U.S. DEPARTMENT OF ENERGY

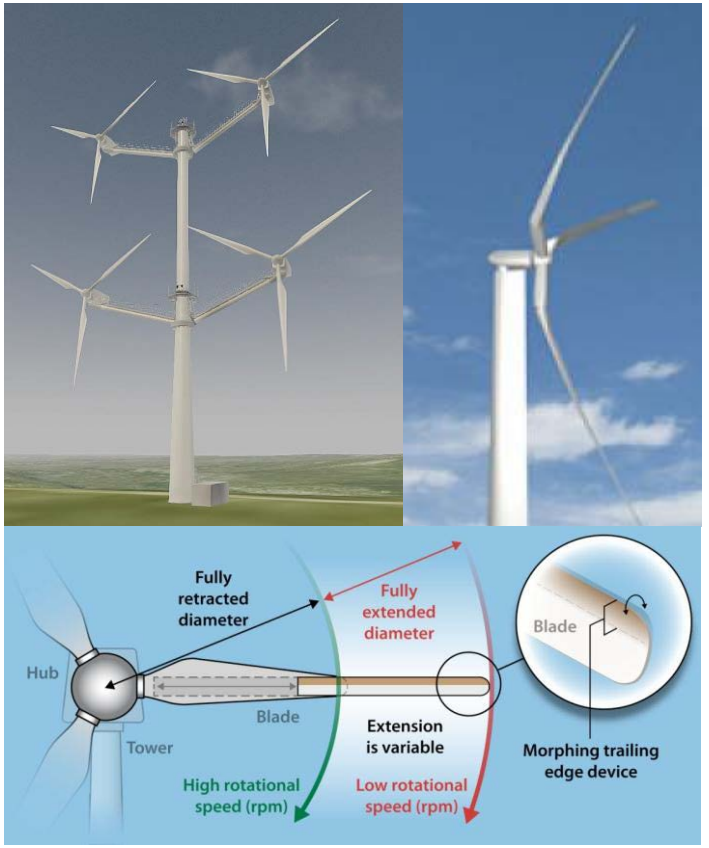
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Big Adaptive Rotor

Project ID #T17

Josh Paquette

Sandia National Laboratories



FY17-FY18 Wind Office Project Organization

"Enabling Wind Energy Options Nationwide"

Technology Development	Market Acceleration & Deployment
Atmosphere to Electrons	Stakeholder Engagement, Workforce Development, and Human Use Considerations
Offshore Wind	Environmental Research
Distributed Wind	Grid Integration
Testing Infrastructure	Regulatory and Siting
Standards Support and International Engagement	
Advanced Components, Reliability, and Manufacturing	

Analysis and Modeling (cross-cutting)

Project Overview

T17: Big Adaptive Rotor (BAR)

Project Summary

- Identify enabling technology for the next generation of high capacity factor wind turbine rotors
- Investigate value of low specific power turbines
- Evaluate all innovative rotor technologies
- Understand logistics challenges for large on-shore blades

Project Objective & Impact

- Design 5MW turbine with 206m rotor
- 65% capacity factor in Class III, low wind speed site
- Impact:
  - Enable high capacity factor wind rotors to maintain grid resilience in high renewable penetration future
  - Open up large areas of the U.S. for potential wind development
  - Reduce all-inclusive LCOE for wind
  - Pushes turbine innovations towards commercialization

Project Attributes

Project Principal Investigator(s)

Josh Paquette, SNL
Nick Johnson, NREL
Ryan Wiser, LBNL
Dominic Lee, ORNL

DOE Lead

Mike Robinson
Lillie Ghobrial
Ben Murray

Project Partners/Subs

Project Partners
- SNL
- NREL
- LBNL
- ORNL

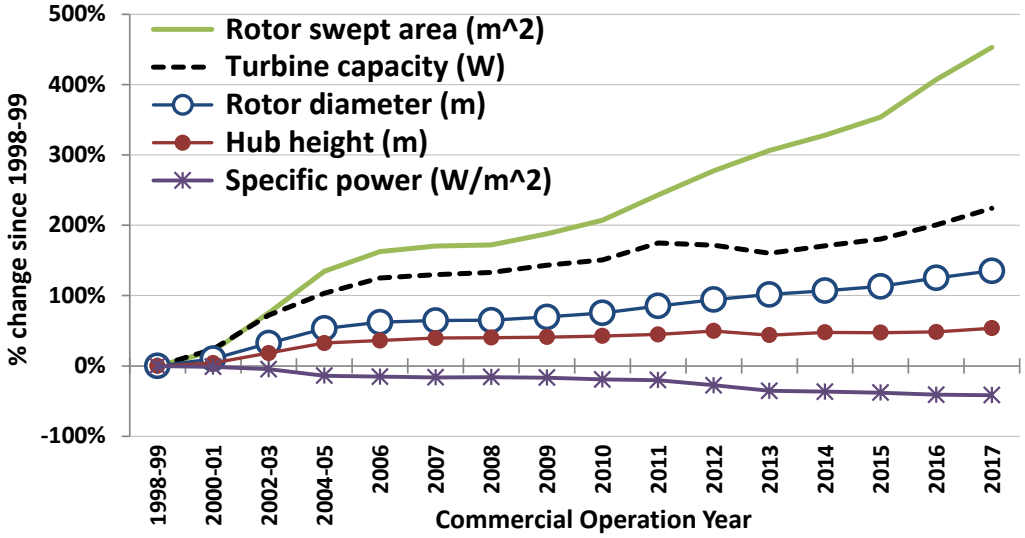
Sub-Contractors
DNV/GL, MAKE/Wood Mackenzie

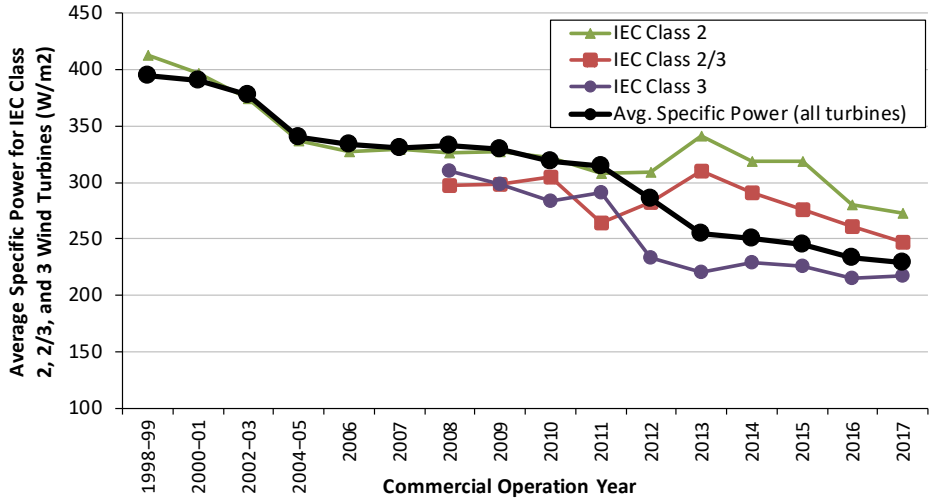
Project Duration

March 2018 – June 2021

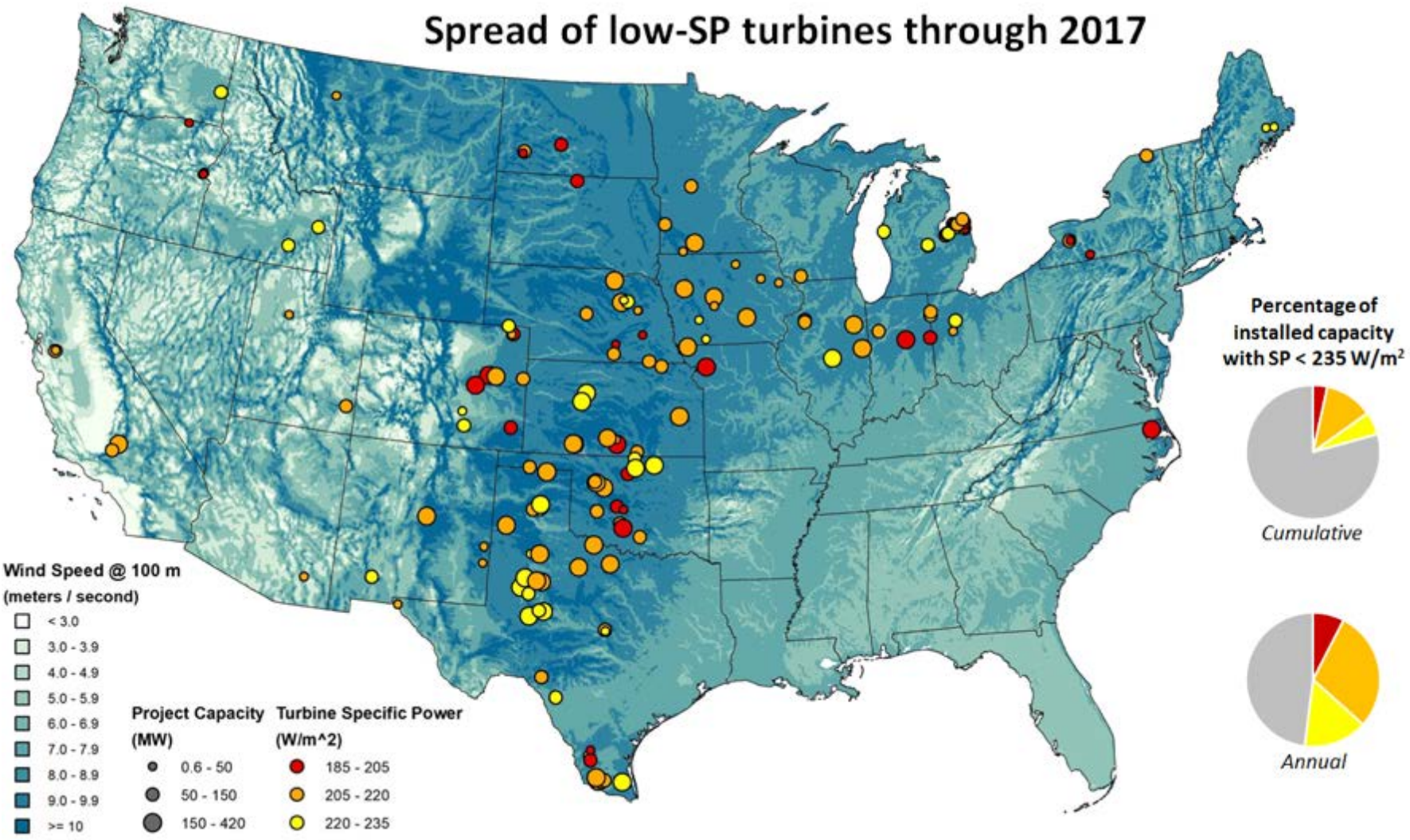
Technical Merit and Relevance

- **Rotors have and continue to grow faster than the turbine**
- **Resulting in:**
  - Lower specific power (power/swept-area)
  - Higher capacity factors
  - Reduction in wind turbine LCOE
  - Lower uncertainty in production
  - Larger area for development
- **Further Potential**
  - Enable the future renewable-heavy grid

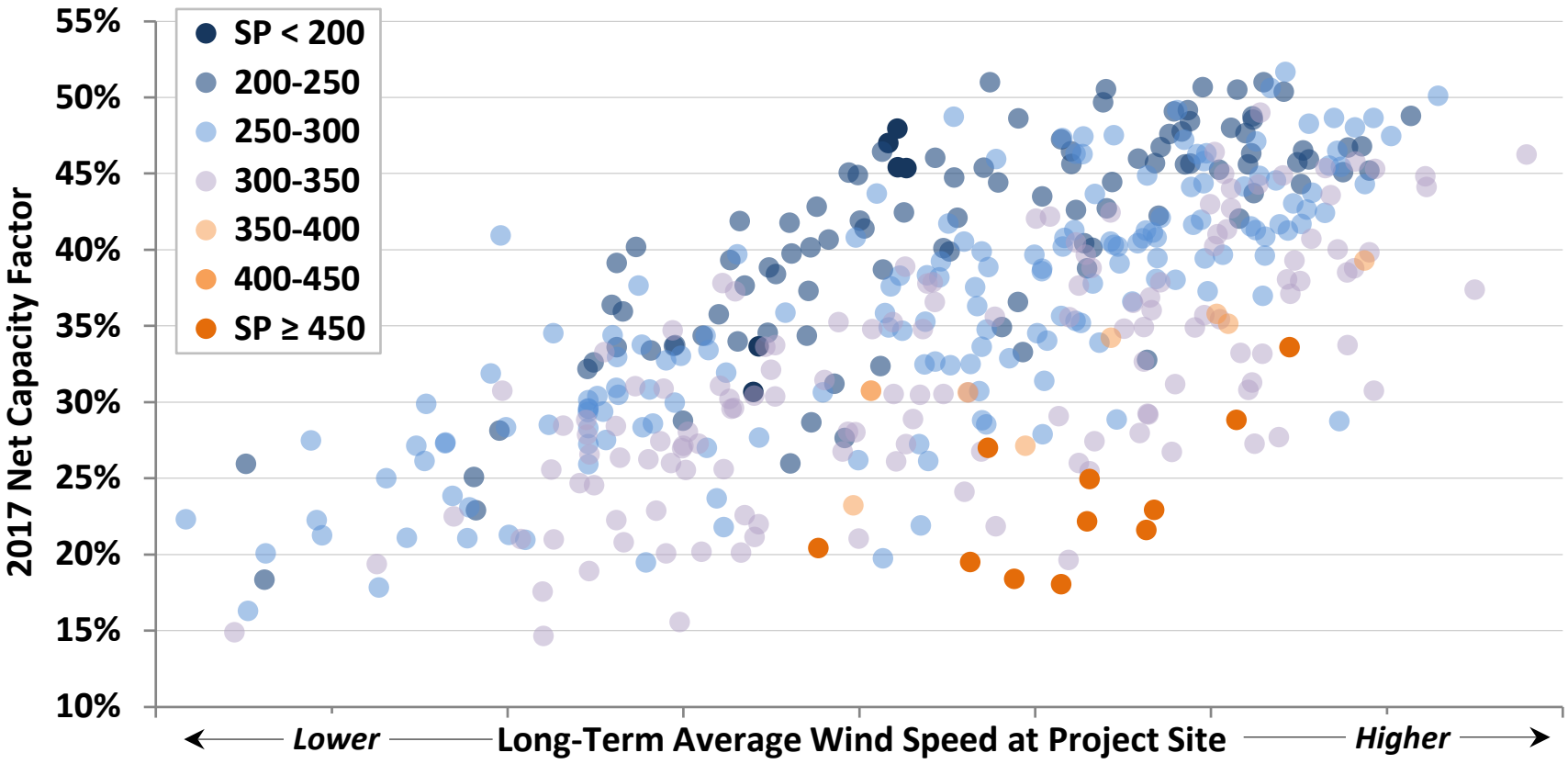




Technical Merit and Relevance



Technical Merit and Relevance



Main driver of low-SP turbines: Higher capacity factors

Technical Merit and Relevance

- Turbine blades are getting longer and longer
- Transportation constraints are being reached for rail and trucking
- Continued cost pressure facing the industry; e.g. PTC phase out, natural gas prices
- Innovative technologies are needed to meet the logistical and cost demands

BAR offers solutions to achieve LCOE parity with conventional technology

Source: Dacotrans with Goldhofer FTV

Approach and Methodology

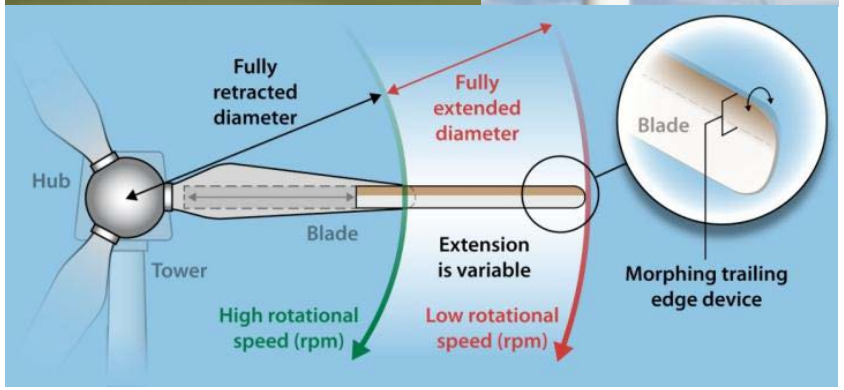
- Task 1: Trends, Impacts, and Value Analysis
- Task 2: Concept Screening
- Task 3: Logistics Challenges
- Task 4: Detailed LCOE analysis
- Task 5: Wind-Optimized Carbon Fiber

Approach and Methodology: Trends/Impacts/Value Analysis

- **Compiled data and conduct analysis on the historical U.S. deployment trends/impacts of low-SP turbines**
- **Assess the impacts of achieving BAR targets**
  - Wind Plant Performance
  - Cost
  - Market Value
  - Electric Sector Benefits
- **Identified markets for low SP turbines through geospatial analysis**
- **Analyzed breakeven costs for BAR baseline turbines**
- **Inform BAR R&D targets**
- **Prioritize specific technology and R&D pathways**

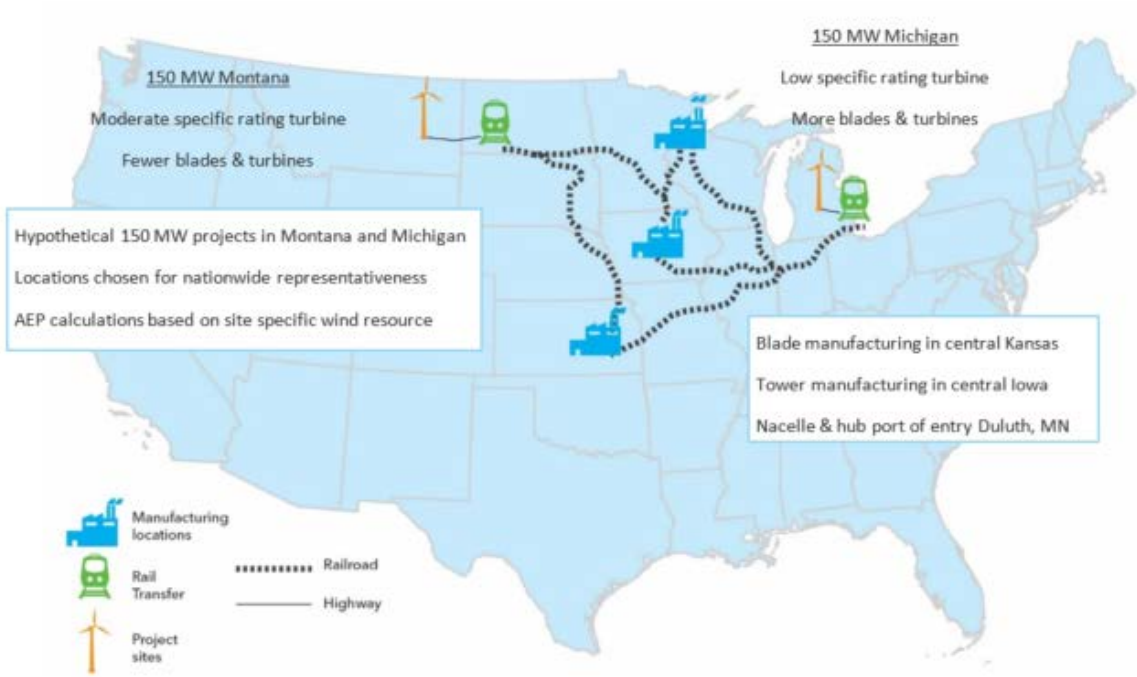
Approach and Methodology: Concept Screening

- Developed large catalogue of innovation concepts
- Qualitative techno-economic assessments concepts selection
- Expert elicitation through workshop and advisory panel
- Identified the science and engineering challenges
- Down-selected/prioritize concepts



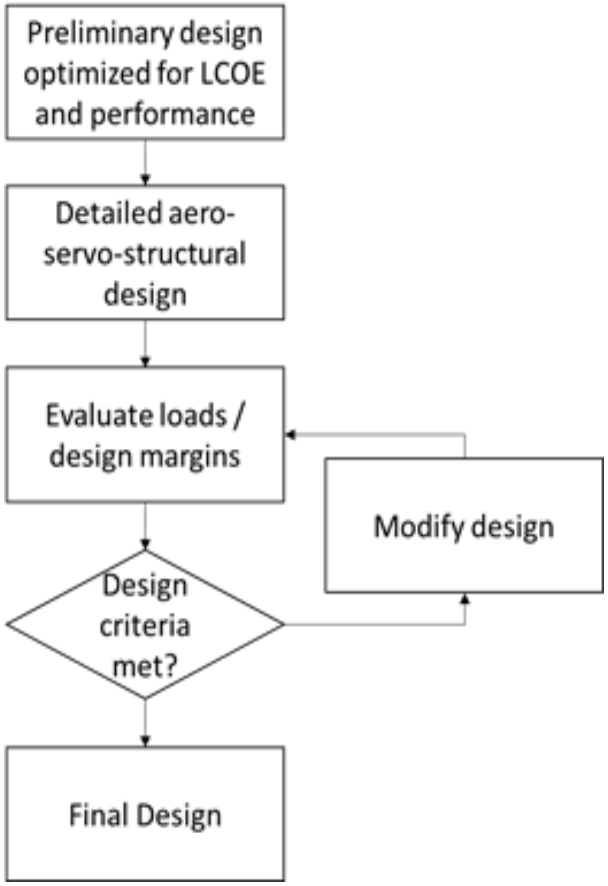
Approach and Methodology: Large Blade Logistics

- **Evaluated conventional off-site manufacturing and transport of large rotor blades**
- **Assessed alternative options**
  - On-site manufacturing
  - Segmentation
  - Alternative Transportation (Airships)
  - Flexible blades
- **Identify most promising opportunities and specific areas where DOE R&D can have high impact**



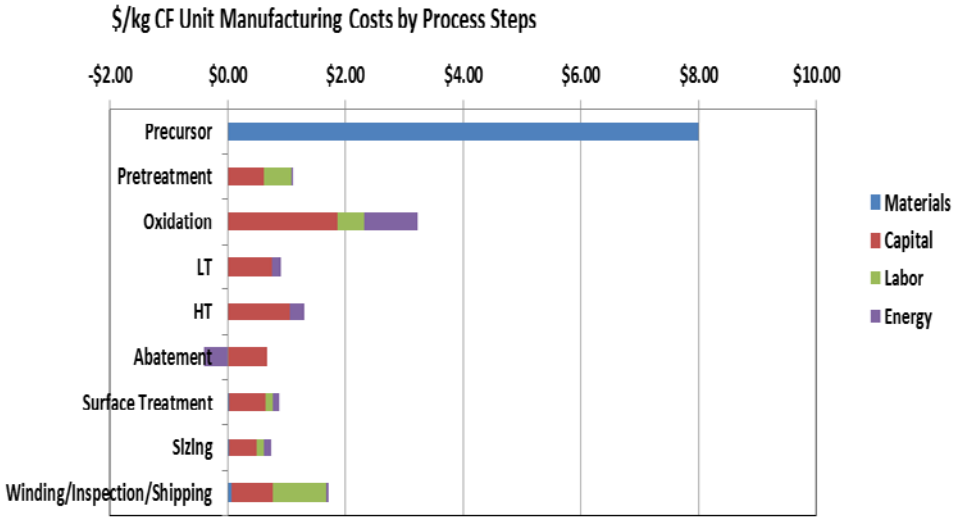
Approach and Methodology: Detailed LCOE Analysis

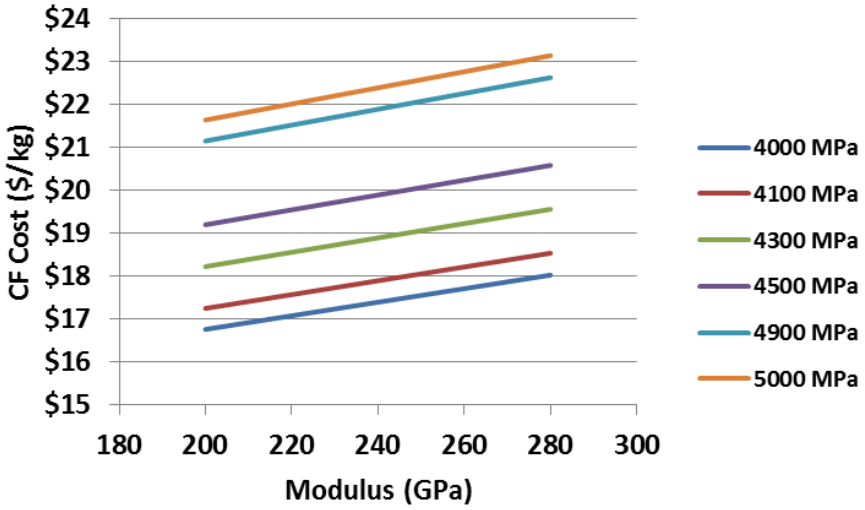
- Address science and engineering challenges
- Update/modify/create analysis codes for BAR concepts
- Develop detailed blade designs of the down-selected BAR innovation concepts
  - Analysis with WISDEM, NuMAD, OpenFAST
- Identify critical technology areas in need of further development
- Propose component-level development and testing



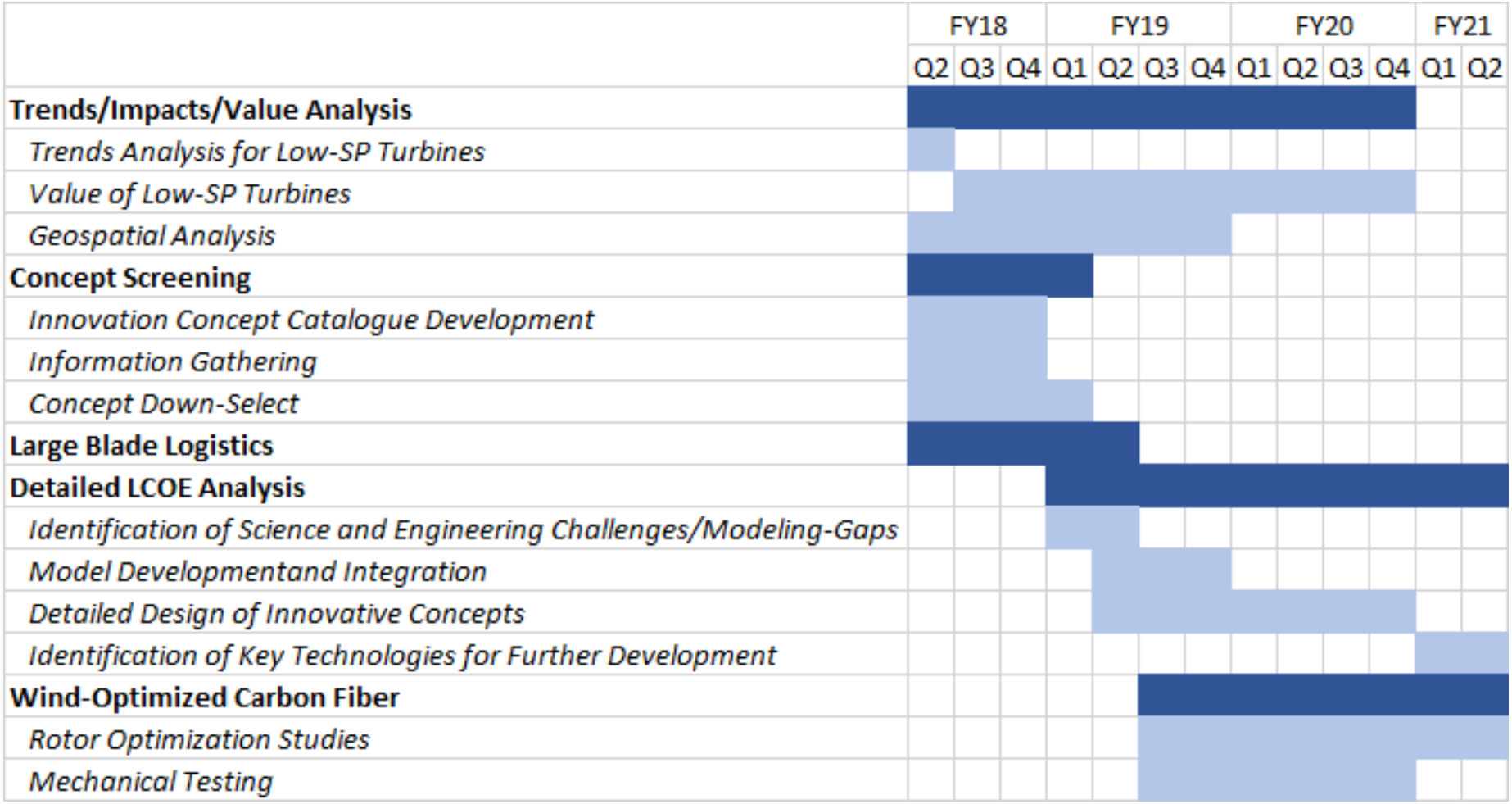
Approach and Methodology: Wind-Optimized Carbon Fiber

- Identify optimal materials material properties/cost
- Mechanical testing of commercial and novel carbon fiber materials
- Cost optimization studies to assess the commercial viability
- Assess the impact of optimized carbon fiber in various applications of a blade design

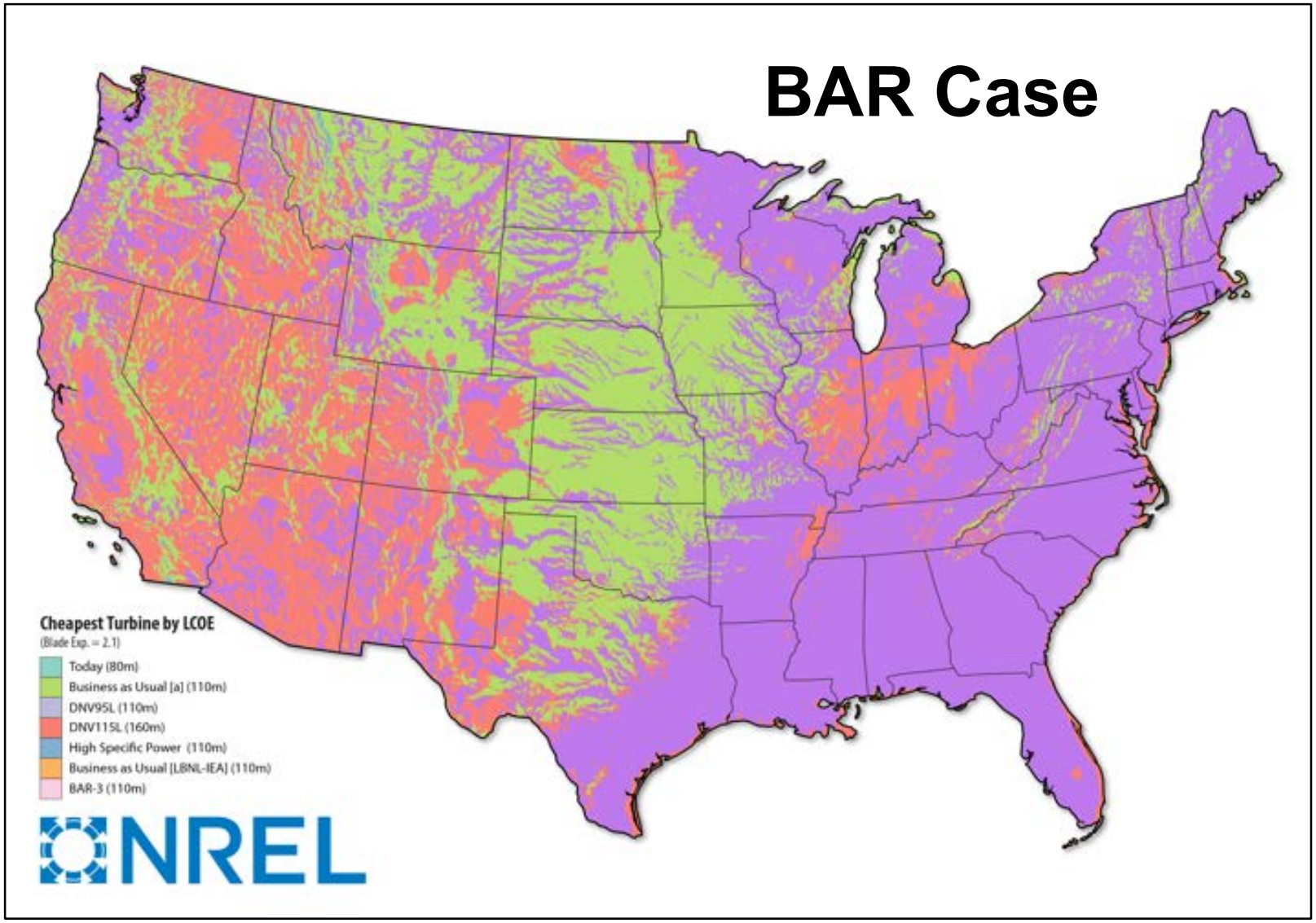




Accomplishments and Progress



Accomplishments and Progress: Trends/Impacts/Value



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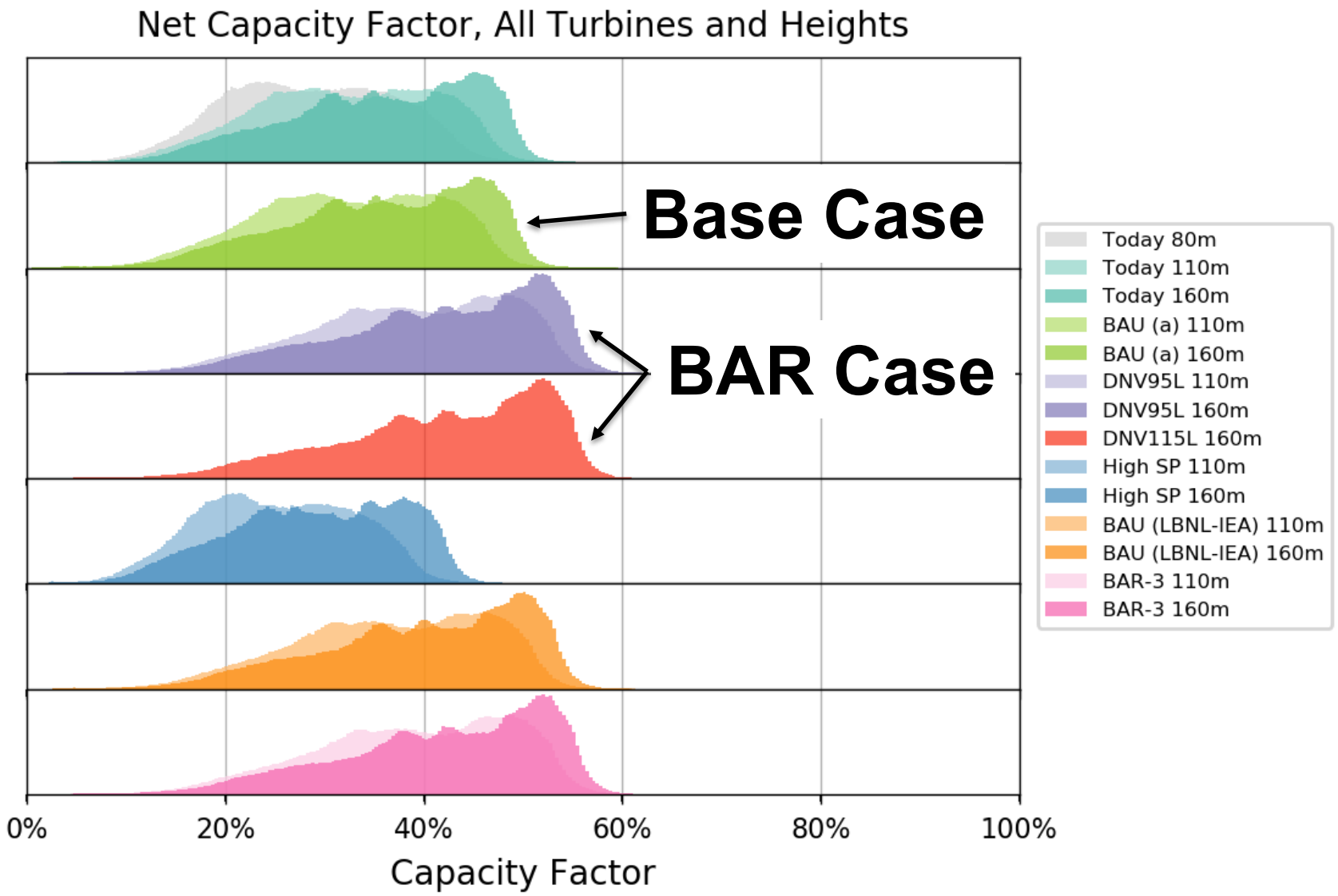
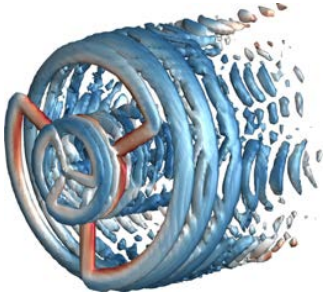
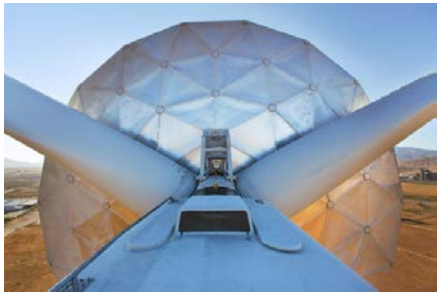
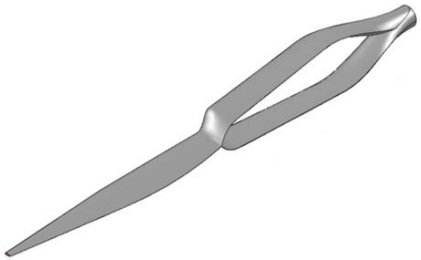


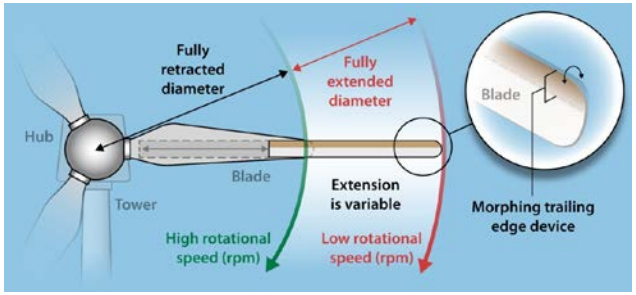
Accomplishments and Progress: Concept Screening

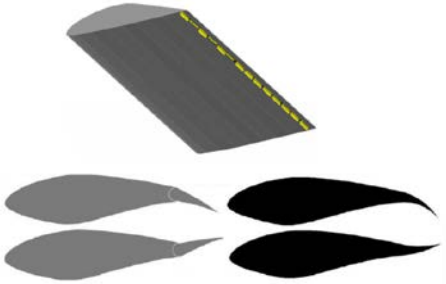
- Innovation Catalogue

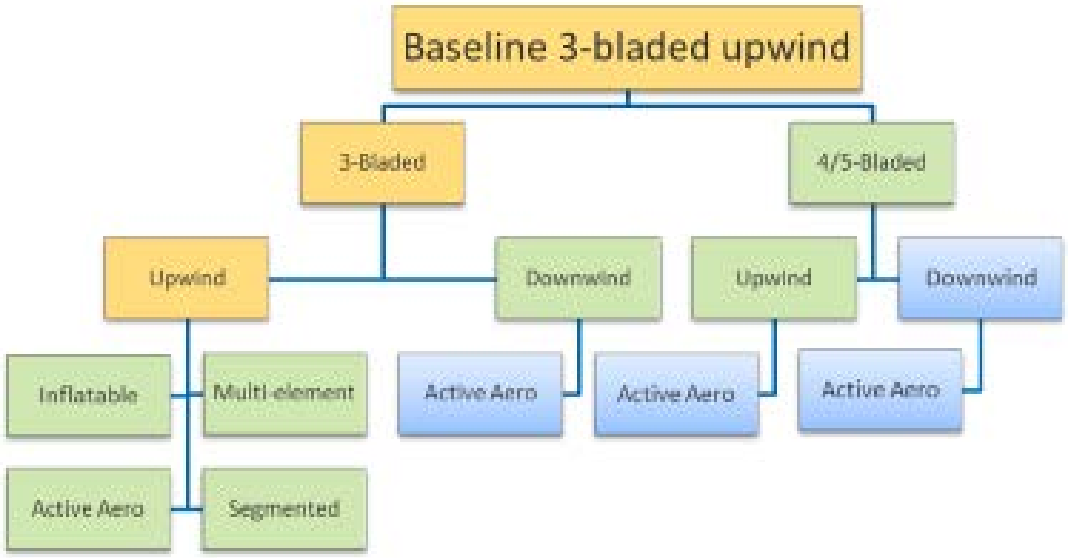



Accomplishments and Progress: Concept Screening

Qualitative Assessment of

- LCOE Impact
- Science & Engineering Challenges

Concept categories are used to define first and second phases of project study



- Baseline: 3-bladed upwind
- First Phase: One perturbation away from Control (3-Bladed Upwind) where it addresses S&E challenges
- Second Phase: Combining First Phase concepts where it addresses S&E challenges

Controls

Accomplishments and Progress: Large Blade Logistics

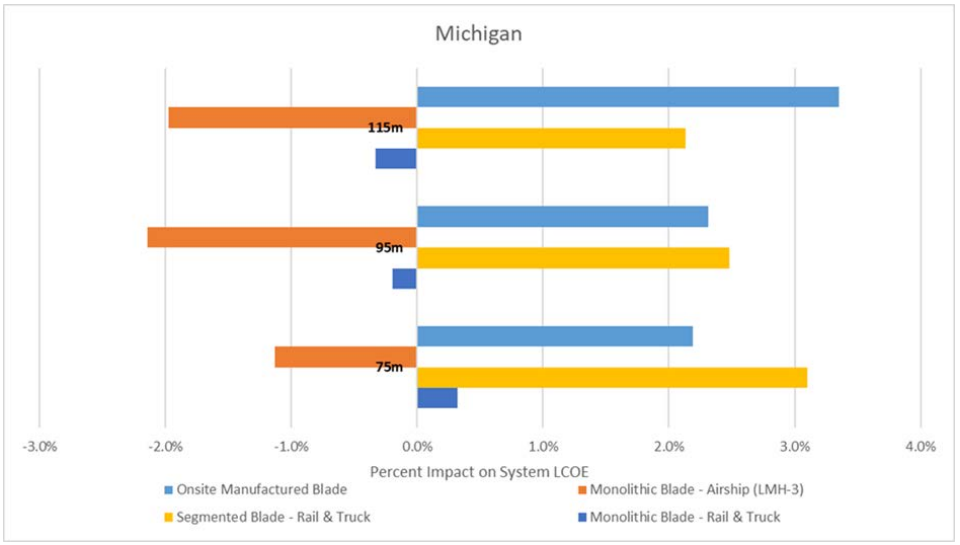
DNV·GL

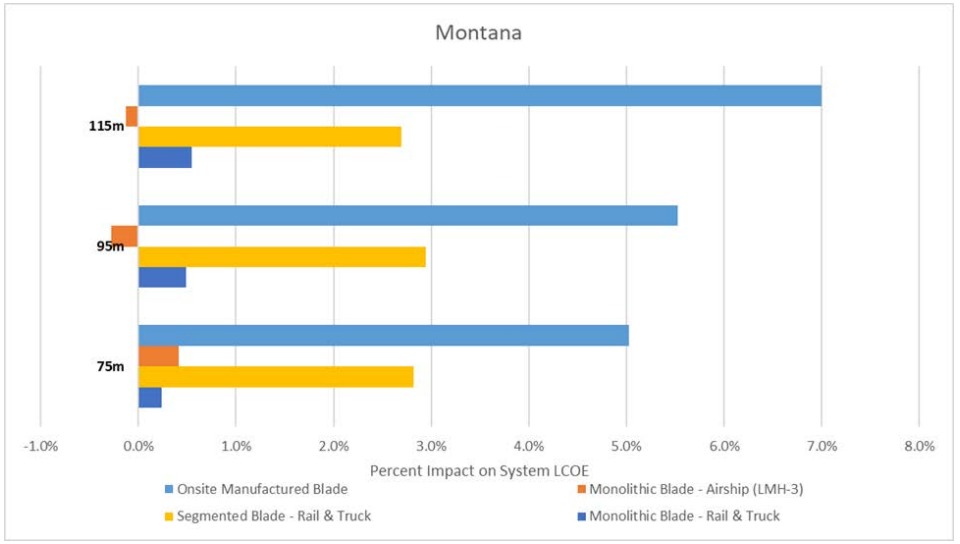
SUPERSIZED WIND TURBINE BLADE STUDY

R&D Pathways for Supersized Wind Turbine Blades

Lawrence Berkeley National Laboratory

Document No.: 10080081-HOU-R-01
Issue: D, **Status:** FINAL
Date: 07 March 2019





Communication, Coordination, and Commercialization

- **Journal Publications (Anticipated)**
  - Wind Energy
  - Renewable Energy
- **Presentations (Upcoming)**
  - AWEA WindPower
  - Wind Energy Science Conference
  - Science of Making Torque from Wind
  - NAWEA
- **Workshops:**
  - Pathways to Success for Supersized Wind Turbine Blades (March 2018)
  - BAR Workshop (August 2018)
- **Industry/Lab Coordination**
  - Advisory board of prominent, international academic and industrial participants
  - Close coordination with an external advisory board of international experts in rotor design, manufacturing, transportation and operation.

Upcoming Project Activities

- Analyze wholesale energy and capacity value of lower-SP vs. higher-SP turbines
- Assessment of grid integration and transmission implications
- Additional analysis on the value and impacts of low-SP turbines
- Baseline model development/analysis
- Code updates
- Analysis and detailed technical design of BAR concepts using design-level models.
- Sensitivity study of carbon fiber material properties versus cost