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Wind Energy Smart Rotor Control in Extreme Wind Events

Test Turbine near Amarillo, TX

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Presentation Outline

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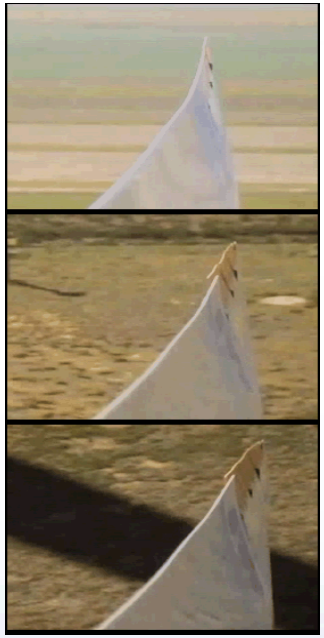
Introduction

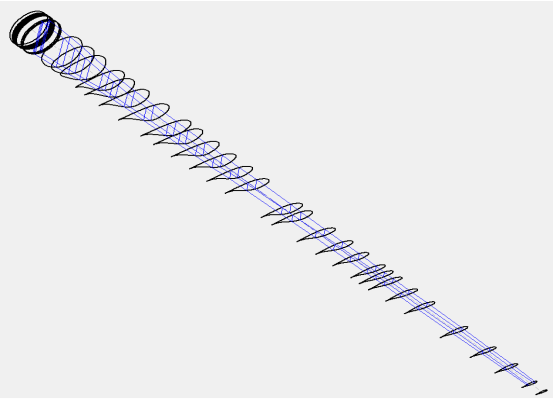
- Improvements to wind energy can be made through use of Active Aerodynamics. Active Aero can increase control over loads which can reduce the cost of wind energy, could allow for the use of lighter components, and can extend the life of the entire turbine.
- To learn how the use of Active Aero will impact turbines, simulations must be run using tools like FAST
- Past simulation focus has been on turbine fatigue, but has now been shifted towards extreme wind events, and how Active Aero can help to prevent damage to the turbine
- My research has been on Active Aero and extreme wind events

Smart Rotor Images

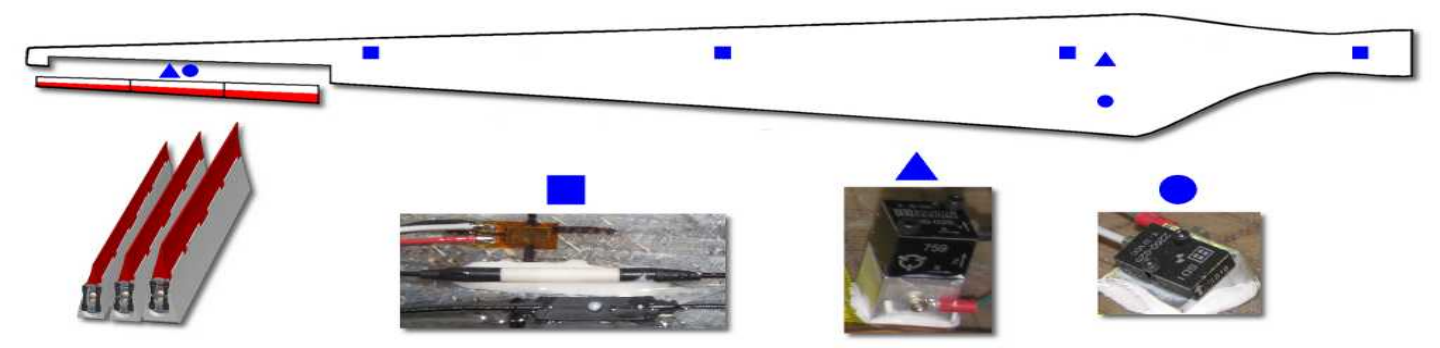


Still images of Smart blade in action

Close up of blades



Blade Airfoil sections in MATLAB



3 flap modules

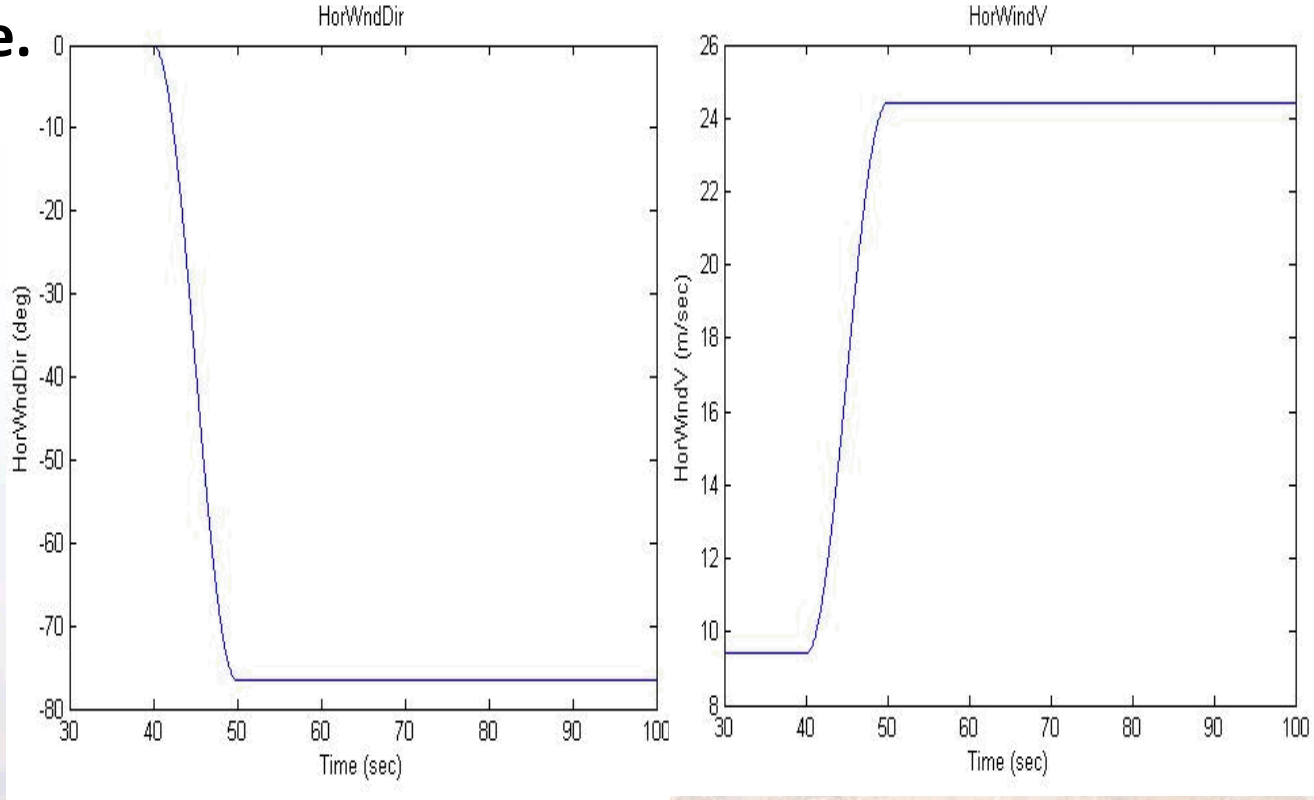
Blade Sensors: strain gages, temp gage, and accelerometers

Objectives

- Learn about the simulation tools
- Help optimize the models used for these simulations
- Run simulations and analyze the results
- My simulations look specifically at extreme wind cases. These cases can be some of the most damaging to wind turbines and often current measures such as blade pitch control don't act quickly enough to the situation. Active Aerodynamics could help to protect the turbine from these situations

Extreme Wind Case Description

- **An example of on extreme wind case would be a case called and ECD case. ECD stands for Extreme Coherent Gust with Direction Change.**



Horizontal wind velocity and Horizontal wind direction

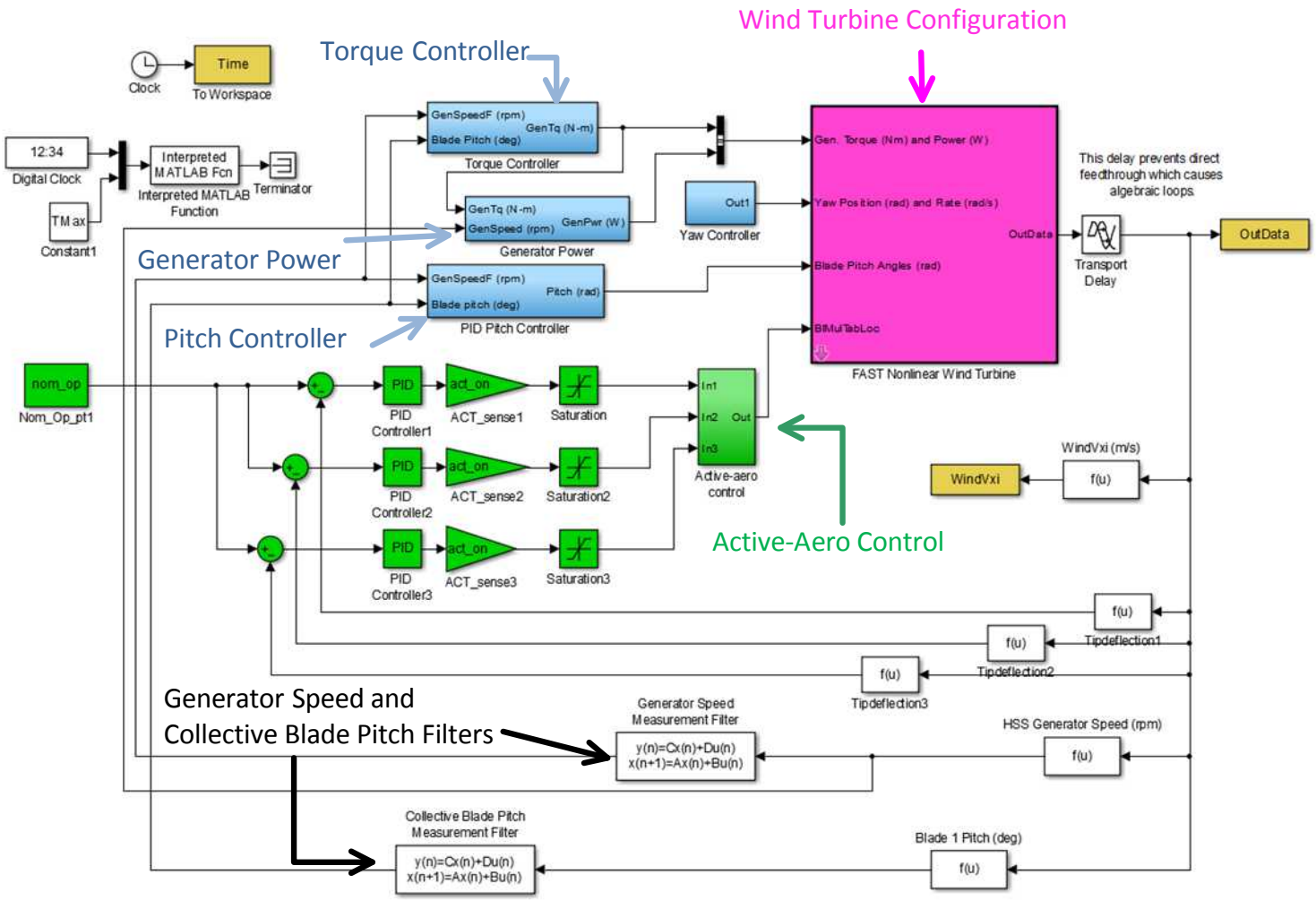
Methods

Tools Used:

- **Matlab: numerical computing environment**
- **Simulink: graphical tool for modeling, simulating, and analyzing systems**
- **FAST: complex simulator capable of predicting loads experienced by horizontal axis wind turbines that have 2 or 3 blades**
- **AeroDyn: wind-turbine aerodynamics analysis routine**
- **NuMAD: blade design tool**

Example Model

NREL Baseline 5MW Onshore FAST



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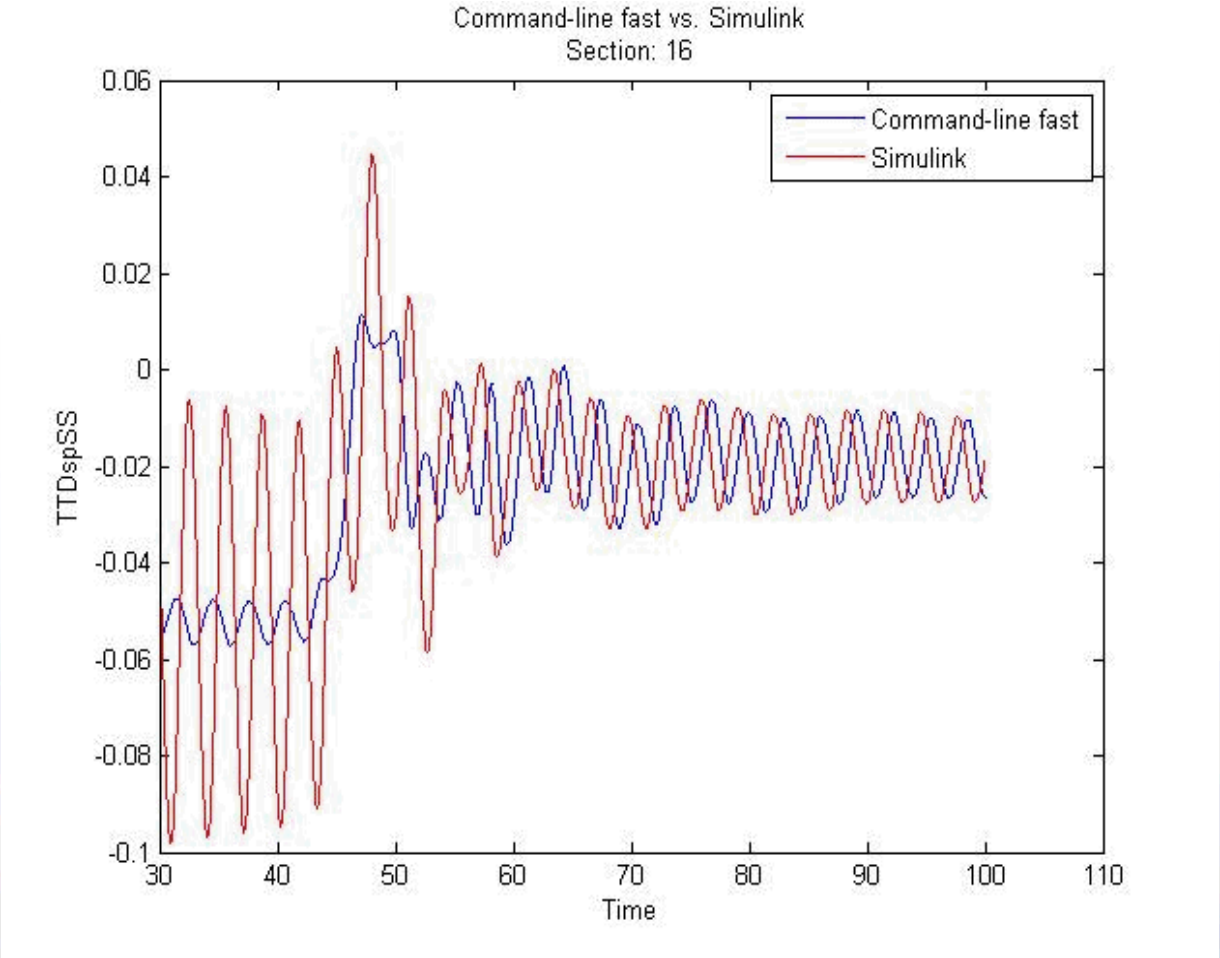
Results

- Helped to discover issue with Simulink model. Issue was how turbine's variable-speed controller was implemented
- Analysis of Active Aero's effects on turbine during extreme wind conditions
- Comparison graphs have shown reductions of tower top deflection, blade deflections, thrust forces, as well as other reductions of fatigue during extreme wind cases
- Simulations have also shown that Active Aero has reduced the need of the blade to pitch
- Due to these improvements, it is very likely that lighter materials can be incorporated over the previously used heavier and sturdier materials

Results Continued



Tower top deflection of both models, differences show issue with Simulink version

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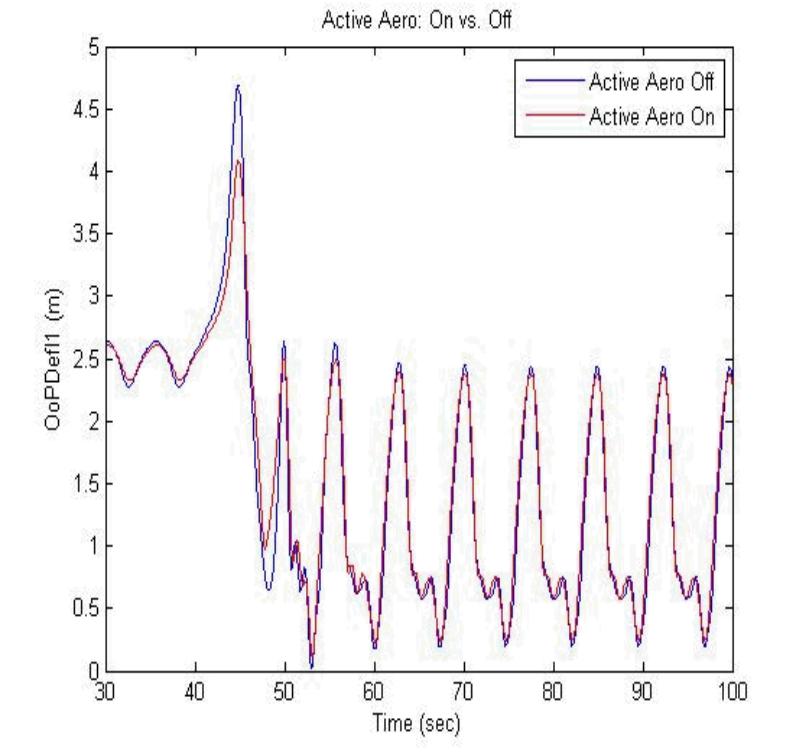
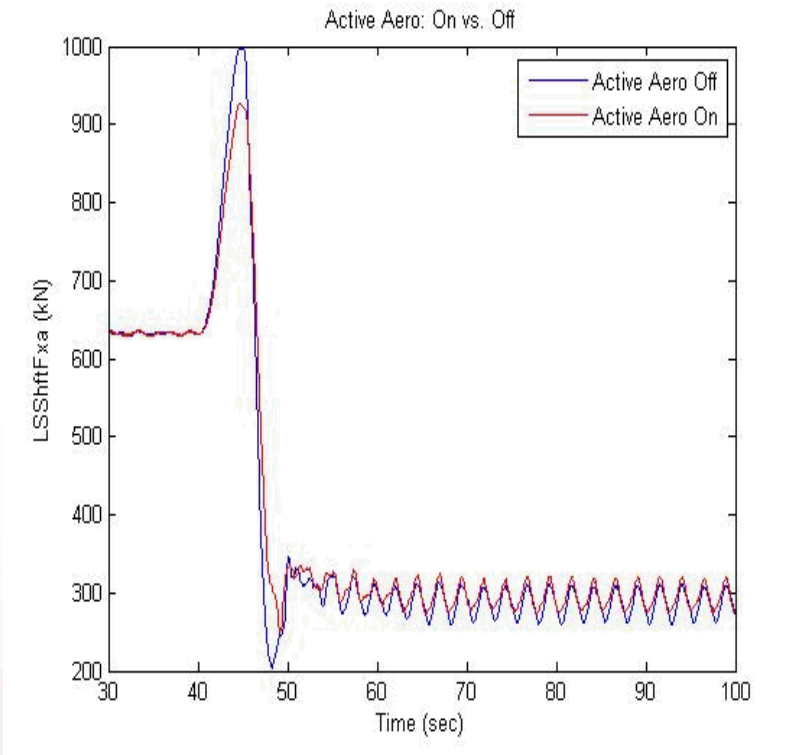
Results Continued



out-of-plane tip deflection (reduction of 12.754% at main spike)



rotor thrust force (reduction of 7.04% at main spike)

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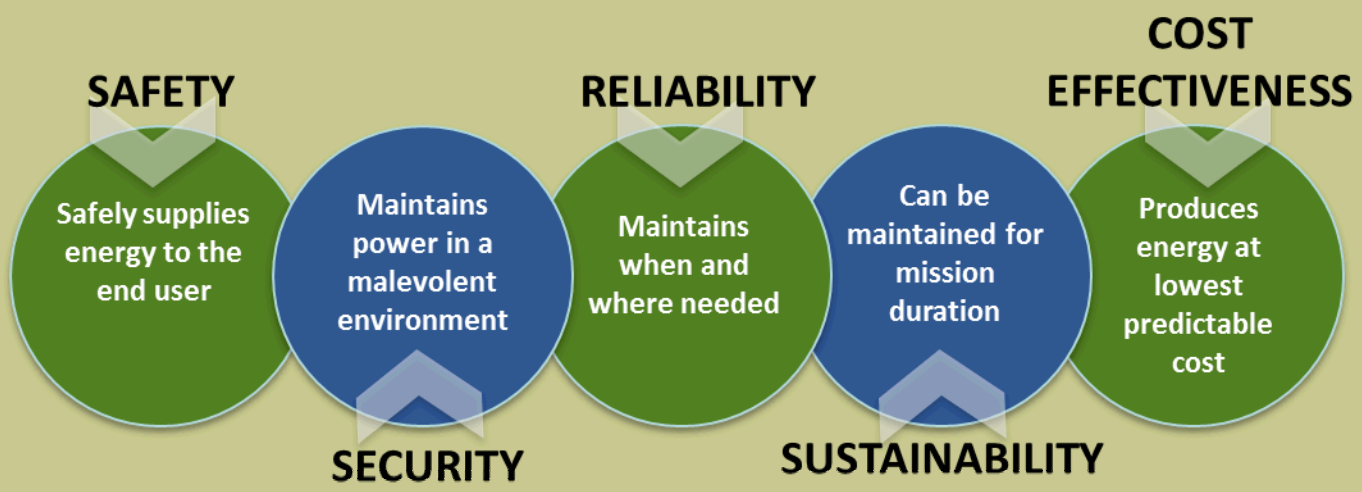
Energy Surety

A Sandia developed risk-based approach to implement and measure Energy Security effectiveness



Safety

Safely supplies energy to the end user

- **Benefits:**
  - **Eco-friendly, doesn't pollute so wind energy is safer for environment**
  - **Safer than other energy sources such as nuclear**
- **Issues:**
  - **Noise**

Security

Maintains power in a malevolent environment

- **Benefits:**
  - Less targeted than other energy sources, less security needed
- **Issues:**
  - Hackers
  - People shooting at turbines
  - Preventing people physical access to turbines

Reliability

Maintains when and where needed

- **Benefits:**
  - Long term source reliability
- **Issues:**
  - Wind energy can only be harvested in certain locations, not ideal everywhere
  - Only producing power when certain wind conditions exist, cannot produce on demand
  - Downtime from maintenance
- **What is being done:**
  - CREW Database: Learn which areas of the turbine research should be focused in so that unexpected maintenance can be reduced, increasing reliability
  - Smart Rotor: Make turbine more efficient and decrease loads on turbine. Turbine more reliable for producing power and less unexpected maintenance will be needed

Sustainability

Can be maintained for mission duration

- **Benefits:**
  - **Wind is a renewable resource, cannot be depleted**
  - **Since wind energy is eco-friendly, the public will be more likely to accept it as long as the turbines are not considered to be in the way**

Cost Effectiveness

Produces energy at lowest predictable cost

- **Benefits:**
  - Fuel for wind energy is free
  - At good wind sites, wind is already competitive compared to other sources such as coal
- **Issues:**
  - Maintenance costs
- **What is being done:**
  - Improvements to reliability improve operation and maintenance costs

Future Work

- **The next step for this research is looking into changing blade properties so that the blade could be lighter**
- **The use of lighter materials might be possible due to the reduced forces on the blade after the addition of Active Aero**
- **Lighter and cheaper materials could be used since the turbine will be less dependent on material strength**