# Taller Wind Turbine for Low Wind Speed Regions

Team Number: 25 – Product Plan and Product Specification

Submission Date: 10/10/2014

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## Abstract

This report outlines the product specifications and current progress on the development of a taller wind turbine for low wind speed regions. The report also defines a team schedule and allocates team member responsibilities. Current wind turbines are not effective to use in Florida because the average wind speed is too low to provide adequate power. The sponsor implemented a series of specifications to be met so that an effective wind turbine can be designed. So far the group has done more extensive research into wind turbine technology and created initial designs for both the structure and blades of the turbine. These initial designs will be drawn and made in CAD and tested with the FAST software provided by the National Renewable Energy Laboratory (NREL). The group will have two primary focuses. The first will be the material selection for the turbine blades and tower. The second focus will be on the design and geometry of the turbine blades. The next report will go into further depth of the forces on a wind turbine and how our designs respond to these forces.

# 1 Introduction

In order to reduce global carbon emissions and continue to generate electricity, renewable energy is a dependable alternative to current power generation methods. There are many renewable sources to access including wind, solar, and hydro energy. In the United States, wind energy accounts for 30% of all renewable energy generated. To generate power a certain wind speed must be present. Unfortunately, the Southeastern United States does not have sufficient average wind speed to make current turbines viable. The goal of this project is to develop a wind turbine that would be effective in low wind speed regions like the Southeastern United States. By designing a wind turbine that is taller than current turbines we will be able to harness larger wind speeds at higher altitudes. We will be working with students from the civil engineering department on developing and designing the tower and blades of a new wind turbine.

This report details a basic background of the project and why there is a need for a taller wind turbine for use in the southeast. To complete the project several objectives and constraints must be met within the class time frame. In order to stick to a consistent schedule, a Gantt chart has been developed. Additionally, specific tasks have been allocated to team members. This will allow the team to effectively approach the project and complete tasks in a timely manner.

# 2 Project Definition

## 2.1 Background research

Wind energy is one of the leading sources of renewable energy in many countries. The Unites States is increasing its investment into renewable clean energy opposed to dirty energy like coal and gas power plants. In 2013, 13% of the country's electricity generated was from renewable sources. Wind power constituted 30% of the total renewable energy generated.[1] The growing use of wind energy in the country has not traveled to the Southeastern United States due to low wind speeds. Most of Florida's renewable energy comes from solar plants. Light winds make commercial wind farms not currently viable.[2] This project seeks to explore new ideas that would make wind power a feasible method to generate power in Florida and the Southeastern United States. Figure 1 below shows average annual wind speeds throughout the United States, higher wind speeds are shown in purple/red.

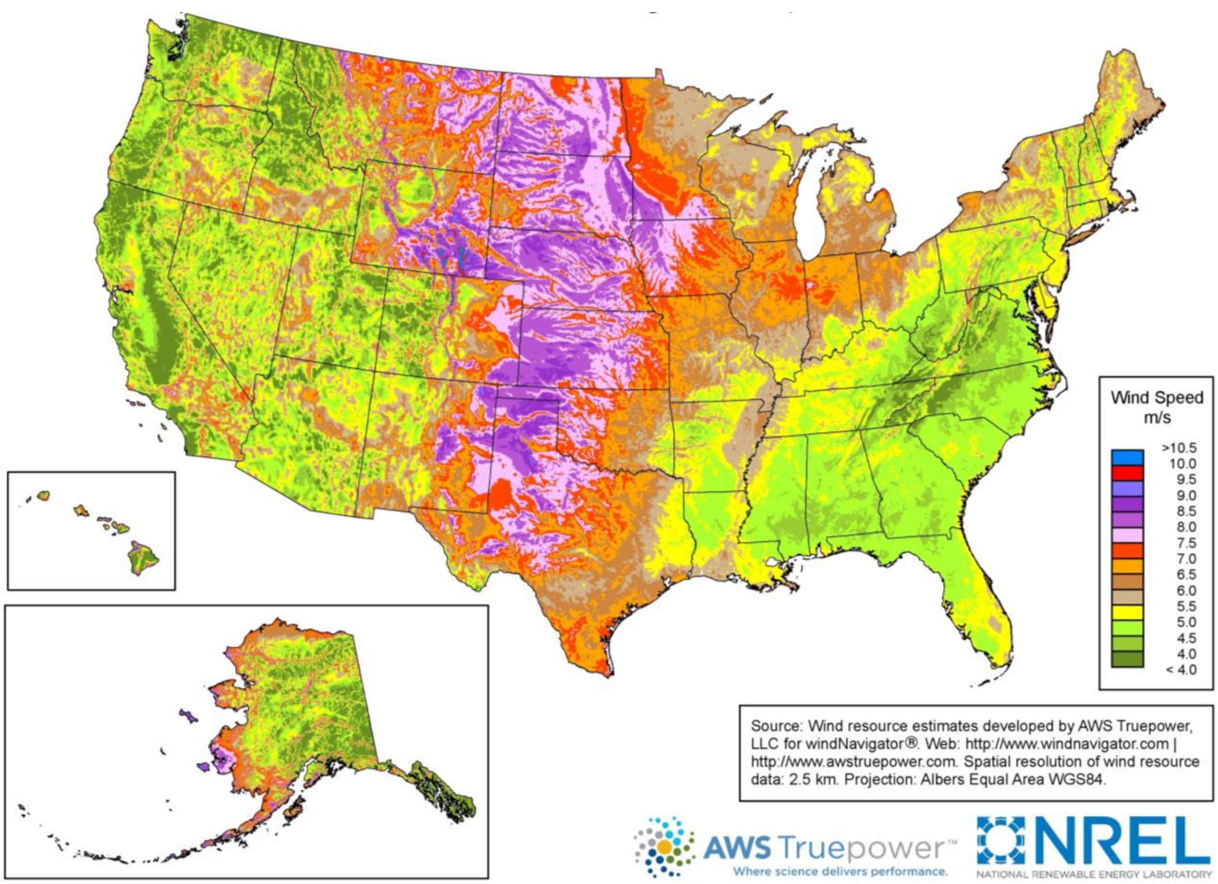


**Figure 1. United States: Annual average wind speed at 80m[3]**

If there was a wind turbine that could operate effectively at lower wind speeds a huge market, roughly two-thirds of the country, would develop for wind turbine producers. The question then becomes how to make wind turbines work in areas where the wind speed is too low for current turbines to operate effectively. The solution proposed by the sponsor is to make the wind turbine taller so it can utilize faster wind speeds at higher altitudes. The higher wind speed at higher altitudes can be explained by looking at wind flow like water flowing through a pipe with a boundary layer being developed. The velocity vectors will increase with distance from the ground. An example of this wind gradient is shown below in Figure 2.

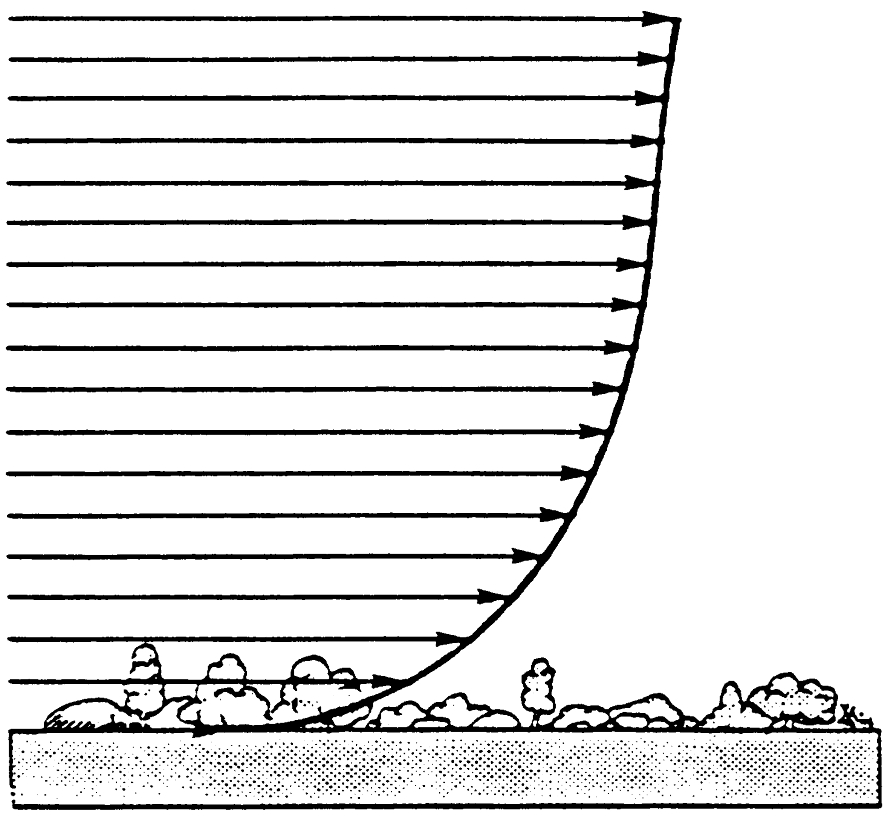

**Figure 2. Development of wind gradient with increasing altitude[4]**

In order to generate electricity, there must be some sort of input energy. In the case of wind turbines, the input kinetic energy is the wind. This wind causes the blades on a turbine to rotate. These blades are attached to a rotor that spins the generator producing electricity. Currently there are two types of wind turbines used to generate electricity. These include horizontal axis turbines and vertical axis turbines.[5] The issue our senior design team is faced with is the lack of input kinetic energy in the wind in low wind speed regions such as Florida. As a result of these low wind speeds, current wind turbines cannot generate sufficient energy. This leaves our senior design group with the task of overcoming the uncontrollable obstacle of low wind speeds and designing a turbine that can generate sufficient energy in low wind speed regions.

The speed of the wind on the wind turbine is critical to generating enough power to be cost-effective. Wind turbines have a "Cut-in Speed" which is the minimum wind speed needed to generate useable power.[6] For most wind turbines this speed is typically 3 to 4.5 m/s. From Figure 1 it can been seen that Florida wind speeds barely make this cut at 80 meters. The most common wind turbine used in the United States is 80 meters tall. This project would like to design a wind turbine 150 to 200% larger to utilize the higher wind speeds at higher altitudes.

Just this month (September, 2014) the Energy Department announced that they would be putting $2 million in funding towards two companies in Iowa and Boston focused on producing taller wind turbines in a cost-effective manner.[7] This commitment to taller wind turbines by the government shows that there is a strong incentive to develop this technology for the private and public sector.

## 2.2 Need Statement

Our project is sponsored by the FAMU-FSU College of Engineering. The project leader/sponsor is Dr. Sungmoon Jung and he wants the group to focus on using new turbine blade and structural materials that will allow for a new, cost-effective wind turbine to be built in Florida. Currently there are no major wind farms in Florida due to low wind speeds at 80 meters. By introducing a wind turbine that is effective in Florida a new market could exist. There is a need to develop and produce a new type of wind turbine that is larger to utilize wind power in areas like Florida.

**“Current 80 meter wind turbines are not cost-effective for use in the Southeastern U.S.”**

## 2.3 Goal Statement & Objectives

Due to the fact that current wind turbines do not exist that can be effectively used in the southeastern united states, this team was presented with the following idea

“Design a new wind turbine that can be used in low wind speed regions to generate electricity”

**Objectives**:

The goal of the project has several important objectives that the team needs to meet to be successful. They are as follows:

- Incorporate innovative technologies into the wind turbine design
- Design wind turbine blades for tower 150-200% larger than current wind turbines
- Design a turbine tower that is structurally sound at higher altitudes
- Construct a scaled prototype of turbine design for testing

# 3 Constraints

The sponsor wants the students to utilize new technologies and ideas in their design of the wind turbine. The new structural/mechanical designs have to be structurally sound at the height of 150 to 200 meters. In order for the turbine to be a realistic option for the southeast the design must be cost competitive with current wind turbines in the market today. Along with being financially competitive, the turbine must be able to generate at least the same electrical power as current turbines. All of these initial designs and prototyping by the team must be accomplished before the end of the spring semester within a budget of $2,000. The design and performance specifications for the project are below.

## 3.1 Design Specifications

The design specifications for this project are as follows

- The wind turbine will be 150-200% taller than current wind turbines
- Must withstand stress of wind at 150m in SE United States
- The structure must support its own weight
- Blades will lighter than average current turbines
- Wind Turbine will be innovative into the wind energy field

## 3.2 Performance Specification

The performance specifications for this project are as follows

- It will use a 5 MW turbine motor
- Operating in all weather conditions with exception of winds >20 m/s
- There will be no energy used or fuel consumed
- The efficiency will be within a range of 30-35%

# 4 Methodology

The general strategy of the team is to split up the various tasks into distinct sections to make the workload more manageable. Although everyone has individual tasks the team will still meet weekly to ensure that progress is being maintained throughout the semester. The team will also meet every other week with the sponsor and faculty advisor to keep them updated and inquire about any issues encountered. The following schedule describes how the project will be broken down.

## 4.1 Schedule

The Gantt chart in the Appendix shows a complete breakdown of the tasks that the team plans to accomplish this semester. The first thing the team completed was research into wind turbines to make sure that team members were informed about the project and its requirements. Several different research topics were focused on including current wind turbine construction techniques, cost of wind turbine production, new materials being developed for turbine blades, and the types of forces and loads imposed on a wind turbine during operation. More extensive research will be done throughout the semester as the needs of the project expand.

With initial research completed the team has begun to consider different possible designs for the wind turbine tower and blades. The civil engineering students focused mainly on the tower structure and the mechanical engineering students focused on the blade materials and design. The designs will incorporate new technologies into the structure and blades.

Once the team has developed several possible designs for the wind turbine we will construct them in CAD software. In order to analyze the forces on the wind turbines the team will use a software program called FAST created by the National Renewable Energy Laboratory. After simulation of the designs is complete the team will select the best design using a decision matrix. By the end of the fall semester the team should have at least two viable designs that can be taken into the spring semester for further analysis and possible prototyping.

## 4.2 Resource Allocation

Every member of the team was responsible for background research on wind turbines. More research will be done if needed. The first three weeks of the project were spent on research about the project and wind turbines in general. The team is currently in the design development phase of the project, three weeks were given for initial designs to be created. The mechanical students focused on design of the blades while the civil students designed the structure. After the design phase the team will move on to force calculations of the blades and structure this will take place over two weeks. Then one week will be spent on cost analysis of the possible designs. Finally, there will be a design selection process at the end of the semester lasting two weeks. The entire team will participate in the design selection process. Table 1, located below provides information on the main tasks that each team member will focus on.

**Table 1. Allocation of resources**

| Name | Tasks |
|---|---|
| Steven Blanchette | • Background Research<br>• Initial Blade Design<br>• Blade CAD Drawings<br>• Design Selection |
| David Delie | • Background Research<br>• Material Selection<br>• Cost Analysis<br>• Design Selection |
| Kimberly Martinson | • Background Research<br>• Initial Structure Design<br>• Structural CAD<br>• Design Selection |
| Jeremiah McCallister | • Background Research<br>• Material Selection<br>• Initial Blade Design<br>• Design Selection |
| Abigail McCool | • Background Research<br>• Initial Blade Design<br>• NREL FAST Operator<br>• Force Calculations<br>• Design Selection |
| Theodore Meros | • Background Research<br>• Initial Structure Design<br>• Structural CAD<br>• Structural Analysis<br>• Design Selection |

# 5 Conclusion

The goal of this project is to design a new wind turbine that is 150-200% larger that can be used in the Southeastern United States. If a turbine that makes wind power feasible for use in Florida is developed, there will be a huge new market for turbine producers to sell to. Preliminary research has been completed for the project and the team has developed a few design ideas for the structure and blades. These designs will be created in CAD and tested with the FAST simulation software given to the team by Dr. Jung. Once the simulation of the designs is completed it can be compared to current turbines and the team can proceed with the best design. With the resource allocation completed, the team can begin to focus on their next tasks. For the next report the team will have calculated forces on the wind turbine designs.

# 6 References


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2) "Renewable Energy for America: Florida." *Natural Resources Defense Council*. Natural Resources Defense Council. Web. 22 Sept. 2014. <http://www.nrdc.org/energy/renewables/florida.asp>.

3) "Wind Maps." *NREL: Dynamic Maps, GIS Data, and Analysis Tools* -. National Renewable Energy Laboratory, 10 Sept. 2014. Web. 22 Sept. 2014. <http://www.nrel.gov/gis/wind.html>.

4) Lake, John. "The Wind Gradient." *CHGPA: Intermediate Study Material from USHGA for Hang Gliding*. United States Hang Gliding Association, Inc., 1 Jun. 1997. Web. 22 Sept. 2014. <http://www.chgpa.org/H3_StudyGuide/h3.study.guide.html>.

5) "How Does a Wind Turbine Work?" *Energy.gov*. U.S. Department of Energy. Web. 22 Sept. 2014. <http://energy.gov/maps/how-does-wind-turbine-work>.

6) "Wind Speed and Wind Energy." *Wind Energy*. EnergyBible.com, 1 Jan. 2012. Web. 22 Sept. 2014. <http://energybible.com/wind_energy/wind_speed.html>.

7) "Energy Department Announces $2 Million to Support Manufacturing of Taller Wind Turbine Towers." *Energy.gov*. Office of Energy Efficiency & Renewable Energy, 18 Sept. 2014. Web. 22 Sept. 2014. <http://www.energy.gov/eere/articles/energy-department-announces-2-million-support-manufacturing-taller-wind-turbine-towers>

# Appendix: Gantt Chart