Over the past decade, the U.S. wind energy industry has achieved significant improvements in energy production and cost efficiency driven in part by increased turbine, blade, and tower size. However, the industry is fast approaching a logistical cost and capability ceiling as turbine components become too large for existing U.S. infrastructure and transportation options to accommodate.

Lawrence Berkeley National Laboratory retained DNV GL to study the key challenges associated with manufacturing and deploying next generation, increasingly larger, land-based wind turbine blades. The study considers three innovation pathways to identify unique, high-value research and development (R&D) activities that the U.S. Department of Energy could undertake to enable the use of “supersized” blades. The study extends current technologies beyond their trajectories to seek insights into areas where R&D could accelerate technology shifts. However, the study did not identify truly disruptive innovations or paradigm-shifting science, nor did it intend to select a “best” or “preferred” innovation pathway.

The following innovation pathways were used to identify potential R&D opportunities:

- **Innovative transportation**: New methods or technology to address physical constraint challenges and facilitate transport of blades from factories to a wind project via road, rail, or air. This includes rail and truck transportation of blades through controlled bending, or air transportation via heavy-lift cargo airships.

- **Segmented blades**: Utilizing segmented or modular blades to enable use of more cost-effective transportation while limiting impacts on blade design, manufacturing, and on-site assembly.

- **On-site manufacturing**: Development of temporary or short-term factories near wind turbine projects so that long-haul transportation from a factory is no longer necessary.
Acceleration of R&D and closer collaboration between U.S. researchers, turbine manufacturers, blade manufacturers, and transportation logistics companies are required to address the challenges of supersized blades. Blades are the most critical component in determining the technical and economic performance of wind turbines. The logistics associated with supersized blades adds additional levels of complexity into the process which the industry and researchers must now work collaboratively to address. The good news is that there appears to be fertile ground for R&D and accessible solutions on the near horizon.

Based on the study, industry insight, and familiarity with national laboratory capabilities, DNV GL identified a number of R&D topics that could make valuable contributions to the viable development of supersized blades. These recommendations are feeding into the DOE-funded multi-year, multi-Lab “Big Adaptive Rotor” project that seeks to assess and prioritize needed technology to develop a cost-competitive land-based 5 MW turbine with long, 100+ meter blades.

With supersized blades, transportation costs are a key variable when considering cost impacts for wind project development. The study analyzed the impact that any R&D opportunities would have on levelized cost of energy (LCOE) to determine which ones were the most viable. Potential high-value R&D areas include:

- Further advances in high-stiffness/low-cost materials like industrial carbon fiber and thermoplastics materials. Advances in materials available for blade fabrication would have significant benefits to all the possible pathways and takes advantage of a U.S. DOE core competence.

- Advanced controls / sensor technologies that could be applied to monitor and enable blade bending in transport or monitor and control segmented blade loads so that lower-weight blades are possible.

- Reducing the blade chord dimension to enable operation at higher tip seeds and improve transport potential; however, issues related to aeroacoustics and leading-edge erosion will need to be improved.

- Advanced aeroelastic modeling into dynamic stability and deflections to enable the development of more slender blades that can result in narrower blade shape and controlled deflection during transport.

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