RE-WIND NETWORK

BLADE REPURPOSING SOLUTIONS

WWW.RE-WIND.INFO

NYC DDC

TOWN +GOWN: NYC

March 25, 2021

NSF

sfi Science Foundation Ireland

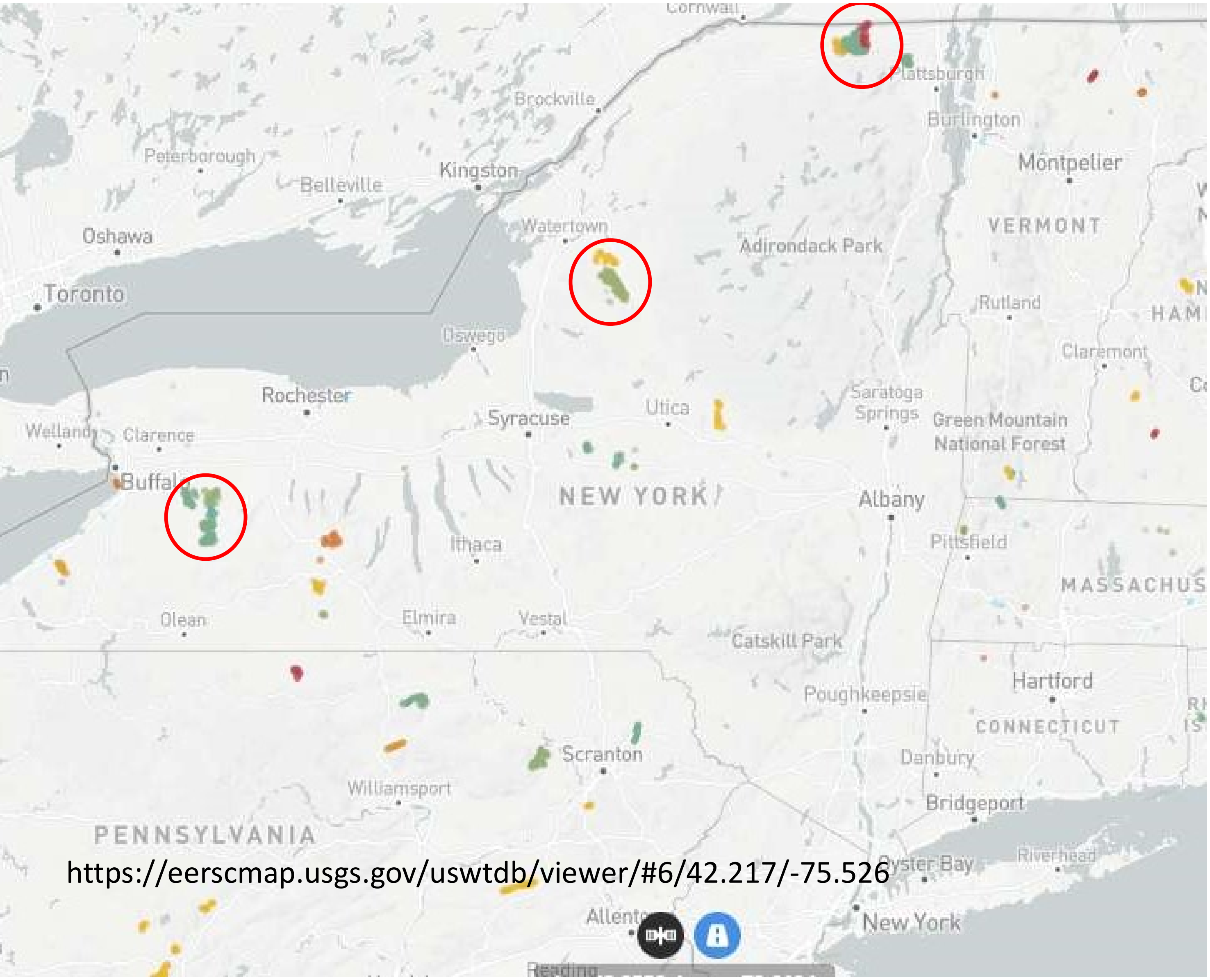
Department for the Economy

Georgia Tech

CUNY THE CITY UNIVERSITY OF NEW YORK

UCC University College Cork, Ireland Coláiste na hOllscoile Corcaigh

QUEEN'S UNIVERSITY BELFAST



https://eerscmap.usgs.gov/uswtdb/viewer/#6/42.217/-75.526

NY Total Onshore Capacity

1.99 GW (Gigawatts)
1,125 Wind Turbines
3,375 Wind Blades

~21,000 tons of Non-biodegradable fiber reinforced polymer composite material

US Total = 111 GW

Maple Ridge Wind Farm, Lowville, NY
(installed 2005-2006)

195 Vestas model V82
1.65 MW wind turbines

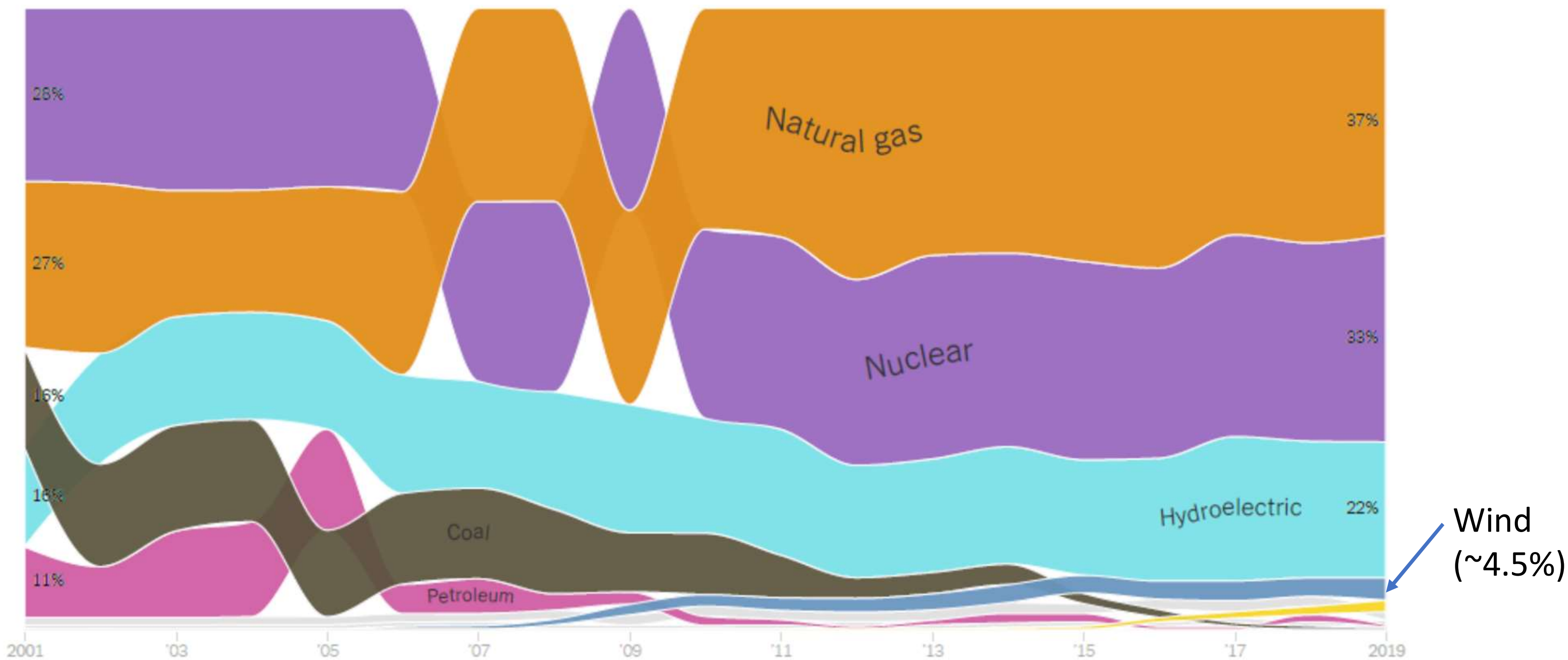
40 m (130 ft) long blades
approx. 15,000 lbs each

322 MW output
136,000 New York homes

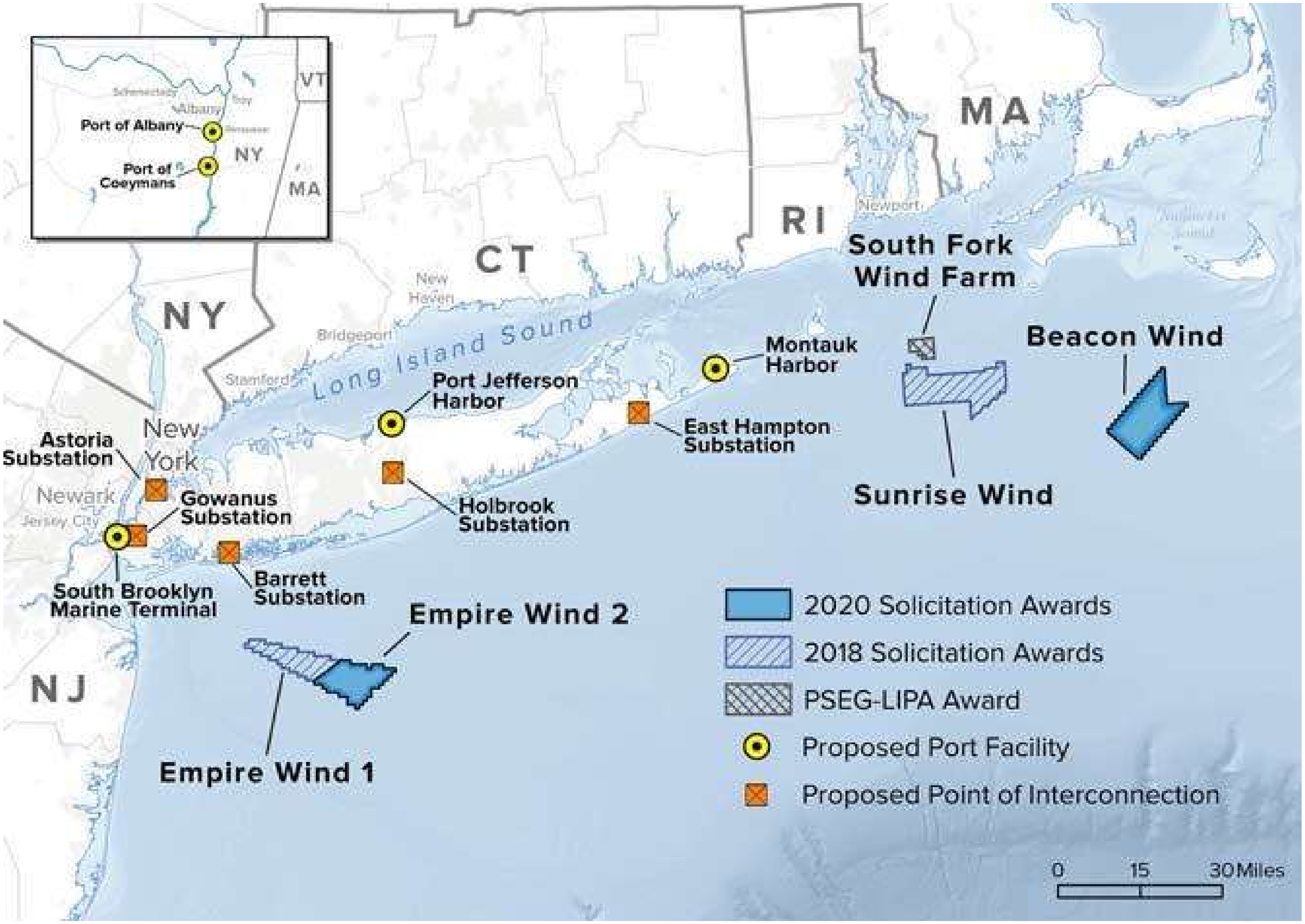
EDP Renewables

How Does Your State Make Electricity? New York Times
NEW YORK STATE (updated 2020)

Net generation 2019 (megawatthours) 131,603,289
All NY Wind – 2 GW = approx. 6,000 MWh (4.5%)



"Enshrined into law through the Climate Leadership and Community Protection Act, New York is on a path to achieving its mandated goal of a zero-emissions electricity sector by 2040, including **70 percent renewable energy generation by 2030**, and to reach economy-wide carbon neutrality." NY Governor's 2021 State of the State address

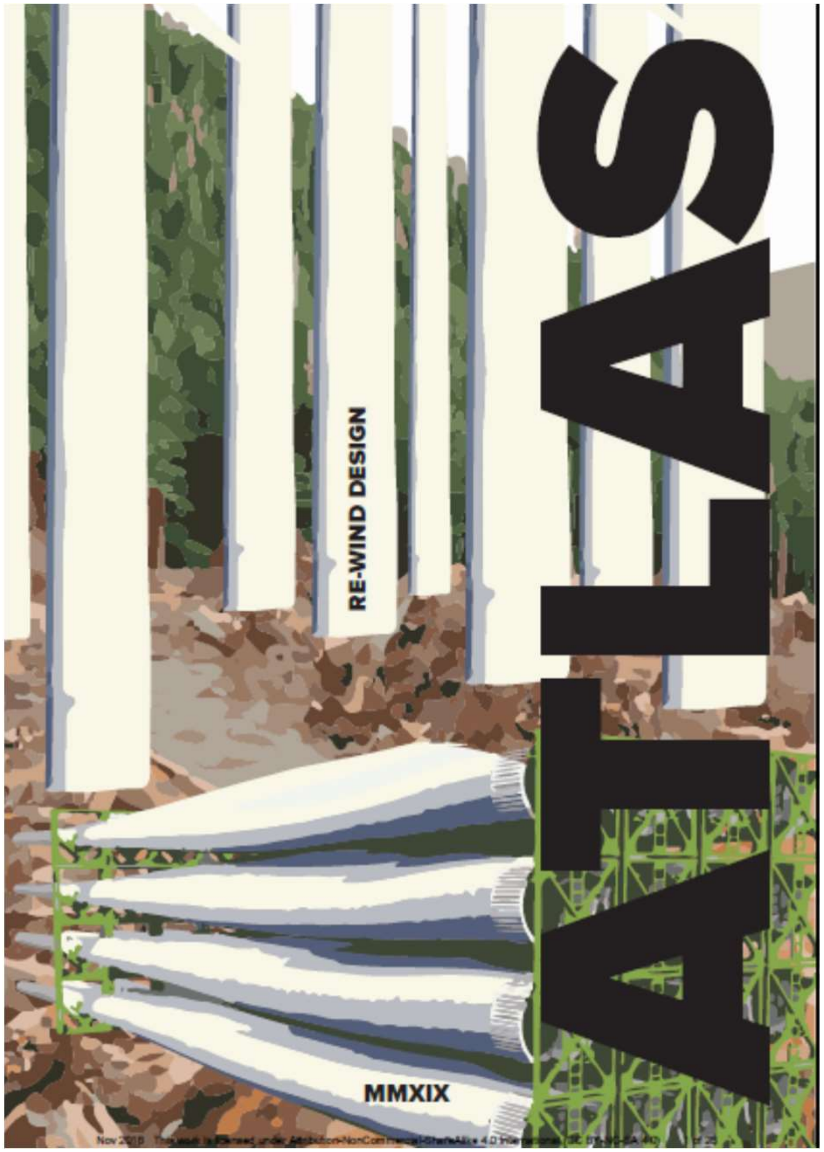


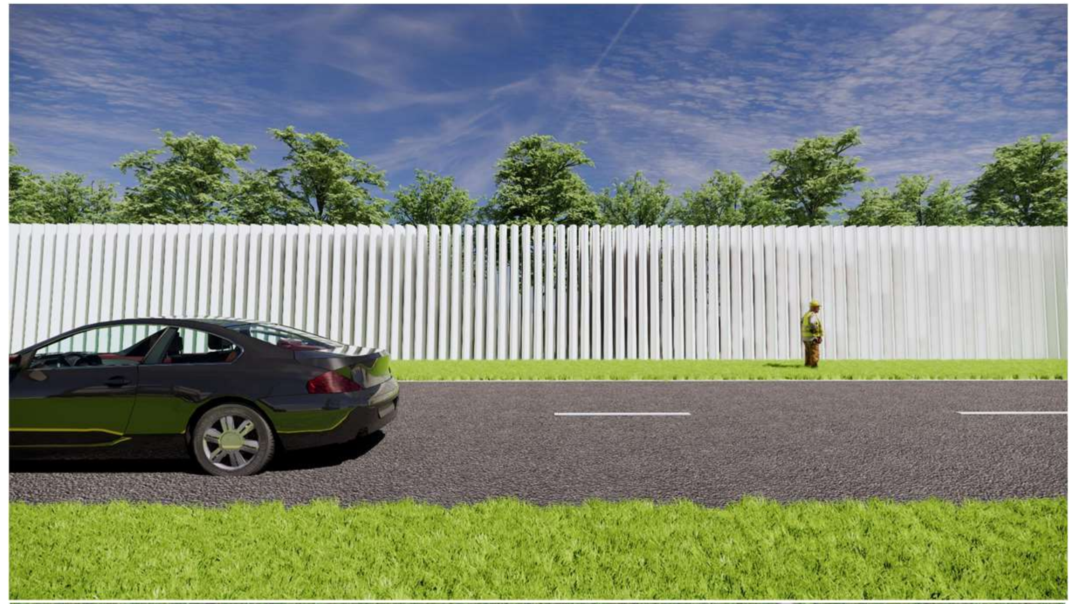
NYS Offshore Wind in development

2018 and 2020 NYSERDA contracts Total 4.3 GW

Expected length of blades for 12 GW turbine ~100 m (330 ft)

(football field is 360 ft with end zones!)


ATLAS
RE-WIND DESIGN
MMXIX



TOWN +GOWN: NYC

BladePole
Georgia Tech Re-Wind Team

Russell Gentry
NYC T+G
25 March 2021

Georgia Tech | Digital Building Laboratory
College of Design

Georgia Tech Re-Wind Team


Ammar Alshannaq


Kimberly Bass-Seaton


Zoe Zhang


Emily Lau


Alex Poff


Tristan Al-Haddad


Yulizza Henao-Barragan


John Respert


Russell Gentry

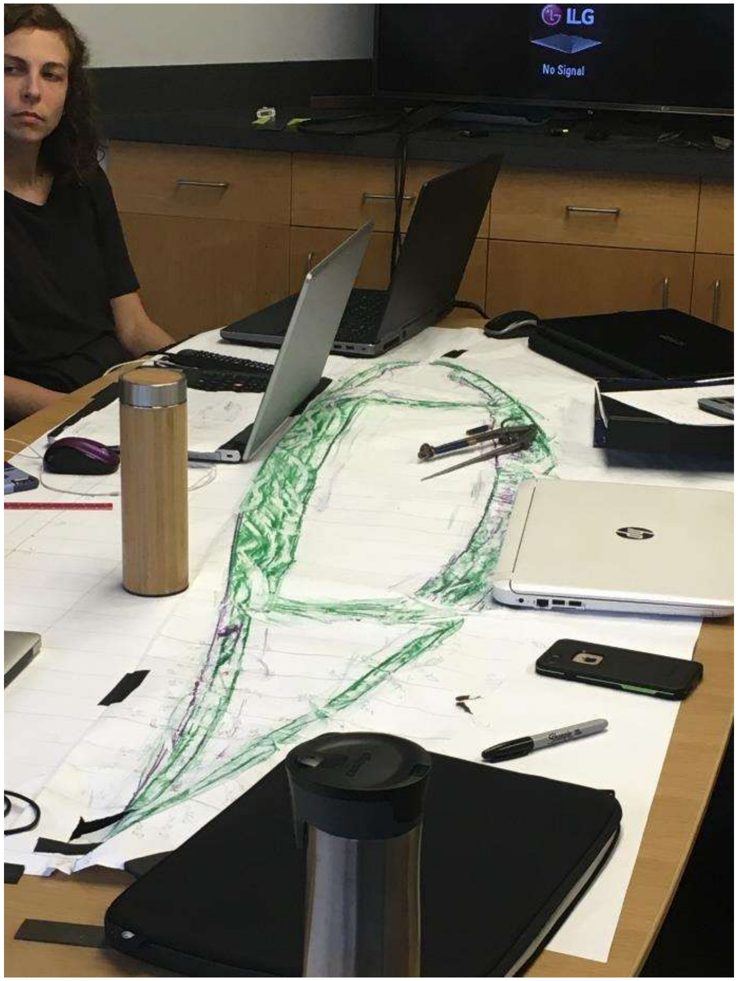

Mehmet Sinan Bermek


Larry Bank


Adam Devlin


James Marlow


Chloe Kiernicki



design + fabrication

RE-WIND NETWORK

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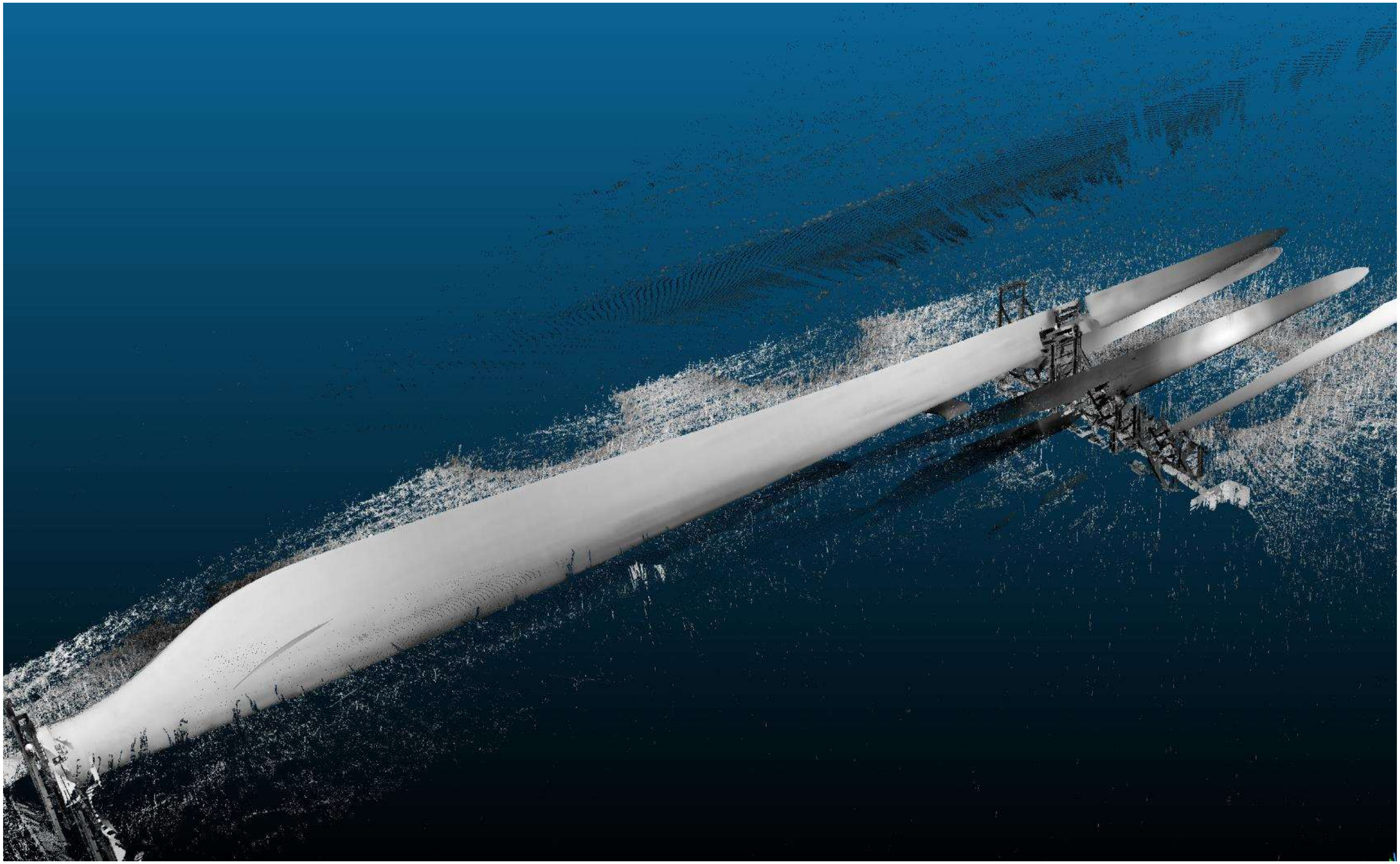
ENEL Smoky Hills Wind Farm Lincoln, Kansas 11 March 2021 GE37c Wind Turbine Blades



ENEL Smoky Hills Wind Farm Lincoln, Kansas 11 March 2021 GE37c Wind Turbine Blades

RE-WIND NETWORK

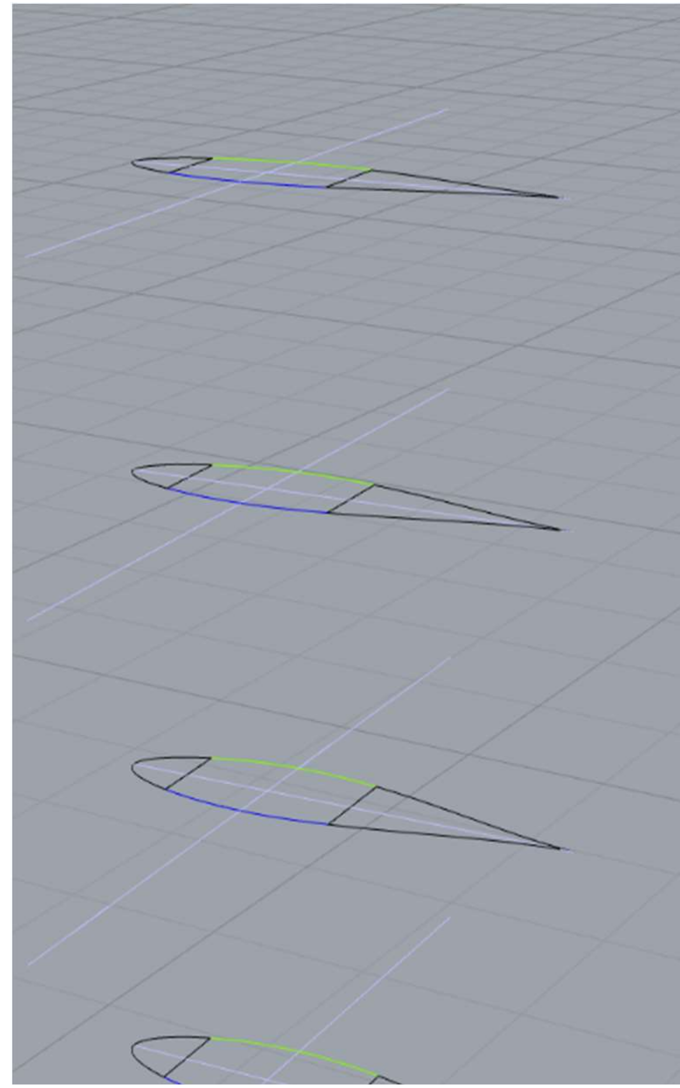
Georgia Tech

BladeMachine

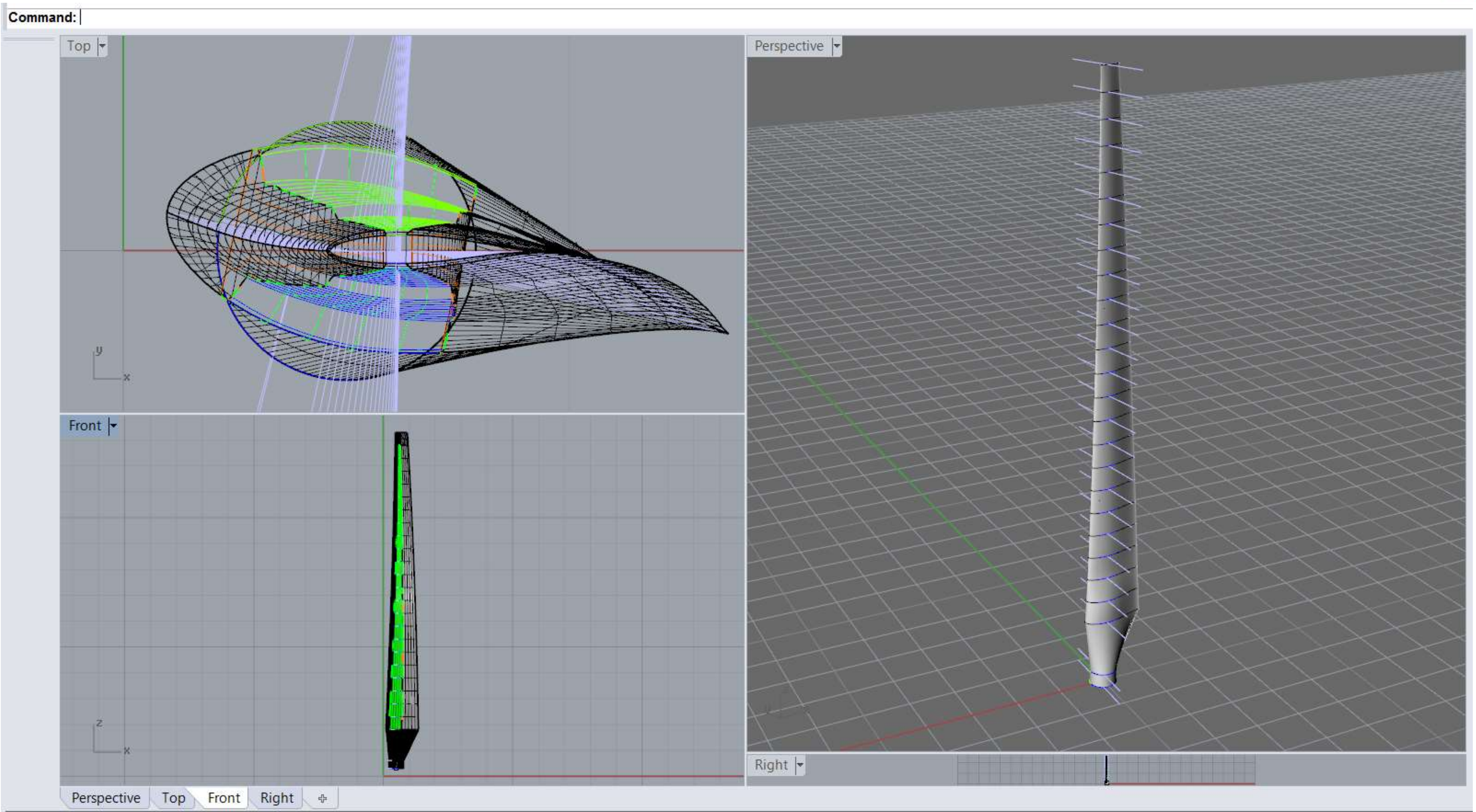
BladeMachine is software that automates the generation of architectural, engineering and fabrication models of the wind blades – it is divided into four “phases”. The BladeMachine is written largely in Rhino/Grasshopper and python.

We have a pending patent on BladeMachine based largely on initial work from 2017-2018 but much work has gone into the algorithms since that time.

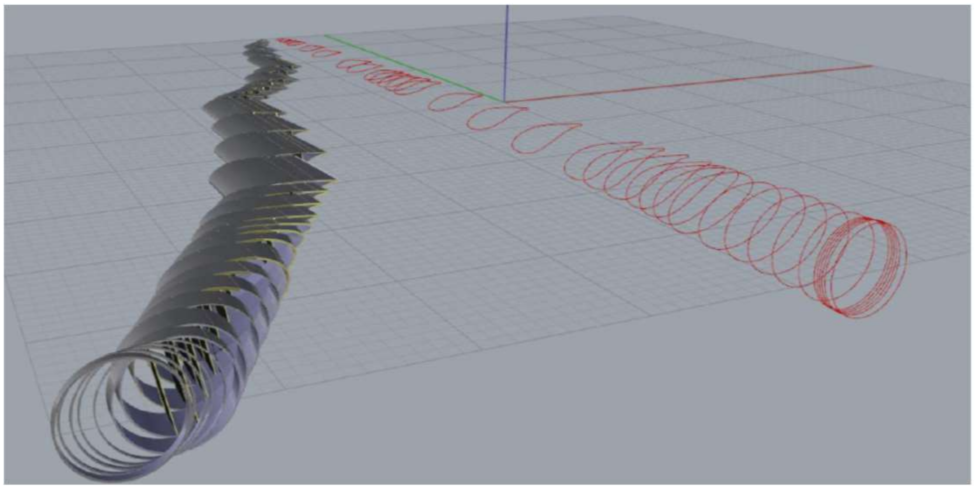
Phase 1 – Airfoils from LiDAR

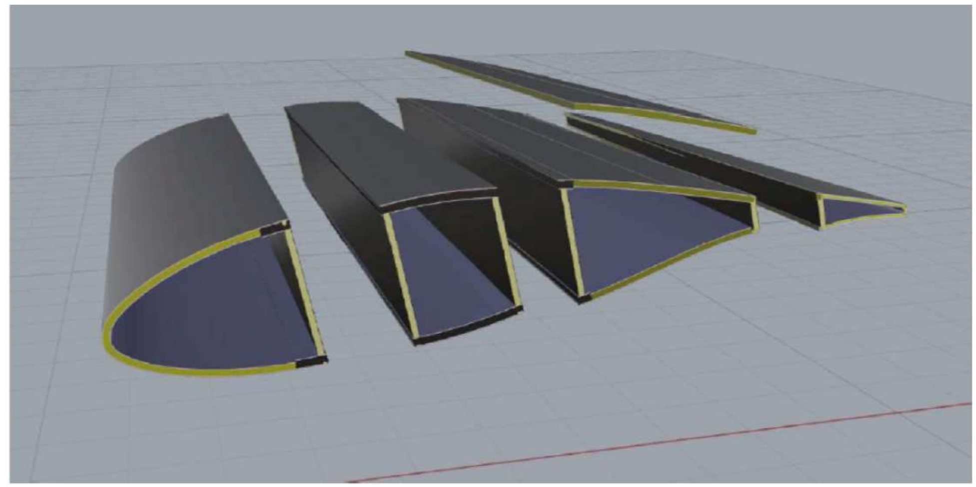


Blade Machine – Phase 2 Model – Vestas V27

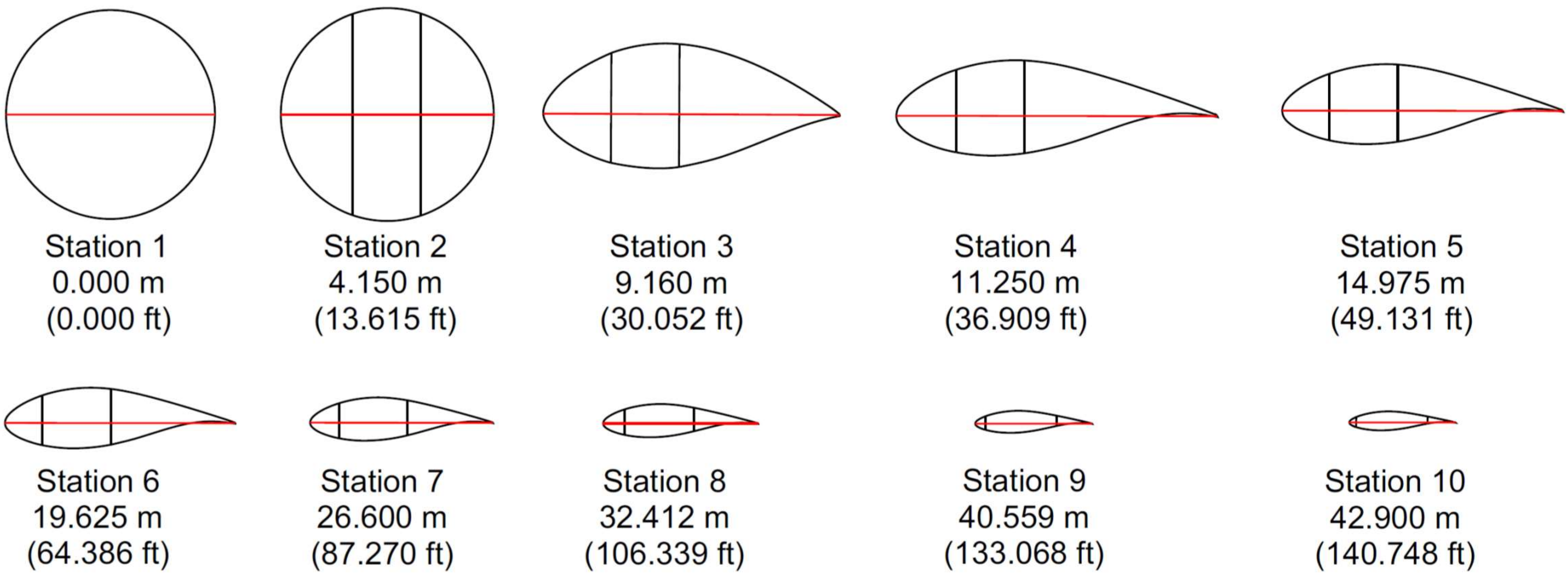


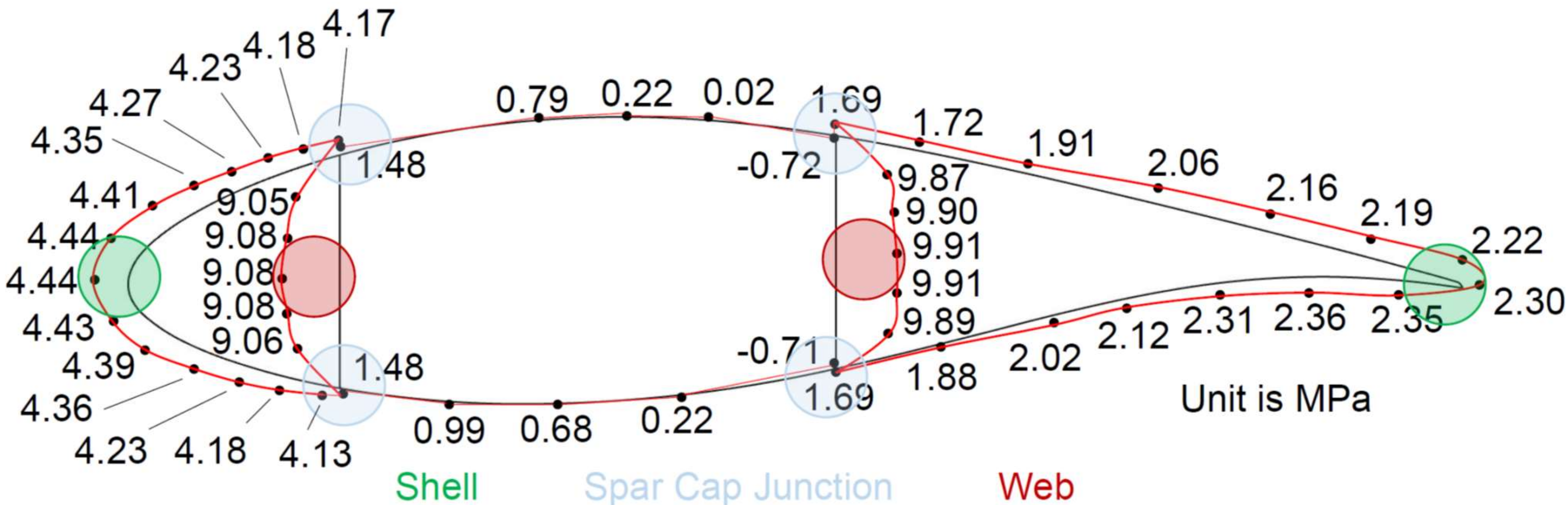
BladeMachine Phase 3 “Thick” Model





BladeMachine Phase 4 Engineering Properties





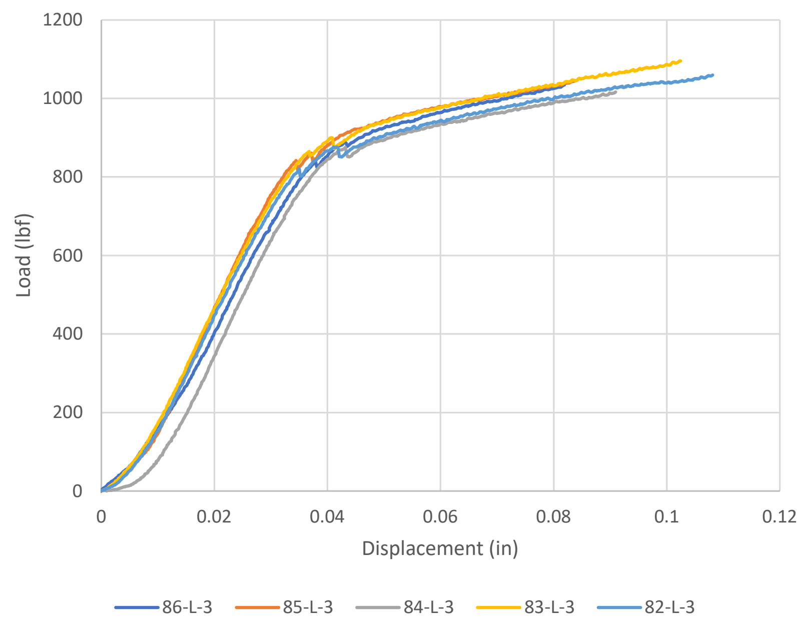
Shear stresses from flapwise loading

material and structural evaluation

Material Evaluation

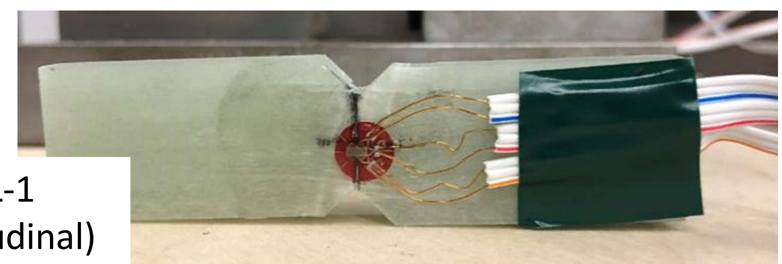
9. Fabrication of Open-Hole Tensile specimen
10. Fabrication for V-Notch Shear testing
11. Fabrication of Dogbone and Straight-Sided Tensile specimens

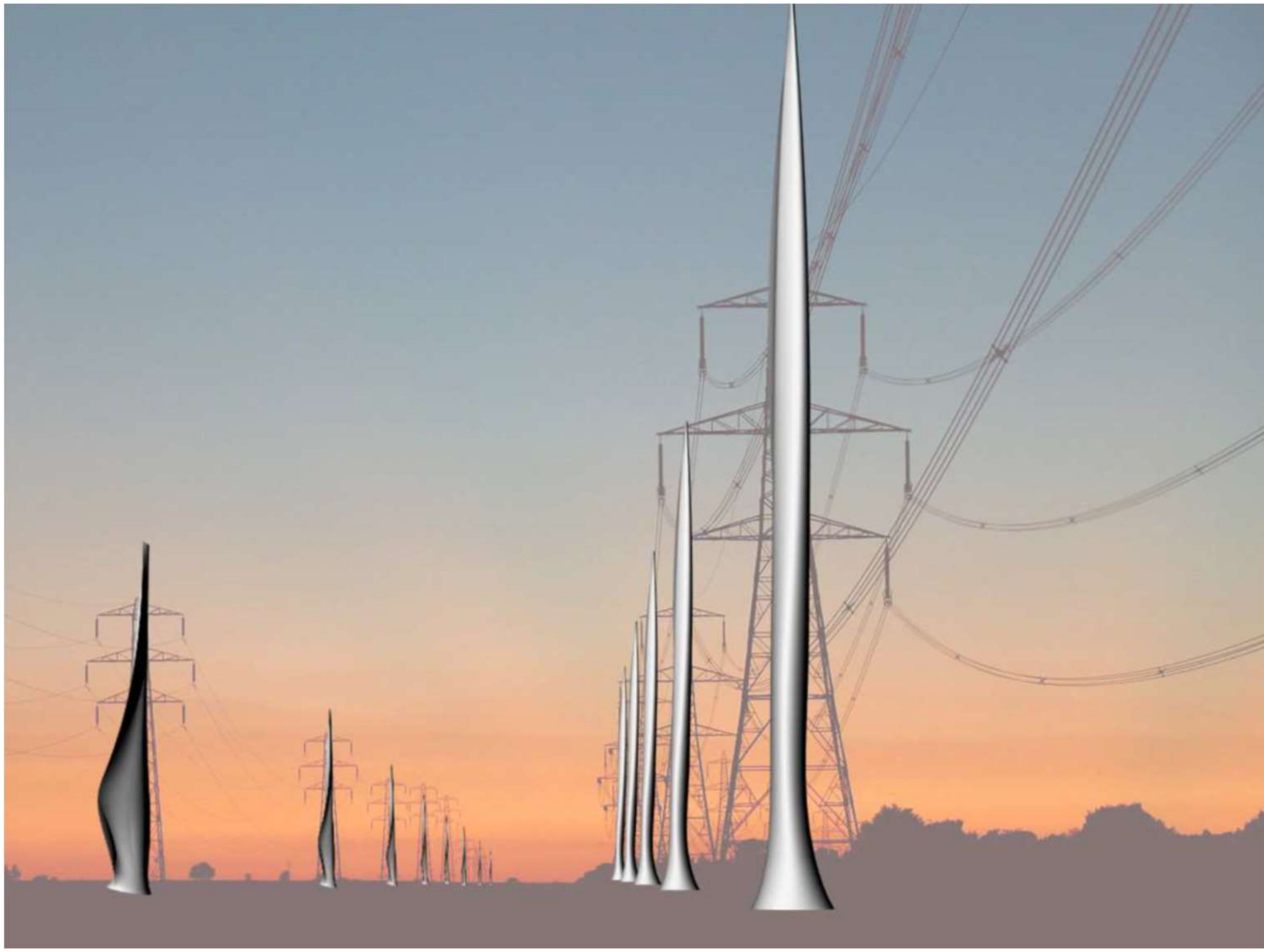
Shear Testing



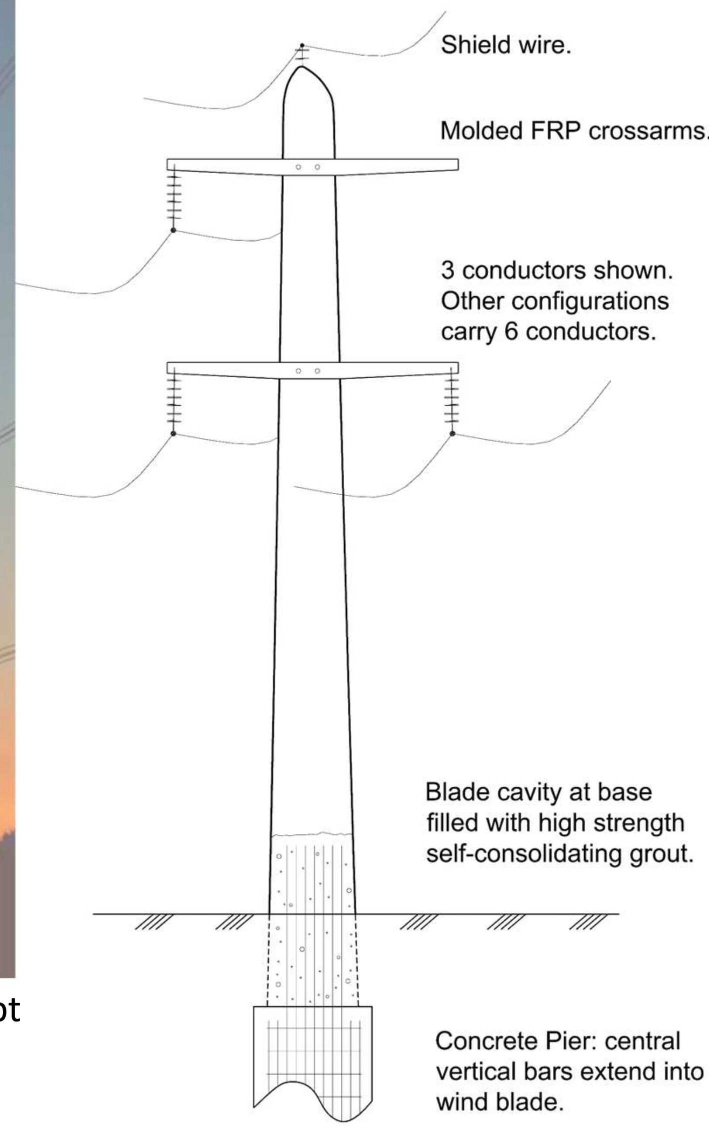
*Testing per ASTM D5379 - Standard Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method

35-L-1 (Longitudinal)





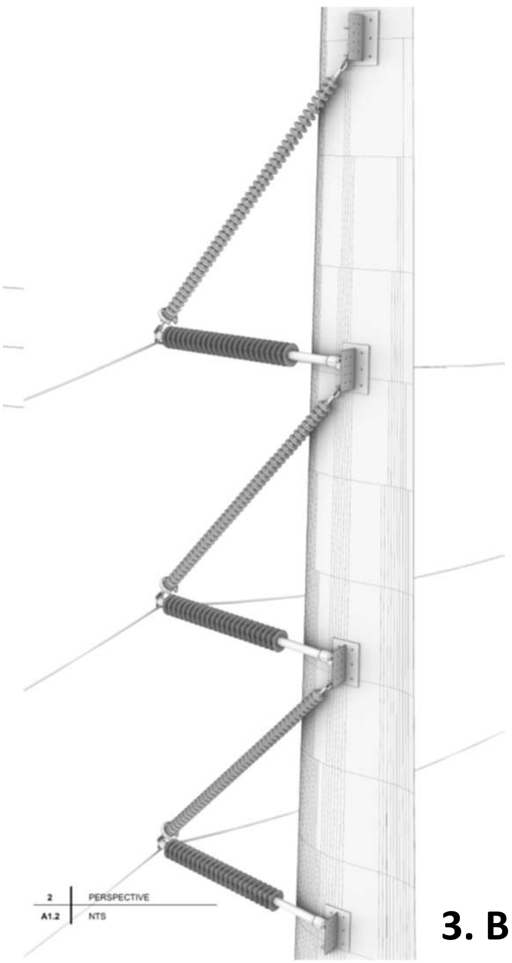
BladePole Concept



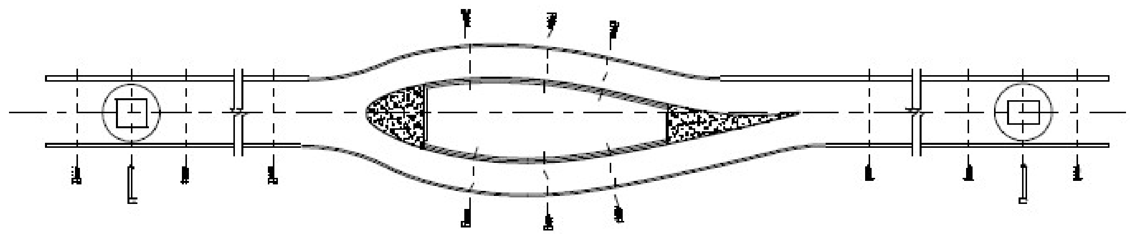
Georgia Tech

Competitors: Pre-Cast Concrete + Steel

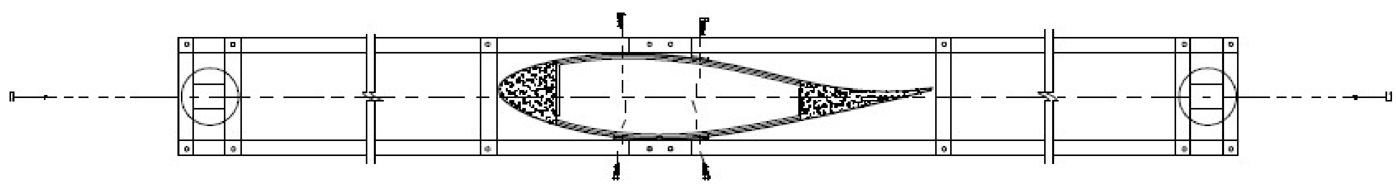
Crossarms Options



1. Molded FRP Composite

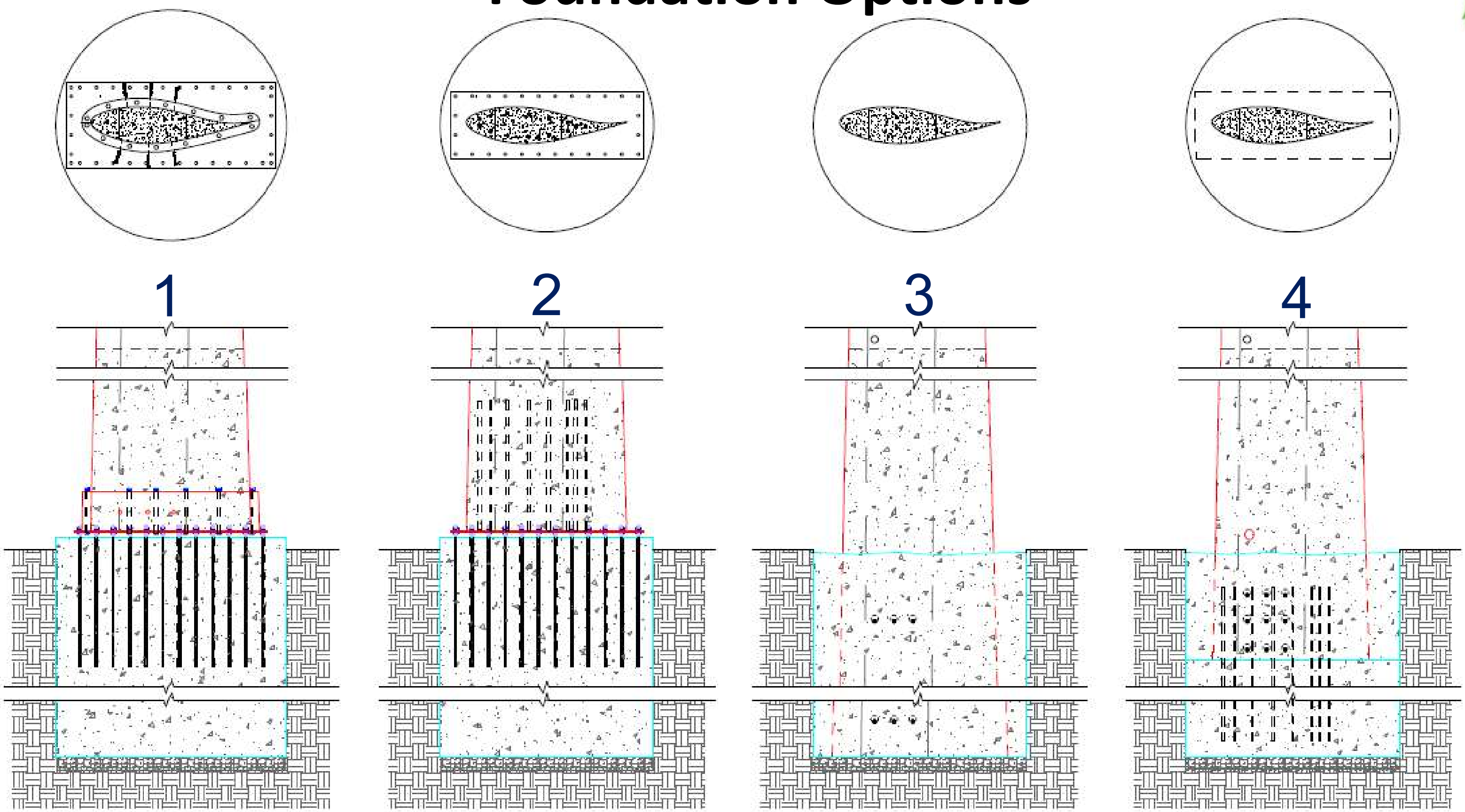


2. Conventional Timber Frame



3. Braced Line Post

Foundation Options

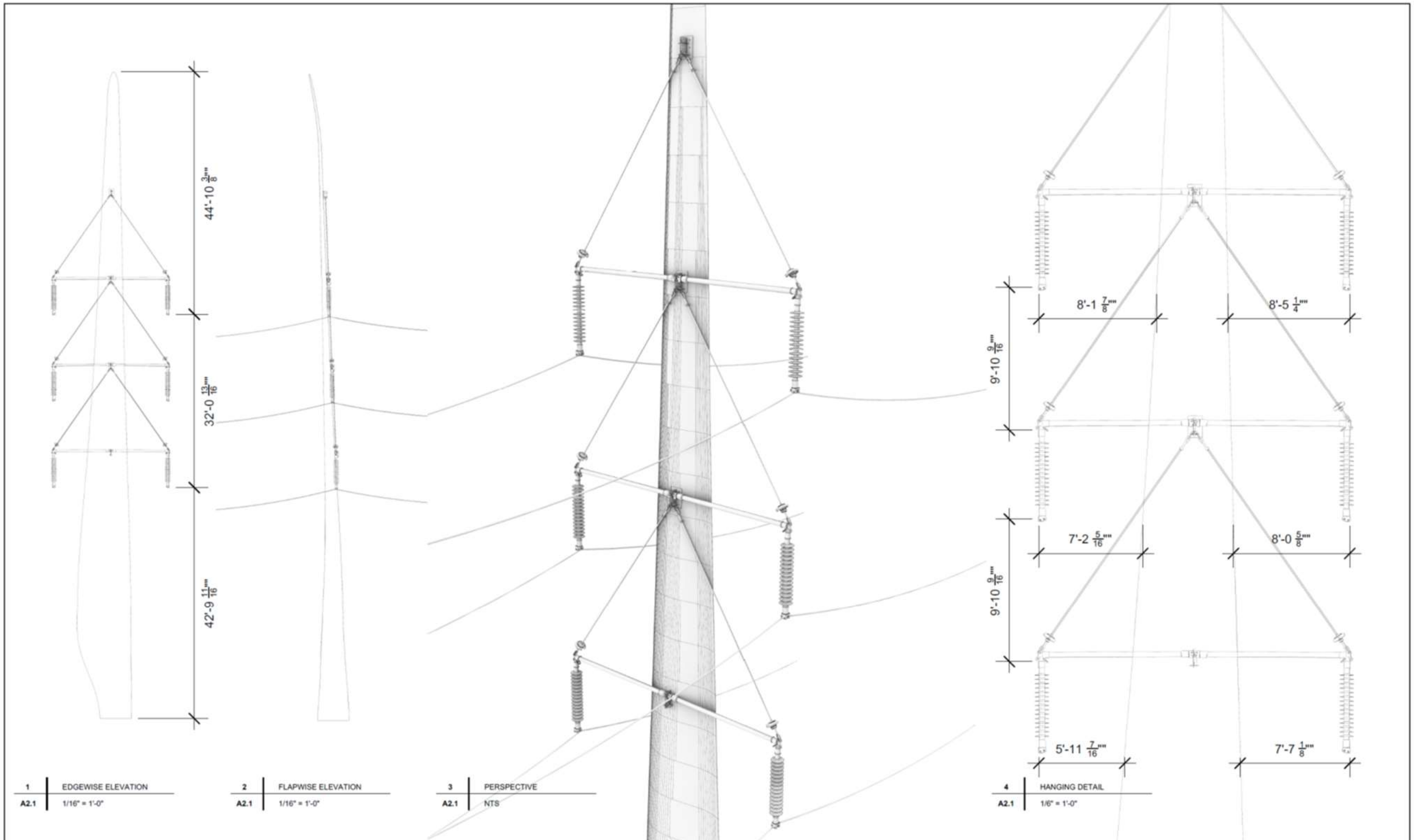


Base plate with welded rebars inserted in concrete filling and outside steel jacket

Base plate with welded rebars inserted in concrete filling

Direct Burial: Wind blade inserted in the concrete foundation with inside filling

Wind blade inserted in the concrete foundation with inside rebars and concrete filling



re-wind	RE-USE OF DESOMISSIONED WIND TURBINE BLADES	GEORGIA INSTITUTE OF TECHNOLOGY ATLANTA, GA 30332	DRAWN BY: AP 2/22/20	SIX HANGING	**A2.1**


end

BladeBridge: Repurposing Wind Turbine Blades as Greenway Bridges

Environmental, Social and Business Sustainability

25.03.21

Turbine end-of-life & the mounting GFRP blade ‘waste’ issue

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

2323

Emma Delaney, Re-Wind Queens University Belfast

Landfill will soon no longer be an option for end-of-life blades in Ireland

Circular Economy thrust @ Re-Wind

- The Re-Wind UCC team is focussed on:
  - Environmental sustainability
  - Social acceptability
  - Sustainable business models
- for second (& third) life applications for decommissioned wind turbine blades
- Complex, multifactorial problem…

Complex challenges require transdisciplinary approaches

- Re-Wind adopts a transdisciplinary approach to determine environmentally, socially and economically sustainable repurposing options for blades
- Academic Investigators (UCC)
    - Dr. Paul Leahy, Wind Energy Engineering,
    - Dr. Niall Dunphy, Political Science, Cleaner Production Promotion Unit
    - Dr. Ger Mullally, Sociology
- Postdocs & PhDs
    - Dr Peter Deeney (Finance),
    - Angela Nagle (Environmental),
    - Fergal Gough (Social/Community),
    - Heloisa Lemmertz (Circular Business Models)

Greenway network in Ireland

- €1 million/day allocated to cycle & walking infrastructure *(2020 Irish Program for Government)*

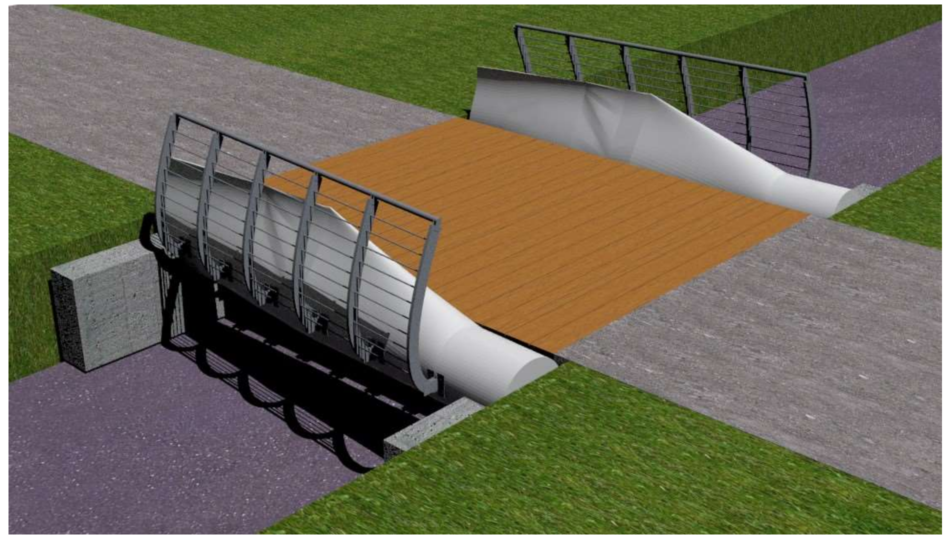
- UN SDG 12: Sustainable Consumption and Production - Ireland's Eurostat indicator for circular material use is the second lowest *(Clark et al, 2020)*

- An Excellent opportunity exists for repurposing blades in greenway bridges!

Map legend
Green: already exists,
Red, yellow, blue: planned or under construction

Greenway Blade-Bridge Project

- 5.5m bridge using Nordex N29 blades
- Strength testing on 3rd blade
- Development of fasteners
- Common blade model - replicable

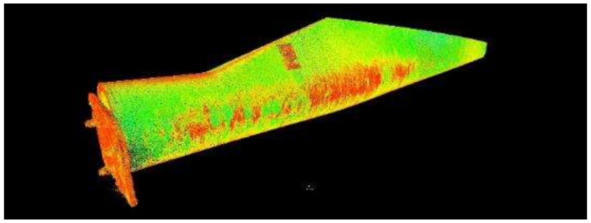


(Zoe Zhang, Re-Wind, Georgia Tech)

- Bridge design developed by Re-Wind structures group at Georgia Tech / Queens University Belfast

Blade Bridge Development, Test & Fabrication at MTU

- Nordex N29 blades sourced in Everun, Northern Ireland
- Delivered December 2020 to Structures Lab - Kieran Ruane, Lecturer in Structural Engineering at Munster Technological University, Chartered Civil Engineer
- Blade tests, bridge detailed design, build and load testing at MTU by the Technical Staff and Research Students
- Zoe Zhang visiting from Georgia Tech Jan-May 2021



3-D blade scan in Everun, Belfast by Conor Graham, QUB Re-Wind


NISSAN

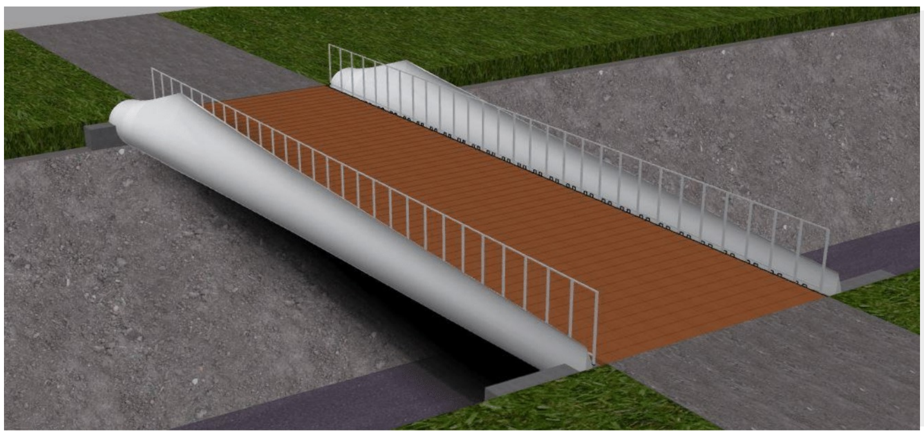

Keohane

Blade load testing at MTU

- 4-point bending test
- 4 m section taken from smaller end of blade
- Maximum load carried: 8,200 kg = 18078 lbs

BladeBridge Repurposing: Environmental Analysis

Functional Unit: Delayed disposal of 4500 kg 22m long blade (Vestas V44) over 60 years (Cradle to Grave)



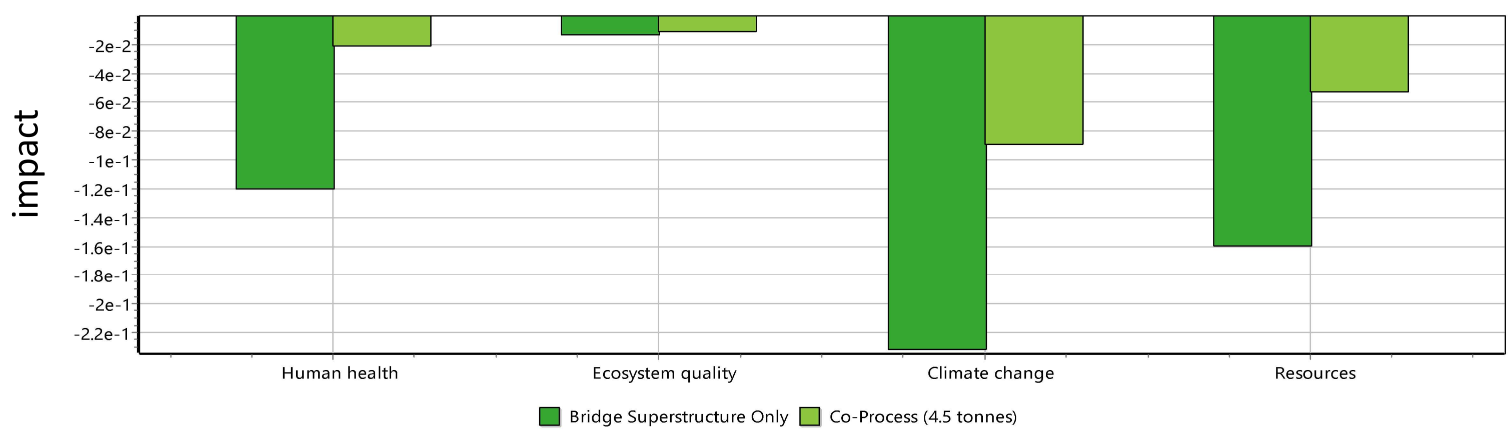
- Blades transportation 500 km Belfast to Cork
- Lower 2/3 blade replaces steel girders made with partially recycled material
- Top 1/3 blade sent to landfill
- Blades coated in epoxy protective layer
- End of Life Plan: Co-processing of GFRP girders, recycling of hardware

Wooden decking material, abutments, and maintenance schedule assumed equal to bridge made with steel girders
The BladeBridge case study will inform the environmental, social and business model research of Re-Wind

Presented by Angie Nagle, ReComp 25th November 2020

Blade bridge : environmental results

- Blade bridge environmentally preferable to alternative end-of-life treatments: co-processing or landfill (baseline, not shown)
- Integrated environmental, social and economic assessments
  - P. Deeney, article in review" Multi-criteria Decision Analysis using the Sustainable Development Goals for end-of life choices for wind turbine blades"



Method: IMPACT 2002+ V2.15 / IMPACT 2002+ / Normalisation
Comparing 1 p 'Bridge Superstructure Only' with 1 p 'Co-Process (4.5 tonnes)';

Thank you!

Acknowledgements to Re-Wind research team at University College Cork, Queens University Belfast, and Georgia Tech and Munster Technological University

Photos: Angela Nagle, Kieran Ruane, Conor Graham, Zoe Zhang

Re-Wind contacts:

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www.re-wind.info

New Frontier for Construction Materials
Decommissioned Wind Blades

BladeLogic — A GIS logistics framework for wind blade repurposing

Jennifer McKinley, Emma Delaney and Conor Graham, Marios Soutsos, Chantelle Niblock, An Huynh

Geography, Civil Engineering and Architecture

School of Natural and Built Environment,

Queen's University Belfast, UK

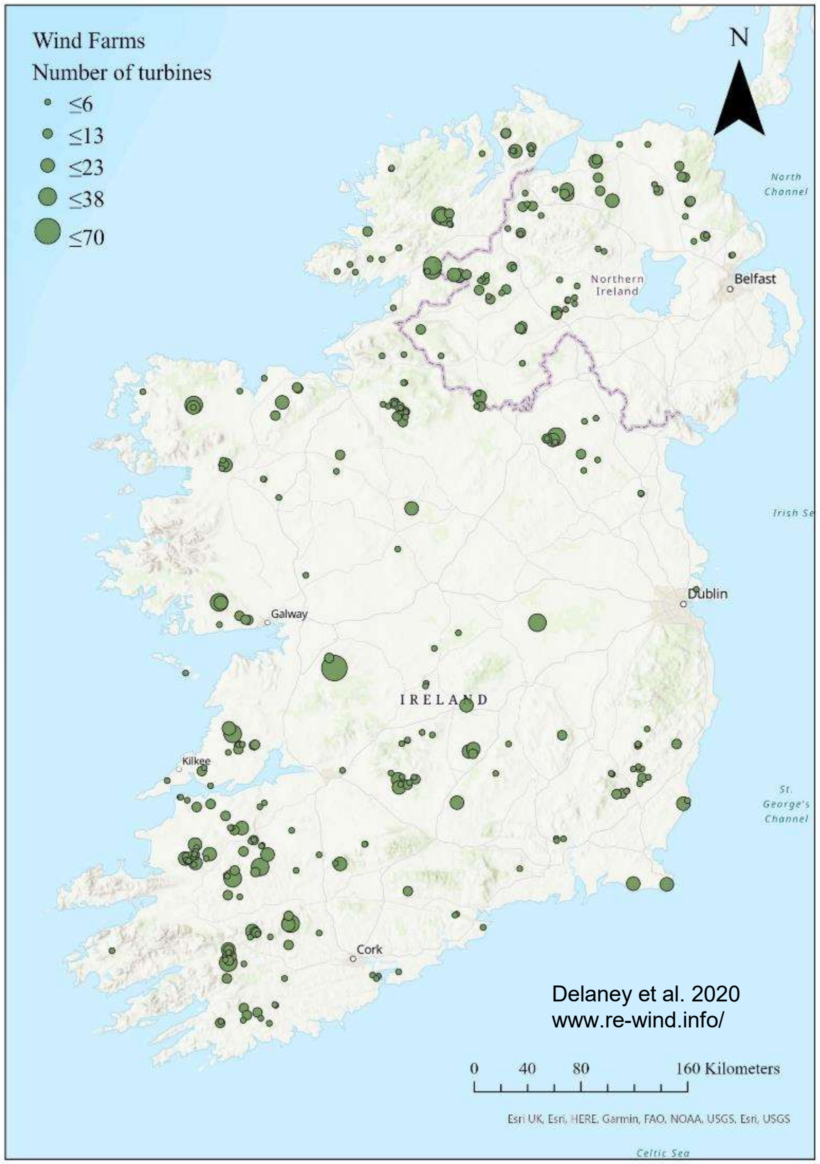
www.re-wind.info/

Re-Wind: Driving Innovation in the Re-Use of Decommissioned Wind Turbine Blades

Supported by InvestNI/Department for the Economy (DFE), Grant USI-116; by Science Foundation Ireland, Grant 16/US/3334; and by the U.S. National Science Foundation under grants numbers 1701413 and 1701694, under the project "Re-Wind".
Re-Wind, 2020.

Georgia Tech | Queen's University Belfast | The City University of New York | UCC University College Cork, Ireland – Coláiste na hOllscoile Corcaigh

- Wind Thrust
- Mechanics Thrust
- Design Thrust
- Geographical Information Science (GIS) Thrust



Driving Innovation through Geographical Information Science (GIS)

A GIS-based decision framework to provide wind energy stakeholders with a methodology to evaluate and compare sustainable repurposing strategies for FRP composite material wind turbine blades

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Re-wind GIS Dashboard

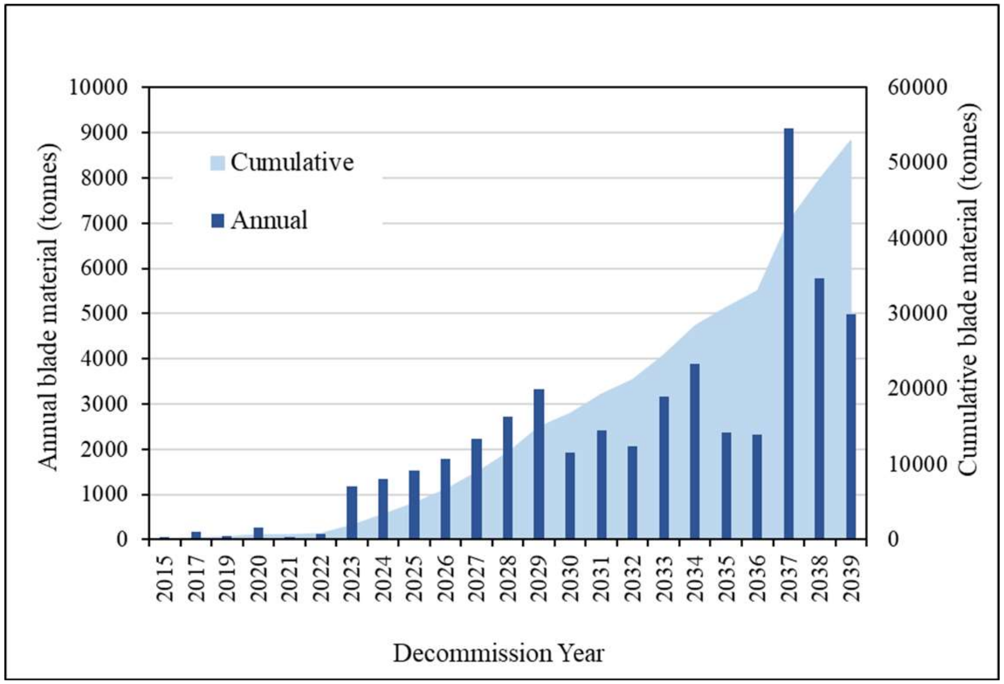
The Re-Wind database provides information on wind farm locations represented as point data with attribute data including manufacturing details, developers and commission dates.

This has resulted in a comprehensive and most up-to-date database for onshore wind in Ireland which enables the prediction of decommission dates and waste material quantities

https://www.re-wind.info/

Delaney et al. 2020 in review

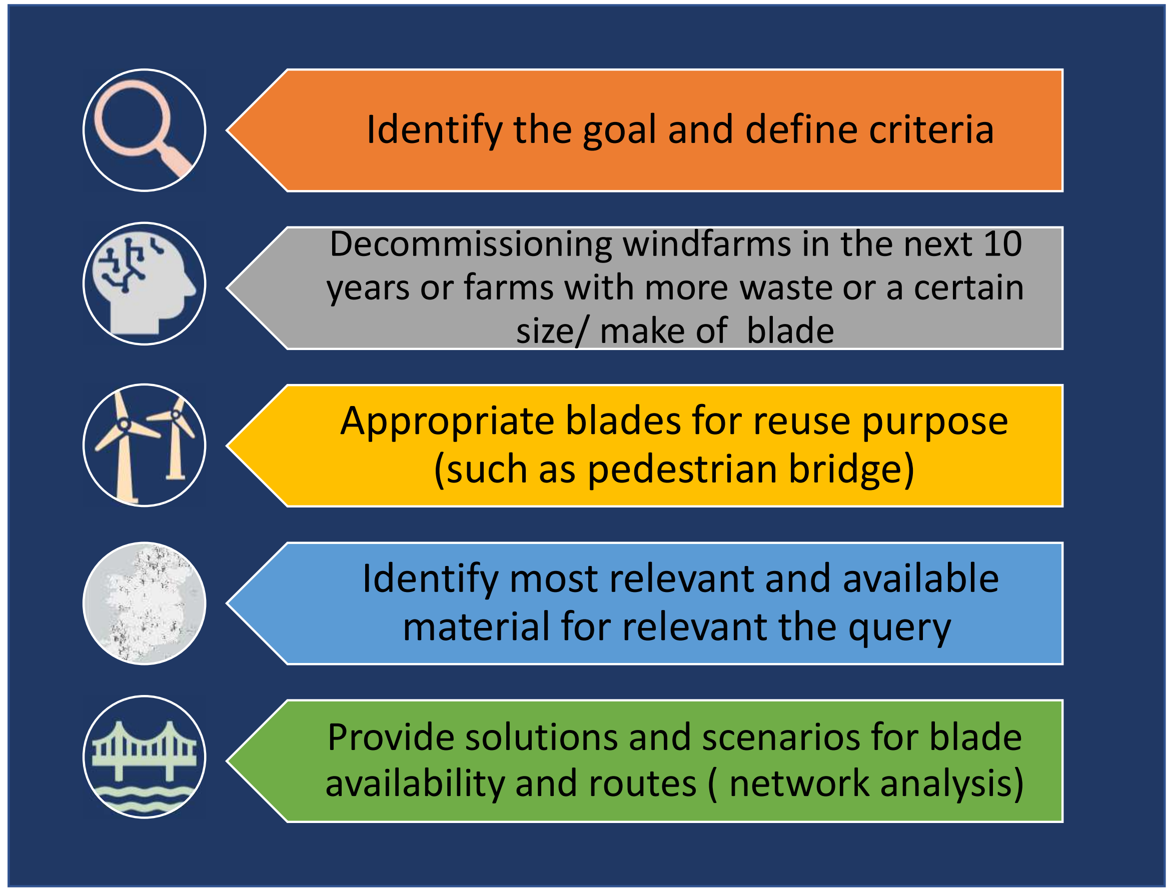
Irish blade material



- Approximately **53,000** tonnes expected by 2039
- 20-year design life
- Exact blade weights & 10.33t/MW
- Begins to accumulate around 2023
- Varies annually

GIS Decision-making process

GIS analysis to assist in finding the most sustainable re-use strategies for wind turbine blades



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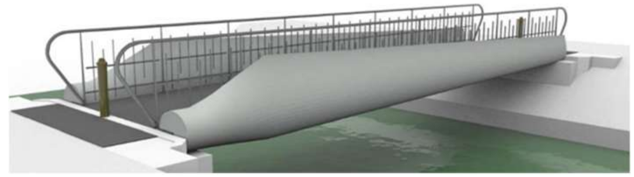
Greenways



Suhail et al. (2019)

Re-Wind, 2020. https://www.re-wind.info/

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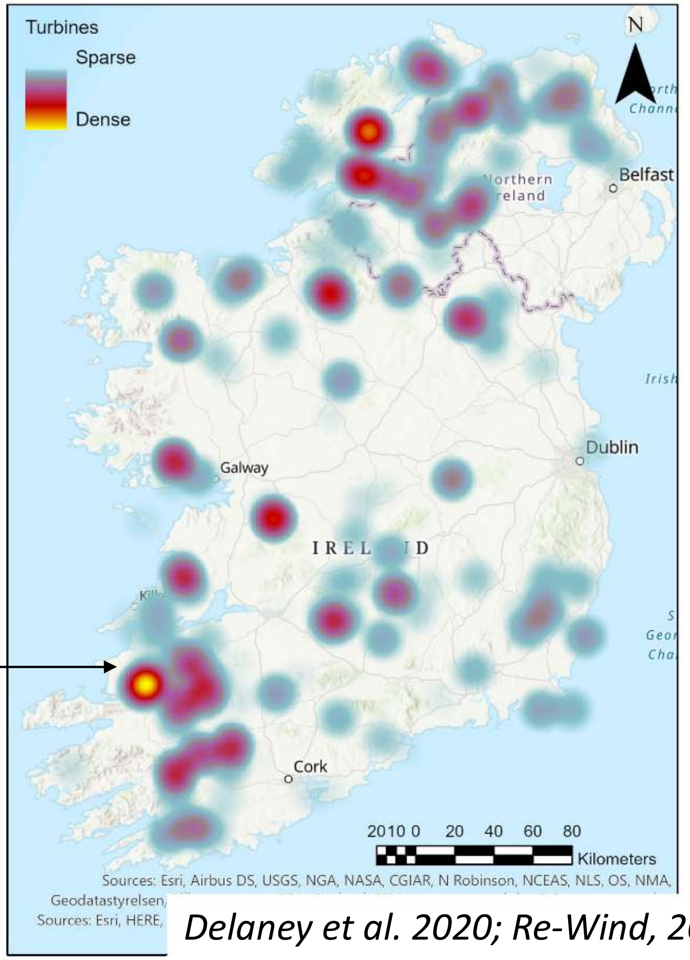
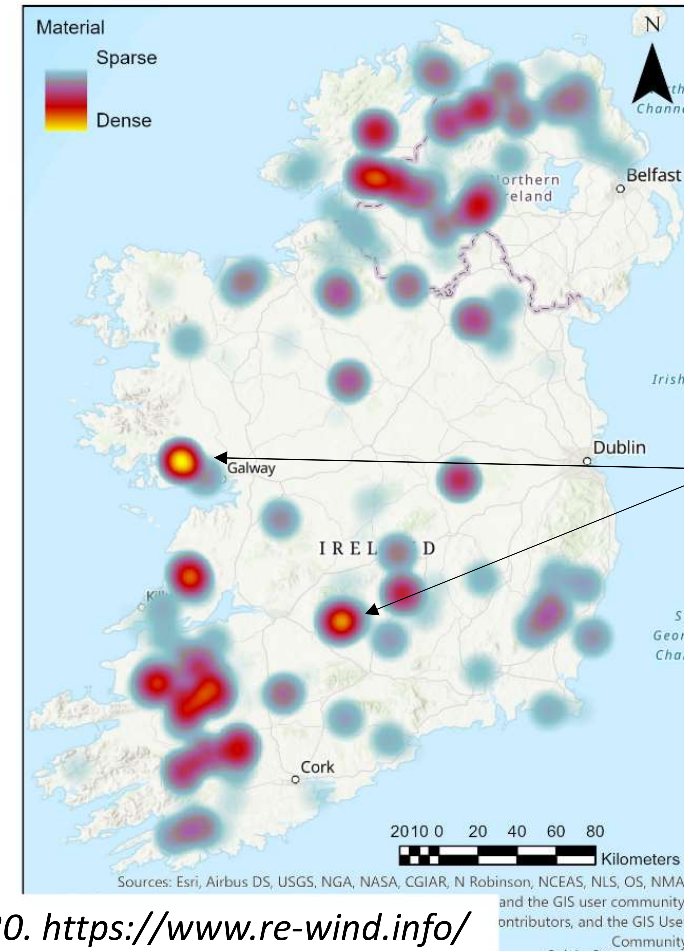
Georgia Tech | QUEEN'S UNIVERSITY BELFAST | THE CITY UNIVERSITY OF NEW YORK | UCC University College Cork, Ireland Coláiste na hOllscoile Corcaigh

Delaney et al. 2020
www.re-wind.info/

Material Locations





Highest density of turbines

Highest density of repurposing material

Delaney et al. 2020; Re-Wind, 2020. https://www.re-wind.info/

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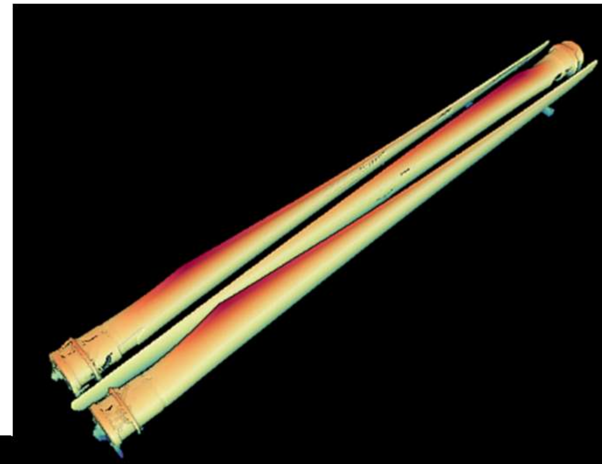
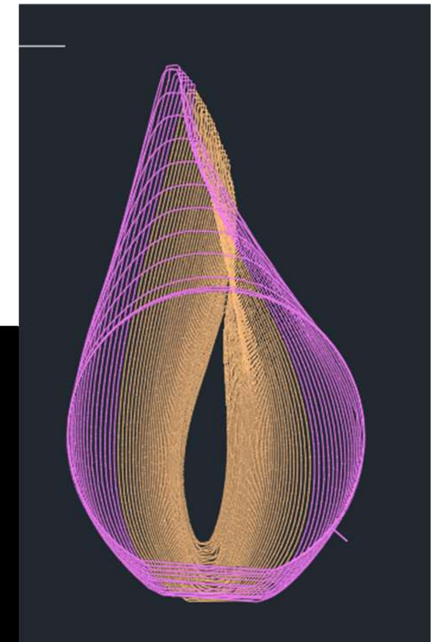
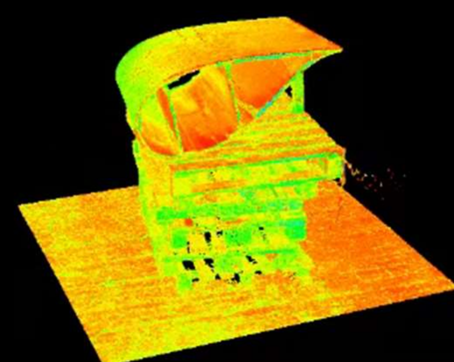
LiDAR scans of Vestas V52
(using Leica ScanStation P30/P40)

Scanner has a range accuracy of 1.2mm and xyz of 3mm up to 50m to target







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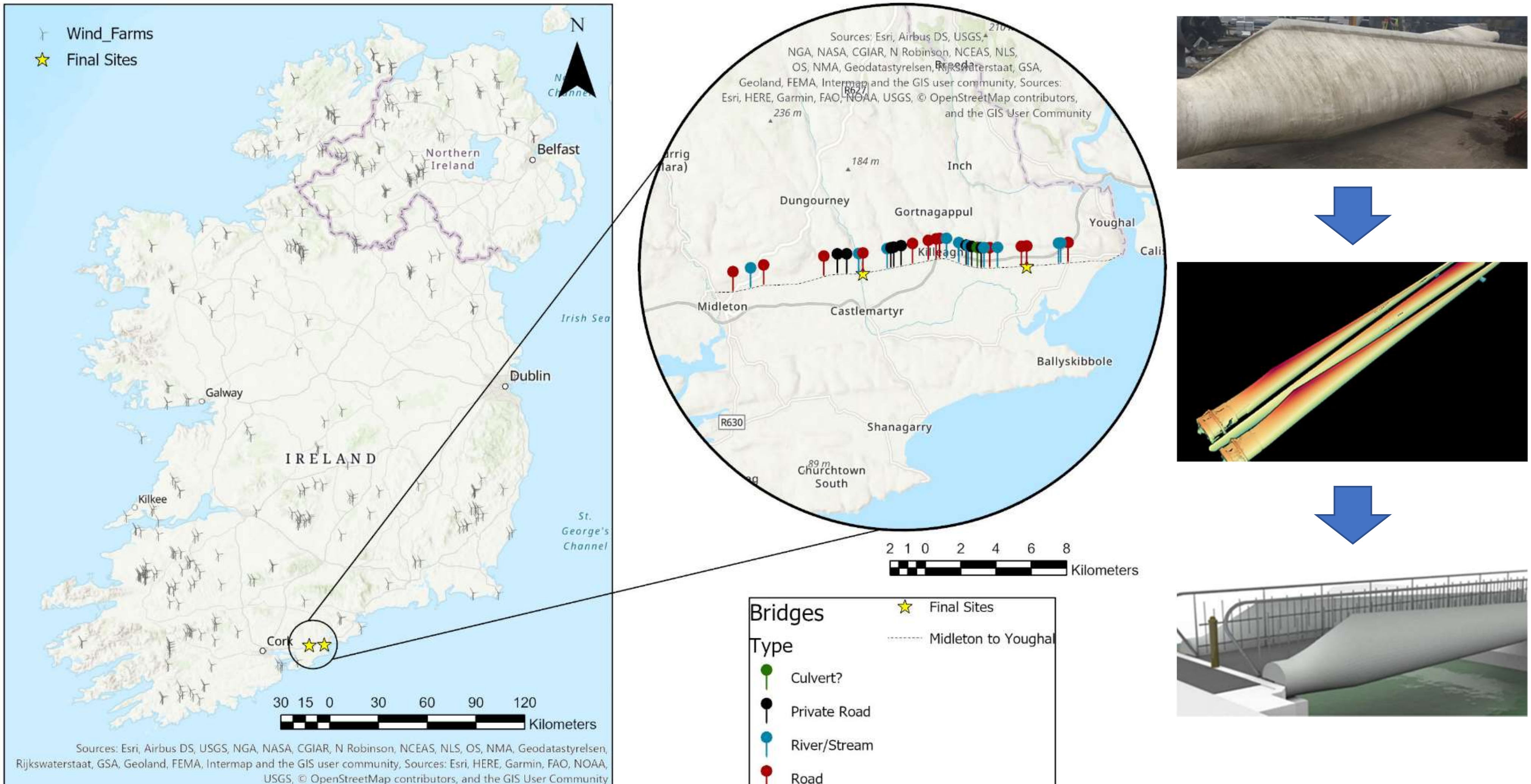
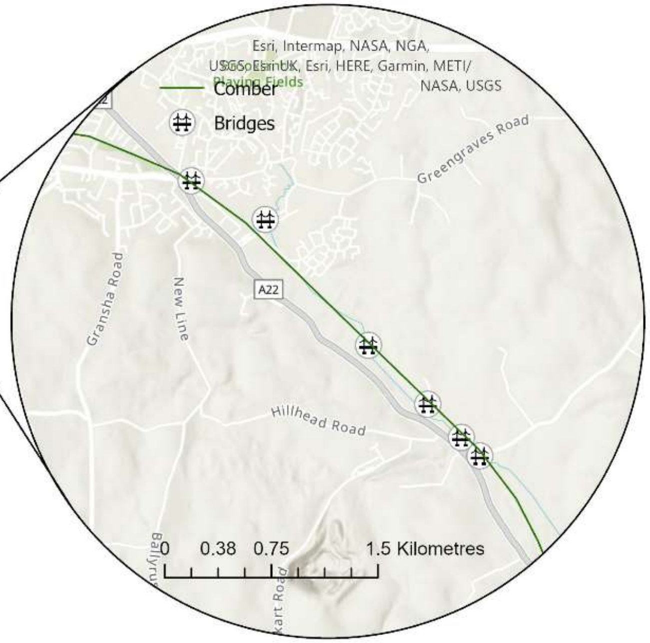


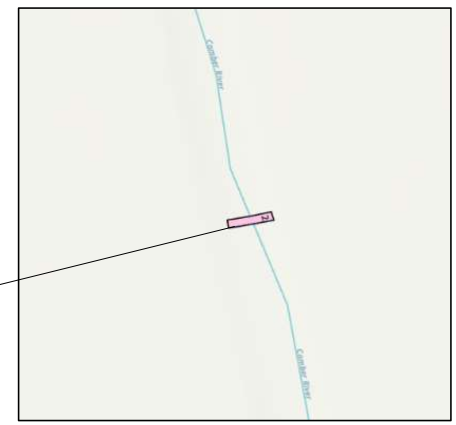
QUEEN'S UNIVERSITY BELFAST

Delaney et al. 2020; Re-Wind, 2020. https://www.re-wind.info/



Comber greenway- existing greenway bridges

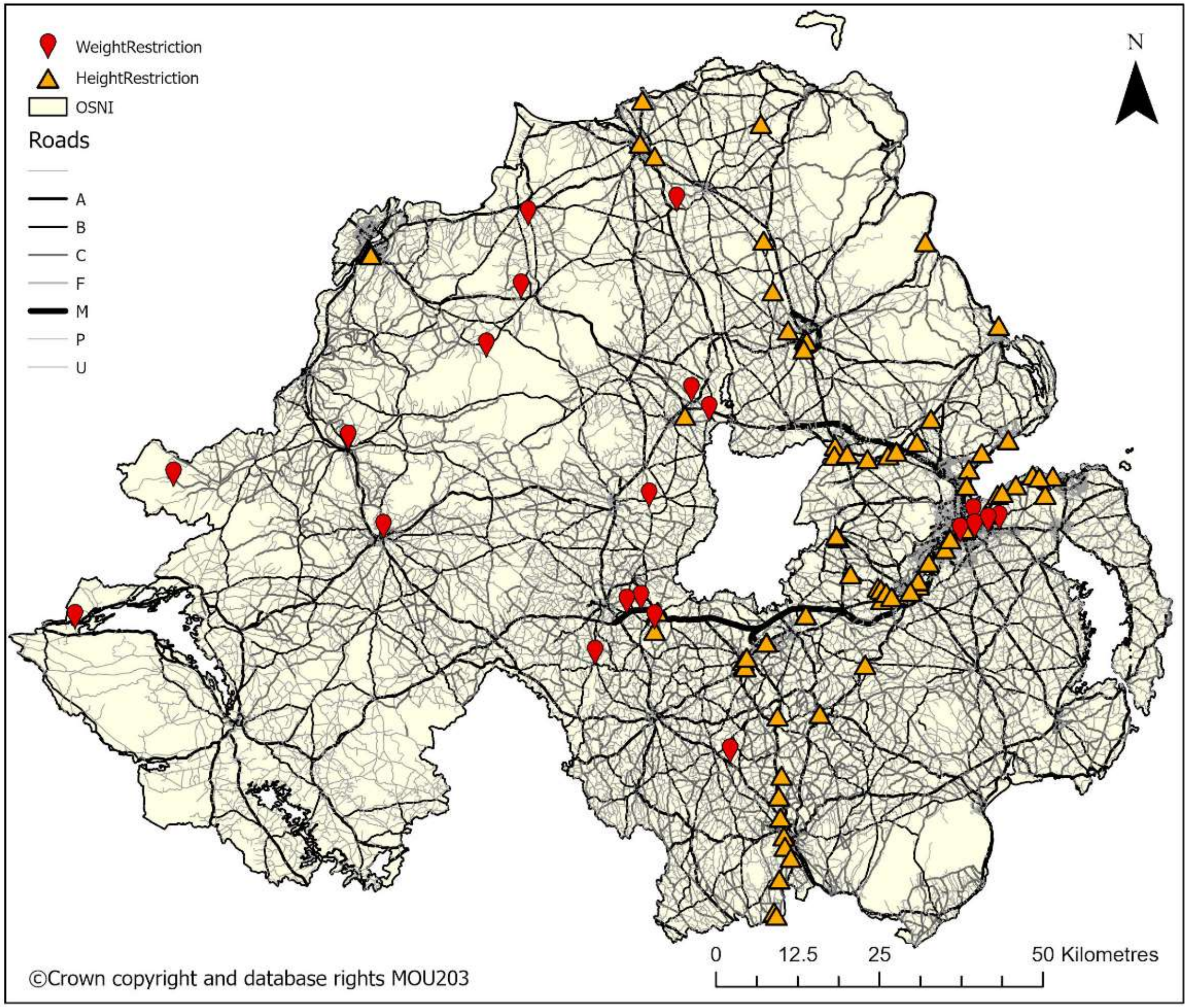
FID	Shape *	Id	Type	Length	Width
0	Polygon	0	River	13	2.35
1	Polygon	0	River	13	4
2	Polygon	0	River	13	2
3	Polygon	0	Road	11	3.5
4	Polygon	0	River	13	3.5
5	Polygon	0	Road	18.5	3.5



Data required	Method	Scenario
• 2D road network • Digital Elevation Model (DEM)	3D Road Network	
• Emissions Model (COPERT) • Case study scenario	Fuel Consumption calculation	
• 3D Network • Wind farm database • Candidate remanufacturing sites	Routing L-A Eco-route	

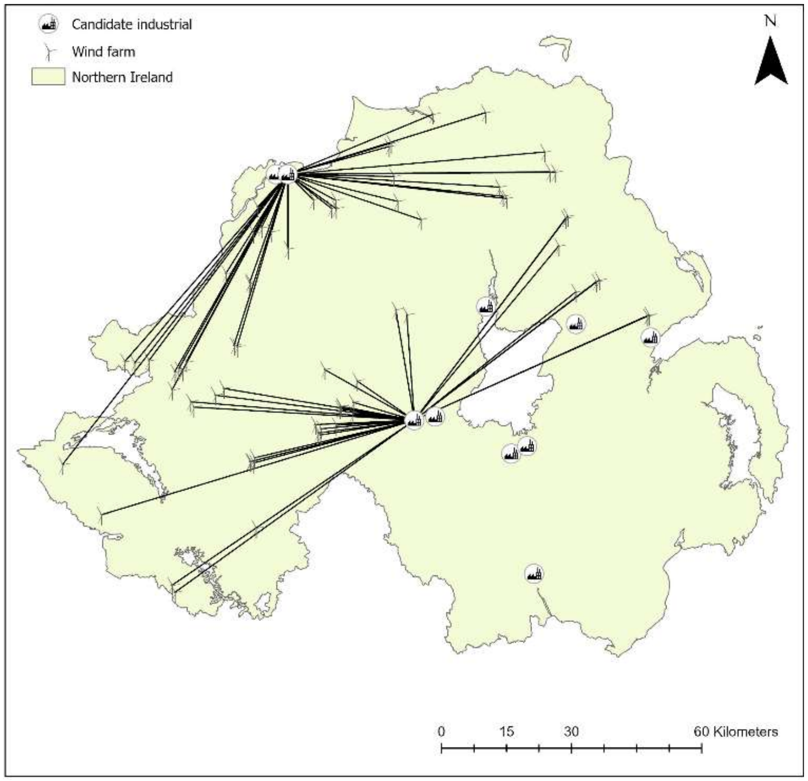
Scenario

- Wind farm locations
- Blades cut to fit a standard flatbed truck ~16-32t truck
- Approximately half loaded – blades are bulky and less likely to be full loads
- Candidate sites (already selected)


WeightRestriction
HeightRestriction
OSNI
Roads
A
B
C
F
M
P
U
N
0
12.5
25
50 Kilometres
©Crown copyright and database rights MOU203

Location-Allocation

Route	Distance (km)	Fuel consumption (L)
Eco (3D)	54.4	19.7
Shortest (3D)	54.2	21



- Optimum location for re-manufacturing sites
- Heavier weight for wind farms with more blade material
- Costs: Minimising fuel consumption

Eco vs shortest route

- Eco route is 0.2 km longer
- Saves 1.3 litres
- Adds up with multiple runs

Final thoughts

Re-Wind, 2020. https://www.re-wind.info/

- With the rapid development of wind energy technology in the past 15 years comes a new conundrum: how to dispose of the non-biodegradable blades in current wind turbines in a sustainable way.
- Reuse and recycling strategies must be found that will prevent environmentally and socially unpalatable and unsustainable landfilling and incineration of composite material wind blades.
- The GIS Thrust aims to show the benefits of a spatial database and GI Science for wind blade reuse and recycling, containing embedded reuse design options and their environmental, economic and social impacts for subsequent network analysis.

Thank you

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www.re-wind.info/

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Queen's University Belfast, UK