

# End-of-life Options for Composite Material Wind Turbine Blades: Recover, Repurpose or Reuse?

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# Growth of installed wind power capacity worldwide

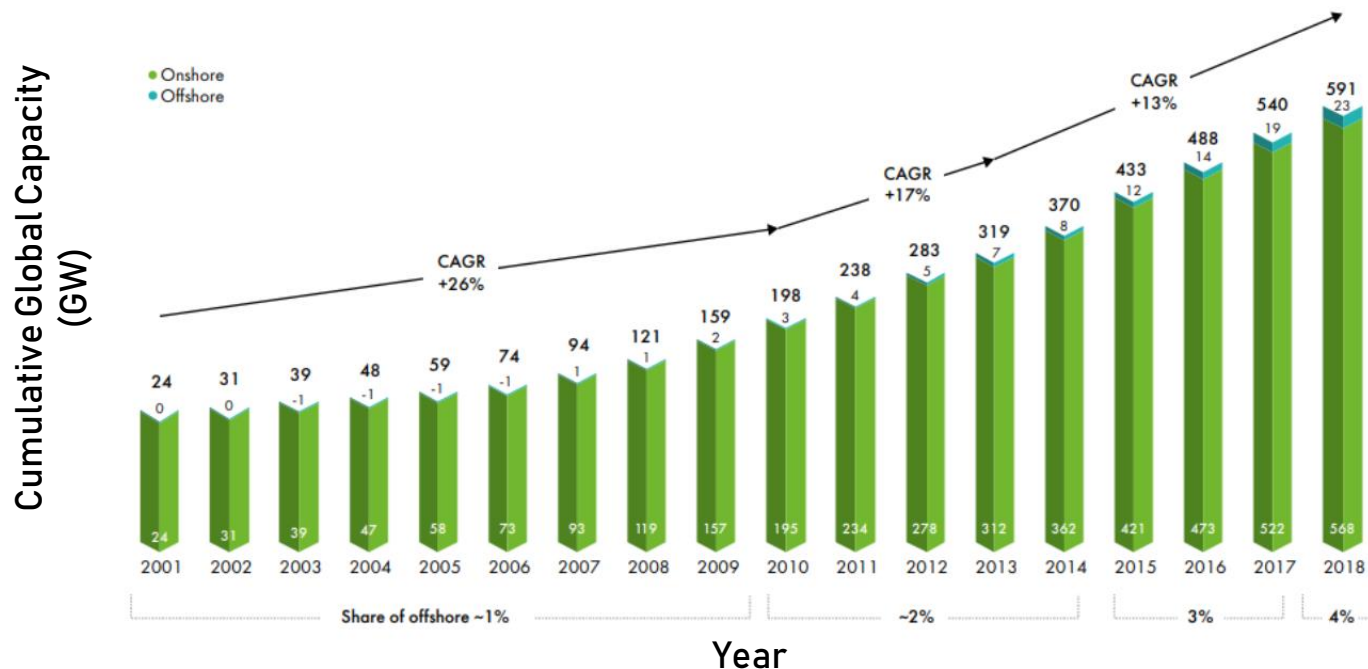


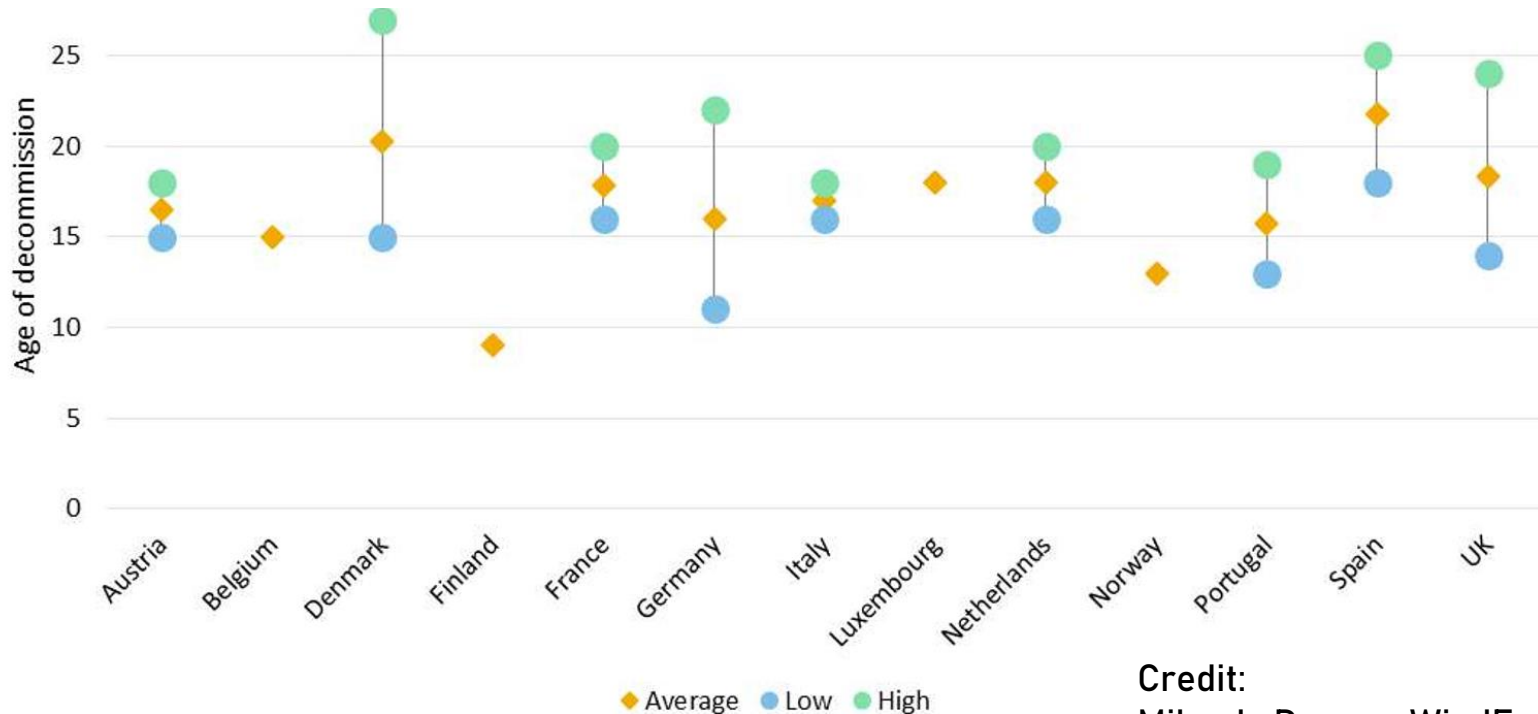
Image: GWEC

- Global installed wind power capacity grew from c. 14 GW to 159 GW in the decade 1999-2009 (3).
- In the following decade total capacity increased to c. 600 GW

# Wind farm lifetimes

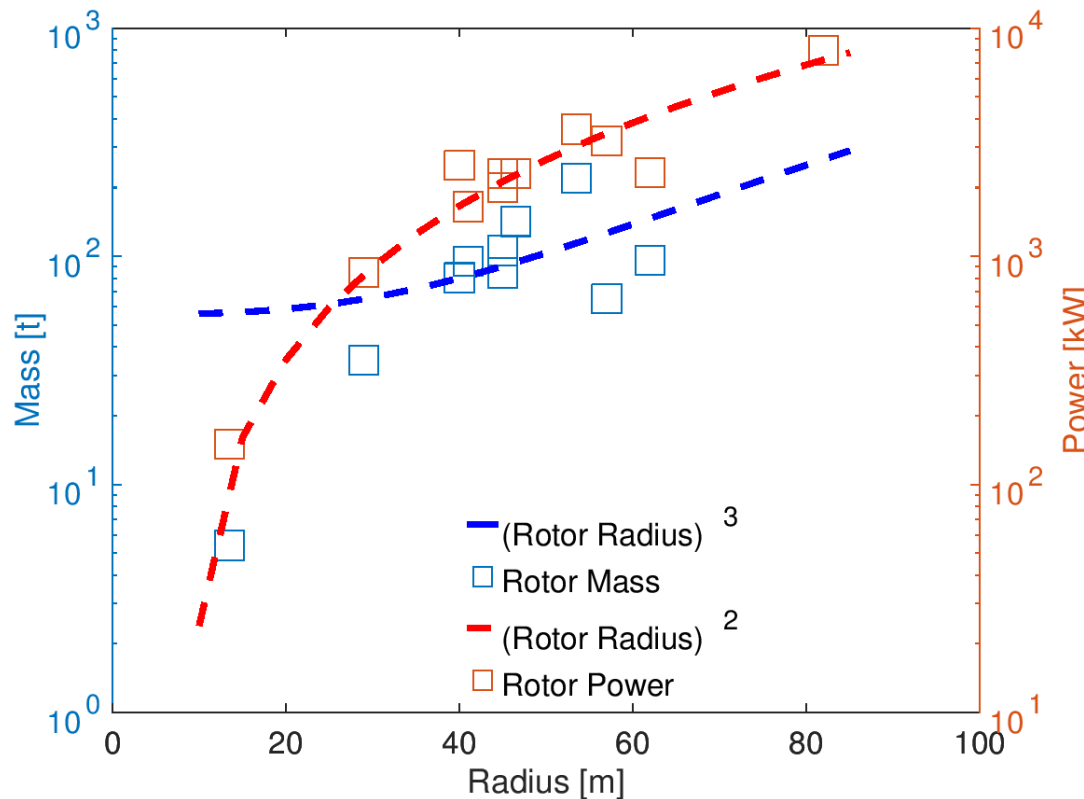
Average years to decommissioning in repowering projects

- Varies widely by project (9-27 years)
- ... and by country (Spain average 22 years; Germany 16 years)



Credit:  
Mihaela Dragan, WindEurope

# Increase in blade mass: the square-cube 'law'



Rotor power increases with square of blade length

Rotor mass increases with cube of blade length

=> Blade mass has grown faster than the rated power as turbine rotor sizes have increased

Data:  
thewindpower.net & Schubel et al.  
<http://www.mdpi.com/1996-1073/5/9/342>

# End of life blades: waste or resource?

- Wind turbine blades primarily composed of non-biodegradable GFRP composites
- Annual global blade waste is expected to reach 40 million tonnes by 2050
- Current solutions: incinerate, stockpile, landfill, grind for aggregates
- Can feasible repurposing options be found?



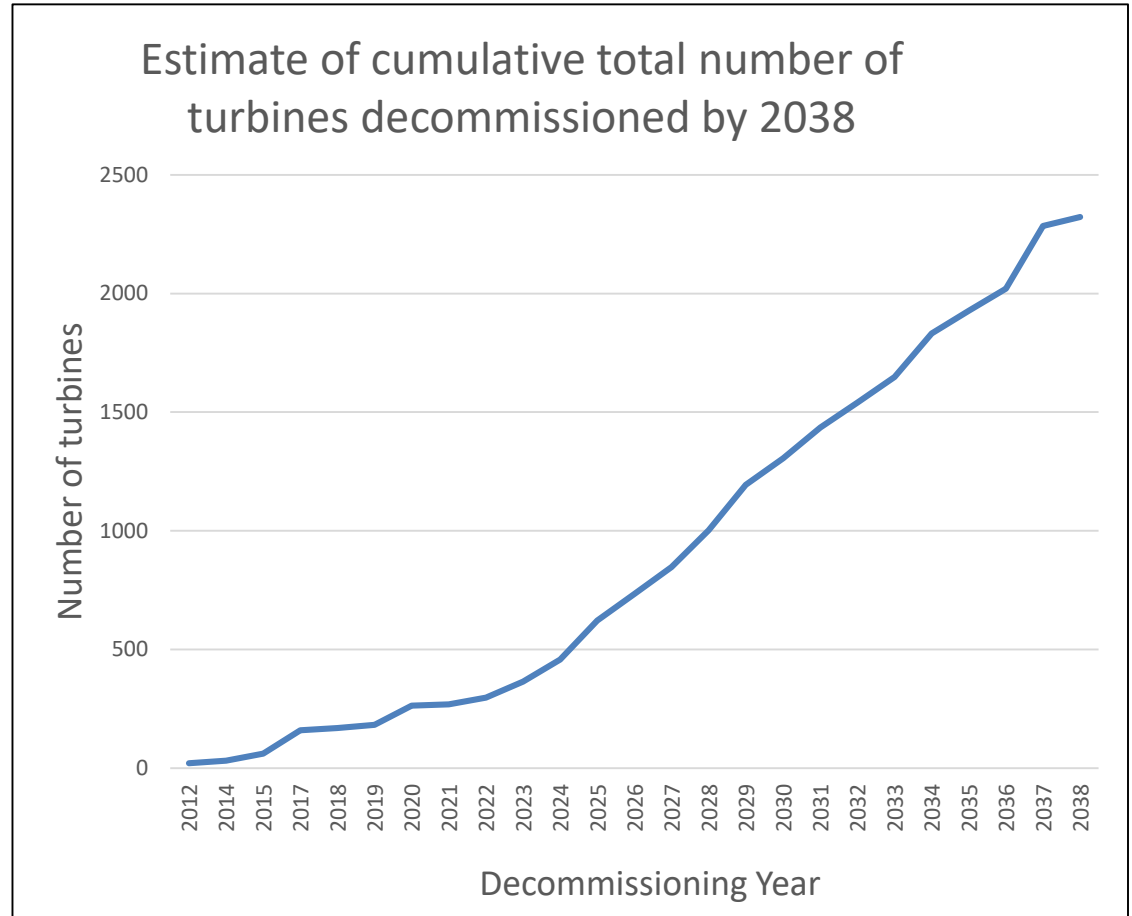
Cut GFRP composite waste  
Image: BRIO project  
Credit: Elhuyar Fundazioa

# Turbine end-of-life & the GFRP blade 'waste' issue



Approximate total number of turbines to be decommissioned in Ireland by 2038:

**2323**



Emma Delaney, QUB

# Wind farm end of life decision factors

When does a wind plant reach end of life?

- End of design life
- Expiration of planning permission
- Market reforms
- Expiration of subsidies
- Operating costs: wear, fatigue, failures, outages, repairs
- Obsolescence

What happens next?

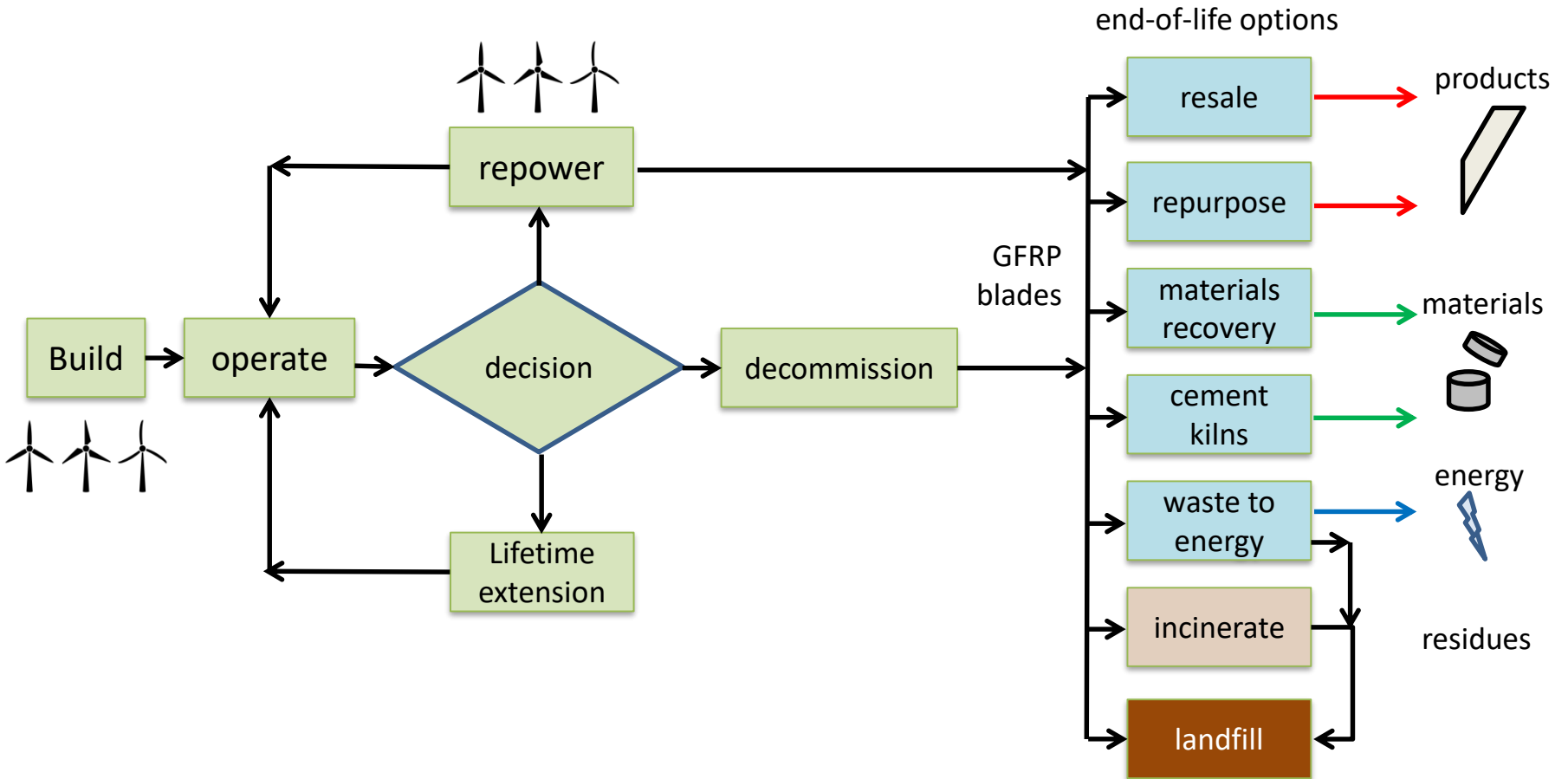
- Decommission
- Repower
- (continue operation)



Altamont Pass, USA.

Image: Noah Berger, National Geographic

# Wind farm lifecycle

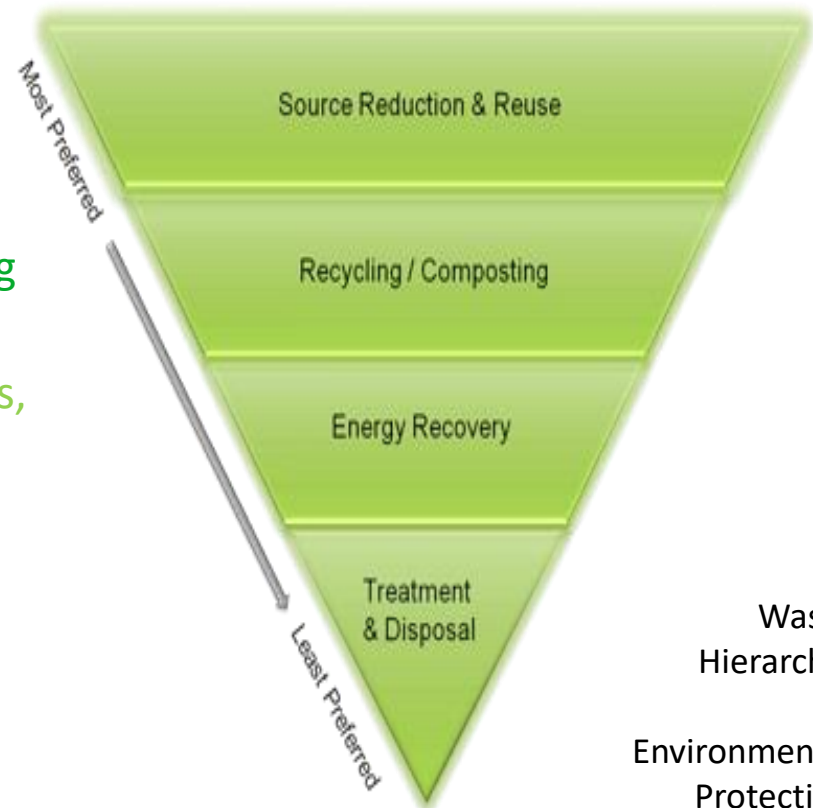




# US EPA Waste Hierarchy

## Repurposing lies near the top of the Waste Hierarchy

- **Prevent:** either extend project lifetime or sell blades on secondhand market
- ★ **Repurposing:** Remanufacturing for use in new products
- **Recycling:** Shredding, grinding and milling for filler for FRP or concrete
- **Materials Recovery:** Pyrolysis, thermolysis, solvolysis to recover polymer resins or fibers or gasses for energy
- **Co-processing in cement kilns: raw material substitution**
- **Incineration** – with or without energy recovery, then landfill ash
- **Landfilling**



Waste  
Hierarchy:  
US  
Environmental  
Protection  
Agency

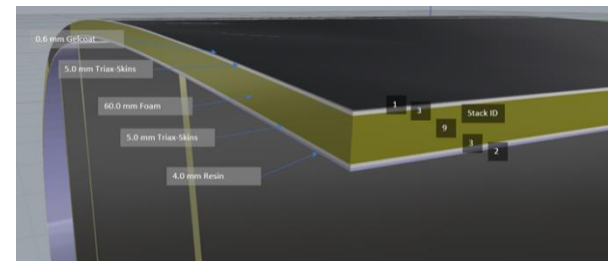
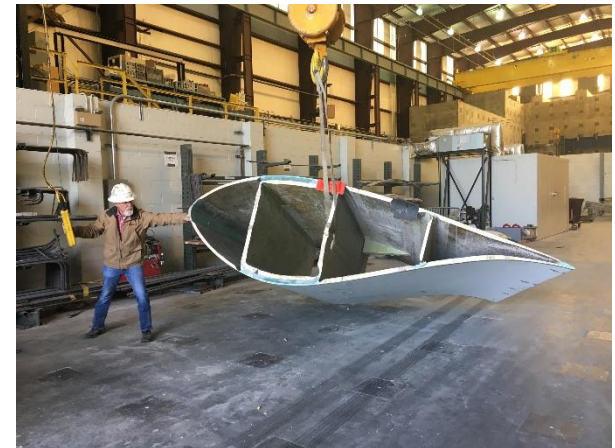
# Blade Repurposing: Methodology

More than 50 blade repurposing concepts identified initially  
Design Office exercise (Winter 2019, Belfast) will develop and  
refine three concepts

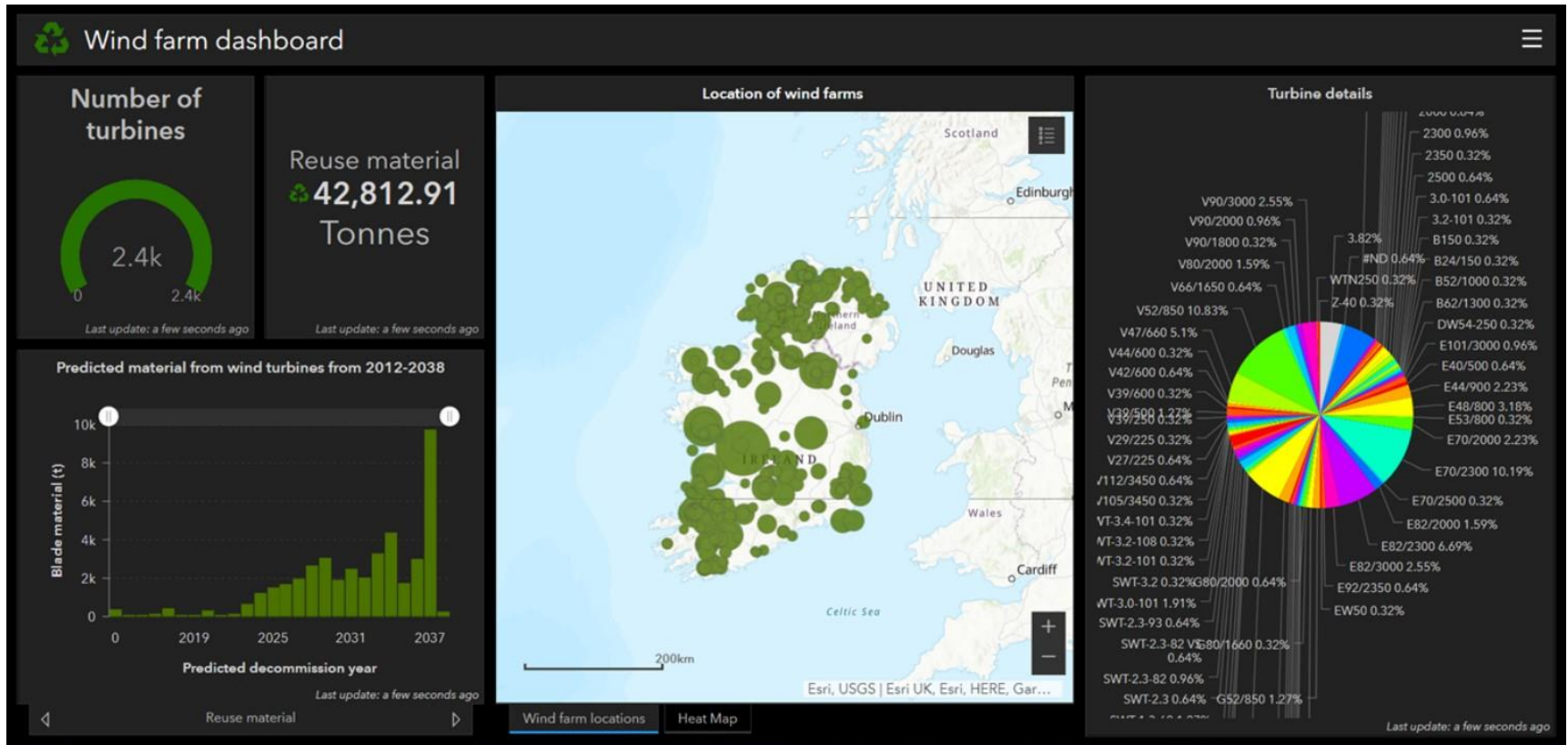
The success of reuse cases depends on technical feasibility,  
location & social, environmental and economic sustainability

A transdisciplinary approach has developed tools to assess  
all of these:

- All-Ireland blade geodatabase
- 3-D LiDAR scanning
- Blade geometry reconstruction software
- Structural analysis & testing methods
- Community engagement methodology
- Lifecycle analysis (LCA)
- Robust set of internationally-deployable success indicators : environmental, social and economic

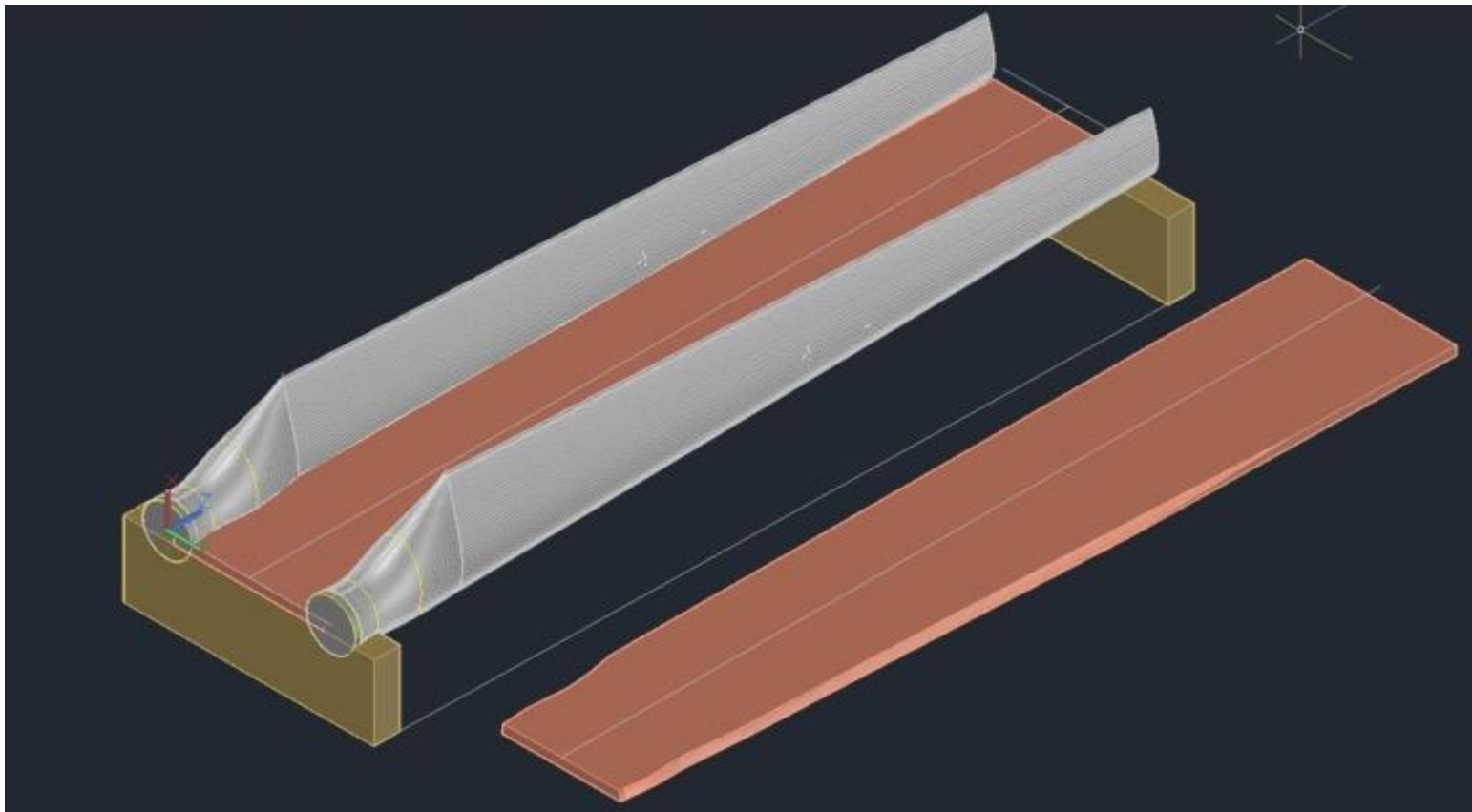


# GIS Dashboard & Database



Tool allows database to be queried by:  
location, turbine type, blade dimensions, projected decommissioning date

# Reuse case: pedestrian bridge

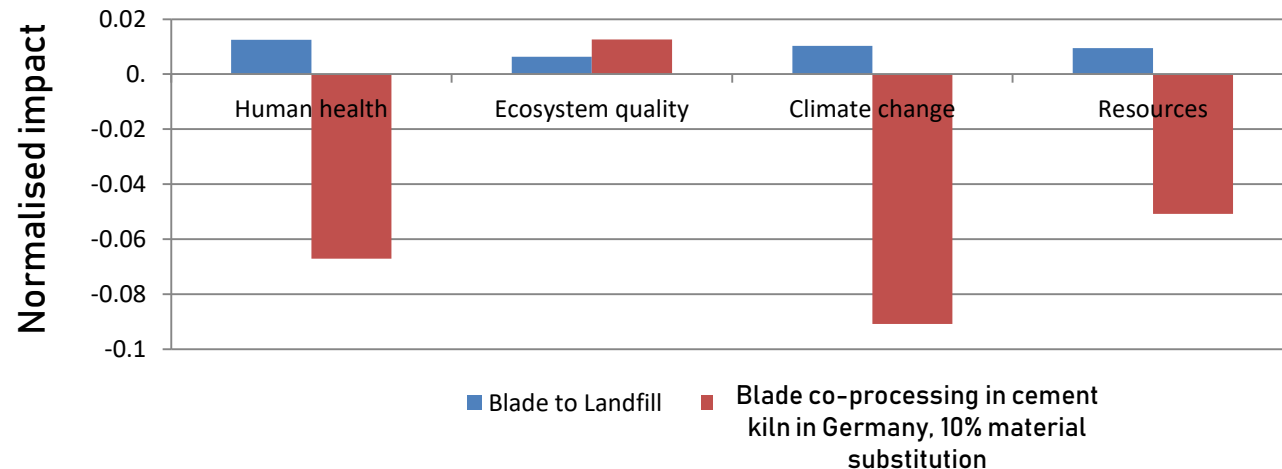


# Reuse case : emergency housing



# Environmental impacts of end-of-life options

- Life cycle assessment carried out on two 'conventional' options



- Cement kiln co-processing has far lower environmental impacts than landfill

# Thank you

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We welcome approaches from all stakeholders in GFRP wind turbine blade end-of-life and reuse

