Managing End-of-Service Composite Structures

Challenges And Case Studies With Focus On Repurposing

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Göteborg/Riga – GlassCircle Final conference, 2024-09-26

Alann André

- PhD in Timber Structures (Strengthening of timber beams with Fibre Reinforced Polymers) (Chalmers, Sweden), Mechanical Engineer background (France)
- **Senior Researcher at RISE** (Research Institute of Sweden):
  - Re-purpose of decommissioned FRP structures
  - Application of composite in the infrastructure sector
  - Modelling of composite structures
- **Since 2018**: Together with my colleague Cecilia Mattsson, initiating and leading several R&D projects related to the sustainable management of decommissioned composite structures (RECINA, RECOMP, IEA Wind task 45, REKOVIND2, COSOVI, CIRCUBLADE, SVPI LAB)

Glass fibre Reinforced Polymers (GFRP)

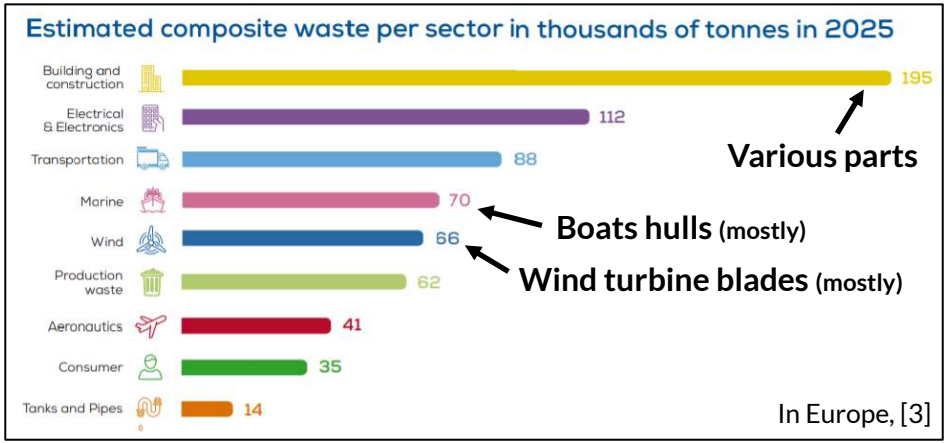
→ Type of structures, Volume and End-of-Service (EoS)

In 2021:

World
12 Million tons of FRP
[1]

Europe
1 Million tons of GFRP
[2]

98 % GFRP
in marine, wind and automotive
[3]



Sources:
[1] JEC Group, 2022. JEC Observer Overview of the global composites market, 2021-2026
[2] Tiseo, I., 2022. Production of glass fiber reinforced plastics (GRP) in Europe 2000-2021. Glass Fiber Reinforced Plastic Production in Europe 2021. Statista.
[3] ETIPWind (2019), HOW WIND IS GOING CIRCULAR blade recycling https://etipwind.eu/files/reports/ETIPWind-How-wind-is-going-circular-blade-recycling.pdf

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Why managing EoS GFRP is challenging?

1. Most GFRP are made with **thermosets** resin (~75%)

2. If only GF and thermoset resin are used in the part:
   → **Very difficult to separate** them due to the chemical structure (cross linking)

3. **In most cases, other materials** are also used:
   → Increased complexity: Need to separate these other materials before separating the fibres from the matrix

4. If separation of GF and thermoset is done:
   → The **recovered material** (fibre and resin) are **not (yet) able to compete** with virgin material

Complex structures with integrated functions and materials. Ex: Wind turbine blades

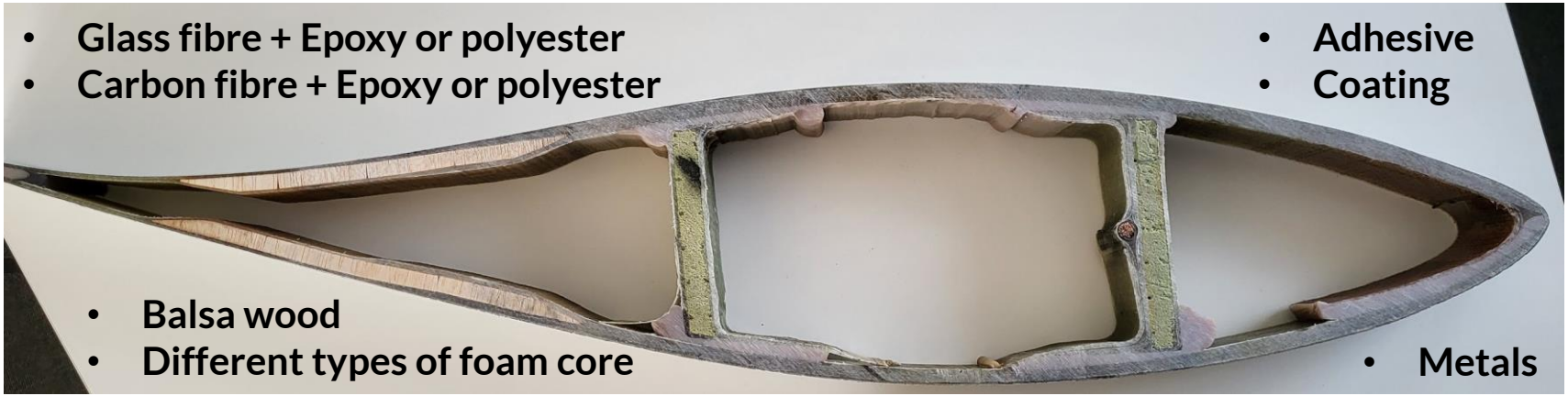

Photo: Cecilia Mattsson, RISE

- ❑ Blades: composite materials (GFRP and CFRP), 80% in weight + several other materials
- ❑ Very strong, stiff and durable structure, but difficult to separate when reaching decommission
- ❑ Approx. 30% organic material

Circular management of EoS GFRP:
→ 3 main pillars missing today

Policies and Guidelines for circular management

Circular and sustainable **Value chains**

Technologies not always available at scale

→ + tough economically

- Competition with price of new glass fibres (**1-2 €/kg**)
- Cheapest EoL route: incineration or landfill (**130-140 €/ton**)

Repurposing EoS GFRP: What advantages?

→ Great potential within construction and infrastructure

- Resource efficient solution - transform waste material into resource
- Uses material that goes to landfill/energy recovery
- Strong and durable material
- Low maintenance costs
- Replace high CO2 emission materials such as concrete and steel

Content

1. Managing EoS Wind Turbine Blades
   → *looking at the Swedish case*
2. How simple and innovative concepts can help repurposing EoS GFRP
   → *Concept of a pedestrian bridge deck system*
3. Conclusion and Future Work

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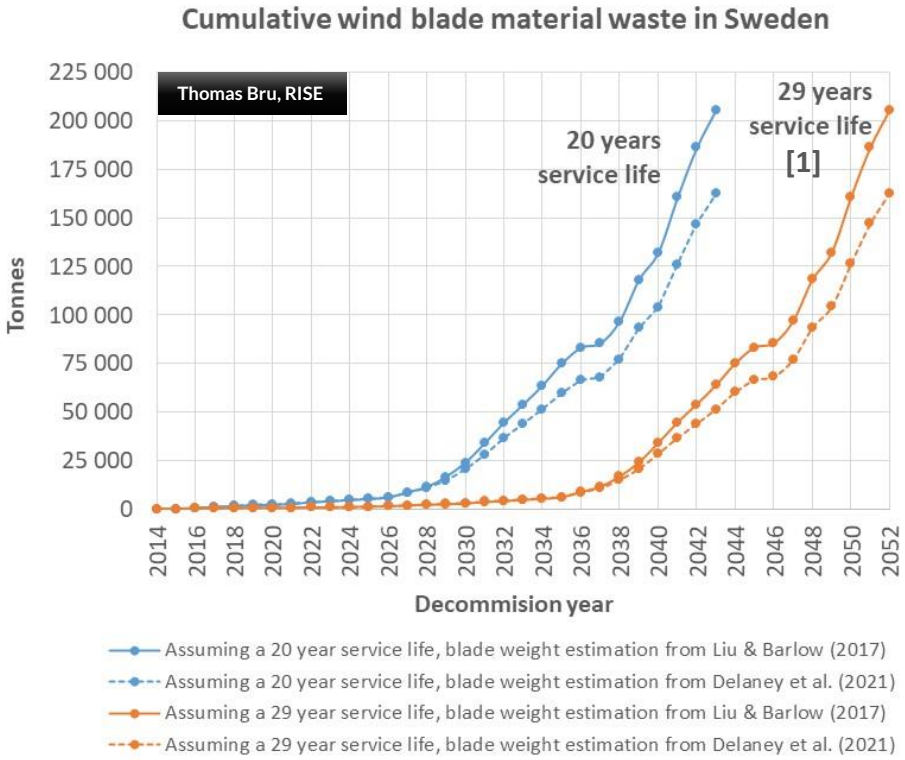
Ageing wind park in Sweden

→ Many turbines to be decommissioned in the coming years!



The number of wind turbine blades to be decommissioned is expected to **increase significantly** in the coming years.

There is today **no industrial and established value chain** to secure a sustainable management of these decommissioned blades.

More than **5000** turbines

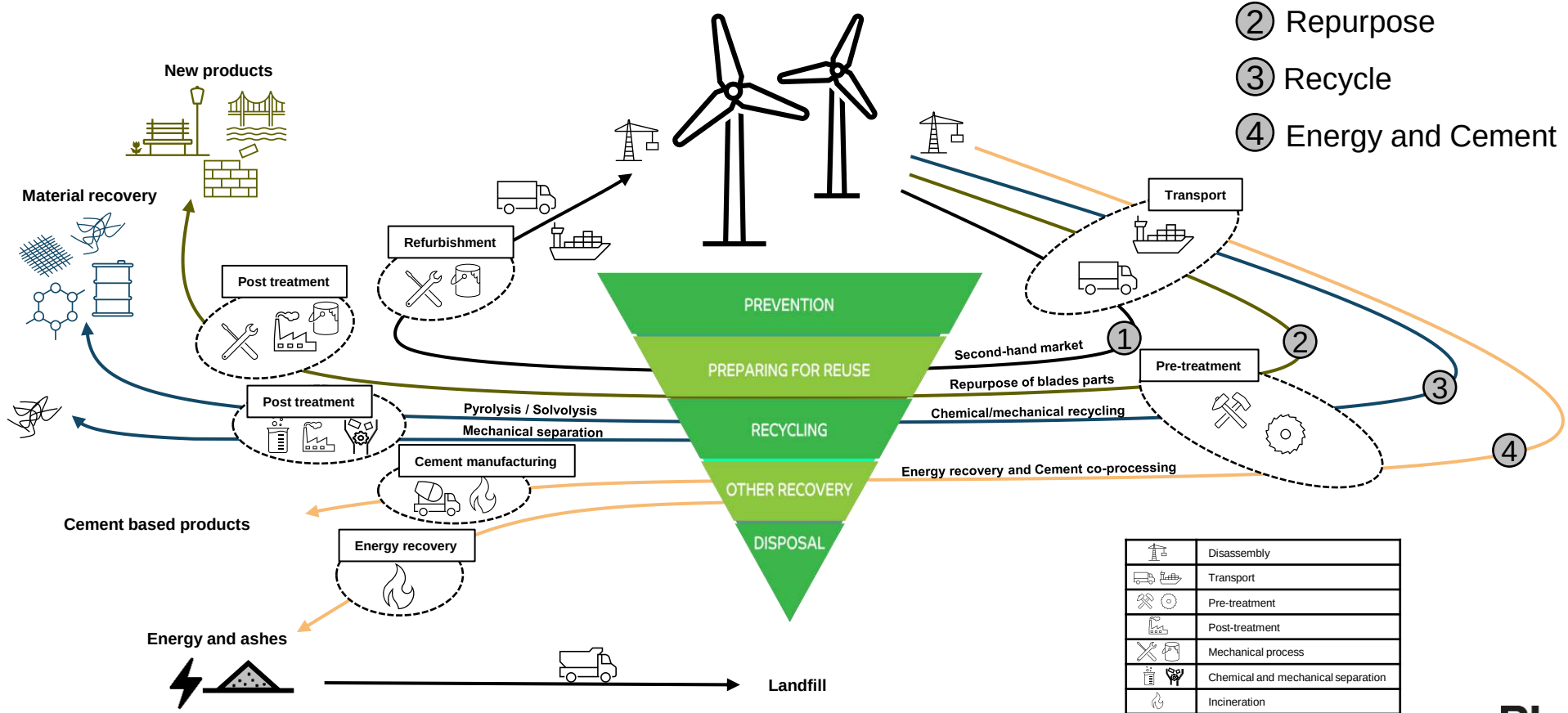
Till 2030 **1500** reach EoS

service life **20** years

[1] **"Method for estimating the future annual mass of decommissioned wind turbine blade material in Denmark",** Abrahamsen et al (2023)
DOI:10.22541/au.168105743.37926484/v1

What alternatives?

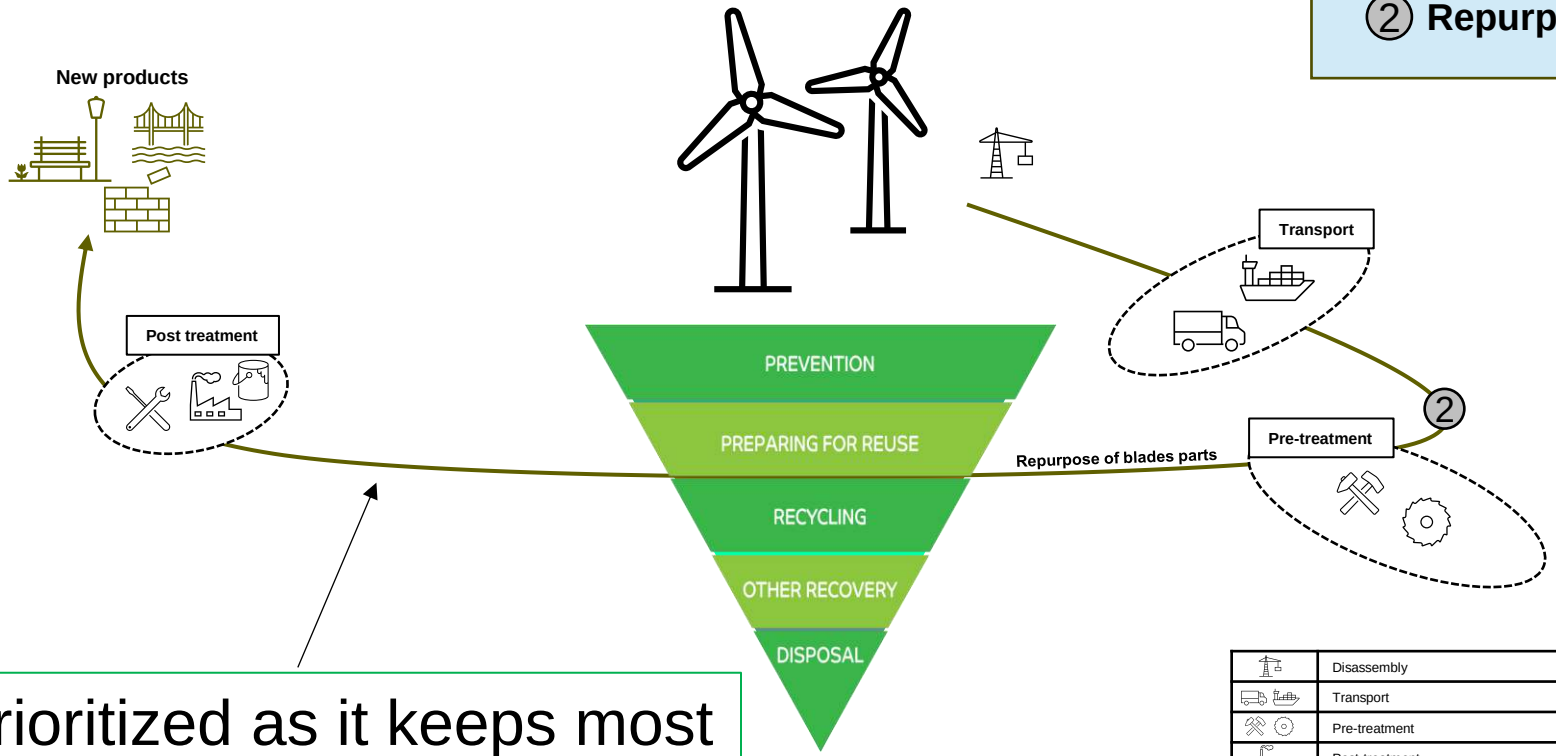
1. Second hand
2. Repurpose
3. Recycle
4. Energy and Cement



	Disassembly
	Transport
	Pre-treatment
	Post-treatment
	Mechanical process
	Chemical and mechanical separation
	Incineration
	Energy recovery
	Landfill / Ashes

What alternatives?

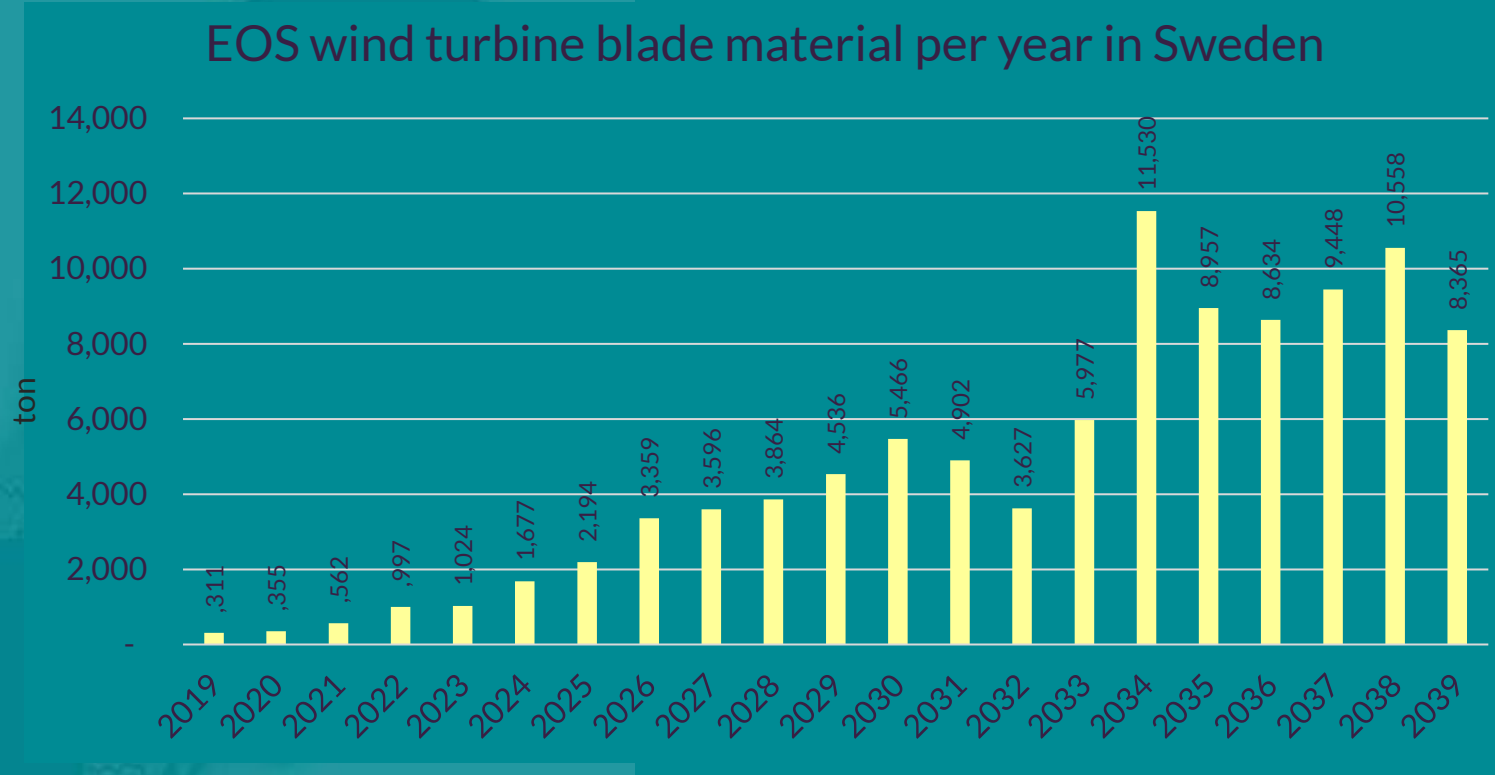
② Repurpose



Prioritized as it keeps most of the blade inherent value

	Disassembly
	Transport
	Pre-treatment
	Post-treatment
	Mechanical process
	Chemical and mechanical separation
	Incineration
	Energy recovery
	Landfill / Ashes

SWEDEN – What are the numbers?



Within 5 year

970 blades

6800 tons

Circular management of EoS GFRP:
→ 3 main pillars missing today

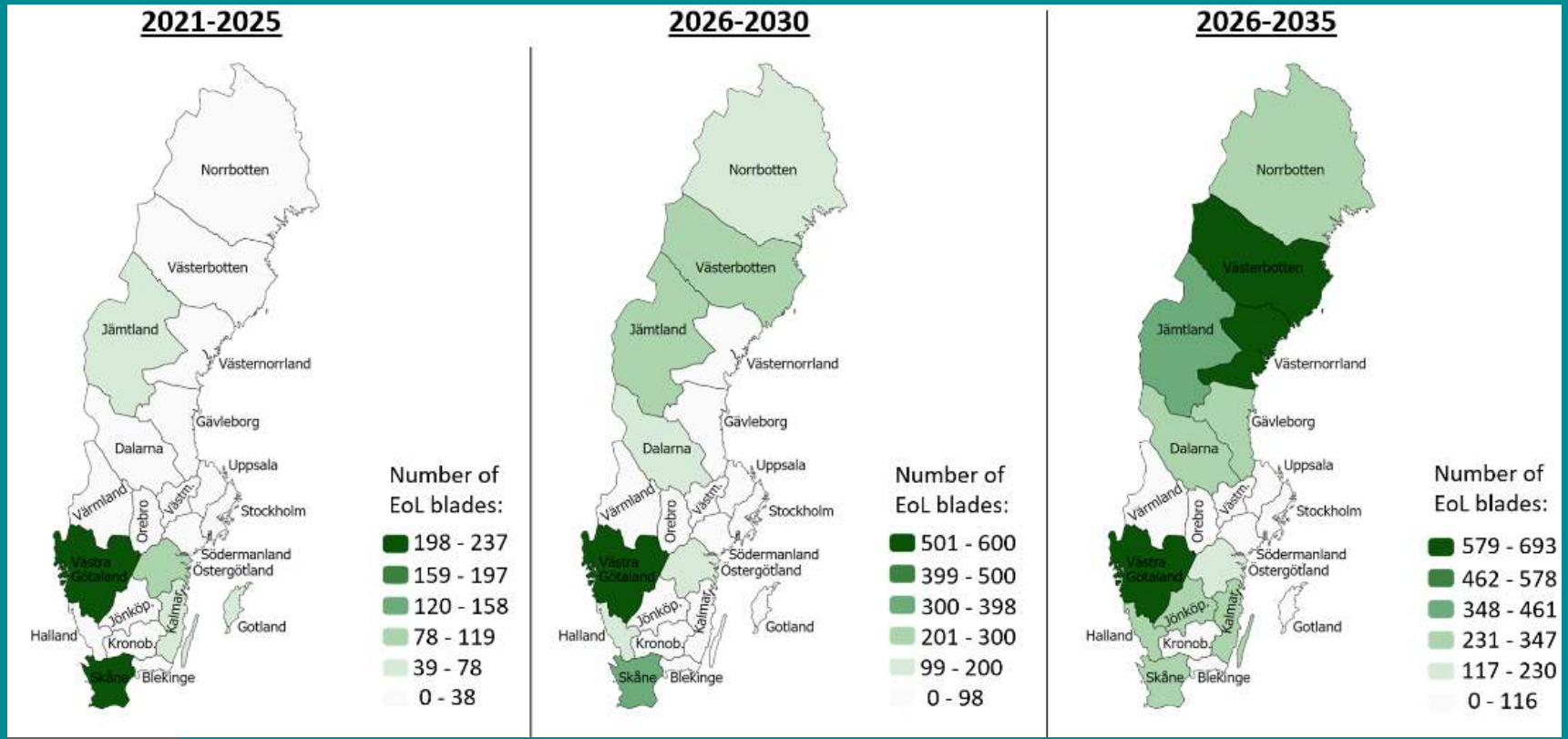
Policies and Guidelines for circular management

Circular and sustainable **Value chains**

Technologies not always available at scale

For potential value chain actors:
need to know the volumes and their availability (in space and time)
→ **data needed**!

SWEDEN – What are the numbers? + When and Where!!

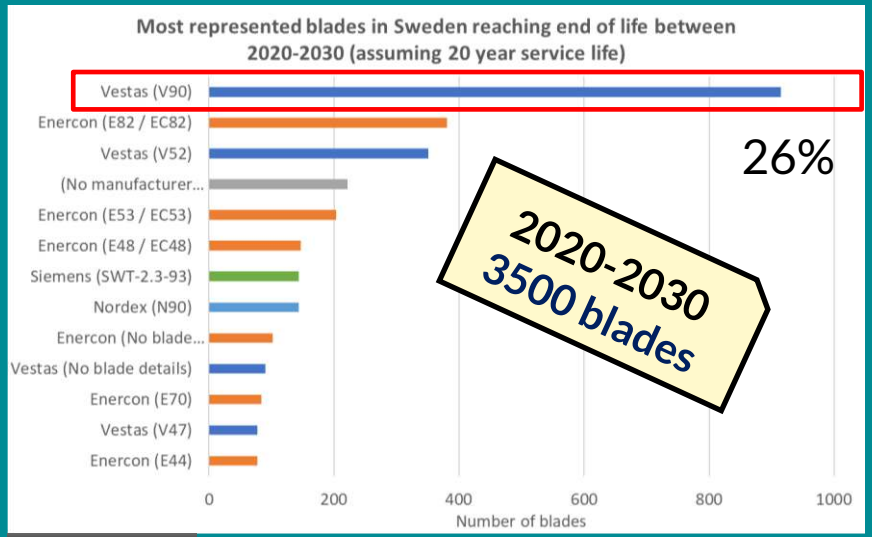


Thomas Bru, RISE

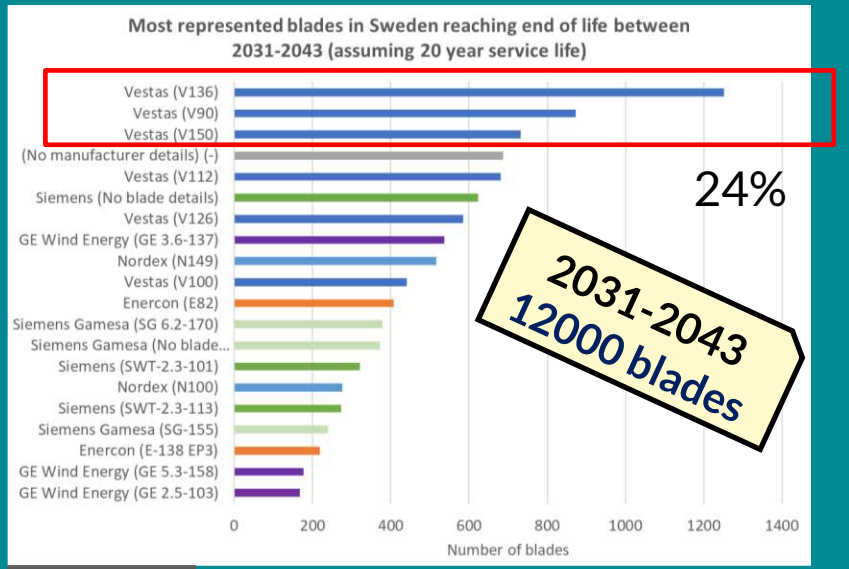
SWEDEN – What are the numbers? + What type!!

Data collection

Estimated number of decommissioned blades by type and year



Thomas Bru, RISE

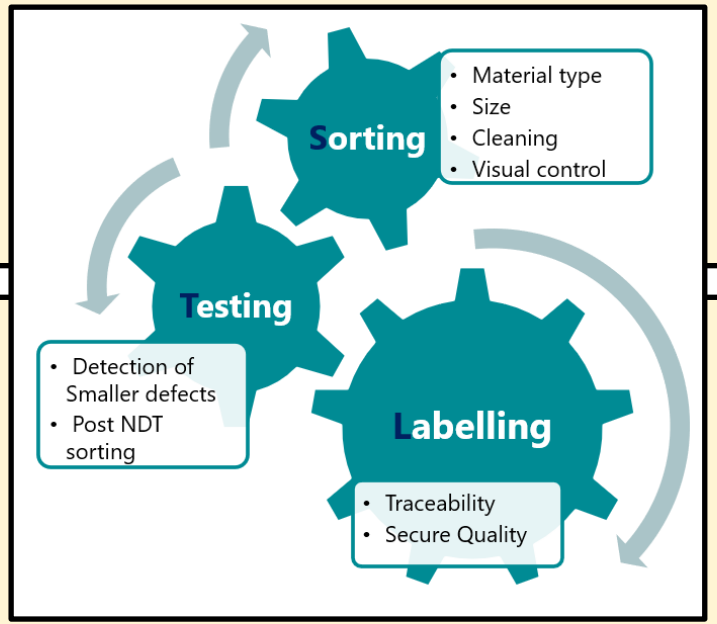


Thomas Bru, RISE

How to repurpose the blades at scale?

Need robust certification processes

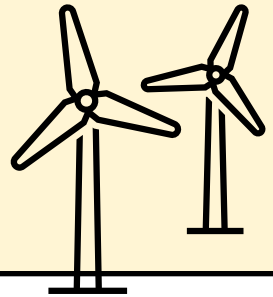
Circularity enabler

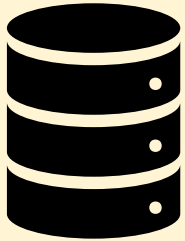


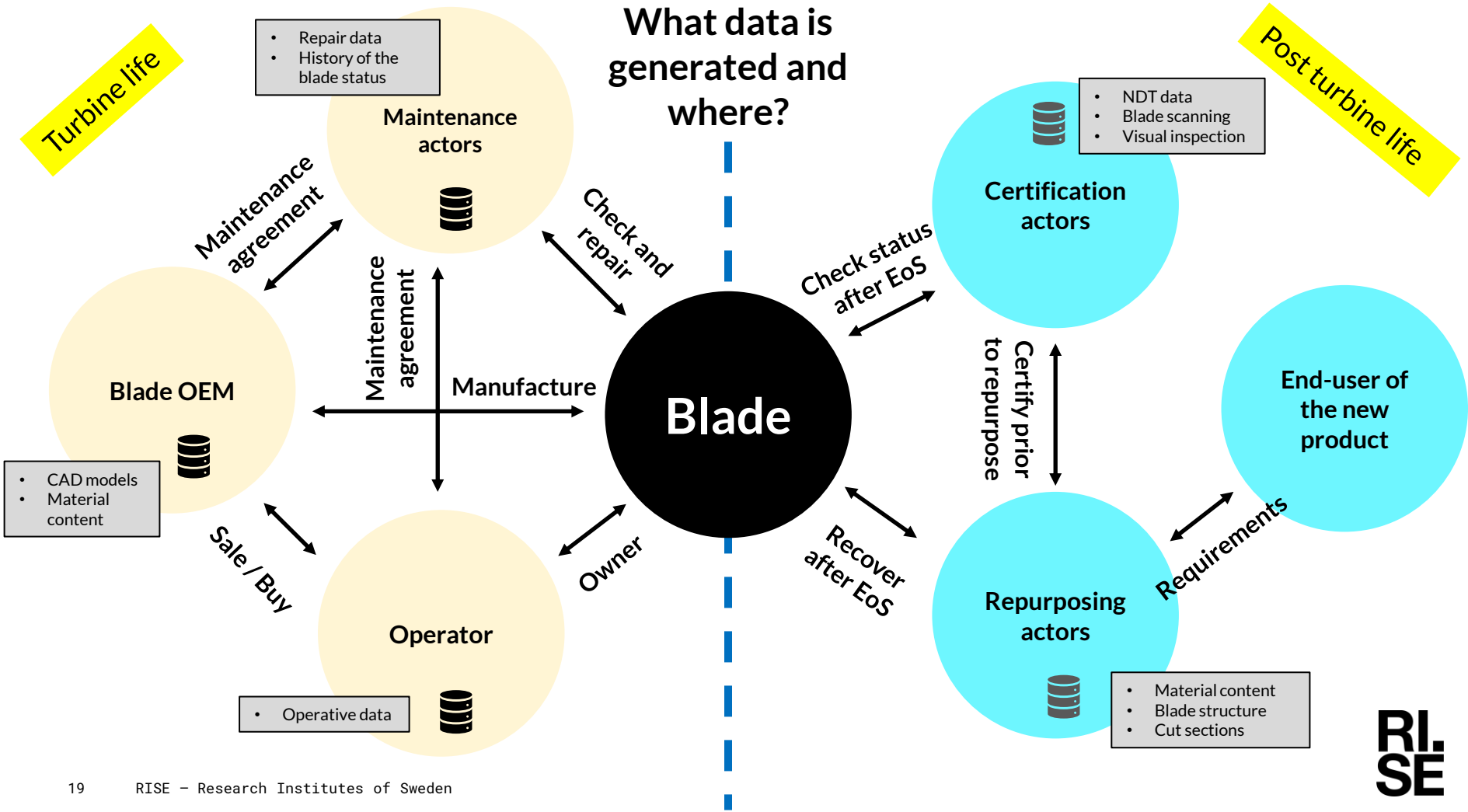
How to repurpose the blades at scale?

Need access to blade data

Circularity enabler



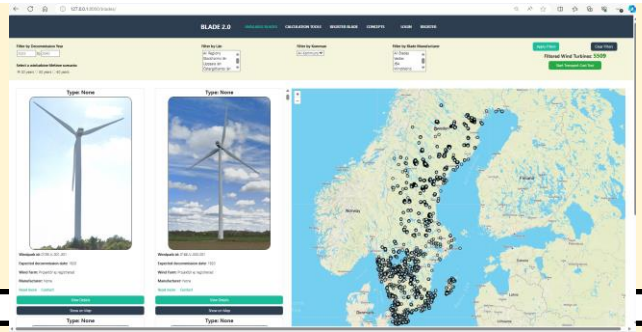


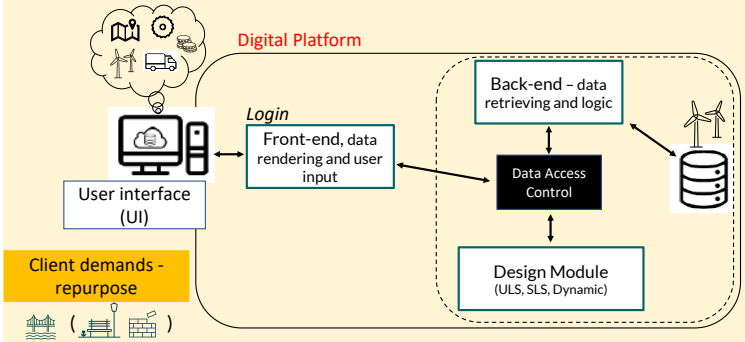

What data is generated and where?
Turbine life
Post turbine life
Repair data
History of the blade status
Maintenance actors
Maintenance agreement
Check and repair
Blade OEM
CAD models
Material content
Maintenance agreement
Manufacture
Blade
Sale / Buy
Owner
Operator
Operative data
Check status after EoS
Certification actors
NDT data
Blade scanning
Visual inspection
Certify prior to repurpose
End-user of the new product
Recover after EoS
Requirements
Repurposing actors
Material content
Blade structure
Cut sections

How to repurpose the blades at scale?

Need to use new digital tools

Circularity enabler





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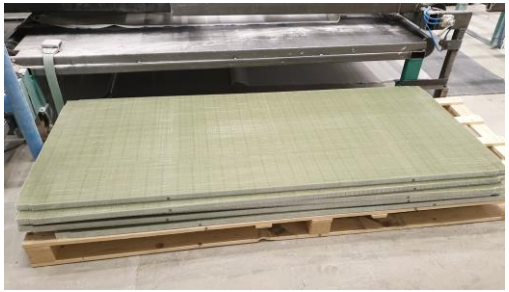
Case study – pedestrian bridge deck

- ***Objective***

Repurpose of EoS GFRP structures in new products

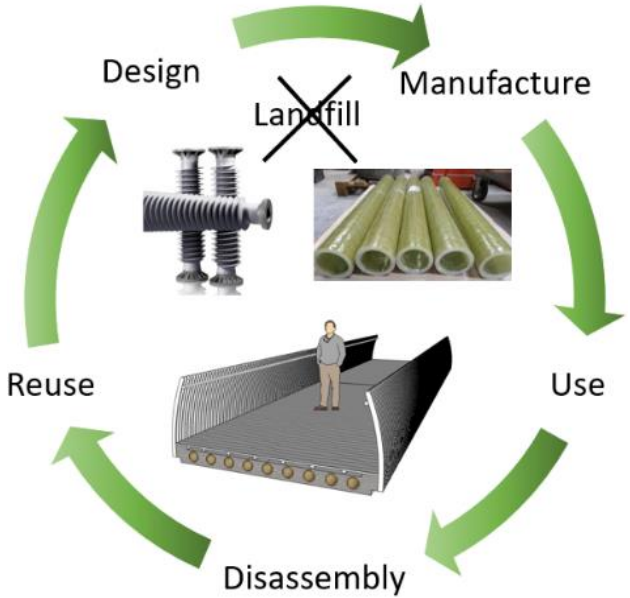
- ***Current End-of-Service***

Landfill or incineration



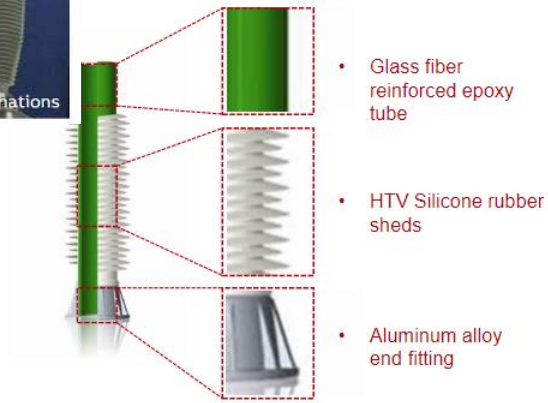
- ***Aimed Application area***

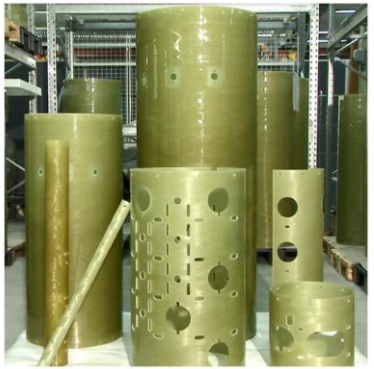
Bridge deck, balcony, wall elements



Case study

- *Material **Repurposed*** – **GFRP pipes aiming for landfill**

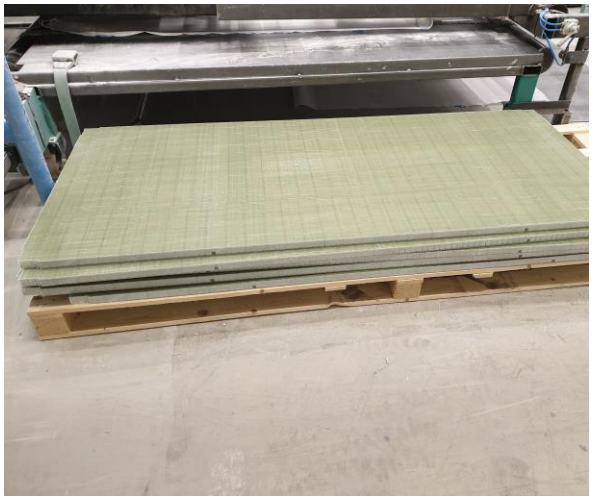




Material Source →

Case study

- *Material* ***Repurposed*** **-GFRP sandwich panels aiming for incineration**



Material Source →

Conceptual design – What solutions for a robust design?

Objective: Develop a resilient deck design (KISS principal).

Key Requirements:

- Accommodate various GFRP pipe lengths and diameters.
- Adapt to pipe availability.

Challenges:

- Unpredictability of production waste exact nature and volume

Solution:

→ Create a flexible concept to effectively utilize GFRP pipes of varying dimensions.

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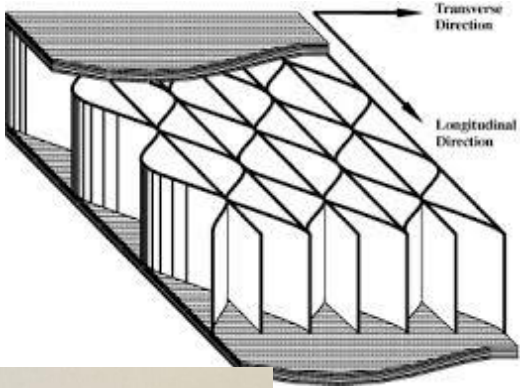
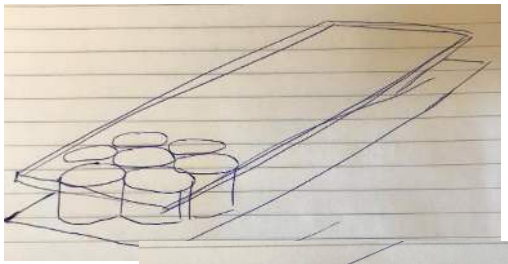
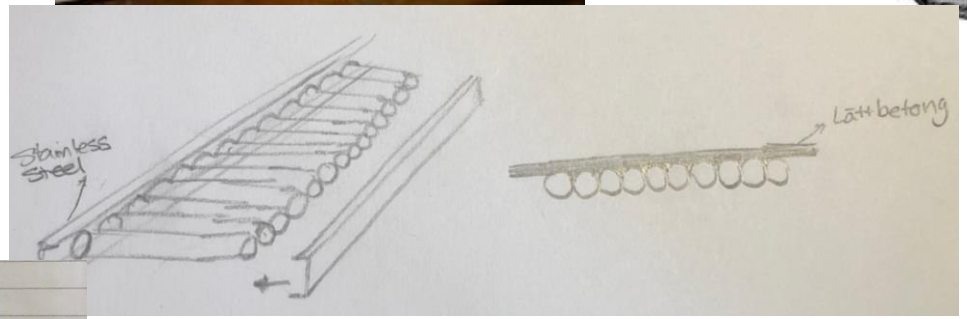
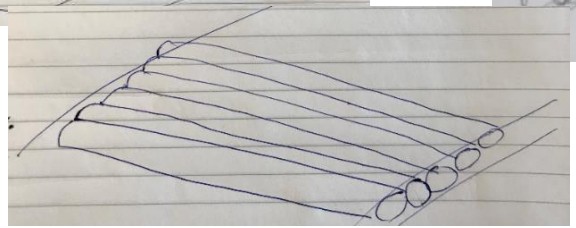
Conceptual design – What solutions for a robust design?

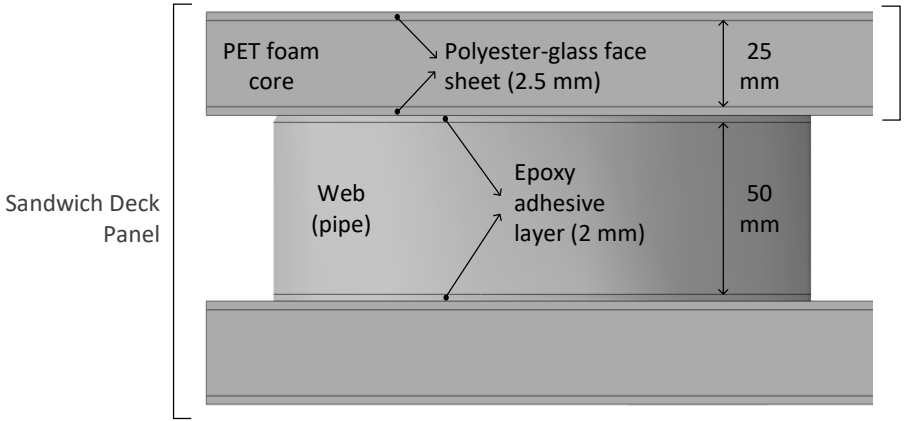


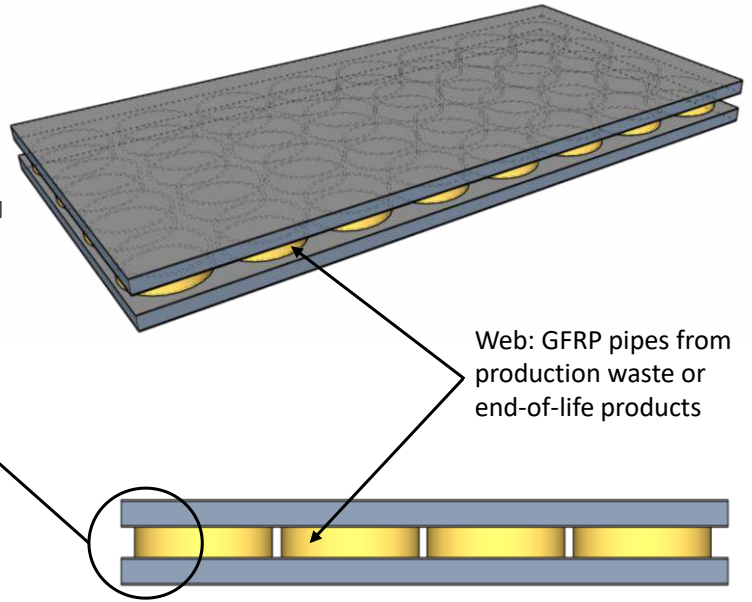


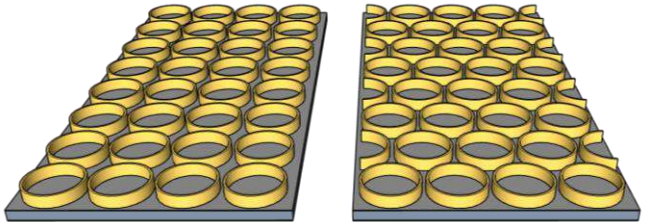




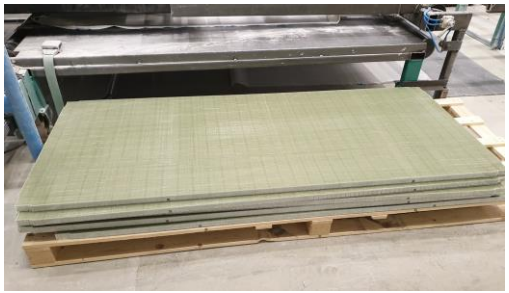
Conceptual design: sandwich panel





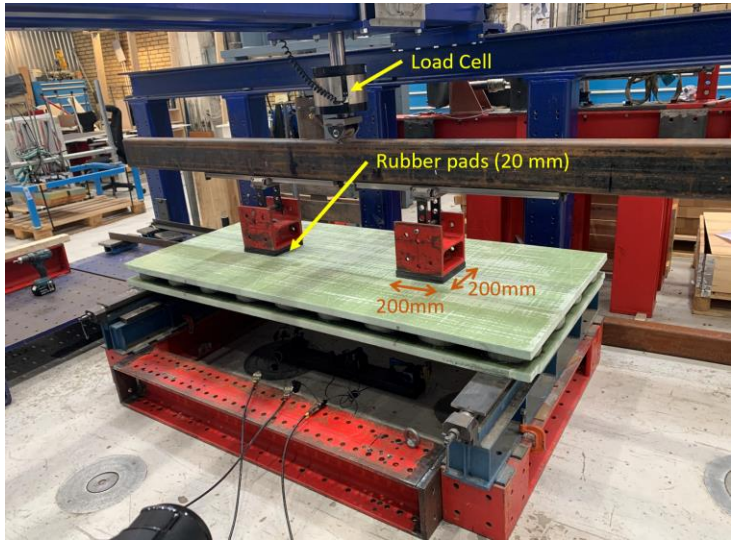


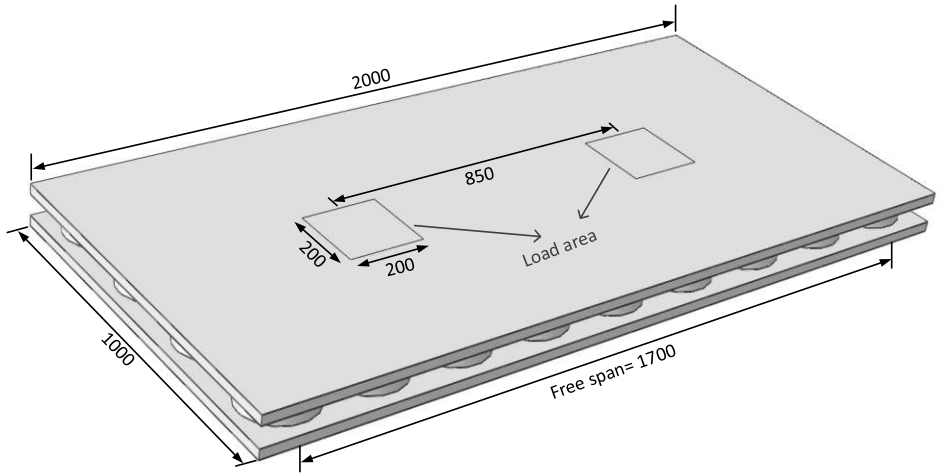
Manufacturing of a bridge deck panel



- Two step assembly
- Adhesive bounding
- Press

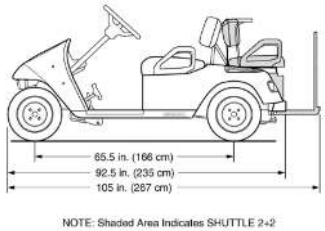
Experimental tests



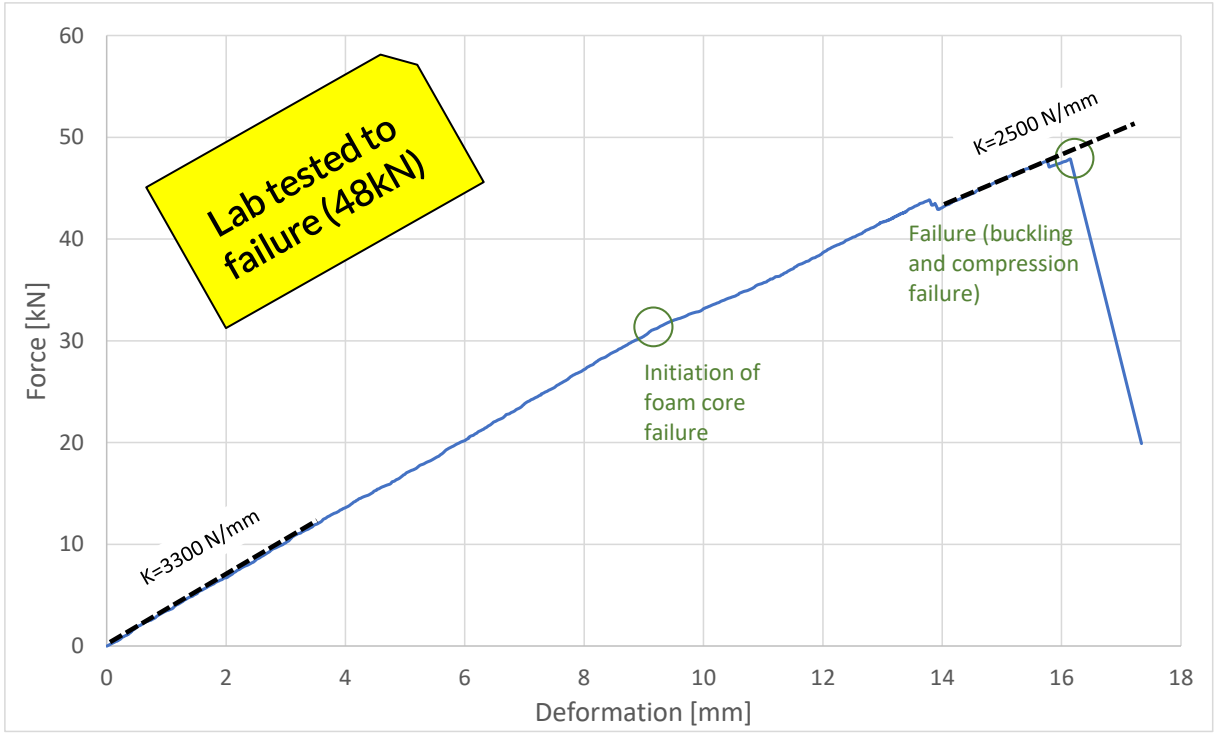


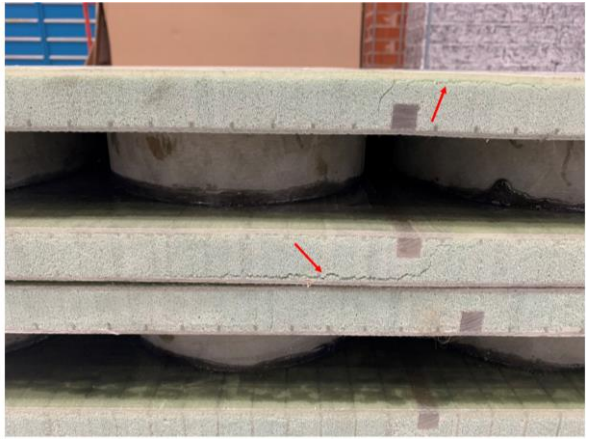
Very light: 35kg/m2

Design load: 15kN (Golf cart)



Experimental tests

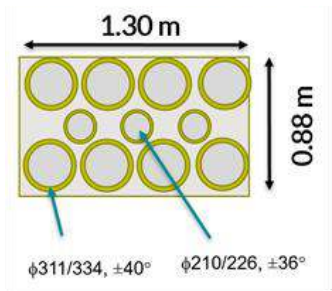


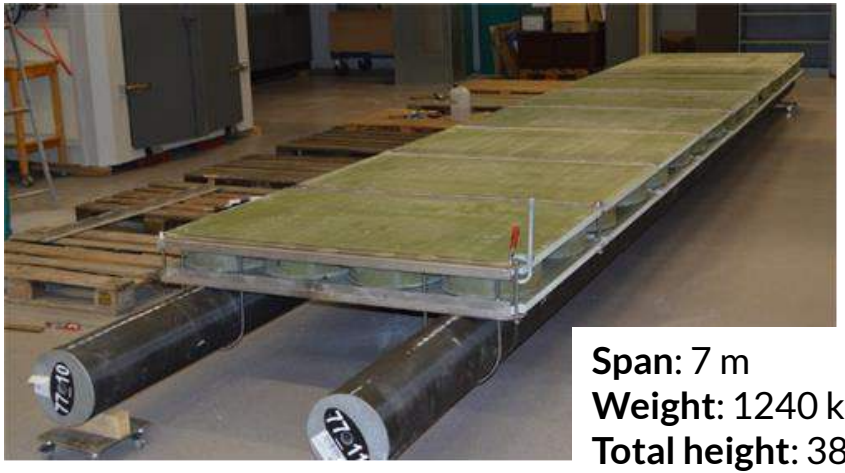


Shear failure running through the top and bottom skin of the sandwich panel.

Manufacturing bridge prototype

- 8 deck panels with pipes of different diameter
  → robust design
- Girder made of discarded GFRP poles
- Circular design for easy disassembly

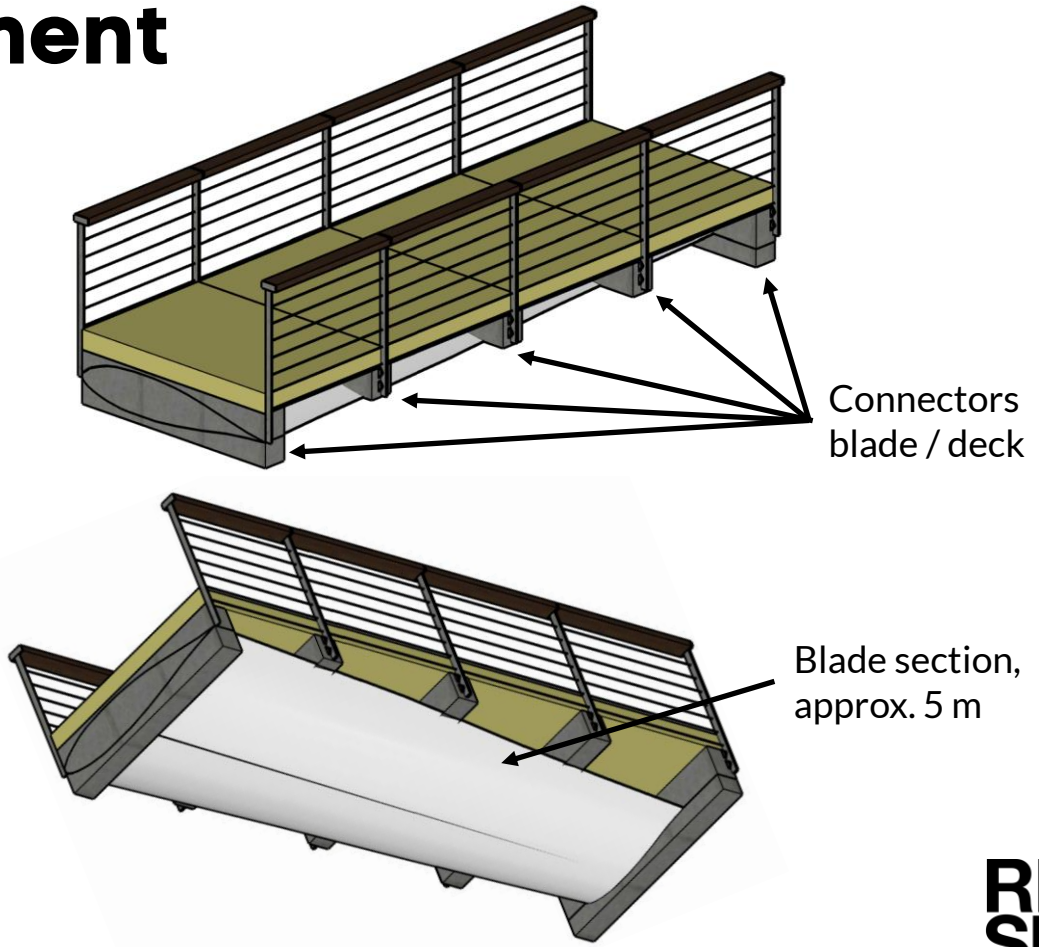




Span: 7 m
Weight: 1240 kg
Total height: 388 mm

Further development

- Section of a decommissioned wind turbine blade used as girder
- Custom made support between the blade section and the deck panels
- Mechanical test of prototype planned for the coming weeks



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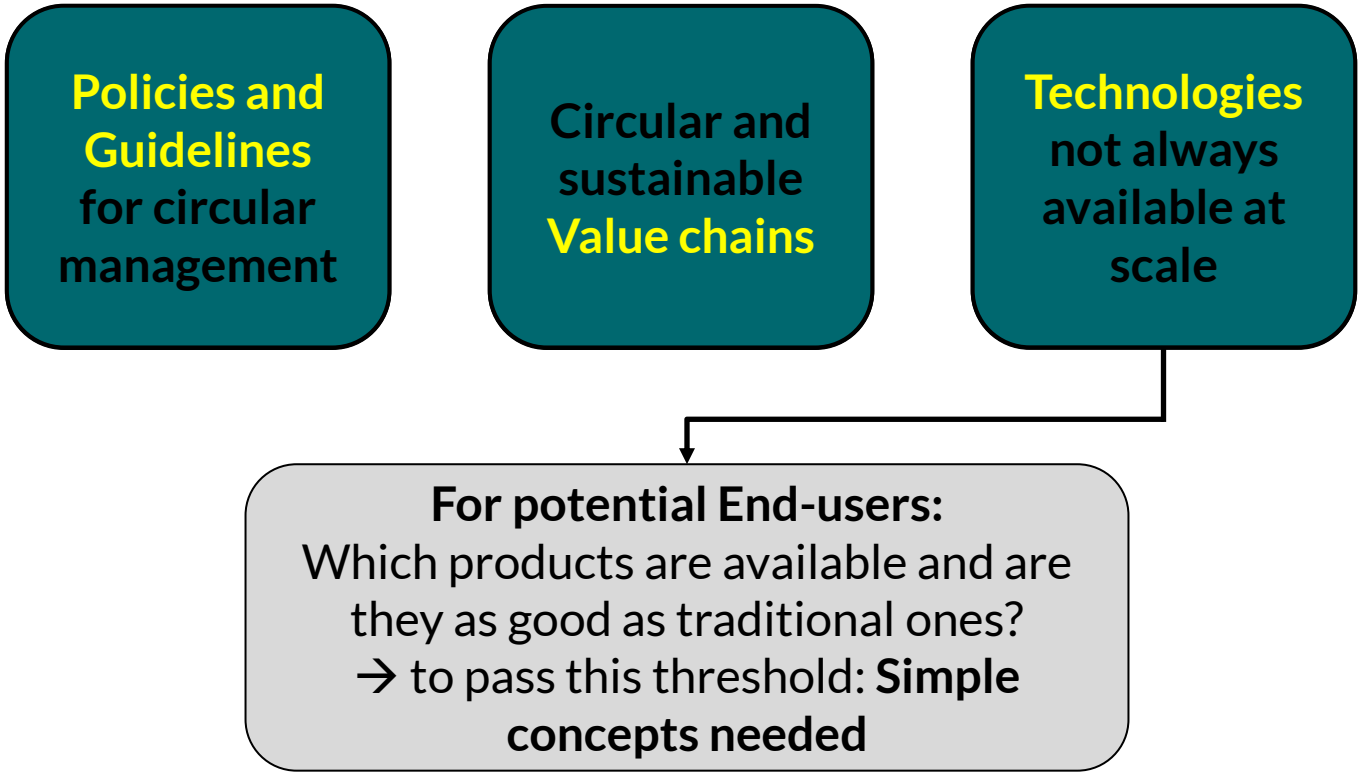
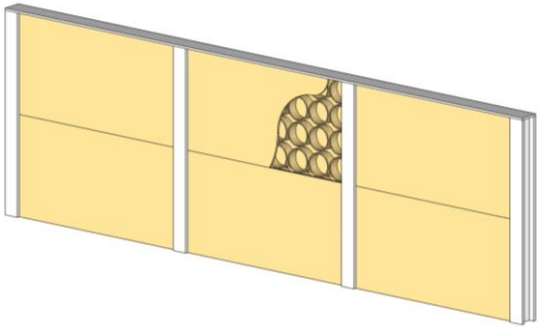
→ 3 main pillars missing today

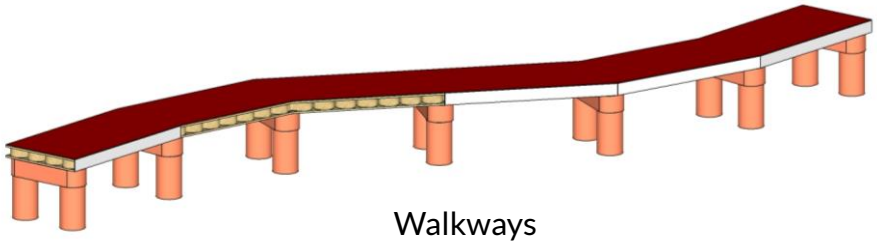


Other potential applications



Sound barrier walls

Roofing panels



Walkways

Balconies

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Conclusion and Future work

1. We have **large volumes** of EoS GFRP structures to manage (e.g. wind turbine blades, boats, … B&C 😱 !)

2. **High competition** with virgin GF and cheap EoS routes (e.g. incineration)

3. **Policies and value chains** missing for sustainable management at scale

4. **Repurposing EoS GFRP structure:** keep their inherent value (high up on the waste hierarchy)

Conclusion and Future work

5. Repurposing blades needs **robust certification processes** and access to **blade data** – work is ongoing, but more is needed!
6. Establishment of a **digital platform for data access** will ease repurposing

7. **We need simple concepts** to trigger end-users to choose product made of repurposed GFRP
8. **New policies are needed** to accelerate the creation of economically sound value chains

Recent publications for further reading

Journal of Environmental Management
Volume 367, September 2024, 122015

Research article

Sustainable repurpose of end-of-life fiber reinforced polymer composites: A new circular pedestrian bridge concept

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[c] HiFIT USA LLC, Fairfax, VA, USA

https://www.sciencedirect.com/science/article/pii/S0301479724020012

sustainability

Article

A Holistic and Circular Approach for Managing End-of-Service Wind Turbine Blades

Alann André [1,*], Thomas Bru [1], Abdul Ghafoor Abbasi [1], Sugandh Sinha [1], Stephanie Nunes [1], Magdalena Juntikka [1], Karolina Kazmierczak [2], Nils Ólafur Egilsson [2], Gustav Frid [3], Marcin Sobczyk [4] and Reza Haghani [5]

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https://www.mdpi.com/2071-1050/16/17/7858

2024

Cirkulärt omhändertagande av solcellspaneler och vindturbinblad för vindkraftverk

En rapport framtagen av forskningsinstitutet RISE på uppdrag av Energimyndigheten

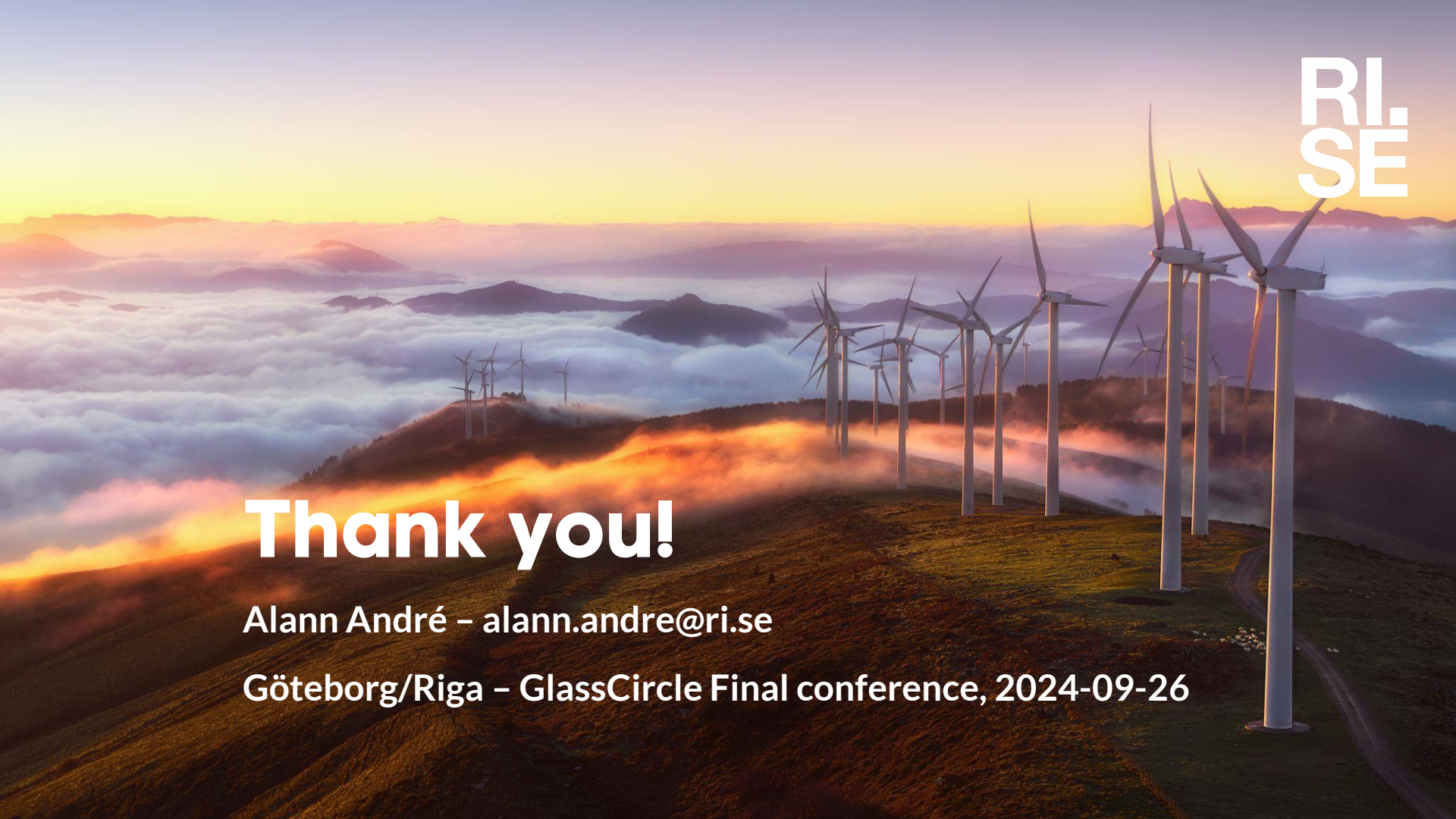
https://ri.diva-portal.org/smash/record.jsf?pid=diva2%3A1855222&dswid=1660

Thank you to all project partners!

RECINA project: REuse of Composite parts for Infrastructure Applications

CIRCUBLADE project: Circular approach for end-of-life wind turbine blades

Financial support: Innovations program RE:Source, Vinnova,and Energimyndigheten



Thank you!

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Göteborg/Riga – GlassCircle Final conference, 2024-09-26

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