Carbo4Power - New generation of offshore turbine blades with intelligent architectures of hybrid, nano-enabled multi-materials via advanced manufacturing

Tatjana Kosanovic Milickovic, National Technical University of Athens – R-NanoLab & Carbo4Power

Open Innovation Workshop

Processes and methods for recycling, reuse, and recovery of advanced composite materials in the transport sector

REPOXYBLE - Depolymerizable bio-based multifunctional closed loop recyclable epoxy systems for energy efficient structures
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

repoxyble
BIO-BASED MULTIFUNCTIONAL RECYCLABLE COMPOSITES

CARBO4POWER

NEW GENERATION OF OFFSHORE TURBINE BLADES WITH INTELLIGENT ARCHITECTURES OF HYBRID, NANO-ENABLED MULTI-MATERIALS VIA ADVANCED MANUFACTURING

Open Innovation Workshop (Repoxyble)

Process and methods for recycling, reuse and recovery of advanced composite materials in the transport sector

June 7th, 2024, Brussels

"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 953192".

R-NANO

Project ID:

- **Full title:** New generation of offshore turbine blades with intelligent architectures of hybrid, nano-enabled multi-materials via advanced manufacturing
- **Acronym:** **Carbo$_4$Power**
- **Call identifier:** H2020-NMBP-ST-IND-2018-2020
- **Topic:** LC-NMBP-31-2020 Materials for offshore energy (IA)
- **Number of partners:** 18
- **Duration:** 48 months (1.11.2020 – 31.10.2024)
- **Funding:** ~7M €
- **Coordinator:** NTUA, R-NanoLab, Prof. C. Charitidis

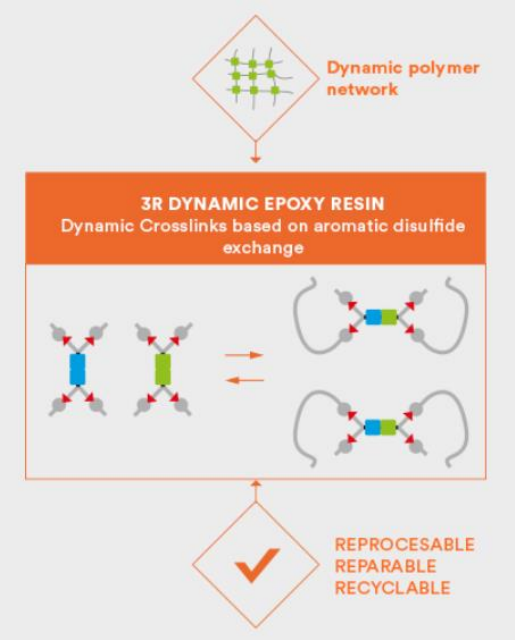
Carbo4Power Concept

- Robust **new material architectures,** **hybrid nano-engineered multi-materials** with tailored **diverse functionalities**.
- Feedstock for **composites**, **adhesives** and **coatings** manufacturing technologies for offshore energy applications.
- **Digital tools**: **multi-scale modelling**, **design**, **topology optimization** and **data analytics**

"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 953192".

Sustainable materials for offshore wind and tidal blades

cidetec
surface engineering

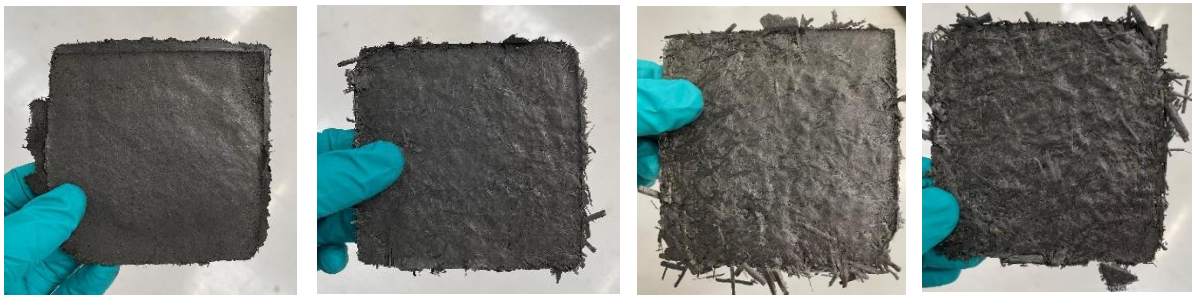


C4P's R3 Resins:

Reprocessing, **R**epairing, **R**ecycling resins due to dynamic hardeners

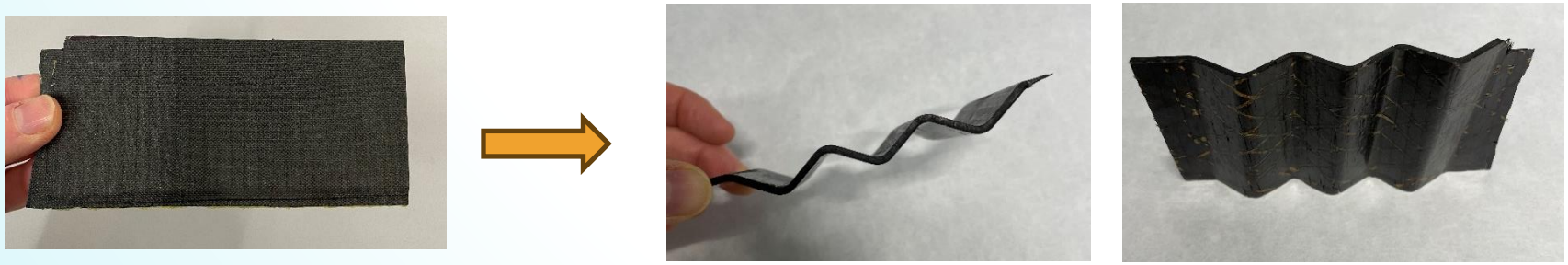
MECHANICAL RECYCLABILITY OF 3R COMPOSITES

1. Recycling of 3R GFRP and CFRP composite powder.



0,5 mm **1 mm** **2 mm** **4 mm**

2. Recycling via thermoforming of 3R composites.



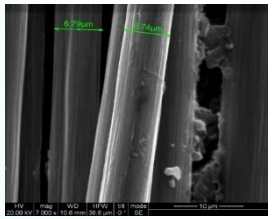
https://www.cidetec.es/en/top-achievements/3r-leading-technology

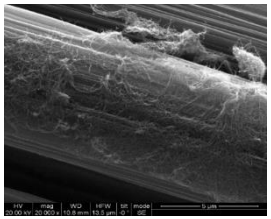
"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 953192".

Innovative materials for offshore wind and tidal blades

Fiber surface Functionalisations

- Plasma treatment
- Electropolymerisation
- Nanoenhanced C-based sizing

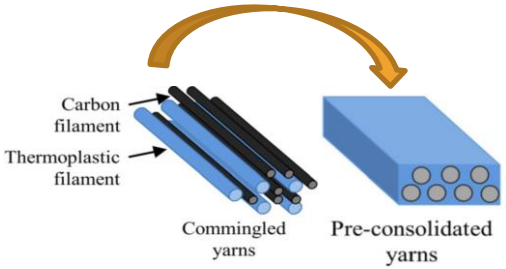




- Pilot line for NE sizing

Hybridization of conventional fibres, in the form of CY or tapes

- Successful & stable production of PPS/Cf commingled yarns
- Novel UD TP tapes with CY produced via pultrusion and hot-melt process



Novel non-intrusive quantum sensors (QRS):

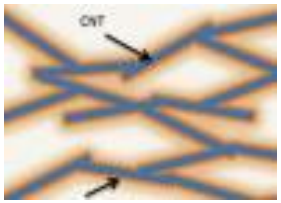
- monitor different thermal/ mechanical events during fabrication & operation
- Strain sensing → SHM
- pQRS, tQRS, fQRS and hQRS for process health monitoring

"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 953192".

Functional materials for offshore wind and tidal blades

Functional resistive heaters for de-icing

- Graphene-based nanocomposite layers
- Embedded on the composite for active de-icing



Functional prepregs for Lightning Strike Protection

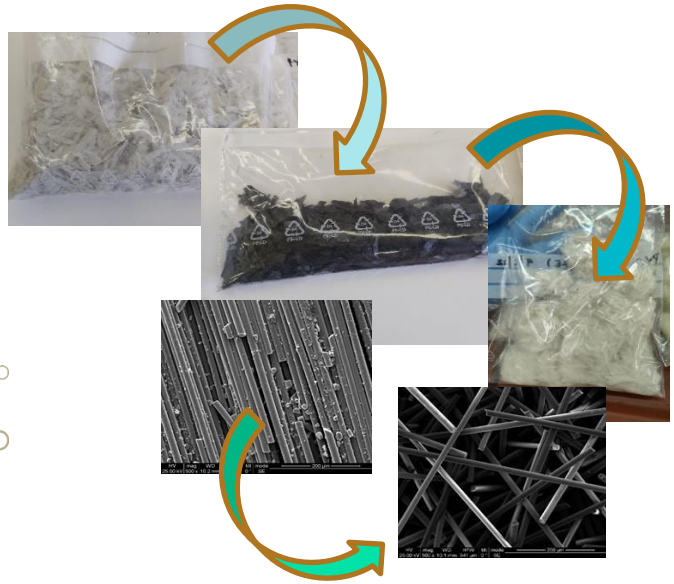
- Conductive C-based nanomaterials
- Prepregs manufactured with 3R resin

Adhesive joints with debonding on demand capabilities

- Adhesive modifications with thermo-expandable particles (TEP)
- Adhesive modifications with Magnetic Nanoparticles
- Introduce a damage mechanism for the disassembly

Functionally graded recycled fibre adhesive carrier

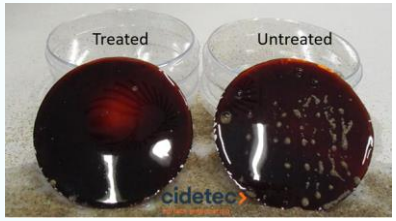
- Recycling of WTB blades for GF reclamation
- Manufacturing of FGA mat

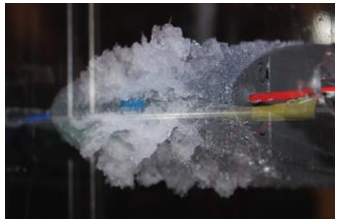
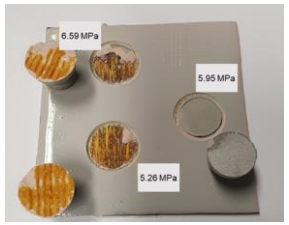


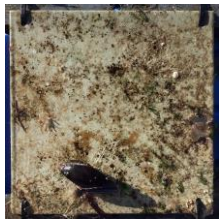
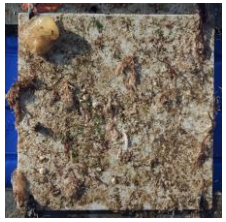
"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 953192".

Multifunctional surface protective coatings - improved durability

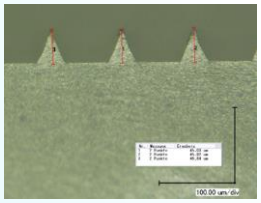
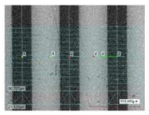
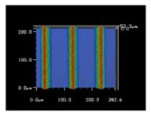
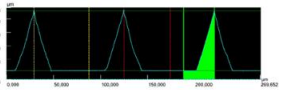
Low surface energy coatings with self-cleaning properties to reduce surface contamination / corrosion effects (incl. ice, biofouling, soiling, water)

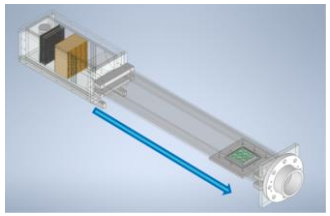


Drag-reducing riblet and lift increasing surfaces for improved energy harvesting



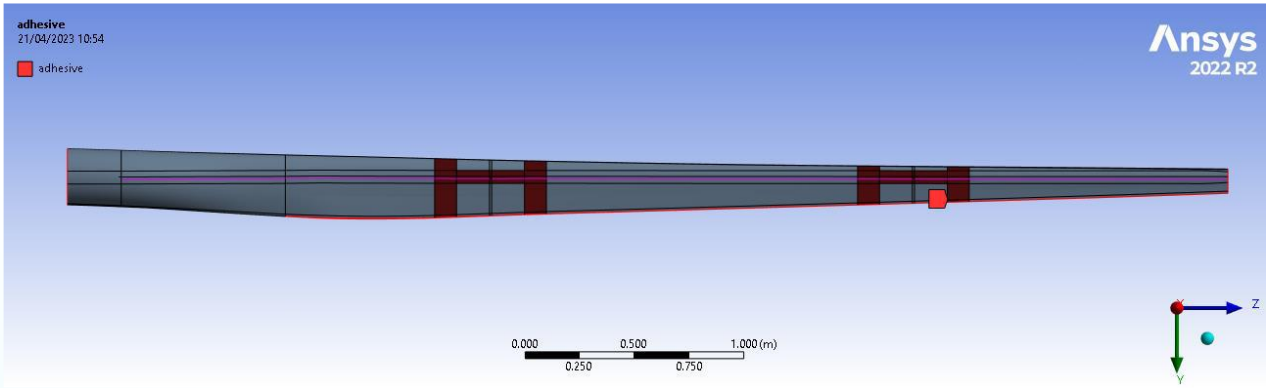
LE erosion protection coatings considering high strength / self-healing properties




"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 953192".

Wind turbine modular blade demo

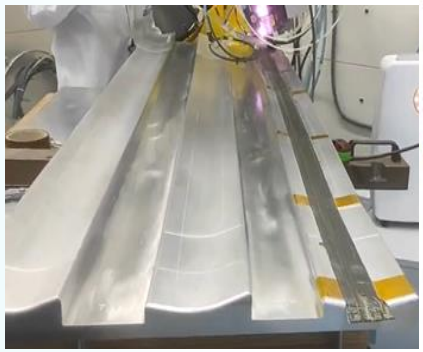
Scale down 1:20 (>15MW turbine, 104m) wind turbine blade demonstrator (infusion & ATL/AFP manufacturing)

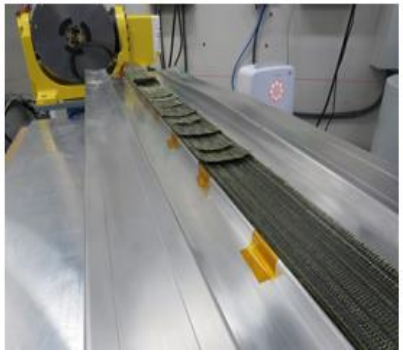


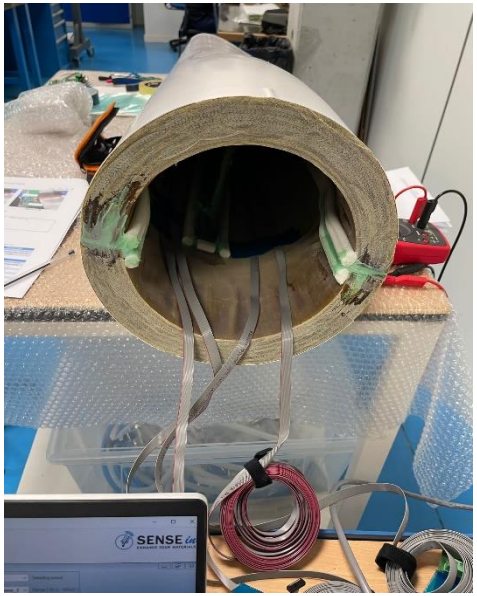
"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 953192".

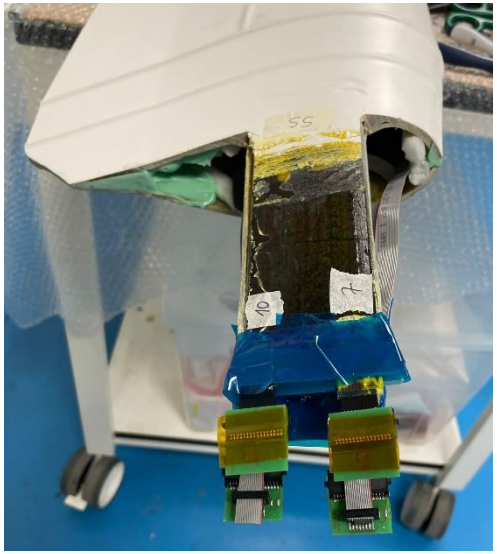
Wind turbine modular blade demo

Scale down 1:20 modular blade (>15MW turbine, 104m) wind turbine blade demonstrator ((infusion & ATL/AFP manufacturing)





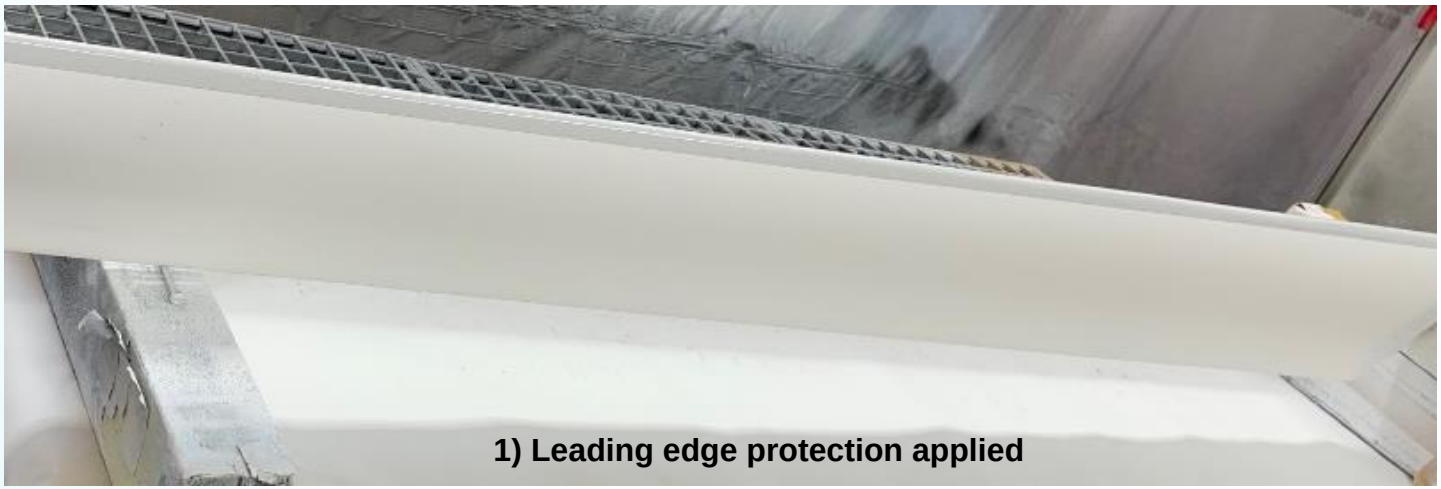




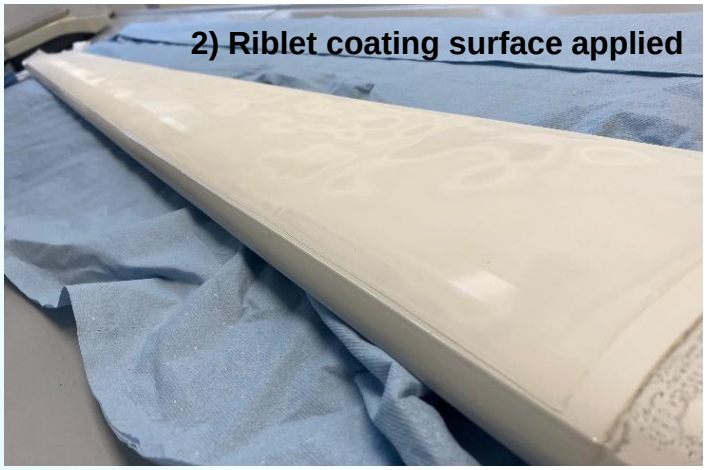
"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 953192".

Wind turbine modular blade demo

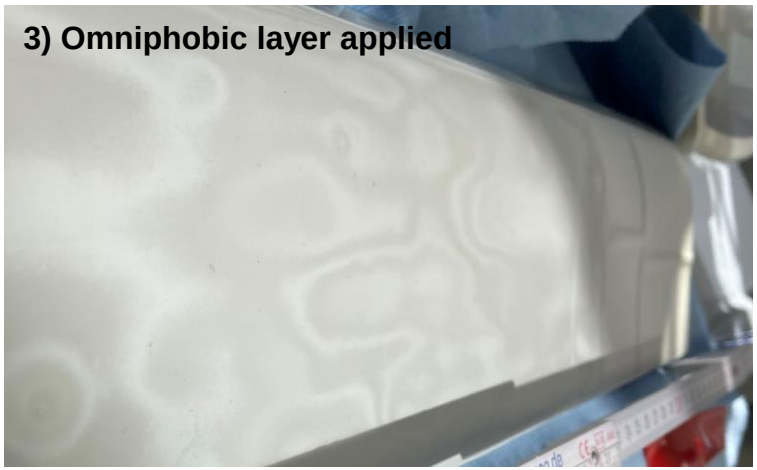
Scale down 1:20 15MW wind turbine blade demonstrator – coating application



1) Leading edge protection applied



2) Riblet coating surface applied



3) Omniphobic layer applied

"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 953192".

Tidal turbine blade demo

MADRAS demonstrator: Scale 1 tidal turbine blade D12 truncated, Sabella (half-shell); NCF/DFP/infusion manufacturing

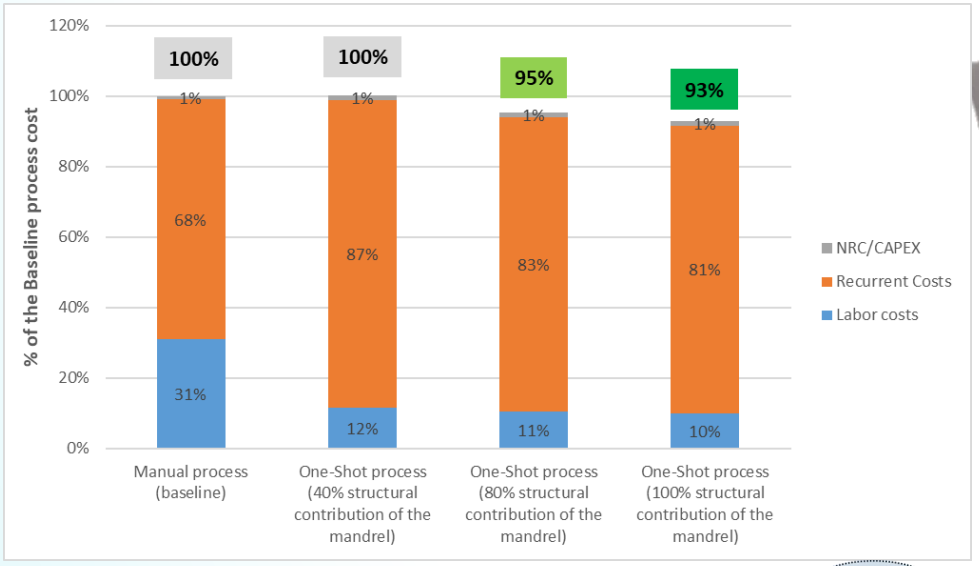
Final Weight: ~ 220 kg
Length: ~ 4 m

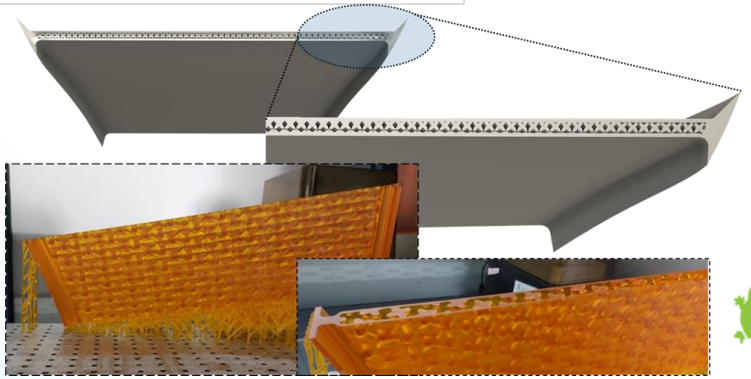
"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 953192".

Tidal turbine blade demo

ONE-SHOT DEMONSTRATOR – Scale 1 root section (0.7m)

- Cost depends on the structural contribution of the mandrel
- -5% (on total cost/blade with depreciation) if considering 80% structural contribution
- Iso-cost with 40% structural contribution



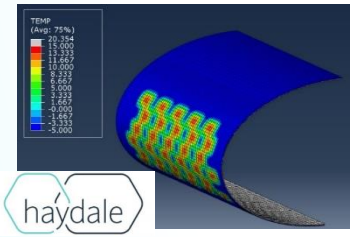


BIOG3D

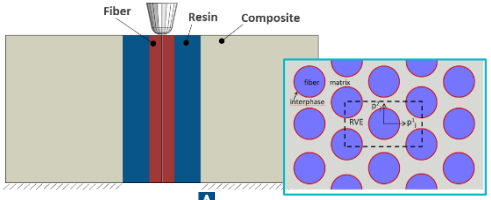
"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 953192".

Modeling and Design to support developments

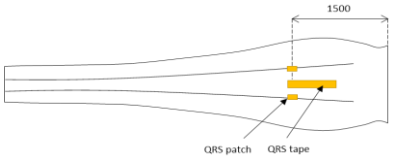
Design of Nanomaterial-enhanced heater system for de-icing



Study of carbon fibre treatments to improve CFRP properties



ITAINNOVA

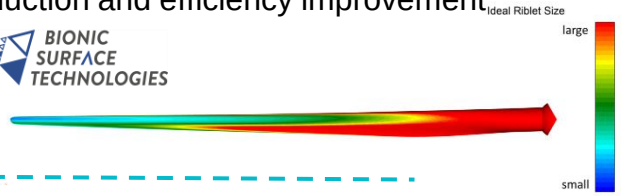


Localization of QRS sensors

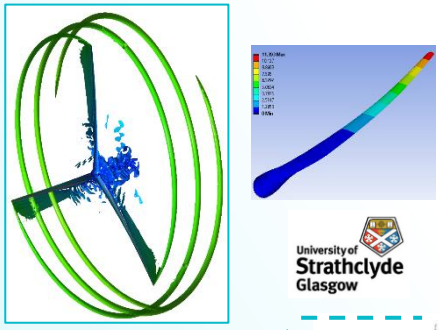
SENSE in ENHANCE YOUR MATERIALS

Design of Riblets introduction for drag reduction and efficiency improvement

BIONIC SURFACE TECHNOLOGIES

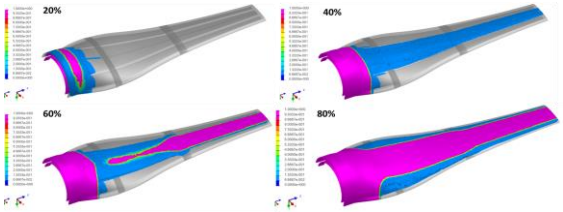


Coupled CFD-FEM simulations for accurate evaluation of blade operation



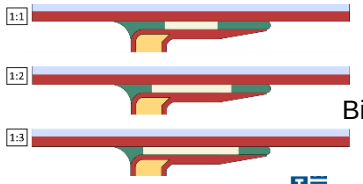
University of Strathclyde Glasgow

Support in TTB demo infusion process definition

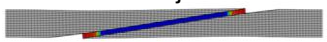


ITAINNOVA

Analysis of innovative bonded joints solutions



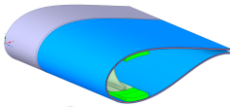
Scarf-joints

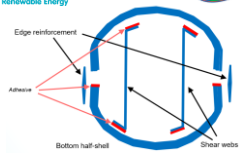


Bi-adhesive joints

ITAINNOVA

CATAPULT Offshore Renewable Energy





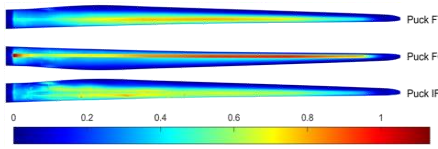
Demonstrators design

sabella

Optimised Bladelet design

BIOG3D

Structural analysis of blades at full and demo scales



University of Strathclyde Glasgow

R-NANO

"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 953192".

Impact

Operational & Maintenance Costs

Significant reduction of life cycle costs maintaining or improving other performance properties

Significant reduction of maintenance cost

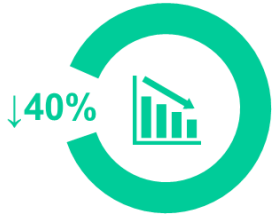
Production and Acquisition costs **< 30%.**

Installation and Commissioning costs - reducing transportation costs from the production factory to the port of **~ 60%.**

Operation and Maintenance (O&M) **< 50%.**

Decommissioning and Disposal **~ 15% reduction.**

Levelized CoE



Optimised materials cost & improved durability

↓ 40% Levelized Cost of Energy

<10 ct€/ kWh for wind

<15 ct€/kWh by tidal stream

Increase in the **annual energy** >6%.

Overcome durability-related issues affect the in-service life of offshore turbine blades .

Increase the lifetime of blades by 100% and decrease maintenance costs by approx. 50% (OPEX).

Overall cost of blades which is expected to be reduced by at least 40% (CAPEX).

Environmental impact

Reduction of environmental impact by 35% based on life cycle assessment (LCA) and eco-design:

Thermo-mechanically **reprocessable** composites.

High rate of **recyclability** at EoL

Enhanced repairability.

Environmentally-friendly nature (no chemicals used) coatings.

Focus on **on-demand debonding** functionality in joints.

Cost-effective transportation - new modular blade design.

"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 953192".

Consortium

R-NANO
iRT JULES VERNE
aimen CENTRO TECNOLÓGICO
cidetec surface engineering
IRES Innovation in Research & Engineering Solutions
ITAINNOVA INSTITUTO TECNOLÓGICO DE ARAGÓN
SENSE in ENHANCE YOUR MATERIALS
Fraunhofer IFAM
UNIVERSITY OF BIRMINGHAM
University of Strathclyde Glasgow
CAMBRIDGE NANOMATERIALS TECHNOLOGY LTD
haydale
AIDEAS
BIONIC SURFACE TECHNOLOGIES
inegi driving science & innovation
BIOG3D
CATAPULT Offshore Renewable Energy

"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 953192".

THANK YOU!

Contact details:

info@carbo4power.eu

Carbo4P

Carbo4Power

Contact

Twitter

LinkedIn

carbo4power.net

"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 953192".