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Plastindustriens kompositgruppe, 23. maj, 2024

Glass Fibre Remelting – Proof of Concept [GFR-PoC]

Pyrolysis value chain for decommissioned Wind Turbine Blades [WTBs]

Closing the loop

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Project Manager

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Chemical process optimization

DecomBlades partners:

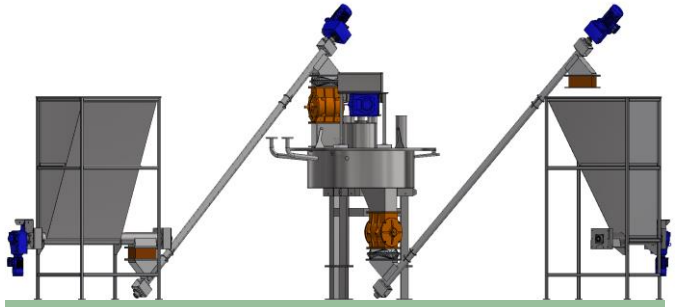
Partially funded by the Innovation Fund Denmark:

Glass Fibre Remelt – Proof of Concept

Description of trial, scale, expected outcome.

Pyrolysis value chain:

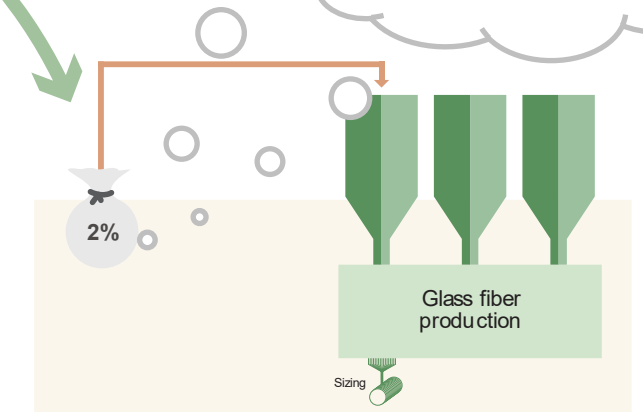
Investigate **pyrolysis as enabler** to prepare **recovered glass fibres** for **remelting**



MAKEEN Energy

Sustainable, no degradation, full circular

Can off-take coming qty



3B-Fibreglass

BLADE TO BLADE recycling for the glass fibres - Probably the only way!

In new WTBs at LM Wind Power & Siemens Gamesa Renewable Energy

3B + DTU

Publication: Melting glass fibres recovered from wind turbine blades into new glass fibres for wind turbine blades.
Authors: Justine Beauson, Asger Bech Abrahamsen, Irene Bach Velling Villadsen, Luc Peters, Bernard Kaesmacher, et al.

Pyrolysis value chain:

Investigate **pyrolysis as enabler** to prepare **recovered glass fibres** for **remelting**

Scale of trial

Real process equipment

Pyrolysis: Large scale test-setup continuous process

Real process

Two 37m wind turbine blades

9.9 tons shredded **composite material**

5.5-6.0 tons on storage

1.5 tons of cleaned glass fibres

(*Commissioning, process parameters, “cleaning” equipment, learning, remelting)

76 tons of bobbins with recovered content

Outcome of GFR-PoC?

Investigate pyrolysis as enabler to prepare recovered glass fibres for remelting

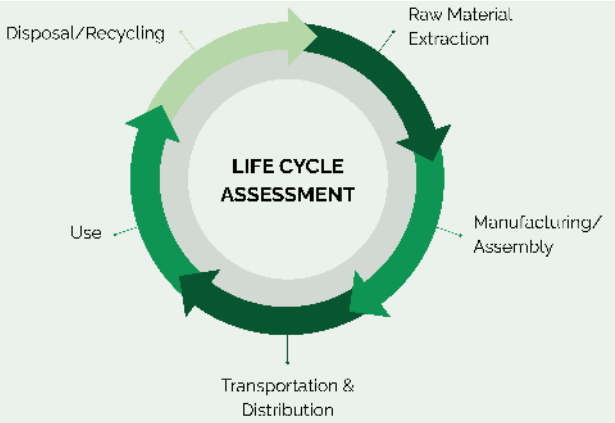
IS IT POSSIBLE?

A process/technical **baseline for further development**

=> Learnings to design commercial process setup

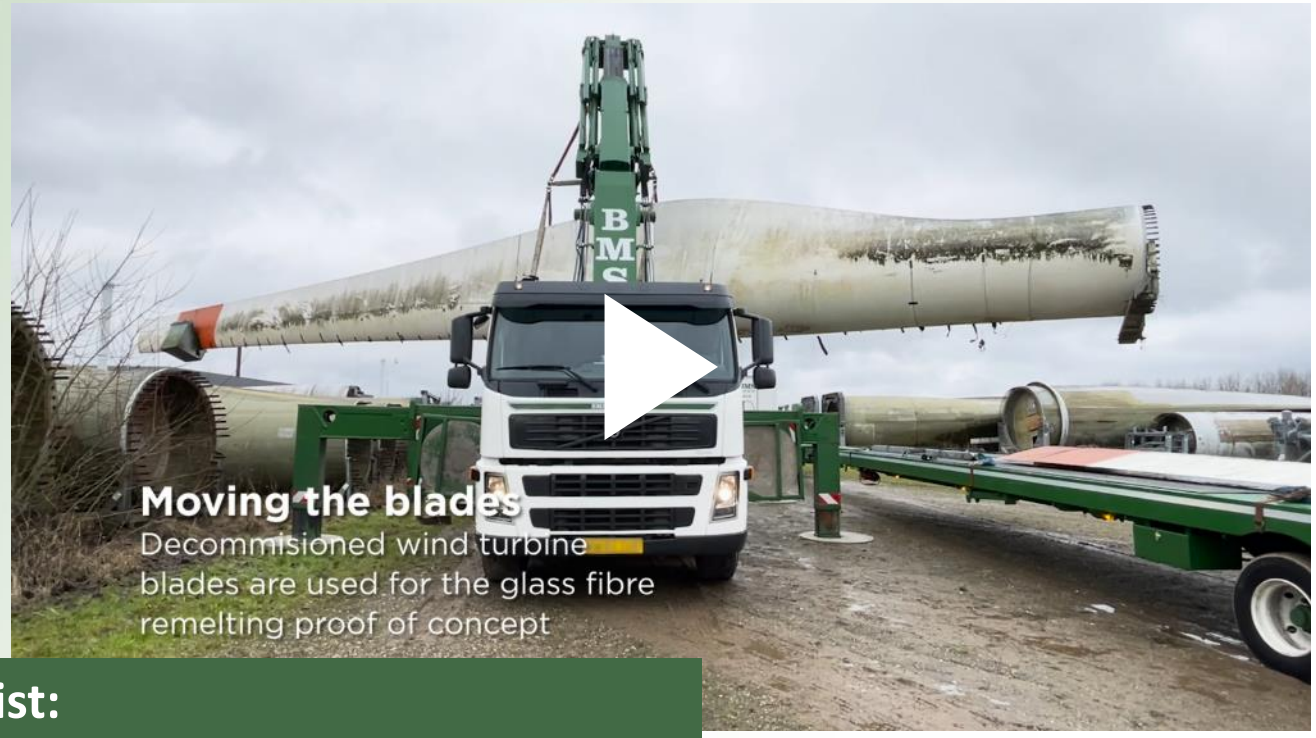
Environmental impact (LCA) in a commercial value chain

The processes applied MINUS the processes avoided



Glass Fibre Remelt – Proof of Concept

What actually happened?



Value chain does NOT exist:

=> Use process equipment not designed for this material

=> Use process equipment processing other materials

GFR-PoC: Results

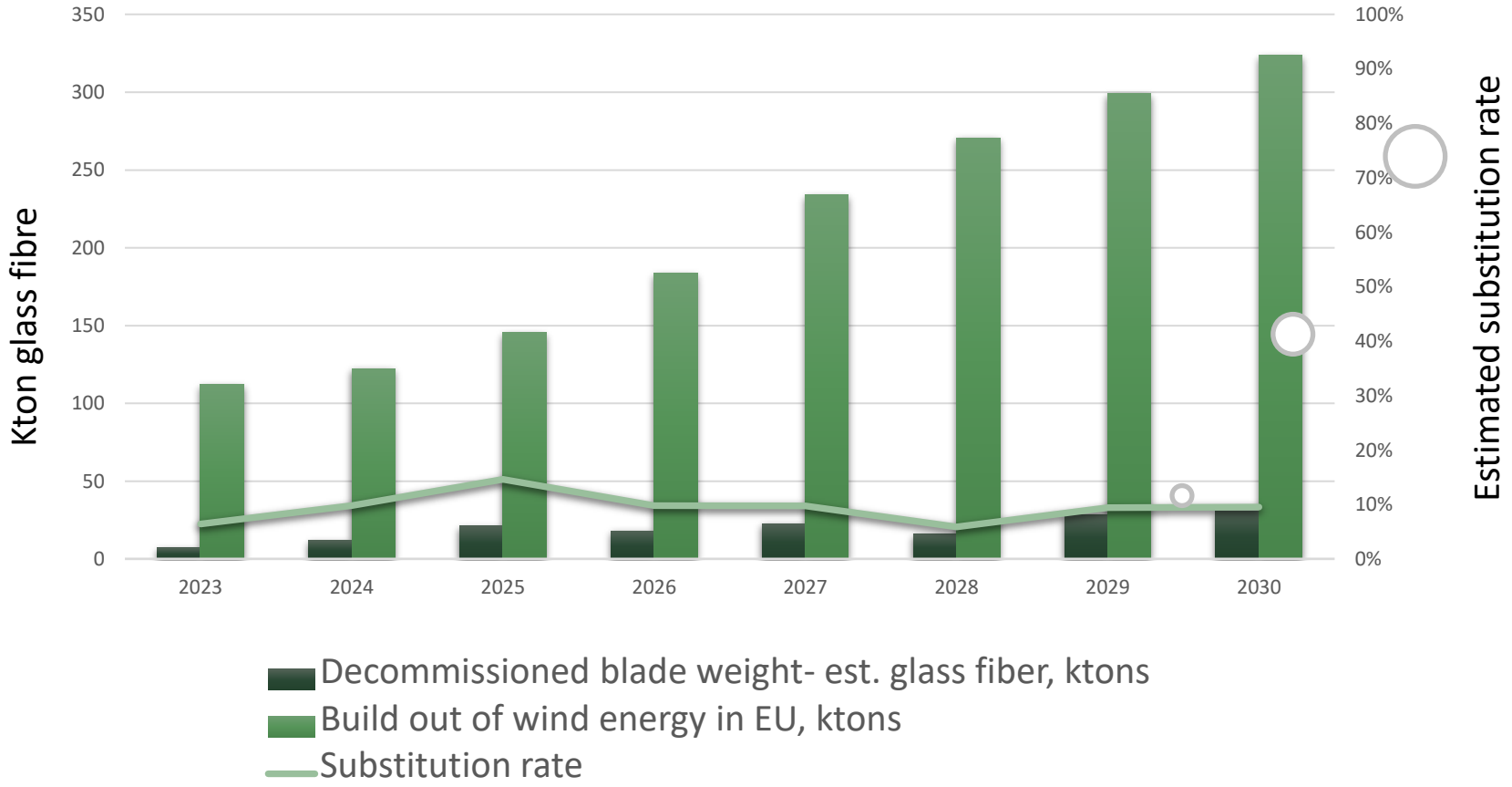
Commercialization

Necessary substitution rate

Necessary substitution rate - Europe

Estimated MAXIMUM necessary substitution rate – Europe (ALL numbers from WindEurope)

Only LOW substitution rate is needed!
Preferable => low risk!
Time to learn -> upscale



DecomBlades study:
Decommissioning of Wind Turbine Blades:

- Several forecasts
- Differs in qty and timing
- Agrees on “steep slope”

Purpose: Investigate MAXIMUM necessary substitution rate in Europe – NOT timing.

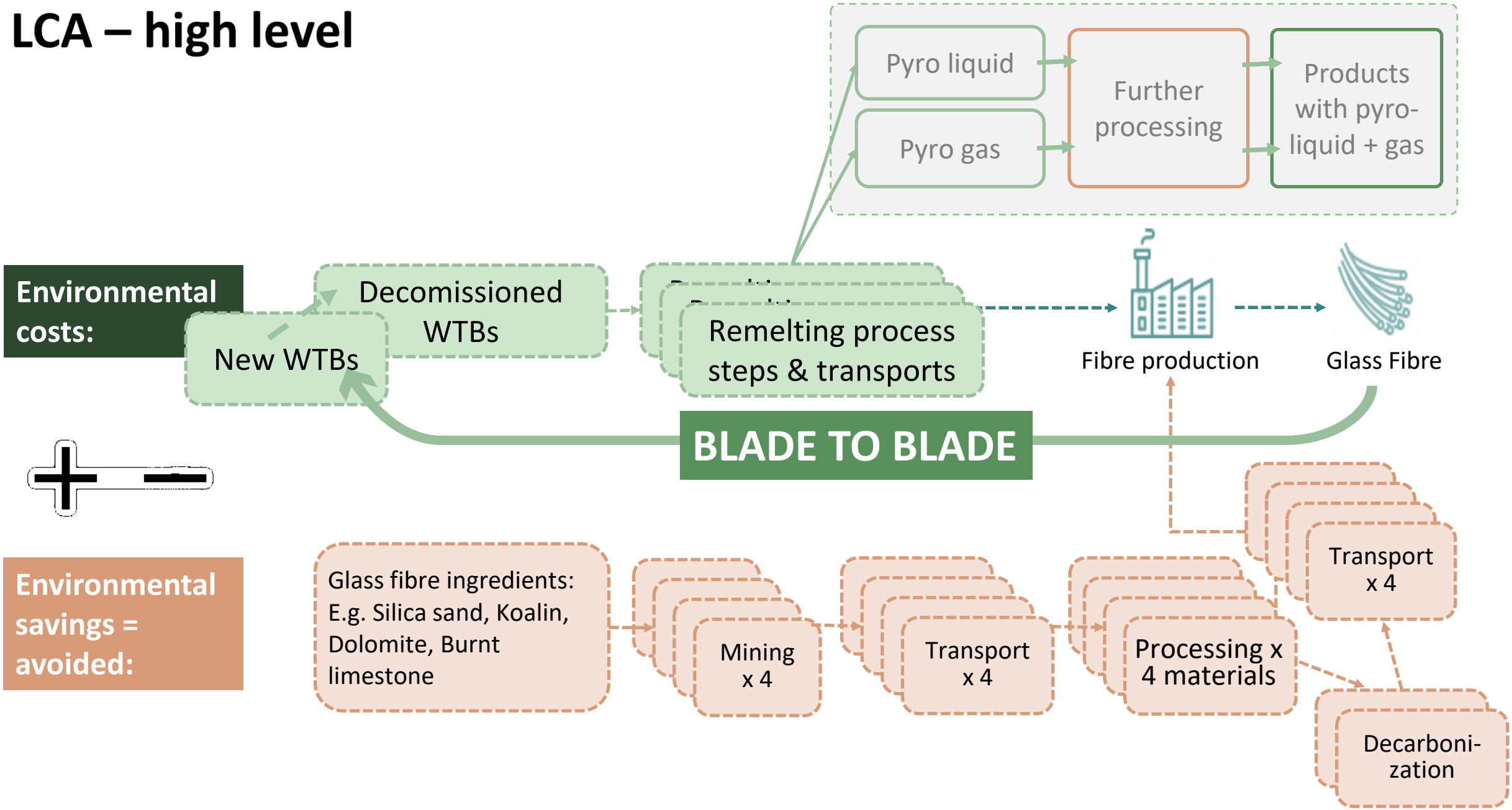
GFR-PoC: Results

LCA assessment:

LCA: High level considerations, pre-view on remelting

Scheduled publications

LCA – high level



LCA – results remelting

Scheduled publications, Southern Danish University (SDU):

- Prospective Consequential LCA of all WTB EoL scenarios using state of the art SSP based PREMISE database
- Prospective LCA of a PoC scenario (Pyrolysis, remelting, gasification-bio methanation)

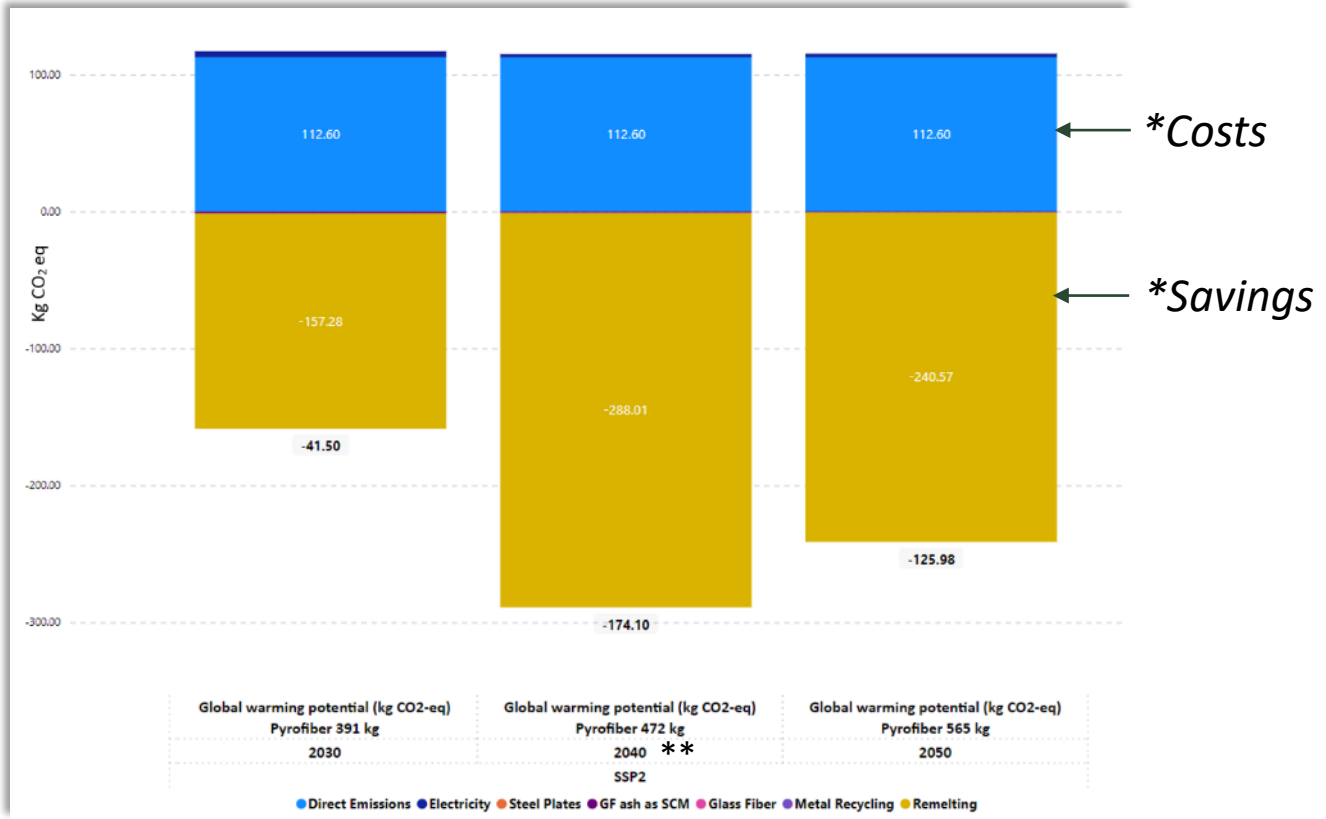
Scenario: SSP2 (model of the "society" depending on the level action towards a green transmission)

2030, 2040, 2050 differences:

- Increasing Glass Fibre content in recycled WTB.
- Increasing recovery efficiency (decreasing loss)
  - 2030: 70%
  - 2040: 80%
  - 2050: 90%
- Decreasing electricity-based emissions from SSP2-scenario

Conclusions:

- Positive environmental impact.
- Transportation gives a surprisingly low contribution to the "environmental cost"



Note:
Functional Unit = 1 ton WTB on ground
*** SSP2 for 2040: Will be updated in publication*

**Reference: Model by SDU. Input data from MAKEEN, 3B-Fibreglass, HJHansen Recycling. Non-disclosed to SDU. Literature data from SDU*

Economical assessment*

Pyrolysis value chain, remelting glass fibres.

Assumptions:

- Gate-fee calculations for pre-processing and pyrolysis value-chain: From DecomBlades project (Economical Analyses).
- LCOE: Calculated as the additional costs of adding pyrolysis value-chain to existing decommissioning budget

Costs

Typical costs have been provided based on a project with the following parameters, typical of an upcoming UK offshore wind project.

Parameter	Data
Wind farm rating (MW)	1000
Wind turbine rating (MW)	10
Water depth at site (m)	30
Annual mean wind speed at 100m height (m/s)	10
Distance to shore, grid, port (km)	60
Date of financial investment decision to proceed (FID)	2019
First operation date	2022

Detailed, bottom-up assessment of this typical project gives the following inputs to the LCOE equation:

$$LCOE = \frac{Sum\ of\ costs\ over\ lifetime}{sum\ of\ electricity\ produced\ over\ lifetime}$$

+0.06% (1,000 MW=WTB-farm)

Turbine foundation	280,000
Transition piece	100,000
Corrosion protection	20,000
Scour protection	10,000
Offshore substation	120,000
Electrical system	45,000
Facilities	20,000
Structure	60,000
Onshore substation	30,000
Buildings, access and security	8,000
Other (includes electrical equipment and systems)	22,000
Operations base	3,000
Installation and commissioning	650,000
Foundation installation	100,000
Offshore substation installation	35,000
Onshore substation construction	25,000
Onshore export cable installation	5,000
Offshore cable installation	220,000
Cable burial	20,000
Cable pull-in	7,500
Electrical testing and termination	6,500
Other (includes cable-laying vessel, survey works, route clearance, cable protection systems	186,000

Category	Rounded cost (£/MW)
Development and project management	120,000
Development and consenting services	50,000
Environmental impact assessments	8,000
Other (includes developer staff hours and other subcontract work)	42,000
Environmental surveys	4,000
Benthic environmental surveys	450
Fish and shellfish surveys	400
Ornithological environmental surveys	1,000
Marine mammal environmental surveys	1,000
Onshore environmental surveys	550
Human impact studies	350
Resource and metocean assessment	4,000
Structure	3,000
Sensors	650
Maintenance	300
Geological and hydrological surveys	4,000
Geophysical surveys	700
Geotechnical surveys	2,500
Hydrographic surveys	800
Engineering and consultancy	4,000
Other (includes lost projects that incur development expenditure)	54,000
Turbine	1,000,000
Nacelle	400,000
Bedplate	20,000
Main bearing	20,000
Main shaft	20,000
Gearbox	70,000
Generator	100,000
Power take-off	70,000
Control system	25,000
Yaw system	17,000
Yaw bearing	7,000
Nacelle auxiliary systems	7,000
Nacelle cover	10,000
Small engineering components	25,000
Structural fasteners	7,000
Rotor	190,000
Blades	130,000
Hub casting	15,000
Blade bearings	20,000
Pitch system	10,000
Spinner	2,000
Rotor auxiliary systems	4,000
Fabricated steel components	8,000
Structural fasteners	7,000
Tower	70,000
Steel	60,000
Tower internals	7,000
Other (includes assembly, wind turbine supplier aspects of installation and commissioning, profit and warranty)	340,000
Balance of plant	600,000
Cables	170,000
Export cable	130,000
Array cable	35,000

*https://guidetoanoffshorewindfarm.com/wind-farm-costs

Conclusion GFR-PoC:

REMELTING IS POSSIBLE!

No degradation, Blade-to-Blade circularity

Can off-take the quantity in the coming years

=> We are on our way to 100% recyclable WTBs

LCA-results: Later this year, published by SDU

Thank you for your attention

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