IOWA STATE UNIVERSITY
Wind Energy Science, Engineering, and Policy

IGERT 2013 VIDEO AND POSTER COMPETITION

Improving the reliability and sustainability of wind energy

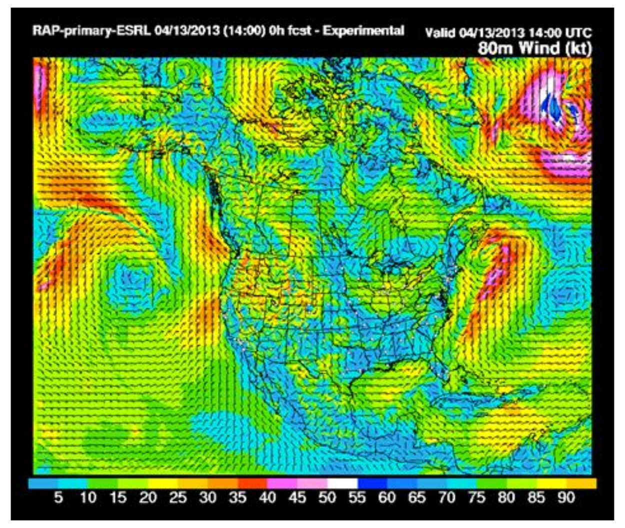
David Jahn, Michael Johnson, Ashley Mui, and Huiyi Zhang

1. FORECASTING

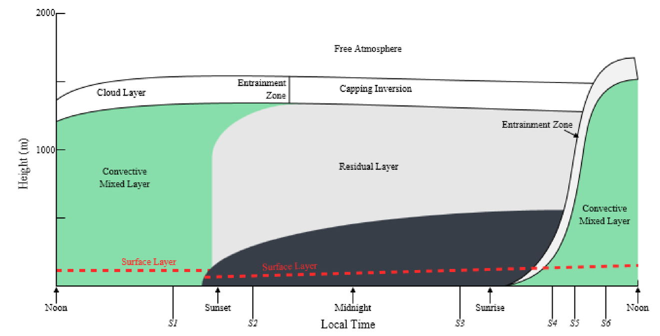
- Wind as a resource is highly volatile and presents a significant challenge for producing reliable energy.
- It is imperative to increase current capability of numerical weather prediction (NWP) models to forecast wind speeds at hub height .
- Current NWP models do not handle well the evolution of the atmospheric boundary layer (ABL) winds especially under stable conditions at night.

GOAL

To improve the representation of boundary layer evolution in existing NWP models.



RAP model 80m wind forecast (from the Nat. Weather Service http://rapidrefresh.noaa.gov)



Diurnal evolution of the ABL (adapted from Stull, R.B. 1988. An Introduction to Boundary Layer Meteorology.)

METHODOLOGY

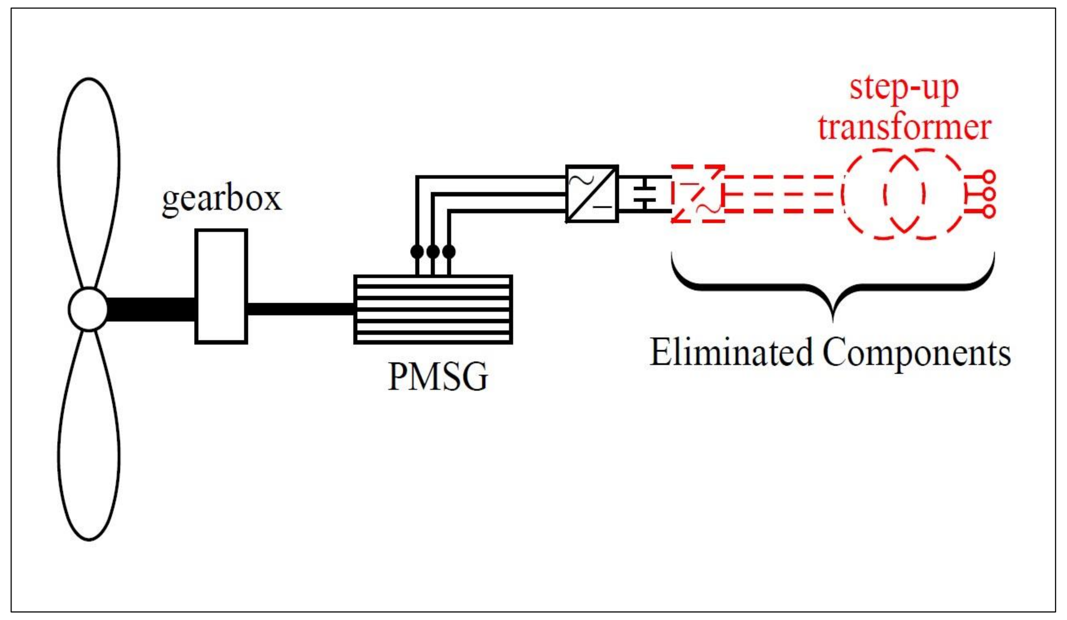
- Document ABL evolution under various stability conditions using
  - field observations.
  - numerical studies using a LES model
- Identify variable signatures on the relatively coarse scale (e.g. mesoscale) based on ABL dynamics on the fine scale
- Propose means for modifying turbulence parameterization schemes in NWP models in order to represent more accurately subgrid scale ABL effects.

2. POWER COLLECTION

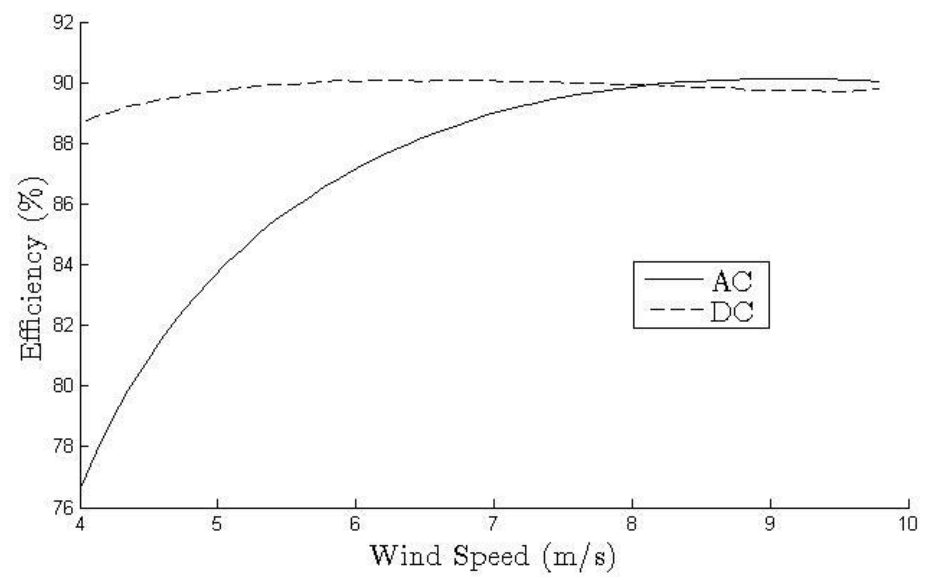
Offshore wind farms far from shore often use medium voltage alternating current (AC) collection systems with high voltage direct current (DC) transmission to shore. The AC output of permanent-magnet synchronous generators is usually converted to DC which is converted back to AC to allow the turbine to operate with variable speed.

By eliminating the inverter stage, DC collection can allow variable DC-link voltage, decreasing losses at low wind speeds, and reducing voltage stress on power electronic components possibly increasing component life.

The results below suggest a DC collection system could result in fewer losses and higher revenue for an offshore wind farm.



Efficiency of DC and AC Designs Compared



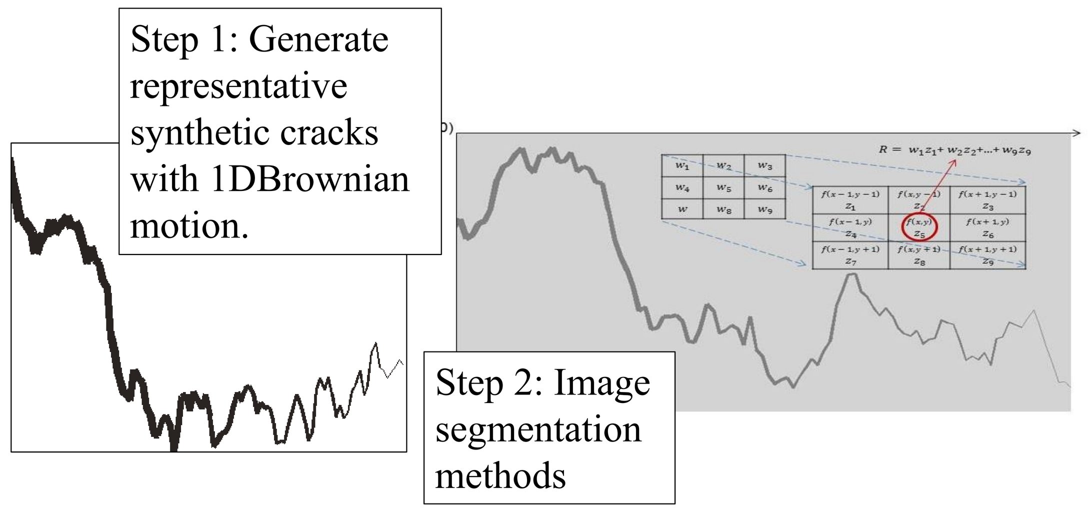
Expected Annual Energy/Revenue Loss

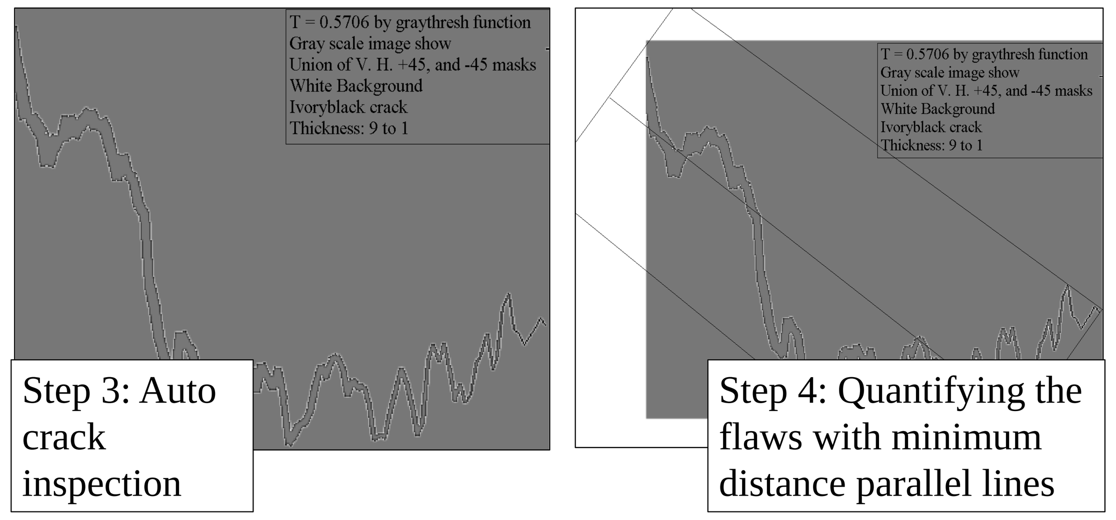
Design	Energy Lost	Revenue Lost
DC	123,580 MWh	$6.19 Million
AC	126,690 MWh	$6.35 Million

3. MAINTENANCE

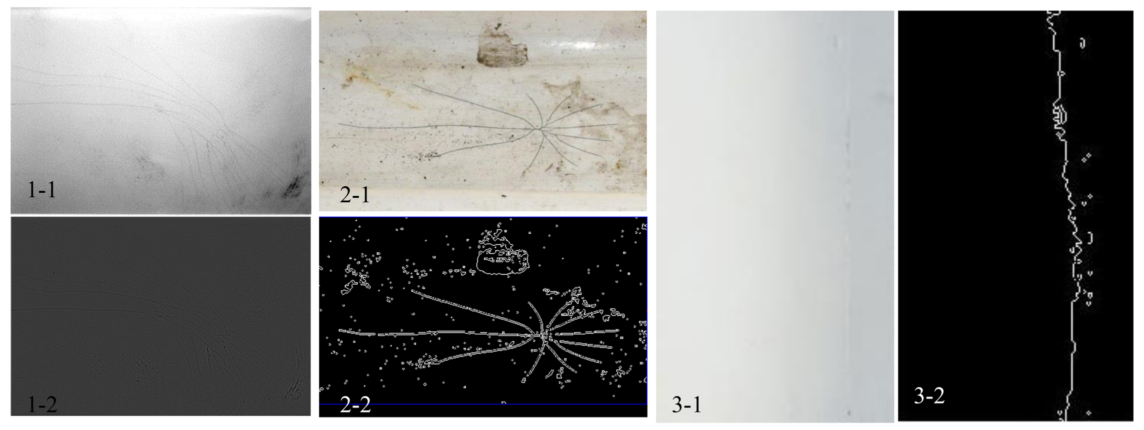
A new image processing technique was investigated to assess its capability in detecting surface flaws on a wind turbine blade (WTB) on-tower. The method was tested by varying parameters of the surface flaws as well as parameters of the method. It was found that WTB surface flaws can be observed and quantified with computers.

Digital image processing can detect hairline cracks easily, which are usually hard to be see with the human eye. Image processing is not sensitive to image orientation.





Representative Field Image Testing



Hairline cracks can be detected easily and accurately with this method but not with the human eye. The method can recognize hairline crack from every angle, which indicates the angle of camera set up is not cortical.

Experiments illustrate that the brightness/uneven illustration of the background significantly affects the visibility of the crack.

4. DISPOSAL

Currently, landfilling of wind turbine blades is practiced. 172,000 tons / year of spent blades will be created if the US reaches 20% wind energy.

The development of recycling methods can keep the fiberglass blades out of the landfill and recover energy and materials.

Blade derived cement from Holcim company in Germany

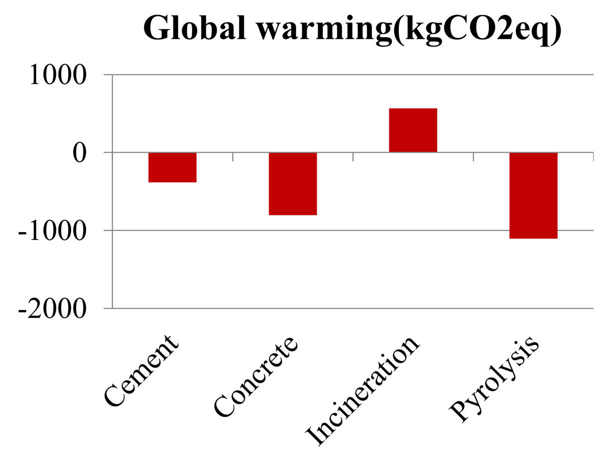
Insulation mat from pyrolysis, developed by ReFiber in Denmark

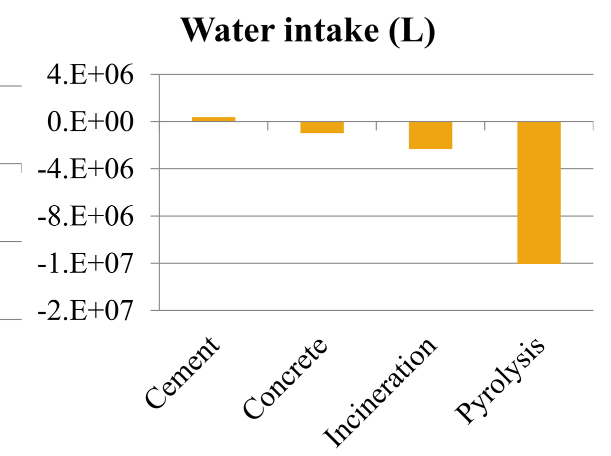
Concrete aggregate processed at Iowa State

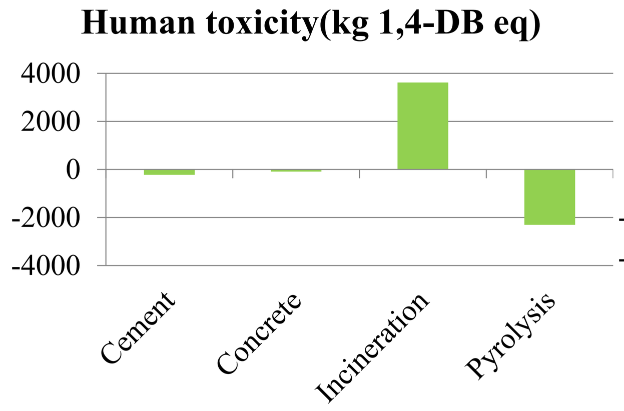
POTENTIAL SOLUTIONS

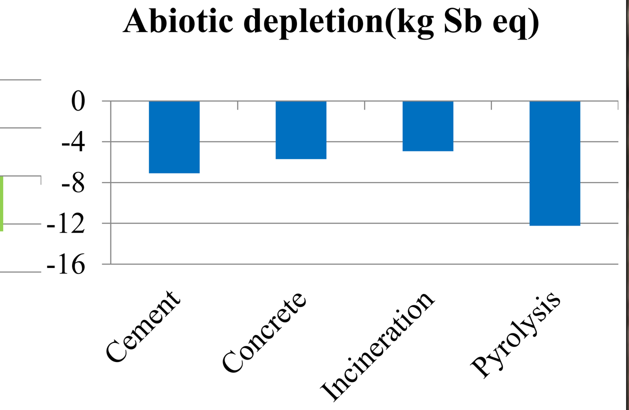
1) Incineration - Energy recovery and volume reduction. No recovery of materials is attempted.
2) Cement Co-Processing - Turbine blade chips are incinerated in a cement kiln. Ash can be recovered and incorporated into the cement clinker, substituting chalk and sand. Energy in the resin replaces bituminous coal combustion for the cement kiln.
3) Pyrolysis - Thermal degradation in an oxygen-free environment. The hot gases released from the resin provide energy to further fuel the process and surplus energy can generate electricity. The recovered glass fibers can be used as insulation materials or fiber reinforcement for concrete and plastic parts.
4) Concrete Additives - Blade chunks can substitute for aggregates, producing lightweight concrete.

We used life cycle analysis methodology (CML 2001 Impact Assessment method) to evaluate the environmental impacts of each method. Expansion of system boundaries is used to credit methods for the avoided production of virgin materials that the products of recycling can provide.









For most methods besides incineration, the net impacts are negative, meaning emissions are avoided. Harmful environmental impacts are avoided through recycling of the blades.

Acknowledgements: We would like to thank Dr. James McCalley for his leadership of the WESEP program and Nicholas Brown for his contribution to video editing.