What can we do with old blades?

- Chemical recycling
- Reuse

SERO årsstämma
2021-09-10

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Anmet

IEA Wind TCP **Task 45: Recycling wind turbine**

RISE Research Institutes of Sweden

Division of Material and Production
Department of Polymer Material och Composites
Unit Structural analysis and Modelling &
Unit Materials, Processes and Recycling

Expertise

- Composite materials manufacturing, testing and modelling; structural analysis and NDT.
- Composite mechanics and micromechanics, material model development
- Sustainable composites: recycling (mechanical and chemical), circular design, re-use of EoL composite structures
- HTL/Solvolysis and pyrolysis and elucidation of chemical composition of produced oils

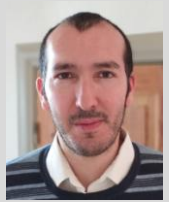
Interests

- **Topics:** *Design for recycling, sustainable and economical viable recycling solutions, mechanical and chemical recycling, re-use of blades*
- **Looking for:** *International contacts and possible to build larger international projects over the whole value chain and broader increased knowledge within this scientific field.*
- **Contribution:**
  - *Expertise in Chemical recycling: HTL/Solvolysis (small scale), Pyrolysis (batch, 1 kg scale), chemical analysis of oils*
  - *Expertise in re-use of EoL composite structures and sustainable material design of composites*

Projects

- **RECINA (2020-2021)** Re-use of EoL composite structures in the design of a pedestrian bridge deck.
- **Pyrolysis GFRP & CFRP (2020-2022)** Resource-efficient recycling via pyrolysis on an industrially relevant scale
- **RECOMP (2019-2021)** Circular streams from GFRP
- **Cirkomp (2021)** New technology for circular use of fibers and polymers from composite materials.
- **REKOVIND (2019-2020)** Chemical recycling of glass fiber composites from wind turbine blades

Contact persons



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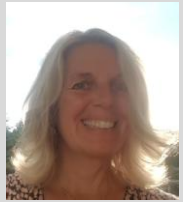

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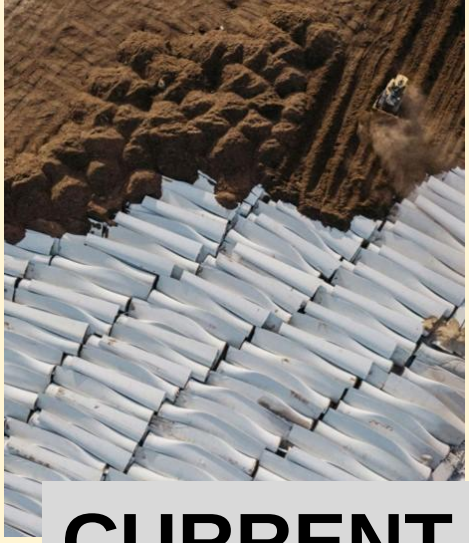
Tilldelningsbeslut – dnr. 2021-28035

Avropsförfrågan omfattar/avser:	IEA Wind TCP Task 45 – Recycling of Wind Turbine Blades
Upphandlingsförfarande:	Förenklat förfarande.
Avtalstid:	2021-09-01 – så länge tasken pågår men max 4 år.
Avtalstyp (avrop eller leveransavtal):	Avropsavtal.

Beslut
Energimyndigheten beslutar att följande leverantör tilldelas kontrakt:
RISE SICOMP AB

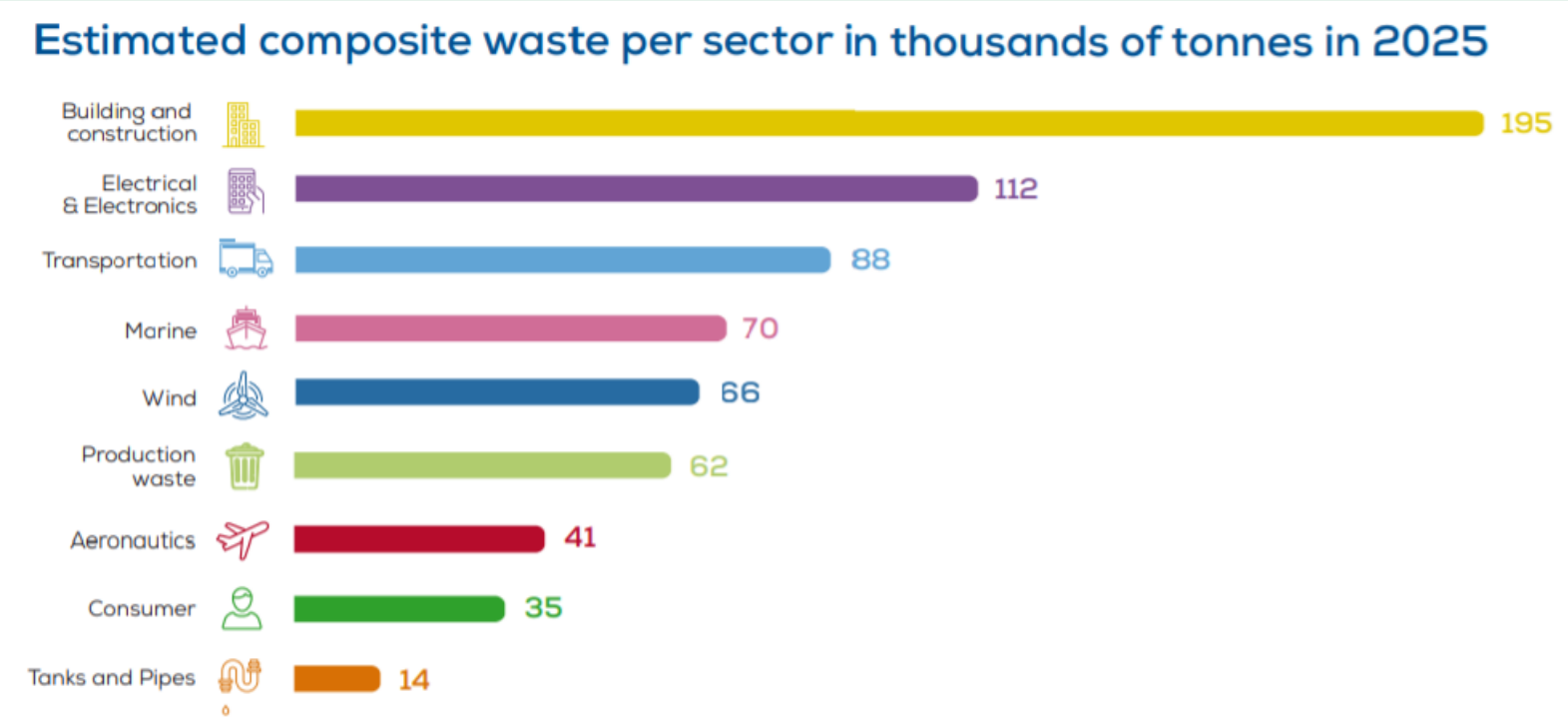
- **First generation wind turbines installed in 1990 - need to be recycled**
  - 12 000 wind turbines reach End-of-Life within 5 years (36,000 blades)
  - 2 MW turbine with three 50 m blades consists of about 20-ton GFRP (one blade 7 tons)
- **30% of all recreational boats are near end of life…**
  - Europe 6 million pleasure boats (2015, Boatcycle)
  - Estimated in Europe 140,000 used boats / year, about 160,000 tons GFRP / year (Sirris)
- **Last owner responsible**
- **Composite recycling solution: landfill and incineration - no sustainable solution**



CURRENT SITUATION

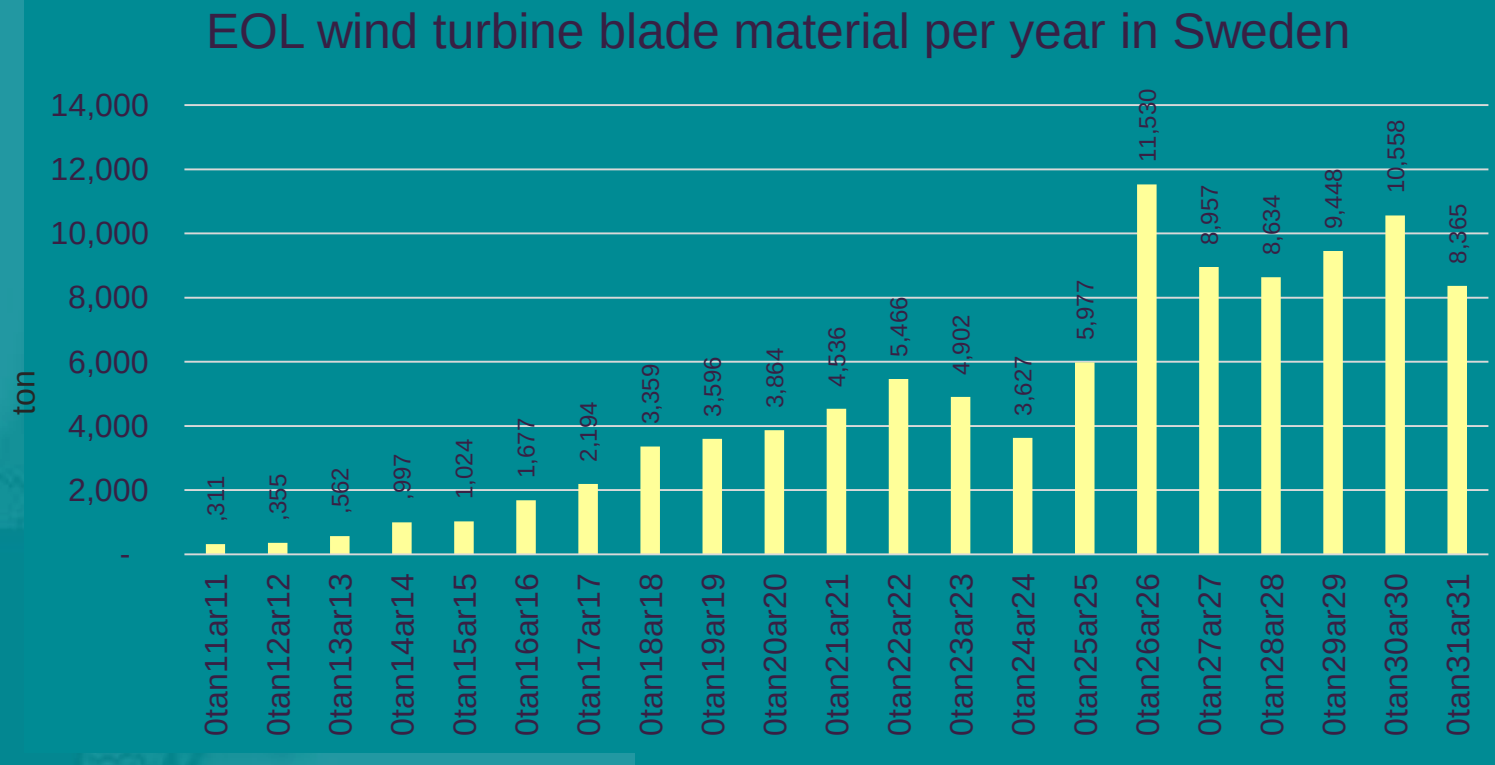
https://www.bloomberg.com/news/features/2020-02-05/wind-turbine-blades-can-t-be-recycled-so-they-re-piling-up-in-landfills
https://www.svd.se/sa-undviker-vi-att-skapa-fler-giftoar

Europe by 2025 – ca 700 000 tons of composite waste !



ETIPWind (2019), HOW WIND IS GOING CIRCULAR blade recycling
https://etipwind.eu/files/reports/ETIPWind-How-wind-is-going-circular-blade-recycling.pdf

SWEDEN – What are the numbers?



Within 5 year

970 blades

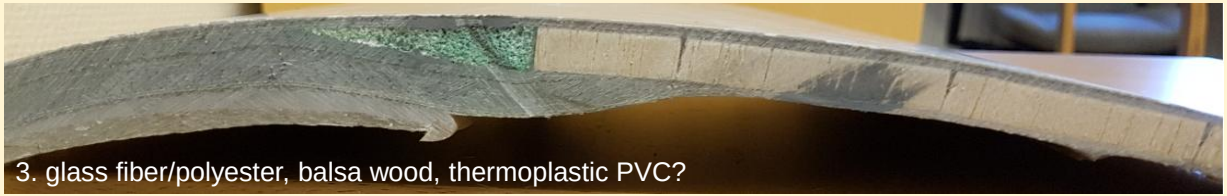
6800 tons

End-of-Life wind turbine blades

- complex material composition
- unknown composition

1. Glass fiber epoxy, laminate polystyrene foam, balsa wood and more?

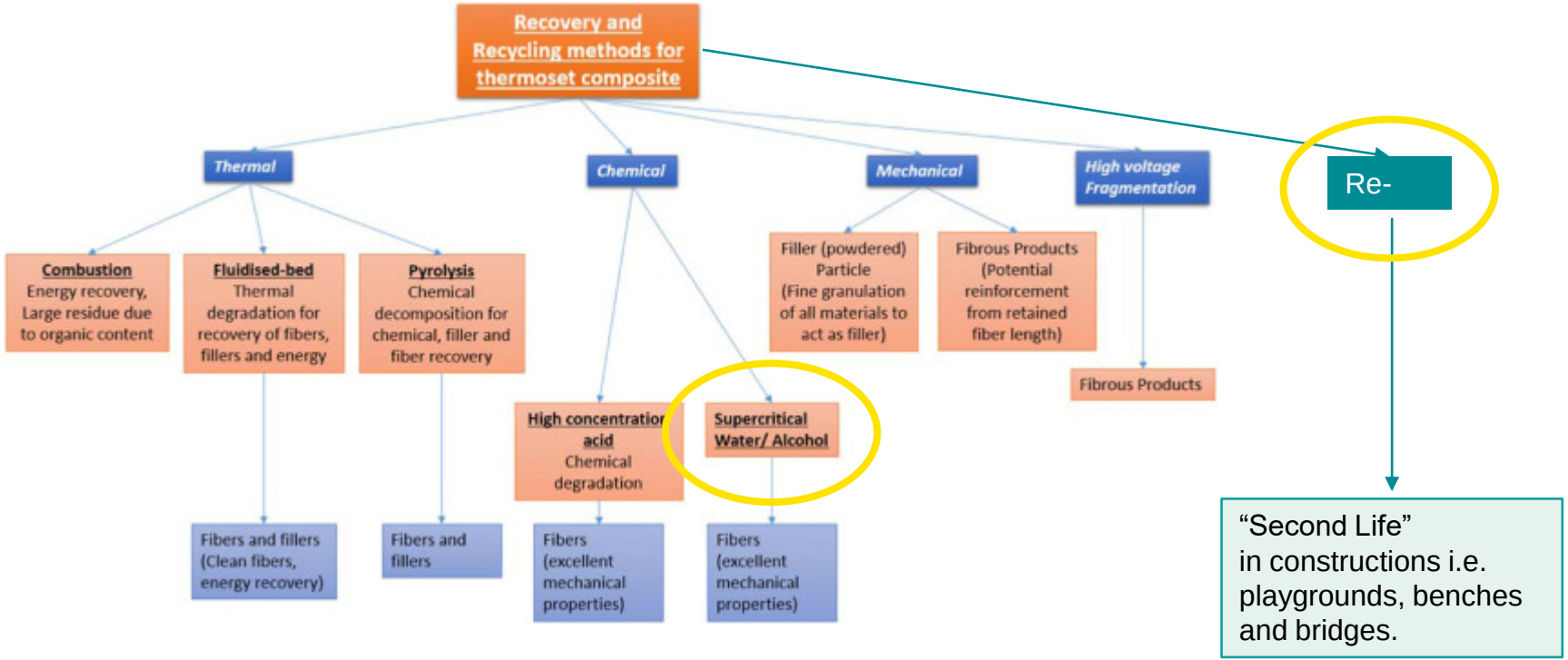
2. glass fiber/polyester laminate, balsa wood, black rubber?, grey?



3. glass fiber/polyester, balsa wood, thermoplastic PVC?

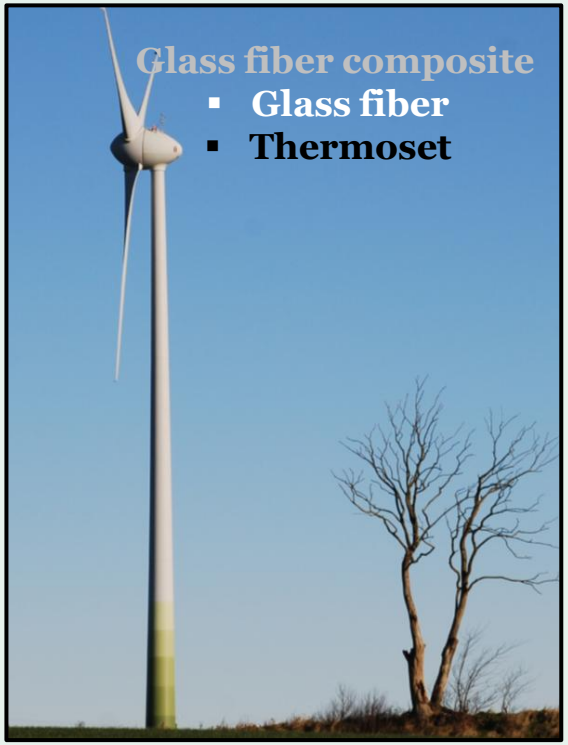
- **Thermosets (epoxy, polyester, vinyl ester, PUR)**
- **Thermoplastic (PVC, PET)**
- **Balsa wood**

Overview of composite recycling technologies



Utekar et. al (2021). Comprehensive study of recycling of thermosetting polymer composites–Driving force, challenges and methods. *Composites Part B: Engineering*, *207*, 108596. https://www.sciencedirect.com/science/article/pii/S1359836820336428#bib85

Chemical recycling of GFRP from wind turbine blades with solvolysis

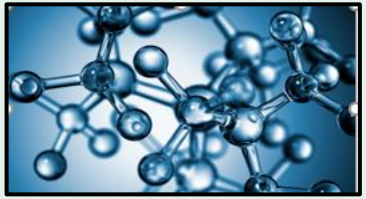


Solvolysis/
HTL

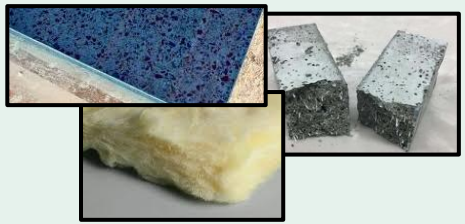
270-330 °C
175 bar

Recycled materials

Glass fiber



Plastic building blocks



Concrete,
Insulation,
Composites, glass

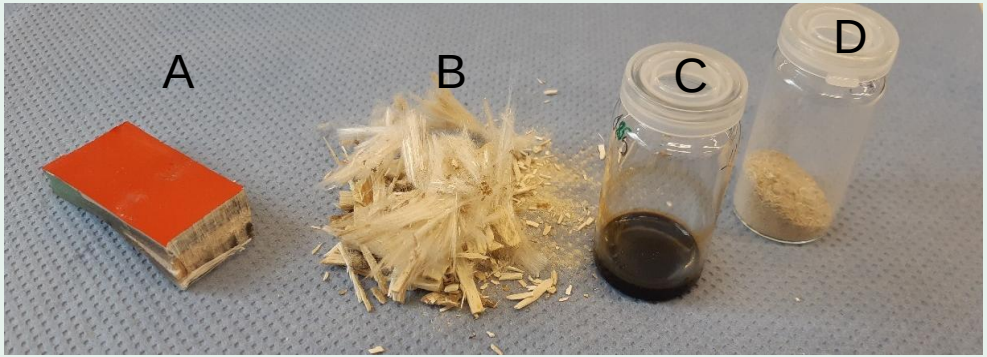
New products

Thermosets,
thermoplastics, refinery
feed, fuels

Chemical recycling – Solvolysis/HTL of thermoset composites from wind turbine blades (pieces)

Results:

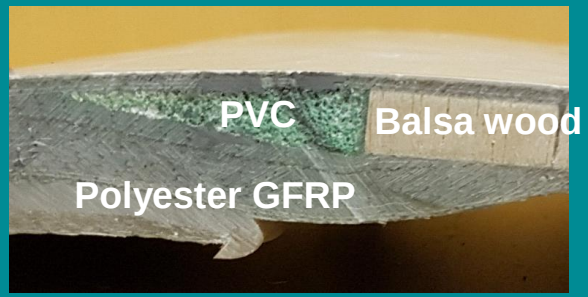
- **Long reaction times needed:** 20 h at high temperature and pressure (270 °C, 175 bar)
- **Low yield of valuable "solvolysis oil" <15%** due to high fiber/fillers content . Can be a substitute for fossil oil after additional upgrading similar quality as bio-oil from wood. Need upgrading before used in refineries.
- **Recycled glass fibers mixed with clean and partly clean glass fibers.** In total approx. 10% thermoset left on glass fibers.



Product fraction from blade piece A	
Glass fiber (B)	65 %
Solvolysis oil (C)	15 %
Woodfibers (D)	13 %
Water soluble molecules	7 %

Results published in scientific journal October 2020
Chemical recycling of End-of-Life wind turbine blades by solvolysis/HTL. *IOP Conference Series: Materials Science and Engineering* (Vol. 942, No. 1, p. 012013). IOP Publishing.

Summary of solvolysis of wind turbine blades

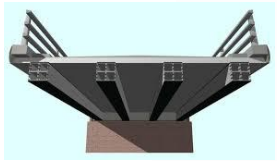


- **All different materials are possible to degrade or separate by solvolysis:**
  - Polyester are more degradable than epoxy GFRP
  - Foam cores and balsa wood are possible to separated in a pre-step process.
- **Challenge to develop a cost effective solvolysis process for EOL material**
- **Recycled glass fibers more expensive and lower quality** than virgin glass fibers 10-20 SEK/kg.

ReUse of FRP in infrastructure

Our idea aims to promote sustainability in the infrastructure sector by Re-using durable and lightweight FRP materials

Done/Ongoing/Coming at RI. SE



1998-2002

- **ASSET project**

West Mill bridge, UK

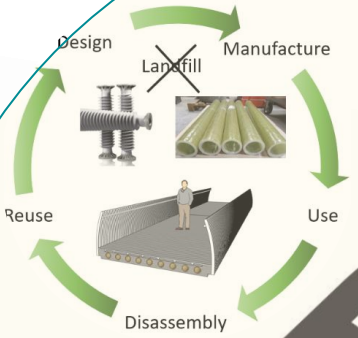
2016-2018

- **FALCON I project**

→ **Neptuni FRP Bridge, Malmö**

2019-2021

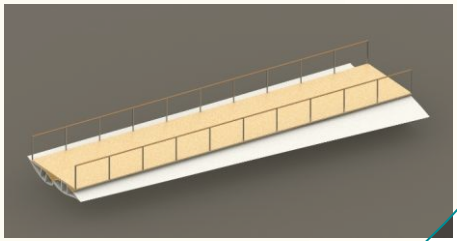
- **RECINA project** - bridge elements out of GFRP isolator



2022 EU standard released!

2021-2023

- **Blade2Bridge -** Pedestrian bridge out of re-used Wind turbine blade



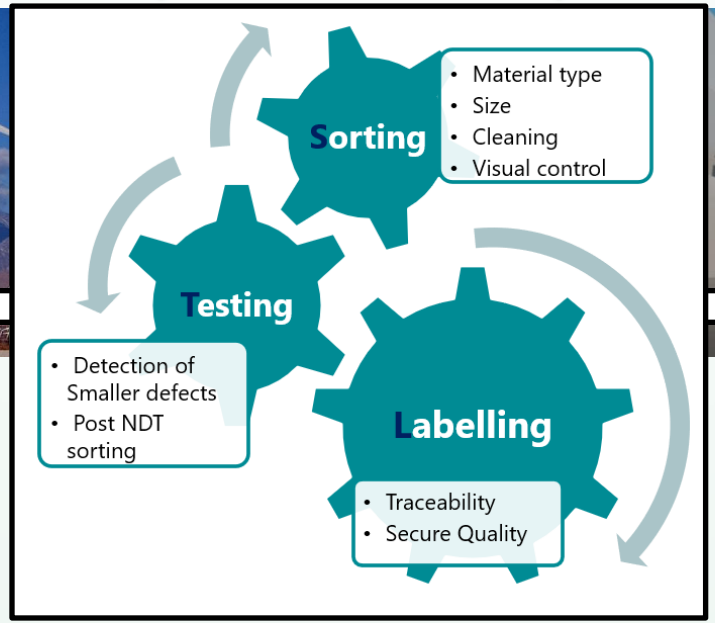
”Second Life” solution:

- **→ 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


Bank et al, 2018, Re-wind project


® Denis Guzzo, Superuse Studios

Materials for Wind Turbine Blades: An Overview
Mishnaevsky et. al. materials 2017
Bank et. al. Concepts for Reusing Composite Materials from DecommissionedWind Turbine Blades in Affordable Housing 2018
https://www.windpowerengineering.com/mechanical/blades/recycling-wind-turbine-blades/



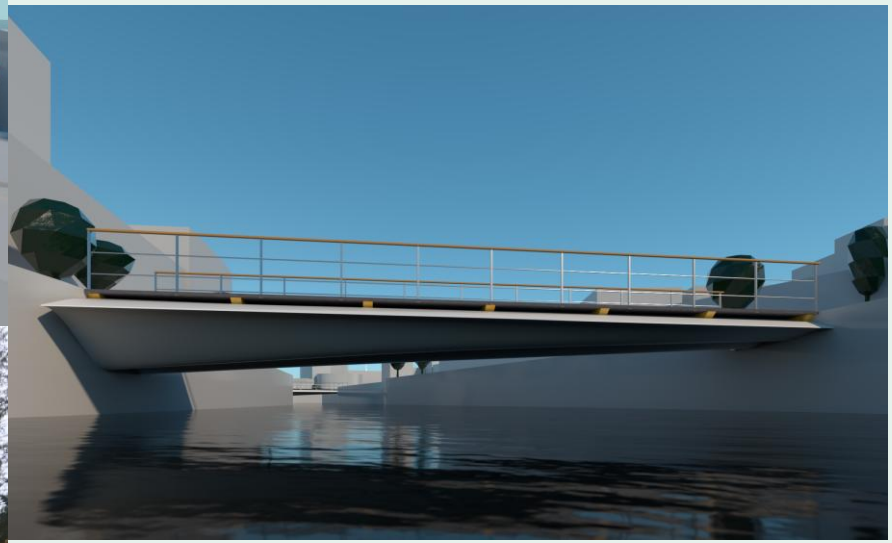
The “wind forest”

The next generation infrastructure

Robust quality processes

Circularity enabler

ReUse of FRP - Bridge application (ReComp)



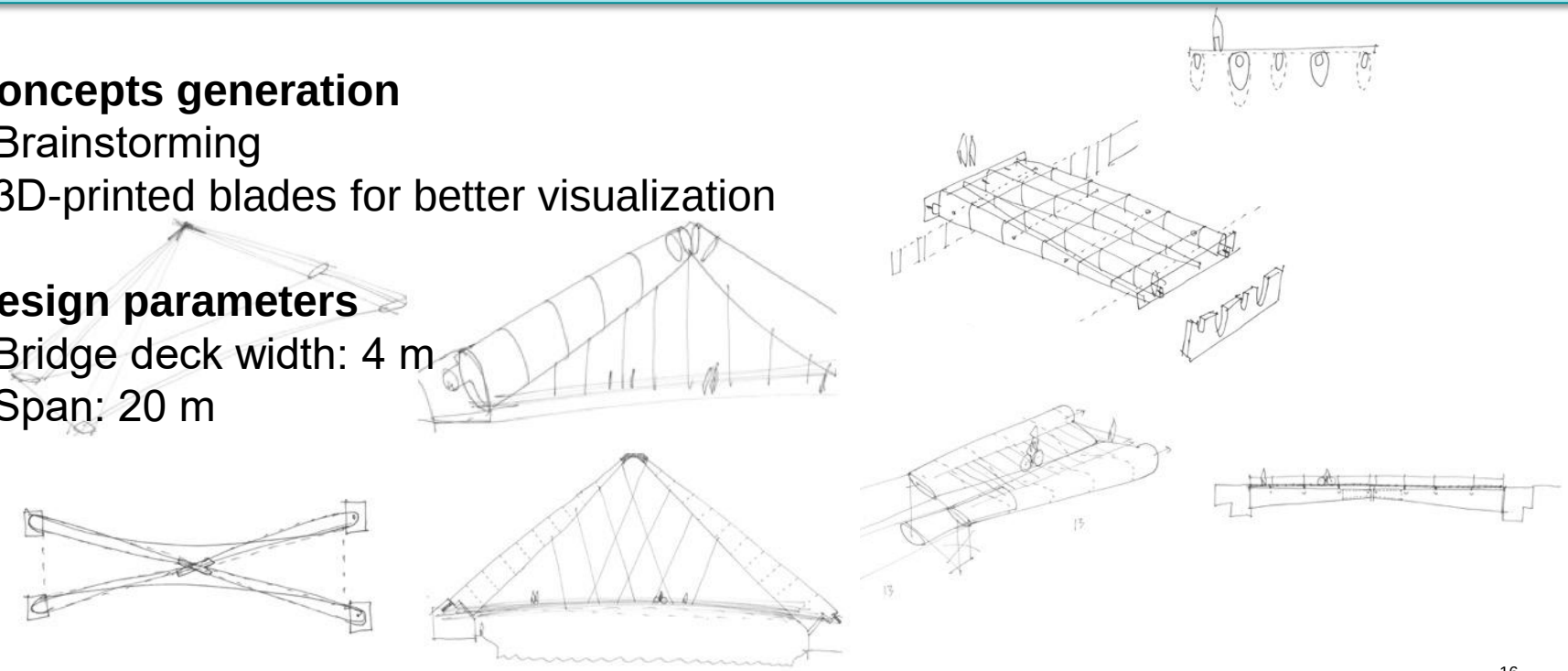
André, A., Kullberg, J., Nygren, D., Mattsson, C., Nedev, G., & Haghani, R. (2020, October). **Re-use of wind turbine blade for construction and infrastructure applications**. In *IOP Conference Series: Materials Science and Engineering* (Vol. 942, No. 1, p. 012015). IOP Publishing.

ReUse of FRP - Bridge application (ReComp)

Find a cost effective and viable solution to reuse wind turbine blades in innovative bridge designs and increase the lifetime of the blades.

Concepts generation
- Brainstorming
- 3D-printed blades for better visualization

Design parameters
- Bridge deck width: 4 m
- Span: 20 m



ReUse of FRP - Bridge application (ReComp)

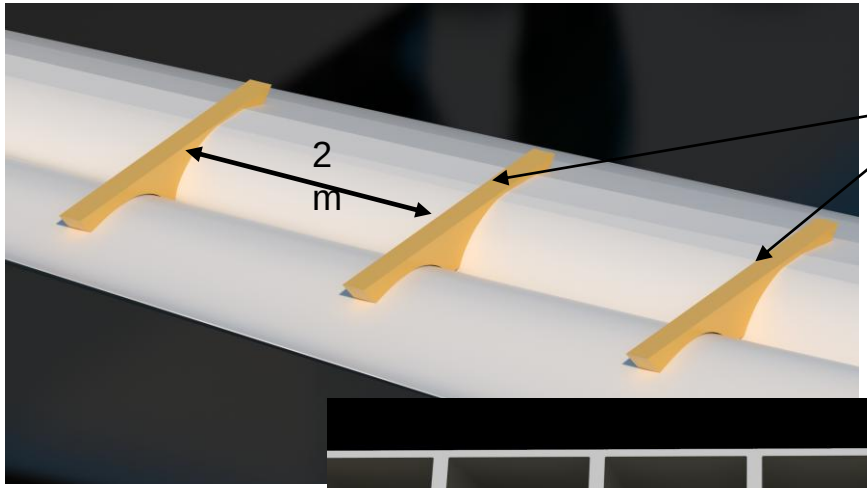
Further design

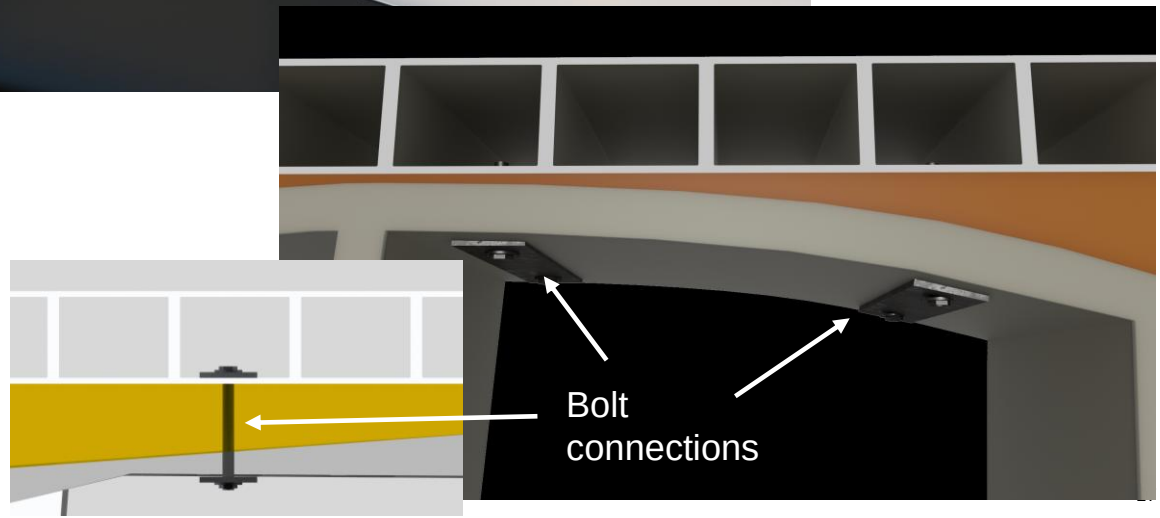
Bridge deck
- Box section in FRP
- 80 mm high
- Spans 2 m

Connections
- Polyurethane
- Bolts

Railing
- 1.4 m high

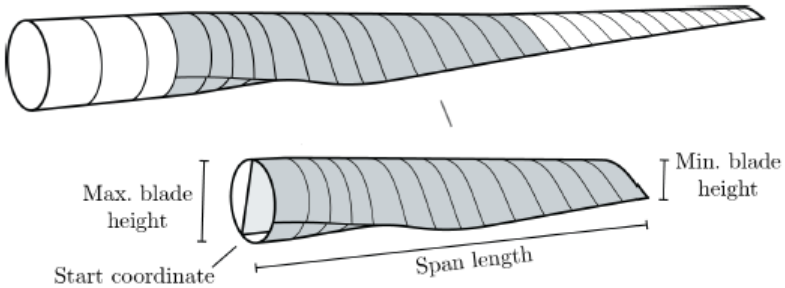
Supports
- Elastomeric bearings

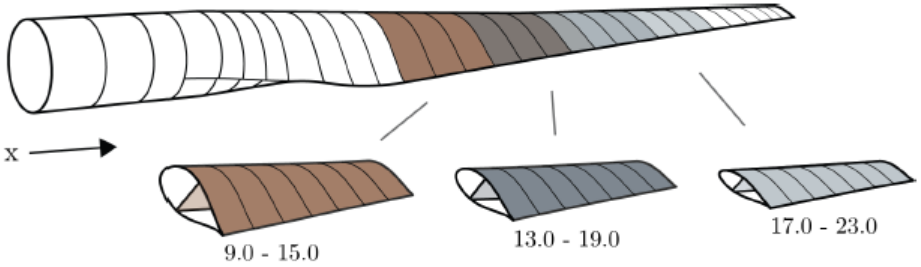




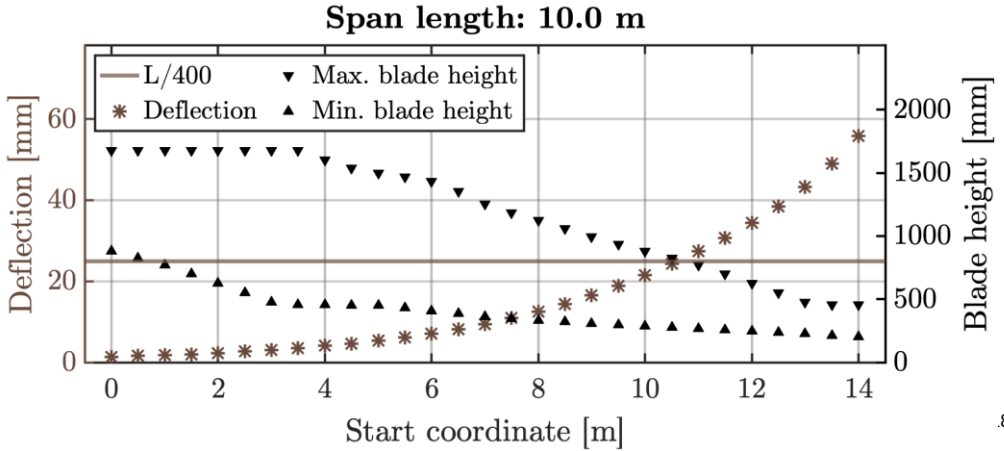
ReUse of FRP - Bridge application (ReComp)

<u>Further design</u> –
Recent analysis – Work around a real decommissioned blade





→ Numerical models developed.
→ Which part would be optimum to cut for a specific span?



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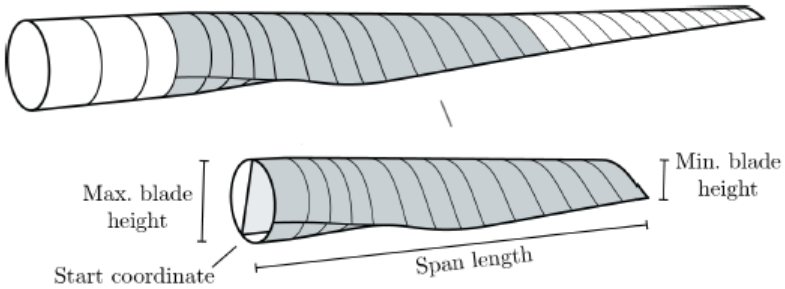
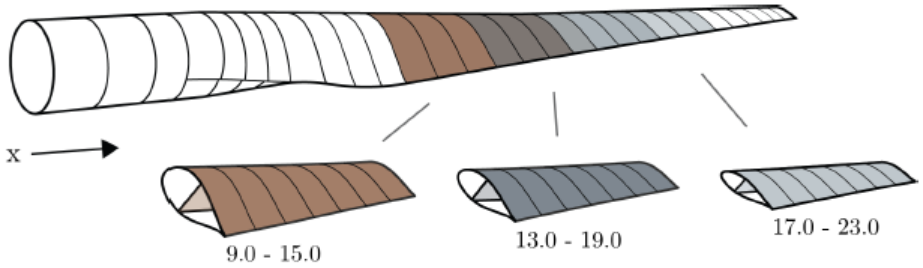




→ Numerical models developed.
→ Which part would be optimum to cut for a specific span?

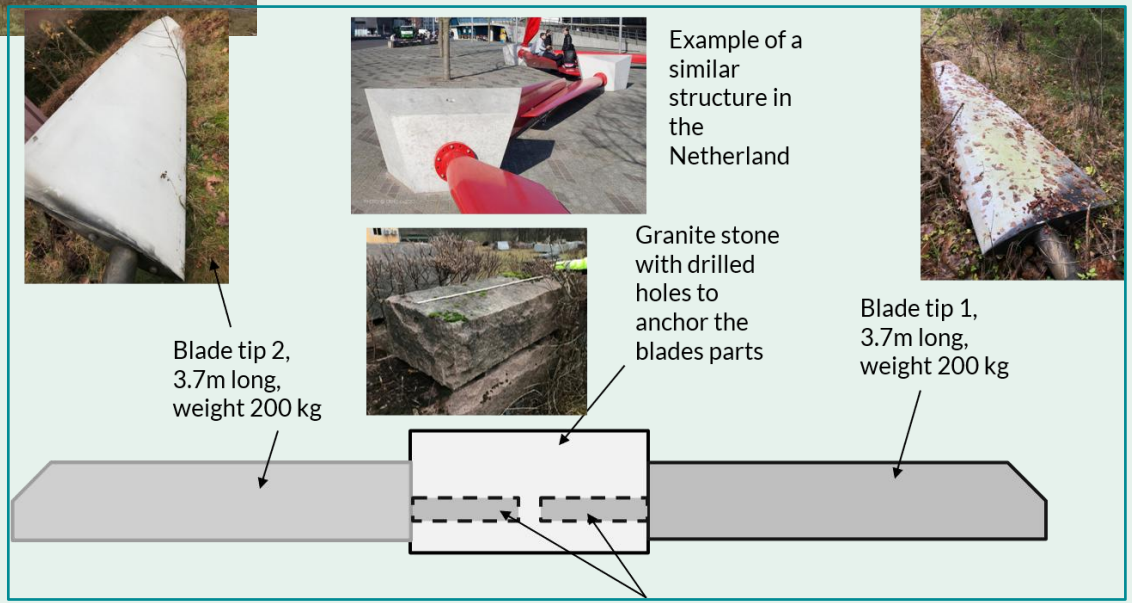
Span length	Start coord.	Max. height	Deflection	Acceleration
6.0 m	18.0 m	333.7 mm	✓	✓
8.0 m	14.5 m	452.0 mm	✓	✓
10.0 m	9.0 m	993.8 mm	✓	✓
12.0 m	5.2 m	1485.0 mm	✓	✓
14.0 m	1.75 m	1675.0 mm	✓	✓
16.0 m	1.6 m	1675.0 mm	✓	✗
20.0 m	-	1675.0 mm	✗	✗

First demonstrator in Sweden from old blades ReUse of FRP – Lane divider from End-of-Life

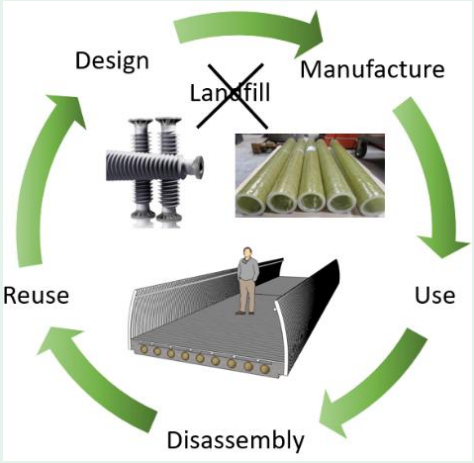
- Two 4m long tips of EoL blades will be used with a center piece of stone (granite)

- Replacing lane divider in concrete sov

- The demonstrator to be built soon in 2021



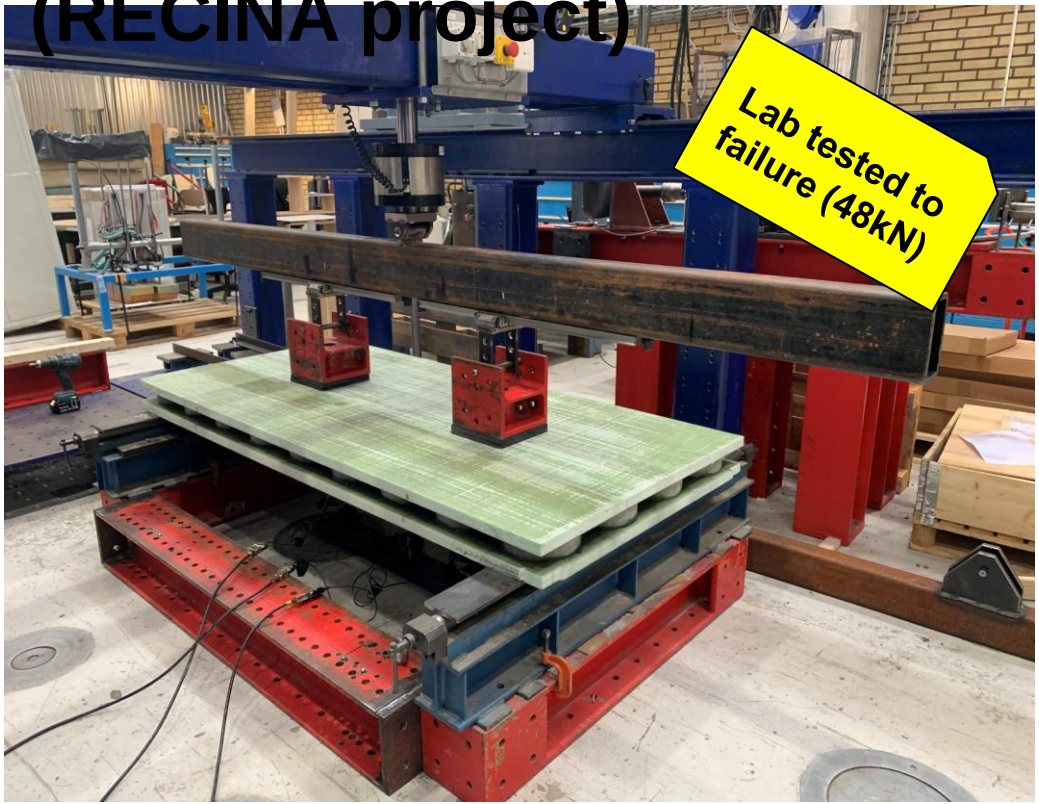
Reuse of Composite Components in Infrastructure (RECINA project)

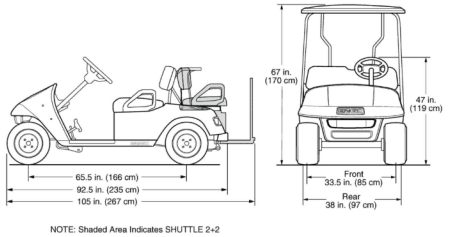


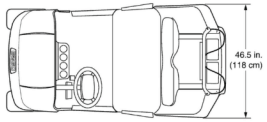
→ **Sandwich panel system**

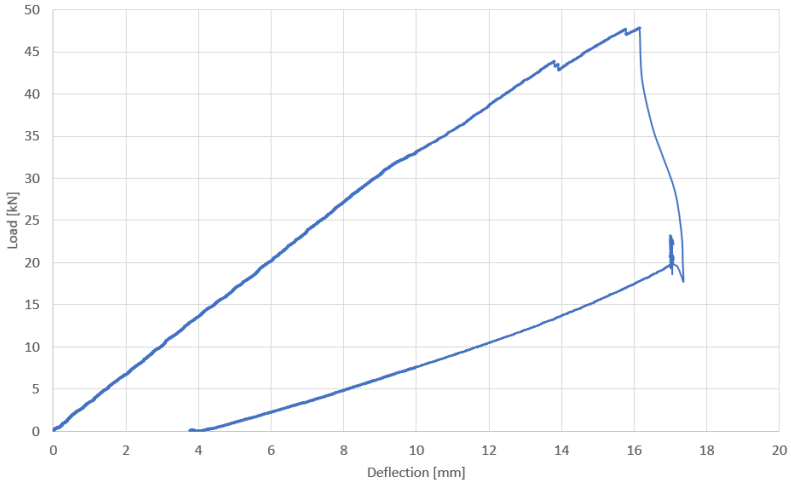
GFRP production waste re-used in innovative bridge decking system

Reuse of Composite Components in Infrastructure (RECINA project)





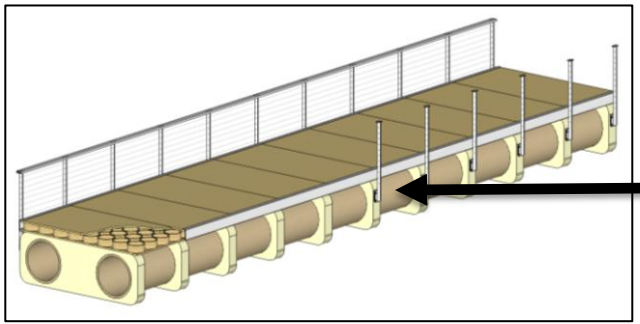




Reuse of Composite Components in Infrastructure (RECINA project)

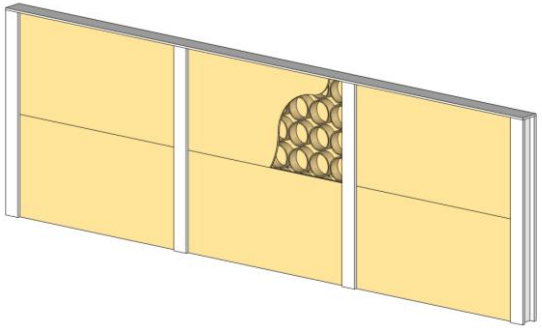
- Almost 100% made of re-used GFRP
- 600kg (lightweight)
- x7 lighter than a concrete alternative
- x2-3 more durable than timber alternative

→ **Cost-effective and circular**

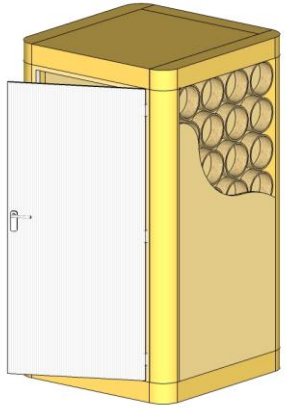


Reuse of Composite Components in Infrastructure (RECINA project)

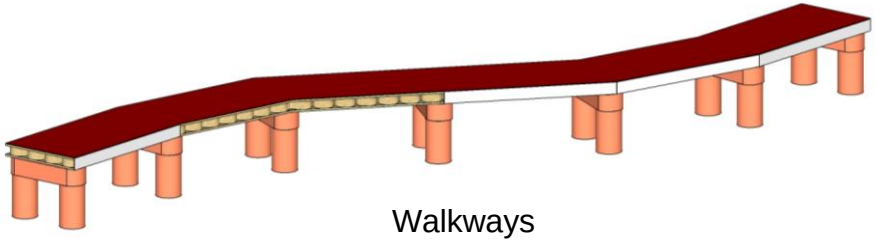
Roofing panels



Sound barrier walls



Field toilets



Walkways

Balconies

Conclusion:

Need for development of new waste valorization system for GFRP composite waste

- **Unknown composition**
- **Need for qualification and sorting of blades and other composites**

Waste sorting, digital tracking systems, logistics

Technical solutions recycling and re-use

- **High quality blades**
  - Re-Use
- **Damage blades and production waste**
  Recycling
  eeded

System perspective and legislations, circular design

End users of new recycled material streams

- **End user responsible**
- **Producer responsibility?**

- **Re-use of structures and parts**
- **Recycled glass fibers**
- **Oil product**

Thank you for your attention

Rekovind
Chemical recycling of glass fiber composite from wind turbine blades

ReComp
Creating circular streams from GFRP composite waste

RECINA
REuse of Composite parts for Infrastructure Applications

Partners Recomp: RISE, Nimbus boats, MTC, LTU, SMTF, Volvo Cars, Renova, PodComp, BladeSolutions, Librixer, Skene skog ÅVC
Partners RECINA: RISE, Chalmers, Composite Design, Marstrom Composite, Eventhotell , ABB
Blade samples: Enercon (Germany), Anmet (Polen)

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