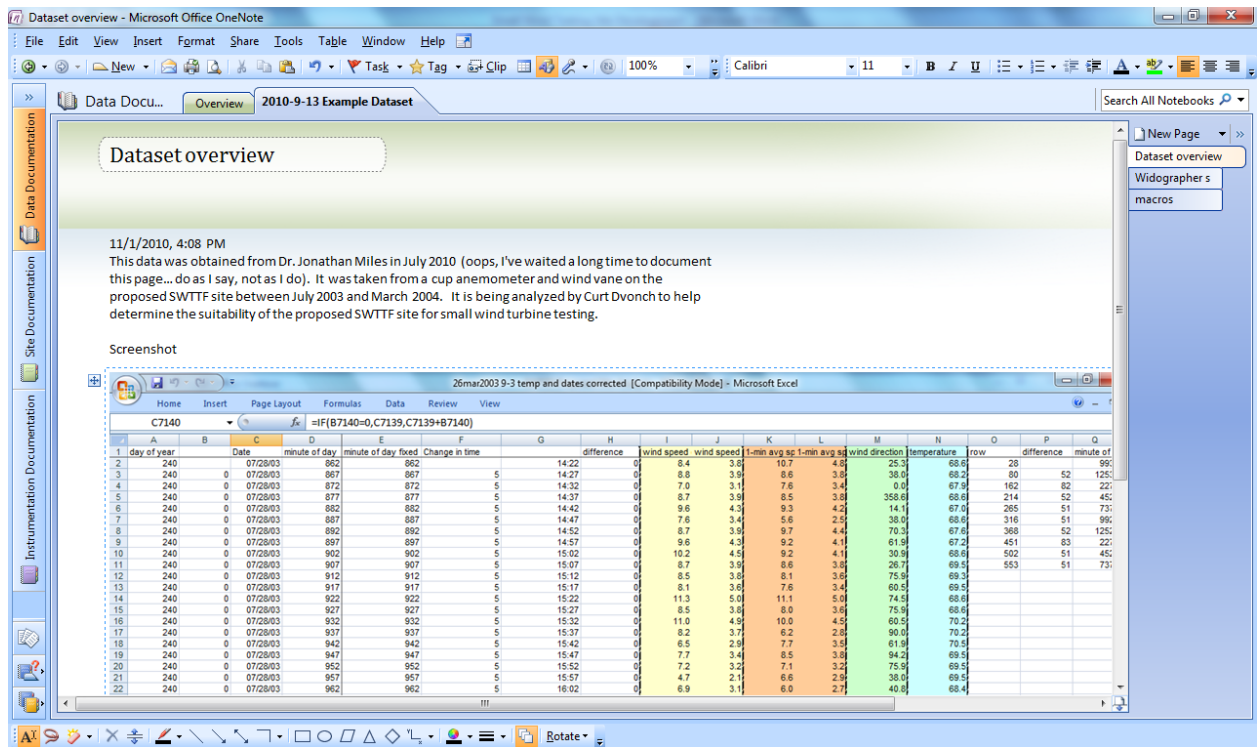


Figure 29. Example documentation in OneNote. Notice the notebooks along the left side of the interface which correspond to major issues, the tabs along the top which break the issues down into components, and the pages along the right which contain raw notes.

It is strongly recommended that all developments and changes related to the SWTTF be noted within the proper OneNote notebook. These notebooks can and should be synced across computers, eliminating the need for multiple copies of the notebooks. A single version should be maintained across all relevant computers including the master and secondary computers and all users of the facility should be instructed in how to use the system.

### 6.5.2. Data Repository

This work does not include the creation of a data repository because this task requires access to the JMU network and the purchase of networking components. Instead, it is recommended that a central server location be created for the purpose of storing data. The implementation of the data repository should include the establishment of folder and file naming and organization conventions which should be documented in the documentation repository.

## **7. Conclusion**

This work is intended to serve as a reference and guide to those who are tasked with continuing the development of the SWTTF. This document, combined with the thesis titled *Regional Small Wind Turbine Test Facility on JMU/CISAT Campus* authored by Denise Caspar (Caspar, 2008), and the raw notes contained within the data repository (section 6.5.2) will be invaluable to the students, faculty, and staff who take the lead in further developing the SWTTF into a robust small wind testing facility.

This study provides an analysis of the small wind energy industry in the Mid-Atlantic region of the United States. In addition to the analysis, comprehensive stakeholder maps have been created. These interactive maps can be used to inform future decisions regarding the stakeholders that the SWTTF will serve. A sample of regional stakeholders have been surveyed to gauge their small wind turbine testing needs and to acquire more information about the region's small wind industry. Many recommendations based on this interaction with stakeholders has been made. The entire survey is located in Appendix C, and the actual responses are located in the note repository in the Dvnoch Thesis notebook.

The proposed site for the testing facility has been analyzed for its wind resource. Other factors such as the area, accessibility, terrain, and infrastructure of the site have been addressed. Additional research into those factors is needed once the AWEA *Small Wind Turbine Performance and Safety Standards* have been acquired.

A visit Appalachian State University's Small Wind Research and Demonstration Site at Beech Mountain greatly informed this work's discussion of site development. A comprehensive instrumentation package that is tailored to the needs of the facility has been generated based on the system employed at the Beech Mountain site and on recommendations provided by renewable energy application engineers at Campbell Scientific, Inc. A very important discussion addressing system stability and reliability is presented, along with solutions that allow students and faculty to carry out experimental projects at the facility while mitigating the risk of downtime. An advanced instrumentation package is detailed to support research projects for the facility, and a documentation repository has been created to track all changes and developments within the facility.

### **7.1.Recommendations**

Recommendations have been gathered and discussed here. The chapter and section relevant to each recommendation is listed, and a short discussion of each is included.

Table 5. Collection of recommendations for further development of the SWTTF

Chapter and Section	Recommendation	Discussion
3.4 Using the Maps	Use the interactive maps and corresponding spreadsheet as a data repository. Update them as stakeholder information changes.	The maps provide a means of identifying stakeholders by location and allow for comprehensive assessment of the small wind industry at a glance. Regular upkeep of the database is necessary to keep the maps relevant and will provide the SWTTF with a comprehensive list of stakeholders in the region.
4.4 Survey Responses Question 1	Build partnerships with both known and any other regional manufacturers that are identified	Manufacturers are the primary group of stakeholders that are able to make use of the testing capabilities that the facility will provide. Manufacturers generally pay for testing services, which can lead to the SWTTF's financial self sustainment. The two known manufacturers are listed in the note repository under the survey tab of the Thesis notebook.
4.4 Survey Responses Question 1	Build partnerships with educational institutions that show an interest in small wind energy.	No educational institutions responded to the stakeholder survey, however institutions with an interest in small wind energy are known to exist in the region. The use of outreach activities to connect with these institutions is recommended.
4.4 Survey Responses Question 1	Develop solar and wind hybrid system testing capability.	Small wind and solar are considered complementary technologies, and are often found within the same hybrid system. Therefore, it is important to be able to test both technologies. These tests may provide empirical evidence that assesses how well the two technologies complement each other.
4.4 Survey Responses Question 2	Develop and maintain a comprehensive, umbrella website for small wind energy activities in Virginia.	A singular, comprehensive web presence would greatly benefit the small wind industry in Virginia. Collaboration with the Virginia Center for Wind Energy, the Virginia Wind Energy Collaborative, the Virginia Department of Mines, Minerals, and Energy, and other energy organizations is essential. This website would help promote the facility and act as a vehicle to bring in stakeholders who might benefit from testing and training services provided by the SWTTF. See the Maryland Energy Administration website for an excellent model.
4.4 Survey Responses Question 2	Investigate the special requirements for vertical axis wind turbine testing and consider tailoring the facility to those needs.	Two survey responses out of 11 mentioned vertical axis wind turbines and one indicated future manufacturing in the region. Providing specialized vertical axis testing capabilities and expertise would distinguish the SWTTF from other testing facilities.



4.4 Survey Responses Question 7	Consider joining the NABCEP to providing certification for installers.	A diverse set of capabilities that bring funds into the SWTTF is essential for the self-sufficiency of the facility. Certifying the reliability and skill of a small wind installer will improve the long term prospects of the industry, and the NABCEP has a developed installer certification program.
5 Proposed Site Analysis	Purchase the IEC standards for Small Wind Turbine Testing.	These standards are what the SWCC certifies to, and will provide valuable guidelines for further development of the facility. Three sections and one Amendment will be necessary for a total cost of approximately \$3100 dollars. These are IEC 61400-1 (2005-08) Ed. 3.0 English, IEC 61400-1-am1 (2010-10) Ed. 3.0, English IEC 61400-2 (2006-03) Ed. 2.0 English, and IEC 61400-12-1 (2005-12) Ed. 1.0 English.
5.2.2 Wind Power Class	Carry out additional wind speed and direction analysis with a minimum of 1 year of data taken at multiple heights.	A full understanding of the proposed SWTTF site's wind resource is essential to the operation of the facility. This study may also investigate the effects of the East Campus Library building on wind speed and direction. This topic would be excellent for a senior thesis project.
6.3 DAQ Stability and Reliability	Resist the temptation to develop LabVIEW, Matlab, and other software programs on the basic instrumentation system	The basic instrumentation system should be dedicated to taking data for small wind turbine tests. This system needs to be completely reliable, and therefore should not be used for any other purposes.
6.3 DAQ Stability and Reliability	Develop a secondary, advanced instrumentation package to support experimental projects which do not directly relate to the primary training and testing functions of the facility.	This secondary system should not interfere with the basic system in any way. After being instructed in how to avoid interfering with the basic system, students and faculty should be encouraged to experiment on this secondary system.
6.5.1 Documentation Repository	Maintain detailed documentation of all changes and developments related to the SWTTF OneNote notebooks that are synced across all necessary computers.	Detailed documentation is the only method of overcoming the problems created by the temporary nature of student technicians. All students and faculty involved with the SWTTF should be instructed in the use of the documentation repository and should make detailed notes about their activities.
6.5.2. Data Repository	Create and maintain a data repository for the purpose of storing data.	It is impossible to predict when SWTTF staff will need historic data. Therefore, it is imperative that all data be stored in both its raw and processed form at a location where it will be safe and accessible for years to come. The data should be well documented, properly named, and properly filed.

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# **AWEA Small Wind Turbine Performance and Safety Standard**



American Wind Energy Association  
1501 M Street NW, Suite 1000  
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## **AMERICAN WIND ENERGY ASSOCIATION STANDARDS**

Standards promulgated by the American Wind Energy Association (AWEA) conform to the AWEA Standards Development Procedures adopted by the AWEA Board of Directors. The procedures are intended to ensure that AWEA standards reflect a consensus to persons substantially affected by the standard. The AWEA Standards Development Procedures are intended to be in compliance with the American National Standards Institute (ANSI) Essential Requirements. Standards developed under the AWEA Standards Development Procedures are intended to be eligible for adoption as American National Standards.

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## **FOREWORD and BACKGROUND**

The Foreword and Background sections are included with this document for information purposes only, and are not part of the AWEA Small Wind Turbine Performance and Safety Standard.

### **Foreword**

The goal of this standard is to provide meaningful criteria upon which to assess the quality of the engineering that has gone into a small wind turbine meeting this standard, and to provide consumers with performance data that will help them make informed purchasing decisions. The standard is intended to be written to ensure the quality of the product can be assessed while imposing only reasonable costs and difficulty on the manufacturer to comply with the standard.

### **Background**

AWEA is recognized by the American National Standards Institute (ANSI) as an Accredited Standards Developer and the AWEA standard will be submitted for adoption as an American National Standard. This standard has been developed in a regimented ANSI process for “voluntary consensus standards” which requires participation from a range of representatives for manufacturers, technical experts, public sector agencies, and consumers.

The draft that follows has been developed over the last five years in a process that involved over 60 participants, three meetings, 22 hours of conference calls, countless e-mails, a list serve, and five intermediate drafts. It represents hundreds of hours of detailed discussion, debate, compromise, revision, and formal response. The Canadian Wind Energy Association has been actively involved since the beginning and the British Wind Energy Association has now adopted and approved this standard almost word for word.

The proposed standard was developed by the AWEA Small Wind Turbine Standard Subcommittee, which was chaired by Mike Bergey of Bergey Windpower Co. Members of the subcommittee have included the following people. Please note that there has been some turnover in the subcommittee, some positions have changed, and not all members were active (though they did receive the drafts and correspondence).

<b>Name</b>	<b>Affiliation</b>	<b>Stakeholder Category</b>
Bill Colavecchio	Underwriters Laboratory	Certifying Agency
Lex Bartlett	Aeromag	Manufacturer
David Blittersdorf	Earth Turbines	Manufacturer / Consumer
David Calley	Southwest Windpower	Manufacturer
Jito Coleman	Northern Power	Manufacturer
David Laino	Endurance	Manufacturer
Robert Preus	Abundant Ren. Energy	Manufacturer
Steve Turek	Wind Turbine Industries	Manufacturer
Dr. Craig Hansen	Windward Engineering	Technical Expert
Robert Poore	Global Energy Concepts	Technical Expert
Ken Starcher	Alternate Energy Institute	Technical Expert
Trudy Forsyth	National Renewable Energy Laboratory	Researcher / Technical Expert
Jim Green	National Renewable Energy Laboratory	Researcher / Technical Expert
Hal Link	National Renewable Energy Laboratory	Researcher / Technical Expert
Brian Vick	USDA/Bushland	Technical Expert
Brent Summerville	SWCC	Technical Expert
Alex DePillis	Wisconsin Energy Office	State Energy Office / Consumer
Jennifer Harvey	NYSERDA	State Energy Office
Cassandra Kling	New Jersey BPU	State Energy Office
Dora Yen	California Energy Comm.	State Energy Office
Paul Gipe	California	Consumer
Mike Klemen	North Dakota	Consumer
Heather Rhoads Weaver	Washington	Consumer / AWEA
Mick Sagrillo	Wisconsin	Consumer
Brad Cochran	Colorado	Interested Party
Samit Sharma	Canada	CanWEA
Svend de Bruyn	Deltronics	Canadian Industry

Other participants in the development of this proposed standard have included (as they were affiliated at the time of their involvement):

Mark Bastasch  
 Ralph Belden, Synergy Power  
 Michael Blair  
 David Blecker, Seventh Generation  
 Bob Clarke, Ventera Energy  
 Dean Davis, Windward Engineering  
 John Dunlop, AWEA  
 Henry DuPont, Lorax

Mike Gray, Gray Engineering  
Jeffrey Haase, State of Minnesota  
Tod Hanley, Bergey Windpower  
Robert Hornung, CanWEA  
Arlinda Huskey, NREL  
Dale Jones, Geocorp  
Dan Juhl, DanMar  
Steve Kalland, NCSU  
Peter Konesky, State of Nevada  
Andy Kruse, Southwest Windpower  
Jean-Daniel Langlios  
Amy Legere, Southwest Windpower  
Malcomb Lodge, Entegritty Wind  
Charles Newcomb, Entegritty Wind  
Chuck Maas  
Dennis Makeperce, E.R.D.  
Tom Maves, State of Ohio  
Michael Mayhew  
Richard Michaud, US-DOE  
Jacques Michel, E.R.D.  
Paul Migliore, NREL  
Lawrence Mott, Earth Turbines  
Jennifer Oliver, Southwest Windpower  
Philippe Quinet  
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David Sharman, Ampair / BWEA  
Robert Sherwin, Vermont Wind Power Int'l  
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P.V. Slooten  
Eric Stephens  
Brian Smith, NREL  
Jeroen van Dam, NREL / UL  
David VanLuvanee  
Jane Weismann, IREC  
Kyle Wetzel, Consultant  
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# AWEA Small Wind Turbine Performance and Safety Standard

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# AWEA Small Wind Turbine Performance and Safety Standard

## 1 General Information

### 1.1 Purpose

This standard was created by the small wind turbine industry, scientists, state officials, and consumers to provide consumers with realistic and comparable performance ratings and an assurance the small wind turbine products certified to this standard have been engineered to meet carefully considered standards for safety and operation. The goal of the standard is to provide consumers with a measure of confidence in the quality of small wind turbine products meeting this standard and an improved basis for comparing the performance of competing products.

### 1.2 Overview

1.2.1 This performance and safety standard provides a method for evaluation of wind turbine systems in terms of safety, reliability, power performance, and acoustic characteristics. This standard for small wind turbines is derived largely from existing international wind turbine standards developed under the auspices of the International Electrotechnical Commission (IEC). Specific departures from the IEC standards are provided to account for technical differences between large and small wind turbines, to streamline their use, and to present their results in a more consumer-friendly manner.

1.2.2 No indirect or secondary standards references are intended. Only standards directly referenced in this standard are embodied.

### 1.3 Scope

1.3.1 This standard generally applies to small wind turbines for both on-grid and off-grid applications.

1.3.2 This standard applies to wind turbines having a rotor swept area of 200 m<sup>2</sup> or less. In a horizontal-axis wind turbine this equates to a rotor diameter of ~ 16 m (~ 52 ft)

1.3.3 A turbine system includes the wind turbine itself, the turbine controller, the inverter, if required, wiring and disconnects, and the installation and operation manual(s).

1.3.4 In cases where several variations of a turbine system are available, it is expected that a full evaluation would be performed on one of the most representative arrangements. Other variations, such as different power output forms, need only be evaluated or tested in the ways in which they are different from the base configuration. For example, a wind turbine available in both grid-intertie and battery charging versions would need

separate performance tests if both versions were to be certified, but would not need a separate safety evaluation in most cases.

- 1.3.5 Except as noted in Sections, 4.2, 4.5, 5.2.3, 5.2.4, 5.2.5 and 6.1.8, towers and foundations are not part of the scope of this standard because it is assumed that conformance of the tower structure to the International Building Code, Uniform Building Code or their local equivalent will be required for a building permit.

## 1.4 Compliance

- 1.4.1 Certification to this standard shall be done by an independent certifying agency such as the Small Wind Certification Council (SWCC) or a Nationally Recognized Testing Laboratory (NRTL). Self-certification is not allowed.
- 1.4.2 It is the intent of this standard to allow test data from manufacturers, subject to review by the certifying agency.
- 1.4.3 Compliance with this standard for the purposes of advertising or program qualification, or any other purpose, is the responsibility of the manufacturer.

## 1.5 Definitions

- 1.5.1 Definitions contained in IEC 61400-12-1, ed.1 (Performance); IEC 61400-11, ed.2 (Acoustic Noise); and IEC 61400-2, ed.2 (Design Requirements) are hereby incorporated by reference.
- 1.5.2 Additional Definitions
  - 1.5.2.1 AWEA Rated Power: The wind turbine's power output at 11 m/s (24.6 mph) per the power curve from IEC 61400-12-1, except as modified in Section II of this Standard.
  - 1.5.2.2 AWEA Rated Annual Energy: The calculated total energy that would be produced during a one-year period at an average wind speed of 5 m/s (11.2 mph), assuming a Rayleigh wind speed distribution, 100% availability, and the power curve derived from IEC 61400-12-1 (sea level normalized), except as modified in Section II of this Standard.
  - 1.5.2.3 AWEA Rated Sound Level: The sound level that will not be exceeded 95% of the time, assuming an average wind speed of 5 m/s (11.2 mph), a Rayleigh wind speed distribution, 100% availability, and an observer location 60 m (~ 200 ft.) from the rotor center<sup>1</sup>, calculated from IEC 61400-11 test results, except

<sup>1</sup> Appendix A contains guidance on obtaining sound levels for different observer locations and background sound levels.

as modified in Section III of this Standard.

- 1.5.2.4 Cut-in Wind Speed: The first wind speed bin in the averaged power curve that is positive.
- 1.5.2.5 Cut-out Wind Speed: The wind speed above which, due to control function, the wind turbine will have no power output.
- 1.5.2.6 Maximum Power: The maximum one-minute average power output a wind turbine in normal steady-state operation will produce (peak instantaneous power output can be higher).
- 1.5.2.7 Maximum Voltage: The maximum instantaneous voltage the wind turbine will produce in operation including open circuit conditions.
- 1.5.2.8 Maximum Current(s): The maximum instantaneous current(s) the wind turbine will produce on each side of the system's control or power conversion electronics.
- 1.5.2.9 Overspeed Control: The action of a control system, or part of such system, which prevents excessive rotor speed.
- 1.5.2.10 Power Form: Physical characteristics which describe the form in which power produced by the turbine is made deliverable to the load.
- 1.5.2.11 Rotor Swept Area: Projected area perpendicular to the wind direction swept by the wind turbine rotor in normal operation (un-furled position). If the rotor is ducted, the area inscribed by the ducting shall be included.
- 1.5.2.12 Turbulence Intensity: The standard deviation of wind speed divided by the mean wind speed based on 1-minute averaged data that is sampled at 1 Hz.

## 1.6 Units

- 1.6.1 The primary units shall be SI (metric). The inclusion of secondary units in the English system is recommended [e.g., 10 m/s (22.4 mph)].

## 1.7 Test Turbine and Electronics

- 1.7.1 Tested wind turbines and their associated electronics shall conform to the specific requirements of the governing IEC wind generator standard referenced for each test, but incorporating any amendments contained in this standard.



## 2 Performance Testing

- 2.1 Wind turbine performance shall be tested and documented in a test report per the latest edition of IEC 61400-12-1, Annex H, but incorporating the additional guidance provided in this section.
  - 2.1.1 In item b, battery banks are considered to be part of the wind turbine system for grid-connected wind turbines that incorporate a battery bank.
  - 2.1.2 In item e, the total wire run length, measured from the base of the tower, must be at least 8 rotor diameters and the wiring is to be sized per the manufacturer's installation instructions.
  - 2.1.3 In item n, the database shall include 10 minutes of data for all wind speeds at least 5 m/s beyond the lowest wind speed at which power is within 95% of Maximum Power (or when sustained output is attained).

## 3 Acoustic Sound Testing

- 3.1 Wind turbine sound levels shall be measured and reported in accordance with the latest edition of IEC 61400-11 ed.2, but incorporating the additional guidance provided in this section.
  - 3.1.1 The averaging period shall be 10-second instead of 1-minute.
  - 3.1.2 Measuring wind speed directly instead of deriving wind speed through power is the preferred method.
  - 3.1.3 The method of bins shall be used to determine the sound pressure levels at integer wind speeds.
  - 3.1.4 It shall be attempted to cover as wide a wind speed range as possible, as long as the wind screen remains effective.
  - 3.1.5 A description shall be provided of any obvious changes in sound at high wind speeds where overspeed protection becomes active (like furling or pitching).
  - 3.1.6 A tonality analysis is not required, but the presence of prominent tones shall be observed and reported.

## 4 Strength and Safety

- 4.1 Except as noted below, mechanical strength of the turbine system shall be assessed using either the simple equations in Section 7.4 of IEC 61400-2 ed.2 in combination with the safety factors in Section 7.8, or the aeroelastic modeling methods in the IEC standard. Evaluation of, as a minimum, the blade root, main shaft and the yaw axis (for horizontal axis wind turbines) shall be performed using the outcome of these analyses. A quick check of the rest of the structure for obvious flaws or hazards shall be done and if judged needed, additional analysis may be required.
- 4.2 Variable speed wind turbines are generally known to avoid harmful dynamic interactions with towers. Single/dual speed wind turbines are generally known to have potentially harmful dynamic interactions with their towers. Therefore, in the case of single/dual speed wind turbines, such as those using either one or two induction generators, the wind turbine and tower(s) must be shown to avoid potentially harmful dynamic interactions. A variable speed wind turbine with dynamic interactions, arising for example from control functions, must also show that potentially harmful interactions are likewise avoided.
- 4.3 Other safety aspects of the turbine system shall be evaluated including:
  - 4.3.1 procedures to be used to operate the turbine;
  - 4.3.2 provisions to prevent dangerous operation in high wind;
  - 4.3.3 methods available to slow or stop the turbine in an emergency or for maintenance;
  - 4.3.4 adequacy of maintenance and component replacement provisions; and
  - 4.3.5 susceptibility to harmful reduction of control function at the lowest claimed operating ambient temperature.
- 4.4 A Safety and Function Test shall be performed in accordance with Section 9.6 of IEC 61400-2 ed.2.
- 4.5 The manufacturer shall submit design requirements for towers including:
  - 4.5.1 mechanical and electrical connections;
  - 4.5.2 minimum blade/tower clearance;
  - 4.5.3 maximum tower top loads; and
  - 4.5.4 maximum allowable tower top deflection.

## 5 Duration Test

- 5.1 To establish a minimum threshold of reliability, a duration test shall be performed in accordance with the IEC 61400-2 ed.2 Section 9.4.
- 5.2 Changes and additional clarifications to this standard include:
  - 5.2.1 The test must include at least 25 hours in wind speeds of 15 m/s (33.6 mph) and above.
  - 5.2.2 Minor repairs are allowed, but must be reported.
  - 5.2.3 If any major component such as blades, main shaft, generator, tower, controller, or inverter is replaced during the test, the test must be restarted.
  - 5.2.4 The turbine and tower shall be observed for any tower dynamics problems during the duration test and the test report shall include a statement of the presence or absence of any observable problems.
  - 5.2.5 The tower used for the duration test must comply with the tower design requirements described in section 4.5.

## 6 Reporting and Certification

- 6.1 The test report shall include the following information:
  - 6.1.1 Summary Report, containing a power curve, an Annual Energy Production curve, and the measured sound pressure levels (Section 9.4 of IEC 61400-11 ed.2). The report is intended to be publicly available once approved by the certifying agency.
  - 6.1.2 Power Performance Test Report
  - 6.1.3 Acoustic Test Report
  - 6.1.4 The AWEA Rated Annual Energy
  - 6.1.5 The AWEA Rated Sound Level
  - 6.1.6 The AWEA Rated Power
  - 6.1.7 Wind Turbine Strength and Safety Report
  - 6.1.8 The tower design requirements shall be reported
  - 6.1.9 Duration Test Report
- 6.2 The manufacturers of certified wind turbines must abide by the labeling requirements of the certifying agency.

## 7 Labeling

- 7.1 The AWEA Rated Annual Energy (AWEA RAE) shall be stated in any label, product literature or advertising in which product specifications are provided.
  - 7.1.1 The AWEA RAE shall be rounded to no more than 3 significant figures.
- 7.2 The manufacturer shall state the AWEA Rated Power if a rated power is specified.
- 7.3 The manufacturer shall state the AWEA Estimated Sound Level if a sound level is specified.
- 7.4 Other performance data recommended to be stated in specifications about the turbine are:
  - 7.4.1 Cut-in Wind Speed
  - 7.4.2 Cut-out Wind Speed
  - 7.4.3 Maximum Power
  - 7.4.4 Maximum Voltage
  - 7.4.5 Maximum Current(s)
  - 7.4.6 Overspeed Control
  - 7.4.7 Power Form

## 8 Changes to Certified Products

- 8.1 It is anticipated that certified wind turbines will occasionally be changed to provide one form of improvement or another. In some cases such changes will require review by the certifying agency and possible changes to the certified product parameters. The following guidance is provided concerning when product changes will require certifying agency review:
  - 8.1.1 Any changes to a certified wind turbine that will have the cumulative effect of reducing AWEA Rated Power or AWEA Rated Annual Energy by more than 10%, or that will raise the AWEA Rated Sound Level by more than 1 dBA will require retesting and recertification by the certifying agency. Only those characteristics of the wind turbine affected by the design change(s) would be reviewed again.
  - 8.1.2 Any changes to a certified wind turbine that could reduce the strength and safety factors by 10%, or increase operating voltages or currents by 10%, will require resubmission of the Wind Turbine Strength and Safety Report and recertification by the certifying agency.
  - 8.1.3 Any changes to a certified wind turbine that could materially affect the results of the Duration Test will require retesting, submission of a new Duration Test Report, and recertification by the certifying agency.
- 8.2 The manufacturer is required to notify the certifying agency of all changes to the product, including hardware and software, for the life of the turbine certification. The certifying agency will determine whether the need for retesting and additional review under the guidelines provided in Section 8.1.
- 8.3 The use of Engineering Change Orders or their equivalent is recommended.

## 9 References and Appendices

### 9.1 References

- 9.1.1 Evaluation Protocol for Small Wind Systems, Rev. 3. NREL internal document
- 9.1.2 IEC 61400-12-1 ed.1, Wind Turbines – Part 12-1: Power performance measurements of electricity producing wind turbines
- 9.1.3 IEC 61400-11 ed.2, Wind turbine generator systems - Part 11: Acoustic noise measurement techniques
- 9.1.4 IEC 61400-2, ed.2, Wind Turbines – Part 2: Design requirements of small wind turbines

## Appendix A

### Sound Levels for Different Observer Locations and Background Sound Levels

The AWEA Rated Sound Level is calculated at a distance of 60 meters from the rotor hub and excludes any contribution of background sound. As the distance from the turbine increases, the background sound becomes more dominant in determining the overall sound level (turbine plus background).

Background sound levels depend greatly on the location and presence of roads, trees, and other sound sources. Typical background sound levels range from 35 dBA (quiet) to 50 dBA (urban setting)

Equation 1 can be used to calculate the contribution of the turbine to the overall sound level using the AWEA Rated Sound Level. Equation 2 can be used to add the turbine sound level to the background sound level to obtain the overall sound level.

$$\text{turbine sound level} = L_{\text{AWEA}} + 10 \log(4\pi 60^2) - 10 \log(4\pi R^2) \quad (1)$$

Where:

$L_{\text{AWEA}}$  is the AWEA Rated Sound Level [dBA].

R is the observer distance from the turbine rotor center [m]

$$\text{overall sound level} = 10 \log(10^{\frac{\text{turbine level}}{10}} + 10^{\frac{\text{background level}}{10}}) \quad (2)$$

**Table 1 Overall Sound Levels at Different Locations for an AWEA Rated Sound Level of 40 dBA**

Distance from rotor center [m]	$L_{\text{AWEA}}$ : 40 dBA				
	background noise level (dBA):				
	30	35	40	45	50
10	55.6	55.6	55.7	55.9	56.6
20	49.6	49.7	50.0	50.9	52.8
30	46.1	46.4	47.0	48.6	51.5
40	43.7	44.1	45.1	47.3	50.9
50	41.9	42.4	43.9	46.6	50.6
60	40.4	41.2	43.0	46.2	50.4
70	39.2	40.2	42.4	45.9	50.3
80	38.2	39.4	41.9	45.7	50.2
100	36.6	38.3	41.3	45.5	50.2
150	34.1	36.8	40.6	45.2	50.1
200	32.8	36.1	40.4	45.1	50.0

**Table 2 Overall Sound Levels at Different Locations for an AWEA Rated Sound Level of 45 dBA**

Distance from rotor center [m]	L <sub>AWEA</sub> : 45 dBA				
	background noise level (dBA):				
	30	35	40	45	50
10	60.6	60.6	60.6	60.7	60.9
20	54.6	54.6	54.7	55.0	55.9
30	51.1	51.1	51.4	52.0	53.6
40	48.6	48.7	49.1	50.1	52.3
50	46.7	46.9	47.4	48.9	51.6
60	45.1	45.4	46.2	48.0	51.2
70	43.8	44.2	45.2	47.4	50.9
80	42.7	43.2	44.4	46.9	50.7
100	40.9	41.6	43.3	46.3	50.5
150	37.8	39.1	41.8	45.6	50.2
200	35.9	37.8	41.1	45.4	50.1

**Table 3 Overall Sound Levels at Different Locations for an AWEA Rated Sound Level of 50 dBA**

Distance from rotor center [m]	L <sub>AWEA</sub> : 50 dBA				
	background noise level (dBA):				
	30	35	40	45	50
10	65.6	65.6	65.6	65.6	65.7
20	59.5	59.6	59.6	59.7	60.0
30	56.0	56.1	56.1	56.4	57.0
40	53.5	53.6	53.7	54.1	55.1
50	51.6	51.7	51.9	52.4	53.9
60	50.0	50.1	50.4	51.2	53.0
70	48.7	48.8	49.2	50.2	52.4
80	47.6	47.7	48.2	49.4	51.9
100	45.7	45.9	46.6	48.3	51.3
150	42.3	42.8	44.1	46.8	50.6
200	40.0	40.9	42.8	46.1	50.4

**Table 4 Overall Sound Levels at Different Locations for an AWEA Rated Sound Level of 55 dBA**

Distance from rotor center [m]	L <sub>AWEA</sub> : 55 dBA				
	background noise level (dBA):				
	30	35	40	45	50
10	70.6	70.6	70.6	70.6	70.6
20	64.5	64.5	64.6	64.6	64.7
30	61.0	61.0	61.1	61.1	61.4
40	58.5	58.5	58.6	58.7	59.1
50	56.6	56.6	56.7	56.9	57.4
60	55.0	55.0	55.1	55.4	56.2
70	53.7	53.7	53.8	54.2	55.2
80	52.5	52.6	52.7	53.2	54.4
100	50.6	50.7	50.9	51.6	53.3
150	47.1	47.3	47.8	49.1	51.8
200	44.7	45.0	45.9	47.8	51.1



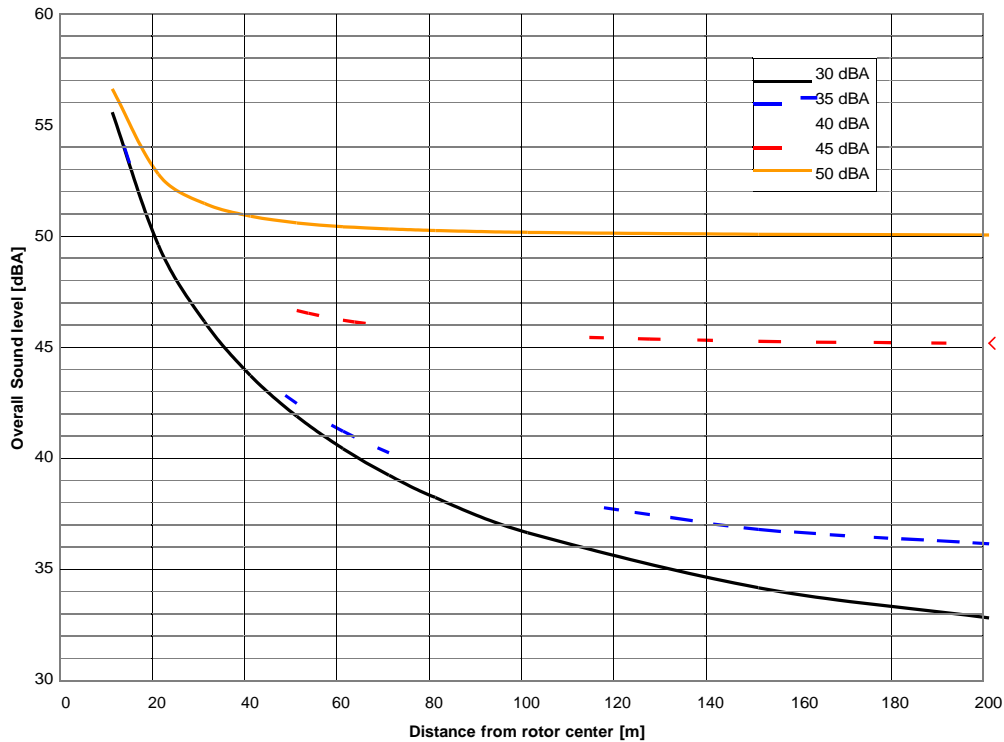


Figure 1 Sound levels as a function of distance and background noise levels for AWEA rated sound level of 40 dBA

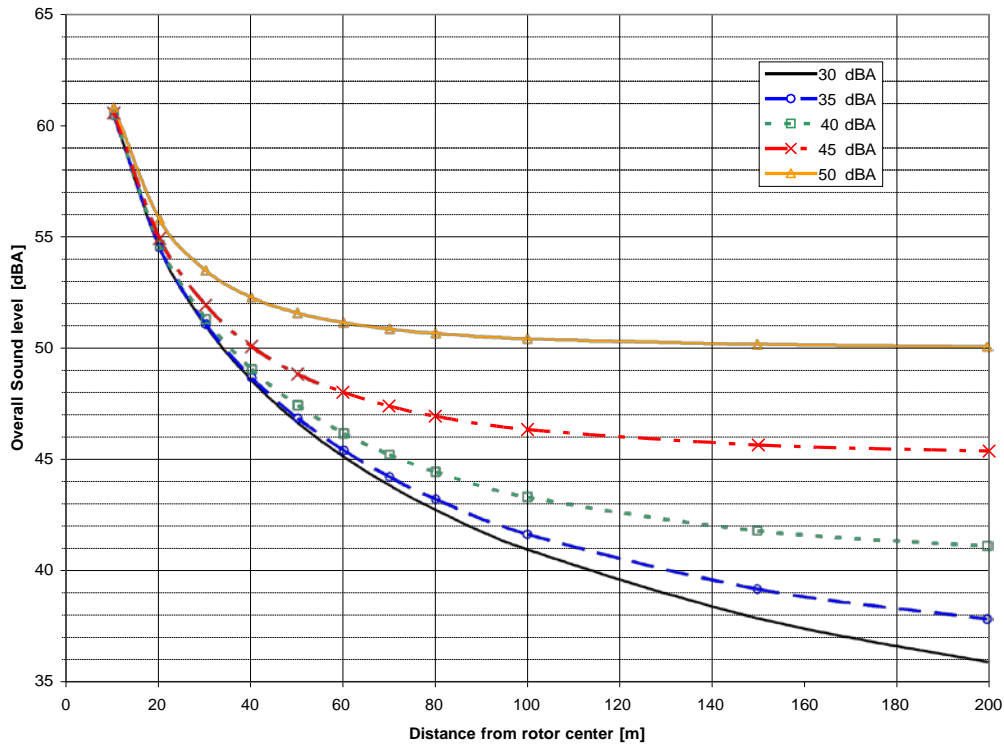


Figure 2 Sound levels as a function of distance and background noise levels for AWEA rated sound level of 45 dBA

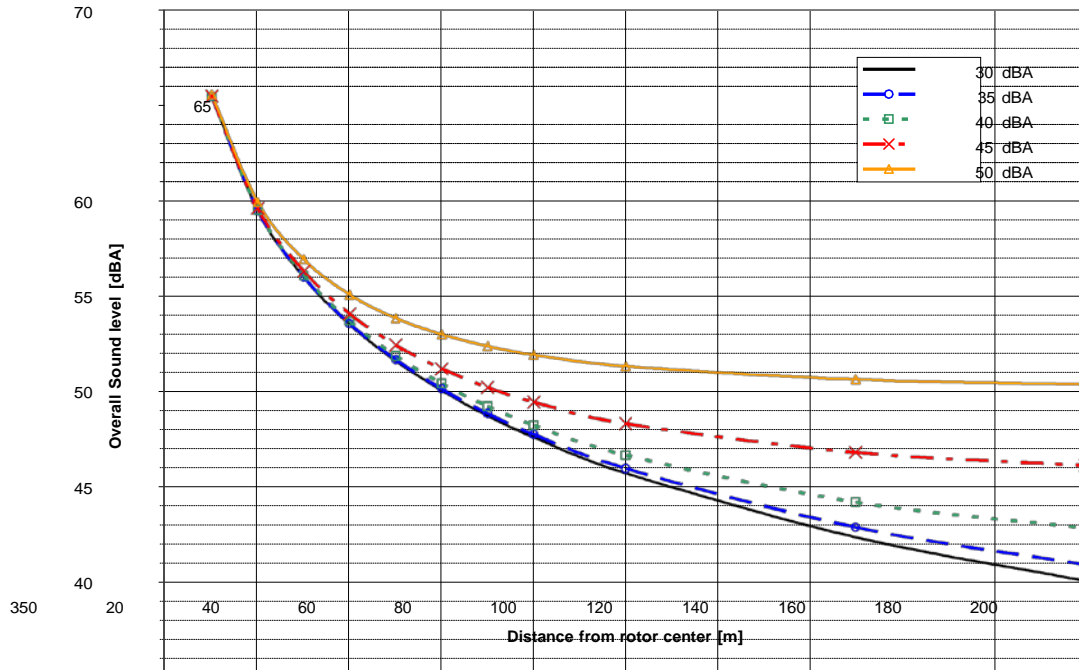


Figure 3 Sound levels as a function of distance and background noise levels for AWEA rated sound level of 50 dBA

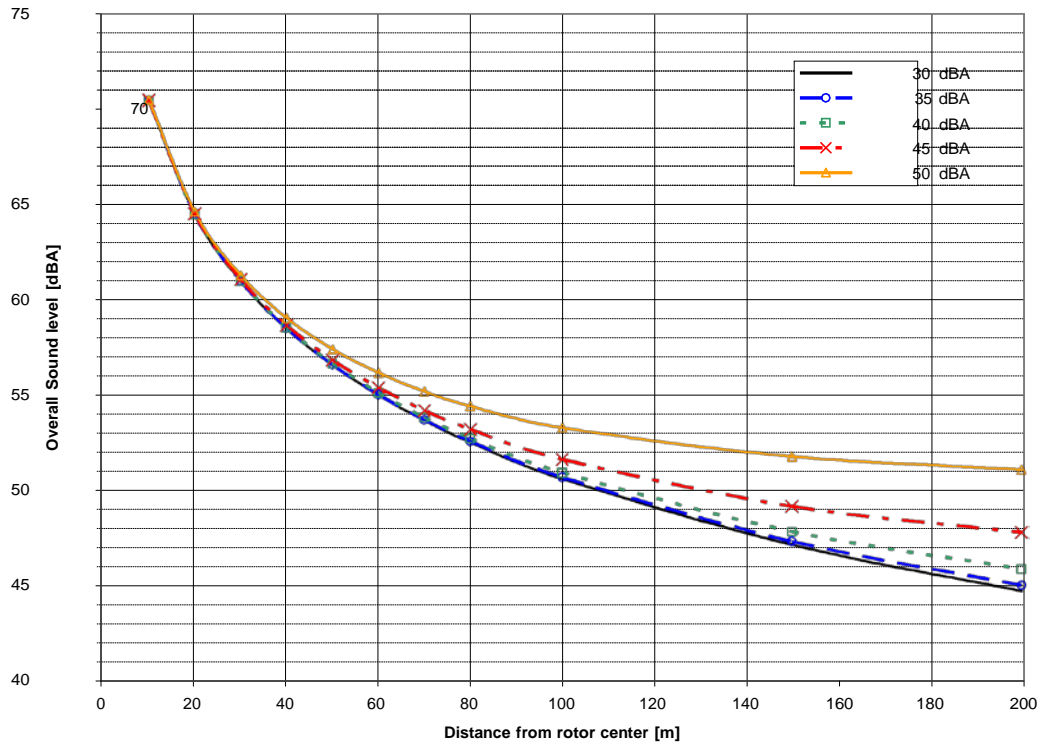


Figure 4 Sound levels as a function of distance and background noise levels for AWEA rated sound level of 55 dBA

## Appendix B Test Organizations for Small Wind Turbines

SWCC

Small Wind Test Organizations: 8 July 2010

### Test Organizations for Small Wind Turbines

This is a running list of test organizations that intend to test small wind turbines for the North American market. The list may not be all-inclusive. This is not an endorsement of any test organization, only an informative list. The list is broken into three groups:



- Organizations Accredited to Test Small Wind Turbines. These organizations have completed third-party accreditation by an accreditation body that has signed the International Laboratory Accreditation Cooperation (ILAC) Arrangement. The accreditation is in accordance with ISO/IEC 17025 with a scope that includes the applicable IEC standards.
- NREL Regional Test Centers. The National Renewable Energy Laboratory (NREL) has selected four independent testing organizations to support with funding and technical assistance in order to expand the testing capacity in North America. These organizations are non-accredited and operate independently (they are not a part of NREL).
- Non-Accredited Test Organizations. These test organizations do not have third-party accreditation to test small wind turbines. For this type of organization, the SWCC will perform a site evaluation where we work with the organization to document compliance with the AWEA Standard, the applicable parts of the IEC 61400 standards and ISO/IEC 17025.

### Organizations Accredited to Test Small Wind Turbines

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#### Global Energy Concepts, Inc. (GEC-DNV)

- a DNV company

**Mail:** 1809 7th Avenue, Suite 900, Seattle, WA 98101

**Phone:** (206) 387-4200

**Contact:** Luke Simmons

**Email:** [Luke.Simmons@dnv.com](mailto:Luke.Simmons@dnv.com)

**Web:** [www.globalenergyconcepts.com](http://www.globalenergyconcepts.com)

**Test site location:** N/A

**Turbines tested to date:** Over 132; all turbines having a rated capacity of 100 kW or larger

**Accreditation:** Accredited by the American Association of Laboratory Accreditation (A2LA) in accordance

with ISO/IEC 17025:2005 to conduct tests per IEC 61400-12-1, -12, -13 and the MEASNET Power Performance Measurement Procedure: 2000

**Other Comments:** While our expertise is in testing of utility scale turbines, we're happy to discuss testing of smaller turbines and can work with all involved parties to come up with a cost effective solution that meets the requirements of relevant standards.

## National Renewable Energy Laboratory (NREL)

National Wind Technology Center (NWTC)

**Mail:** 1617 Cole Boulevard, Golden, CO 80401

**Phone:** (303) 384-6987

**Contact:** Arlinda Huskey

**Email:** [Arlinda.Huskey@nrel.gov](mailto:Arlinda.Huskey@nrel.gov)

**Web:** [www.nrel.gov/wind](http://www.nrel.gov/wind)

**Test site location:** NWTC, Boulder, CO

**Turbines tested to date:** > 20

**Accreditation:** Accredited by the American Association of Laboratory Accreditation (A2LA) in accordance with ISO/IEC 17025:2005 to conduct tests per IEC 61400-11, -12, -21, -23, -13, -1, and -2, MEASNET Acoustic Noise Measurement Procedure: 1997, MEASNET Power Performance Measurement: 2000, and MEASNET Power Quality Measurement Procedure: 2000.

## TUV-NEL

**Mail:** TUV NEL Ltd, Napier Building, SETP, East Kilbride, Glasgow, G75 0QF

**Phone:** + 44 (0) 1355 593788

**Contact:** Alistair Mackinnon, [amackinnon@tuvnel.com](mailto:amackinnon@tuvnel.com)

**Web:** [www.tuvnel.com/tuvnel/wind\\_turbine\\_testing\\_certification](http://www.tuvnel.com/tuvnel/wind_turbine_testing_certification)

**Test site location:** Myres Hill

**Turbines tested to date:** Testing complete on (5) turbines, certification complete on (1) turbine, will have (18 ) turbines under test in summer 2010

**Accreditation:** TUV NEL is accredited by UKAS to test wind turbines to ISO/IEC 17025: 2005 and then certify to EN45011: 1998.

**Other Comments:** The Myres Hill wind turbine test site offers high average winds speeds and complex terrain. The site has grid connections and can accommodate significant generated power levels. The site is available for measurement and testing of wind turbines

## QPS Evaluation Services - Certification, Testing & Inspections

**Mail:** 81 Kelfield St., Unit 8 Toronto, ON M9W5A3

**Phone:** 877-746-4777

**Contact:** Brian Baker/ Tom Mah

**Email:** [bbaker@qps.ca](mailto:bbaker@qps.ca) , [tmah@qps.ca](mailto:tmah@qps.ca)

**Web:** [www.qps.ca](http://www.qps.ca)

**Test site location:** QPS is presently working on potential locations and cooperative agreements.

**Turbines tested to date:** QPS Evaluation has conducted many evaluations globally on both large and small wind turbines from capacity of 1KW to Utility size of 100KW or larger. Current projects include 2.2 MW turbines.

Clients range from small startup companies producing 1K, 5K and 10KW units to large clients such as large power companies installing large grid connected units.

**Accreditation:** QPS is IAS Accredited Product Certification Agency, IAS Field Evaluation and QPS is ISO/IEC Guide 65 (General Requirements for Bodies operating Product Certification Systems), ISO/IEC 17020 (Inspection Agency) and ISO/IEC 17025 (Testing Laboratory). We are also a Certification Body for the CB Scheme and IECEx

Certification Body for Explosion and Intrinsic Safety. QPS is active in standards writing and has been requested by SCC to take the lead in Canada for wind turbine requirements. Accredited to CSA standards C61400-1, -2, -11, -12-1 and -24.

**Other Comments:** QPS serves on the Standards Technical Panels for STP6171 (UL6171 - Wind Turbine Converters and Interconnection Systems Equipment), STP6142 (UL6142 - Wind Turbine Generating Systems – Small) and STP6141 - (UL6141 Wind Turbine Generating Systems – Large). QPS also offers other services such as Product Safety Testing, Medical, Vibration, Performance/ Comparison Testing, Flammability, Hazardous Locations and Intrinsic, Electrical Testing, CE Testing, Environmental Testing, Field Evaluations & Inspections.

## WINDTEST Kaiser-Wilhelm-Koog GmbH

- A GL company

**Mail:** Sommerdeich 14b , 25709 Kaiser-Wilhelm-Koog , Germany

**Phone:** +49 4856 901-0

**Email:** [sales@wtk.windtest.com](mailto:sales@wtk.windtest.com)

**Web:** [www.windtest.com](http://www.windtest.com)

**Test site location:** Germany (up to 50m hub height)

**Turbines tested to date:** over 500; all types from 2.3 kW to 6 MW

**Accreditation:** Accredited by DAP in accordance with ISO/IEC 17025:2005 to conduct power performance measurements, acoustic measurements, mechanical load measurements and other tests

## NREL Regional Test Centers

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### High Plains Small Wind Test Center

- an NREL Regional Test Center

**Mail:** Barry Kaaz, Colby Community College, 1255 South Range, Colby, KS 67701

**Contact:** Barry Kaaz, Mobile 785-462-0411, Office 785-460-5429

**Contact:** Ruth Douglas Miller, Office 785-532-4596

**Email:** [rdmiller@ksu.edu](mailto:rdmiller@ksu.edu), [barry.kaaz@colbycc.edu](mailto:barry.kaaz@colbycc.edu)

**Web:** [www.ece.ksu.edu/psg/wac](http://www.ece.ksu.edu/psg/wac)

**Test site location:** KSU Agricultural Research property just south of Colby, KS, at 39.38 N, 101.08 W.

**Turbines tested to date:** None; the High Plains Test Center is just starting up under a grant from NREL. However our Engineering team has twenty years' experience testing and evaluating manufacturing processes and products across many industries

**Accreditation:** N/A

**Other Comments:** Mean average wind speed is 6.5 to 7m/s at 30m, and strong directional winds, prevailing N-S are common in all months of the year, so we anticipate rapid durability testing.

## **Intertek**

- a Nationally Recognized Testing Laboratory (NRTL)
- an NREL Regional Test Center

**Mail:** 3933 US Route 11, Cortland, NY 13045

**Phone:** (607) 758-6482

**Contact:** Brian Kramak

**Email:** [brian.kramak@intertek.com](mailto:brian.kramak@intertek.com)

**Web:** [www.intertek.com](http://www.intertek.com)

**Test site location:** Intertek is currently testing wind turbines at customer sites to CSA C61400-12-1 and -11 and -21. We are in the permitting process for our own test sites in NY and OR.

**Turbines tested to date:** Intertek has done design reviews and field evaluations of over 1.6 GW of large wind turbines for GE Wind, Gamesa, Vestas, Acciona, REPower and Aaer. Intertek has tested small wind turbine components – generators on a test stand and inverters – and is testing our first full small wind turbine in Oregon.

**Accreditation:** Accredited by OSHA to test all components of a wind turbine in the US and SCC in Canada. We are pursuing certification accreditation now that Canada has adopted CSA C61400-2. As soon as our first test site is online and AWEA standard is released, we will seek testing accreditation by A2LA or equivalent.

## **West Texas A&M University**

The Alternative Energy Institute, Wind Test Center

- an NREL Regional Test Center

**Mail:** P.O. Box 60248 W.T, Canyon, Texas 79016

**Phone:** (806) 651-2295

**Contact:** David Carr, [dcarr@wtamu.edu](mailto:dcarr@wtamu.edu)

**Email:** [aeimail@wtamu.edu](mailto:aeimail@wtamu.edu)

**Web:** [www.windtestcenter.org](http://www.windtestcenter.org)

**Test site location:** Canyon, TX

**Turbines tested to date:** AEI has had a cooperative agreement with USDA since 1976. Between AEI and USDA we have installed over 70 wind turbines (50 W to 100 kW), most of them prototypes or first production units.

Turbines have been installed at AEI Wind Test Center (Canyon, TX); USDA location (Bushland, TX) and others at field locations, primarily in Texas. Presently at the Wind Test Center, we are testing 8 turbines, and another one is used for electricity for the Renewable Energy Demonstration Building; Bergey 10 kW, installed in 1994. We also have 2 kW PV, so we are a net energy producer.

**Accreditation:** N/A

**Other Comments:** We also have a test stand for small blades. In the past we have tested 10 blades.

## **Windward Engineering**

- an NREL Regional Test Center

**Mail:** 10768 S. Covered Bridge Canyon, Spanish Fork, UT 84660

**Phone:** (801) 798-8784

**Email:** [info@windwardengineering.com](mailto:info@windwardengineering.com)

**Web:** [www.windwardengineering.com](http://www.windwardengineering.com)

**Test site location:** Spanish Fork, UT

**Turbines tested to date:** >9. Not all for the purpose of collecting IEC test data.

**Accreditation:** N/A

**Comments:** We are limited for space and resources with 6 existing or proposed installed turbines already. Client willing to do their own installation and testing will get quicker results. The test site wind is excellent for producing performance and duration test data rapidly. It should be noted that we are involved with producing small wind turbines with Endurance Wind Power as well as running the test facility for Windward Engineering.

## Non-Accredited Test Organizations

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### Appalachian State University

Beech Mountain Small Wind Research & Demonstration Facility

**Mail:** ASU Energy Center, 20 Kerr Scott Hall, Boone, NC 28608

**Phone:** (828) 262-7333

**Contact:** Dr. Dennis Scanlin

**Email:** [wind@appstate.edu](mailto:wind@appstate.edu), [scanlindm@appstate.edu](mailto:scanlindm@appstate.edu)

**Web:** [wind.appstate.edu](http://wind.appstate.edu)

**Test site location:** Beech Mountain, NC

**Turbines tested to date:** 12; 200W to 20kW

**Accreditation:** N/A

**Other Comments:** Energetic class 5 ridge top research and demonstration site. Open to the public.

### Architectural Testing

**Mail:** 849 Western Avenue North, St. Paul, MN 55117-5245

**Phone:** (651) 636-3835

**Contact:** Dan Braun

**Mobile:** (612) 805-0033

**Email:** [dbraun@archtest.com](mailto:dbraun@archtest.com)

**Web:** [www.archtest.com](http://www.archtest.com)

**Test site location:** Currently Architectural Testing has the ability to generate wind using various wind machines. (Fresno, CA, Wausau, WI and York, PA) We anticipate these devices may be used in research and development efforts. We are also in the process of identifying a site where natural wind conditions are conducive to natural wind testing.

**Turbines tested to date:** Architectural Testing has evaluated some wind turbine components to various performance attributes but not in accordance with the AWEA standard.

**Accreditation:** Accredited by the International Accreditation Service (IAS) in accordance with ISO/IEC 17025:2005 to conduct architectural tests per a variety of ASTM standards.

### Channel Islands Acoustics

**Mail:** 676 West Highland Drive, Camarillo, CA 93010

**Phone:** (805) 484-8000

**Contact:** Bruce Walker

**Email:** [bwalker@channelislandsacoustics.com](mailto:bwalker@channelislandsacoustics.com), [noisebw@aol.com](mailto:noisebw@aol.com)

**Web:** [www.channelislandsacoustics.com](http://www.channelislandsacoustics.com)

**Test site location:** Nationwide, western states preferred

**Turbines tested to date:** Bonus, Nordtank, Micon, Mitsubishi, GE, Tacke, Zond, Jacobs, Windmatic, Polenko, Clipper, Vestas, Aeromann, Carter, ESI, FlowWind, Danwin, Floda, NedWind, Vawtpower, etc. Sizes ranging from



10 KW to 2+ MW.

**Accreditation:** INCE Board Certified

**Other Comments:** Bruce Walker, Ph.D., INCE Bd. Cert. is principal consultant and has been providing acoustical testing and consulting services to the wind energy industry for over 25 years. We offer targeted diagnostic sound and vibration testing and acoustic noise emissions testing according to IEC 61400-11. We maintain a full complement of acoustical test and analysis equipment, with current NBS-traceable certifications.

## **DynaTech Engineering, Inc.**

**Mail:** 1830 Sierra Gardens Drive, Suite 30, Roseville, CA 95661

**Phone:** (916) 783-2400

**Contact:** Lyn Greenhill, PE

**Email:** [lyng@dynatechengr.com](mailto:lyng@dynatechengr.com)

**Web:** [www.dynatechengr.com](http://www.dynatechengr.com)

**Test site location:** Northern California

**Turbines tested to date:** 4

**Accreditation:** N/A

**Other Comments:** Authorized by California Energy Commission for IEC 61400-2 testing and analysis. DynaTech is a mechanical engineering consulting firm specializing in rotating machinery.

## **GENIVAR**

**Mail:** 1600 Rene-Levesque West, Montreal, QC, H3H 1P9

**Phone:** (514) 340-0046 5471

**Contact:** Frederic Tremblay, eng. Ph.D.

**Email:** [frederic.tremblay.wind@genivar.com](mailto:frederic.tremblay.wind@genivar.com)

**Web:** [www.genivar.com](http://www.genivar.com)

**Test site location:** N/A

**Turbines tested to date:** GENIVAR has been or is currently involved in the power performance testing of megawatt class turbines in 7 different projects.

**Accreditation:** N/A

**Other Comments:** GENIVAR is a leading Canadian engineering firm with over 20 years of experience in the wind industry. Our extensive team of engineering and wind energy professionals provides you with the full range of expertise for the wind turbine certification process.

## **GREAT (Global Renewable Energy Assessment Testing) Laboratory**

**Mail:** World Cal, Inc., 2012 High St., Elk Horn, IA 51531

**Phone:** (712) 764-2197

**Contact:** Mike Howard

**Email:** [MHoward@liberty-labs.com](mailto:MHoward@liberty-labs.com)

**Web:** [www.world-cal.com](http://www.world-cal.com)

**Test site location:** 2012 High St., Elk Horn, IA 51531 and 1346 Yellowwood Rd., Kimballton, IA 51543

**Turbines tested to date:** 3 and 6kW VAWT with Ginlong PMG

**Accreditation:** We have applied for accreditation under ISO 17025 with A2LA and expect to have this completed by mid summer

**Other Comments:** Obtain GREAT Seal for your turbine from our Global Renewable Energy Assessment Testing Lab. We have over 40 acres available at this time for turbine testing as well as indoor labs for inverter test and evaluation. Additional acreage of up to 200 acres will be added later this summer.

## Narec

**Mail:** Eddie Ferguson House, Ridley Street, Blyth, Northumberland, UK, NE24 3AG

**Phone:** +44 (0) 1670 357680

**Contact:** Dave Hails, [dave.hails@narec.co.uk](mailto:dave.hails@narec.co.uk)

**Web:** [www.narec.co.uk](http://www.narec.co.uk)

**Test Site Location:** N/A at present

**Turbines tested to date:** Testing nearing completion on (1) turbine, (1) further turbine on test, and (3) additional turbine tests to commence shortly.

**Accreditation:**

- ISO/IEC 17025 accredited calibration laboratory for calibration of high voltage voltmeters, voltage dividers, and high voltage sources.
- ISO/IEC 17025 accredited testing laboratory for full scale testing of large wind turbine blades
- Not accredited for small wind turbine testing, but currently assessed and recognised by BRE Global (a UK accredited certification body) as operating in accordance with ISO/IEC 17025 for this activity

**Other comments:** Currently in the process of identifying a small wind turbine test site, however in the meantime we continue to work with clients who wish to test their product at their own test facilities in accordance with the requirements of the standards.

## Northern Colorado Wind Test Center (NCWTC)

A collaboration between RRD Engineering and CPP Wind Engineering

**Mail:** 670 Cody St. Lakewood, CO 80215

**Phone:** (970) 581-8091

**Contact1:** Rick Damiani, RRD Engineering

**Email:** [r.damiani@rrdengineering.com](mailto:r.damiani@rrdengineering.com)

**Web:** [www.RRDEngineering.com](http://www.RRDEngineering.com)

**Contact2:** Brad Cochran, CPP Wind Engineering

**Email:** [bcochran@cppwind.com](mailto:bcochran@cppwind.com)

**Web:** [www.cppwind.com/services/renewable\\_energy/renewable\\_energy.html](http://www.cppwind.com/services/renewable_energy/renewable_energy.html)

**Test site location:** The test site is located in Weld County, Colorado. The site is open grassland with annual mean wind speed of 5 m/s at a height of 20 m above grade and experiences approximately 185 hours per year of mean wind speeds in excess of 15 m/s. The site utilizes state-of-the-art data collection and communication instrumentation and software to minimize response times and man hour requirements for data analysis and reporting.

**Turbines tested to date:** Five turbines at various sites throughout the Rocky Mountain West. Testing has included power performance, duration, and acoustical noise evaluations following the IEC 61400-11 (noise) and IEC 61400-12 (power performance) test standards. In addition, CPP has conducted turbine development tests for dozens of wind turbines (hundreds of configurations) in their large atmospheric boundary layer wind tunnels and through CFD modeling.

**Accreditation:** N/A

**Other Comments:** The Principal Investigators are Registered professional Engineers in the State of Colorado. They have been actively involved in the development of both the AWEA and IEC test standards. RRD Engineering and CPP have 15 years of experience providing turbine design and evaluation services using a combination of wind tunnel modeling, FEA and CFD modeling and field testing, along with conducting wind resource assessments for small and utility sized wind applications.

## **Pine Ridge Products LLC**

**Mail:** 1646 East Highwood Rd, Belt, MT 59412

**Phone:** (406) 738-4283

**Contact:** Logan Bryce

**Email:** [wlbryce@pineridgeproducts.com](mailto:wlbryce@pineridgeproducts.com)

**Web:** [www.pineridgeproducts.com](http://www.pineridgeproducts.com)

**Test site location:** Belt, MT

**Turbines tested to date:** 11

**Accreditation:** N/A

**Other Comments:** Specializing in 10kW and below, turbulent class 5 wind site.

## **Retlif Testing Laboratories**

**Mail:** 795 Marconi Avenue, Ronkonkoma, NY 11779

**Phone:** (631) 837-1500

**Contact:** Walter A. Poggi

**Email:** [wpoggi@retlif.com](mailto:wpoggi@retlif.com)

**Web:** [www.retlif.com](http://www.retlif.com)

**Test Set Location:** Retlif maintains test laboratories in Ronkonkoma, Long Island, NY, Goffstown, NH and Harleysville, PA. We are currently preparing a test site at our Ronkonkoma, NY location along with a satellite location on Long Island in Bethpage, NY.

**Turbines Tested To Date:** At this point Retlif has only tested components and wind technology instrumentation.

**Accreditation:** Retlif is fully accredited by both A2LA and NVLAP for over 300 test methods in the areas of Electromagnetic Compatibility, Electro-Static Discharge, Lightning, Environmental Simulation and Body Armor Conditioning. Retlif is also a corporate member of NACLA.

## **South Dakota Wind Application Center (SDWAC)**

South Dakota State University (SDSU)

**Mail:** South Dakota Wind Application Center, Box 2219, Crothers Engineering Hall 234, Brookings, SD 57007

**Phone:** (605) 688-4301

**Contacts:** Michael Twedt, [Michael.Twedt@sdstate.edu](mailto:Michael.Twedt@sdstate.edu); Matthew Hein, [matthew.hein@sdstate.edu](mailto:matthew.hein@sdstate.edu)

**Test Set Location:** 141 Acres (over ½ square-kilometer). Testing site is within 3-miles of the SDSU campus and is located on SDSU property. All access rights are controlled by SDSU and the surrounding land is primarily used for agriculture with all residential structures being far outside the required setback distances. Interstate-29 is

approximately two-miles from the proposed site and the Brookings Regional Airport is with 4-miles of the proposed site for efficient transportation. The northern climate of eastern South Dakota provides excellent performance testing conditions with an appropriate wind regime, temperature profile, and precipitation matrix.

**Latitude:** 44.3530 **Longitude:** -96.7913

**Turbines Tested To Date:** N/A

**Accreditation:** The South Dakota Wind Application center is actively pursuing accreditations recommended by the National Wind Testing Center (NWTC) and American Wind Energy Association (AWEA).

**Other Comments:** We monitor performance of 7 small wind turbines and all technical concerns related to the South Dakota Wind for Schools program are directed through our office. The Engineering College of SDSU has extensive material testing capability. The imaging, mechanical testing, and Non-Destructive Evaluation (NDE) techniques can identify the material structure, the structure's correlation to strength and performance, and help evaluate the material pre- and post-manufacturing characteristics as well as operation fatigue. The Department of Wildlife and Fisheries at SDSU indicates an opportunity to explore interactions between wind machines and wildlife. The Climatology Department at SDSU places an emphasis on renewable resource evaluation and houses the South Dakota Wind Resource Assessment Network (WRAN), which specializes in wind resource assessment and turbine performance prediction in South Dakota. Recruitment opportunities may also present themselves, as interaction with the university and your company will undoubtedly include capable members of the student body.

## **The Cadmus Group, Inc.**

**Mail:** 57 Water St., Watertown, MA 02472

**Phone:** (617) 673-7106

**Contact:** Shawn Shaw

**Email:** [shawn.shaw@cadmusgroup.com](mailto:shawn.shaw@cadmusgroup.com)

**Web:** [www.cadmusgroup.com/clean\\_energy](http://www.cadmusgroup.com/clean_energy)

**Test Site Location:** Cadmus conducts small wind turbine testing at various sites across the northeastern US. We will work with interested manufacturers to identify an appropriate test location and conduct testing to IEC 61400 and AWEA standards. Cadmus also conducts design reviews, post-installation inspections, and monitoring of wind projects at existing sites.

**Turbines Tested to Date:** Testing and energy production monitoring is ongoing on over 40 small wind turbines, with detailed testing in progress on 7 turbines. Models tested include the Bergey Excel-S, Aircon 10, ARE 442, Eoltec Scirroco, Endurance S250, and others.

**Accreditation:** N/A

**Other Comments:** Our team conducts a wide range of wind energy related consulting activities such as testing, design reviews, wind resource assessment, site evaluation, and development of software tools for predicting small wind system performance.

## **The Wind Energy Institute of Canada (WEICan)**

**Mail:** 21741 Route 12, North Cape, Prince Edward Island, Canada, C0B 2B0

**Phone:** (902) 882-2746

**Email:** [info@weican.ca](mailto:info@weican.ca)

**Web:** [www.weican.ca](http://www.weican.ca)

**Test site location:** North Cape, Prince Edward Island, Canada

**Turbines tested to date:** WEICan has tested over 20 wind turbines rated from 1kW to 500kW. Since 2006 we have partnered with DEWI the German wind institute for testing of large wind turbines and are now offering power performance, power quality, duration, and noise tests; in accordance with IEC 61400 on small and large wind turbines. Presently we have two small wind turbines being tested to IEC 61400-12-1, -2, -11, and -21.

**Accreditation:** We are currently investigating the resources required to become accredited.

**Other Comments:** We have been doing power performance and durability testing since 1981 and have tested as well as participated in R&D activities on many wind turbines during that period. We are currently investigating the resources required to become accredited. WEICan also works with DEWI who are accredited to provide certification for international markets. If requested by the client, WEICan will test to other standards such as: AWEA, BWEA or CSA standards: C61400-2,-11,-12-1 and -21. WEICan has compiled twenty years of wind data at the test site; as well as a detailed report from DEWI which gives results of the sites wind regime and characteristics.

## USDA-Agricultural Research Service

Conservation & Production Research Laboratory

**Mail:** P.O. Drawer 10, Bushland, TX 79012-0010

**Phone:** (806) 356-5724

**Contact:** Brian Vick

**Email:** [Brian.Vick@ars.usda.gov](mailto:Brian.Vick@ars.usda.gov)

**Web:** [www.cprl.ars.usda.gov](http://www.cprl.ars.usda.gov)

**Test site location:** Bushland, TX

**Turbines tested to date:** Between AEI and USDA we have installed over 75 wind turbines (50 W to 100 kW), most of them prototypes or first production units.

**Accreditation:** N/A

## WindGuard North America

**Mail:** P.O. Box 204, 199 Anglesea Street, Goderich, ON, Canada, N7A 3Z2

**Phone:** (519) 440-0925

**Email:** [info@windguard-northamerica.com](mailto:info@windguard-northamerica.com)

**Web:** [www.windguard-inc.com](http://www.windguard-inc.com)

**Test site location:** N/A

**Turbines tested to date:** >1000 , with various testing services

**Accreditation:** N/A

**Other Comments:** We are experts for loads verification, vibration testing, frequency issues and rotor balancing and blade angle alignment.

## Wind Energy Center (WEC)

University of Massachusetts at Amherst

**Mail:** Bldg ELAB 160 Governors Drive, Amherst, MA 01003

**Phone:** (413) 577-2139

**Contact:** William Stein

**Email:** [wstein@ecs.umass.edu](mailto:wstein@ecs.umass.edu)

**Web:** [www.ceere.org/rerl](http://www.ceere.org/rerl)

**Test site location:** Mt Tom, Leyden, MA (pending)

**Turbines tested to date:** ESI-80, Electro, Umass Windfurnace-WF-1, Dakota Wind and Sun (4 kW Jacobs clone), Windcharger

**Accreditation:** N/A

**Other Comments:** The WEC has been involved in all aspects of wind power since the late 1970's including design, prototyping, wind tunnel and atmospheric testing of both small and large wind turbines.

## **WindTesting.com**

**Mail:** PO Box 1138, Tehachapi, CA 93581

**Contact:** Brent Scheibel

**Email:** [Service@WindTesting.com](mailto:Service@WindTesting.com)

**Web:**

[www.WindTesting.c](http://www.WindTesting.com)

[om](#) Test site

**location:** Tehachapi,

**CA Turbines tested**

**to date:** 30

**Accreditation:** N/A

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## **For more information, corrections or additions please contact:**

Brent

Summerv

ille PE

Technical

Director

Small Wind Certification Council

518-213-9438

[www.smallwindcert](http://www.smallwindcert)

[ification.org](http://ification.org)

[Brent@smallwindcertification.org](mailto:Brent@smallwindcertification.org)

## Appendix C Mid-Atlantic Small Wind Stakeholder Survey

Hello.

You have been identified as a small wind energy stakeholder in the Mid-Atlantic Region. This short (seven question) survey is intended to collect information that will be used to aid in the formation of a Small Wind Training and Testing Facility at James Madison University. Please feel free to forward this survey to other small wind stakeholders or to more appropriate individuals within your organization.

You may respond with as much or as little detail as you like. Your responses are anonymous and will not be published. The results will be used to formulate general conclusions such as "the majority of small wind installers list \_\_\_\_ as a service that will benefit their organization," which may be published as part of my master's thesis.

Thank you for your response,

Curt Dvonch  
(571) 264-9617  
dvonchcl@dukes.jmu.edu

Please identify your organization's functions in the small wind industry.

- ☐ Installation
- ☐ Manufacturing
- ☐ Retail
- ☐ Research
- ☐ Education
- ☐ Other (please specify)

What small wind testing services would your organization benefit from if available at JMU? Please comment on the importance of the services that you list.

Does your organization currently certify the small wind turbines that it manufactures, sells, installs, or uses? If yes, how do you certify and to what standards?

Would your organization benefit from third party small wind certification at JMU? Which ratings - e.g. sound, annual energy output, rated power, durability – are most important to your organization? Please comment on the time frame that your organization would find acceptable.

What experience does your organization have with small wind testing, certification, and labeling programs?