# *Re-Wind*
# A Holistic Approach to Repurposing Decommissioned Wind Blades

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BladesUSA
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Georgia Tech | QUEEN'S UNIVERSITY BELFAST | CUNY THE CITY UNIVERSITY OF NEW YORK | UCC University College Cork, Ireland Coláiste na hOllscoile Corcaigh

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7000 LBS CAP
Triangulation.

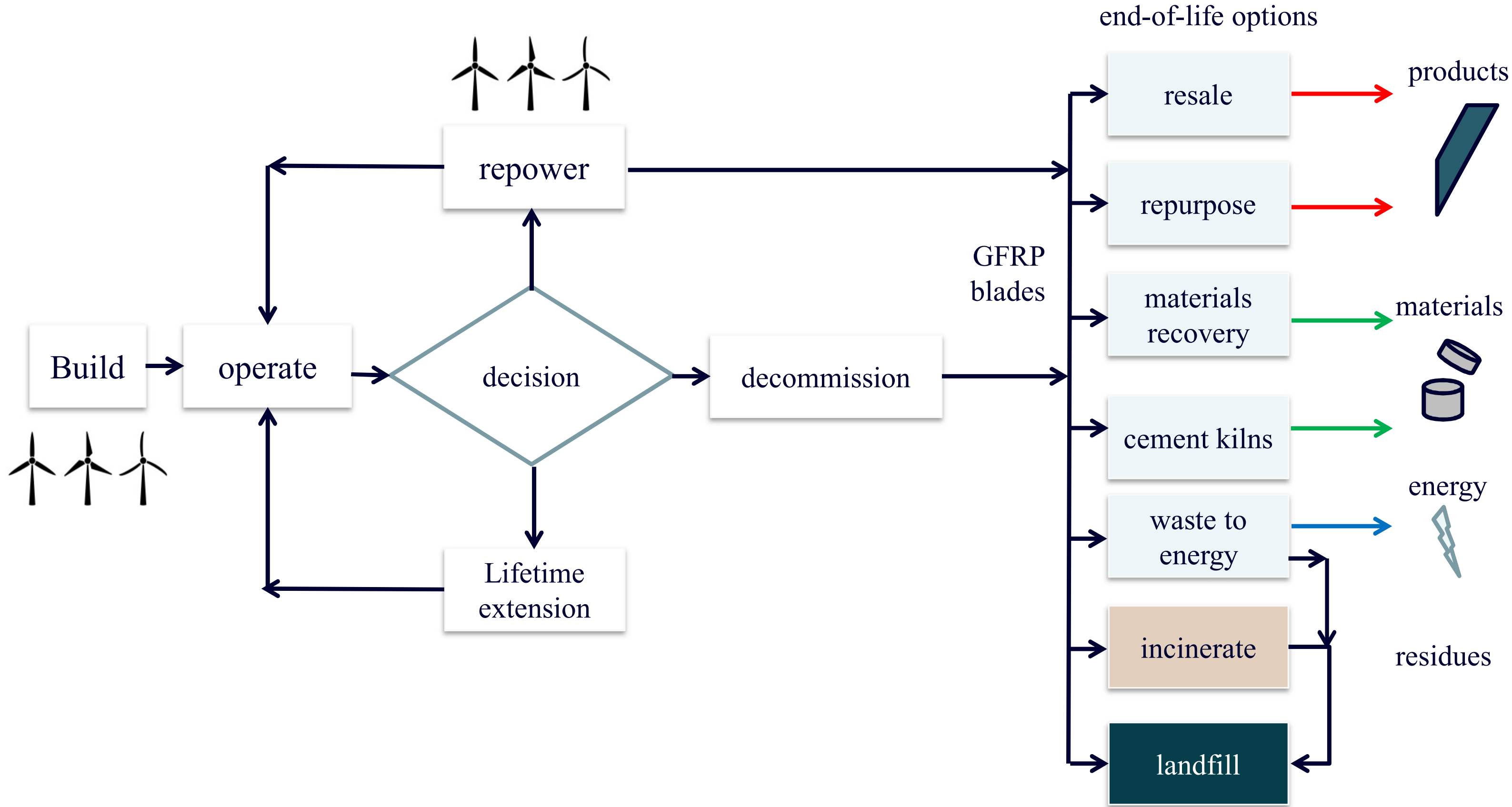
# Outline

- Overview of NSF Tripartite research project
- Recent Re-Wind Research (July 2018 – to-date)
  - Architecture Studio and Design Ideas
  - Pedestrian Bridge, Roof System, Powerline Structures
  - Building blade models from point clouds
  - LCA of landfill versus incineration in Ireland
  - GIS of Irish wind farms and Road networks
  - Community Engagement and Business Models

# Objective of Re-Wind Research

To compare sustainable end–of–life (EOL) repuposing and recycling strategies for composite material wind turbine blades using **Data Driven Structural Modelling**, **Geographic Information Science (GIS)** platform coupled with environmental, economic and social **Life–Cycle Sustainability Assessments (LCSA)**.

# Wind farm lifecycle



# Structural Engineering Design Philosophy

- Probabilistically based Load and Resistance Factor Design (LRFD) or Limit States Design (LSD)

- Nominal Loads are increased - Nominal loads and load combinations (e.g. 1.2 Dead + 1.6 Live) in ASCE 7-16 (2016) or Eurocode EN 1991.

- Nominal Material Properties are reduced - in separate material specific design codes (such as, for concrete, the ACI 318-19 or EN 1992: Design of concrete structures)

- A design code does not exist for composite materials for civil engineering structures. In the absence of a code the material factors for the FRP materials used in this analysis are taken from EUR2766 (2018), the precursor document to the Eurocode. The Material Partial Factor for strength in this analysis was calculated most conservatively to be $\gamma_M$ =2.59.

# Data Driven Structural Modeling

## Architecture Workshop

Design and fabrication of a base connection for a section from Clipper 43.2 m blade (C96 3MW) at Georgia Tech lab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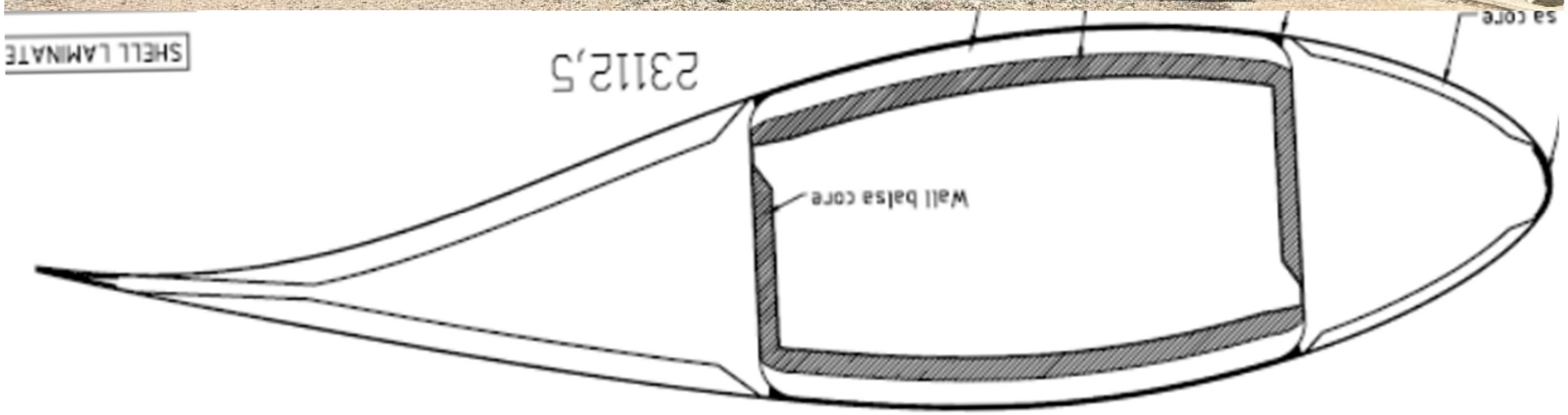
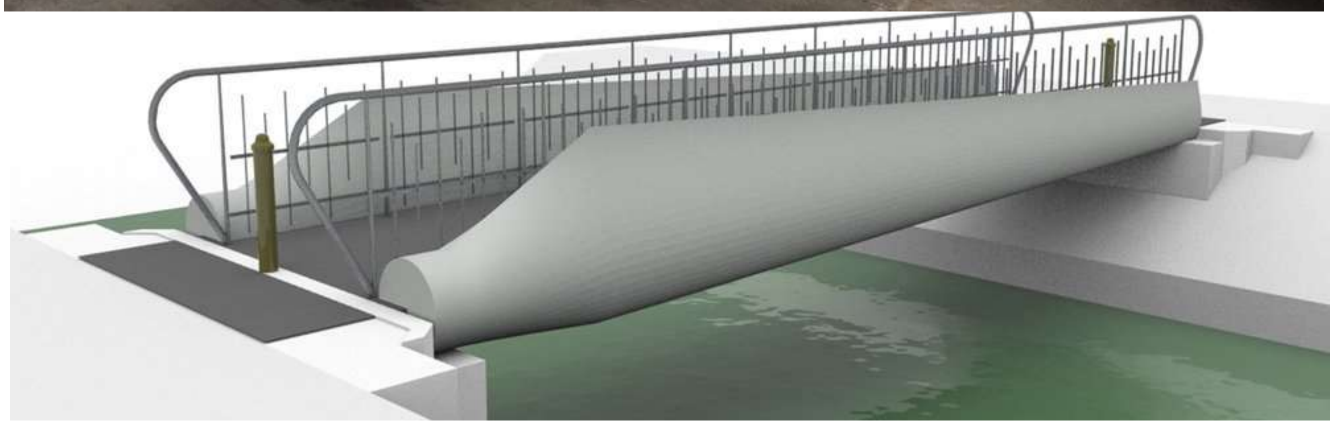
# Section from Clipper 43.2 m blade (C96 3MW) at Georgia Tech lab



| | |
|---|---|
| DISTANCE FROM CENTER OF ROTATION (M) | 23.25 |
| CHORD LENGHT | 2275.8 |
| BLADE TWIST | 2.613 |
| TE THICKNESS (MAX) | 7.5 |

# Design and Analysis of a Pedestrian Bridge

Aftermarket V29 blades (14.3 m) in Northern Ireland



8 m footbridge for greenways in Ireland

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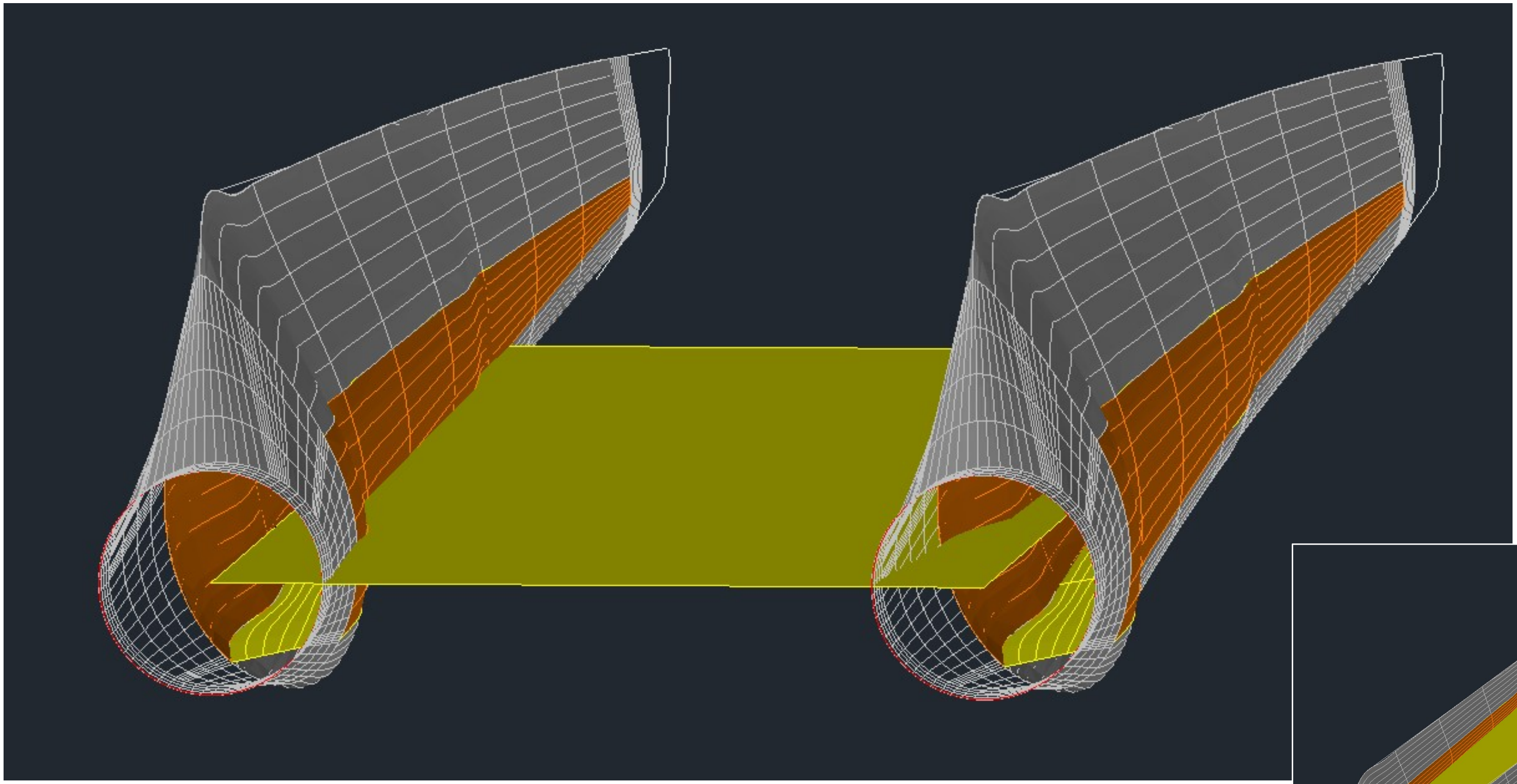

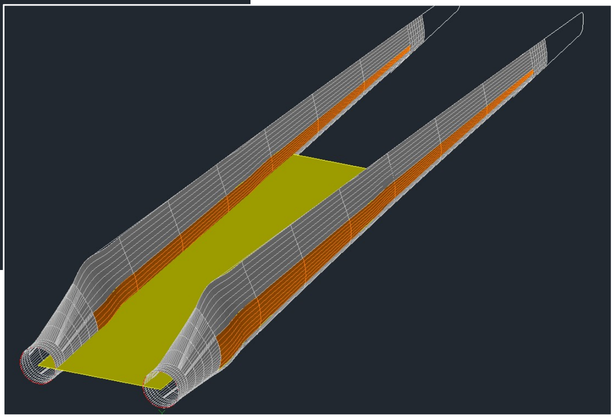

Generating high fidelity CAD and FEM models
Models built from Vestas reports

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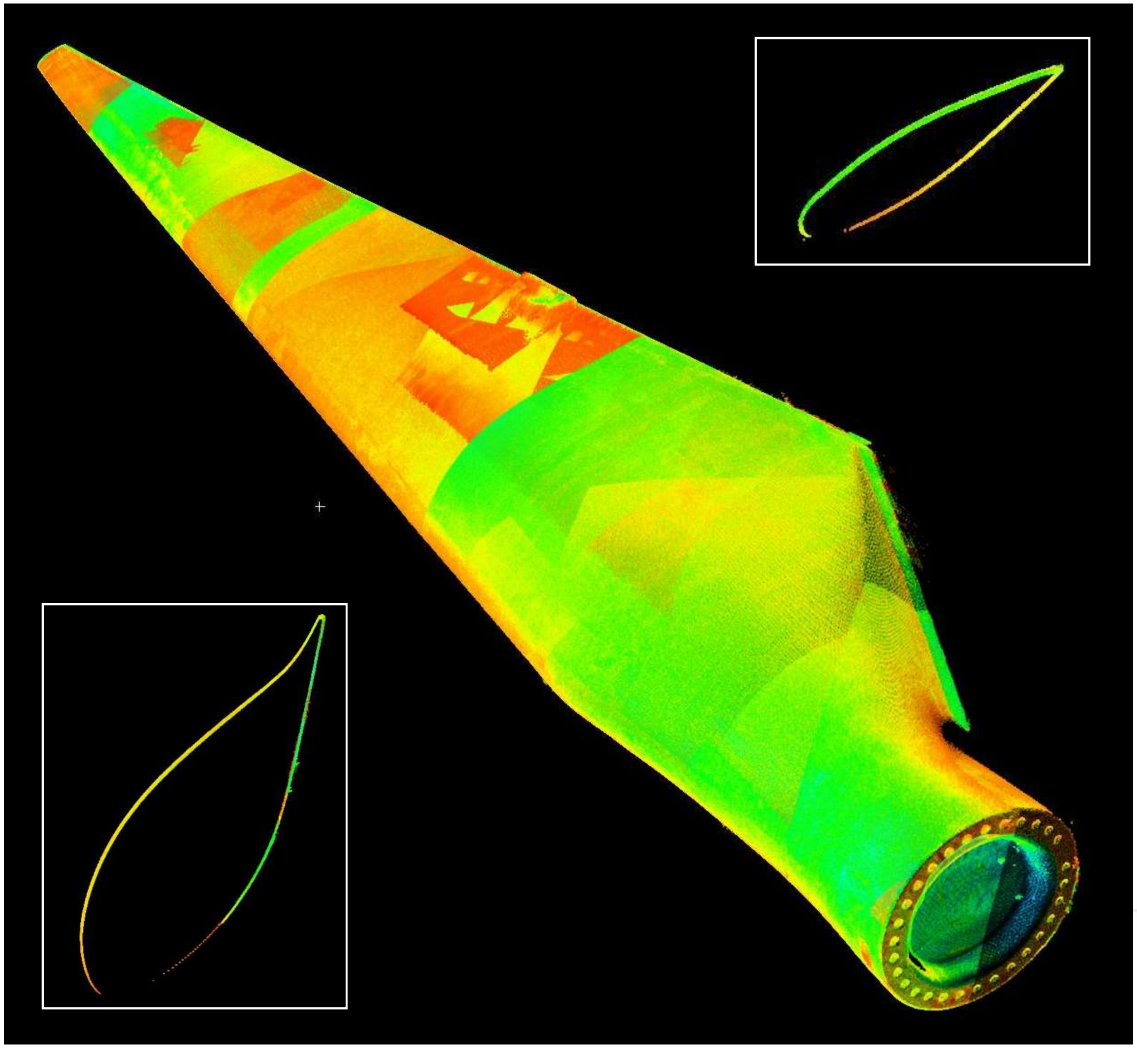
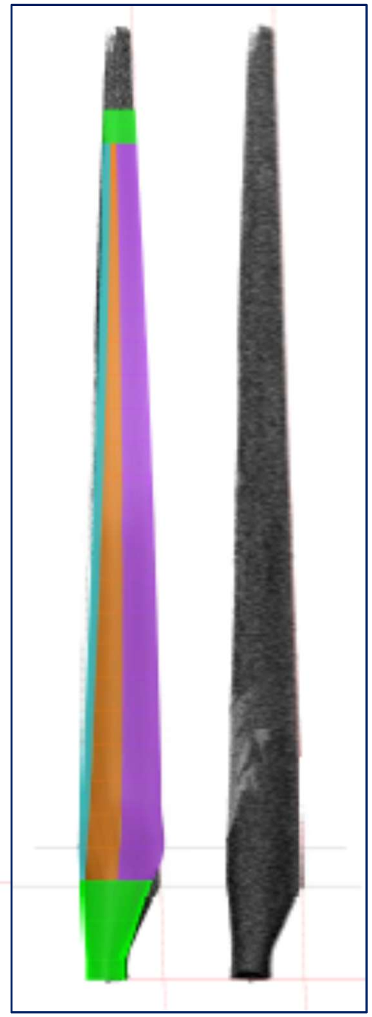
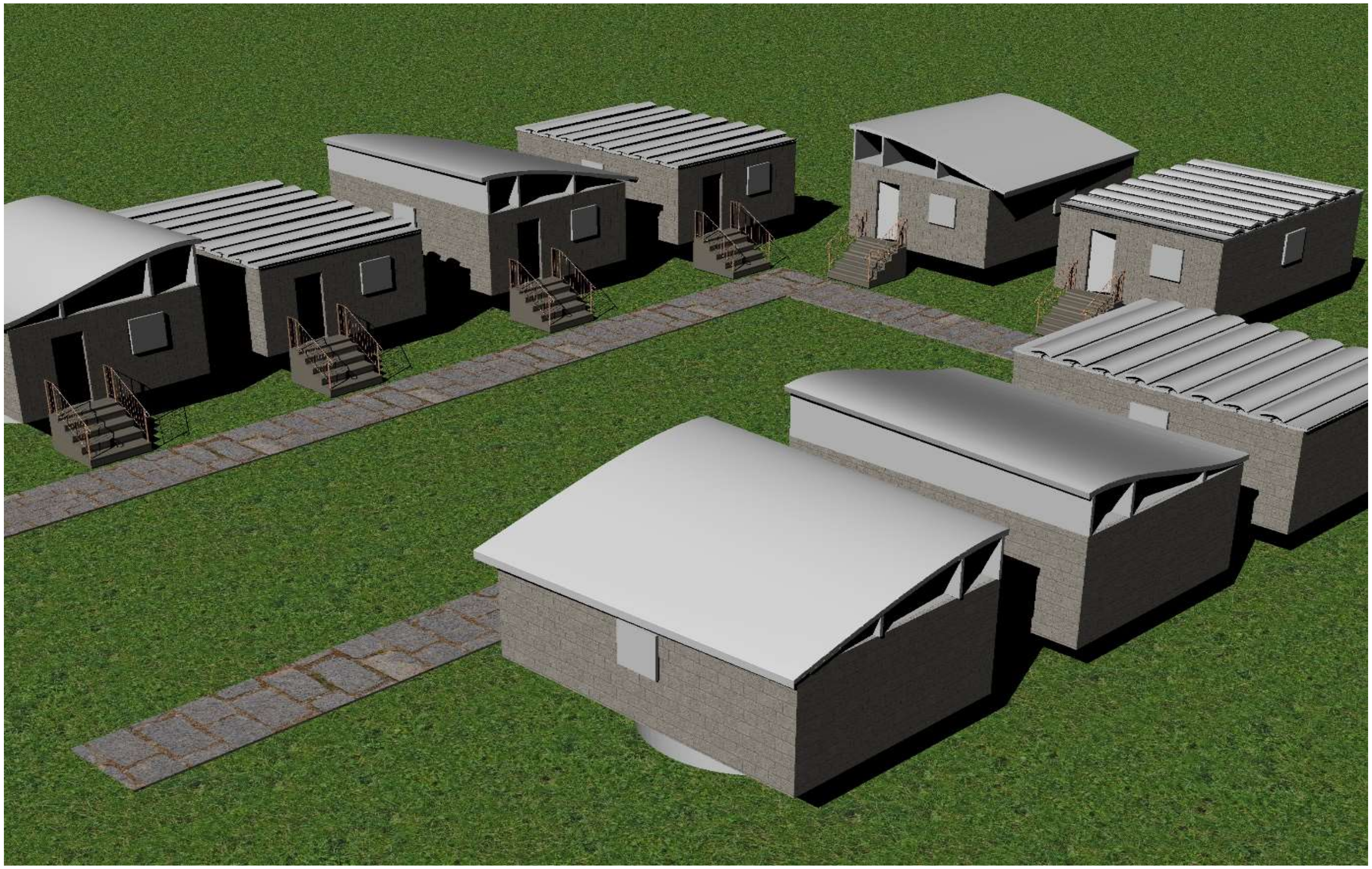
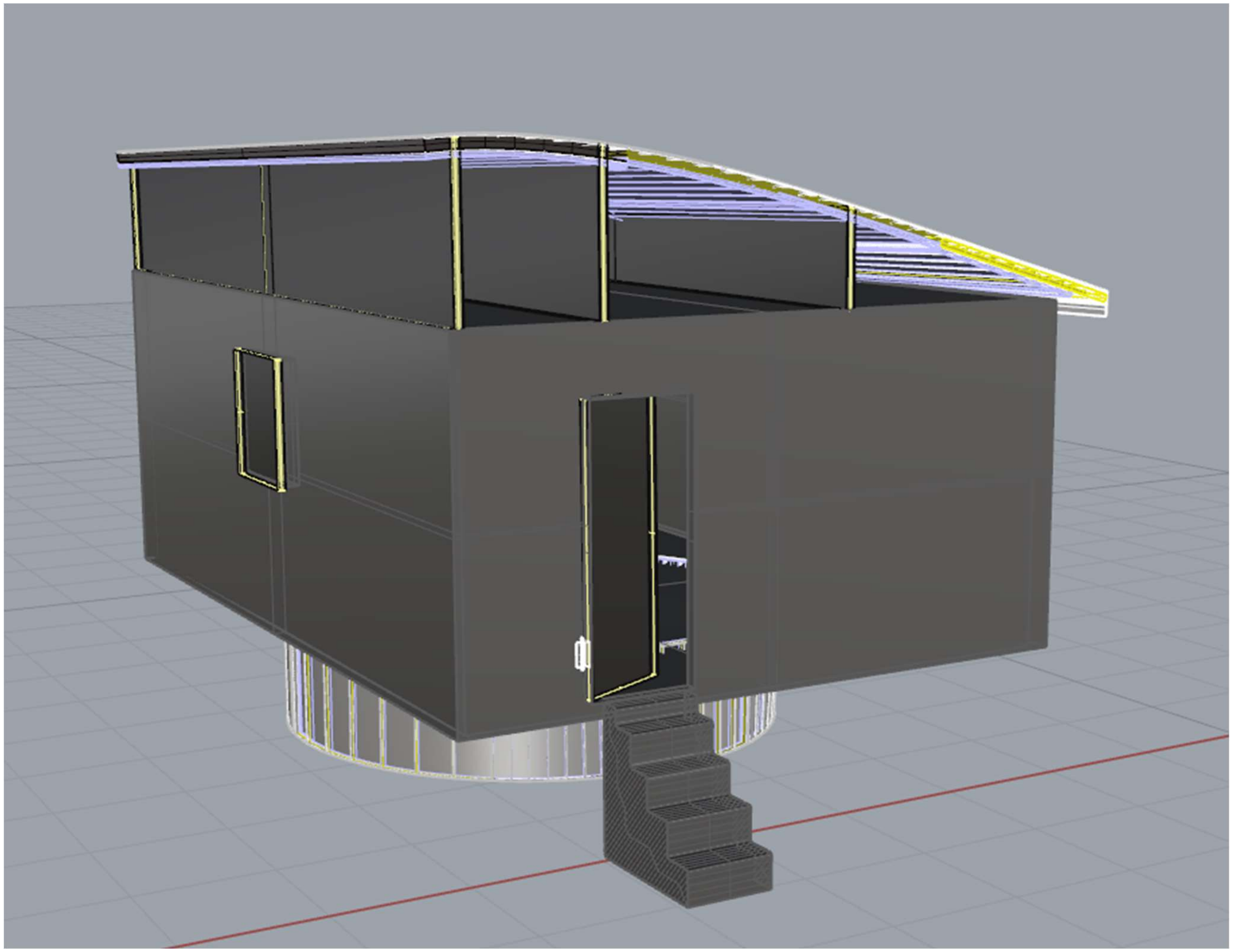


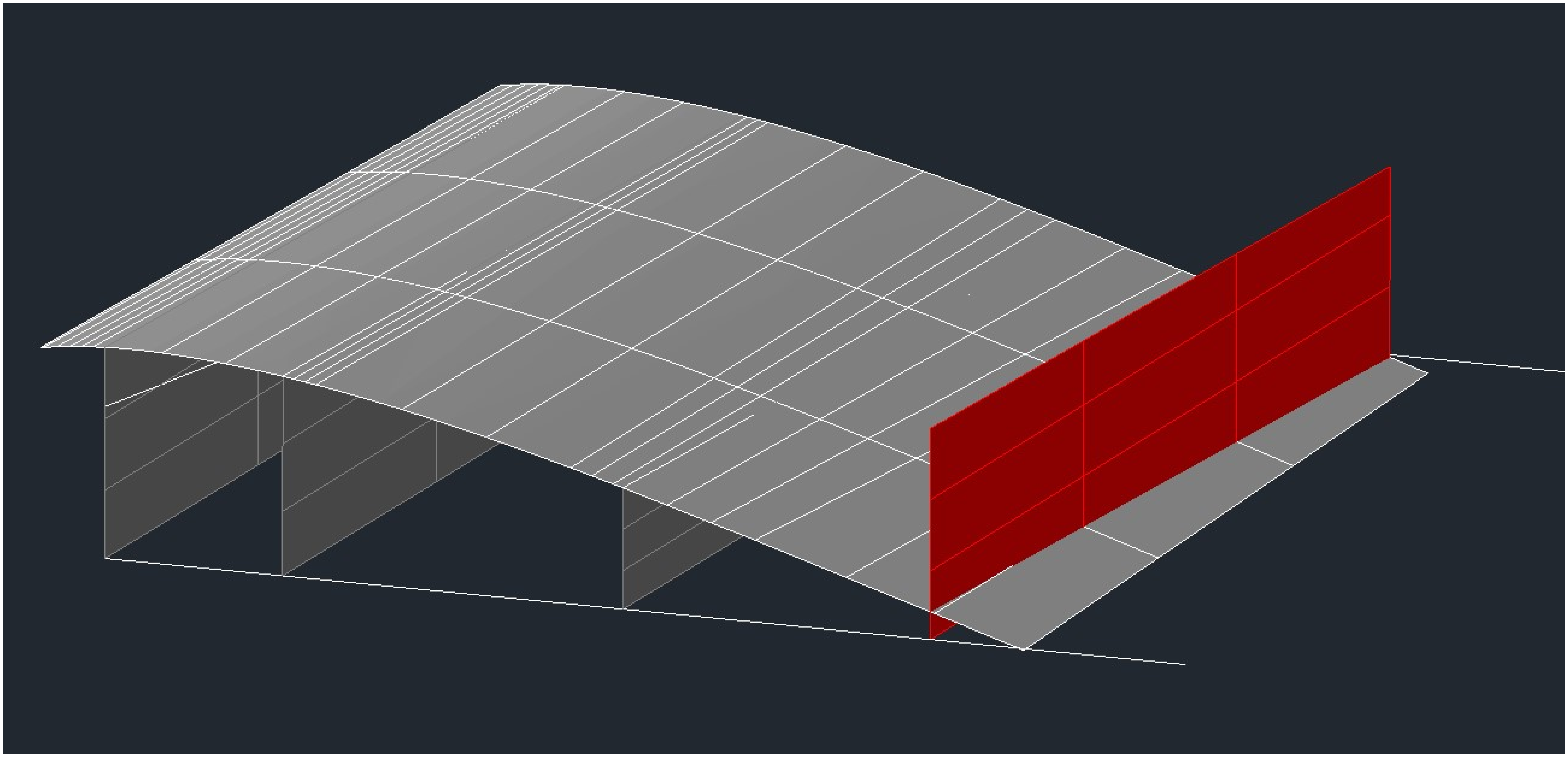


Lidar scans of actual blades and comparison with models

# Design of Roof System







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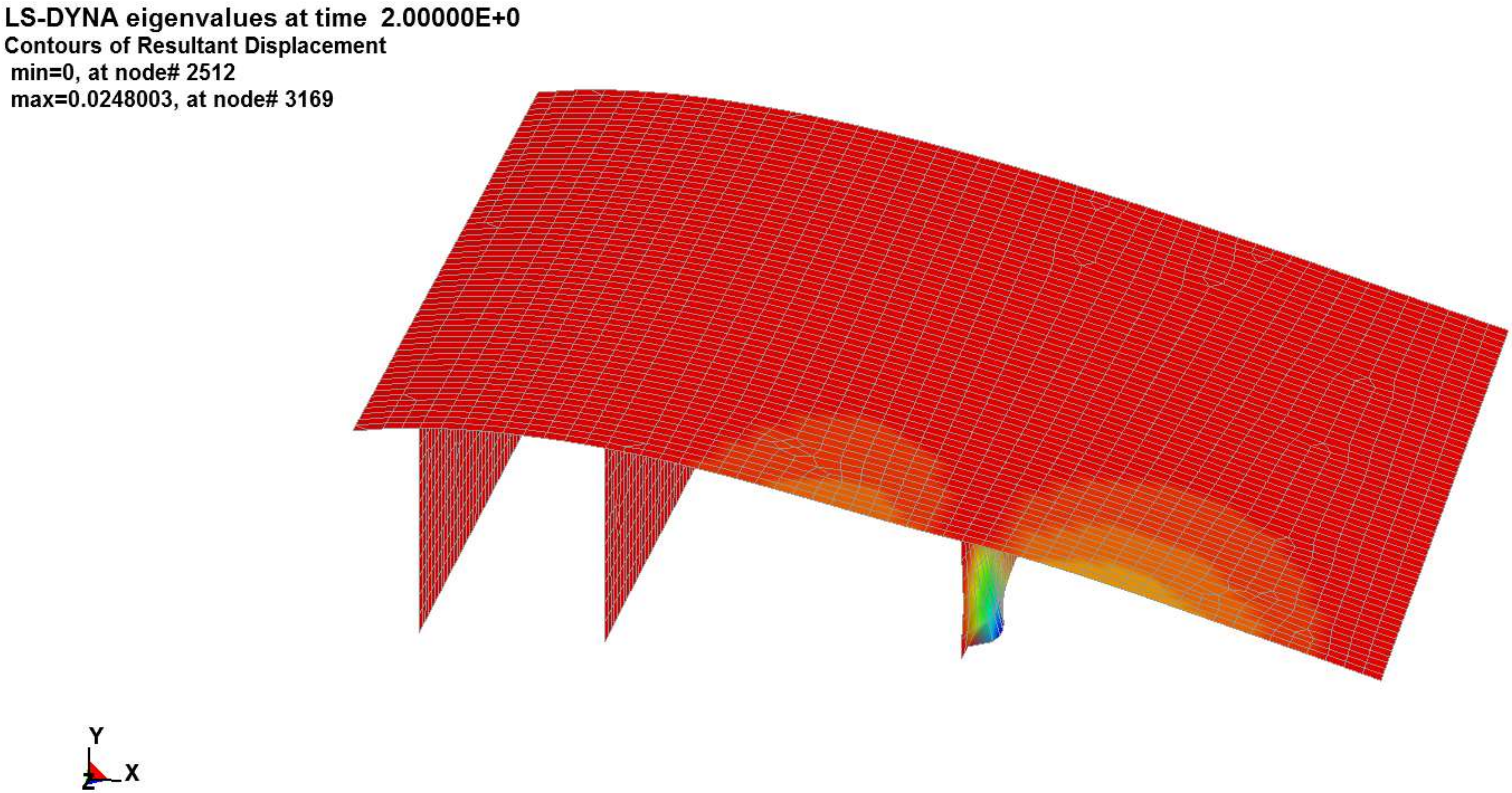
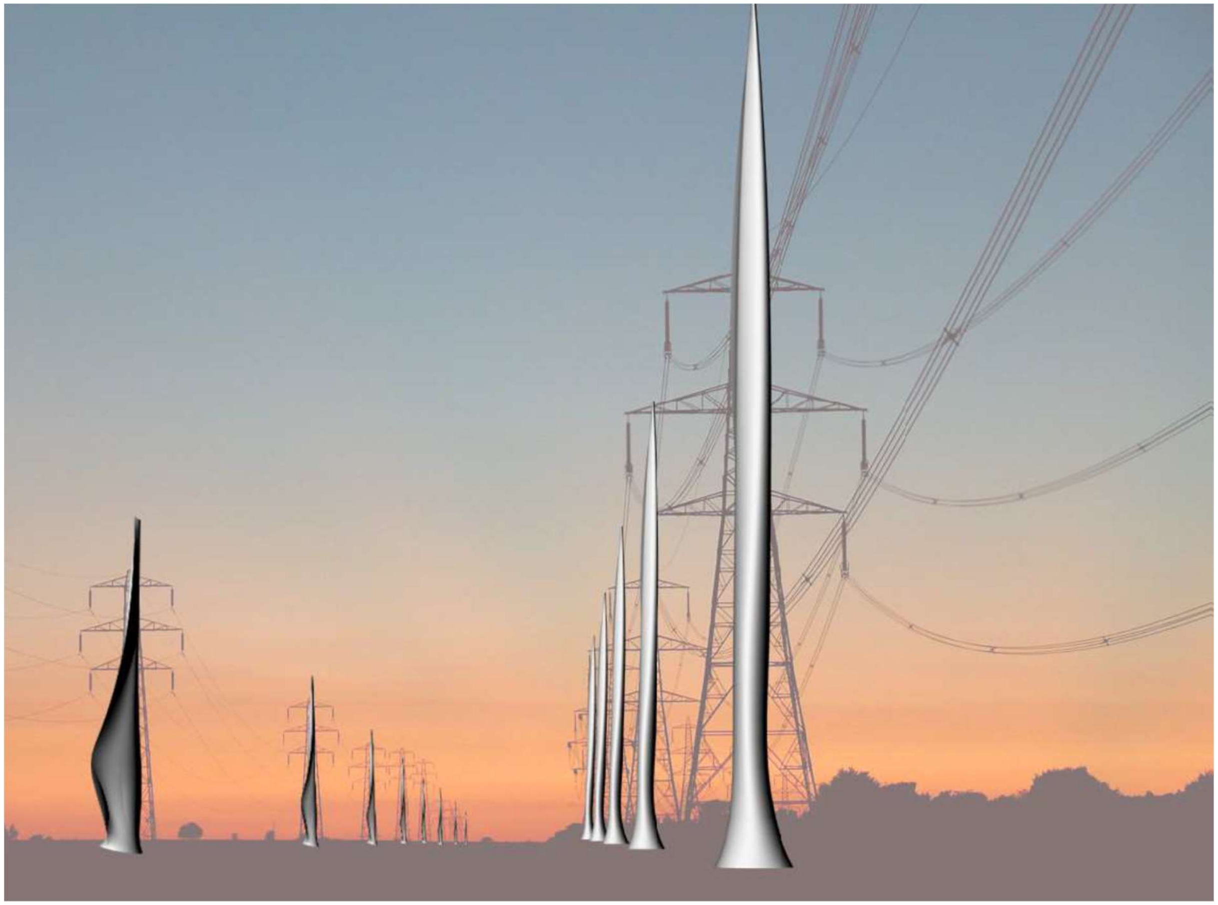

LS-DYNA eigenvalues at time 2.00000E+0
Contours of Resultant Displacement
min=0, at node# 2512
max=0.0248003, at node# 3169
Y
X
Z

# Design of Powerline Structures



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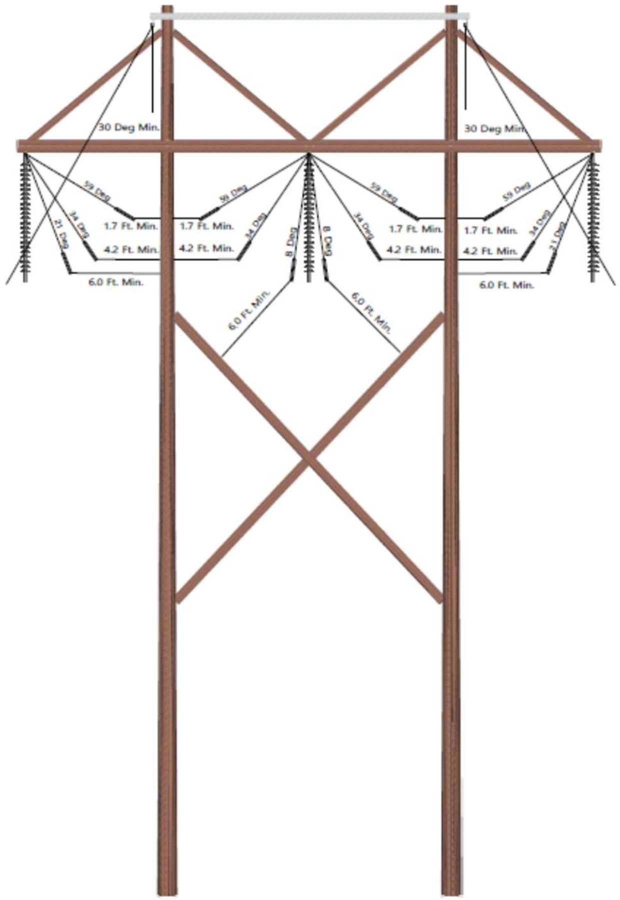
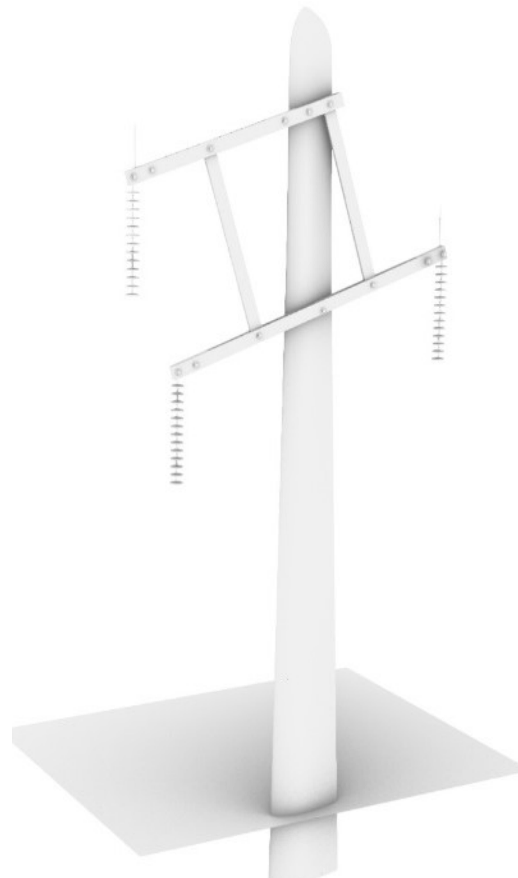
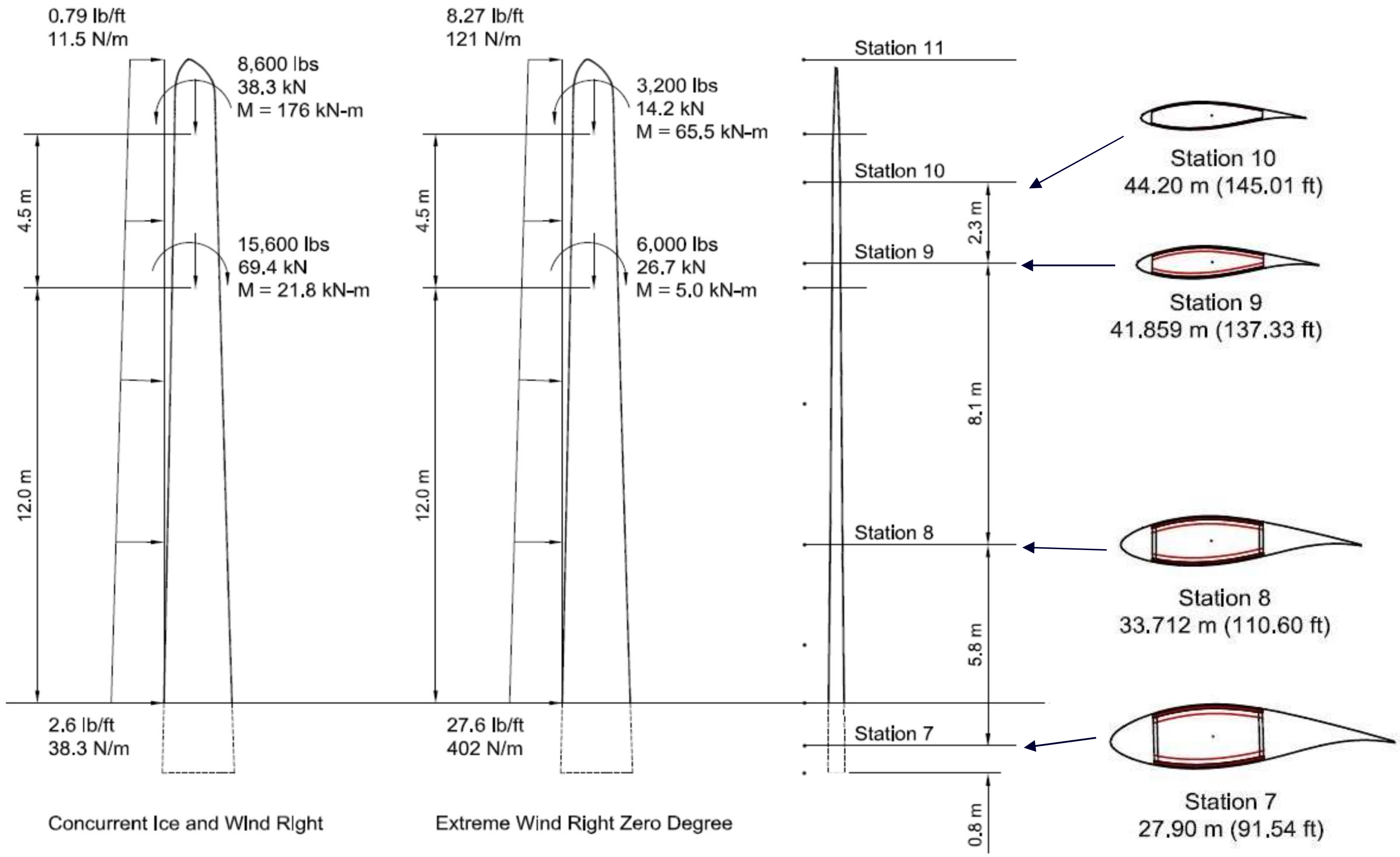
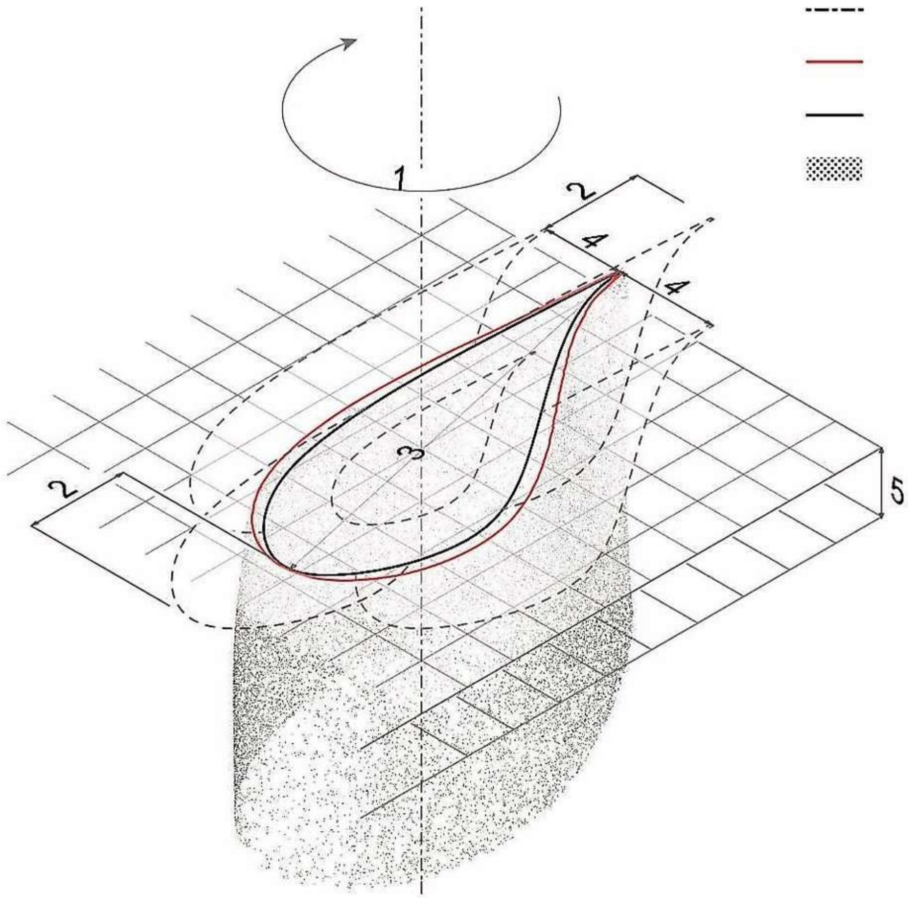


30 Deg Min.
30 Deg Min.
59 Deg
59 Deg
59 Deg
59 Deg
34 Deg
34 Deg
34 Deg
34 Deg
21 Deg
21 Deg
8 Deg
8 Deg
1.7 Ft. Min.
1.7 Ft. Min.
1.7 Ft. Min.
1.7 Ft. Min.
4.2 Ft. Min.
4.2 Ft. Min.
4.2 Ft. Min.
4.2 Ft. Min.
6.0 Ft. Min.
6.0 Ft. Min.
6.0 Ft. Min.
6.0 Ft. Min.




0.79 lb/ft
11.5 N/m
8,600 lbs
38.3 kN
M = 176 kN-m
4.5 m
15,600 lbs
69.4 kN
M = 21.8 kN-m
12.0 m
2.6 lb/ft
38.3 N/m
Concurrent Ice and Wind Right
8.27 lb/ft
121 N/m
3,200 lbs
14.2 kN
M = 65.5 kN-m
4.5 m
6,000 lbs
26.7 kN
M = 5.0 kN-m
12.0 m
27.6 lb/ft
402 N/m
Extreme Wind Right Zero Degree
Station 11
Station 10
2.3 m
Station 9
8.1 m
Station 8
5.8 m
Station 7
0.8 m
Station 10
44.20 m (145.01 ft)
Station 9
41.859 m (137.33 ft)
Station 8
33.712 m (110.60 ft)
Station 7
27.90 m (91.54 ft)

# Building blade models from point clouds

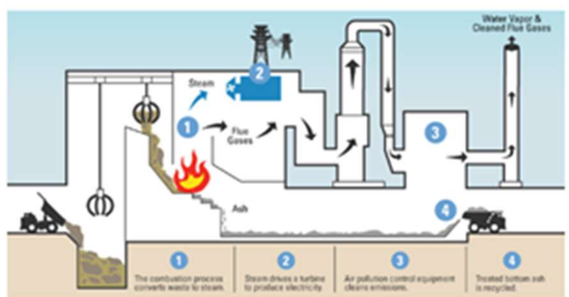


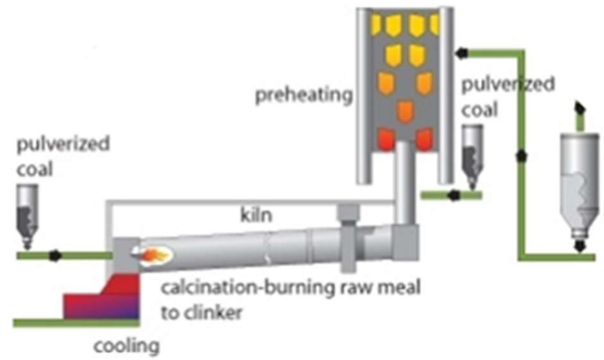
# LCA of landfill versus incineration in Ireland

## Incineration Scenarios


**Incineration without energy recovery**
Consumes polymer but leaves the E-glass

**Incineration with energy recovery:**
Consumes polymer for fuel replacement, but also leaves behind the E-glass.




**Co-processing in Cement Kiln**
Consumes polymer as fuel up to 850°C. Consumes E-glass at temperatures of 1450°C, which serves as raw material replacement. No landfill.

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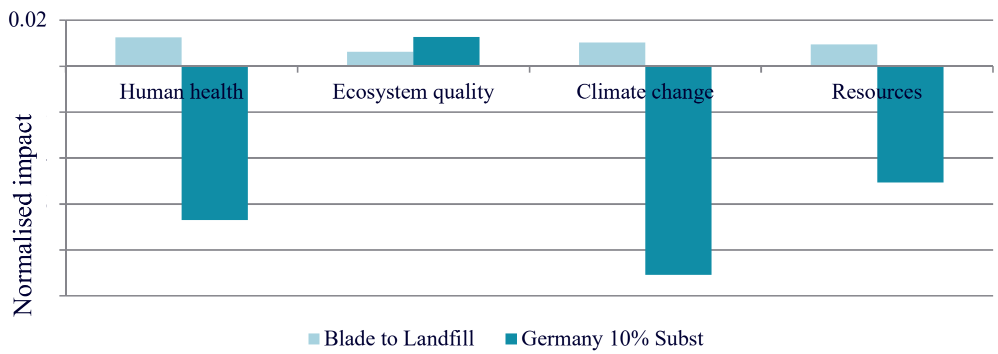
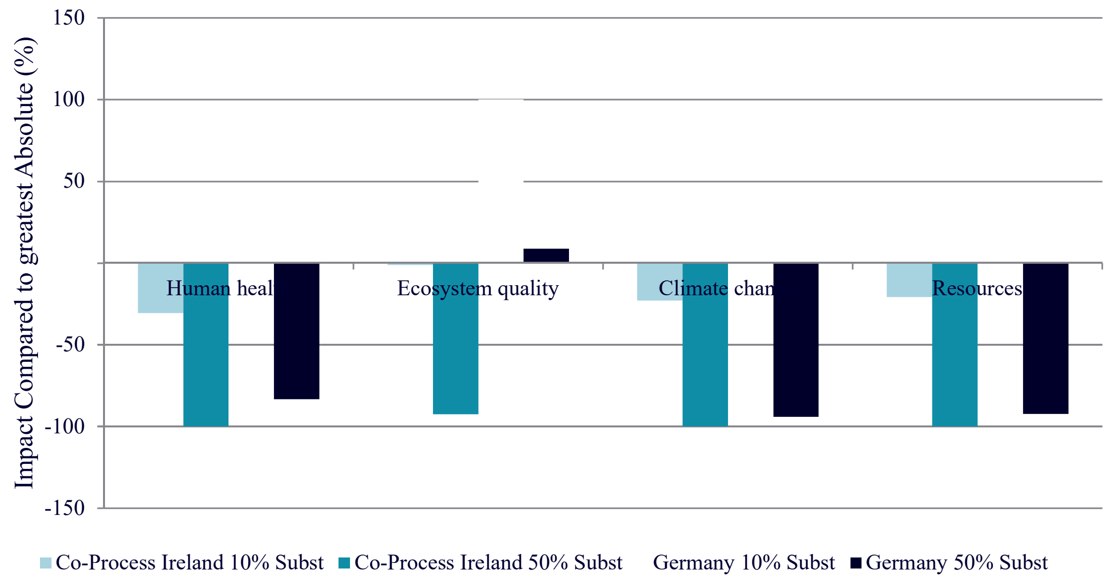
# LCA: Results

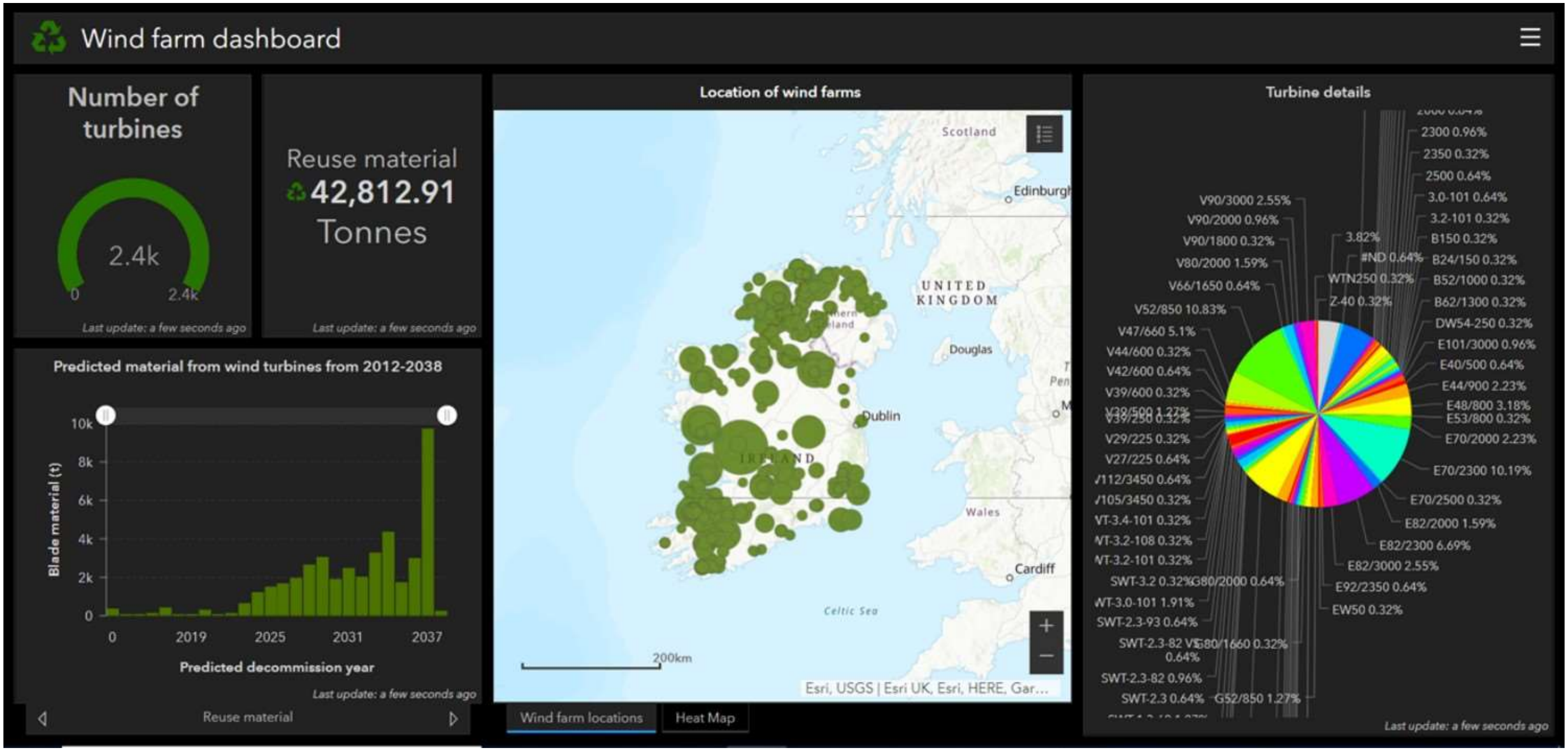



Comparison of Landfill in Ireland to 10% Substitution with processing at Neocomp and co-processing at Holcim:
**Co-processing is better environmentally**

Comparison of the effects of substitution rates as compared to transportation distances (Ireland to Germany):
**Substitution Rates between 10%-50% have a greater environmental impact than transport distances Ireland to Germany**

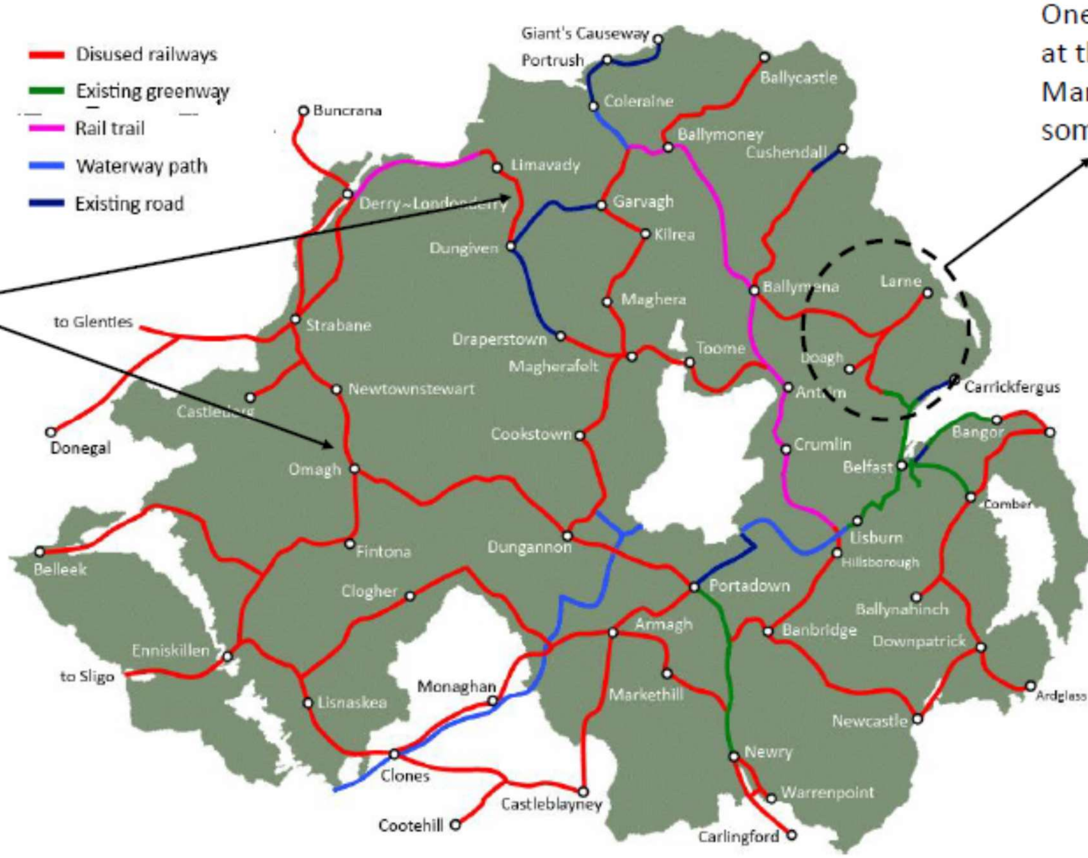


# GIS of Irish wind farms and road networks



# Greenways in Northern Ireland for possible "BladeBridge"

These are areas with lots of wind farms

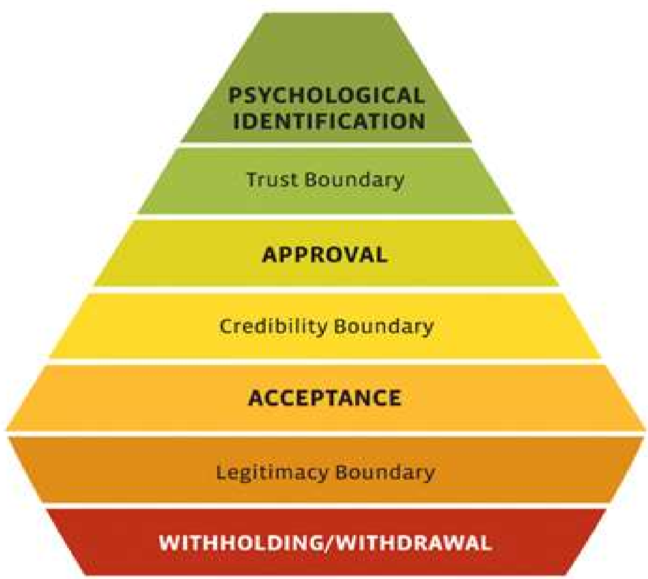



One that is currently at the design stage in March 2019 – close to some wind farms

# Community Engagement and Business Models

Wind Farms are trying to achieve a '**Social Licence**' to Operate: Should blade re-use options seek the same ?

Measuring the Social License




| LEVEL OF SOCIAL LICENSE | SYMPTOMS/INDICATORS |
|---|---|
| WITHHELD / WITHDRAWN | Shutdowns, blockades, boycotts, violence / sabotage, legal challenges |
| ACCEPTANCE / TOLERANCE | Lingering/recurring issues & threats, presence of outside NGOs, watchful monitoring |
| APPROVAL / SUPPORT | Company seen as good neighbour, pride in collaborative achievements |
| PSYCHOLOGICAL IDENTIFICATION | Political support, co-management of projects, united front against critics |

# Conclusion at this stage of Re-Wind

- Material recovery methods are too expensive at the moment (i.e., producing material that is inferior to virgin material at a higher cost). (downcycling.)
- Cement Kiln Co-processing is expensive but better on the environment than landfilling in the EU for now. (downcycling.)
- Structures using large blade parts are structurally feasible – costs and community acceptance are being studied in depth. (upcycling).
- Discussions with a number of large OEMs are in progress to prototype structural concepts. (upcycling).
- Spin-off/start-up opportunities are possible. (win-win)

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Thank you/Questions/Comments

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