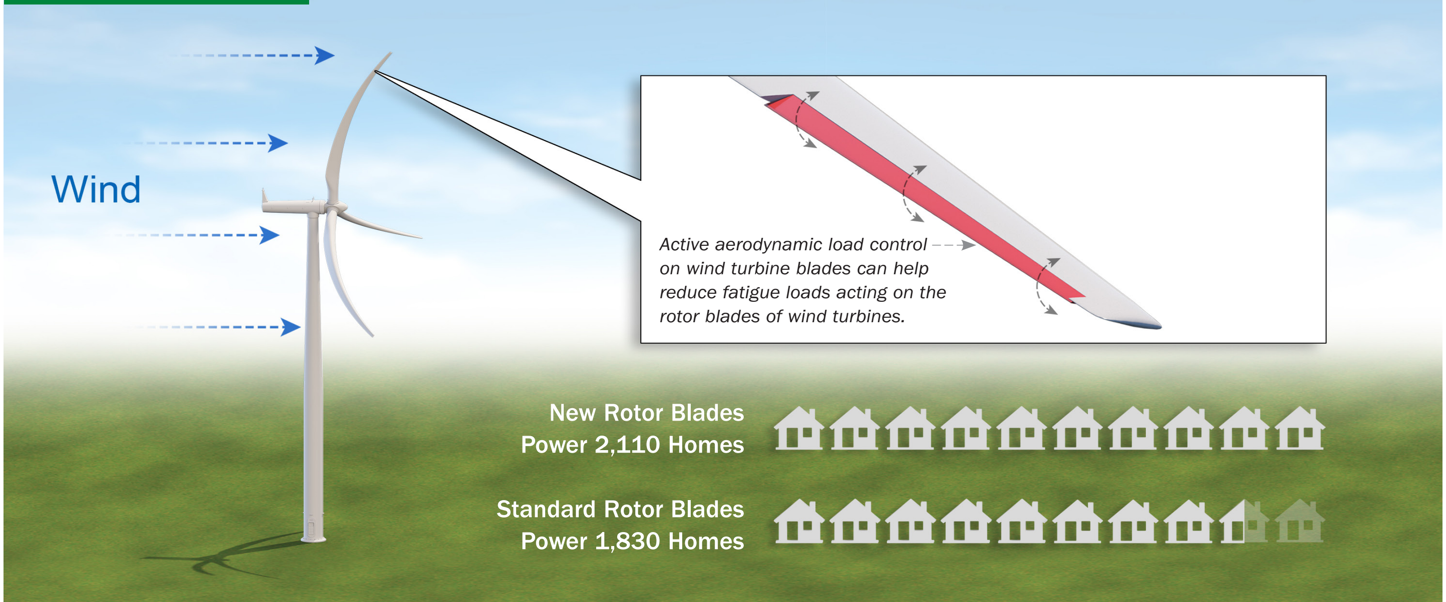
U.S. DEPARTMENT OF ENERGY
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Flexing the Limits of Land-Based Wind Turbine Rotor Growth



Larger wind turbine rotors can increase capacity factors, or the amount of power a turbine outputs on average over the course of a year. Assuming two turbines of the same height—one standard wind turbine with a capacity factor of 0.45 verses another high-energy-capture machine with downwind, highly-flexible blades and a capacity factor of .5175 (a 15% increase)—the high-energy-capture machine can power roughly 280 more homes. *Illustration by Besiki Kazaishvili, NREL*

Slender, Flexible Blades Enable High-Energy-Capture Wind Turbines by Resolving Transportation Challenges

The Big Adaptive Rotor (BAR) project works to design and enable the next generation of land-based wind turbines with rotors that stretch 206 meters (m) in diameter, which will increase capacity factors by 10% or more over a typical land-based turbine. These high-energy-capture turbines have lower specific-power ratings, meaning they have larger rotors relative to the size of their generator, which helps them capture more wind and perform better at lower wind speeds, thereby increasing the turbine capacity factor.

High-energy-capture turbines with larger rotors have many advantages, but the length and width of their blades creates transportation challenges that must be overcome to make true on the adage, bigger is better.

Building a Better (Highly Flexible) Blade:

Greater swept area: A greater swept area helps capture more wind energy and access higher wind speeds at elevated heights.

Increased capacity factors: Increasing the rotor size while maintaining the nameplate generation size—the intended sustained energy output of a turbine at peak performance—can increase the amount of time the turbine operates at rated power. In some circumstances, higher capacity factors may increase the value of wind energy to the electricity system. In this way, these machines complement other renewable energy sources like solar by providing electric power when energy use is high and solar resource availability is low—during twilight and nighttime hours.

Expanded wind energy development and more efficient production: Turbines with low-specific-power ratings can expand wind energy development into new areas like the southeastern United States by allowing plant operators to tap into lower-speed wind areas at a competitive price.

Fewer transportation constraints: Slender, flexible blades can navigate curves in rail lines that conventional blades cannot. The ability to deliver a single-piece, 100-m blade to site by rail likely represents the lowest cost and most reliable option for blades of that size.

Transportation Challenges Inspire Elastic Thinking

The logistics associated with supersized blades create transportation challenges that need to be overcome. The wind industry currently segments blades to overcome transportation challenges, but this can introduce blade reliability issues and adds additional weight to the blade, resulting in higher turbine loads and capital expenditures. When left whole, large blades have difficulty accommodating the bends and shifts of the railway on their journey to a wind plant.

Moving to the Railway Rhythm

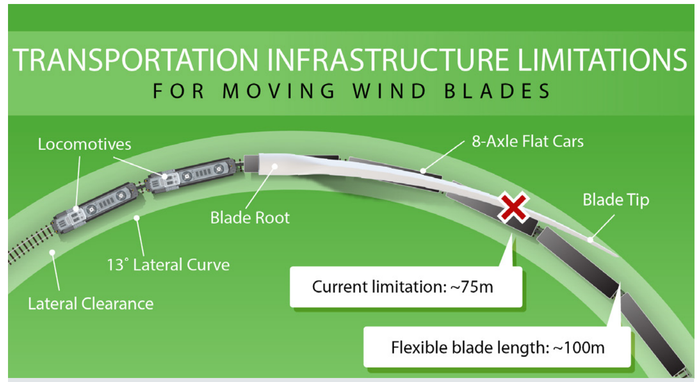
Highly flexible blades help resolve transportation and reliability challenges associated with moving 100-m wind turbine blades by rail. Namely these blades can bend during transport, moving with the twists, turns, and rhythms of the railway system.

Since highly flexible blades are intentionally less stiff they can be designed with slender airfoils which generally have a higher lift-to-drag ratio than thicker airfoils, resulting in more efficient energy capture.

Solutions Emerge from Engineering Challenges

While highly flexible wind turbine blades offer benefits, they also introduce new engineering challenges that need to be considered.

Because wind plant owner-operators look for greater revenue from improved power reduction, high-energy-capture machines will continue growing in popularity because they can produce more electricity over more hours, providing dispatchable power when it is needed most. By resolving challenges introduced by highly flexible turbine blades, BAR researchers help make the giant land-based wind turbines of tomorrow possible today.



High-energy-capture machines with highly flexible blades open many more parts of the United States to wind development by solving logistical and science challenges associated with these machines.

Project Partners

BAR is funded by the U.S. Department of Energy's (DOE's) Wind Energy Technologies Office and involves collaborative work between the National Renewable Energy Laboratory, Sandia National Laboratories, Oak Ridge National Laboratory, and Lawrence Berkeley National Laboratory.

Summary of Challenges and Solutions

	Challenges	Solutions
Transportation and Logistics	• Maximum chord (width) constraint of 4.75 m • Navigating horizontal and vertical curvatures • Segmented blades require mechanical fasteners and onsite assembly.	• Constrain the dimensions of the blade to fit within the transportation envelope • Make single-piece, 100-m blades flexible enough to navigate 13° horizontal curves.
Loads and Deflections	• Greater physical loads impact turbine reliability • Slow pitch rates (the rate at which wind turbines adjust their blade angle relative to the wind to keep rotor speeds within operating limits) for large blades increase turbine system loading.	• Downwind configuration to allow for additional deflections • Active aerodynamics to control loads • Lidar based feed-forward controls to predict extreme loading cases • New, low-cost carbon fiber production methods.

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For more information, visit: energy.gov/eere/wind

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