2014 WIND POWER PROGRAM PEER REVIEW

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Accelerate Technology Transfer

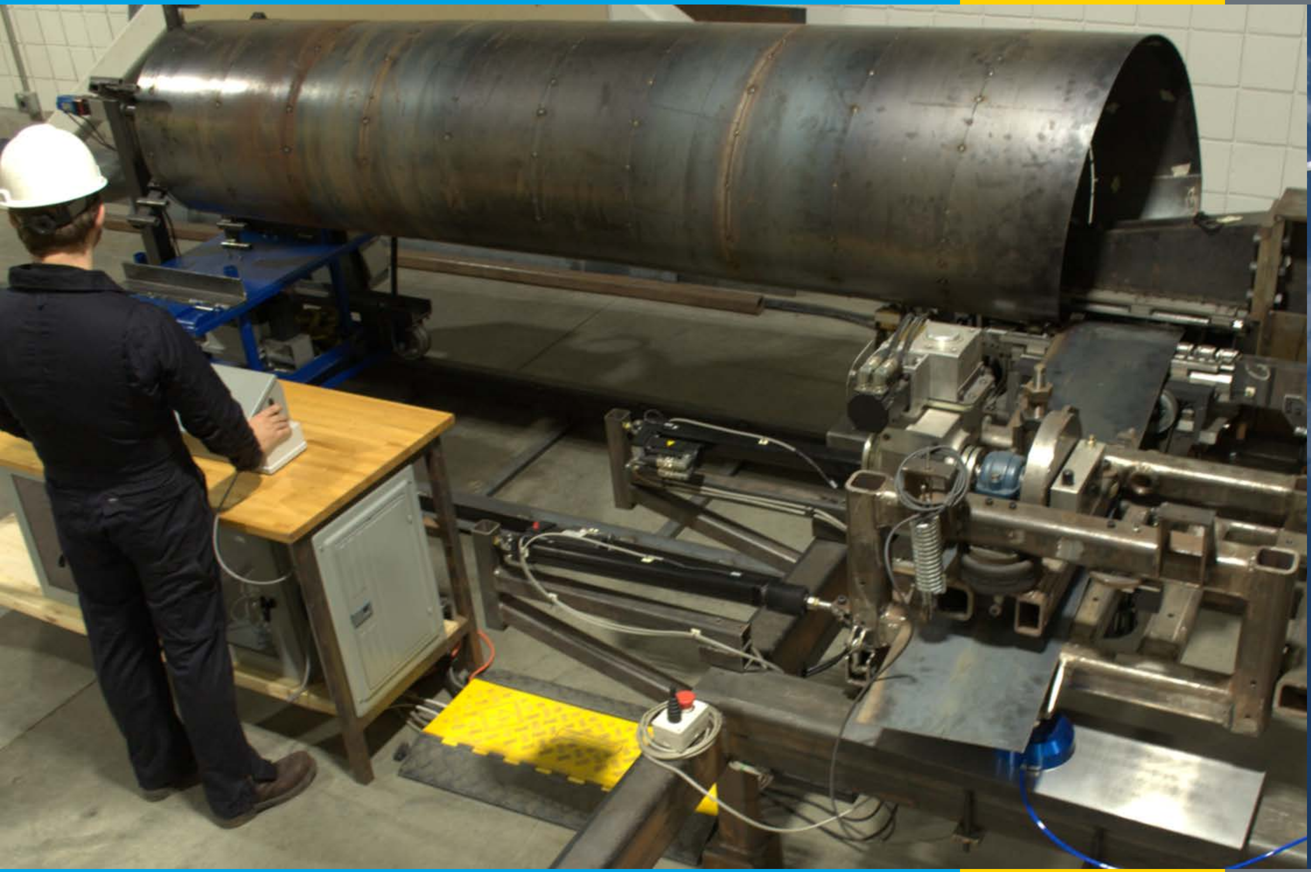
March 24-27, 2014

Wind Energy Technologies

PR-5000-62152

Contents

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



Development of On-Site Conical Spiral Welders for Large Wind Turbine Towers

Eric Smith

Keystone Tower Systems, Inc.

Eric@KeystoneTowerSystems.com

(857)225-0552

March, 2014

Budget, Purpose, & Objectives

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Total DOE Budget [1,2]: $0.000M

Total Cost-Share[1]:$0.000M

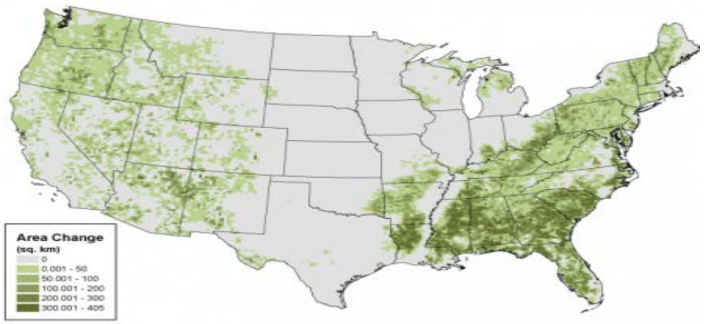
Problem Statement:

- Transport constraints limits tower diameter to 4.3m
- Constraint makes 100m+ towers uneconomical
- Limits wind development primarily to plains regions

Impact of Project:

- 1,800GW of wind unlocked in US (DOE)
- 50% cost reduction for 140m towers
- 150tons+ of steel saved per tower
- 10%+ reduction in LCOE at low wind sites
- Naturally favors domestic manufacturing

Unlocked wind resources at 140m:



This project aligns with the following DOE objectives and priorities

- **Optimize Wind Plant Performance:** Reduce Wind Plant Levelized Cost of Energy
- **Accelerate Technology Transfer:** Lead the way for new high-tech U.S. industries
- **Mitigate Barriers:** Reduce barriers to expand access to quality wind resources

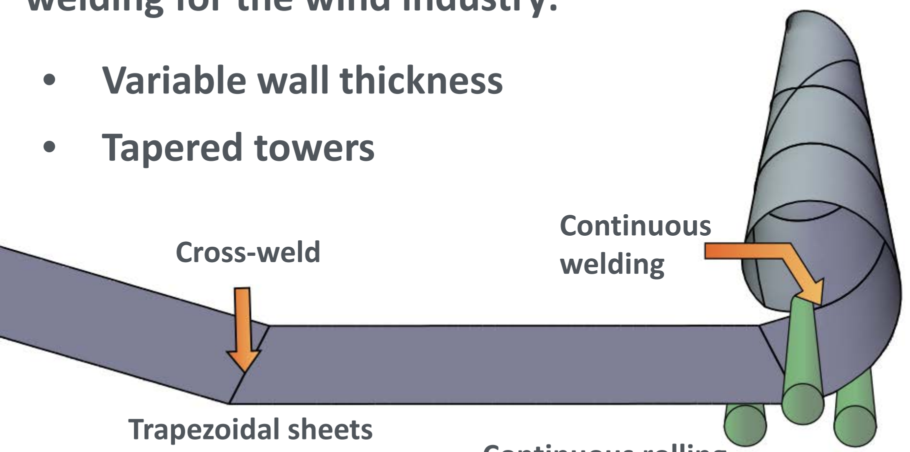
[1] *Budget/Cost-Share for Period of Performance FY2012 – FY2013*
[2] *Project remained active using DOE funds received prior to FY2012*

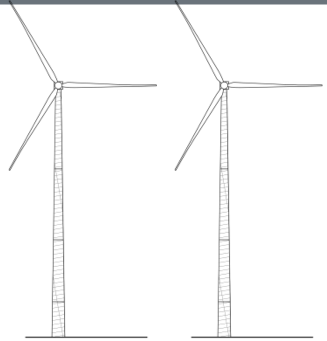
Technical Approach

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Keystone has developed a variant of spiral welding for the wind industry:

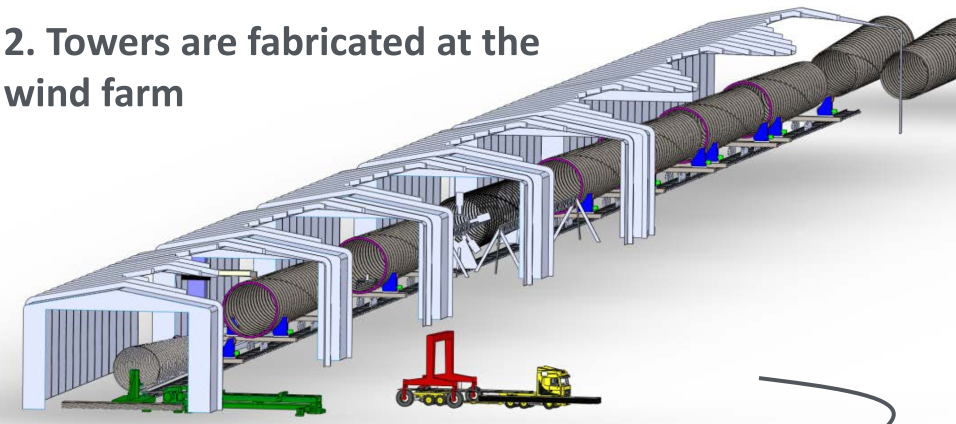
- Variable wall thickness
- Tapered towers



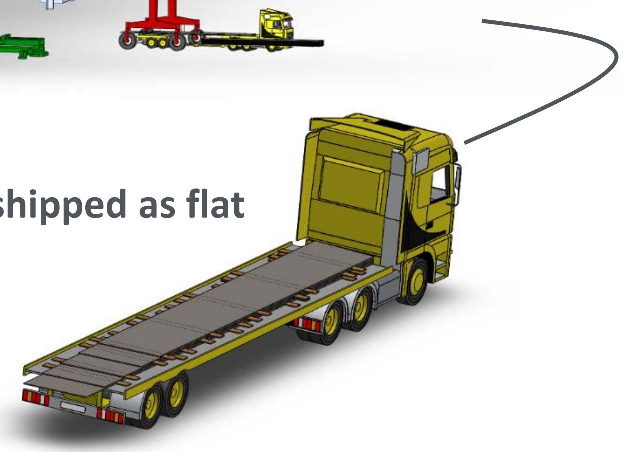


3. Tower dimensions can exceed shipping limits

2. Towers are fabricated at the wind farm



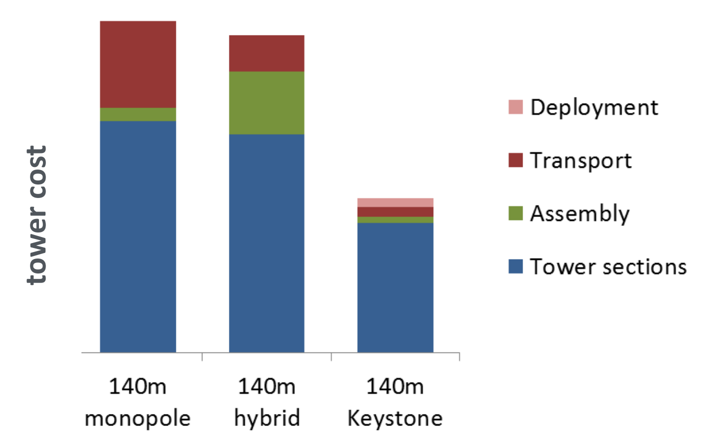
1. Steel is shipped as flat sheets

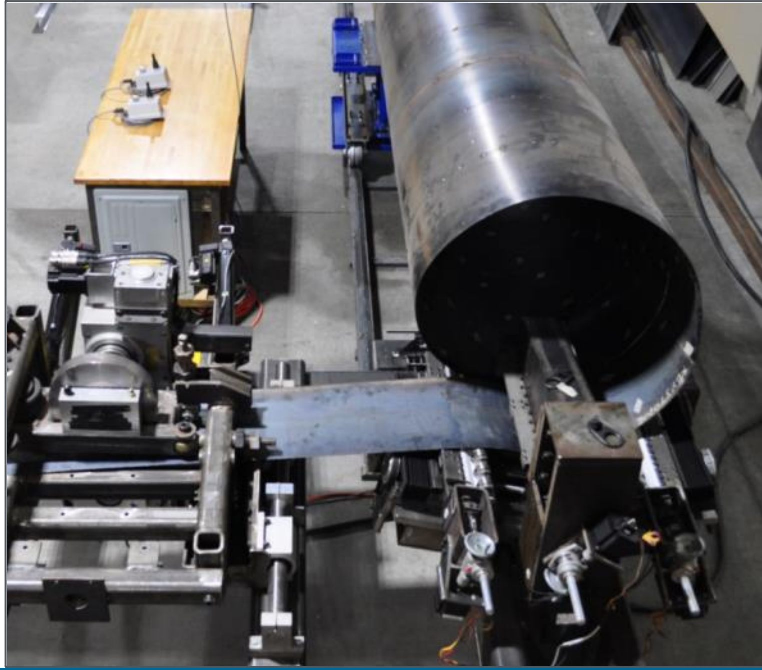


Accomplishments and Progress

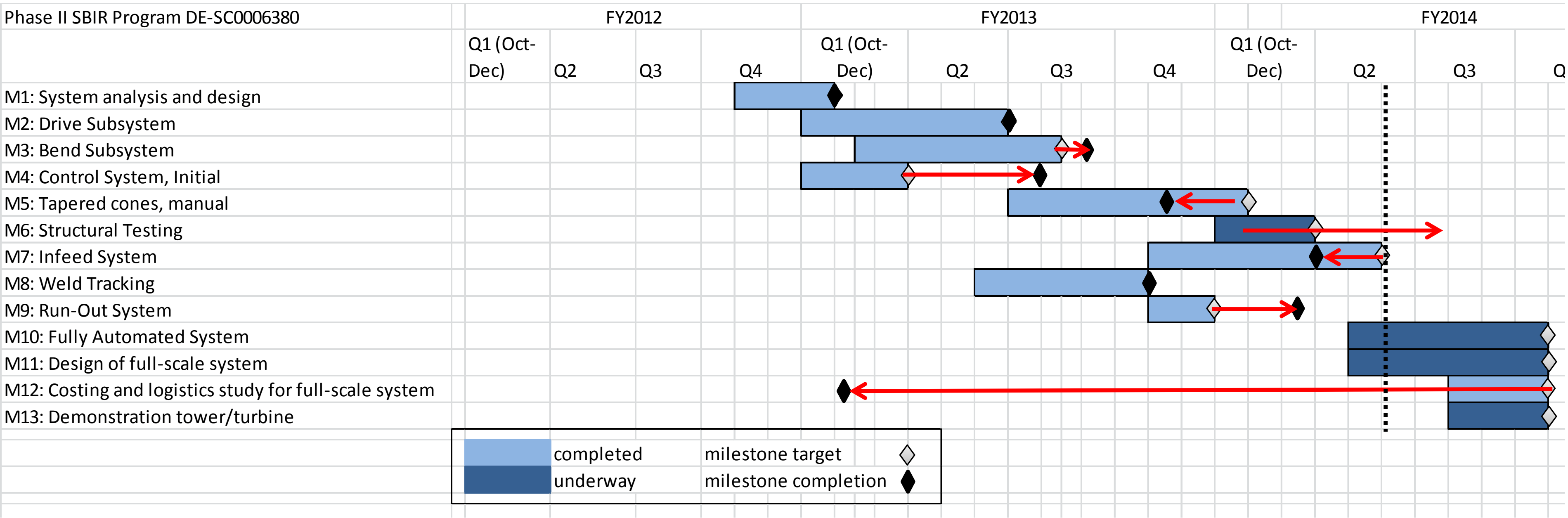
- 3rd party validated design & economics
- Working prototype of manufacturing equipment (partial scale)
- Fundamental patent issued, more pending
- Initial design-in with top turbine manufacturers
- Beginning design-in work with developers.

Keystone accomplishments will meet or exceed all goals for our DOE funded work





Project Plan & Schedule



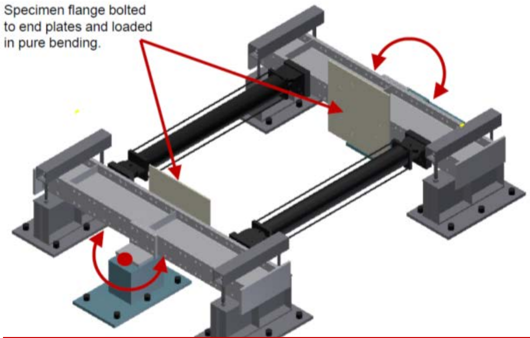
Comments

- Project began August 2012, and will complete August 2014

- Most milestones completed on or near schedule, with two significant variances:
  - Costing and logistics study completed significantly early as part of an OEM evaluation
  - Structural testing delayed due to lab construction delays at NEU, will skip testing of partially manual fabricated tower sections and move directly to testing of fully automated fabricated tower sections

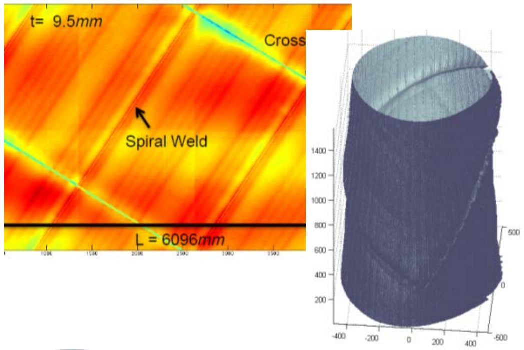
Partners, Subcontractors, and Collaborators:

Structural testing:
(Myers, NEU)



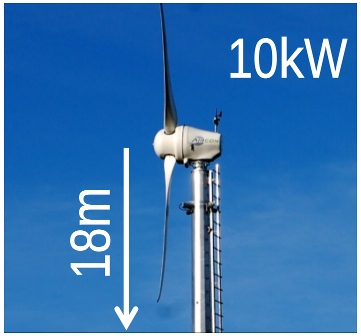
Northeastern University

Buckling characterization:
(Schafer, JHU)



Johns Hopkins University

Demonstration turbine:
(MIT / MassCEC)



Massachusetts Institute of Technology

Massachusetts Clean Energy Center

Communications and Technology Transfer:

Working with turbine manufacturers and wind developers and construction companies to integrate spiral welded tower technology into commercial wind plants

Keystone presented at invited talks at:

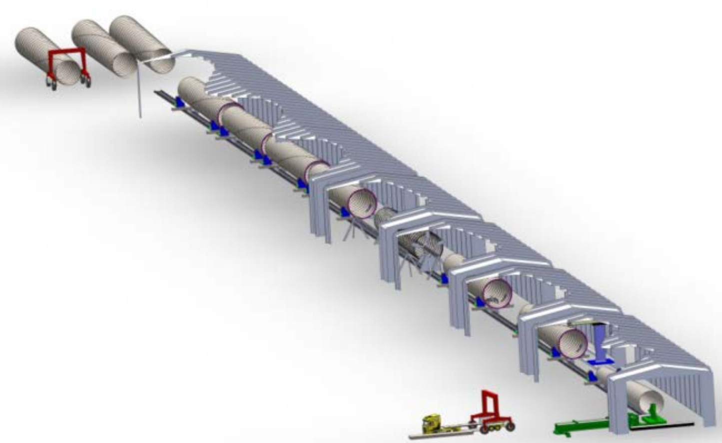
- NAWEA future of wind energy panel
- NREL Industry Growth Forum
- MIT Energy Club & MIT Energy Showcase
- UMass Amherst Wind Energy IGERT

FY14/Current research:

- Structural testing & characterization
- Demonstration install (18m tower, 1m diameter, 10kW turbine)
- Characterization / optimization of manufacturing tolerances

Proposed future research:

Commercial scale machine design and build



Detailed design and integration of mobile operation into wind plant

Full scale demonstration

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Mini

C-1

C-4

High Performance Hollow Fiber Membranes for Lubricating Fluid Dehydration and Stabilization Systems

Stuart Nemser
Compact Membrane Systems
snemser@compactmembrane.com
302-999-7996
March 24, 2014

Budget, Purpose, & Objectives

Total DOE Budget[1]: $1.900M

Total Cost-Share[1]:$0.000M

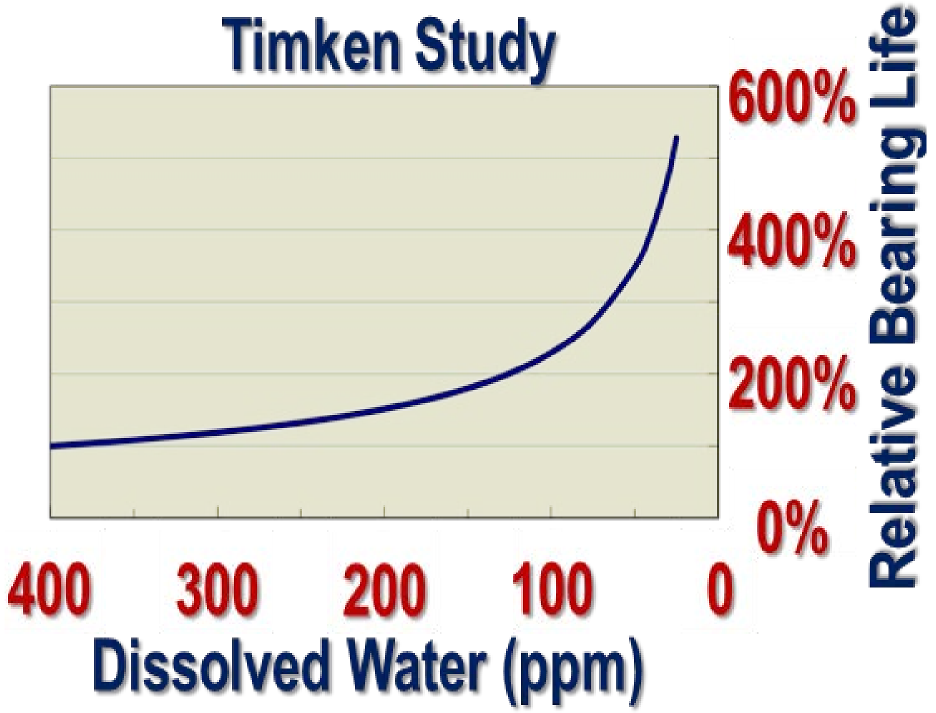
Problem Statement

- **Wind turbine gearbox reliability can be improved significantly by removing free, emulsified and dissolved water from the lubricating oil**
- **Effects of water on lubricating systems**
  - Bearing wear
  - Surface corrosion
  - Micropitting of the gear
  - Reduced lubricity
  - Loss of viscosity
  - Additives dropout
- **This project addresses the problem of dewatering lubricating oil in real time and thereby enhance the gearbox reliability**

[1]*Budget/Cost-Share for Period of Performance FY2012 – FY2013*

Impact of Project

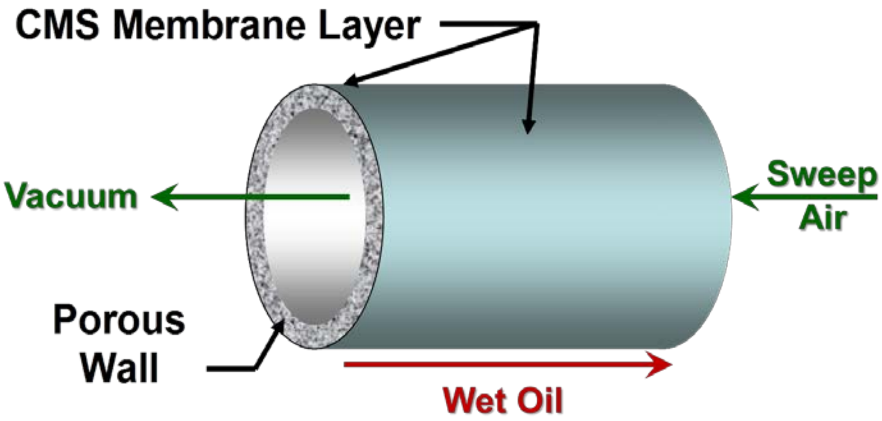
- Bearing life can be extended over 500%, if the dissolved water in oil is reduced from 400 to 25 ppm.
- The same impact is expected for wind turbine and other industrial gearboxes.
- The final product is a compact, lightweight, long life and portable membrane dehydrator for gear oil that works in real time.



Project Alignment with DOE Program Objectives and Priorities

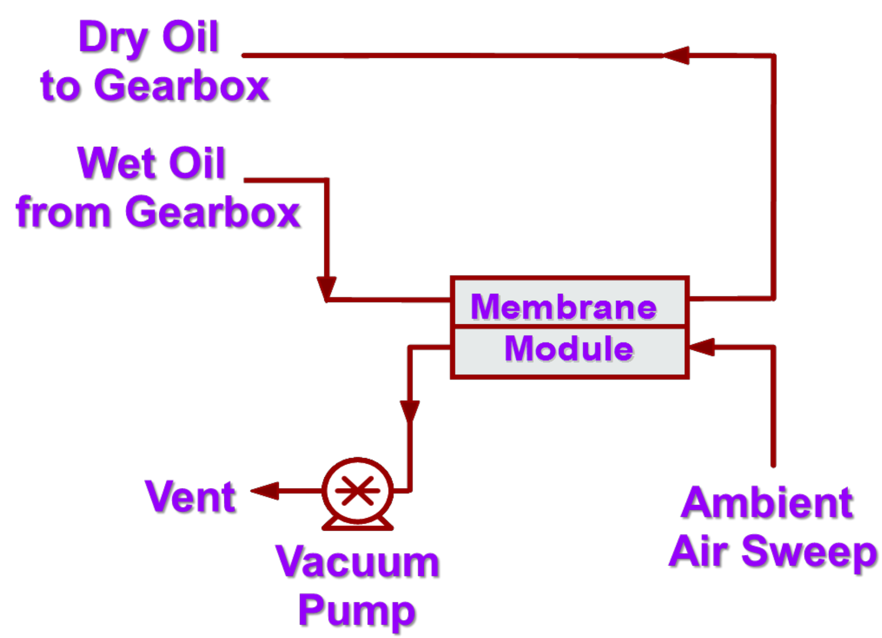
Optimize Wind Plant Performance: Reduce Wind Plant Levelized Cost of Energy (LCOE)

Technical Approach



- ✓ Amorphous perfluorinated membranes
- ✓ Superb chemical and thermal resistance
- ✓ Molecular sieving mechanism
- ✓ High water vapor flux, retains organics
- ✓ Nonporous, non-wetting membrane

- ➢ Gear oil is circulated outside of the membrane
- ➢ Ambient sweep air is drawn through the lumen side using a vacuum pump
- ➢ Easy 'kidney loop' installation in an existing lubrication circuit
- ➢ Removes free, dispersed and dissolved water



Key Issues Currently being Addressed

- Wind turbine field testing and Castrol oil issues
- 20+ prototype installations in various industries
- Scale-up of membrane module for 7X water removal
- Cartridge design improvement for higher efficiency (50-60%)
- New winder; higher productivity and quality; cost reduction

Unique Aspects

- ✓ Removes free, dispersed and dissolved water
- ✓ Compact, lightweight, long life and portable
- ✓ Simple design, minimal moving parts, 110 V
- ✓ Total automatic operation, suitable for remote applications
- ✓ Less energy intensive, no heater, lower cost of operation
- ✓ No flooding, loading, foaming or oil carryover
- ✓ Unlike vacuum purifiers, no complicated floats or drive

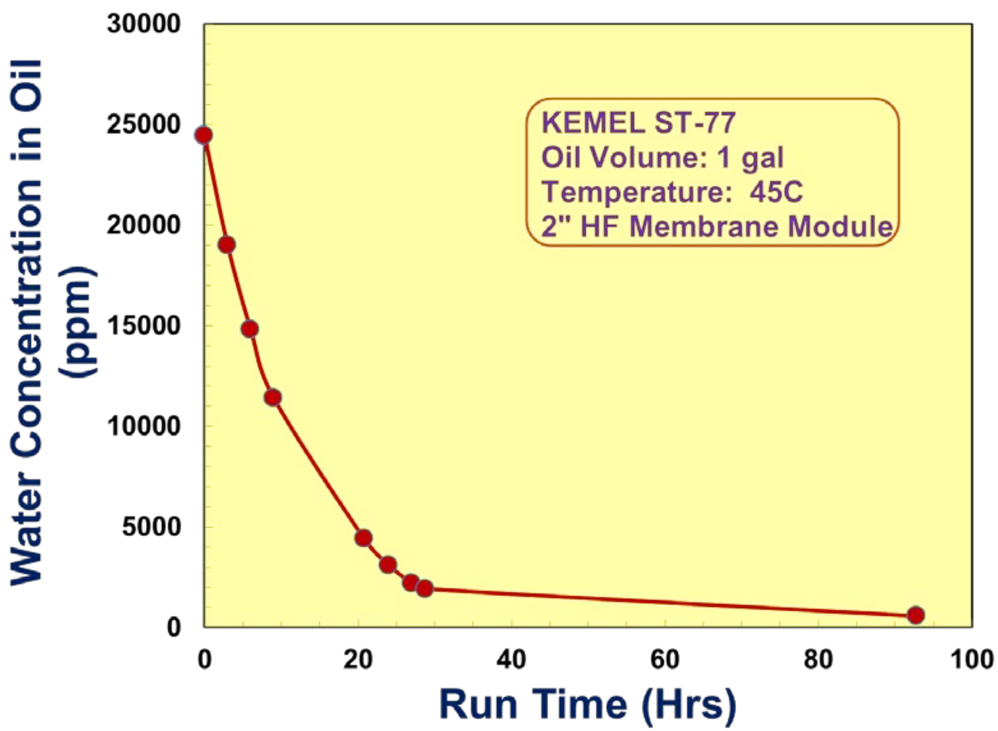
Major Technical Accomplishments in 2012-2013

- ✓ **Wind Turbine Installation –** Installed 2 mini units on 2 different GE 1.5 MW wind turbine gearboxes at AES Wind farm, Belington, WV. Both units running 24/7 with minimal attention. No mechanical issues with membrane or system.
- ✓ **Castrol Wind Turbine Oil Testing –** Resolved measurement issues with Castrol wind turbine gear oils
- ✓ **Salt Water Demo –** Worked well with sea water (offshore application) in lab demo studies; only water permeates; salt precipitates out and is removed by a filter
- ✓ **Nuclear Power Plant Installation –** Installed 2 units on EHC fluid (phosphate ester) at Salem Nuclear Power Plant, NJ. First unit is operating for about 2 years without any issues.

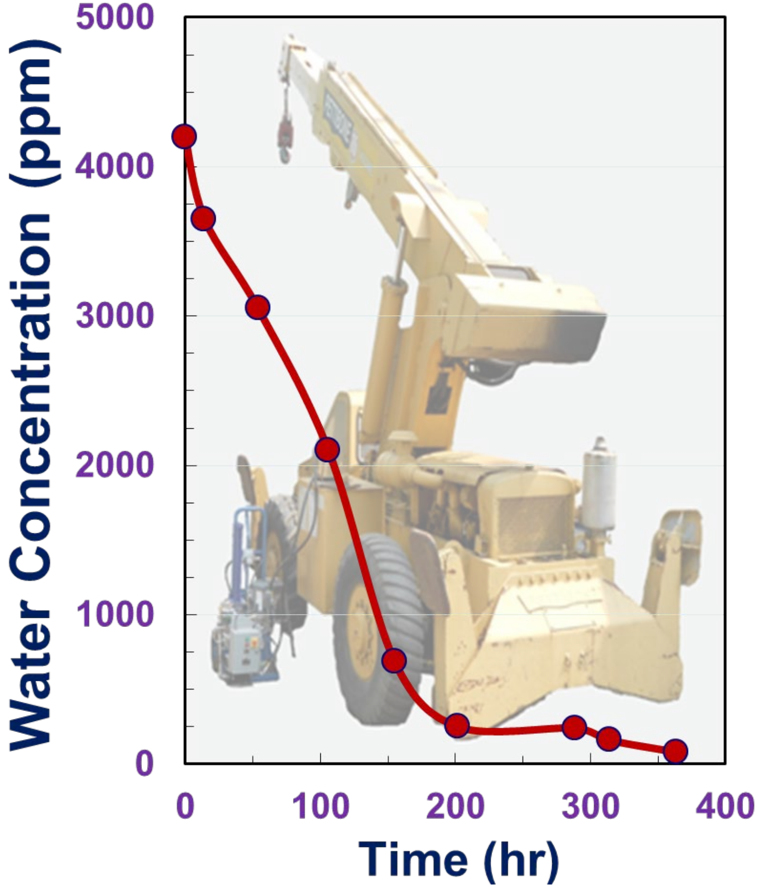
Major Technical Accomplishments in 2012-2013 (Contd.)

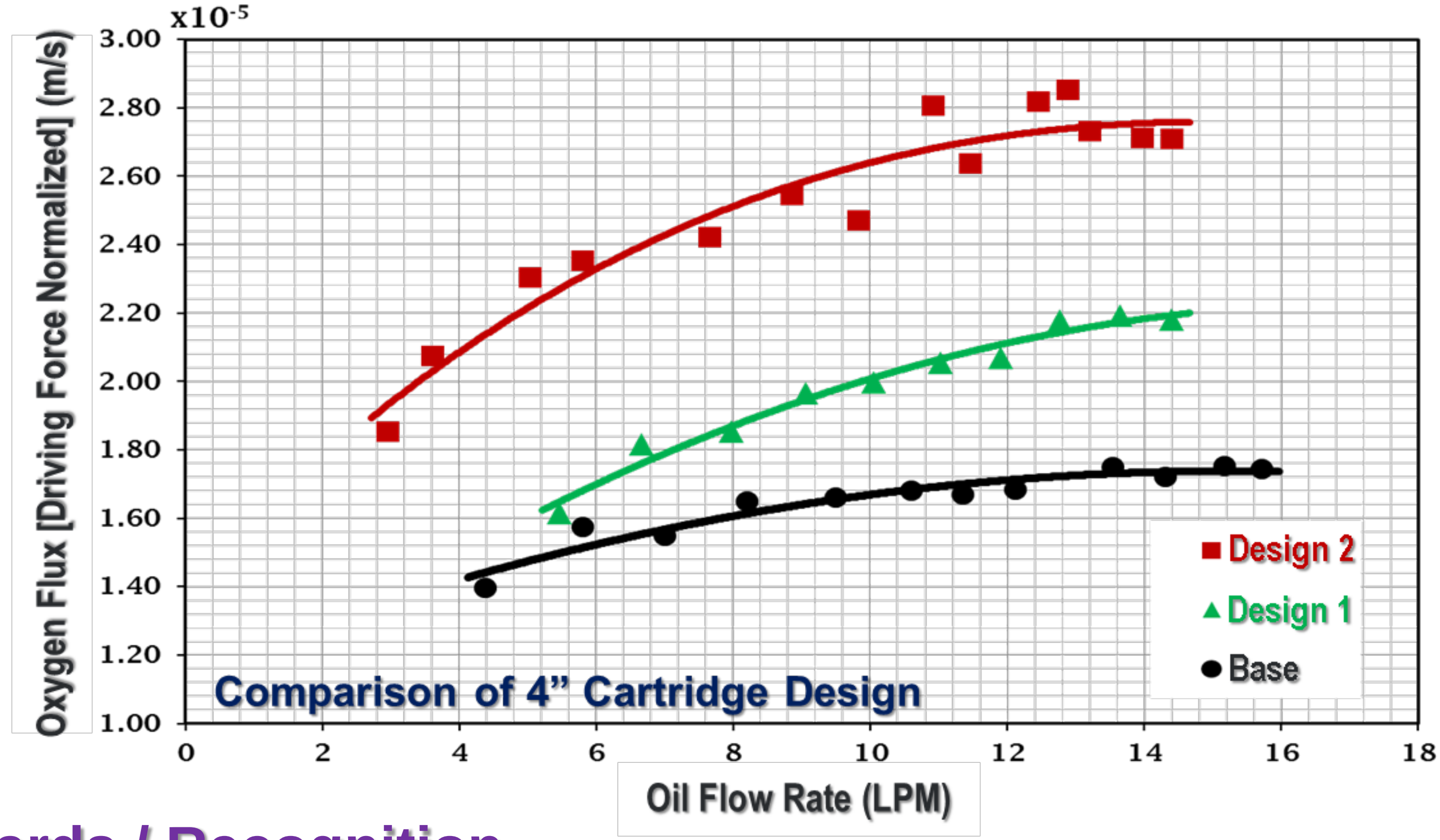
- ✓ **20+ Prototype Installations –** Refined design of Phoenix system through 20+ prototype installations and field testing in paper mill, cooling towers, gold mine etc.
- ✓ **7X Scale-up –** Designed and tested a scaled-up 4” membrane system with 7X water removal capability when compared to a 2” membrane system
- ✓ **Higher Productivity Device –** Demonstrated 50 to 60% enhancement in productivity per device through laboratory testing of improved cartridge design
- ✓ **New Winder –** Specified and purchased a new winder; provides greater flexibility; reduces winding time and scrap; enhances quality; leads to lower cost membrane cartridge

Biodegradable PAG Drying



Hydraulic Fluid Drying





Awards / Recognition

- ✓ A broad patent (US 8,506,815) on removal of water from fluids has been awarded to CMS in 2013
- ✓ Our novel membrane dehydration technology has been recognized in an editorial article featured in the 'TLT' journal of STLE

Project Plan & Schedule

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Summary		Legend	
WBS Number or Agreement Number	DE-EE0004546		Work completed
Project Number			Active Task
Agreement Number	DE-EE0004546		Milestones & Deliverables (Original Plan)
			Milestones & Deliverables (Actual)

Task / Event	FY2012 Q1 (Octt-Dec)	FY2012 Q2 (Jan-Mar)	FY2012 Q3 (Apr-Jun)	FY2012 Q4 (Jul-Sep)	FY2013 Q1 (Octt-Dec)	FY2013 Q2 (Jan-Mar)	FY2013 Q3 (Apr-Jun)	FY2013 Q4 (Jul-Sep)	FY2014 Q1 (Octt-Dec)	FY2014 Q2 (Jan-Mar)	FY2014 Q3 (Apr-Jun)	FY2014 Q4 (Jul-Sep)
Project Name: High Performance Hollow Fiber Membranes for Lubricating Fluid Dehydration and Stabilization Systems												
Milestone M2.1: Winder Specifications												
Milestone M2.2: Respooler Specifications												
Milestone M2.5: Demonstrate Optimized Prototype Hollow Fiber Cartridge												
Milestone M3.1: Finalized Specifications for Production Cartridge												
Milestone M4.1: Finalized Specifications for First Generation Product												
Milestone M5.1: Quality Control Document												
Milestone M8: Deploy First Generation Product												
Current work and future research												

Comments

- **1OCT2010 to 30SEP2014**
- **A nearly 12 month funding lag in 2012 caused serious delays in completing the effort, this resulted in delays in purchasing the winder and concurrently completing associated milestones. Budget Period #2 was effectively FY12 & 13.**

Partners, Subcontractors, and Collaborators

- **MSC Filtration Technologies** (System Integration)
- **Pall Trincor** (Marketing and Distribution)
- **AES Corporation** (Wind Turbine Trials)
- **HYDAC** (System Integration and Marketing in Europe)
- **United States Coast Guard** (Sea Trial on Ice-breaker)
- **Dow** (Environmentally Acceptable Lubricants Drying)
- **Major Bearing Company** (Third Party Technology Validation)

Communications and Technology Transfer

- **NREL** - National Renewable Energy Laboratory, presented at the 2011 Wind Turbine Condition Monitoring Workshop, Broomfield, CO
- **ICOM** - International Congress on Membranes and Membrane Processes, presented at the 2011 Meeting, Amsterdam, Netherland
- **STLE** - Society of Tribologists and Lubrication Engineers, presented at the 2012 Annual Meeting, St. Louis, MO
- **AIChE** - American Institute of Chemical Engineers, presented at the 2013 Annual Meeting, San Francisco, CA
- **Noria** - Reliable Plant Conference 2012 and 2014 (Accepted)

Next Steps and Future Research

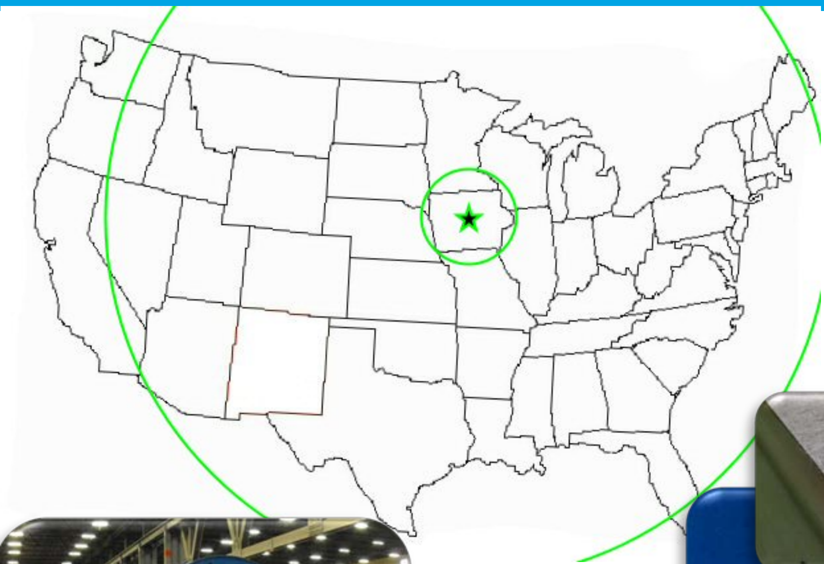
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

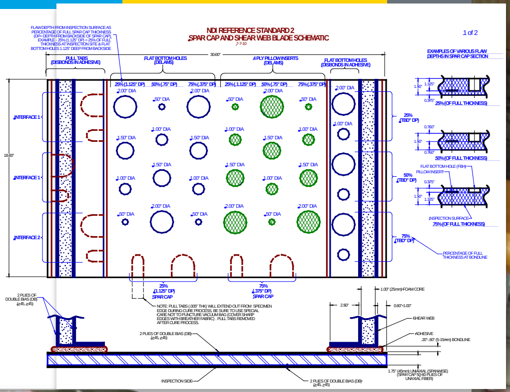
FY14/Current Research

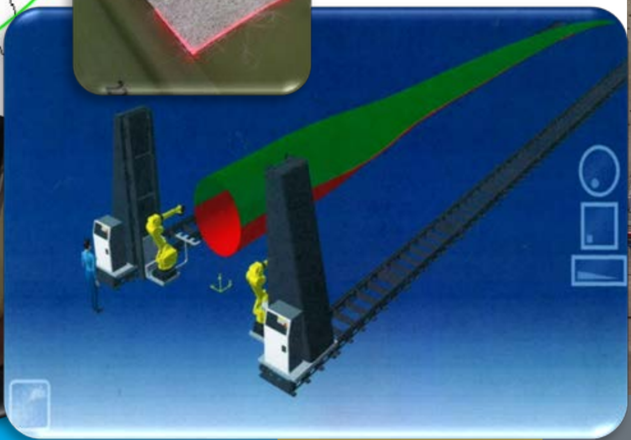
- **Better cartridge design for higher productivity**
- **Field testing and refinement of larger (C-4) prototype**
- **Implement new winder – reduce manufacturing cost; improve quality**
- **Polyalkylene glycol (PAG) drying for sea/marine trial**
- **Trial on a wind turbine with non Castrol lubrication oil (DOE help needed)**
- **No new milestones to date – all existing milestones will be completed by the end of the project**

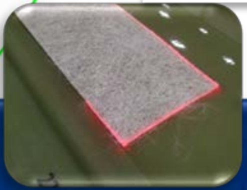
Proposed Future Research

- ✓ **Cross-cutting technology; can be applied to other renewable energy areas, e.g., drying of ionic liquids with specific focus on enhancing biomass conversion to glucose (collaborating with JBEI)**
- ✓ **Explosion proof dehydrator system for chemical process industries; increase market and volume; reduce cost for wind turbine application**
- ✓ **Accelerated statistical bearing life tests (similar to Timken, 1977 study)**









AMI – Advanced Manufacturing Initiative

Daniel Laird

Sandia National Laboratories

Daniel.Laird@sandia.gov; 505-844-6188

March 27, 2014

Budget, Purpose, & Objectives

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Total DOE Budget [1,2]: $0.000M

Total Cost-Share[1]:$0.000M

Problem Statement:

- High relative cost of U.S. labor makes it difficult to competitively manufacture blades in the U.S.

Impact of Project:

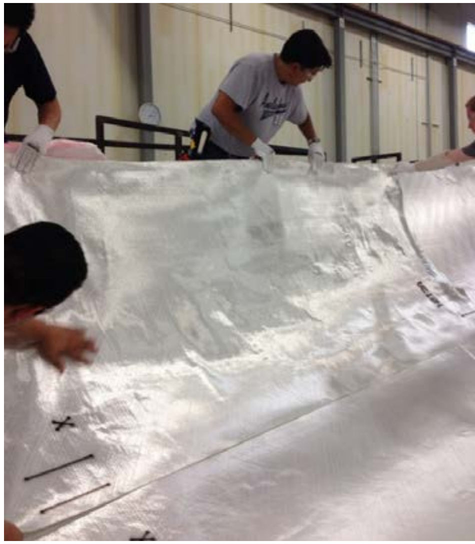
- Significantly improve labor productivity (and leverage transportation advantage) to make U.S. wind turbine blade manufacture for the U.S. market economically viable

Aligns with these DOE Program objectives:

- Accelerate Technology Transfer
- Mitigate Market Barriers

[1] *Budget/Cost-Share for Period of Performance FY2012 – FY2013*

[2] *Project remained active using DOE funds received prior to FY2012.*



- **Improve Labor Productivity by 35%**

- **Reduce Cycle Time by 35%**

- **Improve/Maintain Reliability and Cost**

Organizational Approach

Three-way Manufacturing Research Collaboration

- Multi-year effort
  - Aug 2009 start
- Equal funding
  - DOE ($2100k)
  - Iowa OEI ($2100k)
  - TPI ($2100k)

PI – Steve Nolet

PI – Frank Peters

PI – Daniel Laird

Challenges:

- Collaborating at "industry speed"
- Intellectual Property
- Disseminating Results

First DOE Wind AMI project

First year Iowa OEI Project

Organizational Approach (2)

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Technical Steering Committee (TSC)

- Laird, Nolet, Peters
- Generate and Solicit Proposals for AMI
  - Cost, Timeline, etc.
  - Very significant interaction with industrial suppliers
- Monthly Telecons/Meetings to Consider Proposals
  - Cost/Time versus Impact on Objectives
- Approved Proposals Presented to Oversight Committee

Oversight Committee

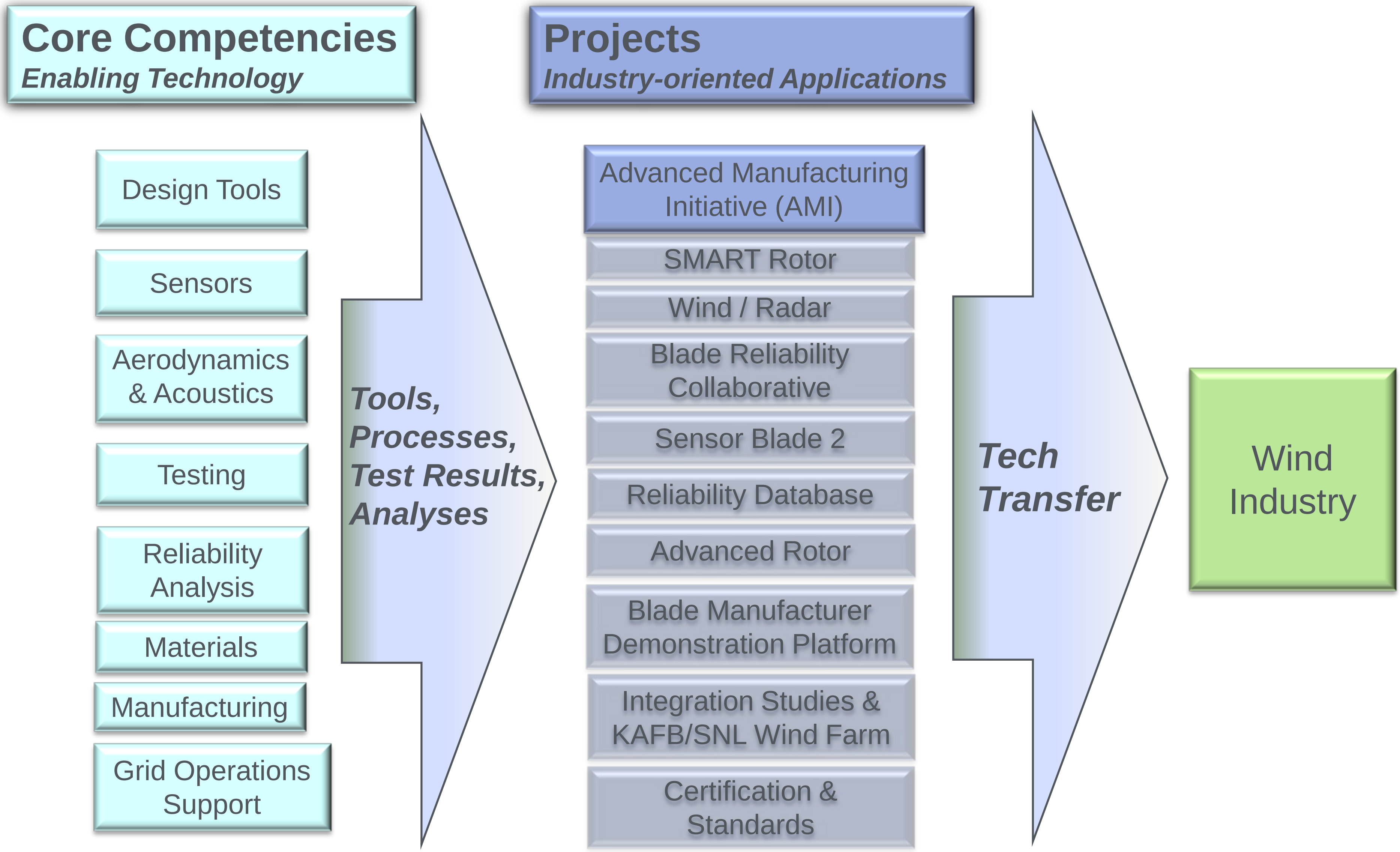
- Project Status/Spending
- Consider Proposals from TSC

Exact research directions unknown (or falsely known) at beginning

Technical Approach

Leveraging Broader Sandia Capabilities for AMI

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



Technical Approach

Leveraging Broader Sandia Capabilities for AMI

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Broader SNL Capabilities

- H. Arris, B. Anderson — Chemistry
- D. Roach, K. Rackow — Non-Destructive Inspection
- D . Callow — Factory Simulation
- B. Drotning, C. Loucks — Robotics and Automation
- K. Schmidt, D. Calkins — Composites Manufacturing

Facilities, Processes, NDI equip, Simulation Capability, Analyses, Robots

Projects

Industry-oriented Applications

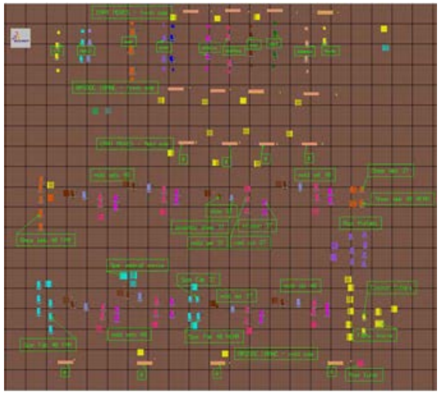
- Advanced Manufacturing Initiative (AMI)
- SMART Rotor
- Wind / Radar
- Blade Reliability Collaborative
- Sensor Blade 2
- Reliability Database
- Advanced Rotor
- Blade Manufacturer Demonstration Platform
- Integration Studies & KAFB/SNL Wind Farm
- Certification & Standards

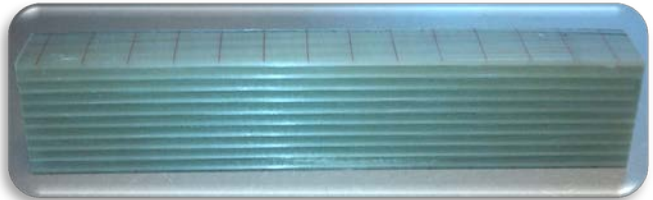
Tech Transfer

Wind Industry

Accomplishments and Progress
Sub-project List

- **49 proposals considered by the TSC**
  - **27 rejected**
  - **22 accepted**
- **Sub-projects (partial list)**
  - **Automation**
    - **Fabric Laying**
    - **Finishing**
  - **Factory Logic/Process Flow Simulation**
  - **True 3D Laser Projection**
  - **Edge Operations Study**
  - **Non-Destructive Inspection Capabilities Evaluation (2)**
  - **Engineering Data Software Platform**
  - **Spar Cap Assembly Fiber Placement**
  - **Ply Nesting Optimization**
  - **Novel Materials Assessments**
  - **Fabrication and Testing of Utility-scale Demonstration Blade**



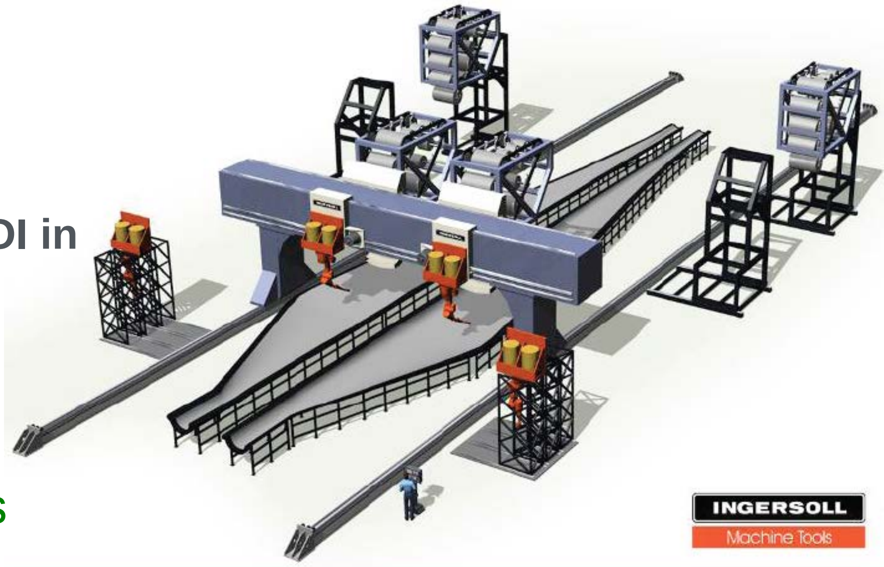


AMI Project actually a collection of smaller targeted projects

Accomplishments and Progress

Automation

- **Initially, automation was a primary thrust of AMI**
- **Significant time/effort spent in this area**
- **Fabric Laying**
  - **Significant effort spent with commercial suppliers**
    - **KMT, MAG, Ingersoll, Globe**
  - **Several proposals evaluated**
  - **No proposals passed ROI**
- **Finishing**
  - **Feasibility Analysis - Cliff Loucks**
  - **Most processes not viable candidates for automation**
  - **Viable processes did not yield enough ROI in terms of saved labor**
  - **Most viable was robotic trim/grind/sand work cell due to human safety issues**

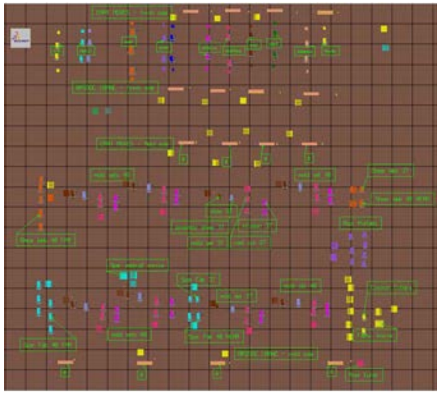


Automation could not meet AMI ROI requirements

Accomplishments and Progress

Sandia-led sub-projects

- **Factory Logic / Process Flow Simulation**
  - **Immediately identified and quantified overhead crane bottleneck**
  - **Spawned other AMI efforts**
  - **Assisted with cost/benefit evaluations**
- **Engineering Data Software Platform**
  - **Coupled to 3D laser for fabric positioning**
- **Finishing Automation Feasibility Analysis**
- **Robotic Edge Trim and Grind**
- **Epoxy Compatible Reusable Bags**
- **Spar cap cure modelling**
- **Non-destructive Inspection**



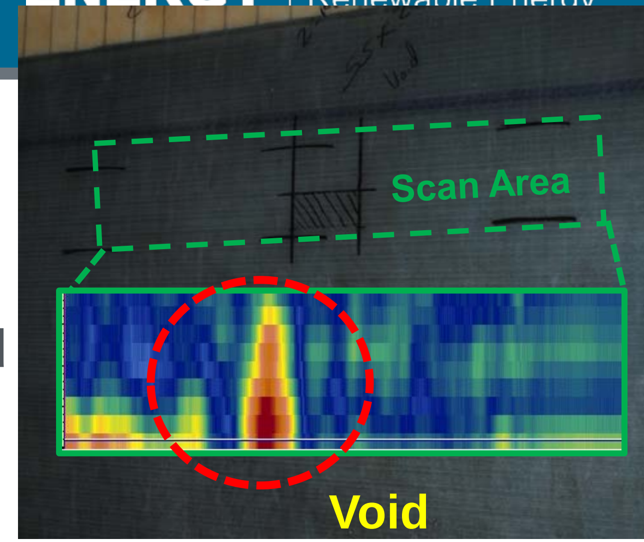
“Tip” Cart

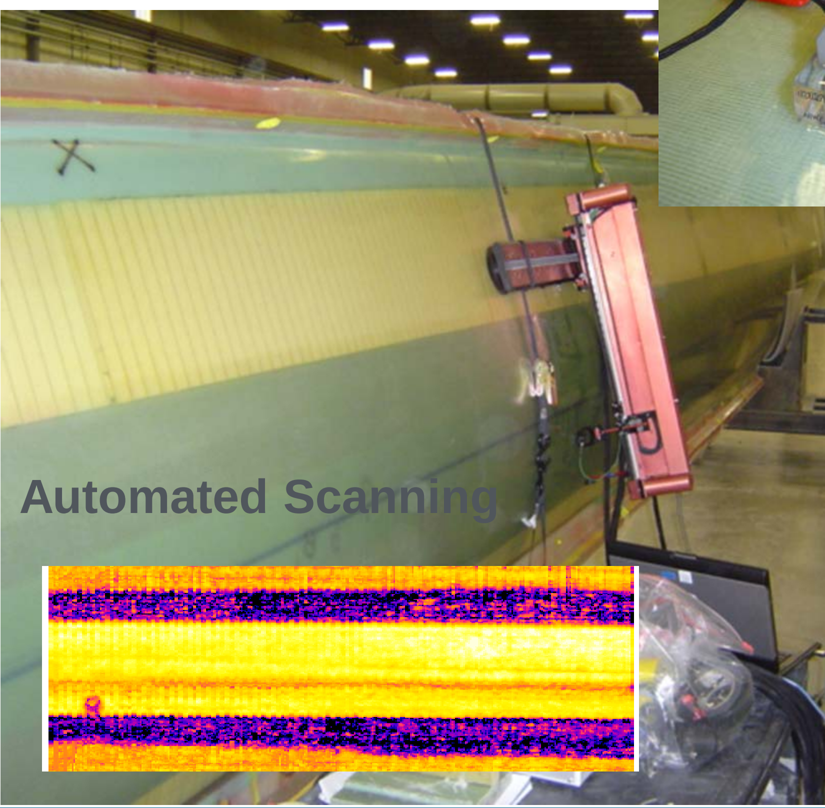
Root Cart

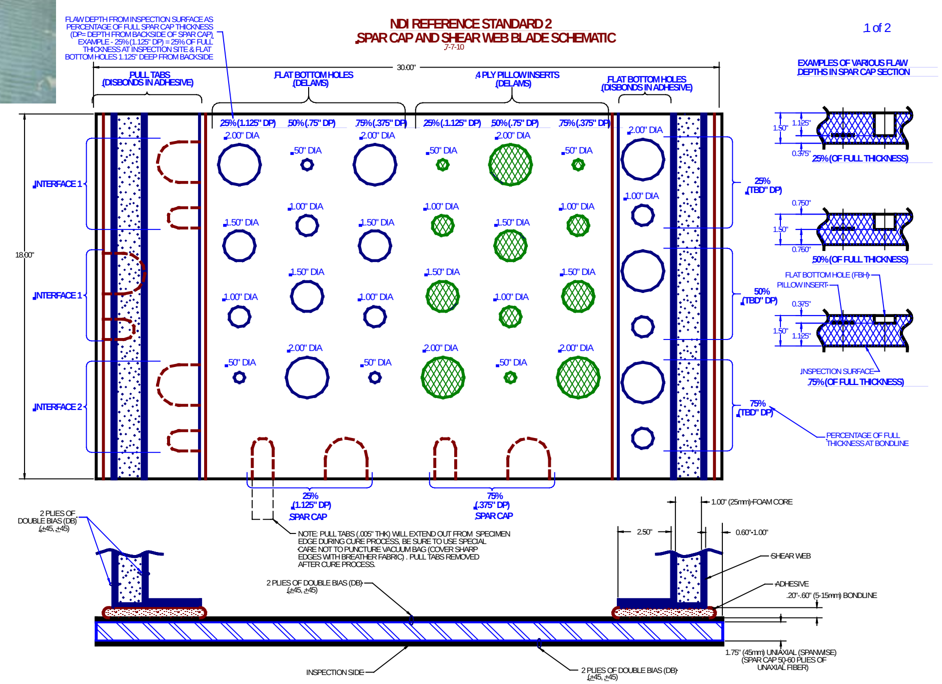
Accomplishments and Progress

Sandia Non-destructive Inspection (NDI)

- **Comparison of NDI technologies for wind turbine blade application**
- **Wind-specific hardware**
- **Development of Reference Standards for Wind Turbine Blade NDI**



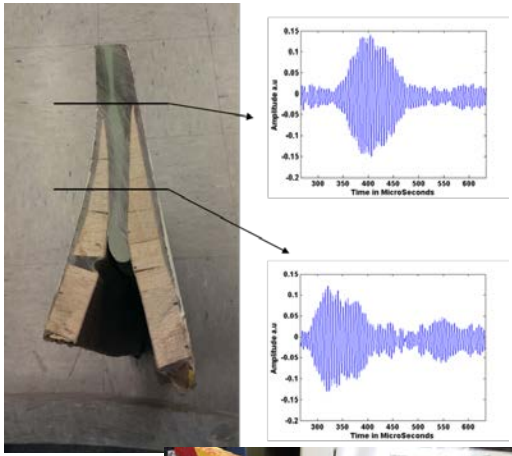


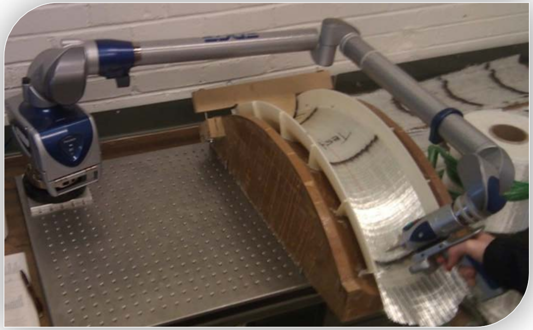


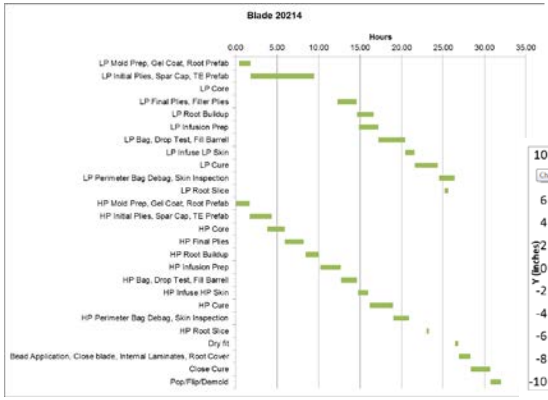
Accomplishments and Progress

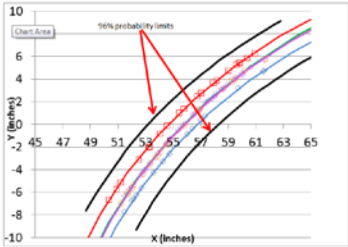
ISU-led sub-projects

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy





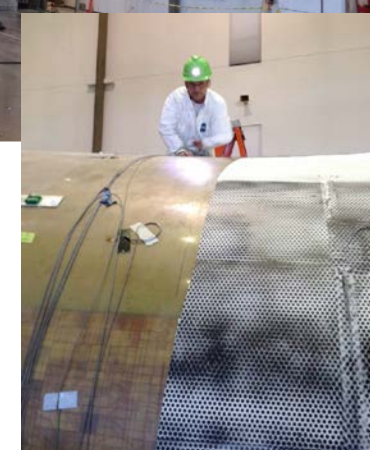




Accomplishments and Progress
Utility-scale Blade Build and Test

- **Significant support from GE**
- **Most AMI improvements brought together in one blade at utility-scale**
- **Static and flap fatigue completed**
- **Edge fatigue nearly complete**
- **Results will be published as comparisons to GE baseline product**



Accomplishments and Progress

Labor Reduction

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

AMII Supported Project	Labor Reduction	Notes
Rotating Carts/Material Handling Systems	2.1%	Reduced surface preparation and peripheral trim
Use of B-Side Heating for Blade Skin Cure Time Reduction	1.1%	Cure Time of each Skin reduced
Trailing Edge Preform Fabrication	1.1%	Layup to preform is MUCH quicker than direct to Skin Mold
Component Handling Systems	2.0%	Improved material movement eliminates wasted time waiting for overhead bridge crane movements.
Development of Bond Cap Preform Section	1.1%	Much less complex layup of bond cap. 8 D/L save an hour.
3D Projected Laser Guidelines for Layup and Fixture Location	3.6%	Labor Savings in Lay-up and Assembly Op's with 8 Person Crew
Advanced Technology Blade Demonstration Efforts		
Fiberglass RodPack	8.2%	Significant savings in Layup, infuision preparation and Infusion time and cure time
TYCOR Sandwich Core	1.6%	Reduction in labor content for core installation
Latent Cure Epoxy Resin	1.3%	Reduction in labor content for part cure
Use of MMA/PU Bond Paste	1.7%	Reduction in Labor for bond assembly
	23.7%	

Accomplishments and Progress

Cycle Time Reduction

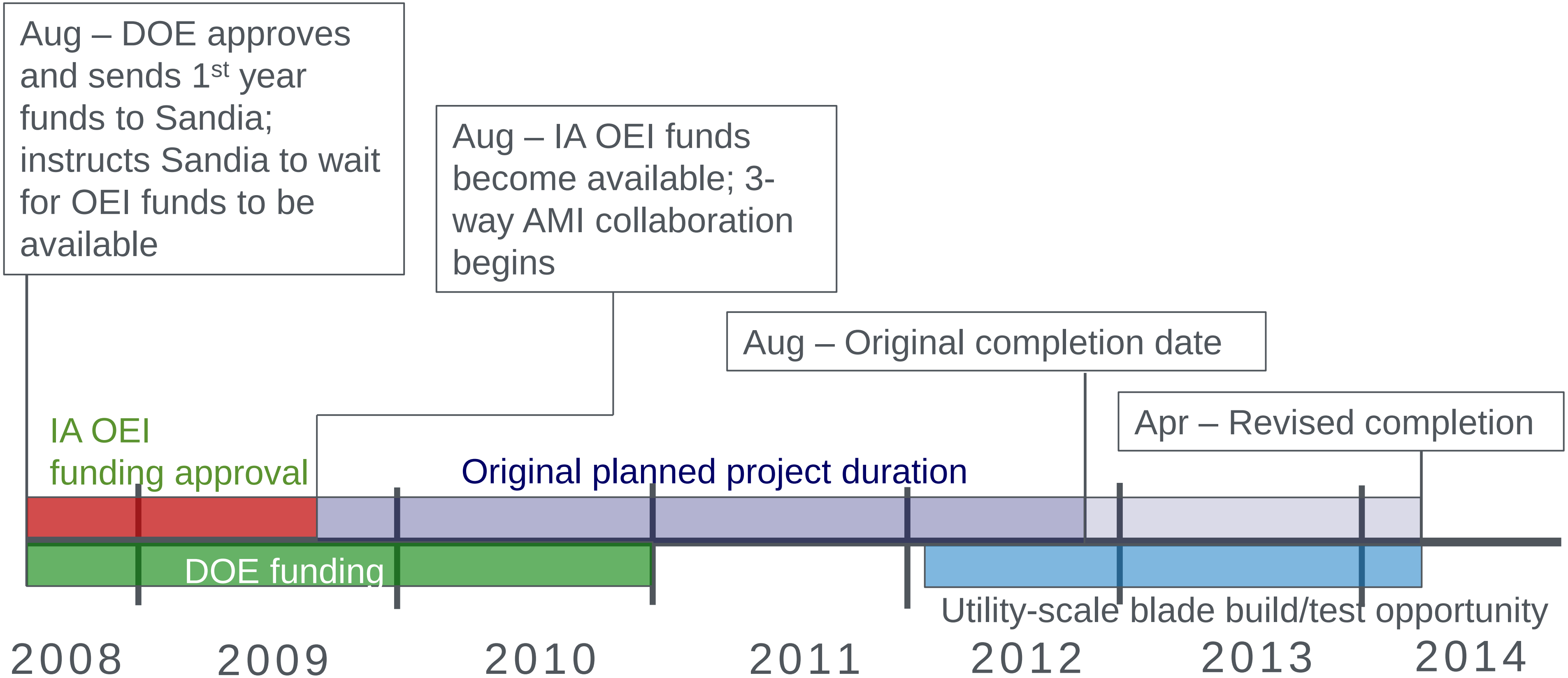
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

AMII Supported Project	Cycle Time Reduction	Notes
Rotating Carts/Material Handling Systems	6.6%	Reduced surface preparation and peripheral trim
Use of B-Side Heating for Blade Skin Cure Time Reduction	5.3%	Cure Time of each Skin (LP 7 HP) reduced by one hour
Trailing Edge Preform Fabrication	2.6%	Reduction in infusion time and layup time
Component Handling Systems	6.6%	Improved material movement eliminates wasted time waiting for overhead bridge crane movements
Development of Bond Cap Preform Section	2.6%	Reduction gained by parallel fabrication of complex bond cap layup
3D Projected Laser Guidelines for Layup and Fixture Location	4.6%	Gained efficiencies in both dry layup of kitted glass as well as location of critical bonded components
Advanced Technology Blade Demonstration Efforts		
Fiberglass RodPack	0.0%	Spar Cap Manf does not impact Mold Shell Cycle (Parallel Operation)
TYCOR Sandwich Core	3.2%	Shortened core installation
Latent Cure Epoxy Resin	5.4%	reduced curing time in mold
Use of MMA/PU Bond Paste	4.3%	Shortened bond cycle time
	41.3%	

Exceeded cycle time goal (35%)!

Project Plan & Schedule

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



Comments

- Several sub-projects within independent timelines

Research Integration & Collaboration

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Partners, Subcontractors, and Collaborators:

Partners: TPI Composites, Iowa State University

- True 3-partner collaboration
- Only unanimous sub-projects pursued

Industry Interaction:

- KMT, Ingersoll, MAG, Globe
- Neptco, BASF, Carter, Henkel, Milliken
- GE

Universities: Iowa State University

Communications and Technology Transfer (partial list):

- Sandia Blade Workshops, 2010, 2012 (Albuquerque)
- AWEA WindPower, 2011, 2012
- 2011 Wind & Ocean Energy Conference (Portland Maine)
- 2011 University of Massachusetts Wind Energy Research Workshop
- Wind Turbine Blade Manufacture Conference, 2012 (Dusseldorf)
- 2012 JEC America's Conference & Exhibition
- 2013 Thermosetting Resin Formulators Association Technical Conference
- International Conference on Future Technologies for Wind Energy, 2013
- Industrial Engineering Research Conference, 2013
- IAWind Conference, 2010
- Iowa Wind Energy Association Annual Meeting, 2011-2014
- QNDE, 2011-2013

Final Report currently in-progress

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Iowa State University Student Contributors:

Fanqi Meng	Ph.D.	Industrial Engineering
Sunil Chakrapani	MS, Ph.D.	Aerospace Engineering
Siqi Zhu	MS, Ph.D.	Industrial Engineering
Huiyi Zhang	MS, Ph.D.	Industrial Engineering
Ben Wollner	MS	Industrial Engineering
Corey Magnussen	MS	Industrial Engineering
Wade Johanns	MS	Industrial Engineering
Luke Schlanglan	MS Industrial Engineering	
Luke Mitchell	NSF Funded Summer REU student from Penn State	
David Deisenrogh	NSF Funded Summer REU student from Michigan Tech	

BS Industrial Engineering

- Travis Kieffer
- Brittany Becker
- Dan Chrusciel
- AJ Fitzsimmons
- Tom McGee
- Kyle Laska
- Camila Dantas
- Laura McMullen
- Sam Berg

BS Aerospace Engineering

- Andrew Gross
- Aaaron Edal
- Ryan Krafka
- Alex Wilhelm
- Shivansh Upreti
- Steven Green

Next Steps and Future Research

FY14/Current research:

- Complete Comprehensive AMI Project Report
- Make publicly available
- No follow-up work currently planned

Reprinted with permission. Fischer, Martin. "World's Largest Blade Begins Journey to Scotland." SSP Technology A/S. July 17, 2013

Manufacturing and Supply Chain R&D, Wind Turbine Logistics and Planning Issues Analysis

Manufacturing and Supply Chain R&D

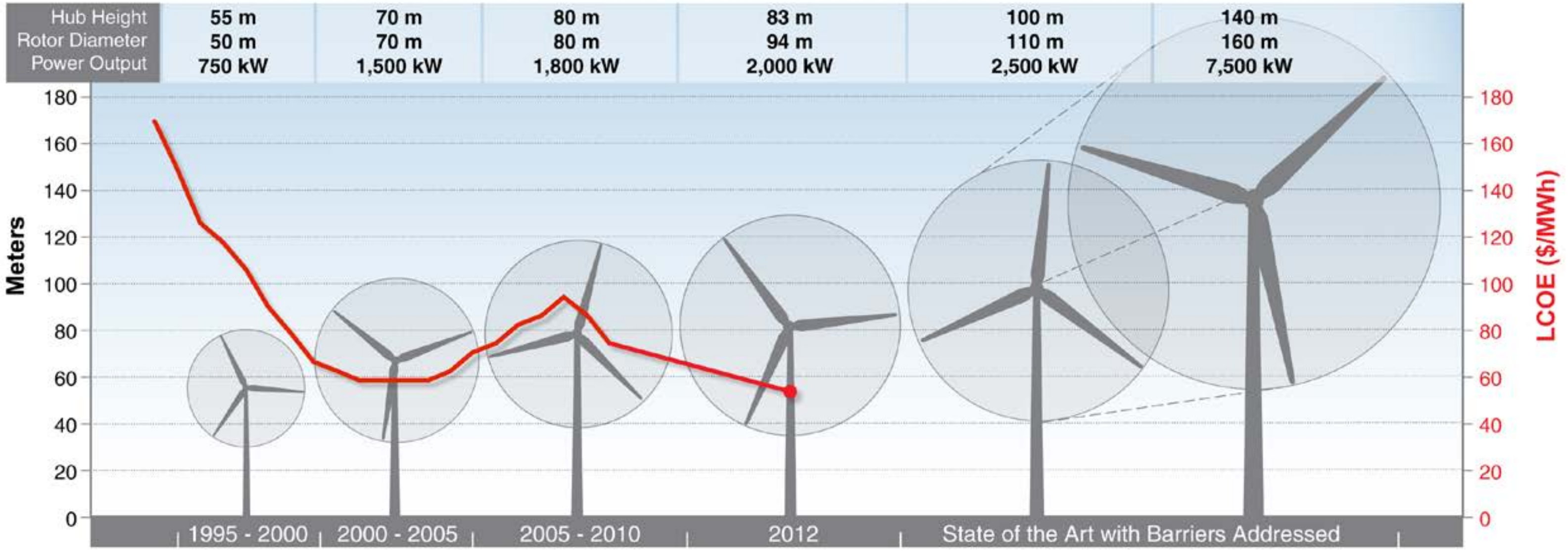
Jason Cotrell

NREL

Jason.Cotrell@NREL.gov, 303-384-7056

March 24, 2014

Budget, Purpose, & Objectives



Problem Statement:

1. Transportation and logistics challenges limit the size and tower height of land-based turbines that can be deployed in the United States.

2. There is relatively little literature that characterizes transportation and logistics challenges and the associated effects on U.S. wind markets.

Budget, Purpose, and Objectives: Problem Statement

Summary of Transportation and Logistics Barriers

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Exceeding FAA blade-tip height

Trucking large-diameter towers

Hoisting larger nacelles onto taller towers

Trucking larger blades with wider chords

Trucking longer blades

Trucking larger blades with bigger root diameters

Trucking heavier nacelles

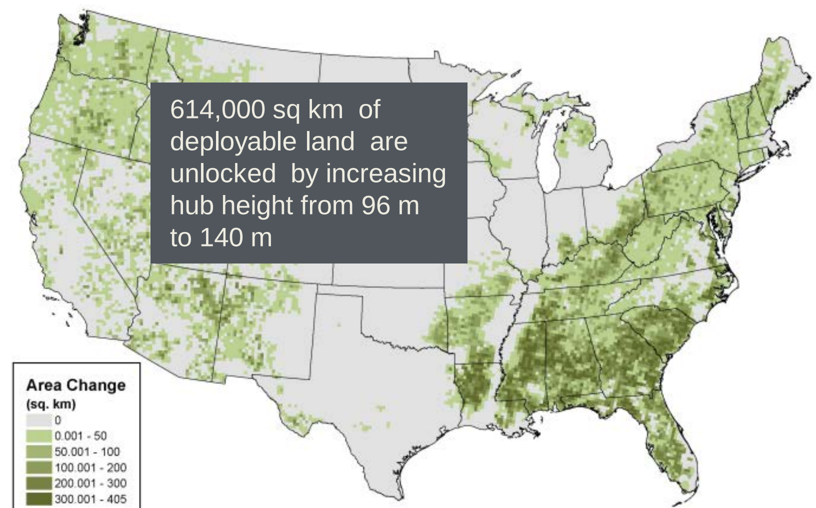
Legend

- Red: Impacts U.S. turbine installations today
- Orange: Potentially impacts U.S. turbine installations today
- Green: Potentially impacts future U.S. turbine installations

Budget, Purpose, and Objectives: Impact of Project

Addressing transportation and logistics barriers provides enduring economic benefits by:

- Enabling larger, taller turbines
  ↘
  - Providing LCOE reduction pathways
  - Unlocking new U.S. land for deployment (~ 3000 GW)
    ↘
    - Improving stakeholder support and market stability
    - Manufacturing competitiveness and domestic content



Budget, Purpose, & Objectives

Total DOE Budget[1]: $0.200M

Total Cost-Share[1]:$0.000M

This project aligns with the following DOE Program objectives and priorities:

- **Optimize Wind Plant Performance:** Reduce Wind Plant Levelized Cost of Energy (LCOE)
- **Accelerate Technology Transfer:** Lead the way for new high-tech U.S. industries
- **Mitigate Market Barriers:** Reduce market barriers to preserve or expand access to quality wind resources
- **Advanced Grid Integration:** Provide access to high wind resource areas, and provide cost effective dispatch of wind energy onto the grid
- **Modeling & Analysis:** Conduct wind techno-economic and life-cycle assessments to help program focus its technology development priorities and identify key drivers and hurdles for wind energy technology commercialization

[1] ***Budget/Cost-Share for Period of Performance FY2012 – FY2013***

Technical Approach

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Identified mass, cost, and size breakpoints for wind turbine blades, tower, and nacelle
  – Performed interviews with wind industry project developers, OEMs, and transportation and logistics companies
  – Reviewed published literature on trends and developments in increasing wind turbine size, logistics, and transportation issues

- Performed analyses to:
  – Identify which transportation and logistics challenges affect wind plant installations today
  – Determine the increase in turbine size that could be achieved if transportation and logistics challenges are solved

Accomplishments and Progress: *Nacelle Hoisting Barrier*

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Barrier

- Current single-crane picks require rare, extremely large cranes to hoist nacelles of larger turbines causing
  - Risk of crane shortages
  - Larger wind plant access roads
  - Limited access to complex terrain
  - Smaller wind turbines and shorter towers

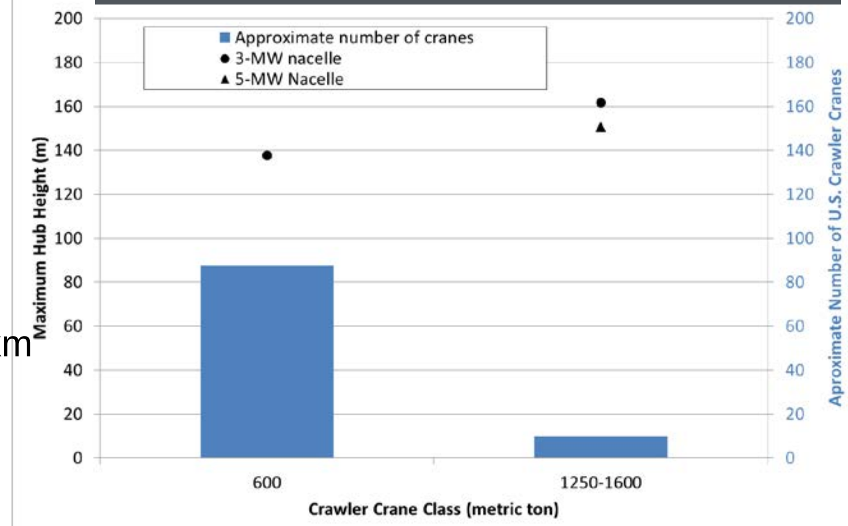
Benefits of Addressing the Barrier

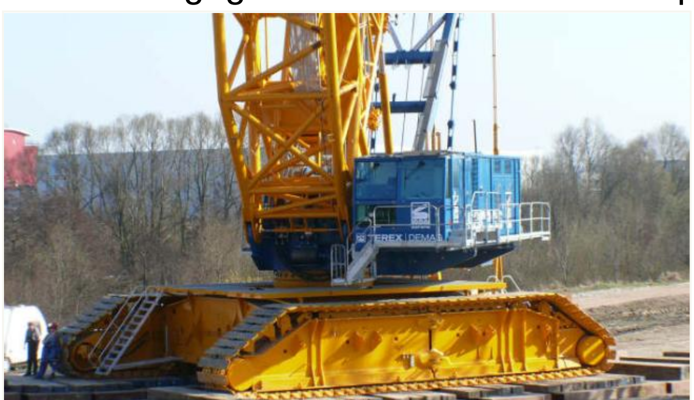
- Nearly doubles the new deployable land to 614,000 sq km (~3000 GW)

Recommended Actions

- Reduce uncertainty of multi-crane lifts via stakeholder engagement and demonstration projects

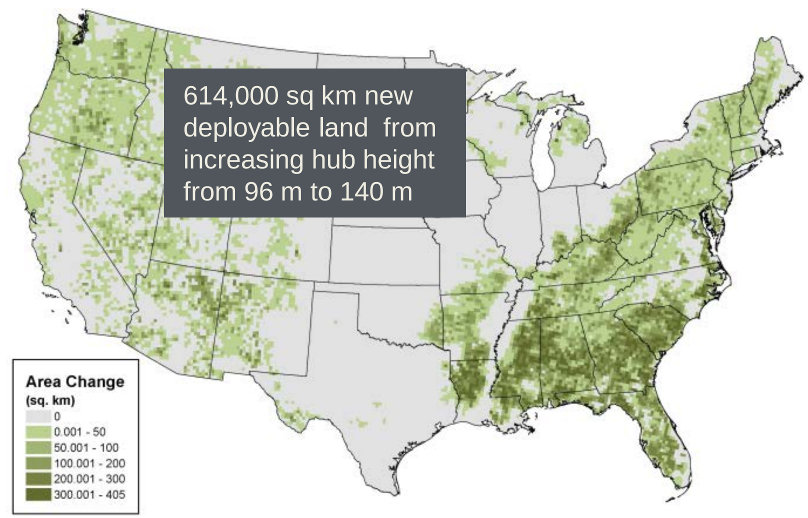
Hub height that crawler cranes can hoist conventional turbine nacelles (with the gearbox and generator hoisted separately) and the number of cranes estimated to be available





The Terex CC-9800 1600 ton has a base width of 41' and requires more than 100 semi-tractor trailers to transport.

Two-crane hoist in Europe



Accomplishments and Progress: *Blade and Tower Transportation Barriers*

Blade designs are limited to lengths of 62 m to accommodate turns

Modern wind turbine blades, tower bases, mid-sections, and nacelles are designed to fit under traffic features and within road weight limits

Barrier

– Dimensional and weight-transportation constraints increase blade and tower costs and limit deployment opportunities

Barrier Impacts

– Smaller, structurally sub-optimal (expensive) tower and blade designs

– Economic upper limit on turbine size

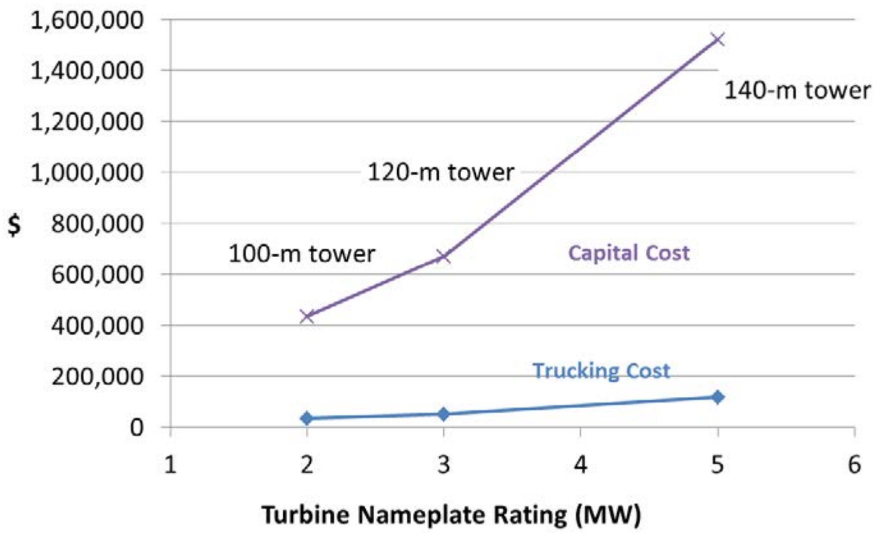
Recommended Actions

– Continued DOE technology development and demonstration of segmented blades and alternative tower manufacturing and assembly methods

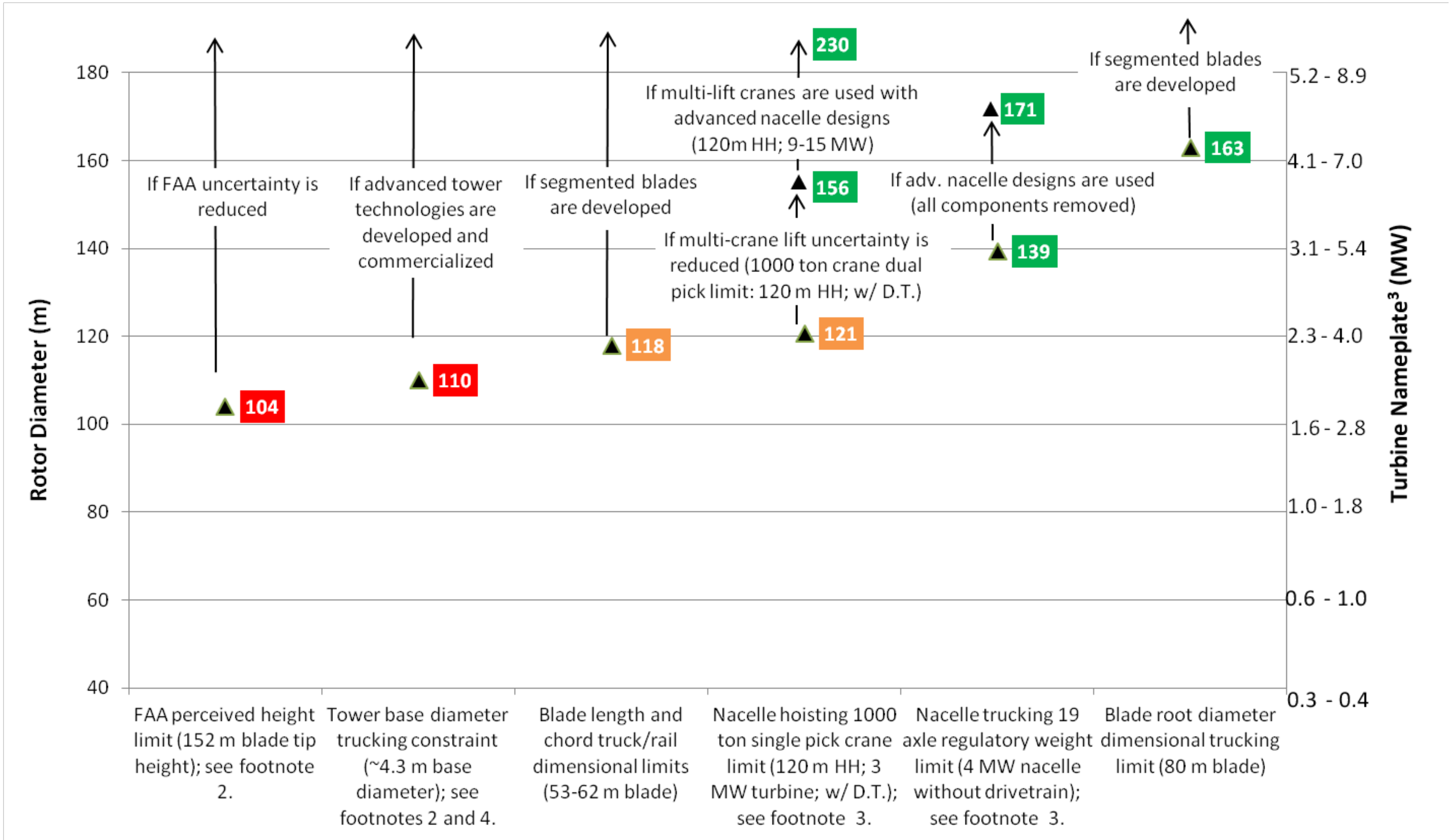
Benefits

– New LCOE reduction pathways

– New deployable land area (will be estimated in FY 14)



Accomplishments and Progress: Potential Impacts of Mitigating Barriers



Footnotes

1. The variability in rotor diameter reflects the variability in U.S. wind turbine design parameters (specific power rating, tower heights, blade precurve, etc...); the variability does not reflect the uncertainity or error in the data
2. Assumes hub height range of 80 m to 120 m
3. Assumes specific power rating range of 204 to 350 W/m2
4. Assumes rotor diameter to tower height ratio of 1.1

Legend

- Red: Impacts U.S. turbine installations today
- Orange: Potential impact on U.S. turbine installations
- Green: Potential impact on U.S. turbine installations
- ▲ Average value

Project Plan & Schedule

Summary	
WBS Number or Agreement Number	6.1.4
Project Number	
Agreement Number	

Legend
Work completed
Active Task
Milestones & Deliverables (Original Plan)
Milestones & Deliverables (Actual)

	FY2012				FY2013				FY2014			
Task / Event	Q1 (Octt-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Octt-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Octt-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Project Name: Wind Turbine Logistics and Planning Issues Analysis												
Q1 Milestone: Submission of draft work plan (December 31, 2012)												
Q2 Milestone: Presentation on initial findings - Qualitative prioritization and breakpoints (March 31, 2013)												
Q3 Milestone: Submission of draft executive summary paper (June 30, 2013)												
Q4 Milestone: Submission of final executive summary paper (September 30, 2013)												
Current work and future research												

Comments

- All work has been completed on time.

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Partners, Subcontractors, and Collaborators

- Coordinating with GLWN blade and tower manufacturing analyses

Communications and Technology Transfer

- NREL Technical Report: Analysis of Transportation and Logistics Challenges Affecting the Deployment of Larger Wind Turbines Summary of Results: http://www.nrel.gov/docs/fy14osti/61063.pdf

- AWEA WINDPOWER 2014 Podium Presentation

Next Steps and Future Research

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

FY14/Current research

Support in the development and execution of DOE FOA 982 *U.S. Wind Manufacturing Taller Hub Heights to Access Higher Wind Resources and Lower Cost of Energy.*

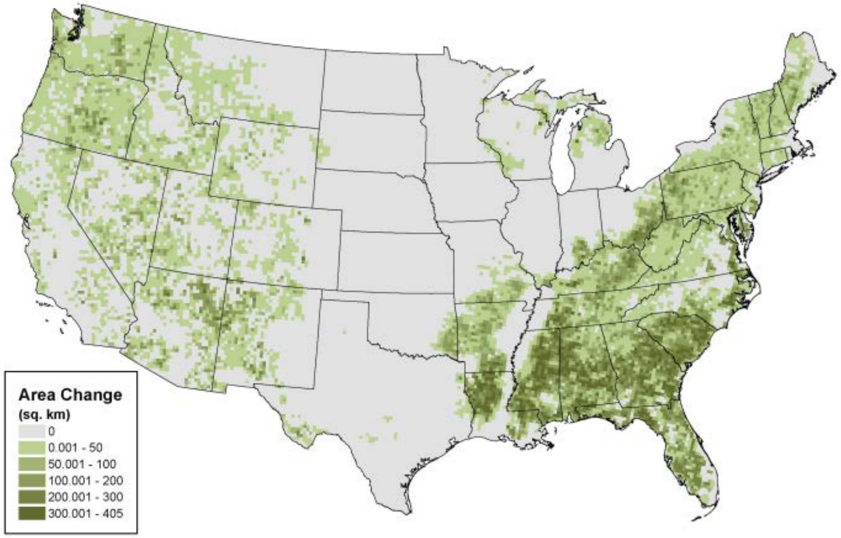
Proposed Future Research

Bigger turbines have potential to

- Provide LCOE reduction pathways
- Unlock new land for deployment
- Increase U.S. manufacturing competitiveness and domestic content

To estimate the deployment rate, we need to quantify

- System cost of energy
  - Costs for big advanced turbines
  - Installation costs
- Permitting and regulatory requirements



U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy




Wind Turbine Repowering and Recycling Assessments

Jason Cotrell

NREL

Jason.Cotrell@nrel.gov; (303) 384-7056

March 24, 2014

Budget, Purpose, & Objectives

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Total DOE Budget[1]: $0.300M

Total Cost-Share[1]:$0.000M

Problem Statement:

- As wind power facilities age, project owners are faced with plant end-of-life decisions on repowering and recycling
- Little literature exists to help with these decisions or policies

Impact of Project:

Informs policymakers and the business community regarding the history, opportunities, and challenges associated with plant end-of-life actions related to repowering and recycling

This project aligns with the following DOE Program objectives and priorities:

- **Optimize Wind Plant Performance:** Reduce Wind Plant Levelized Cost of Energy (LCOE)
- **Accelerate Technology Transfer:** Lead the way for new high-tech U.S. industries
- **Mitigate Market Barriers:** Reduce market barriers to preserve or expand access to quality wind resources
- **Advanced Grid Integration:** Provide access to high wind resource areas, and provide cost effective dispatch of wind energy onto the grid
- **Modeling & Analysis:** Conduct wind techno-economic and life-cycle assessments to help program focus its technology development priorities and identify key drivers and hurdles for wind energy technology commercialization

[1] ***Budget/Cost-Share for Period of Performance FY2012 – FY2013***

Technical Approach
Recycling

Scoped size of the recycling problem

- Projected recycling quantities and expectations

Identified capabilities of recycling technologies and industry using a literature review and interviews for

- Blades (composites)
- Rare earth elements
- Generator (copper and steel)
- Gearbox (steel alloys)
- Towers and hubs (coated steel)

Identified gaps in recycling infrastructure

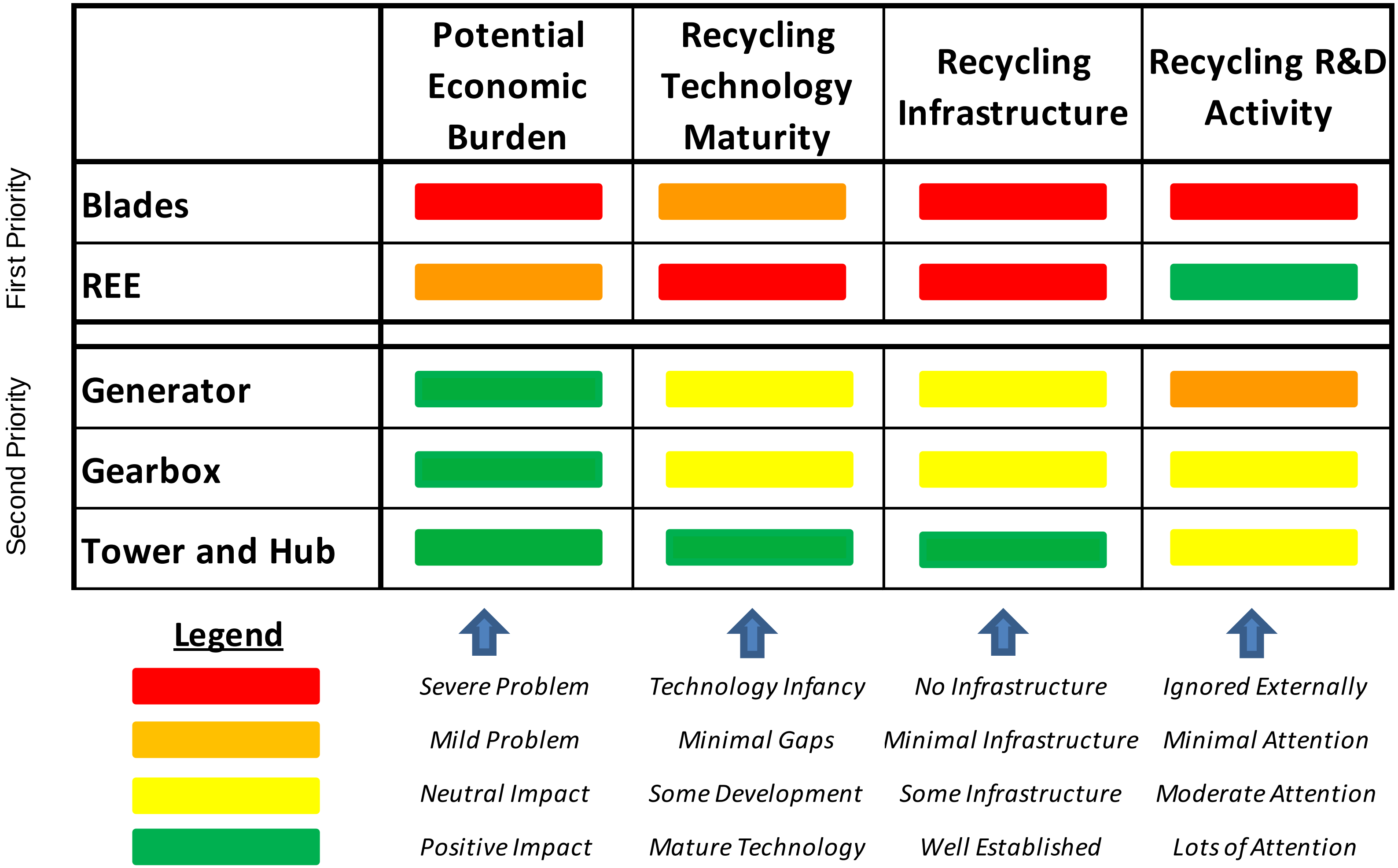
- Recycling supply chain constraints, technology barriers, standards and regulations

Created metrics for assessing the gaps

Provided recommendations to DoE

Accomplishments and Progress
Recycling

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



Project Plan & Schedule

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Summary		Legend
WBS Number or Agreement Number 6		Work completed
Project Number 6.3		Active Task
Agreement Number 6		Milestones & Deliverables (Original Plan)
		Milestones & Deliverables (Actual)

Task / Event	FY2012				FY2013				FY2014			
	Q1 (Octt-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Octt-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Octt-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Project Name: Recycling												
Q3 Milestone: Deliver initial literature review and initial work plan												
Q4 Milestone: Deliver Presentation and Executive Summary Report to DOE												
Q1 Milestone: Publish NREL Technical Report												
Project Name: Repowering												
Q3 Milestone: Deliver initial literature review and initial work plan												
Q4 Milestone: Deliver Presentation and Executive Summary Report to DOE												
Q2 Milestone: Draft NREL Comprehensive Technical Report												
Q3 Milestone: Publish NREL Comprehensive Technical Report												

Comments

- The recycling final report was delayed by DOE to allocate resources to higher priority projects

Technical Approach
Repowering

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

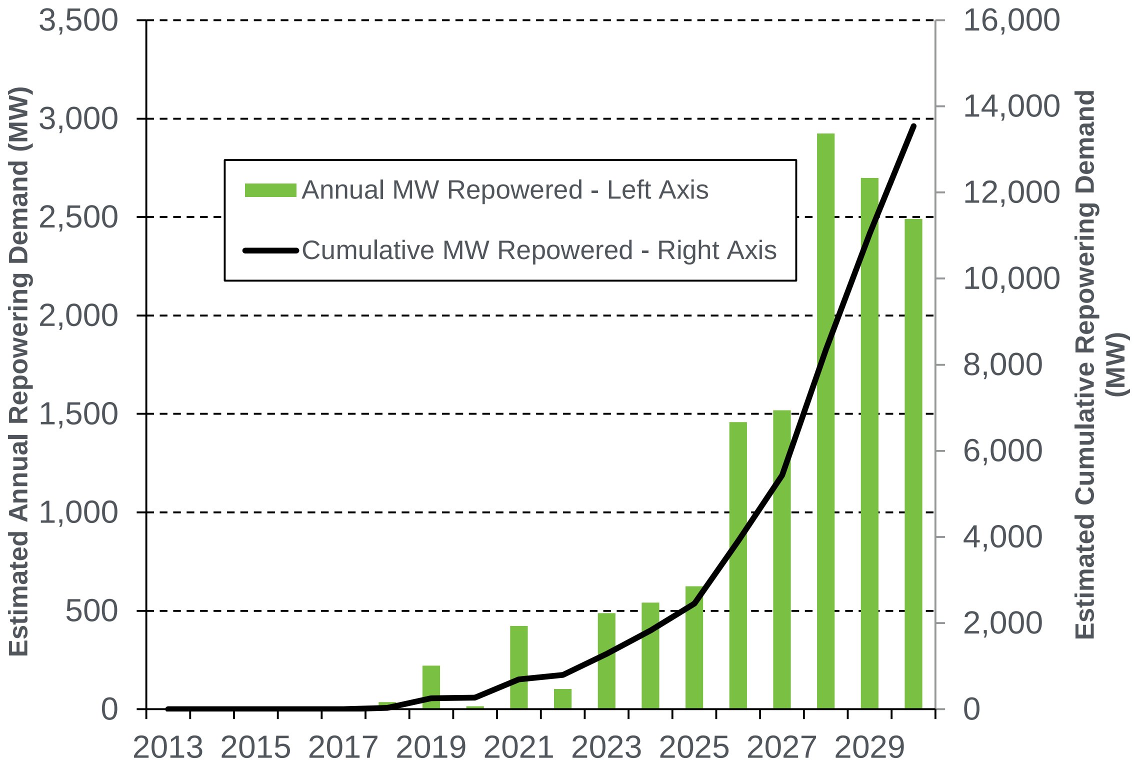
- Two distinct analyses were conducted to understand the plant age when repowering becomes viable
  1. "Proto-typical" with commissioning years of 1999, 2003, 2008, and 2012
  2. Case studies of three actual wind plants operating in the United States selected for varying vintages and geographical diversity

- These analyses utilized NREL's System Advisor Model (SAM)
  1. Predicts estimated cash flows from a variety of electric power generation technologies
  2. Net present value calculations were utilized to enable comparisons across time

- Provided recommendations to DOE

Accomplishments and Progress
Repowering

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



Conclusions

1. Repowering tends to become financially attractive after 20–25 years of service (relative to investing in a nearby greenfield site)

2. Demand for repowering is expected to be low over the next decade
   - Less than 1 GW per year in the early 2020s
   - 1–3 gigawatts per year by the late 2020s.

3. The total estimated value of the repowering market segment is estimated at $25 billion through 2030

Research Integration & Collaboration

Partners, Subcontractors, and Collaborators:

Wind and recycling industry members were consulted for information and review.

Communications and Technology Transfer:

- Repowering: NREL technical report *Wind Power Project Repowering*: *Financial Feasibility, Decision Drivers, and Supply Chain Effects* http://www.nrel.gov/docs/fy14osti/60535.pdf
- Recycling: An NREL technical report will be published in FY 14

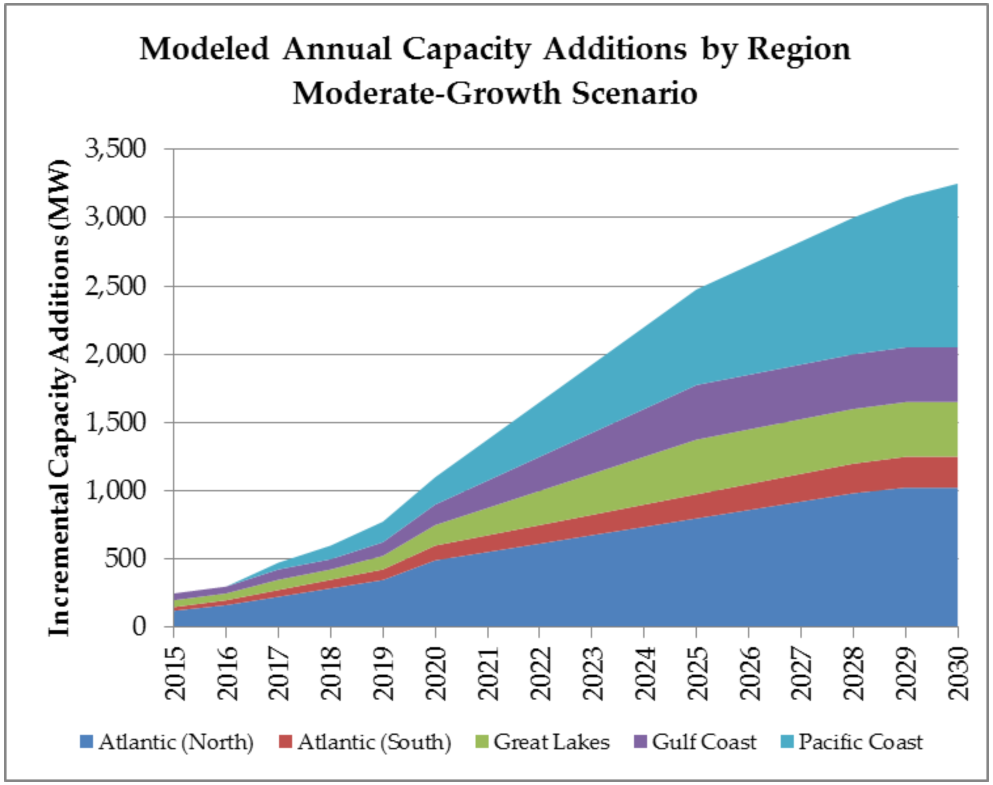
FY14/Current Research:

NREL technical report will be completed in May.

Proposed Future Research:

- Leverage domestic and international recycling technology development efforts.
- Establish a long-term strategy and plan for addressing wind turbine end-of-life disposal and recycling issues and opportunities.

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



U.S. Offshore Wind Manufacturing and Supply Chain Development

Bruce Hamilton

Navigant Consulting, Inc.

bruce.hamilton@navigant.com - 503.476.2711

March 24, 2014

Budget, Purpose, & Objectives

Total DOE Budget[1]: $0.15M

Total Cost-Share[1]:$0.00M

Problem Statement: There are anticipated gaps in the infrastructure and supply chain that will serve the U.S. offshore wind (OSW) industry.

Impact of Project: Identifies strategies for addressing the infrastructure and supply chain gaps based on a comprehensive analysis of the U.S. OSW supply chain.

This project aligns with the following DOE Program objectives and priorities:

Mitigate Market Barriers: Reduce market barriers to preserve or expand access to quality wind resources.

[1] *Budget/Cost-Share for Period of Performance FY2012 – FY2013*

Technical Approach

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Chapter	Data Sources	Methodology
1. OSW Plant Costs and Technology Advancements	• Annual OSW survey • Navigant's OSW project data base • Previous research by NREL, OCC	• Determine the cost breakdown of OSW plants • Identify suppliers of OSW turbines and components with US manufacturing facilities
2. Supply Chain Needs to Support U.S. Offshore Industry	• Analyses conducted with NREL's ReEDs model • Navigant's and NREL's databases of wind turbine component suppliers	• Identify technical trends in OSW manufacturing and construction • Determine the mix of plant locations, sizes, turbine types, and foundation types required • Determine the specific demand on the supply chain needed • Determine the investment and labor required by year for each component type

Technical Approach (cont.)

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Chapter	Data Sources	Methodology
3. Strategy for Future Development	• DSIRE database and its international equivalents • Key industry reports	• Evaluate the benefits of adding manufacturing capacity in the US vs. overseas • Research federal and state policies for promoting OSW • Identify US policy changes to close any competitive gaps.
4. Analysis of Market Entry Pathways	• Development experience by consortium partners • Interviews with industry stakeholders	• Identify market barriers • Assess likely future market entry pathways • Recommendations for removing the identified barriers

Accomplishments, and Progress

Chapter	Accomplishments
1. OSW Plant Costs and Technology Advancements	Data repository for the US OSW industry supply chain, including costs and supplier information for all turbine and BOP components
2. Supply Chain Needs to Support U.S. Offshore Industry	Long-term market forecast for each component for three scenarios
3. Strategy for Future Development	Strategy for the US to close any competitive gaps and maximize domestic market share
4. Analysis of Market Entry Pathways	Road map for domestic suppliers to participate in the OSW market

Summary of Near-term Domestic Supply Chain Opportunities under a Moderate-Growth Scenario

Component	Market Value (M$/year)	Timing of Opportunity	Global Supply Risk	Transferability	Opportunity
Wind Turbine Assembly	$1,817-$2,200	2021-2025	Medium	Low	Moderate
Blades	$320-$391	2021-2025	Low	Low	Moderate
Gearboxes and Generators	$415-$507	2021-2025	Medium	Medium	Moderate
Bearings	$76-$94	2015-2020	Medium	Low	Moderate
Power Converters	$81-$99	2015-2020	Low	High	Favorable
Power Transformers	$58-$71	2015-2020	Low	High	Favorable
Towers	$371-$454	2021-2025	Medium	High	Favorable
Castings	$100-$122	2015-2020	Medium	Medium	Moderate
Forgings	$39-$47	2015-2020	Medium	Medium	Moderate
Pitch and Yaw Systems	$83-$101	2015-2020	Low	Medium	Moderate
Resins	$24-$29	2015-2020	Medium	High	Favorable
Reinforcement Fibers	$36-$44	2015-2020	Medium	High	Favorable
Foundations and Substructures	$1,300-$1,600	2015-2020	Medium	Medium	Favorable
Substations	$174-$213	2021-2025	Low	Medium	Moderate
Array Cables	$282-$345	2021-2025	Low	Medium	Moderate
Export Cable	Incl. w/array	Beyond 2025	Medium	Low	High-Risk

Project Plan & Schedule

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Summary	
Project Number	EE0005364

Legend	
	Work completed
	Active Task
	Milestones & Deliverables (Original Plan)
	Milestones & Deliverables (Actual)

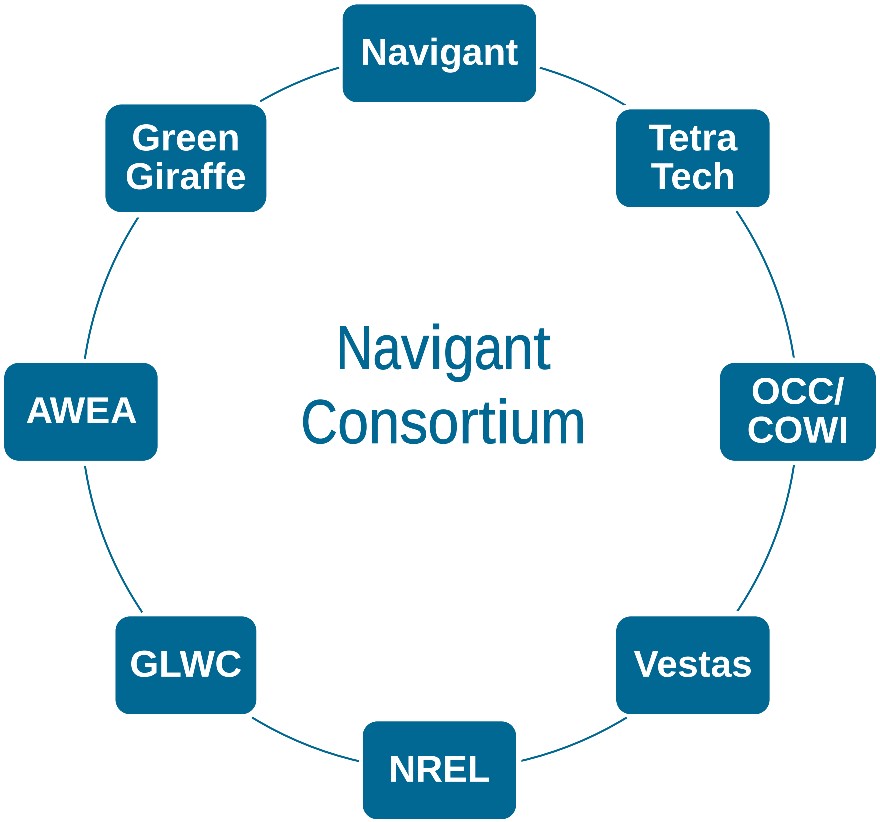
	FY2012				FY2013				FY2014			
Task / Event	Q1 (Octt-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Octt-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Octt-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Project Name: Offshore Wind Market and Economic Analysis												
Q1 and Q2 Milestones: Issue offshore wind survey												
Q2 and Q3 Milestones: Offshore wind workshops												
Q4 and Q1 Activity: Internal and peer review of Technical Report												
Q2 Milestone: Technical Report delivered to DOE												

Comments

- Project original initiation date: 10/1/11
- Project completion date: 2/22/13

Research Integration & Collaboration

Partners, Subcontractors, and Collaborators:



Communications and Technology Transfer:

- 2 workshops (market and technical trends, supply chain, economic impacts, and policy), plus guest speakers from other teams
- Portions of the reports presented at multiple webinars, podium and poster presentations
- Reports available at www.navigant.com.

Next Steps and Future Research

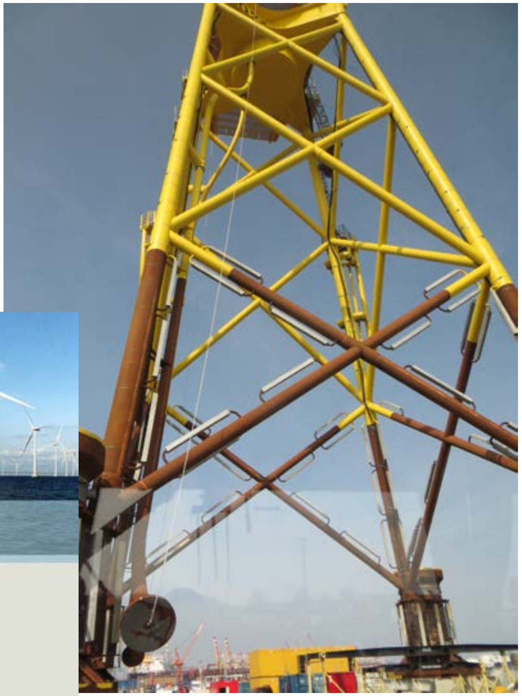
FY14/Current research:

- none

Proposed future research:

- Ongoing maintenance of offshore wind project and supply chain databases

GLWN.org



U.S. Wind Energy Manufacturing and Supply Chain: A Competitiveness Analysis

Patrick Fullenkamp

GLWN, Global Wind Network [WIRE-Net]

pfullenkamp@glwn.org 216-920-1956

March 24, 2014

Budget, Purpose, & Objectives

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Total DOE Budget[1]: $0.300M

Total Cost-Share[1]:$0.000M

Problem Statement: There is a need for greater understanding of the key factors determining wind energy component manufacturing costs and pricing on a global basis in order to enhance the competitiveness of U.S. manufacturers, and to reduce installed system costs.

Impact of Project: This project is carrying out detailed manufacturing comparisons of four large turbine components manufactured in the U.S., Europe and Asia in order to determine the global cost leaders, best current manufacturing processes, key factors determining competiveness, and potential means of cost reduction. GLWN has also developed a wind industry scorecard assessing U.S. manufacturers' readiness to supply the next generation of turbines and key balance-of-plant components.

This project aligns with the following DOE Program objectives and priorities

- **Optimize Wind Plant Performance:** Reduce Wind Plant Levelized Cost of Energy (LCOE).
- **Mitigate Market Barriers:** Reduce market barriers to preserve or expand access to quality wind resources.

[1] ***Budget/Cost-Share for Period of Performance FY2012 – FY2013***

Technical Approach

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Develop **standardized component specifications and drawings** with industry and labs (NREL and SNL) for apples-to-apples comparisons between global manufacturers.

- **Visit and collect first-of-a-kind manufacturing cost and process data from 22 suppliers** across the U.S., Europe, and Asia for towers, blades, foundations, and PM generators, for next-generation wind turbines (3MW and 5MW) for both land-based and offshore applications. *[Note: Contract called for 12 site visits, but 22 were completed to improve data reliability]*

- Utilize **Cost Breakdown Analysis** and **Value Stream Mapping**

- Develop an **Industry Scorecard** for 13 key wind turbine and balance of plant components.
  - Towers
  - Blades
  - Generator
  - Gearbox
  - Forge Ring
  - Forge Shaft
  - Cast Hubs
  - Cast Support Base
  - Fab Support Base
  - Composite Housing

  Balance of Plant
  - Monopile Fdn.
  - Jacket Fdn.
  - Subsea Cable

- Publicly disseminate information via **public access, web-enabled Wind Supply Chain Map** to include offshore wind industry search features.

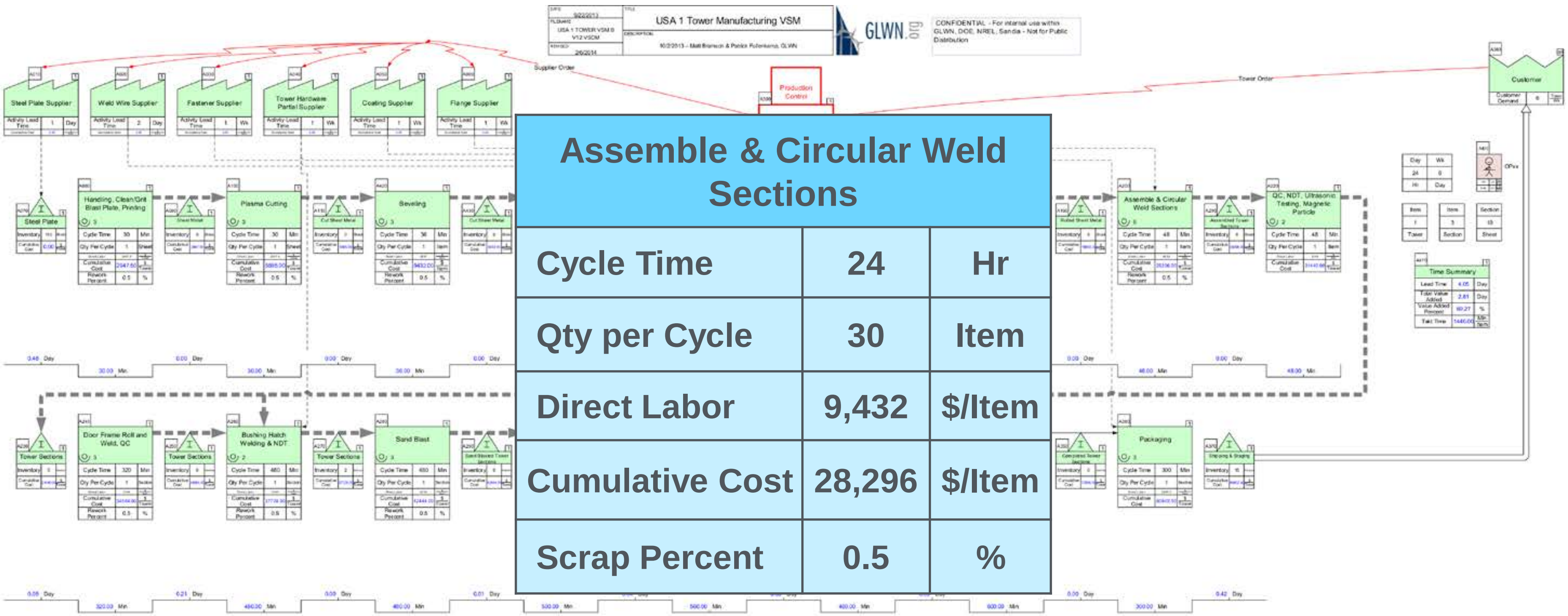
Technical Approach

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- **Manufacturer Selection and Data Gathering Process**
  - **Identified and contacted** current active land based **suppliers in the U.S.A.**, and active land based and offshore suppliers in **Germany and China**,
  - Sent **letter of introduction (DOE & GLWN**) to suppliers explaining scope of project and asked for interest
  - Sent out an official **Request for Quote** with detailed manufacturing drawings, Cost Breakdown Form and set a targeted plant visit date
  - **Plant Visits** included meeting Management Teams, Project Presentation, Hosting Plant Presentation, Review of Process Flow, **Walking the Manufacturing Process** from beginning to end enabling the development of the **Value Stream Map**, Review of the cost data or plan to obtain it.
- **Cost Breakdown Analysis**
  - A Specific cost Breakdown Form was developed which included a complete **Bill of Materials** with weights, general process steps for **Labor** and **Burden**, categories of **SGA, Engineering, Logistics Cost to U.S. Port**, and **Profit**
  - **Quoted Data** was consolidated into spreadsheets for analysis
- **Value Stream Map (VSM)**
  - **VSMs** were generated using data gathered during plant visits.

Technical Approach
Value Stream Map – Towers

USA 1 Tower – 17 Process Steps

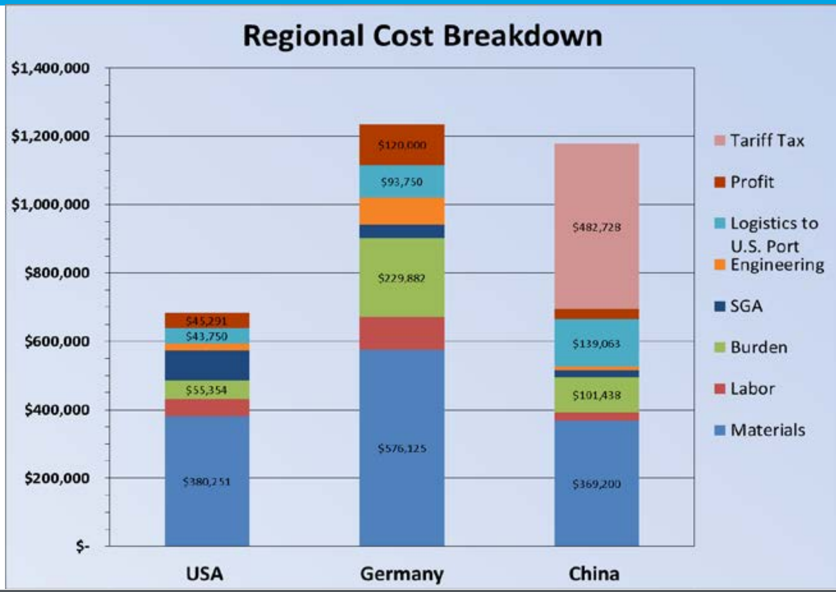


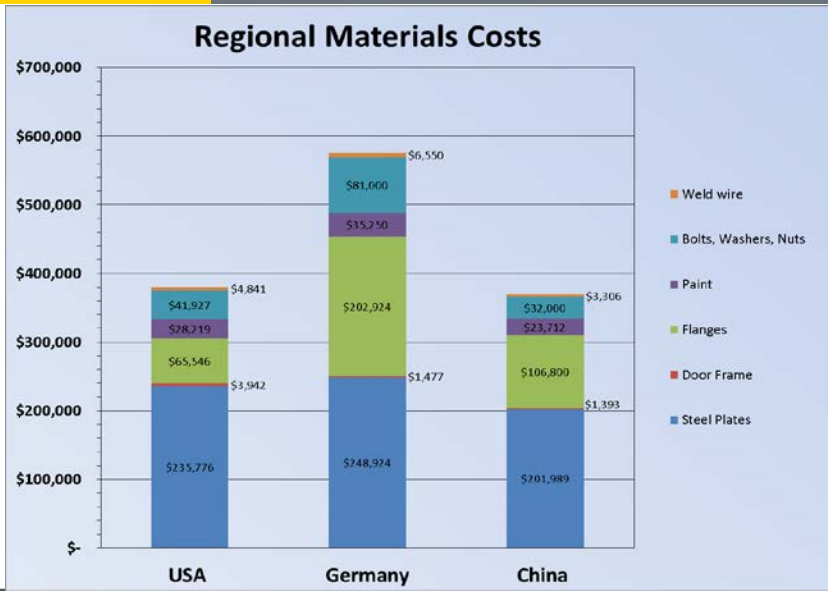
Assemble & Circular Weld Sections		
Cycle Time	24	Hr
Qty per Cycle	30	Item
Direct Labor	9,432	$/Item
Cumulative Cost	28,296	$/Item
Scrap Percent	0.5	%

- Identifies areas of waste and improvement opportunities for domestic suppliers
- Better characterize flow of materials, labor, tasks, and information

Accomplishments and Progress
TOWERS – Cost Breakdown

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

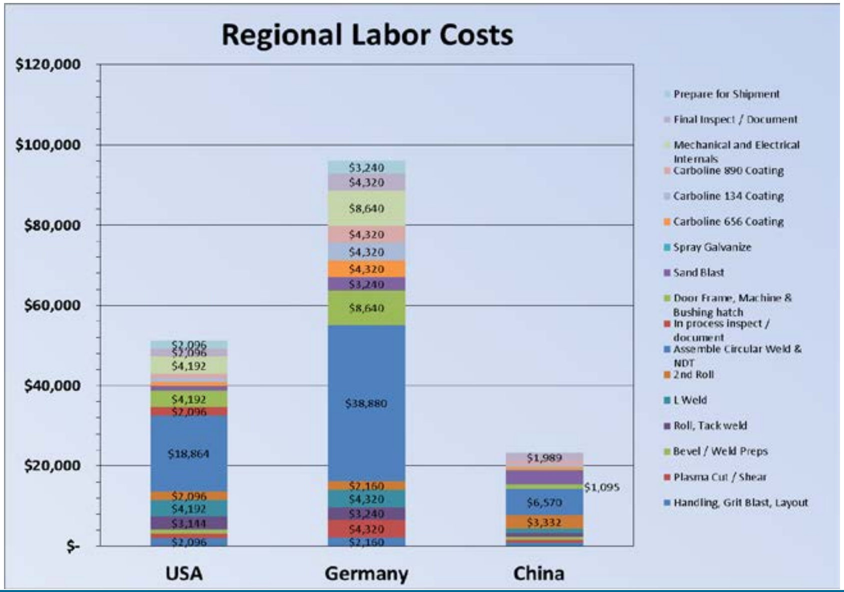




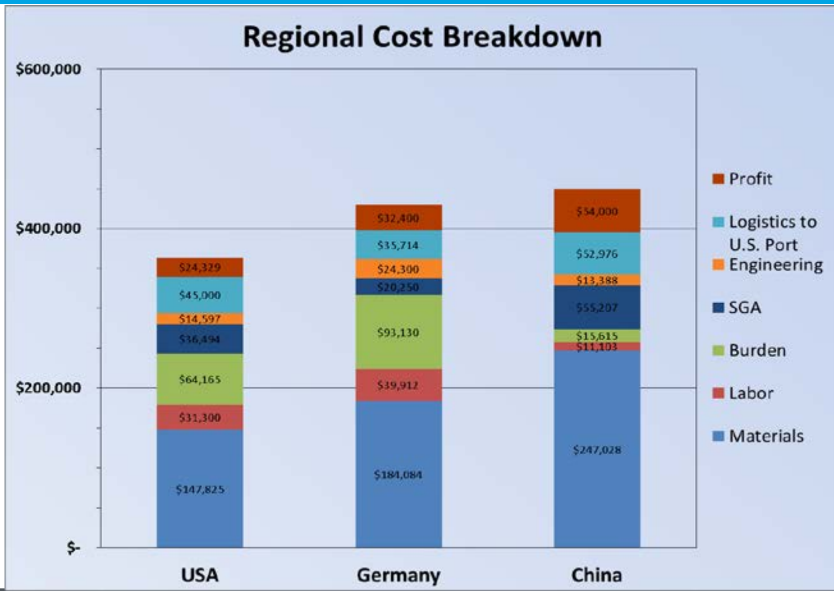
Towers are on avg. 27% of Wind Turbine Cost

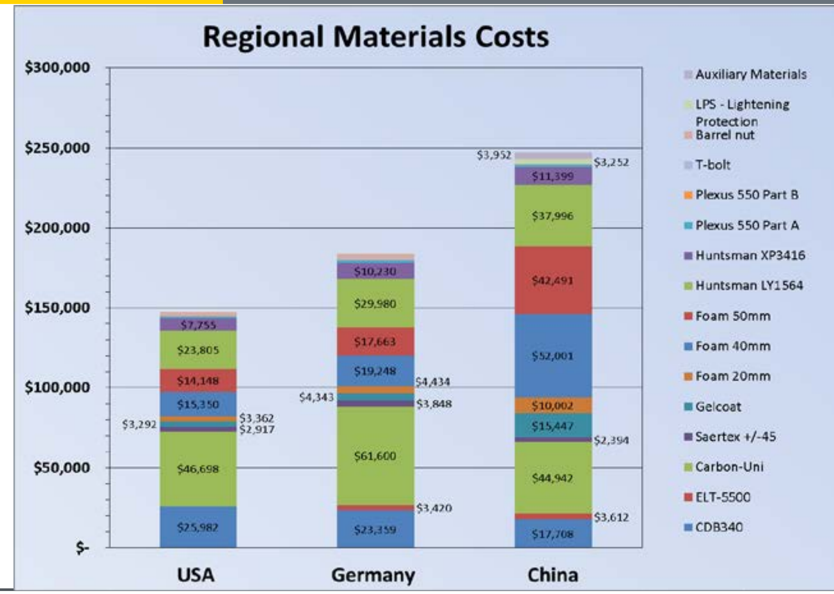
R&D Projects from findings (partial list):

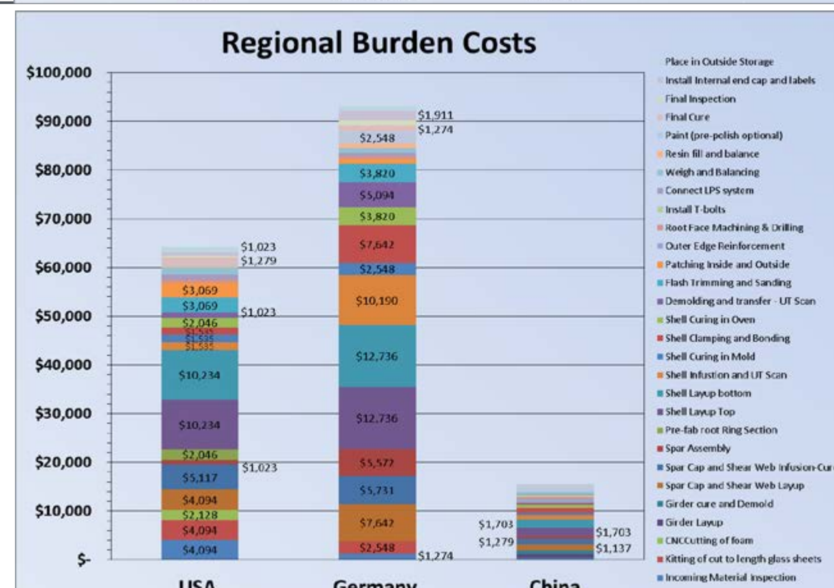
- **Material** is over 50% of the cost of the Tower of which Steel Plate accounts for 62% in the U.S. Mfg's to work with steel mills to **optimize material and size of plate** to reduce mill cost and mfg process weld time. **Welding in flat state** is more efficient. Circular weld highest labor hours
- **Weld wire size and delivery system** – 1 to 5 wires – magnetic field and weld pattern impact



Accomplishments and Progress
BLADES – Cost Breakdown





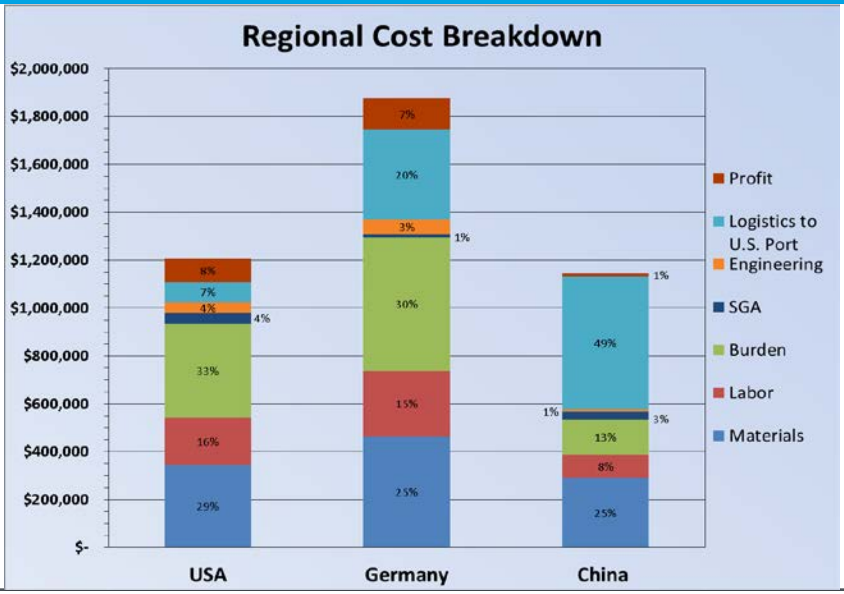


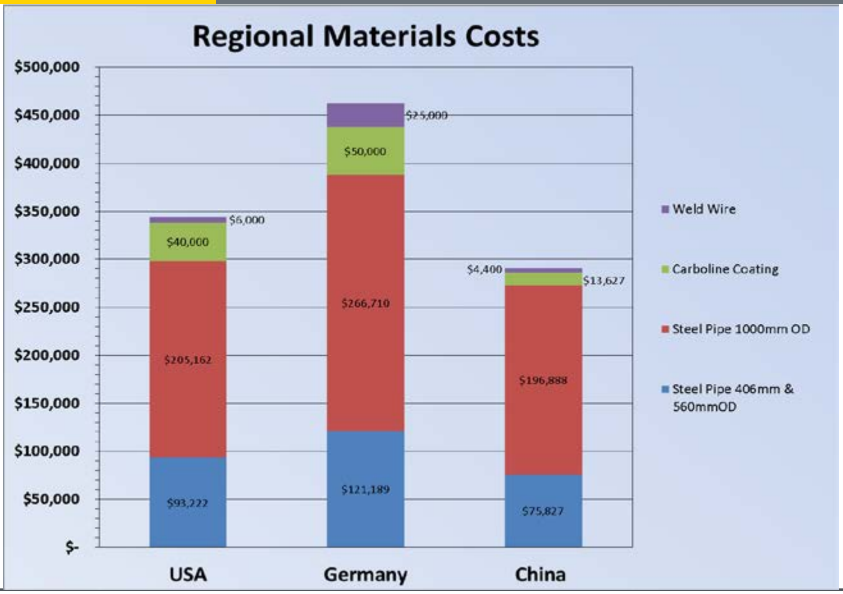
Blades are on avg. 20% of the Wind Turbine Cost

R&D Projects from findings (partial list):

- **Material is ~45%** of the cost of the Blade of which **Resin, Carbon, Glass, & Foam** account for 90% of the U.S. material cost. Material Improvements that provide material cost and process time reductions would be of most benefit
- **Blade design and analysis** looking at: power output, least material usage, shape with 1 or 2 piece for cost and transportability
- **Smart Automation**

Accomplishments and Progress
FOUNDATIONS – Cost Breakdown

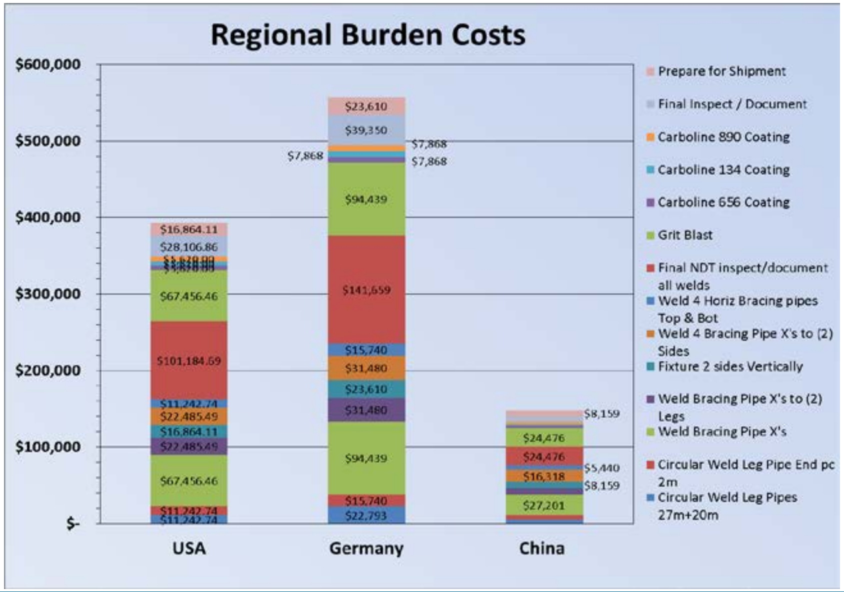




Jacket Foundations are on avg.~15% of Offshore Capital Cost

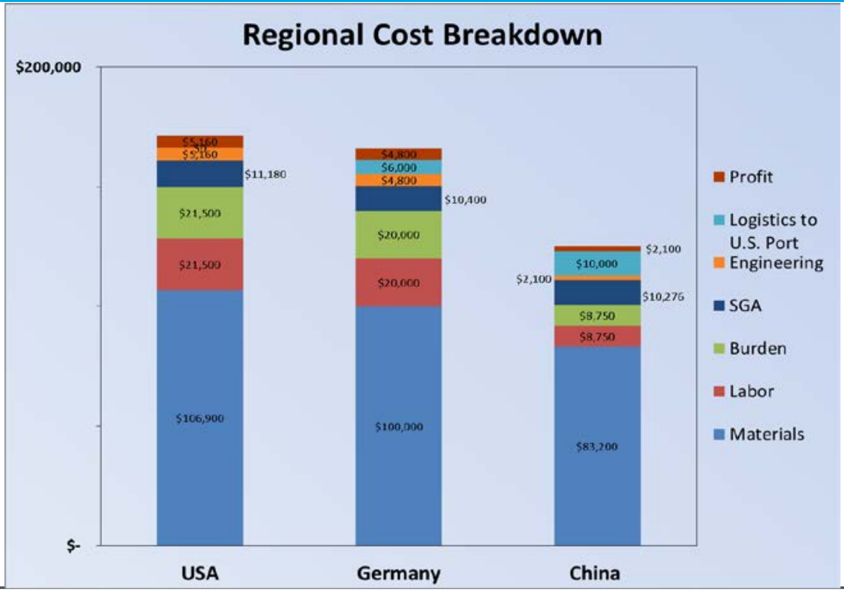
R&D Projects from findings (partial list):

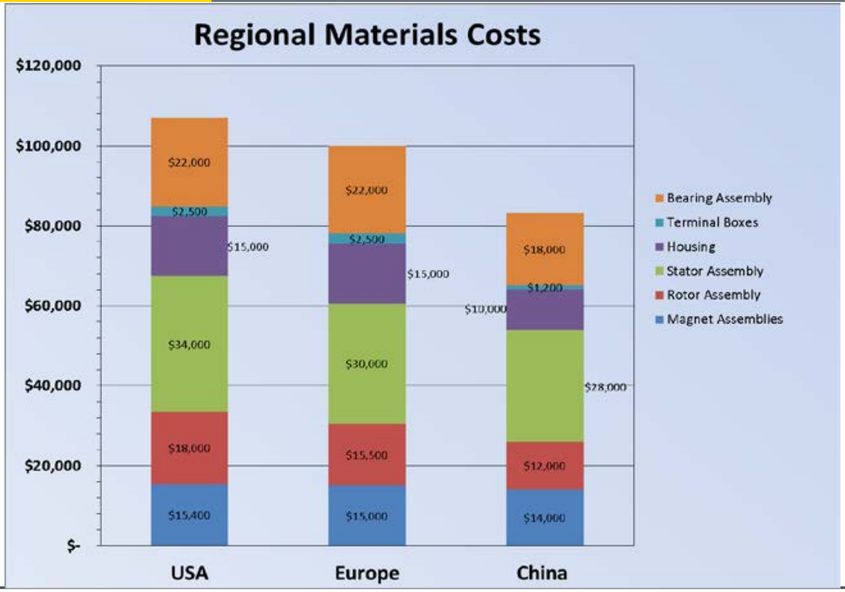
- **Labor and Burden account for 50%** with material ave. 30%.The foundation main lattice is a prime candidate for a design for assembly and design for manufacturing exercise
- A higher volume **series production manufacturing process** needs to be developed and optimized to achieve LCOE



Accomplishments and Progress
GENERATORS – Cost Breakdown

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy





Generators are on avg. 7% of Wind Turbine Cost. This study is of a **1MW PM Generator** that would need to be scaled for 5MW evaluation

R&D Projects from findings (partial list):

- **Material is over 60%** of the cost of the PM Generator of which Stator Assembly, Bearing Assembly, and magnet assemblies account for 75%. Alternate material types, shapes, properties and total pieces should be investigated**. Design for Manufacturing** to be applied.

Conclusions – General Observations

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Detailed Drawings with Bill of Materials were required to get comparative global apples-to-apples quotes

Objective Results:

1. **Determine Global Cost Leaders: China** is the low cost manufacturer in 3 of the 4 product categories (Towers, Foundations, Generators), The **USA** had the lowest cost on Blades. **Germany** was the high cost manufacturer in all categories, although they have ~80% of the content in the North Sea Projects
2. **Determine Best Current Mfg Process: US had the best process** (Towers, Blades, Generators). **Germany best Foundations. China** has the **highest rework and non-value added process** times
3. **Key Factors that Determine Competitiveness: China's advantage** is the lowest material, labor, and burden cost. China's focus is on **volume production**.
4. **Potential Means for U.S. Cost Reduction: U.S manufacturers are within reach of Best Overall: Focus** on Material, **Focus** on Product & Process Design for Lean series production, **Invest** to produce large parts near the coasts .

This **Competitiveness Analysis** was a productive & efficient process to capture detailed global quoted cost data and identify R&D to reduce component cost.

Proposed Next Project – Forgings & Castings with 14% & 8% of the Wind Turbine Cost. OEMs indicate there is **minimum competitive U.S. capacity** today

Accomplishments and Progress

Industry Scorecard – 280 Mfgs

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

		LAND-BASED		OFFSHORE	
Component		Investment Req.	Major Hurdles	Investment Req.	Major Hurdles
Towers	3MW	LOW	Capability Exists	LOW - MODERATE	Logistics: Rail/road challenges to ports. Mfgs located in midwest.
	5MW	MODERATE - HIGH	Logistics: Rail/road challenges Fac/Equip: Upgrades likely	HIGH	Logistics: Rail/road challenges to ports. Only one tower mfg port side.
Blades	3MW	LOW	Capability Exists	MODERATE - HIGH	Logistics: Rail/road challenges to ports. Mfgs located in midwest.
	5MW	MODERATE- HIGH	Logistics: Rail/road challenges. Fac/Equip: Upgrades likely	HIGH	Logistics: Rail/road challenges to ports. No blade mfg port side.
Jacket Fdn.	3MW	n/a		MODERATE - HIGH	Jackets are new product for U.S. mfgs. Learning curve can be expected. Investment likely for serial production. Limited offshore experience on AT & GL coast.
	5MW	n/a		MODERATE - HIGH	
Gen.	3MW	LOW	Capability Exists	LOW	Capability Exists
	5MW	LOW - MODERATE	Fac/Equip: Possible upgrades for crane capacity & finish tanks	LOW - MODERATE	Fac/Equip: Possible upgrades for crane capacity & finish tanks

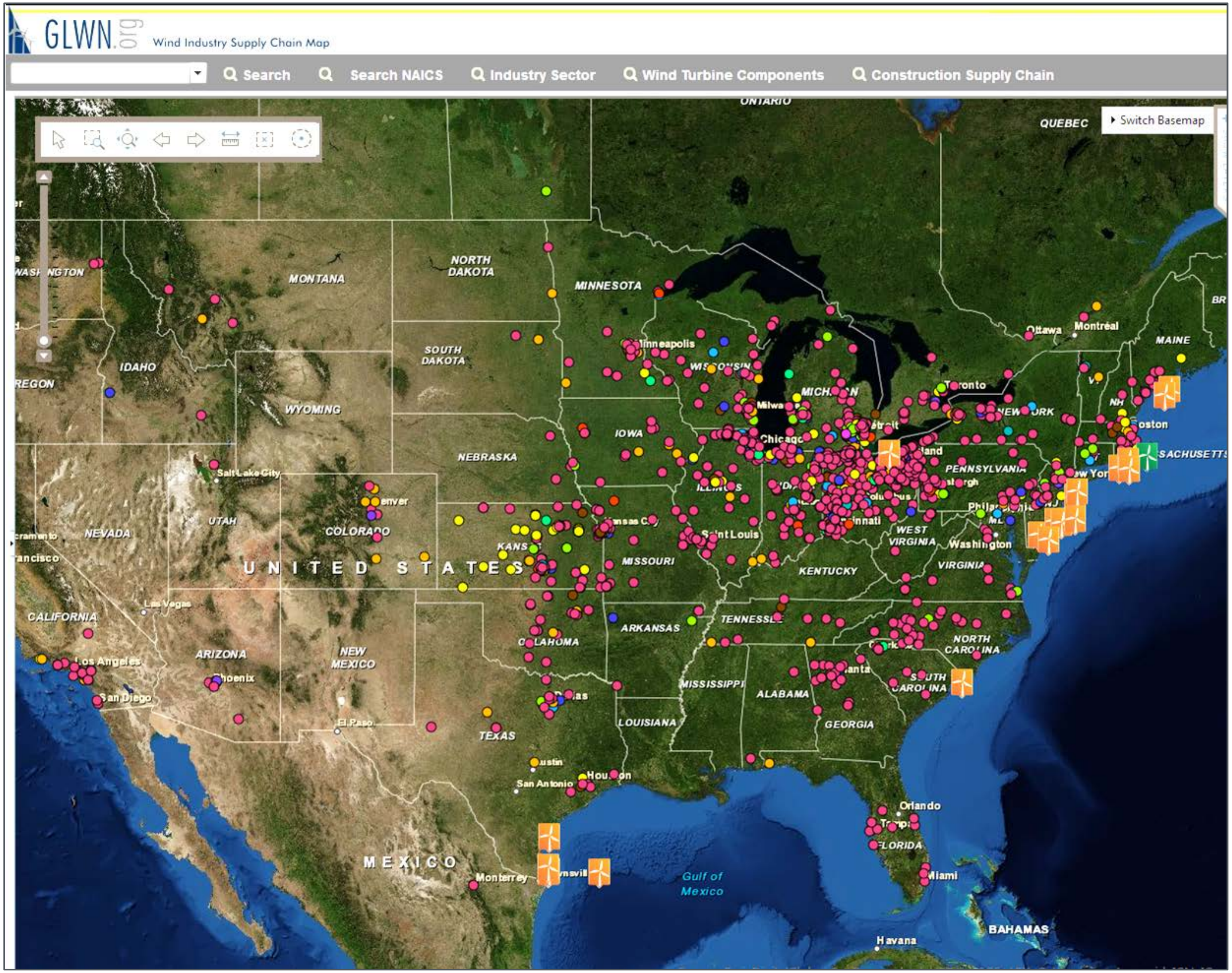
Accomplishments and Progress
Industry Scorecard *– Key Areas of Concern*

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

		LAND-BASED		OFFSHORE	
Component		Investment Req.	Major Hurdles	Investment Req.	Major Hurdles
Cast Hubs	3MW	HIGH	Capability does not exist for larger than 2.5MW.	HIGH	Capability does not exist for larger than 2.5MW. Facilities concentrated in Midwest. Coastal region casting plant needed.
	5MW	HIGH	Capability does not exist for larger than 2.5MW.	HIGH	
Cast Support Bases	3MW	HIGH	Capability does not exist for larger than 2.5MW.	HIGH	Capability does not exist for larger than 2.5MW. Facilities concentrated in Midwest. Coastal region casting plant needed.
	5MW	HIGH	Capability does not exist for larger than 2.5MW.	HIGH	
Forged Rings	3MW	MODERATE - HIGH	Capability exists. Concern: U.S. mfgs are NOT supplying the wind market. They are not competitive.	MODERATE - HIGH	Capability exists. Concern: U.S. mfgs are NOT supplying the wind market. They are not competitive.
	5MW	MODERATE - HIGH		MODERATE - HIGH	
Forged Shafts	3MW	MODERATE - HIGH	Capability exists. Concern: U.S. mfgs are NOT supplying the wind market. They are not competitive.	MODERATE - HIGH	Capability exists. Concern: U.S. mfgs are NOT supplying the wind market. They are not competitive.
	5MW	MODERATE - HIGH		MODERATE - HIGH	

Accomplishments and Progress

GIS Wind Supply Chain Map



Map Search Features

- ✓ Industry Sector
- ✓ Turbine Component
- ✓ Materials
- ✓ Process Equipment
- ✓ Offshore Construction
- ✓ Onshore Construction
- ✓ Area search

Manufacturers Data

- ✓ Industry specialty
- ✓ Component capability
- ✓ Contact info

Wind Farm Data

- ✓ Permitted
- ✓ Proposed
- ✓ Developer
- ✓ Resource links

Project Plan & Schedule

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Summary	
WBS Number : 5.0 Offshore Wind RD&T	
Project Number: DE-EE0006102	
Agreement Number	

Legend
- Work completed
- Active Task
- Milestones & Deliverables (Original Plan)
- Milestones & Deliverables (Actual)

	FY2012				FY2013				FY2014			
Task / Event	Q1 (Octt-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Octt-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Octt-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Project Name: U.S. Wind Energy Manufacturing. And Supply Chain: A Competitiveness Analysis												
Q1 Milestone 1: Data Gathering-Interview industry experts, establish SC capability criteria												
Q1 Milestone 1: Establish SC criteria, Identify potential suppliers, develop & deploy survey												
Q2/3 Milestone 2: Conduct site visits / Develop VSMs for selected mfgs from Europe, Asia & U.S.												
Q2/3 Milestone 2: Develop CBAs for selected manufacturers Europe, Asia & U.S.												
Q2/3 Milestone 2: Update GIS Map with new SC mfgs, and offshore wind search features												
Q4 Milestone 3: Validate and finalize CBA and VSM data / Validate manufacturers data												
Q4 Milestone 3: Develop Scorecard structure and complete rating												
Current work and future research [no cost extension to contract]												
Q1/2 NC Extension: Extend Scorecard kto include forged shafts, forged rings, submarine cable												
Q1/2 NC Extension: Complete Scorecard												
Q1/2 NC Extension: Complete VSM and CBA for 22 mfg site visits												
Q1/2 NC Extension: Complete Final Report												

Comments

- Project start date: 01/01/13 Project planned completion date: 12/31/13
- No cost extension was requested to allow time to further validate VSM & CBA data for the 22 mfgs (Original Scope of 12 mfgs), and scorecard was extended to include forged rings, forged shafts, and submarine cable.
- Data reliability was improved with the added manufacturing visits and analysis

Partners, Subcontractors, and Collaborators:

GLWN collaborated with the NREL, SNL, MassCEC Blade Technology Center, manufacturing industry associations, economic development agencies, and several DOC MEP (Manufacturing Extension Partnership) agencies. **Subcontracts** were issued to Ohio University's Voinovich School of Leadership and Public Affairs for expansion of the GLWN Wind Supply Chain Map, and with Mr. Bowen Liu, a Chinese national, for Chinese manufacturing connections, plant visit arrangements, and correspondence.

Communications and Technology Transfer:

CBA, VSM, and Scorecard Results: Manufacturer's cost and process data is considered confidential and is only available to DOE, NREL, SNL, and GLWN. Sensitive data will be aggregated and compiled into the Final Report, appropriate for public dissemination. Weekly Team meetings were held, and 4 internal DOE webinars to review component findings, have been completed to date.

GLWN Wind Supply Chain Map: The offshore wind supply chain is communicated through the open-access web-based GIS map, located at **www.glwn.org**. Now available for viewing.

Next Steps and Future Research

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

FY14/Current research: Expansion of Scorecard, further review and validation of CBA data, and completion of final report.

Proposed future research:

- Participate in the Evaluation and Implementation of all proposed R&D Projects for Towers, Foundations, Blades, & PM Generators. Continue dialogue with the manufacturers who participated in this study →**This will enable U.S. Manufacturers to be globally competitive, achieve LCOE, capture this new business, and add U.S. jobs**.
- Phase 2 – Apply this same CBA and VSM process to **Forging and Casting** wind turbine content **(14% & 8% of wind turbine cost respectively).**

Assessment of Vessel Requirements for the U.S. Offshore Wind Sector

Offshore Wind: Optimized Vessel Assessment (Subtopic 5.2)

Jim Ahlgrimm

March 24, 2014

(Note – work performed by Douglas-Westwood)

Budget, Purpose, & Objectives

Total DOE Budget [1,2]: $0.000M

Total Cost-Share[1]:$0.000M

Problem Statement: The installation of offshore wind farms requires a highly specialized fleet of vessels, but such a fleet does not currently exist in the US. The project investigated the vessel-related aspects of offshore wind development, and identified challenges and opportunities related to the installation and maintenance of offshore wind turbines in the US under a number of scenarios.

Impact of Project: The final report provides an aggregate view of the vessel-related aspects of offshore wind, and it is intended to serve as a handbook for all stakeholders in the US offshore wind industry. A number of outreach events (including conference presentations and webinars) served to disseminate the findings of the study to a wider audience. A follow-up project with the New Jersey Department of Transportation (completed in 2013) utilized the skillset and findings gained from the completion of the present project.

This project aligns with the following DOE Program objectives and priorities:

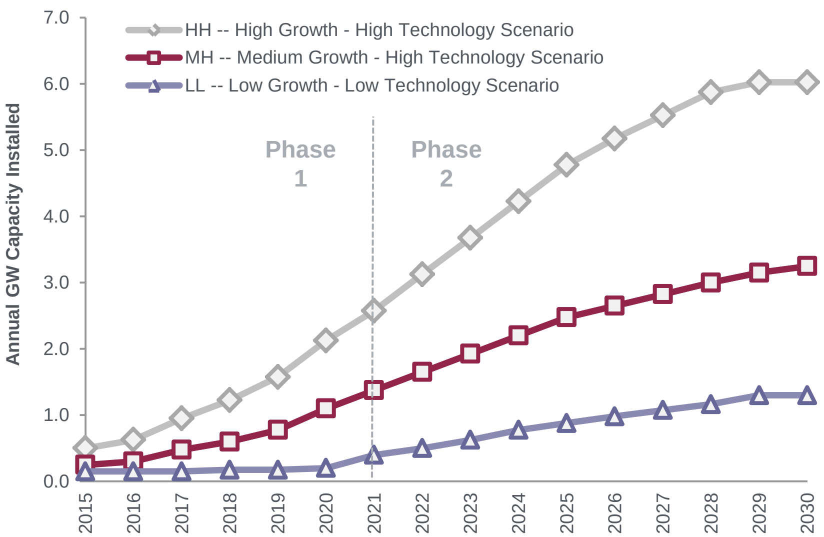
- **Mitigate Market Barriers:** Reduce market barriers to preserve or expand access to quality wind resources

[1]*Budget/Cost-Share for Period of Performance FY2012 – FY2013*
[2] *Project remained active using DOE funds received prior to FY2012*

A model was developed and used to calculate the demand for specialized offshore wind vessels under three scenarios in the US

Deployment Scenarios		54GW by 2030 (HH) High Growth- High Tech Scenario		28GW by 2030 Moderate Growth with High Technology Adoption (MH)		10GW by 2030 - Low Growth - Low Tech Scenario (LL)	
		2020	2030	2020	2030	2020	2030
Total Capacity Deployed by Milestone Date (in GW)		7	54	4	28	1	10
Regional Distribution							
	Atlantic Coast	4	28	2	12	1	8
	Great Lakes	1	6	0.5	4	0	1
	Gulf Coast	1	5	0.5	4	0	1
	Pacific Coast	1	15	0.5	8	0	0

Summary of Rollout Scenarios



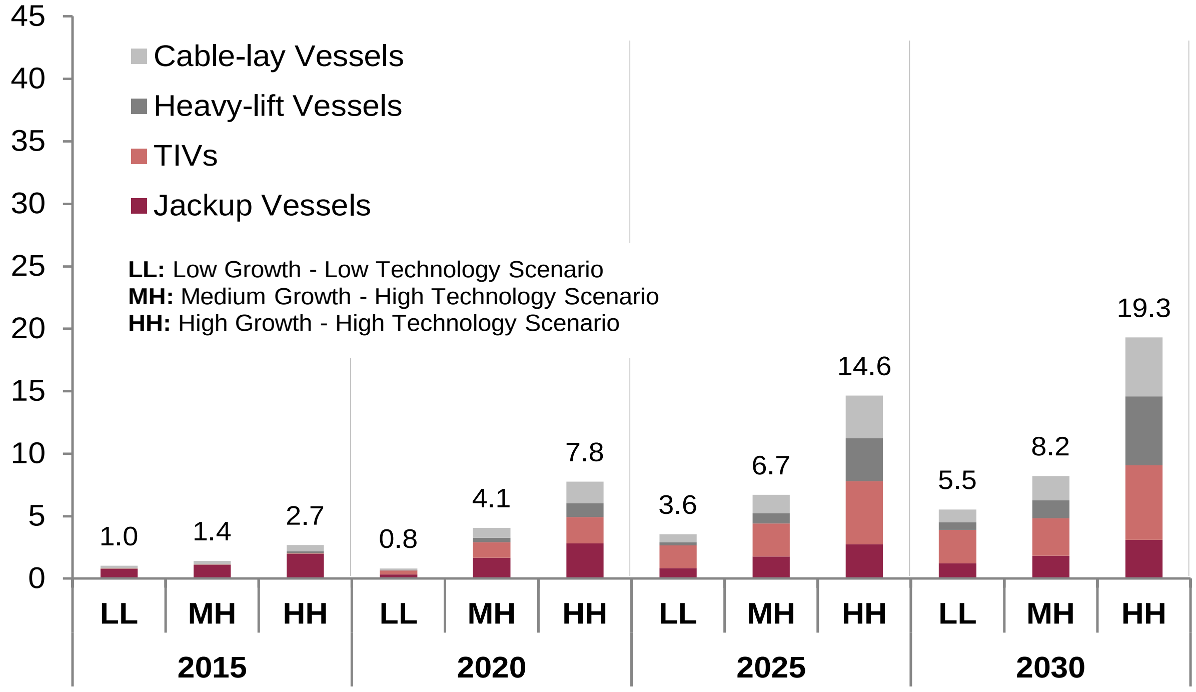
Annual Installation Rate in Each Scenario – US Total

Some practical and economic constraints of vessel deployment (e.g. the Jones Act) were analyzed in detail

Feeder Barge Transporting Turbine Components

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Suitable shipyards for US-flagged vessel construction were identified and a comprehensive list of current and planned installation vessels was provided in the report



Annual Construction Vessel Requirements in the US

Completed gap analysis by vessel type and various installation strategies. Together, rollout scenarios and vessel strategies determine vessel needs.

US Offshore Wind Development Scorecard
Vessel-Related Aspects

		Pre-Construction Phase			Construction Phase								Post-Construction Phase	
		Survey Vessel Availability			Construction Vessel Availability				Support Vessel Availability				O&M Vessel Availability	
		Environmental Survey Vessels	Geophysical Survey Vessels	Geotechnical Survey Vessels	Installation Vessels	Heavy Lift Vessels	Cable Lay Barges (near-shore)	Cable Lay Vessels (open ocean)	Tugs	Feeder Barges / Jackup Barges	Generic Barges / Offshore Supply Vessels	Personnel Transfer Vessels	Heavy Maintenance Vessels	Personnel Transfer Vessels
2013	**Atlantic Coast**	Green	Green	Green	Yellow	Yellow	Red	Orange	Green	Red	Green	Yellow	Yellow	Yellow
	Great Lakes	Green	Green	Green	Red	Red	Red	Orange	Green	Red	Green	Yellow	Red	Yellow
	Gulf Coast	Green	Green	Green	Yellow	Green	Red	Orange	Green	Red	Green	Yellow	Yellow	Yellow
	Pacific Coast	Green	Green	Green	Red	Yellow	Red	Orange	Green	Red	Green	Yellow	Red	Yellow

Legend		
	Red	No vessels available meeting Jones Act requirements
	Orange	Vessels in short supply, but available on global market
	Yellow	Work around with existing vessels feasible
	Green	Vessels readily available

Funding, Accomplishments, and Progress

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Total DOE Budget: $300,000 **Total Cost-Share: $0**

- Completed and published final report
- Conducted series of outreach events
- Conducted follow-on project with New Jersey Department of Transportation

Funding was sufficient to ensure the successful completion of the project

Project Plan & Schedule

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Summary	
WBS Number or Agreement Number	
Project Number	
Agreement Number	

Legend	
	Work completed
	Active Task
	Milestones & Deliverables (Original Plan)
	Milestones & Deliverables (Actual)

Task / Event	FY2012				FY2013				FY2014			
	Q1 (Octt-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Octt-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Octt-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Project Name: Wind Energy Forecasting Methods and Validation for Tall Turbine Resource Assessment												
Finalizing Modeling Effort												
Completion of Final Draft												
Incorporating Modifications and Submission of Final Report												
Current work and future research												

Comments

Project start date: Jan 31, 2012

Planned completion date: Dec 31, 2012 / Actual completion date: Sept 30, 2013

Explanation for slip in schedule: multiple rounds of feedback and peer review, modification requests related to the content of the report and other project work at Douglas Westwood occasionally hindered the completion of the final report

Research Integration & Collaboration

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Partners, Subcontractors:

Clean Energy Group (Warren Leon, Mark Sinclair)
Knud E. Hansen (Douglas Frongillo)
US Offshore Wind Collaborative (Fara Courtney)
Great Lakes Commission, (John Hummer)

Collaborators:

NREL (Ben Maples, Aaron Smith)

Communications and Technology Transfer:

- Presented early findings at two conferences in Chicago and Atlanta
- Hosted and presented preliminary findings on three webinars
- Presented findings at two outreach events in Maine and Delaware
- Presented findings at an AWEA offshore wind conference in Virginia Beach in October 2012
- Published final report on DOE Website (link)
- Published article in DOE's Wind Program Newsletter (link)

Next Steps and Future Research

FY14/Current research: None

Proposed future research: More detailed state and regional level infrastructure and policy analysis.