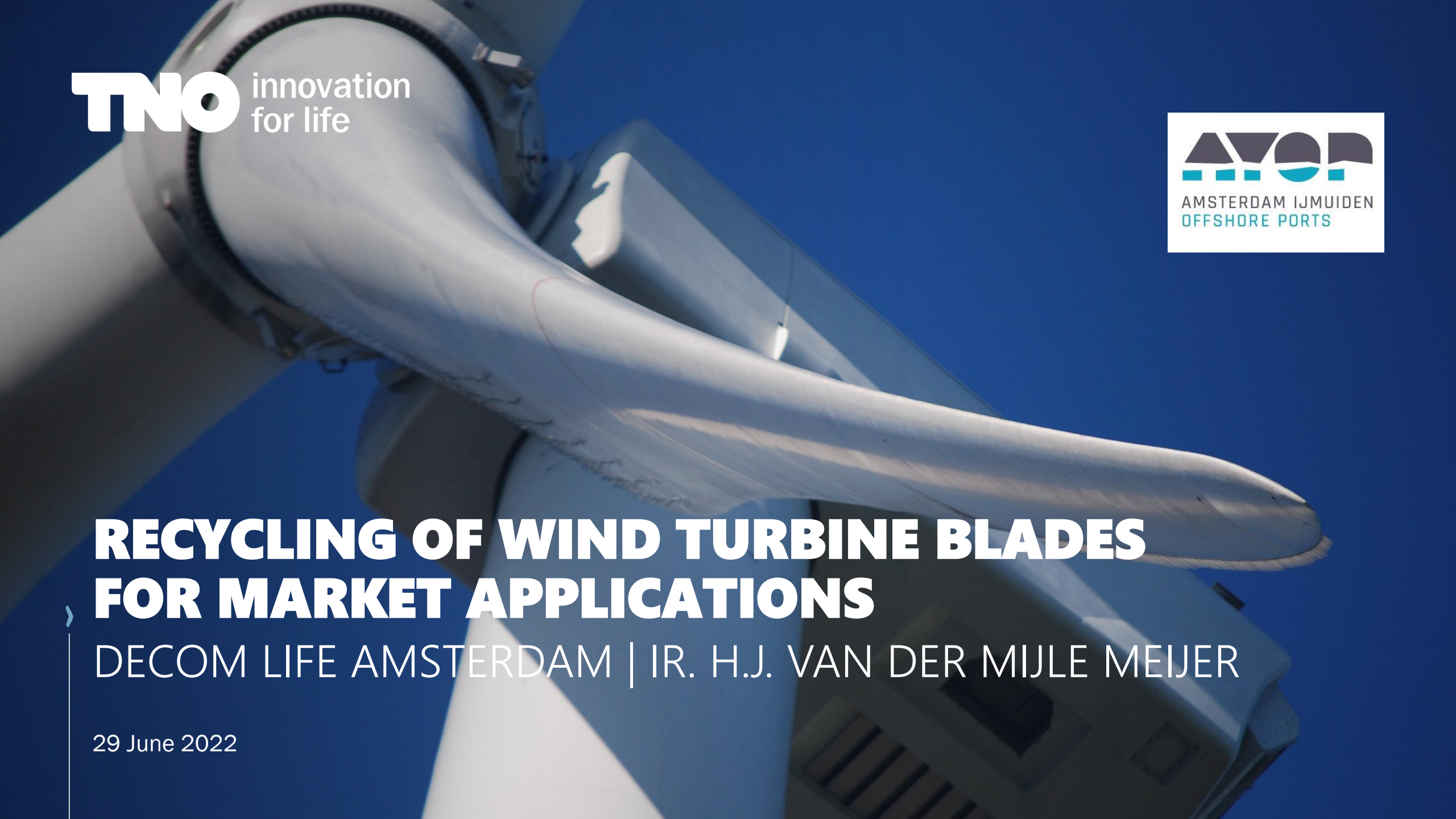


RECYCLING OF WIND TURBINE BLADES FOR MARKET APPLICATIONS

DECOM LIFE AMSTERDAM | IR. H.J. VAN DER MIJLE MEIJER

29 June 2022

RECYCLING OF WIND TURBINE BLADES FOR MARKET APPLICATIONS

AMSTERDAM IJMUIDEN
OFFSHORE PORTS

Brightlands
Materials Center

TNO innovation
for life

CHALLENGE

- Aim to recycle/re-use the wind turbine for 100%
  (now ~80%)
- Up to 60.000 tons of annual composite blade waste in 2025
  800.000 tons in 2050
- Landfill ban in EU → incineration next waste processing baseline
  unwanted: no waste minimisation, no reuse and no recycling
- No commercial End-of-Life solution available for full scale blade recycling
- Offshore wind concession tender requirements Germany, France
  40+% of the rotor must be recycled

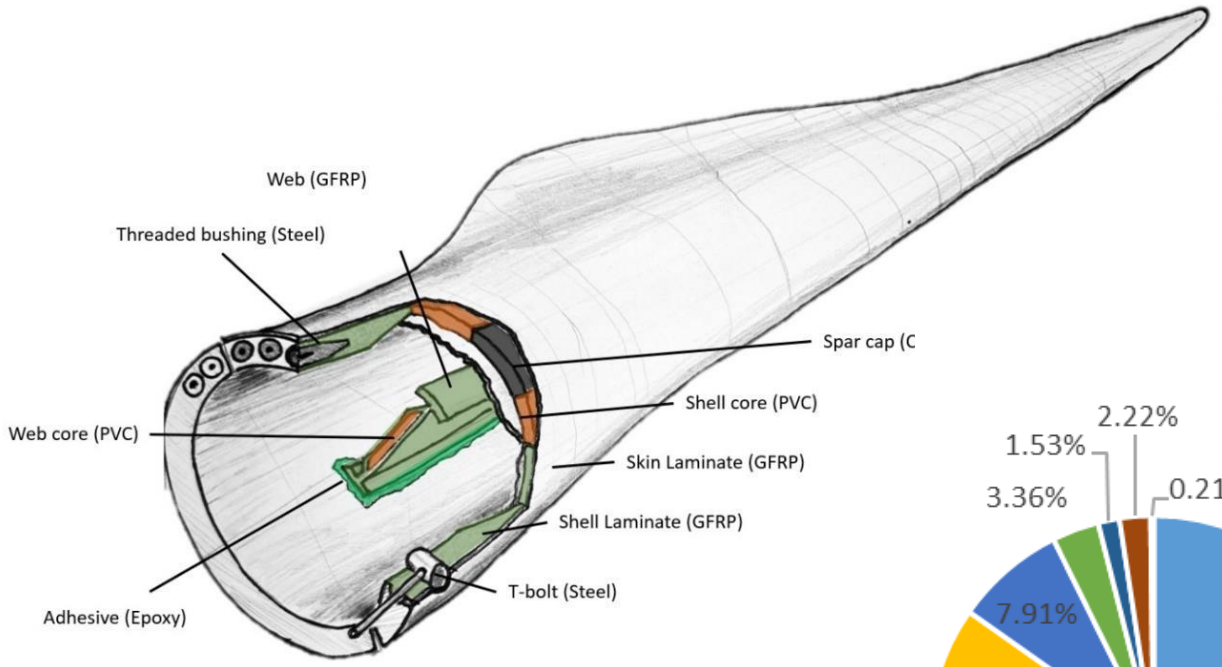
Photo Bloomberg 2021

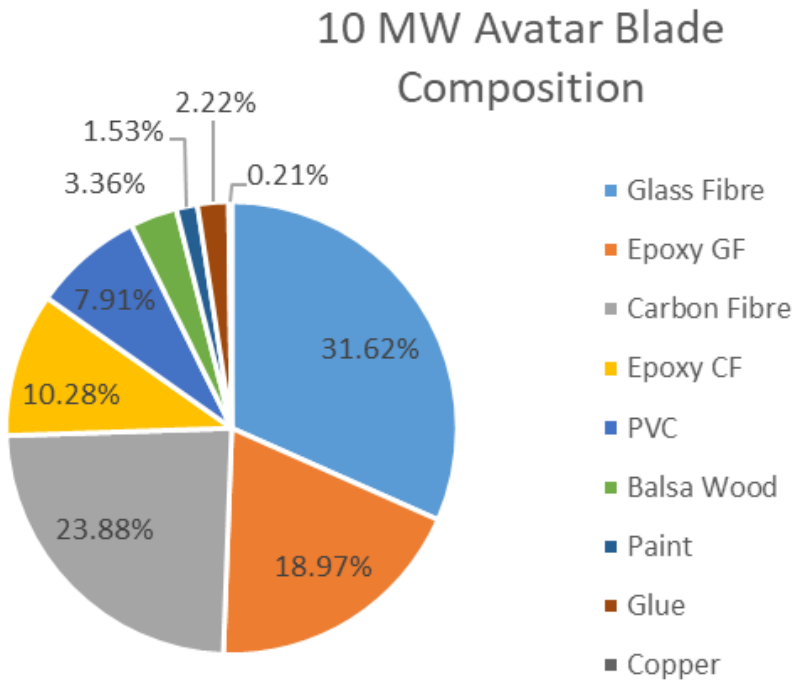
GOAL
DEMONSTRATOR PHASE

- To demonstrate the optimized pyrolysis End of Life (EoL) solution to recover glass fibers (GF) from thermoset blade composite material

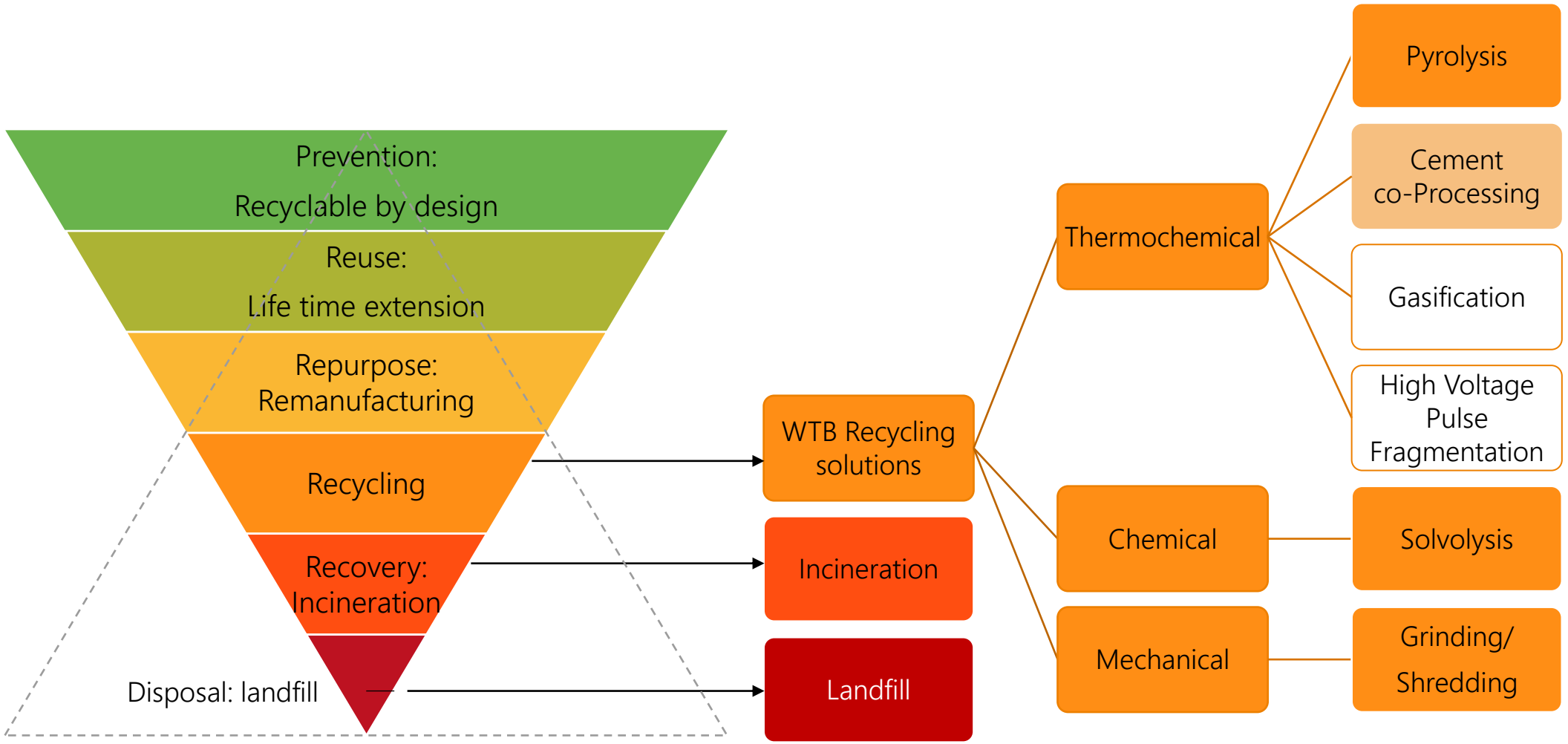
- Use of the recovered glass fibre in recyclable thermoplastic composite products

WIND TURBINE BLADE
MATERIALS AND DESIGN





END OF LIFE SOLUTIONS FOR COMPOSITE BLADES



RE-USE RECOVERED GLASS FIBERS IN THERMOPLASTIC COMPOSITES

processing of wind turbine blades, e.g. pyrolysis

manufacturing of fiber reinforced thermoplastic granules

manufacturing fiber reinforced thermoplastic granules

moulding into product

size reduction

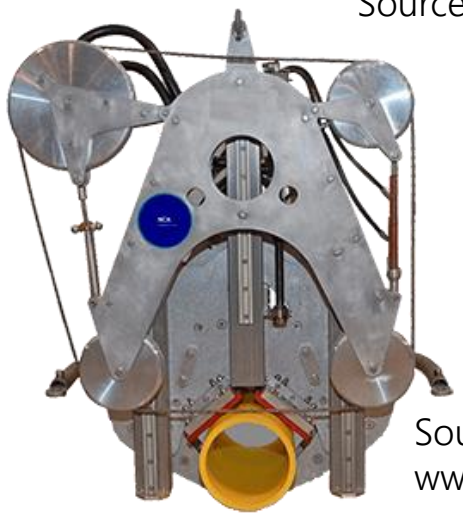
BLADE WASTE MECHANICAL PRE PROCESSING
STATE OF THE ART

- Diamond cutting wheel
- Water jet cutter
- Combined blade pressing and a cutting
- Cutting wire (sub sea pipe cutter)

Source: Geocycle

Source: Demacq

Source: Engie



Source: www.oceaneering.com

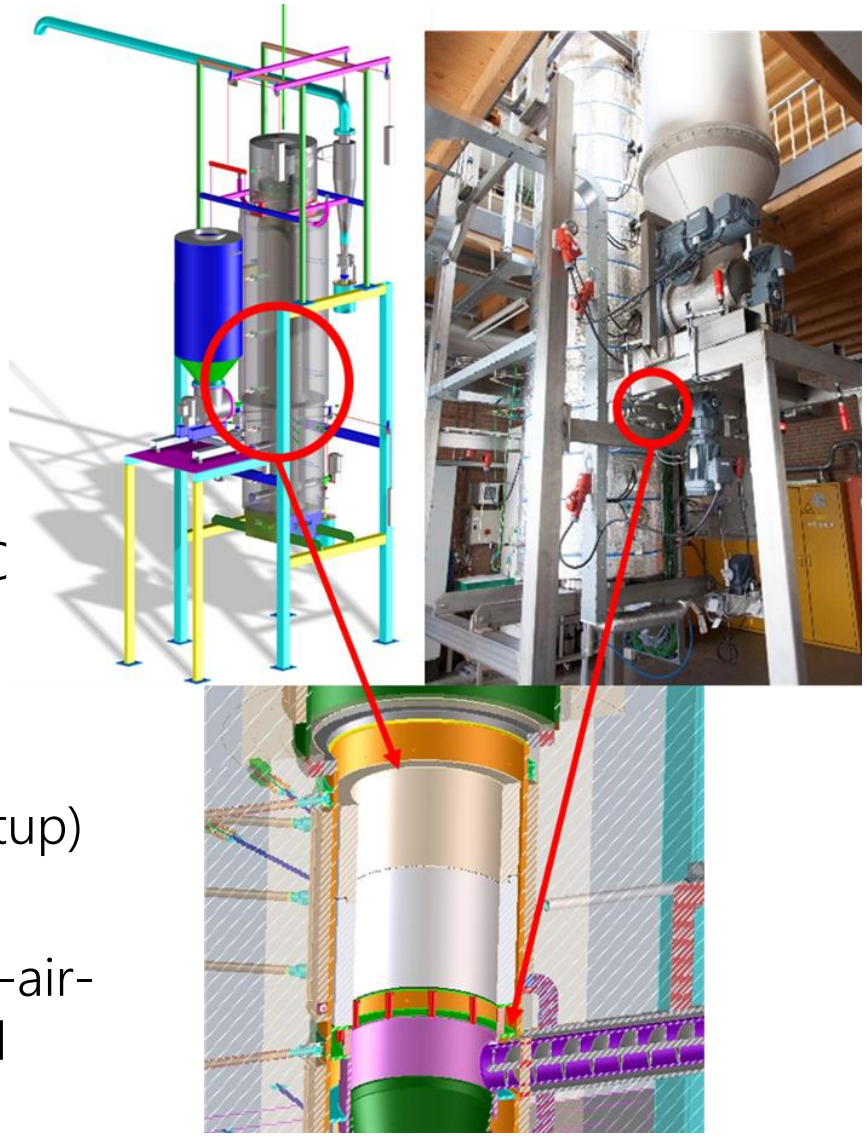
PYROLYSIS

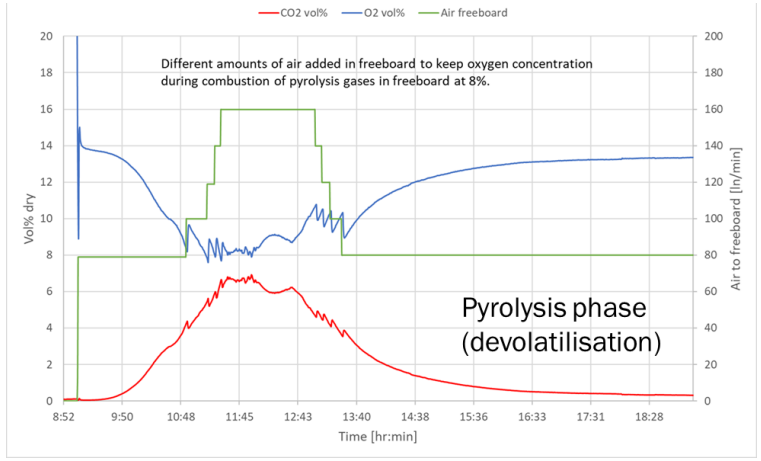
Process applied

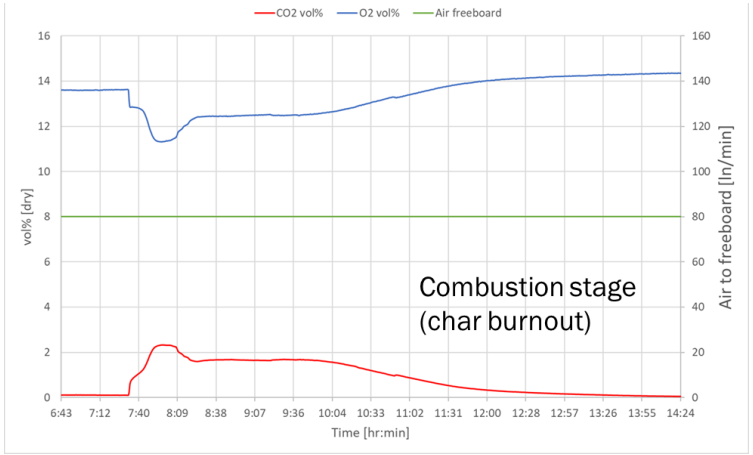
- Sequential pyrolysis and char burnout process
- Batch feedstock
- Temperature limited to 470°C

TNO furnace research facility

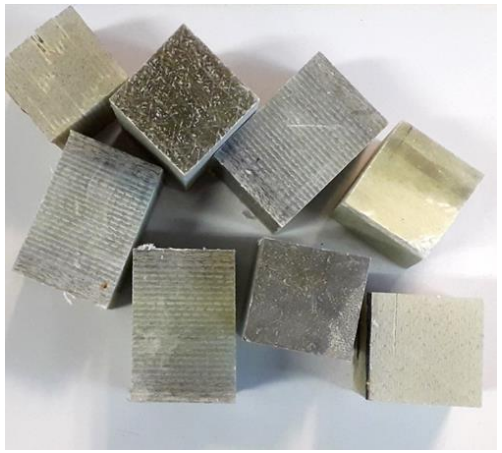
- GROB (large grid biomass setup)
- Designed (2019) for in-depth studies of modern-day, deep-air-staged, fixed- or moving-bed combustion processes



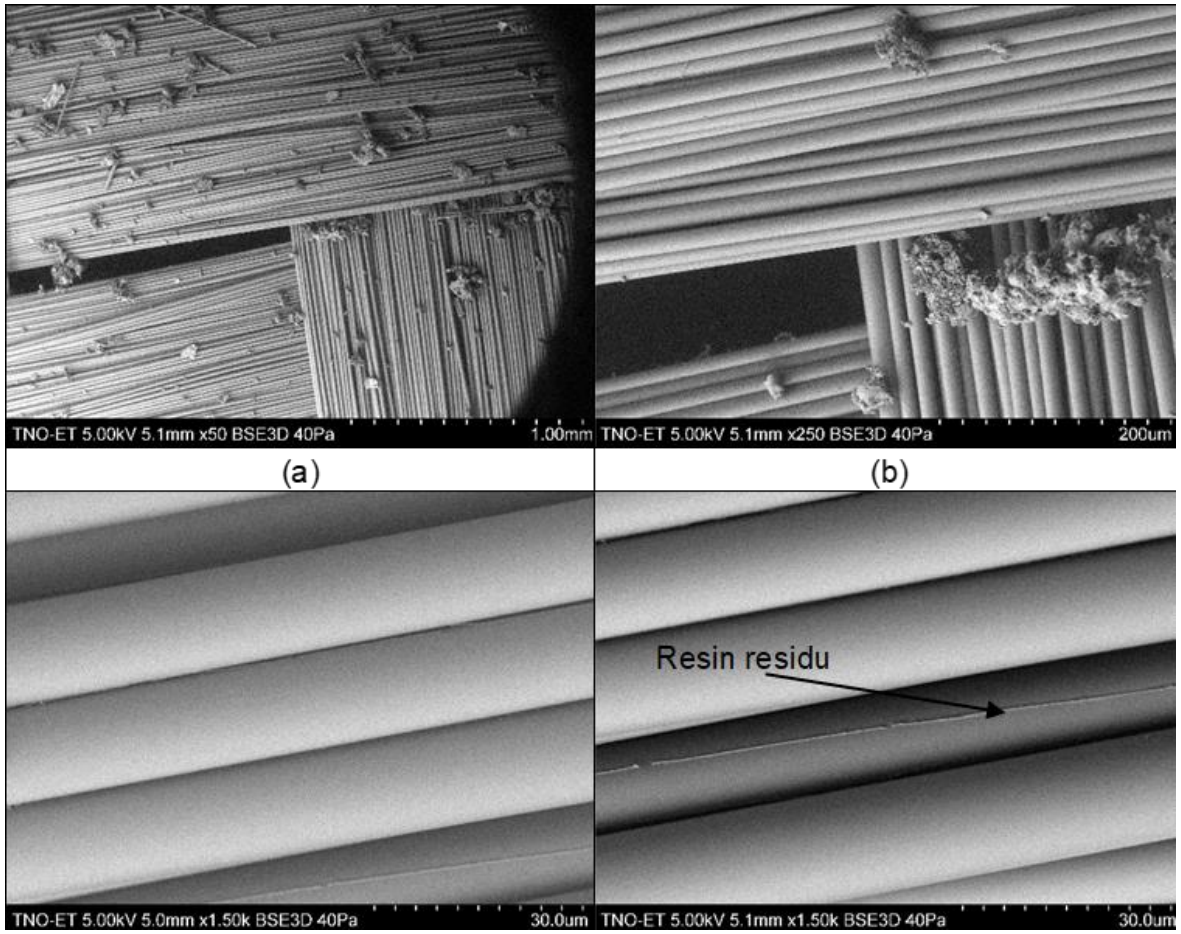




RECOVERED GLASS FIBRE



Sc… Electron microscopic analysis recovered glass fibre



FABRICATION THERMOPLASTIC COMPOSITE WITH RECOVERED FIBRES

Brightlands Materials Center

Fabrication technology

- Extrusion – granules
- Injection moulding – composite product

Materials

- Matrix
  - Nylon (PA6)
  - Polypropylene (PP)
- Fibre materials
  - Recovered glass
  - Virgin glass

Reclaimed GF

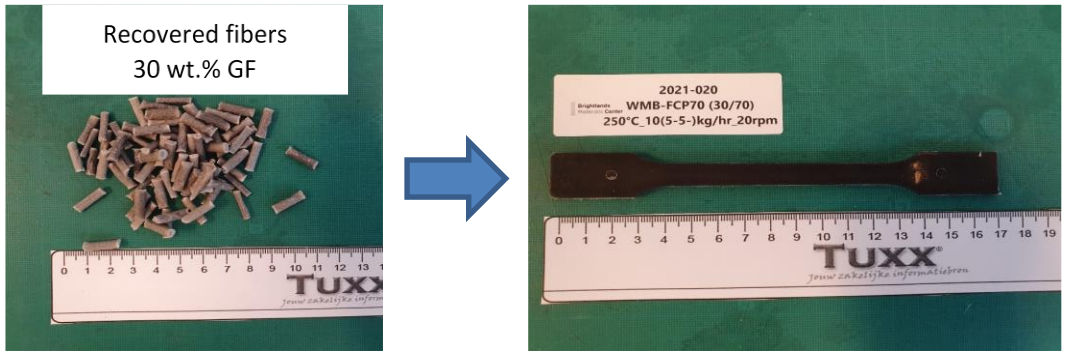
Extrusion mix with PA or PP

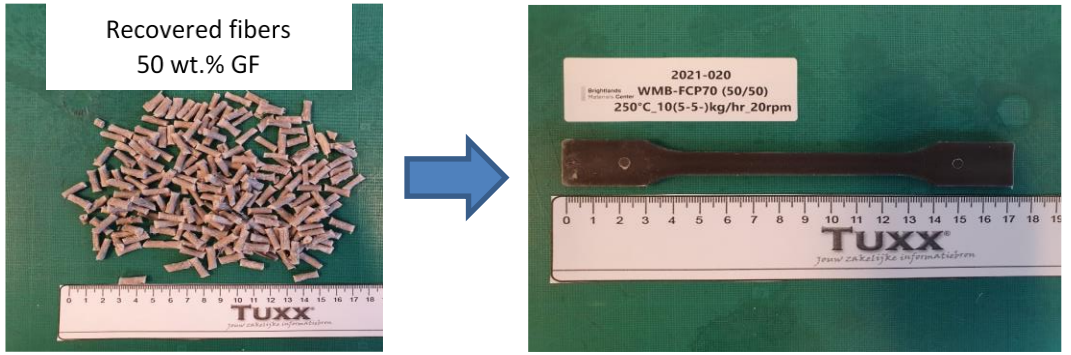
Composite granules

Injection moulding end product

MECHANICAL TESTING

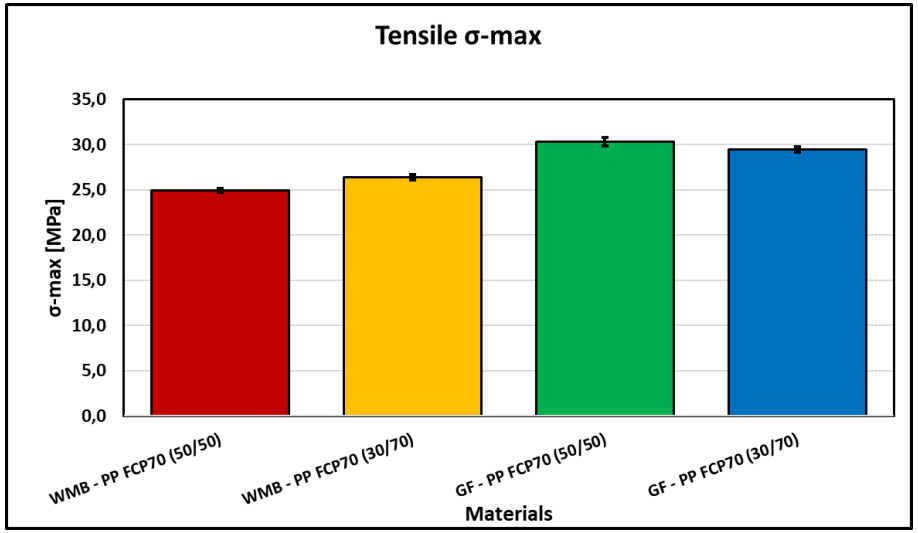
- Type of tests
  - Injection moulded dog bone sample
  - Tensile test, 3P bend test, impact test (Charpy and Izod)
- Tested samples
  - Recovered compared to virgin glass (E-glass)
  - Two different fibre contents 30 and 50 wt%

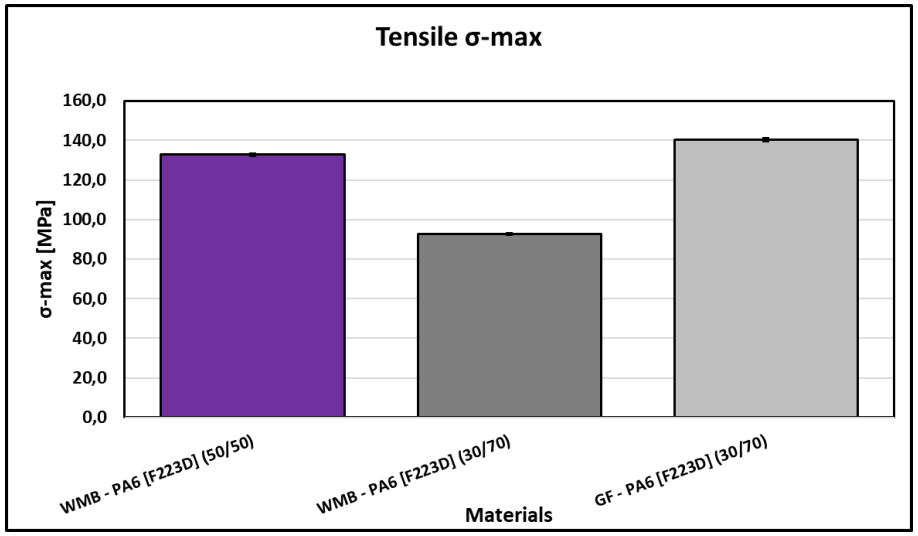




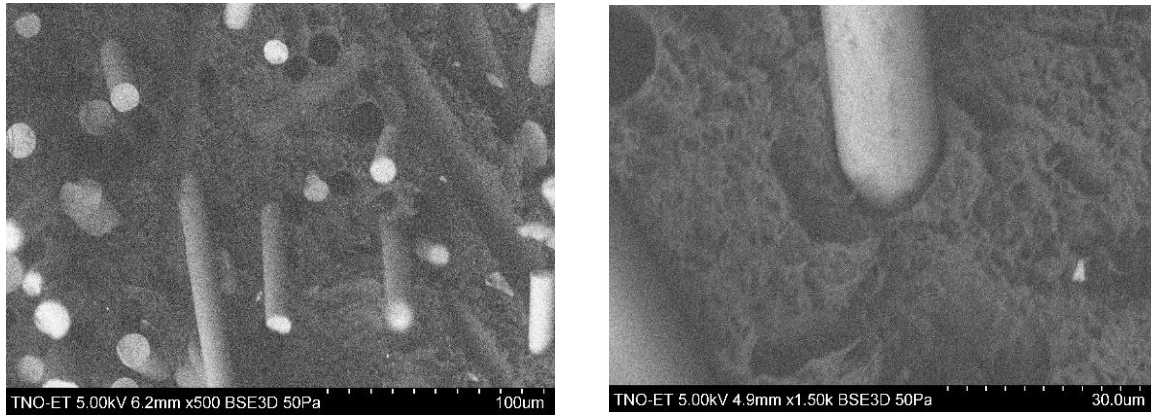
MECHANICAL PERFORMANCE

TENSILE STRENGTH

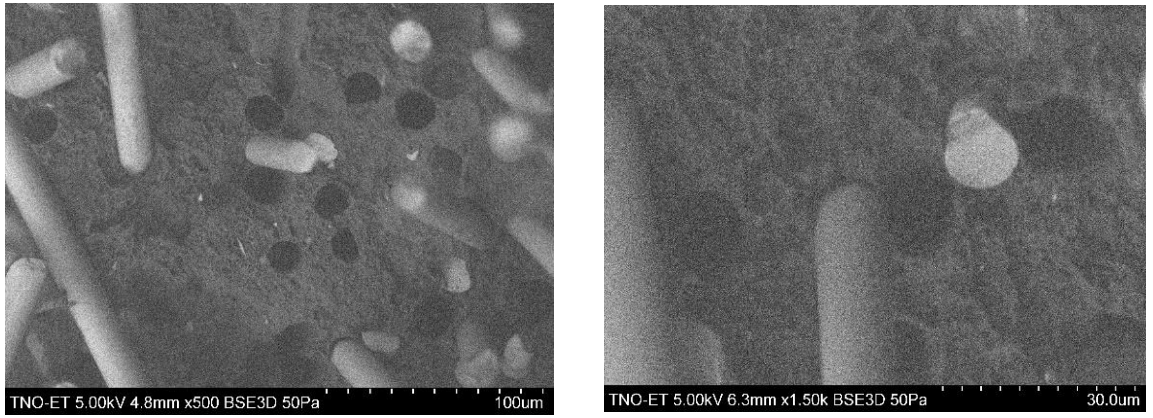




Fracture surface – fibre pull out

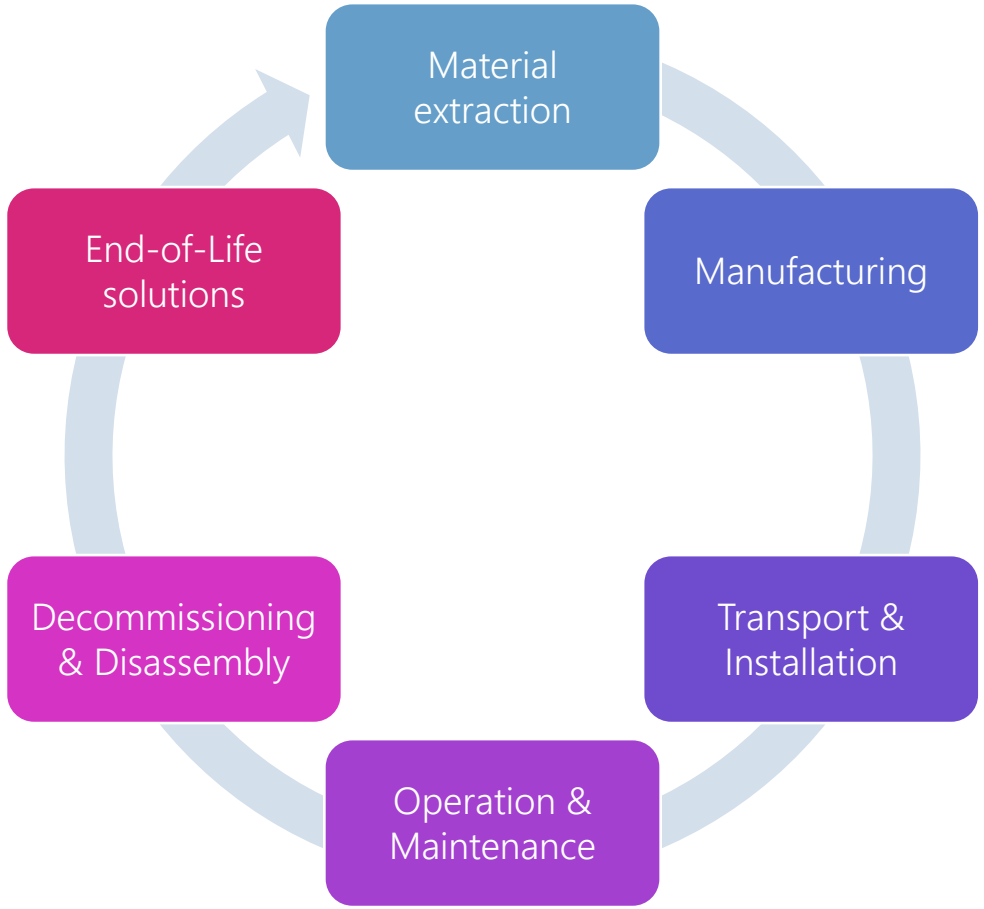


PP-50/50 recovered GF



PP-50/50 virgin GF

LCA ANALYSIS
OFFSHORE WIND FARM MODEL AND DATA



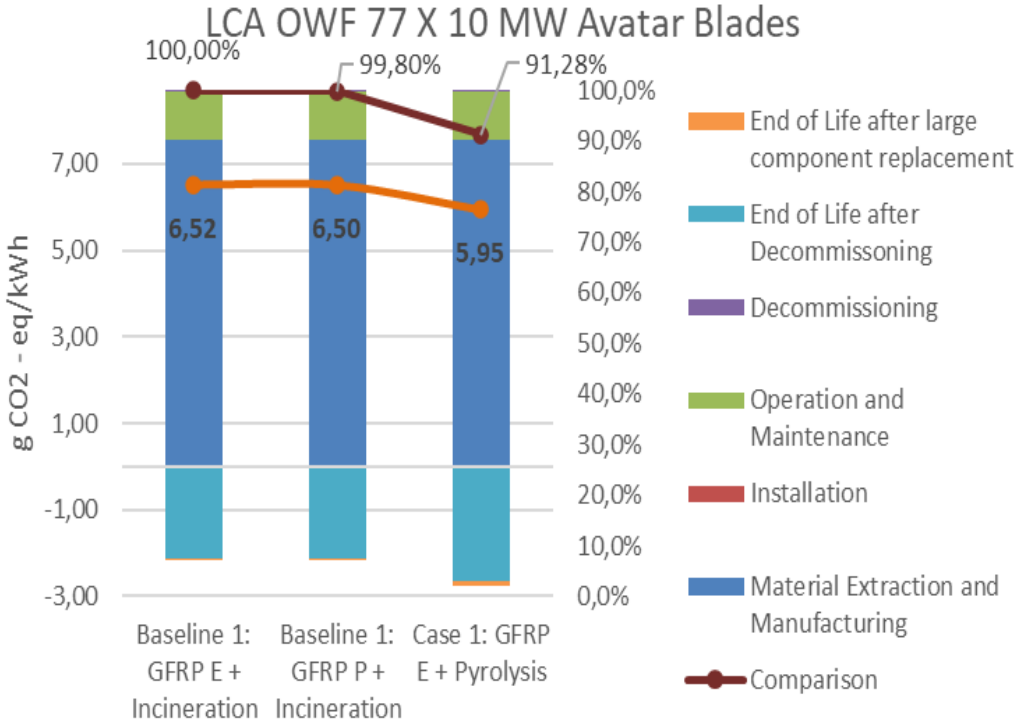
Case	Description	EoL solution
Baseline	Avatar 10 MW, GFR epoxy	Incineration 850°C
Baseline 2	Avatar 10 MW, GFR polyester	Incineration 850°C
Case A 'Legacy'	Avatar 10 MW, GFR epoxy / E-glass	Pyrolysis + combustion 470°C

	Location	Description	Type
Windfarm	Borselle I and II	77 x 10 MW turbines	
Foundation Fabrication port	Rotterdam (NL)	90 km	Barges/vessels
WT Fabrication port	Esbjerg (DK)	550 km	Barges/vessels
Installation port	Vlissingen (NL)	55 km	JUV, CLV, FPV, SOV, barges
O&M port	Vlissingen (NL)	55 km	Vessel (CTVs, JUV, CLV, FPV)
Decommissioning port	Delfzijl / Eemshaven (NL)	380 km	JUVs, barges
EoL port / recycling centre (for other materials)	Delfzijl / Eemshaven (ML)	380 km	-

RESULT LCA ANALYSIS

- The entire decommissioning and blade recycling has been analysed for a reference 770 MW OWF
- Pyrolysis compared to incineration
- Reduction of 8,7% CO_2-eq, 6.52 to 5.95gCO_2-eq/kWh
- 770 MW OWF: 53 kton CO_2-eq with 25 yr operation
- With the applied pyrolysis process, 1000 kg of GFRP WTB composite material supplies 1250 kWh of heat energy

  That can be used as industrial heat!



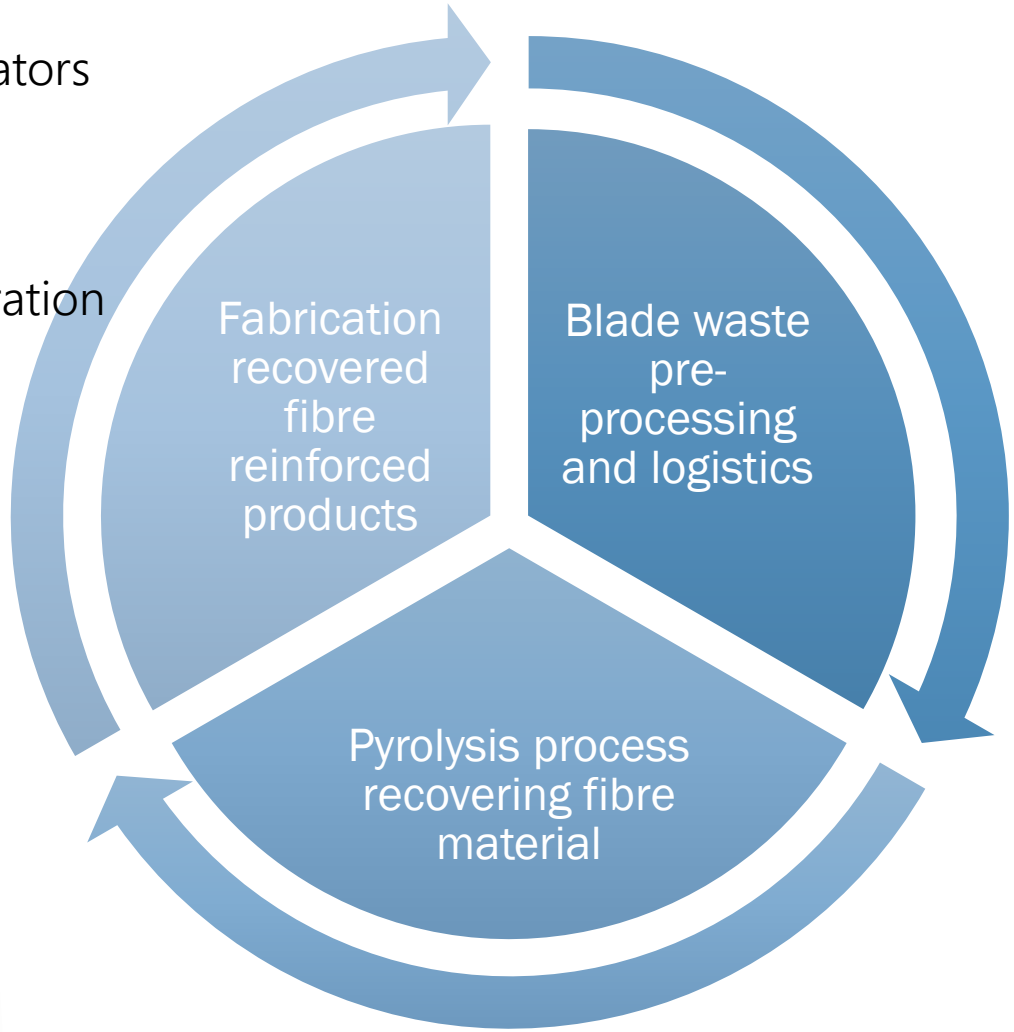
AUTOMOTIVE MARKET – THERMOPLASTIC COMPOSITE PARTS

Source Ifrt-plastic

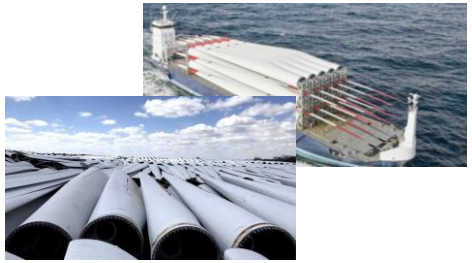
Source PTonline

SUPPLY CHAIN BLADE RECYCLING

- Thermoplastic product fabricators
- Fibre upgrading
- End users
  - Automotive
  - Renewable energy generation
  - Sports
  - Furniture and goods
  - Maritime and offshore
  - Electronics
  - Building and structures



- Wind farm owners
- Offshore contractors
- Recycling companies
- Harbours
- OEMs



- Pyrolysis companies
- Mechanical processing
- Logistics and transport

OUTCOMES AND CONCLUSIONS

- Pyrolysis process developed is effective for recovering of glass fibers (with 1250 kJ heat production/1000 kg composite waste)
- The recovered glass fibre is applicable for injection moulding of thermoplastic composite products
  Demonstrated with injection co-moulded automotive part
- Good material and fabrication properties of Nylon and Polypropylene composite with recovered fibres
  (will be improved with upgrading by application of new sizing)
- 53 ktons CO_2 reduction for decommissioning of a 770 MW wind farm Borssele 1+2 compared to incineration as waste
  (~ CO_2 produced with 6000 return flights from Amsterdam to Paris)

FOLLOW UP

- Optimization of material properties of the thermoplast (semi) products reinforced with recovered glass fibres
- Demonstrator plant for wind turbine blade recycling (logistics, pre-processing, production composite “granules” for injection moulding) – aim 2025
- Scaling up the glass fibre recovery process and manufacturing of (semi) products together with industry – aim 2030

THANK YOU FOR
YOUR TIME

TNO innovation for life

Harald van der Mijle Meijer
E. harald.vandermijlemeijer@tno.nl
M. +31 6 1085 2314