# Assessing Avoided Burden by Recycling & Repurposing of Retiring Wind Turbines

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## ABSTRACT

While wind energy significantly reduces greenhouse gas emissions compared to fossil fuels, the growing challenge of wind turbine waste threatens some of these benefits. Without effective disposal and recycling strategies, decommissioned turbine waste is projected globally to reach 43 million tons by 2050. Much of the waste stream in the U.S. is currently landfilled, leading to the loss of embedded energy and potential economic value. To ensure that environmental benefits of decarbonized electricity extend beyond power generation, a circular economy approach to turbine end-of-life (EOL) management is critical. This study employs Life Cycle Assessment (LCA) analyses to evaluate the environmental impacts of different wind turbine waste management pathways.

We assess impacts for 18 categories and incorporate the avoided burden concept to account for environmental benefits gained from material recovery. Wind turbine components are categorized into three primary material groups—foundation concrete, blades, and structural steel—with concrete and steel assessed solely for recycling. Blades, composed of either glass fibre (GF) or carbon fibre (CF), are evaluated for both recycling and repurposing. Recycling methods analyzed include mechanical, chemical, and thermal processes, with additional cement co-processing considered for GF blades. Repurposing applications include transmission poles, pedestrian bridges, and park benches.

Findings indicate that, across most of the 18 impact categories assessed, recycling provides net environmental benefits, significantly reducing fine particulate matter formation, fossil resource depletion, and land use impacts compared to landfilling, which consistently results in a net burden. Among recycling options, mechanical recycling of GF blades is the most environmentally favorable when considering all impact categories, while solvolysis and pyrolysis of CF blades provide the greatest environmental benefits due to substantial avoided burden credits from virgin CF substitution. Repurposing emerges as a particularly effective strategy, retaining embedded material and energy with minimal additional processing, and yielding overall environmental savings in all 18 categories compared to landfill. Sensitivity analysis highlights the critical role of material quality in maximizing avoided burden benefits, emphasizing the need for high-quality fibre recovery and secondary applications that fully replace virgin materials.

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