COMPARATIVE LIFECYCLE ANALYSIS BETWEEN WIND TURBINE BLADES REPURPOSED AS ENERGY TRANSMISSION POLES AND CONVENTIONAL STEEL POLES

Yulizza Henao, Angela Nagle, Russell Gentry, Lawrence Bank, Tristan Al-Haddad

yulihenao@gatech.edu
www.re-wind.info

NOCMAT 2022

21 June 2022

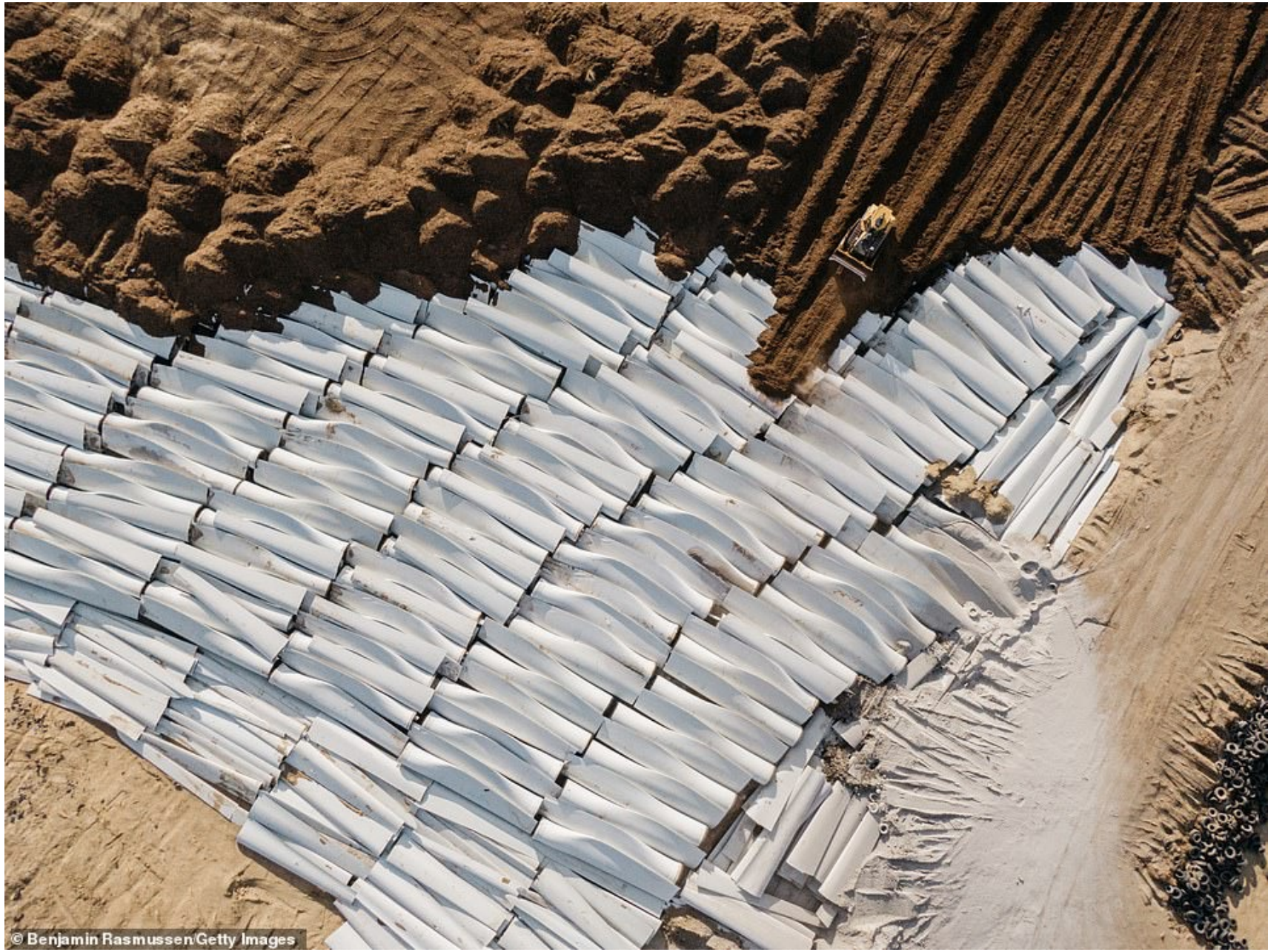
Georgia Tech Digital Building Laboratory
College of Design

RE-WIND NETWORK
BLADE REPURPOSING SOLUTIONS
WWW.RE-WIND.INFO

CUNY THE CITY UNIVERSITY OF NEW YORK
Georgia Tech
QUEEN'S UNIVERSITY BELFAST
UCC University College Cork, Ireland
NSF
SFI
Department for the Economy

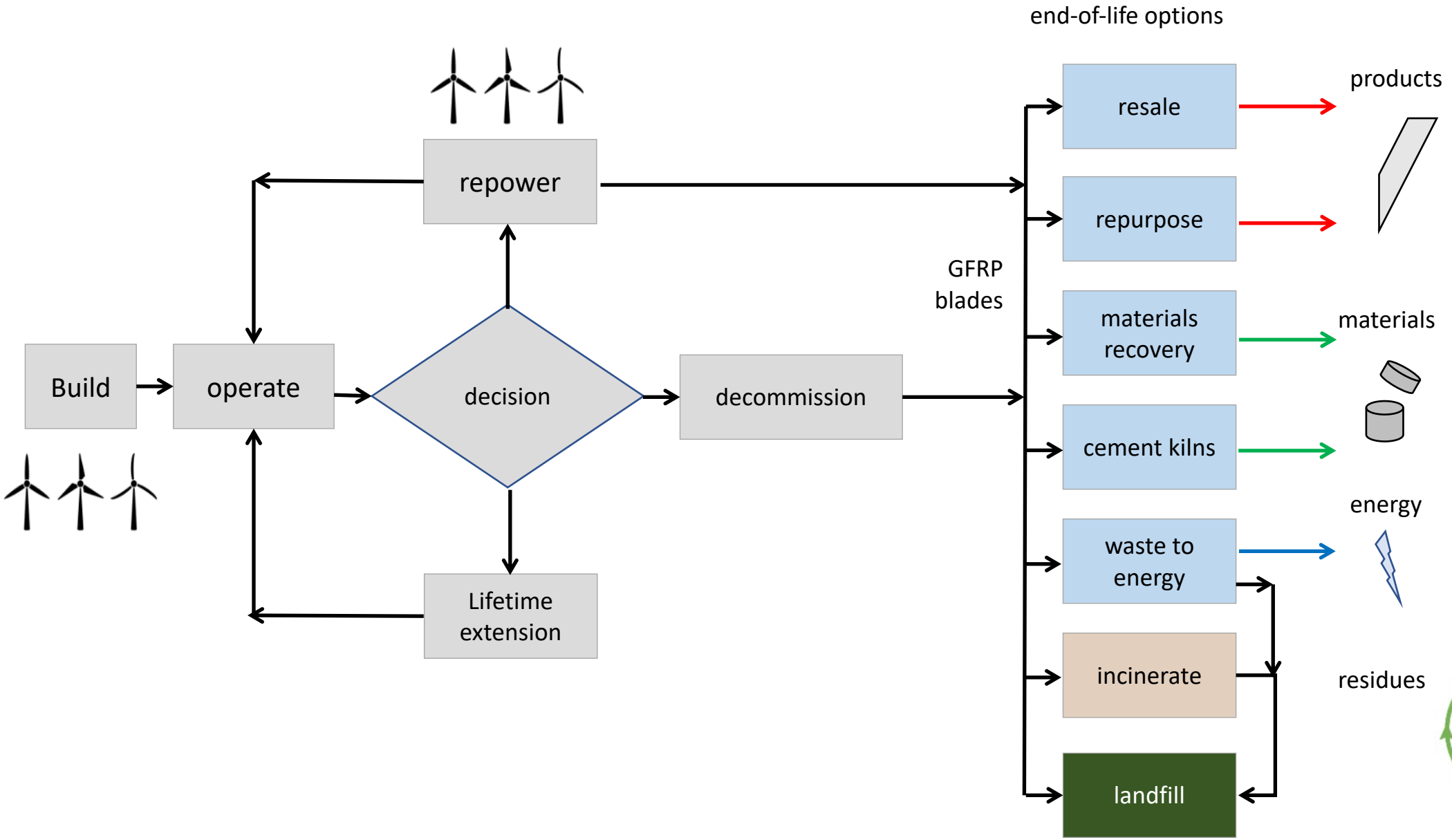
Motivation:

Around 8,000 wind turbine blades will need to be removed and disposed of every year in the United States alone.

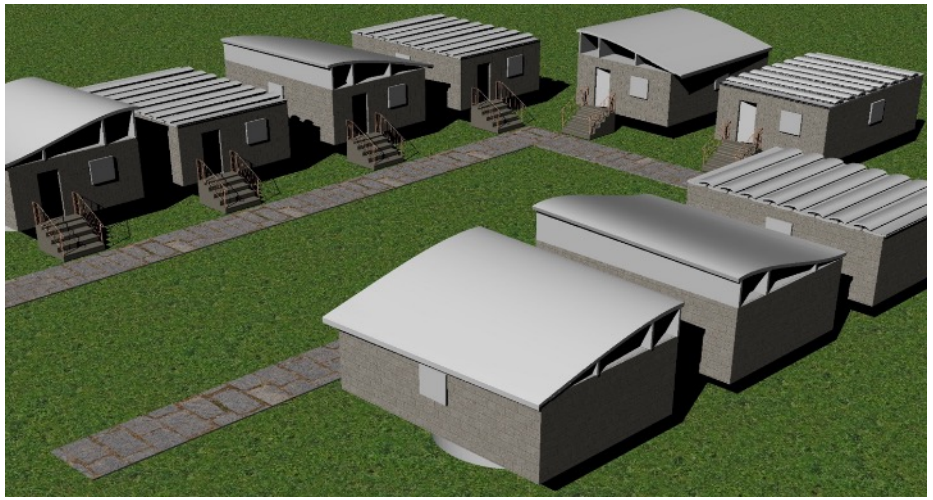


Wind Blades in Landfill
(Bloomberg, 2020)

Wind farm lifecycle



Re-Wind Blade Repurposing Concepts



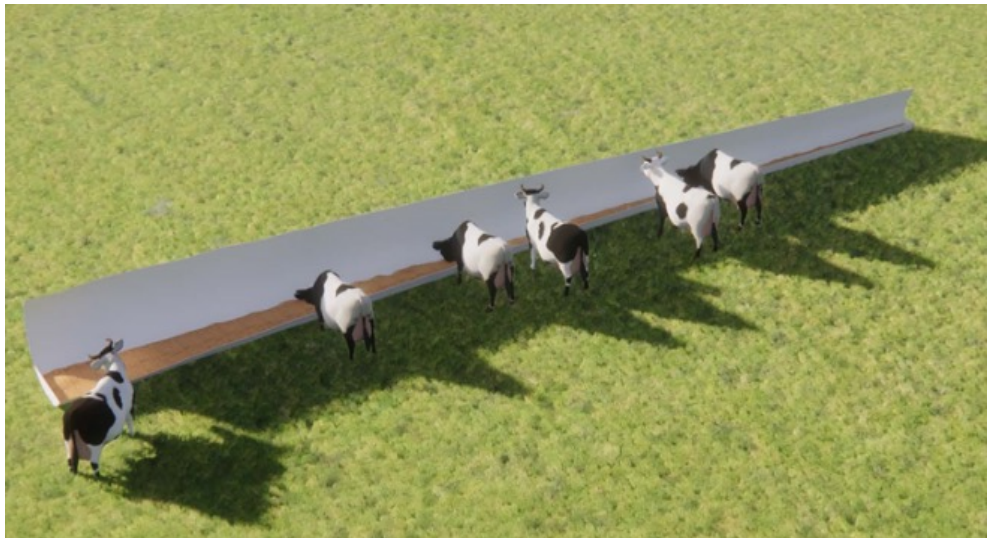
BladeHousing

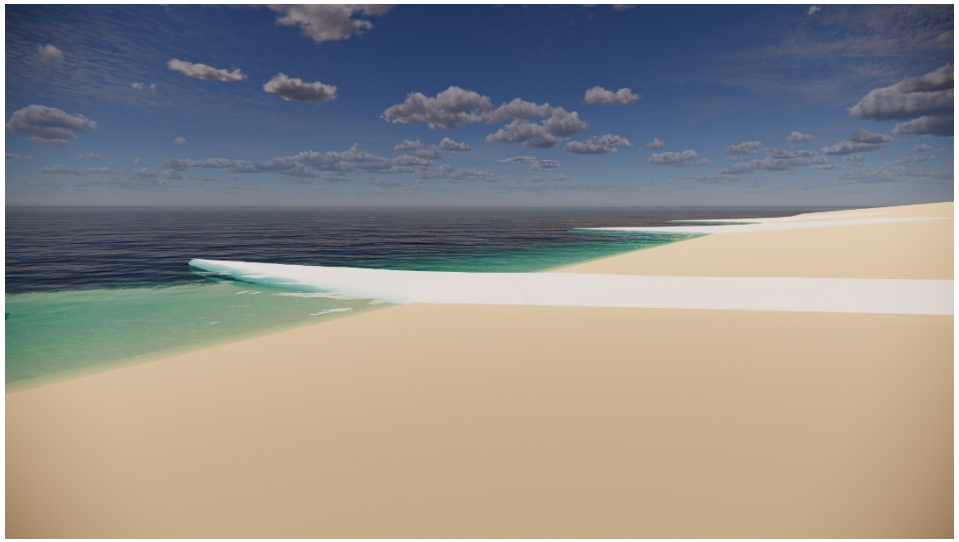
BladeBridge

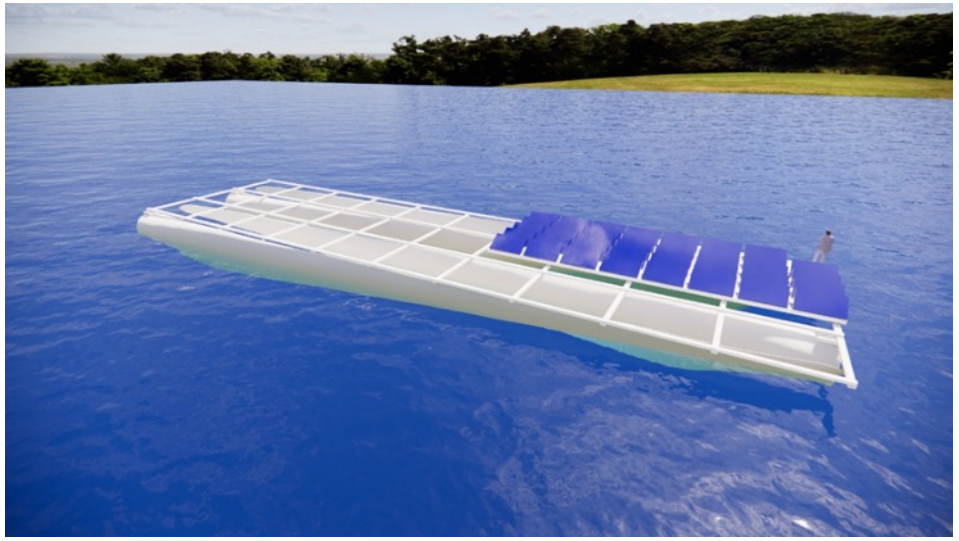
BladePole

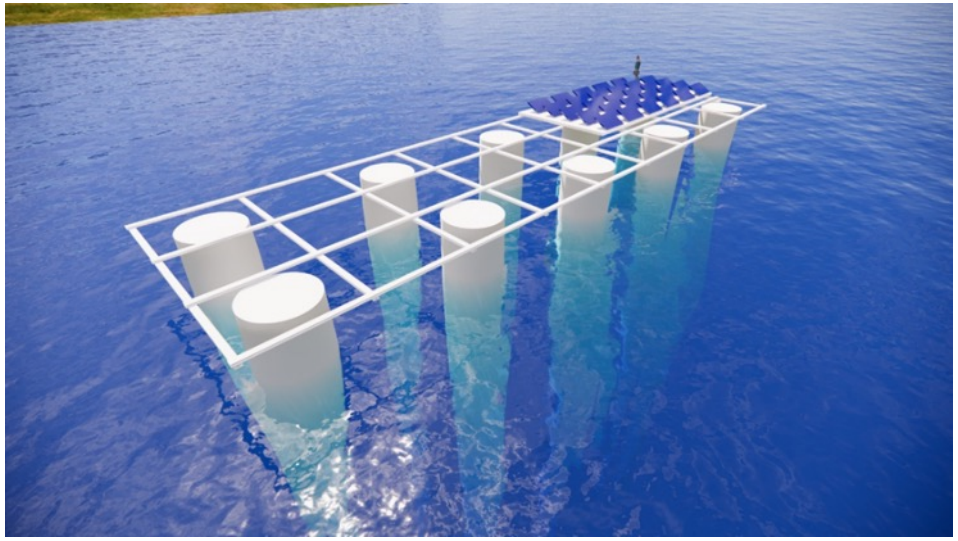
BladeBarrier

Re-Wind Blade Repurposing Concepts









BladeBridges

BladeBridge

Cork, Ireland, January 2022

Nagle, Angela J., et al. "Life cycle assessment of the use of decommissioned wind blades in second life applications." Journal of Environmental Management 302 (2022): 113994.

Georgia Tech

CUNY THE CITY UNIVERSITY OF NEW YORK

UCC University College Cork, Ireland Coláiste na hOllscoile Corcaigh

QUEEN'S UNIVERSITY BELFAST

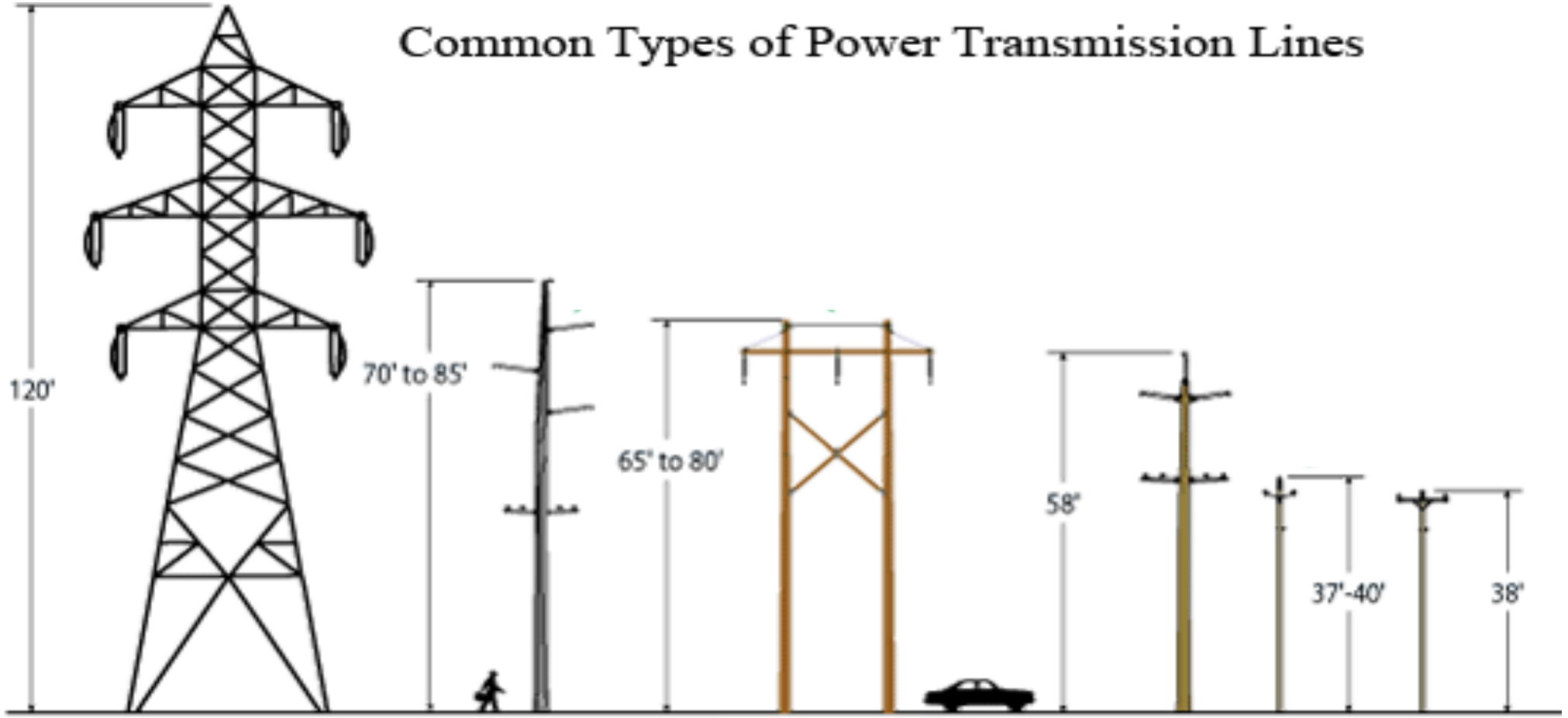
MTU Ollscoil Teicneolaíochta na Mumhan Munster Technological University

RE-WIND NETWORK BLADE REPURPOSING SOLUTIONS WWW.RE-WIND.INFO

BladePole


RE-WIND
NETWORK
BLADE REPURPOSING
SOLUTIONS
WWW.RE-WIND.INFO

Common Types of Power Transmission Lines



Typical Double-circuit 345 Kv Lattice Tower

Typical Single-circuit 138 Kv Wood or Steel Pole Structure at 300' Spacing

Typical Single-circuit 138 Kv H-frame Structure at 600' Spacing

Typical Single-circuit 69 Kv Wood Pole Structure

Typical Single-circuit 12 Kv or 34.5 Kv Wood Pole Structures

Transmission and Sub-Transmission Lines

Distribution Lines

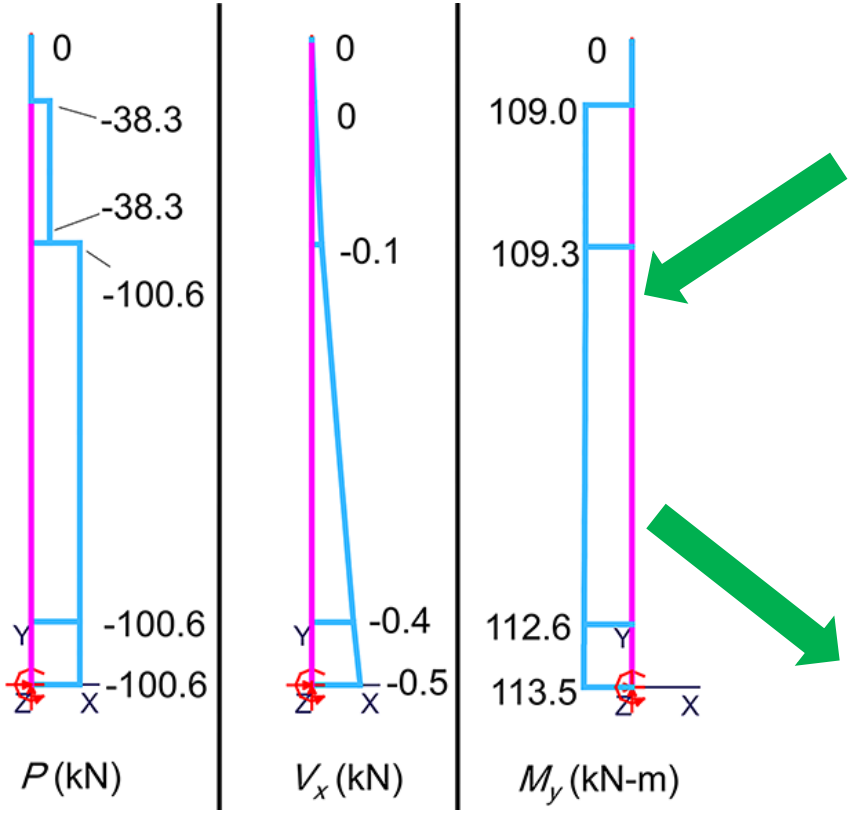
Steel Pole

Tube with a thickness ~ 0.2 in

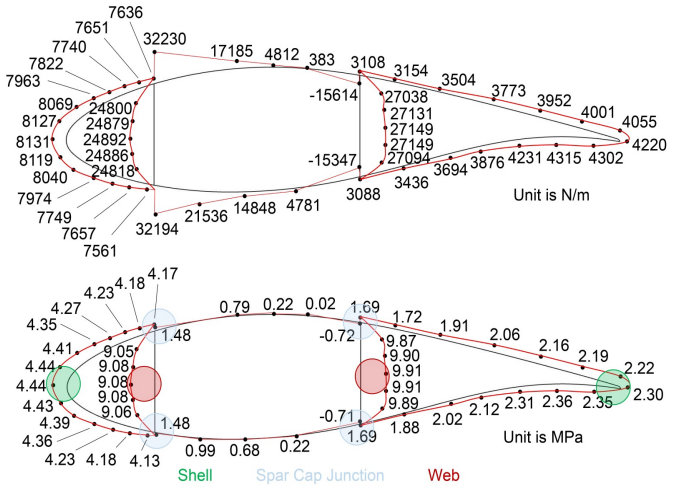
Wood Pole

BladePole Application – Structural Analysis

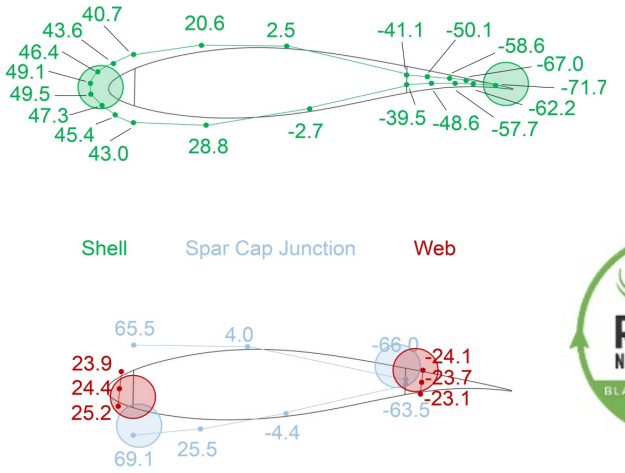
Alshannaq, Ammar A., et al. "Structural analysis of a wind turbine blade repurposed as an electrical transmission pole." Journal of Composites for Construction 25.4 (2021): 04021023.



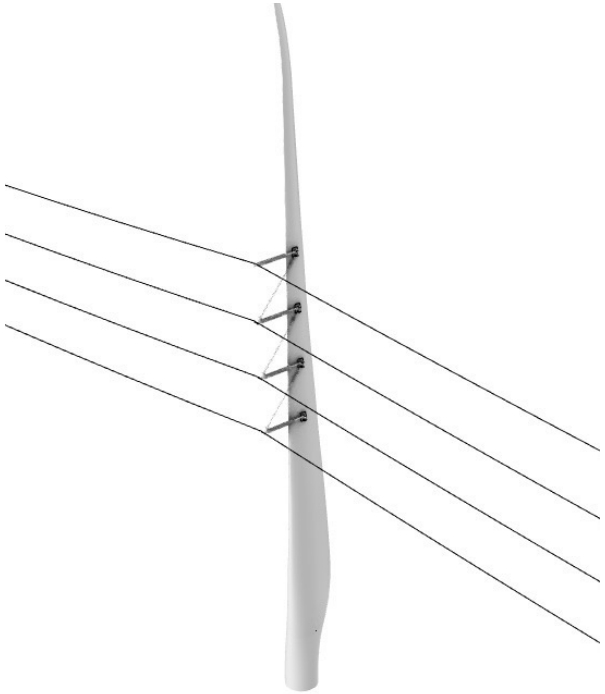
*Based on power poles loads from ASCE 74 and NESC



Shear + Torsion



Axial + Bending

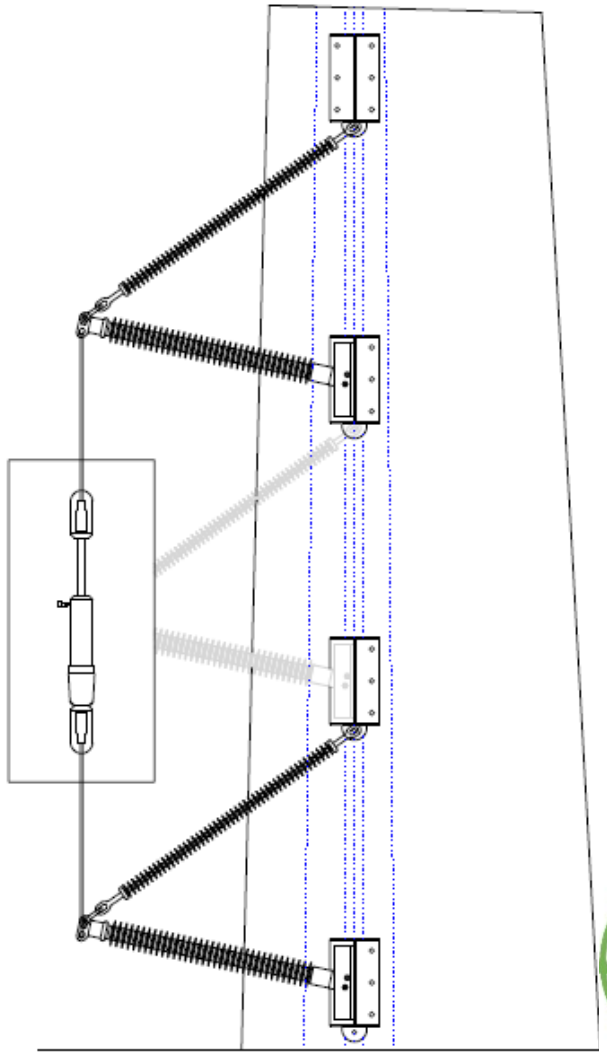


BladePole Prototype

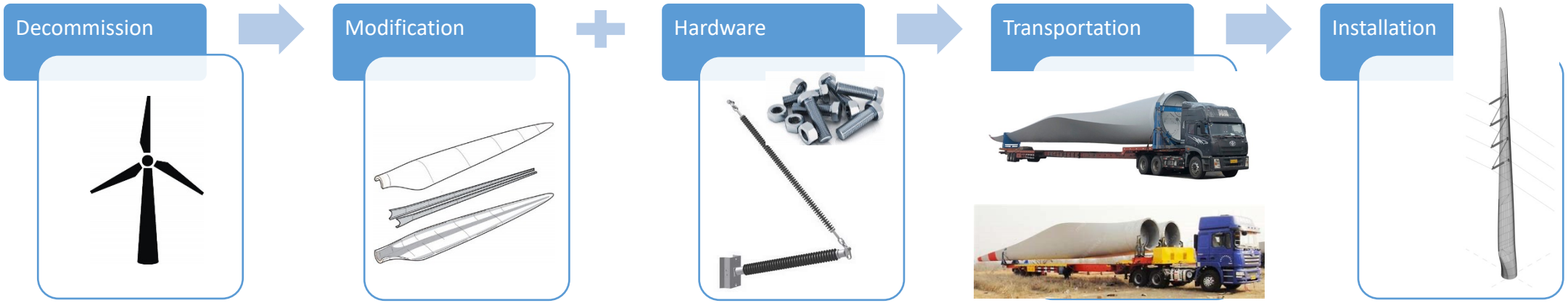
Georgia Tech

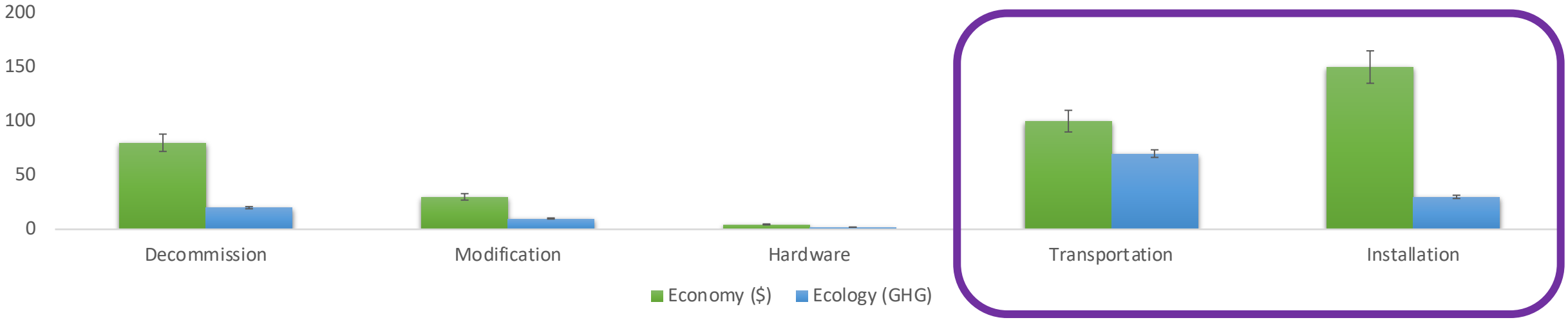
Digital Fabrication Laboratory

BladePole Application – Full-Scale Testing



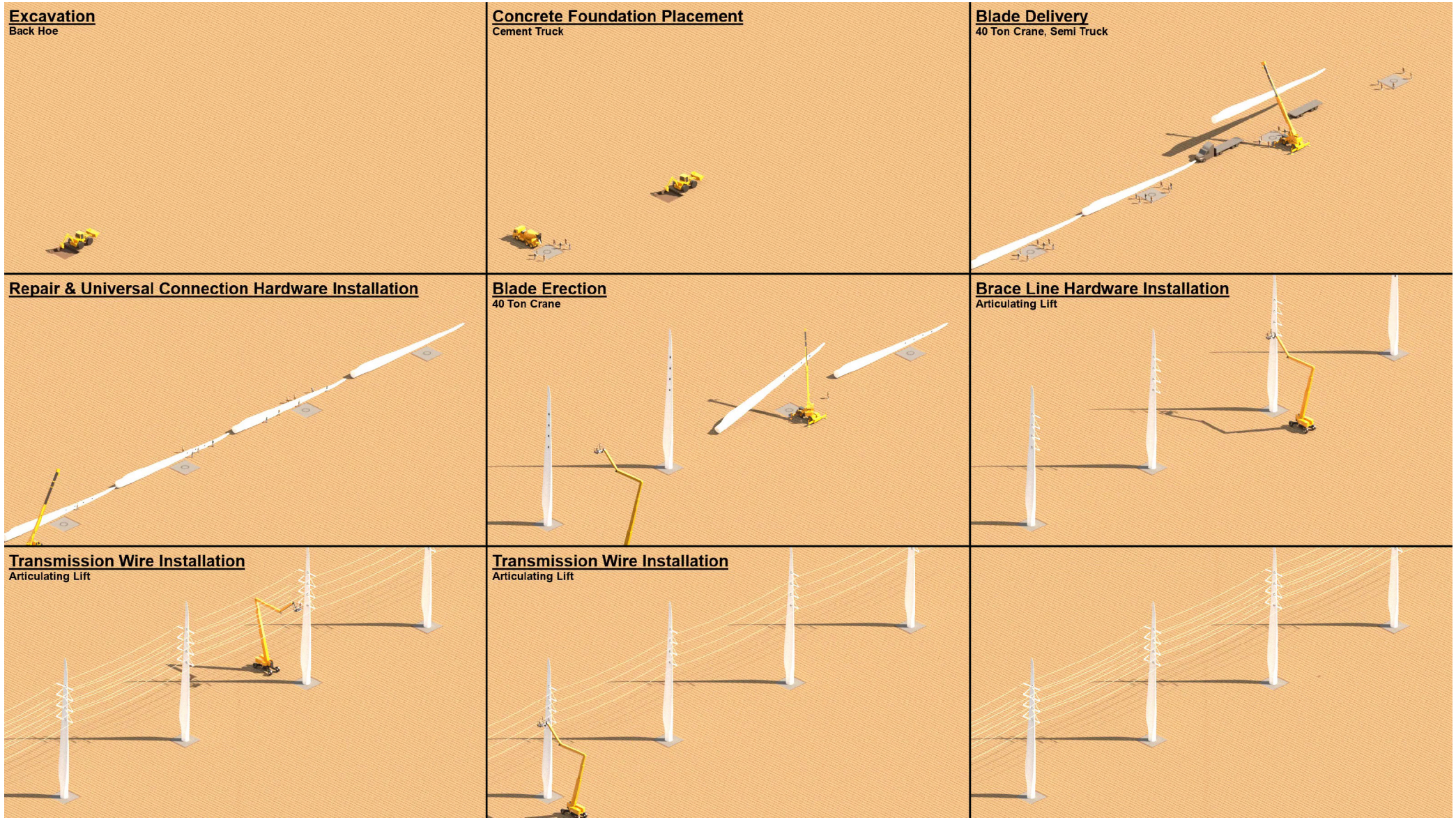
BladePole Process Model



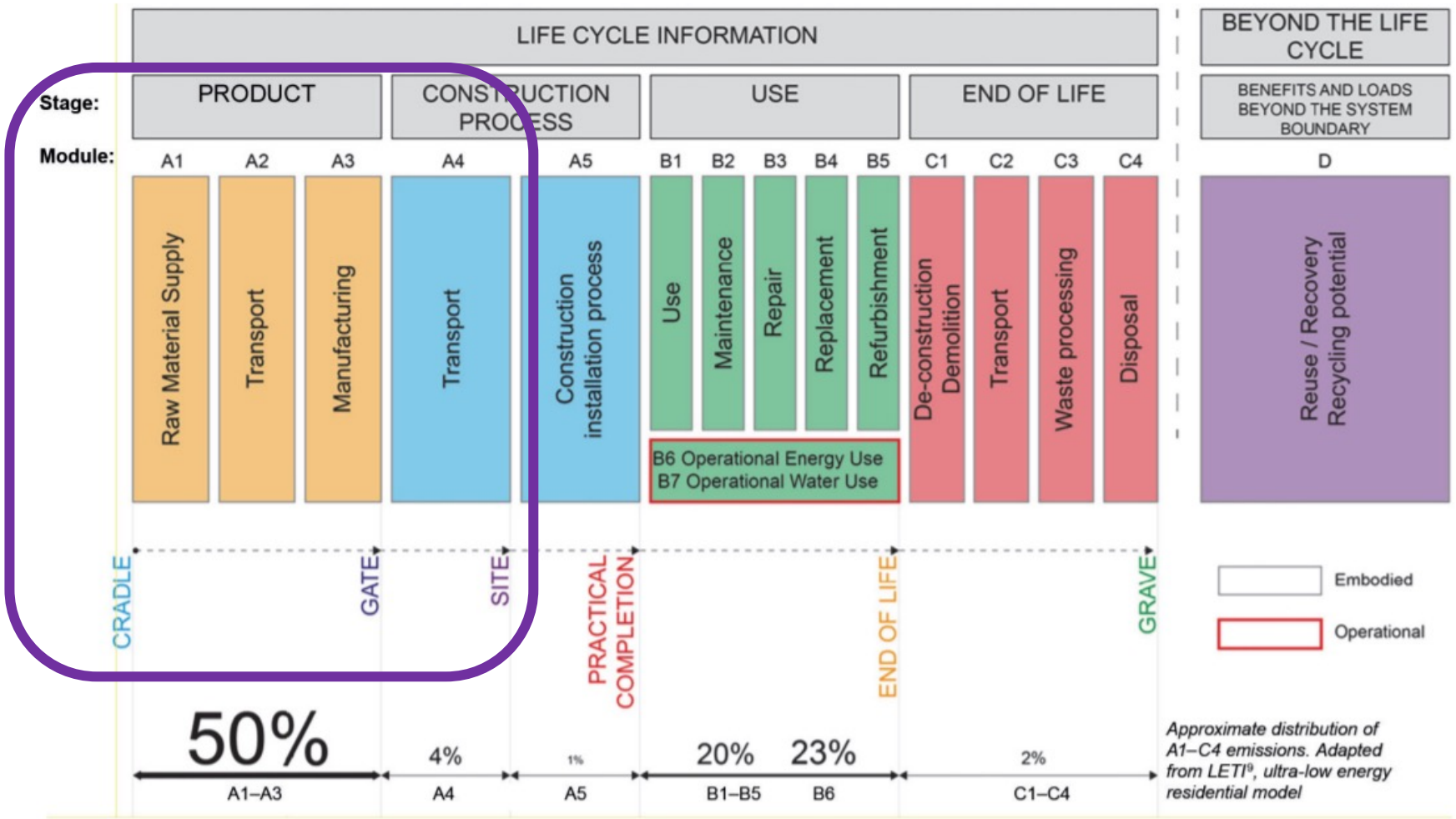


(Henao et al. 2022)

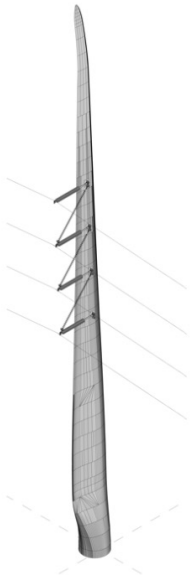
Transportation and Installation



Comparative Life Cycle Assessment



Life Cycle Stages in a Construction Project
(Gibbons and Orr, 2020)



Steel vs. BladePole

RE-WIND NETWORK
BLADE REPURPOSING SOLUTIONS
WWW.RE-WIND.INFO

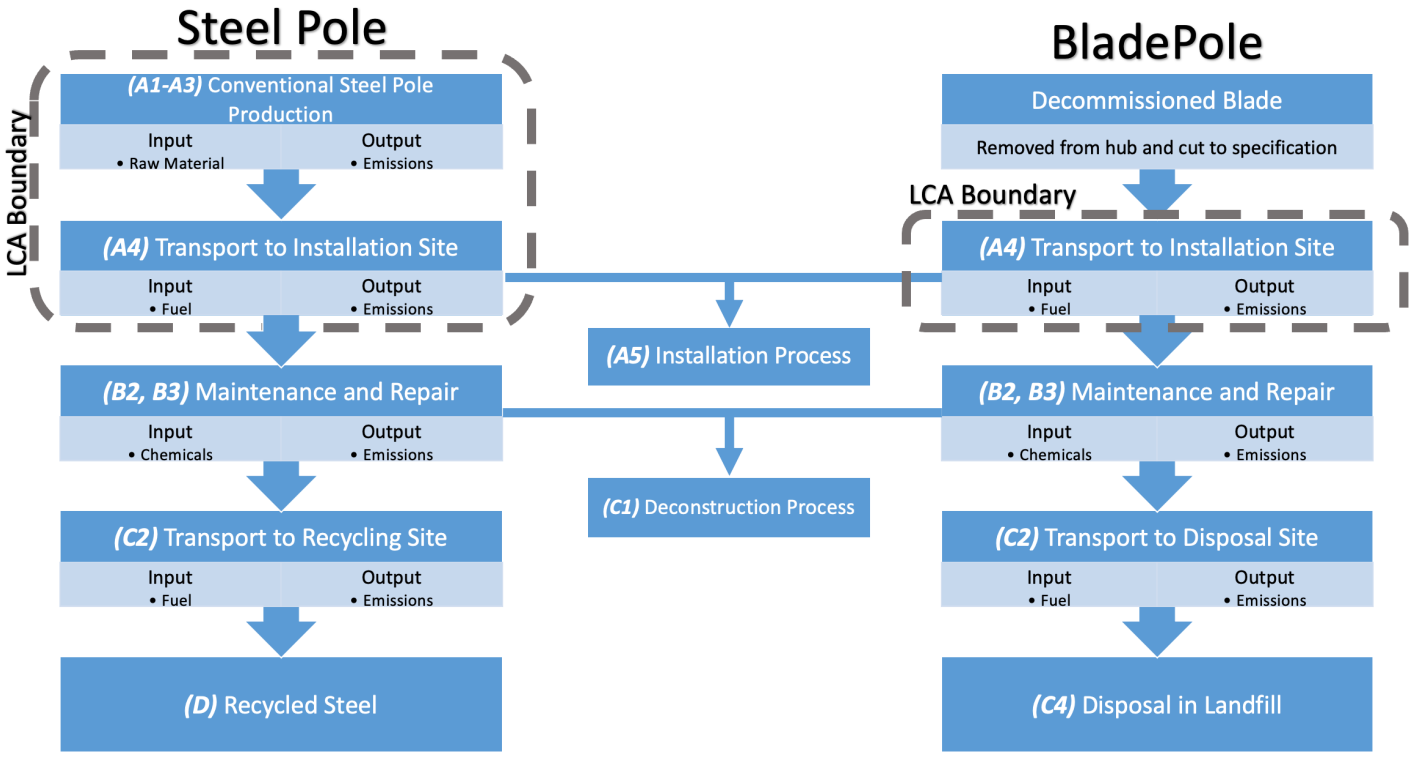
Lifecycle Assessment: Scope

- Functional Unit:

  100 ft long utility pole, 230 kV transmission capacity

- Design life: 60 years
- LCA Analysis:
  - Cradle to site
  - Energy and Environmental Impact Assessment
    - Primary Energy Demand (PED) in MJ
    - Global warming potential (GWP) in kg CO_2eq
    - Freshwater eutrophication potential (EP) in kg P eq
    - Terrestrial acidification potential (AP) in kg SO_2eq
    - Human/ecosystem damage ozone formation in kg NOx eq
    - Particulate matter formation (PMP) in kg PM_{10}eq

- System Boundary



ISO 21931 (ISO 2019)

Lifecycle Assessment: Scope

Product Stage

- Steel pole:
  - Hot dip galvanized steel
  - Steel production with recycling
  - Table below presents data per pole

Primary energy demand	PED (MJ)	56,088
Global Warming Potential	GWP (kg CO2e)	4,191.8
Acidification Potential	AP (kg SO2e)	12.3
Eutrophication Potential	EP (kg Phosphate)	1.2

(WorldSteel 2021)

- System Boundary

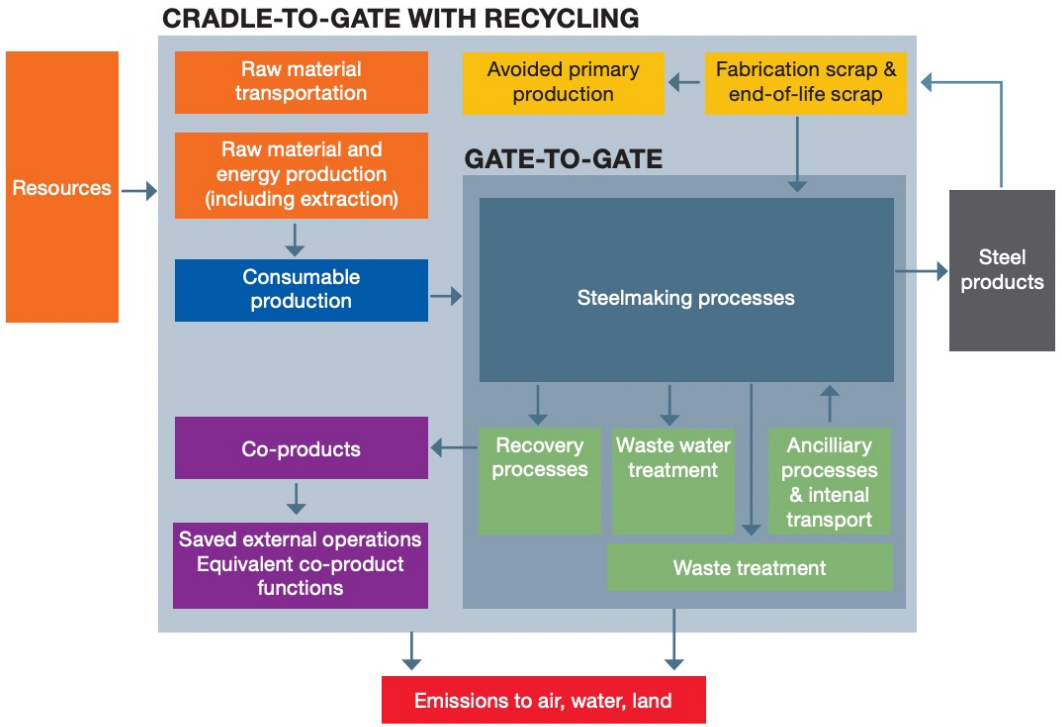


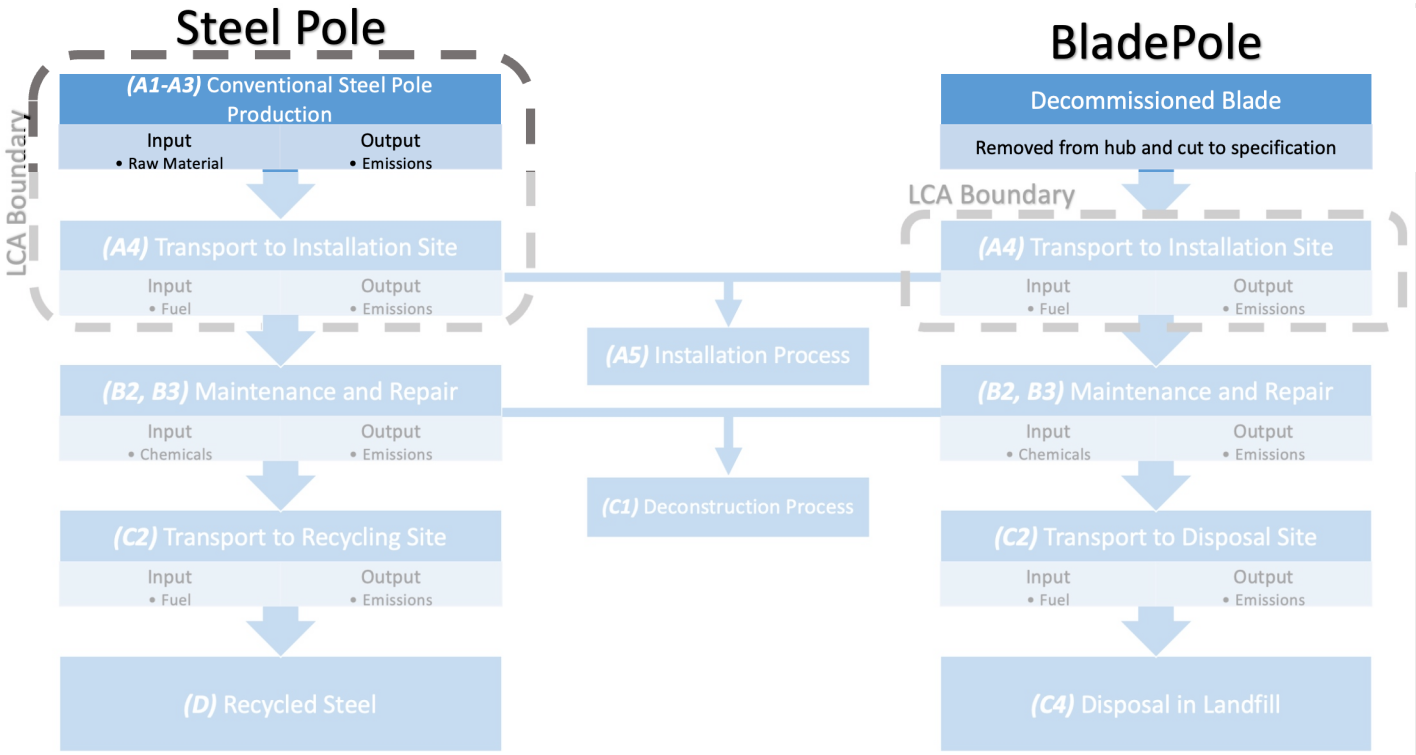
Figure 2: System boundaries overview for cradle-to-gate with recycling system

Lifecycle Assessment: Scope

Product Stage

- BladePole:
  - Production and decommission of blades are not included

- System Boundary



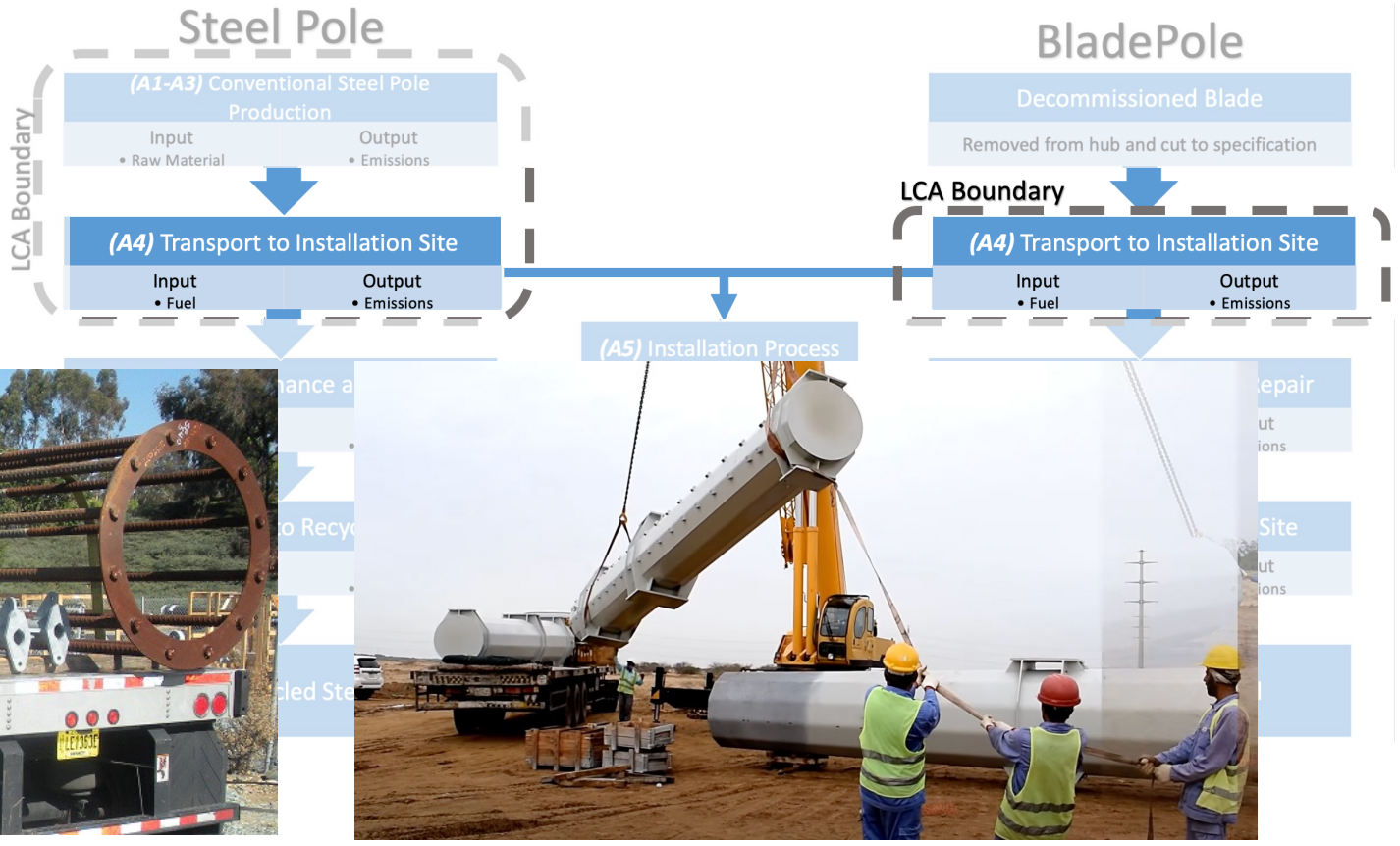
Lifecycle Assessment: Scope

Construction Process Stage

Transportation

- Steel Pole:
  - Transportation from **manufacturing facility** to installation site and return of empty truck at 80% capacity.
  - **1-2 steel poles** per truck

- System Boundary



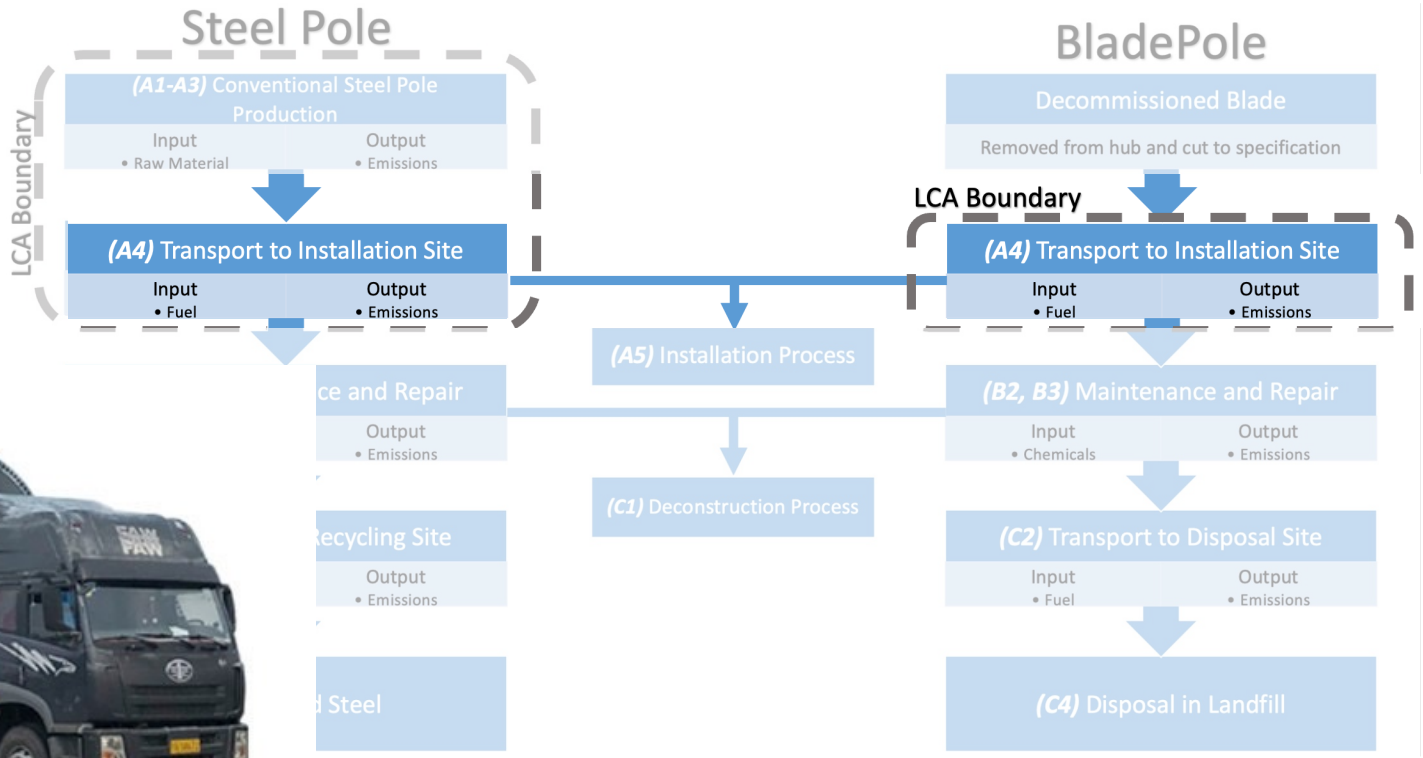
Lifecycle Assessment: Scope

Construction Process Stage

Transportation

- BladePole:
  - Transportation from **wind farm** to installation site and return of empty truck at 80% capacity.
  - **1 BladePole** per truck

- System Boundary



Lifecycle Assessment: Methodology

Comparison between BladePole and Steel Pole

Equation 1 presents the methodology for calculating the total primary energy demand and environmental impacts of producing and transporting a steel pole and transporting a BladePole:

$$Total_{ij} = Production_{ij} + \mathrm{c} \cdot \left(\frac{Transportation_i}{n_j} \cdot Miles \right) \qquad \text{Eq. 1}$$

Where,

i=1, Primary energy demand; i=2, Global warming potential

j=1, BladePole; j=2, steel pole

Production: refer to Table 1 for steel pole, BladePole Production11 and Production 21 are equal to zero

C=1.8, accounts for transportation from pick up to drop off location and 80% return

n=number of poles transported per truck

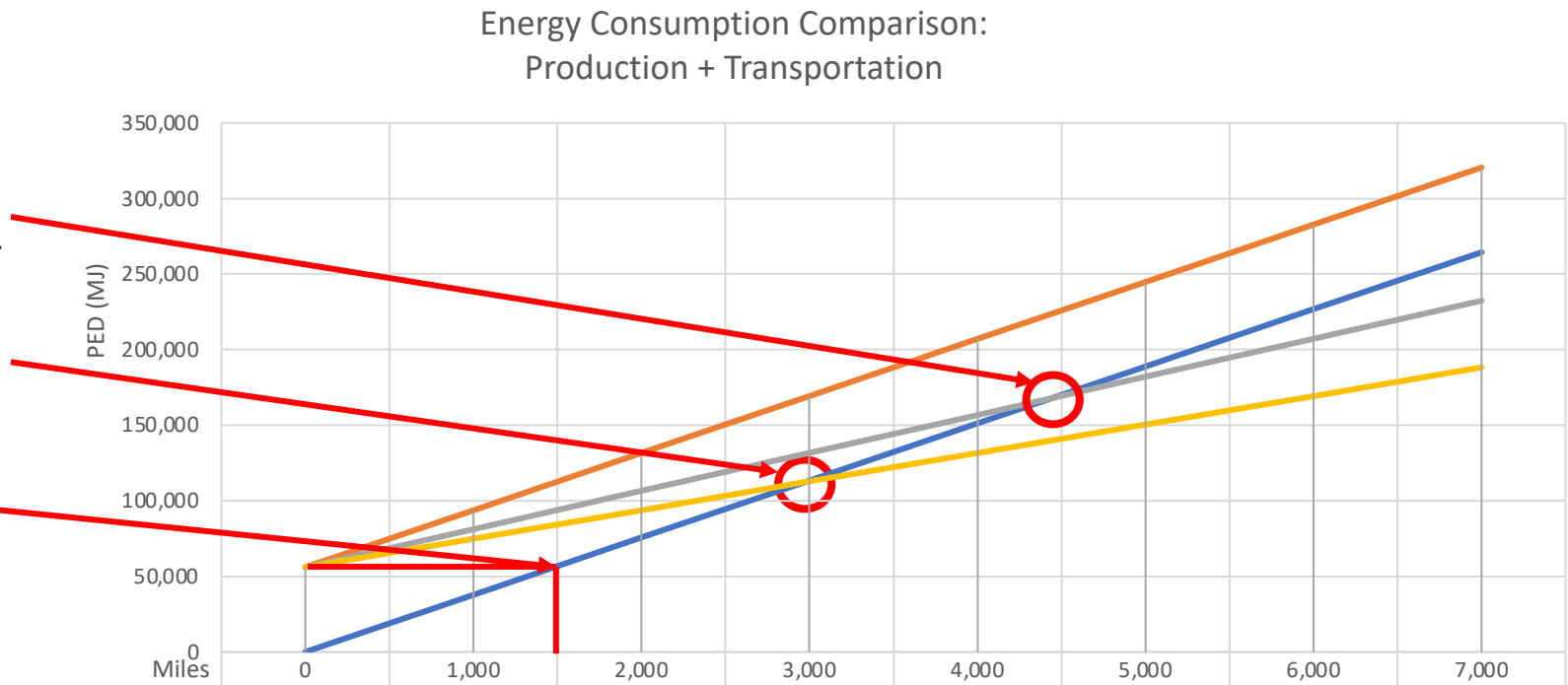
Transportation: refer to Table 2

Miles: distance from pick up to drop off

Lifecycle Assessment: Results

Primary Energy Demand

- Transporting BladePoles primary energy demand at:
  - Most likely scenario: 4,455 miles (breakeven to 1.5 steel poles per truck)
  - Worst case scenario: 2,970 miles (breakeven to 2 steel poles per truck).
  - Best case scenario: 1,485 miles (additional distance than steel poles)

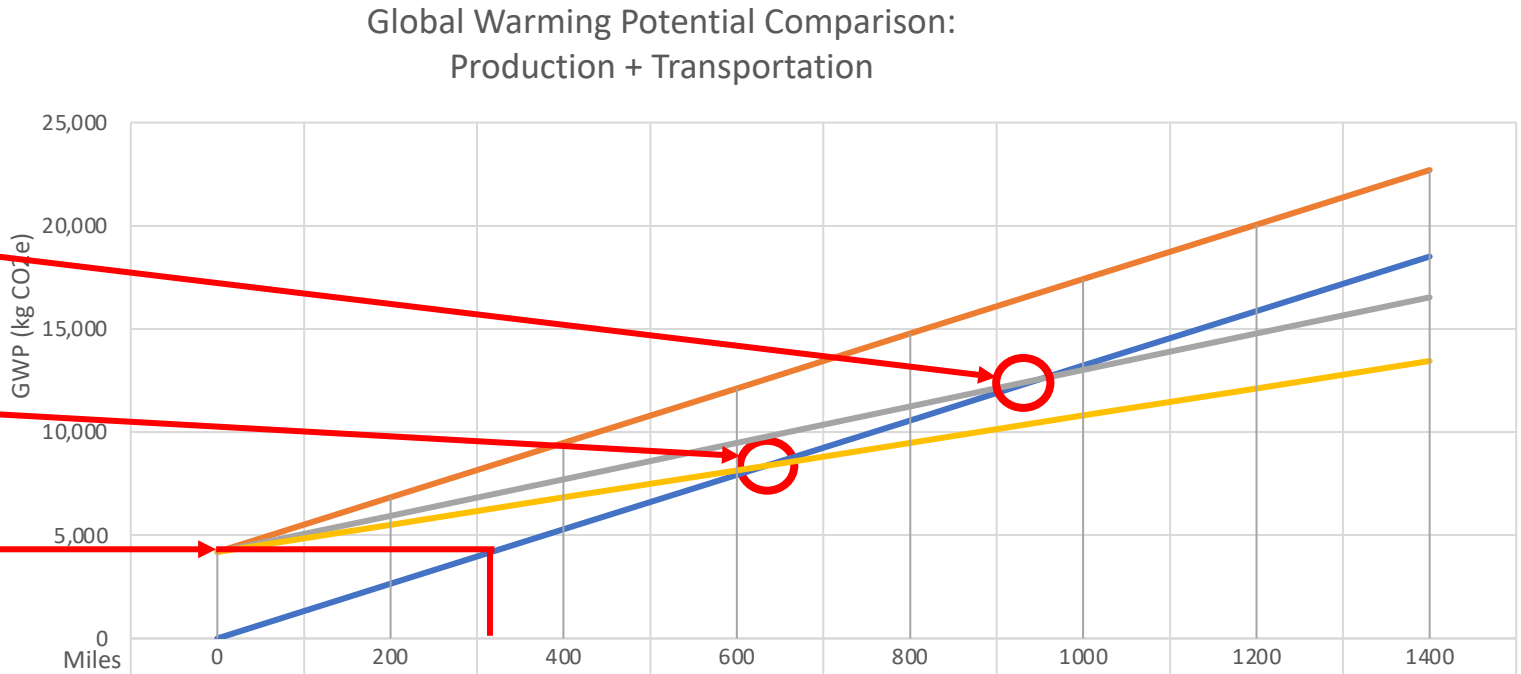


Miles	0	1,000	2,000	3,000	4,000	5,000	6,000	7,000
BladePole	0	37,772	75,543	113,315	151,086	188,858	226,630	264,401
1 Steel Pole per Truck	56,088	93,860	131,631	169,403	207,174	244,946	282,718	320,489
1.5 Steel Poles per truck	56,088	81,269	106,450	131,631	156,812	181,993	207,174	232,356
2 Steel Poles per truck	56,088	74,974	93,860	112,745	131,631	150,517	169,403	188,289

Lifecycle Assessment: Results

Global Warming Potential (Controlling environmental impact)

- Transporting BladePoles break even for GWP at:
  - Most likely scenario: 951 miles (breakeven to 1.5 steel poles per truck)
  - Worst case scenario: 634 miles (breakeven to 2 steel poles per truck).
  - Best case scenario: 317 miles (additional distance than steel poles)



Miles	0	200	400	600	800	1000	1200	1400
BladePole	0	2,644	5,288	7,931	10,575	13,219	15,863	18,507
1 Stee Pole per truck	4,192	6,836	9,479	12,123	14,767	17,411	20,055	22,698
1.5 Steel Poles per truck	4,192	5,954	7,717	9,479	11,242	13,004	14,767	16,530
2 Steel Poles per truck	4,192	5,514	6,836	8,158	9,479	10,801	12,123	13,445

Conclusions

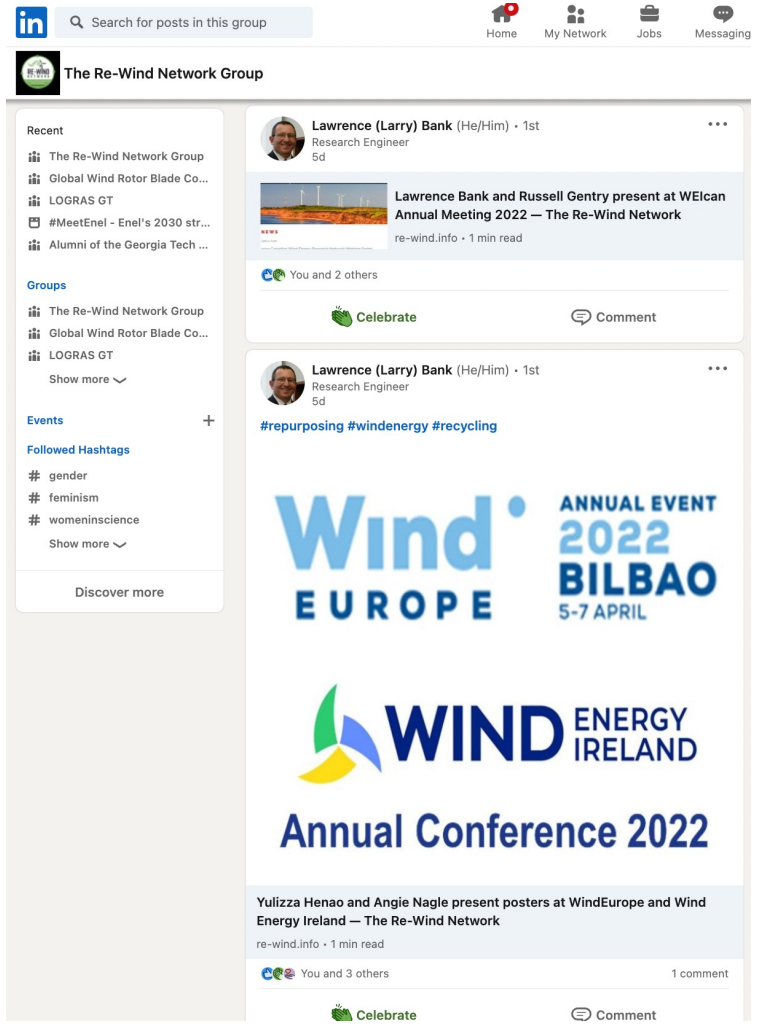
- This study introduces the initial life cycle assessment of repurposing wind turbine blades into energy transmission poles.
- The BladePole fulfils the same functional requirements as traditional steel poles. Therefore, this research focuses on the comparative lifecycle assessment of the BladePole to conventional steel poles production and transportation.
- Our results show that the environmental impact of BladePoles compared to conventional steel poles are dependent on the distance that the material would need to travel, and the total weight of the hot dip galvanized steel used for a steel pole. This research was looking to gage the sensitivity of transporting steel poles and BladePoles.
- Based on the results of this preliminary study, we are looking to assess the environmental impacts of the decisions we make regarding transportation.

Next Steps

- We aim to expand our research to include all the LCA stages and include a sensitivity analysis for remanufactured blades, steel pole weight, and end-of-life decisions.
- Our research will also expand to an LCA/LCC analysis with cost and environmental data.
- Future research should also focus on concrete, wood, and composite poles.

Outreach

Webpage



LinkedIn

Thank you

Yulizza Henao-Barragan
yulihenao@gatech.edu