NATIONAL RENEWABLE ENERGY LABORATORY

Innovation for Our Energy Future

Overview of Device Modeling Status

Dr. Ye Li

Senior Scientist

Ye.li@nrel.gov

1st NREL MHK Modeling Meeting

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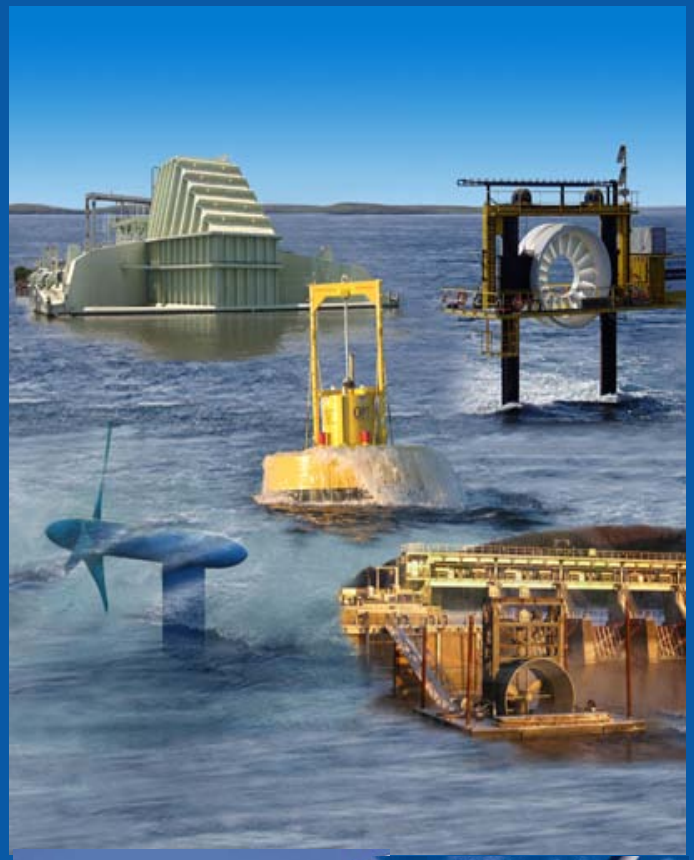
NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Administration's National Renewable Goals

- Double renewable energy capacity by 2012
- 10% renewable energy by 2012
- 25% renewable energy by 2025
- Create 5 million new green jobs
- 80% reduction in GhG (from 1990 levels) by 2050
- Informed by 20% *Wind Energy by 2030* report published by DOE in May 2008

Outline



- National Renewable Energy Laboratory Overview
- MHK R&D Status
- MHK Device Modeling Overview and Challenges
- Relevant R&D efforts

NREL Overview

- Advanced Vehicles & Fuels
- Basic Sciences
- Biomass
- Buildings
- Computational Science
- Concentrating Solar Power
- Electrical Infrastructure
- Energy Analysis
- Geothermal
- Hydrogen & Fuel Cells
- Photovoltaics
- Wind & Water Power

NWTC Overview

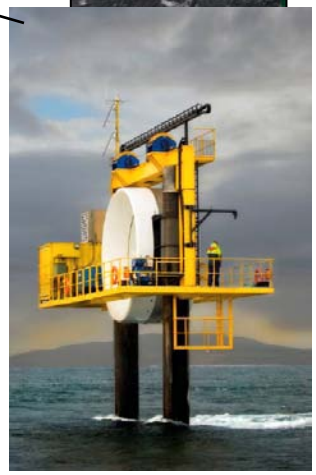
- Turbine testing since 1977
- Leader in development of design and analysis codes
- Pioneers in component testing
- Unique test facilities
  - Blade Testing
  - Dynamometer
  - CART turbines
- Modern utility-scale turbines
- Approx. 100 staff on-site
  - 10 offshore staff
- Budget approx. $35M
- Leadership roles for international standards

Tidal Current Turbine Examples

Marine Current Turbines (axial flow, open rotor)

GCK (cross flow, Gorlov helical rotor)

Open Hydro (axial flow, open rotor, rim-drive)



Lunar Energy (axial flow, shrouded single-rotor)

SeaPower (cross flow, Savonius rotor)

SMD Hydrovision (axial flow, open rotor)

UEK (axial flow, shrouded twin-rotor)

Verdant Power (axial flow, open rotor)

Wave Energy Device Examples

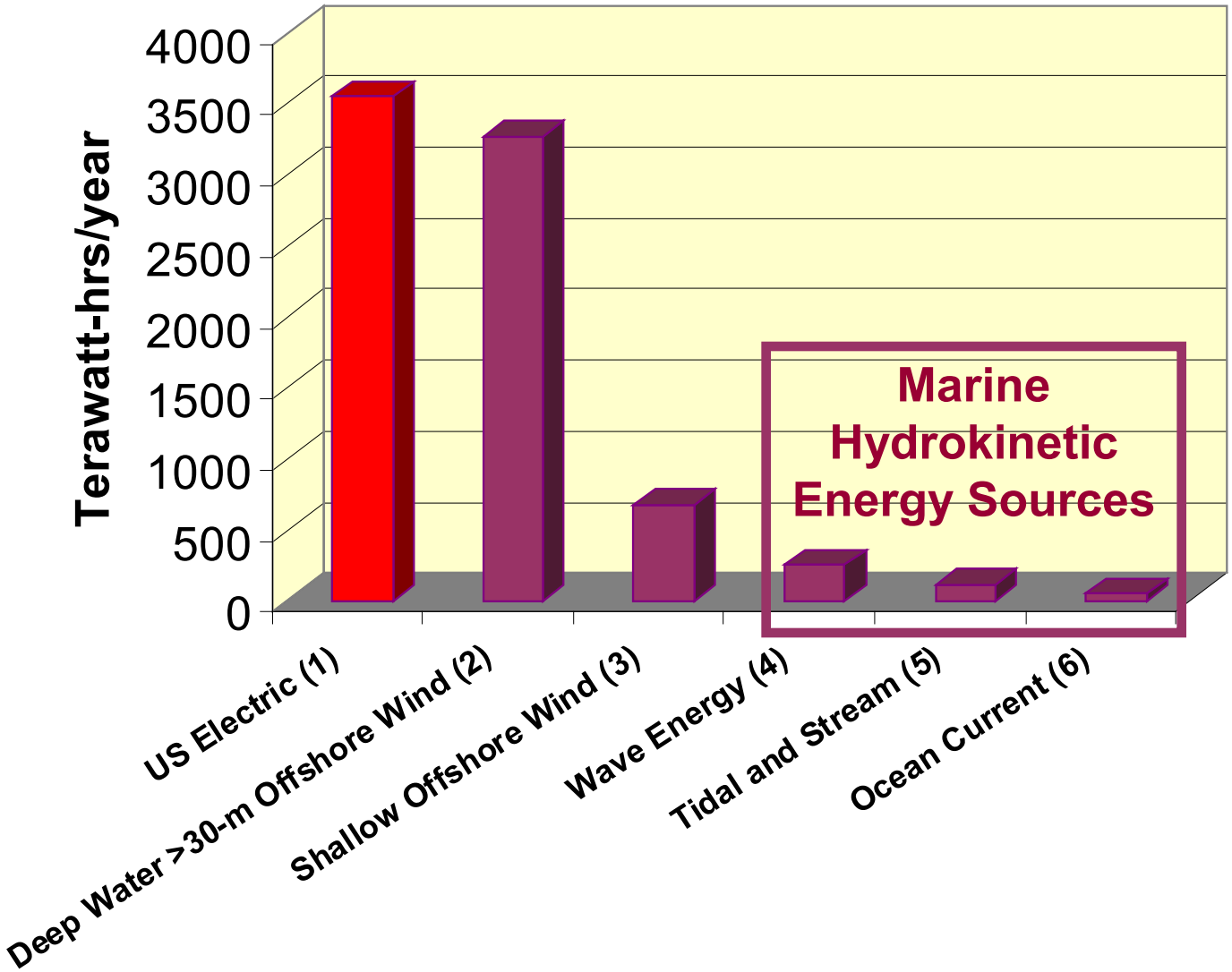
Floating
Point Absorber
(*AquaBuOY*)

Floating **Attenuator** (*Pelamis*)

Oscillating Water Column **Terminator**
(*Oceanlinx*)

Floating Overtopping
Terminator (*Wave Dragon*)

US Ocean Energy Electric Potential Estimates



Assumptions

(1) U.S. electric consumption based on 2005 EIA statistics.

(2) Class 5 wind or better; depths between 30-m and 900-m included; 60% exclusions; HI and AK not included; 0-50nm from shore; 45% Cap factor; Source: NREL.

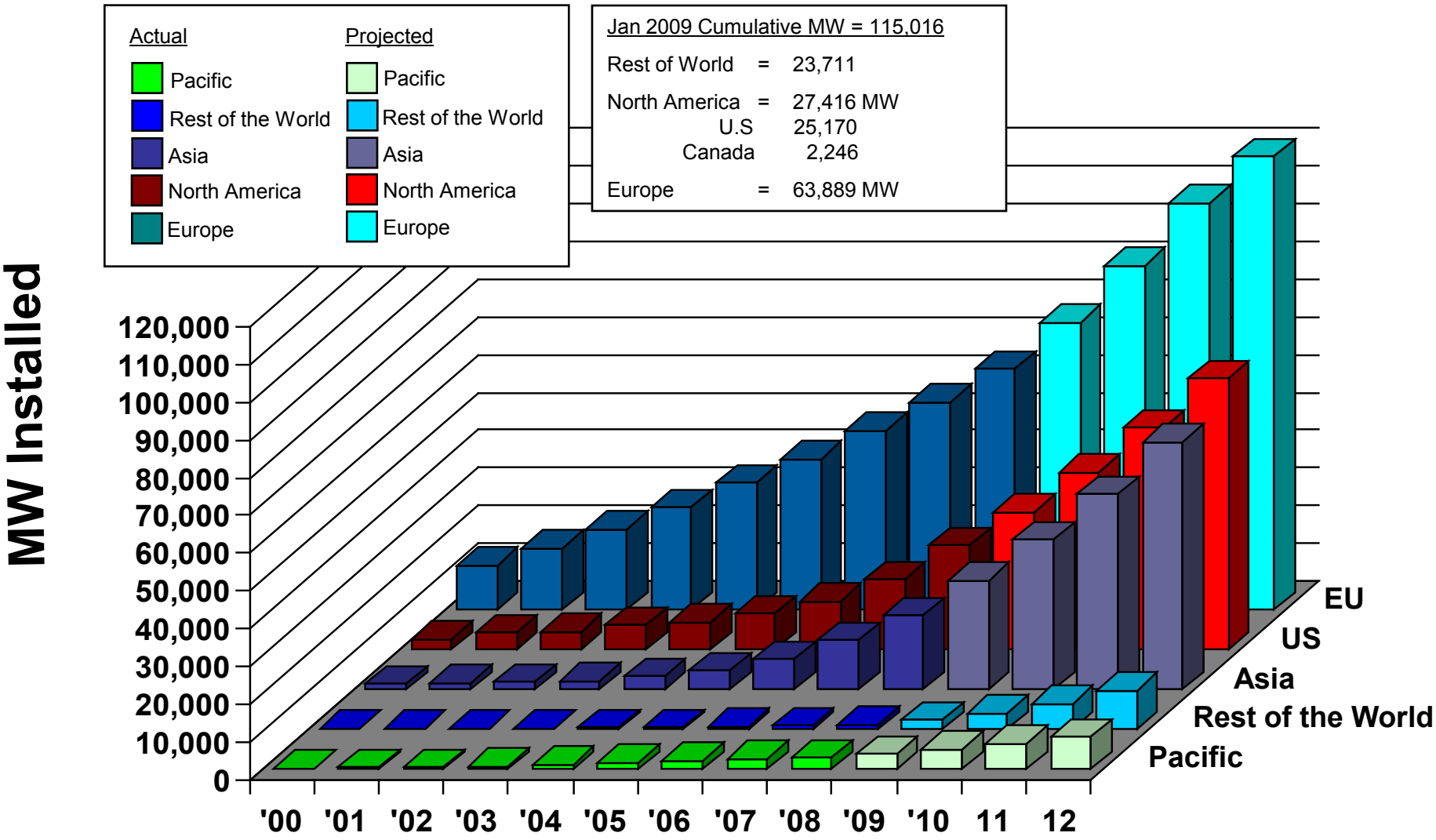
(3) Class 5 wind or better; depths between 0-m and 30-m; included; 60% exclusions; HI and AK not included; 0-50nm from shore; 45% cap factor; Source NREL.

(4) 15% of incident wave energy; 20% conversion losses; AK and HI Included; Wave climate 10kW/m or better; Source EPRI.

(5) Estimated from aggregate siting studies; 15% extraction permitted; In stream river kinetic estimated by EPRI..

(6) Estimated from *Coriolis Study, Aquantis,* and FAU; Miami/Gulf Stream region only, 57% capacity factor; 10-GW rated capacity.

Wind Power Growing



Sources: BTM World Market Update 2007; AWEA, January 2009; Windpower Monthly, January 2009

Ocean Energy Technology Development-Barriers

Immature Technology

- Lack of design tools, standards, and validation data are preventing disciplined approach to design.
- High technical and cost uncertainties due to lack of experience.
- Test facilities are needed where new technologies can be proven outside the commercial regulatory path.

Siting and Permitting

- Conventional hydropower regulatory paradigm for single device technology is hindering development.
- Deployment is limited to a handful of proof of concept devices.
- 2009 promotion act in play for more streamline adaptive management system.

Technology R&D Target

- Determine resource potential for theoretical, technical, and practical energy extraction.
- Characterize technology
- Develop engineering design and analysis tools
- Assess and characterize design environment
- Develop testing protocols and acquire validation data
- Assess environmental impacts and develop mitigation solutions.

Modeling and Design Research-Target

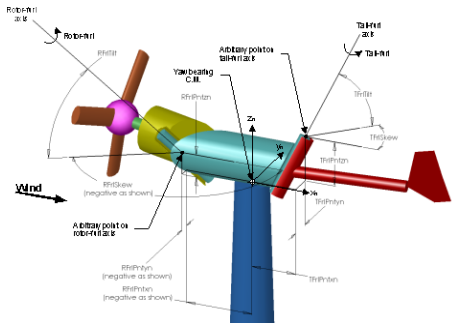
Provide tools and analyses to facilitate:

- Increased component, device, and array efficiency
- Improved component and device survivability and reliability
- Reduced development, deployment, and O&M costs
- Reduce environmental impact

Modeling Effort-Basics

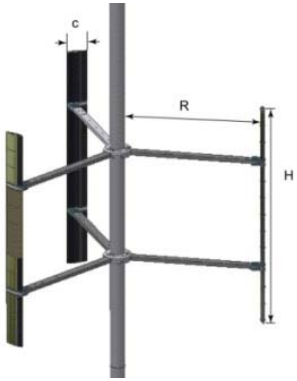
Performance

- Uses advanced heuristics algorithm
- Turbine-optimization → blade profile and rotor control
- Buoy-optimization → buoy geometry and latching control



Reliability

- Simulate unsteady loads
- Simulate hydroelasticity

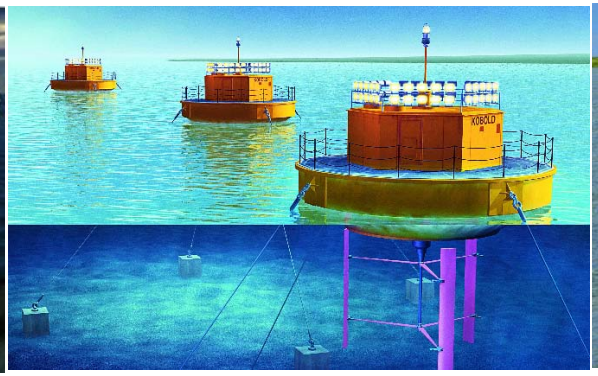


Applications

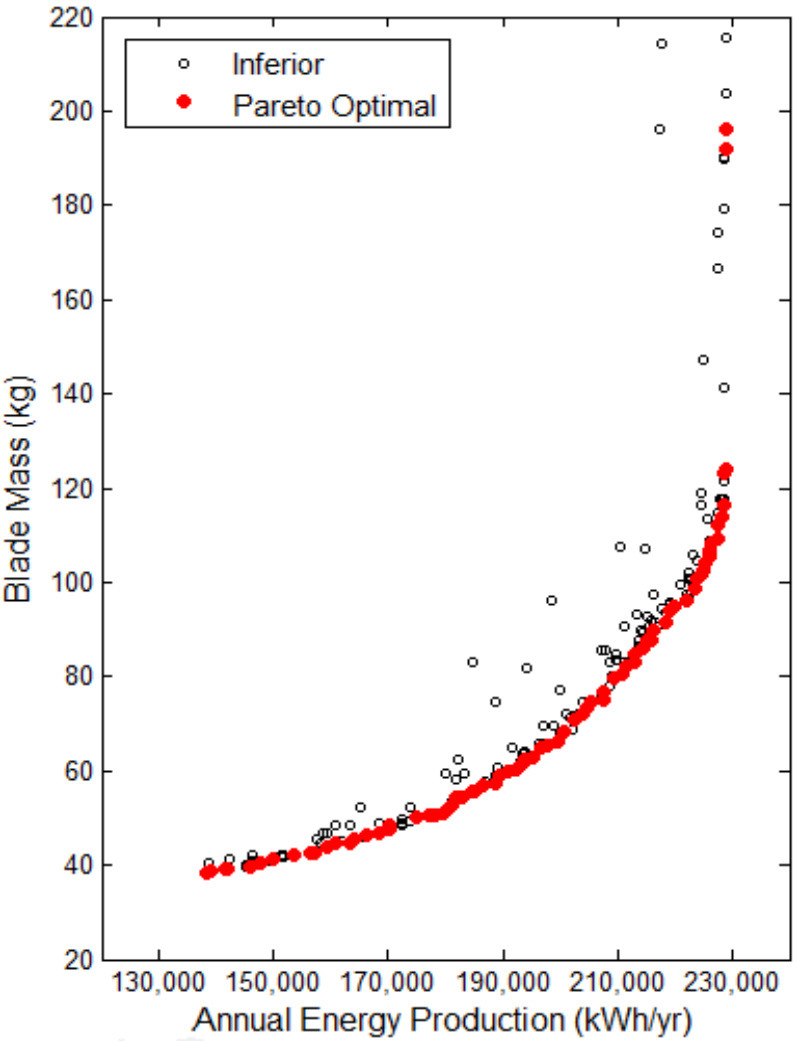
- Horizontal-axis turbines
- Vertical-axis turbines
- Wave buoys

Modeling Effort- Device Array

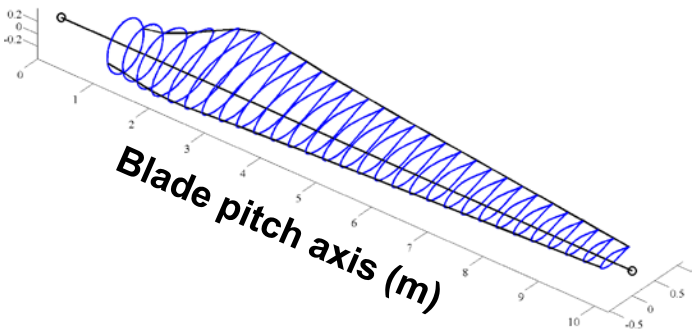
- Understand the hydrodynamic interactions between devices
- Optimize the device distribution, operational parameters, and control strategies at a given site to maximize the array performance and reliability
- Understand the interaction between arrays and ambient flow



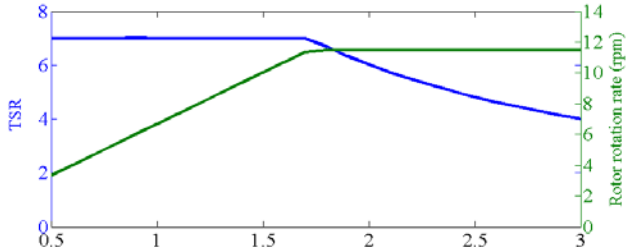
Performance Analysis-Preliminary Analysis



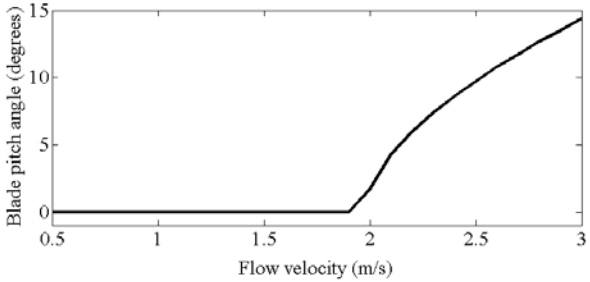
Blade geometry



Turbine operating specifications



Annual Energy Production

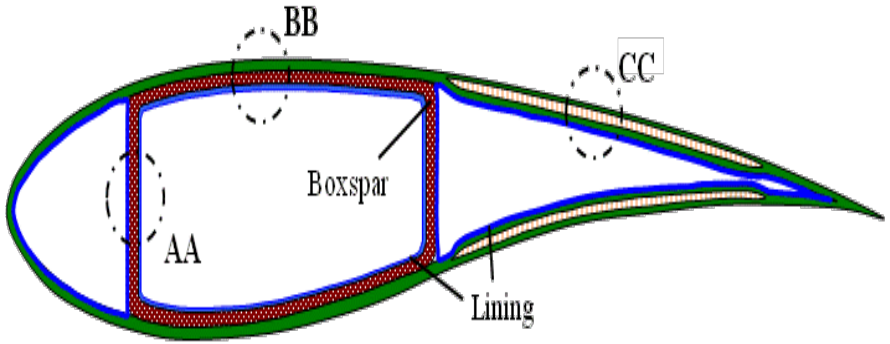


Recent paper-Sale and Li 2010, OMAE

Blade Structural Design

Given:

- blade external geometry
- extreme load distribution
- material properties



Compute:

- composite laminates internal layup
- structural properties: mass, inertia, stiffness (flexural, torsion, axial), elastic axis offset, and c.m. offset variation along the blade.

Recent paper-Bir, Lawson, Li and Snowberg 2011, OMAE

Inflow Characterization

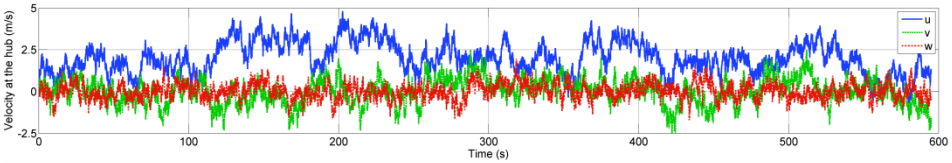
Tidal Flows

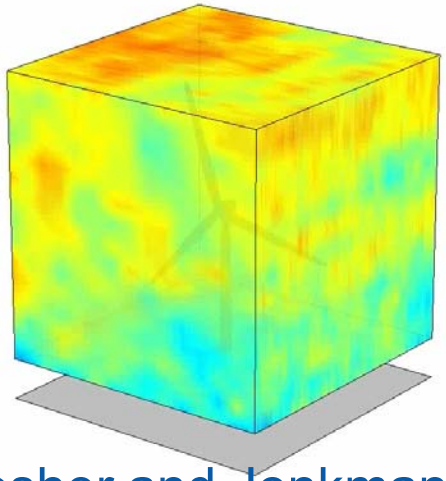
Flow Characterization

- **Two tidal sites being studied**
- **Mean and turbulent inflow**

Inflow Modeling

***Turbsim* generates a time series of 3-component velocities on a rectangular 2-D grid in space**





Recent paper-Li, Kelley, Hughes, Colby, Thresher and Jonkman 2010 OMAE

Wave Buoy-Grid Study

Recent paper-Yu and Li 2011, OMAE and Li et. al, 2011 IWWWFB

Array-Large Eddy Simulation

Recent paper-Churchfield et al., 2011, EWTEC

Challenges

Many methods available in the relevant areas

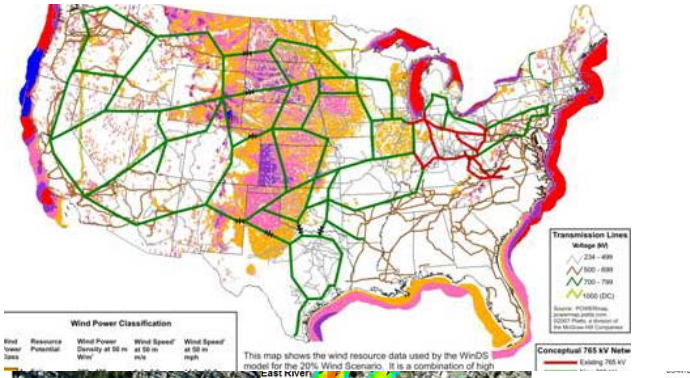
- What methods shall be used for near term analysis?
- What are the appropriate validation methods?
  - CFD and Experimental

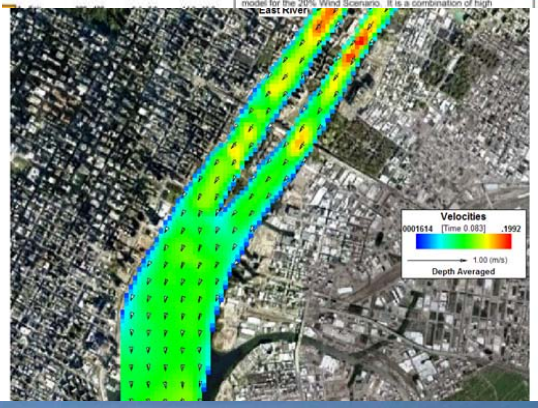
Considerable features can not be addressed by above methods

- What should future methods be?

Other Relevant R&D Efforts

- Instrumentation Development
- Resource Assessment
- Grid Integration Analysis
- Environmental Impacts Analysis
- Far field modeling
  - Flow Impact
  - Wake Interaction
  - Noise Emission
- Support Industries
- University Collaborations





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Questions?

Dr. Ye Li
Senior Scientist, Offshore Renewable
National Wind Technology Center
National Renewable Energy Laboratory

Contact Information:
Phone: 303-384-6988
Email: ye.li@nrel.gov

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