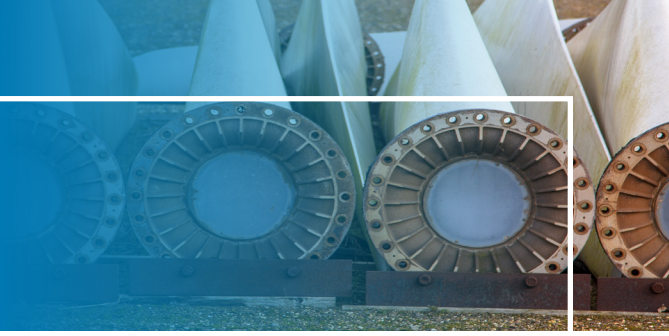
Wind

Wind Turbine Disposal and Recycling Strategies



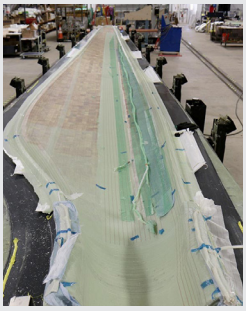
The wind industry is working to help advance sustainable disposal solutions through advanced recycling and repurposing methods while minimizing waste—maximizing the environmental benefits of wind energy.

Key Takeaways

1. **Wind turbines are engineered for longevity,** reducing the need for replacement and minimizing waste.
2. Approximately 80-94% of a wind turbine's mass—including materials like steel, aluminum, and copper—is **readily recyclable.**
3. New recycling approaches **support a circular economy**, like converting turbine materials into raw fuel for cement production.
4. When landfilling is necessary, turbine materials are **among the least harmful wastes in terms of environmental impact.**

Background

Wind energy plays an important role in creating a cleaner, healthier environment. It decreases smog-creating air pollution, reduces energy sector greenhouse gas pollution, and saves billions of gallons of water annually. Studies show a typical wind turbine repays its carbon footprint within six months.



Wind turbines are made up of many materials that have substantial salvage value at the end of its operational life and are recyclable. In fact, 80-94% of a wind turbine's mass consists of easily recycled materials, such as steel / iron (approximately 88% of a turbine's mass), aluminum (approximately 0.7%), and copper (approximately 2.7%).[2,3,4]

Other wind turbine components such as blades, nacelle covers and rotor covers are made of up composite materials, mostly fiberglass and carbon fiber, which, while non-toxic and safe, are more difficult to process for other purposes. However, these components make up roughly only 8% of a wind turbine's total mass.[5] In addition, as described more below, the wind energy industry and other partners are expanding options to recycle and reuse even these historically tougher to process materials.

While wind energy projects are expected to operate for 20 to 35 years, individual wind turbine components like rotor blades and covers may need upgrading or replacing sooner because of normal wear from exposure to the elements, or improvements in technology.

Reduce

Reducing the need to replace components by extending the lifetime of existing blades is one of the most economically and environmentally friendly measures wind developers take to limit the number that need to be disposed of through reuse, recycling or landfilling. While the blades are very durable, decades of exposure to the elements can slowly chip away at their efficiency. Blade repair and monitoring technology is rapidly improving, allowing the industry to use fewer and fewer blades to produce the same amount of clean, zero-carbon electricity. General improvements in turbine technology are also leading to greater electricity generation per turbine, adding to these blade efficiency improvements. Improvements to wind resource assessment and modelling allow manufacturers to better understand the loads on blades, leading to improvements in life and maintenance costs.

Reuse

The U.S. wind power industry, along with multiple stakeholder groups including scientists, researchers, national laboratories, and environmental collaborators, is developing innovative methods to re-purpose turbine blades. Intact blades are being evaluated for reuse at other wind farms to improve performance or reshaped for use as utility poles. For blades that are not suitable for such projects, partial blade reuse may include repurposing as outdoor furniture (e.g., park benches, playground equipment,[6] storage enclosures,[7] etc.) and signage.

The U.S. Department of Energy (DOE) is partnering with businesses to research practical ways to repurpose wind turbine blades. Innovative partnerships like Re-Wind[8], a collaboration between the Georgia Institute of Technology and Queen's University Belfast, are deploying design and logistical concepts in the field, such as prototyping methods to reuse the decommissioned blades in buildings, infrastructure, landscape and public art.[9]

Recycle

Today, wind turbine blades are recycled into raw material and fuel for cement production, through a partnership between GE, Veolia North America, and other companies, generating jobs and reducing the emissions of cement production.[10] Although in the past, blades and other composite materials from wind turbines have been landfilled because of limited options in recycling technology and infrastructure to process and separate the reusable materials, many original equipment manufacturers (OEMs), research institutes and universities, and the DOE's national laboratories are solving the technological challenges of turbine blade recycling. The National Renewable Energy Laboratory is advancing recycling technologies by developing new materials (e.g., thermoplastic resin) that can be used to manufacture fully recyclable blades by making it easier to separate the layers and recapture the materials.[11] OEMs are also pledging zero waste by deploying recyclable blades within the next decade, creating a circular economy of use.[12]

Many OEMs have announced partnerships with companies to recycle blades by turning blade components into raw materials for use in cement manufacturing, other new composite materials, or reclaiming the glass and carbon fibers that can then reused.[13,14] Academic institutions like the University of Tennessee, funded with a grant from the DOE, are developing methods to turn blades into recycled composites for vehicles, other renewable energy system components, agricultural products, and performance sports equipment.[15]

Blade Landfill Disposal

Even if landfilled, wind turbine components are made from safe, non-toxic inert materials that do not represent a threat to the surrounding soil or groundwater. Further, turbine blades represent a vanishingly small portion of the waste going into U.S. landfills and are among the least environmentally harmful materials entering them. Turbine blade waste through 2050 is expected to represent only approximately 0.05 to 1.6% of all the municipal solid waste going to landfills every year.[16] The Electric Power Research Institute estimates there will be 2.1 - 4 million tons of cumulative blade waste between 2020 and 2050.[17] While landfill disposal has been the most common strategy for turbine blade disposal, there is growing research and technology innovations to recycle and repurpose blade waste. However, if landfill disposal is the only option at the time a turbine is decommissioned, like many other industries, the U.S. wind industry pays a fee to dispose some material in landfills.

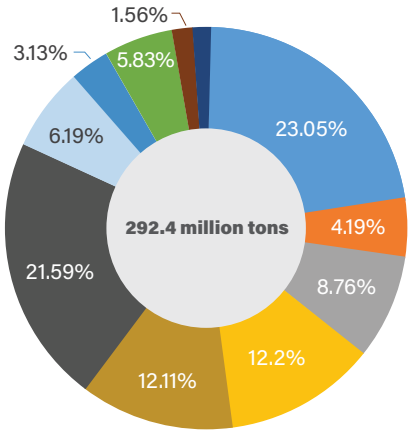
Other U.S. Waste Landfill Disposal

The Electric Power Research Institute estimates there will be 2.1 – 4 million tons of cumulative blades put in landfills between 2020 and 2050. In comparison, 292.4 million tons of municipal solid waste is generated every year on average and 146.1 million tons is landfilled.[18]

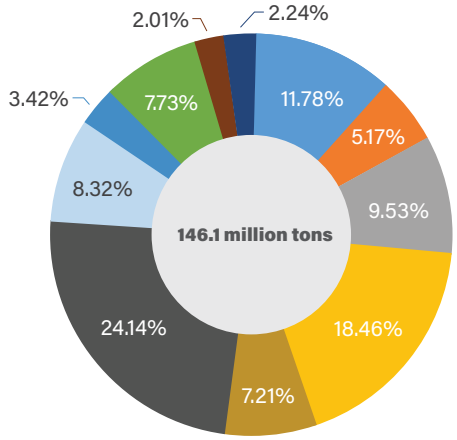
Sustainability

The range of turbine end-of-life technologies will continue to expand, given the continued focus on solutions from the industry, along with public and private organizations. The U.S. wind industry remains committed to protecting the environment by delivering carbon-free power through responsible development and sustainable solutions.

Total MSW Generated by Material, 2018



Total MSW Landfill by Material, 2018



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