EUROPEAN RECYCLING AND CIRCULARITY IN LARGE COMPOSITE COMPONENTS

2ND OPEN WORKSHOP

PRESENTATIONS

24 APRIL 2024

eurecomp.eu

VIGO, SPAIN/ONLINE

Recycle, design and build of second-generation materials

2nd EuReComp Workshop

Vigo, Spain - April 24th. 2024

FAIRMAT®

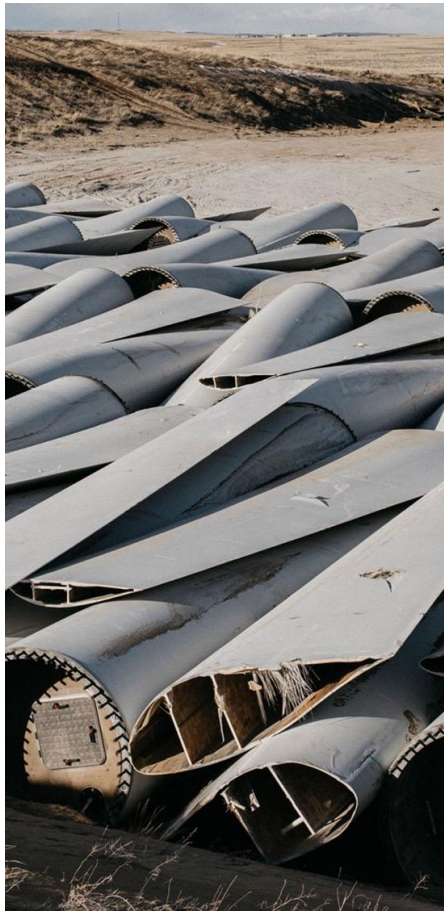
FAIRMAT TECH

The problem

138M T

carbon fiber composite will be landfilled in the next 50 years

There is an increased need for high performing advanced materials



A sustainable solution

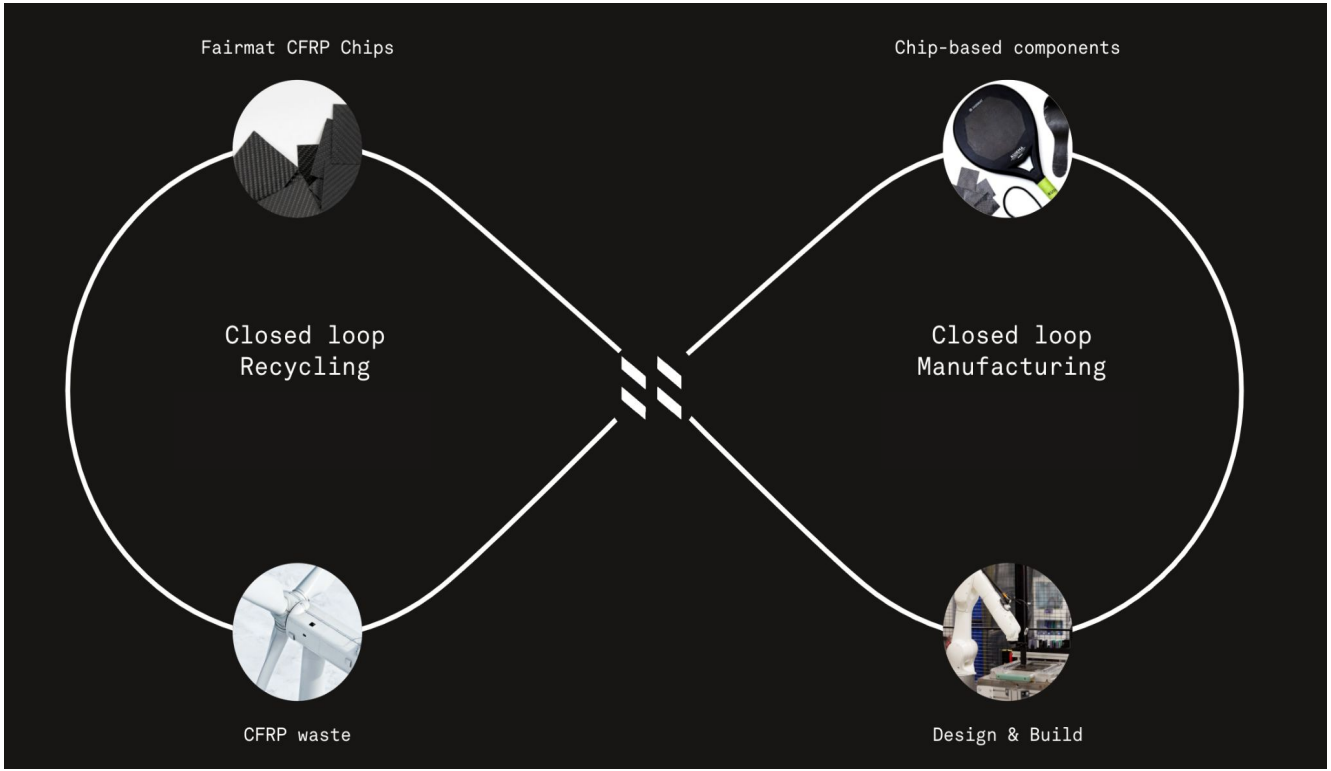
We keep CFRP materials out of landfills:
clean up the planet.

Transform into advanced recycled materials:
innovate and secure supply.

Our ecosystem

Recycle*

Design & Build*

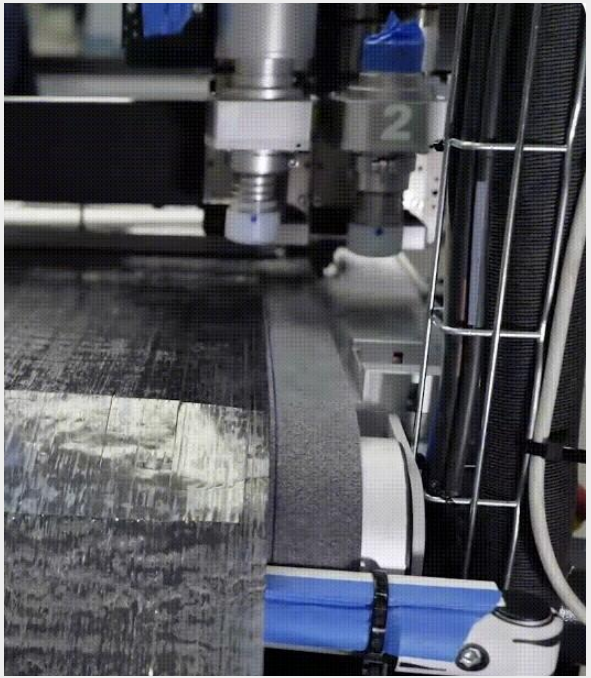


* AVAILABLE BOTH ON & OFF SITE FOR CLIENTS

Recycling loop

Fairmat tech is the most eco-friendly solution for CFRP waste

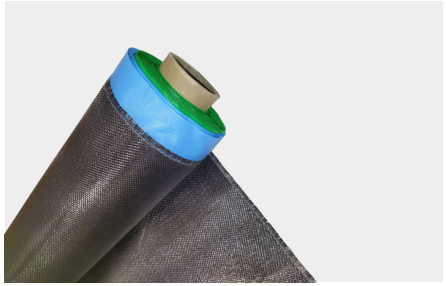
CFRP WASTE



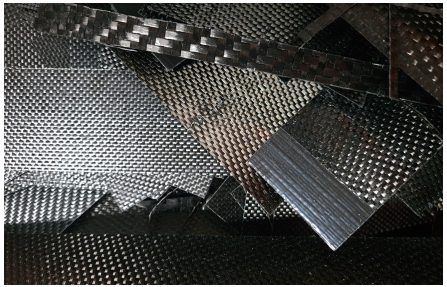
FAIRMAT CFRP CHIPS

We can recycle a large range of CFRP products

By-products of composites materials manufacturers



Material scraps at user places



End of life products

FAIRMAT'S ADVANCED RECYCLED MATERIALS

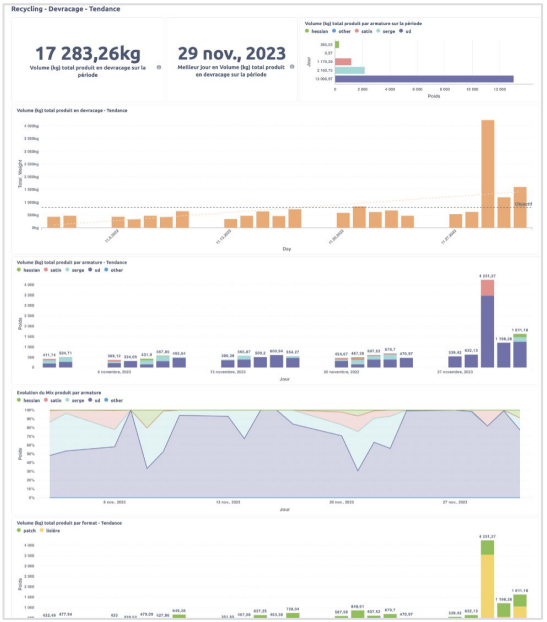
High-performing, sustainable carbon fiber composite

Low environmental impact

High mechanical performance

Competitive price

Fairtrack



Fairmat’s advanced recycled material

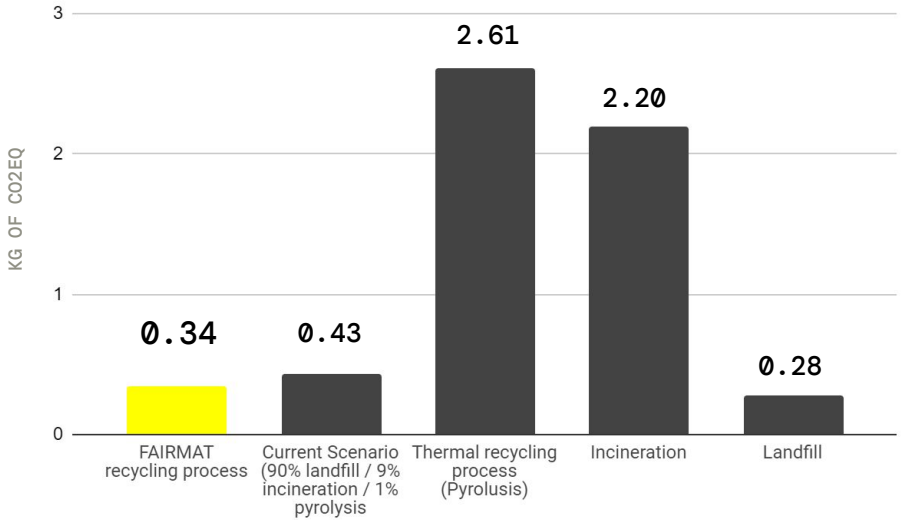
High quality, traceable CFRP at a conventional price

TO CHOOSE FAIRMAT IS TO CHOOSE SUSTAINABILITY

An exceptionally low environmental impact

Recycling process **7x less impacting** than thermal recycling

GHG emissions of Fairmat's recycling process, compared to the other end-of-life scenarios, without accounting for avoided impacts

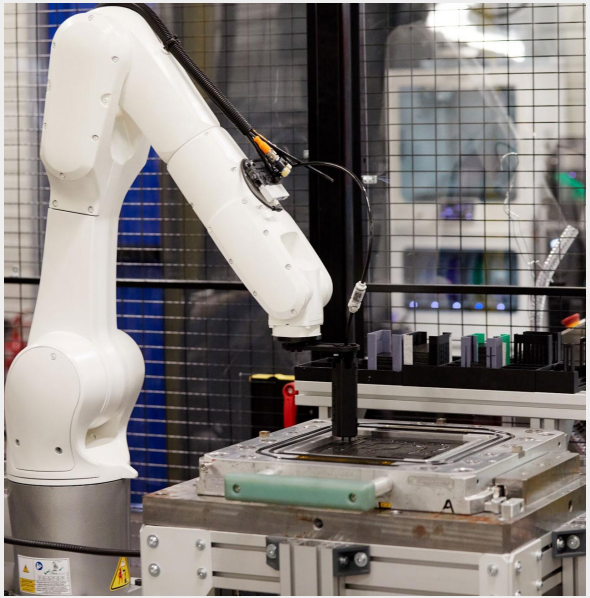


* Results arising from simplified LCA conducted with leading environmental consultancy. External data collected on Simapro database. Conservative assumptions. Cradle to gate perimeter.

Manufacturing loop

Create tailor-made products using robotics, in-house algorithms and our CFRP Chips

FAIRMAT CFRP CHIPS

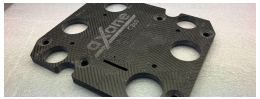


END PRODUCTS

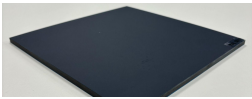
THIN LAYERS

COSMETIC PARTS

SEMI STRUCTURAL AND STRUCTURAL PARTS



STIFFENERS, CASINGS…

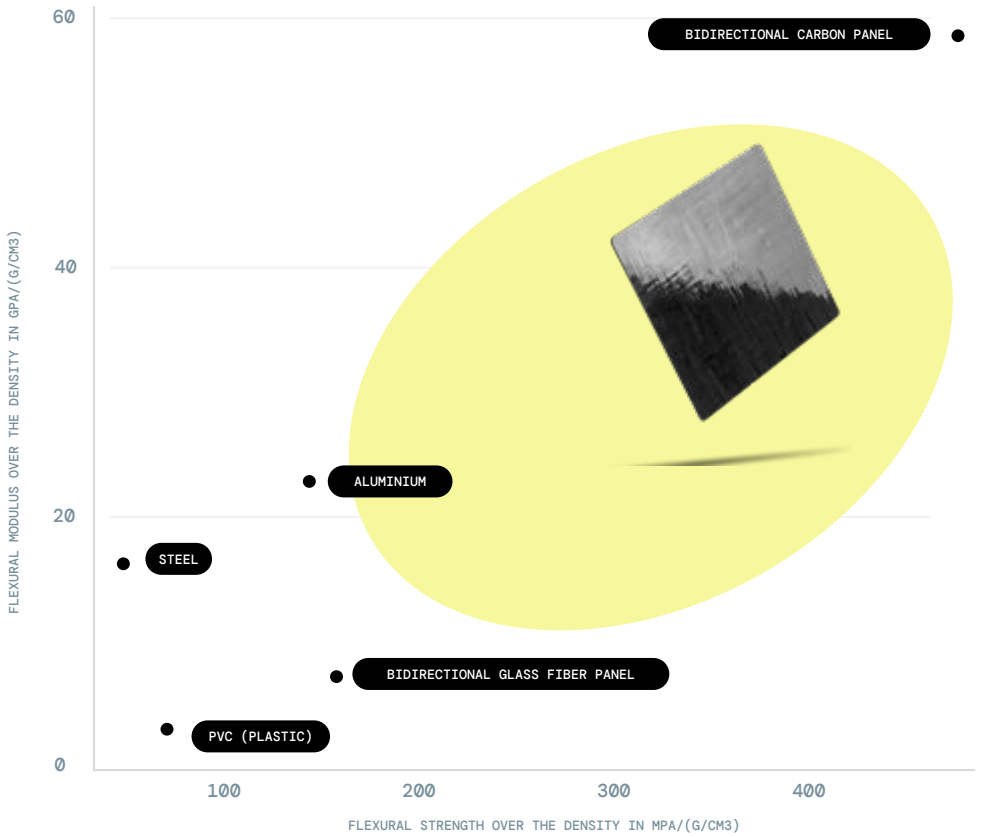


LARGE PLATES

FAIRMAT'S ADVANCED RECYCLED MATERIALS

Fills the gap of performance between Al and CFRP

Mechanical properties of different materials vs. density



FAIRMAT'S ADVANCED RECYCLED MATERIALS

One of the lowest CO_2 emitting materials

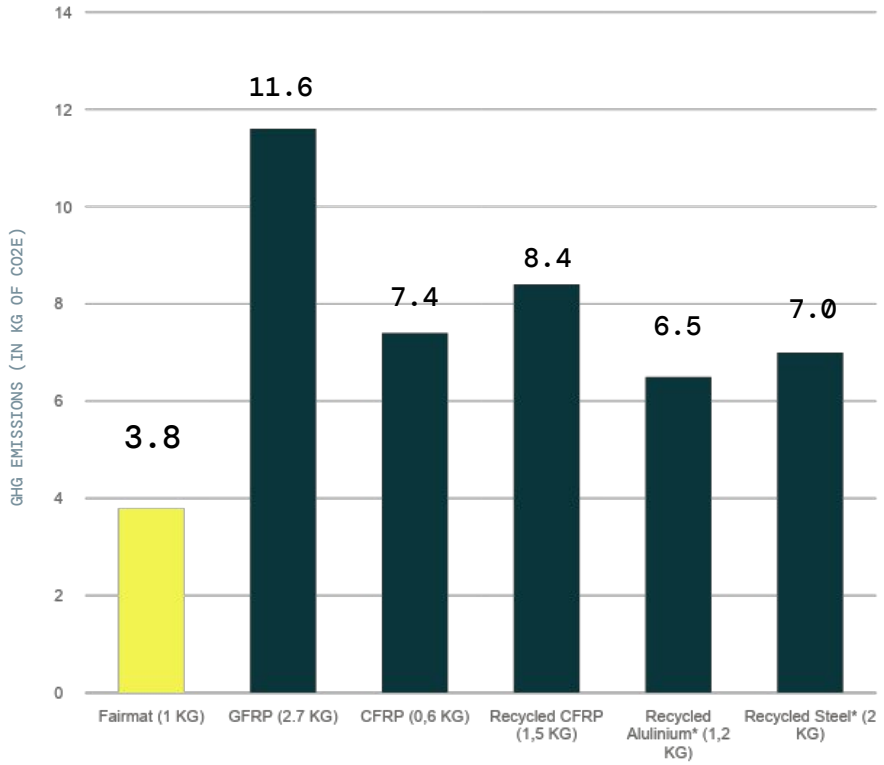
Simplified representation.

For additional details see FAIRMAT

Simplified LCA, conducted with GreenFlex

CO2e emissions of Fairmat vs standard materials

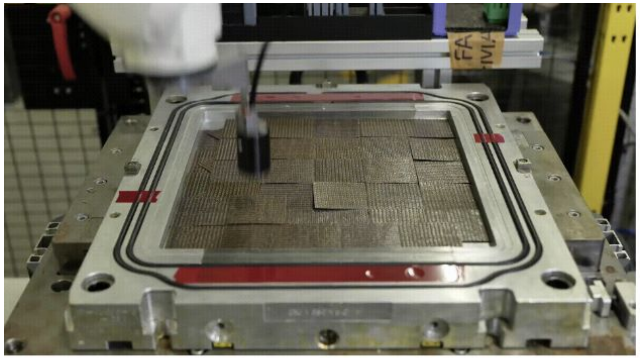
(COMPARED AT EQUIV. PERFORMANCE)

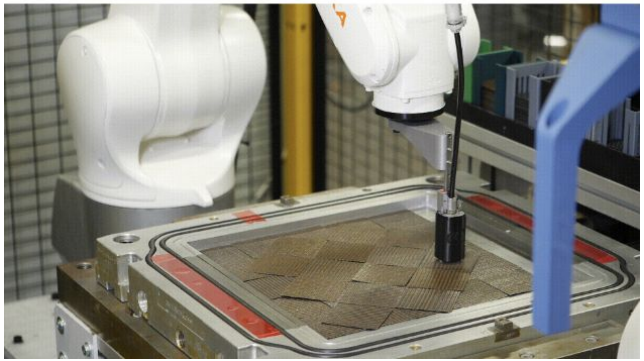


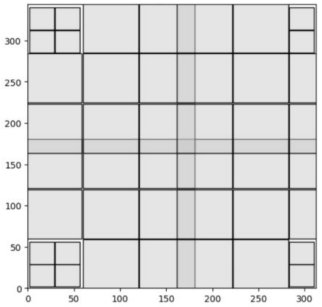
FAIRMAT'S ADVANCED RECYCLED MATERIALS

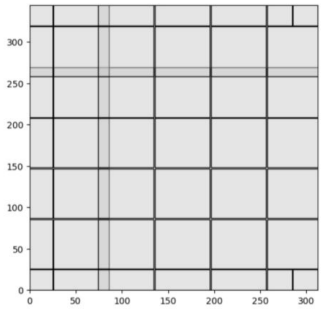
Chip placement is performed using in-house robotics software

Intelligent placement algorithms and autonomous production lead to reproducible and scalable production, at our factory, or at yours.





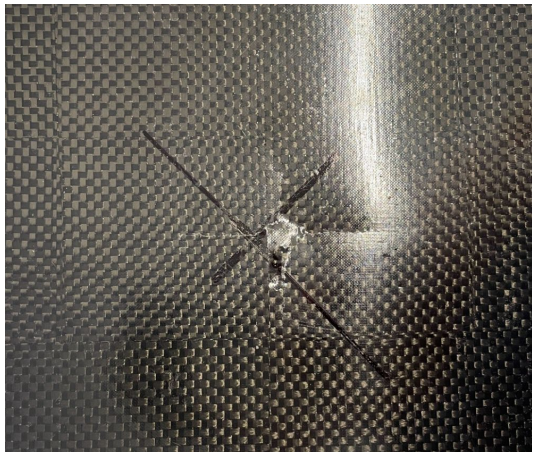


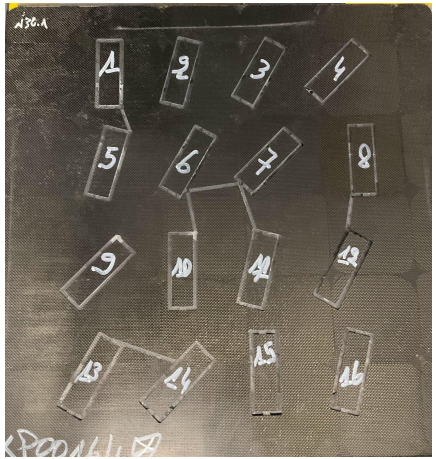


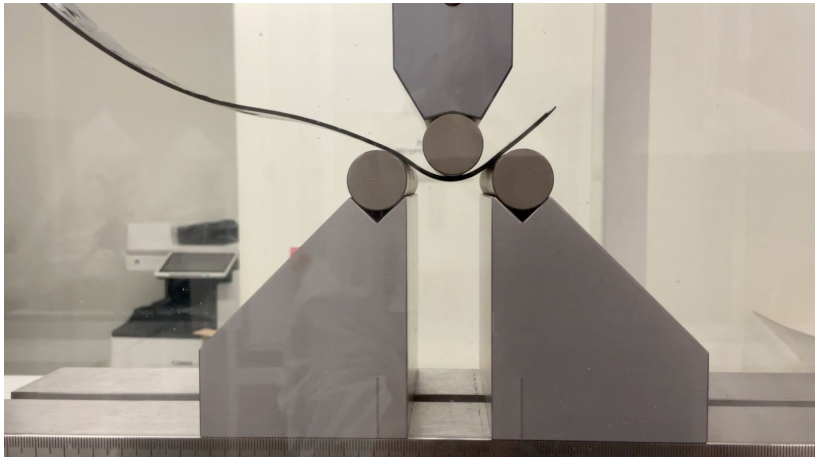
FAIRMAT'S ADVANCED RECYCLED MATERIALS

Designs are validated by our mastery of property measurements

In-house bespoke instruments, methods, and expertise





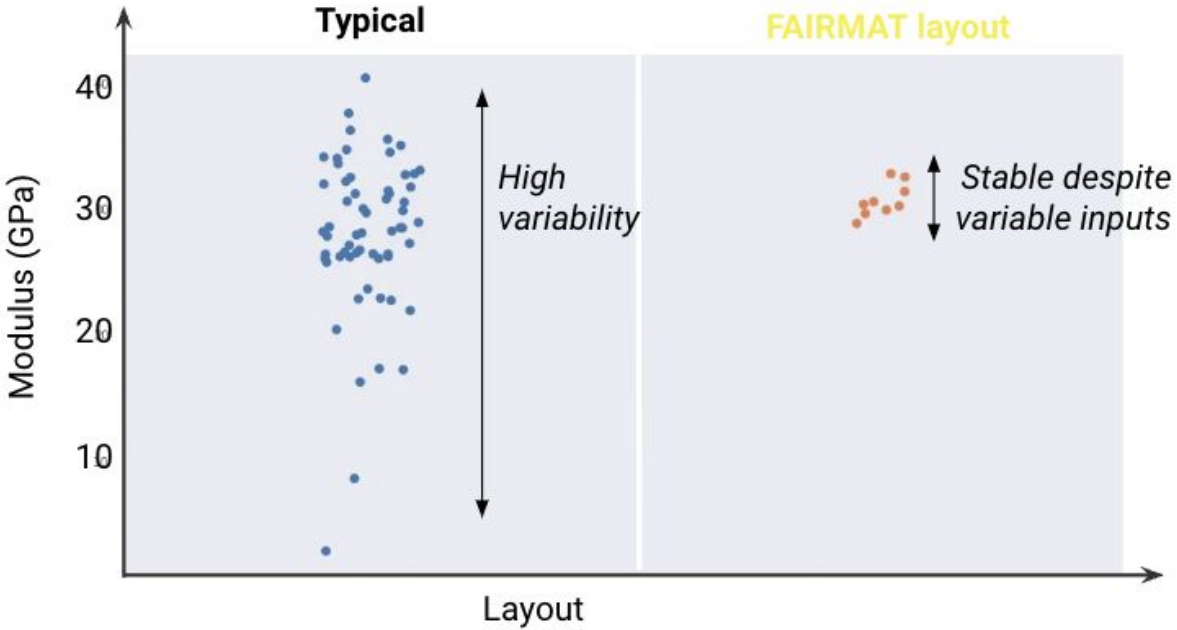


→ Impact test up to 40 J energy
→ High-speed video for failure analysis
→ experienced engineering team

→ full-prototype mechanical testing
→ Angle-dependent mechanical measurements
→ Physico-chemical measurements (e.g. DSC)

Enabling rapid iterative design

FAIRMAT'S ADVANCED RECYCLED MATERIALS



Bespoke FAIRMAT processes provide controlled properties

Control of fibre volume fraction, fibre placement, and process ensure that properties can exceed those of virgin materials.

Client Use Cases

Fairmat materials replace aluminum, plastic & other materials to improve performance, reduce costs & reduce environmental impacts.

SEMI-STRUCTURAL PART

Sustainable & Performing padel rackets

DECATHLON

COSMETIC PART

Premium speaker casing with unique aesthetics

FOCAL

THE SPIRIT OF SOUND

STRUCTURAL PART

Light & Sustainable stiffener for smart scale

WITHINGS

Unlock new possibilities with advanced recycled carbon fiber

From R&D to Industrial Scale

In less than 18 months of operations, we have scaled the Fairfactory:

+25

machines installed

85 FTEs

recruited

450t

yearly recycling capacity reached at end 2023

MARCH 2022

SEPTEMBER 2023

We have achieved outstanding milestones to date

150+ FTE
95% satisfaction rate

5 locations
USA, FRANCE, SPAIN

> 3 000 tons
Secured materials to be recycled, covering output needs over 2028

42%
female representation

+50
engineers and tech specialists

3 patents
Covering engineering, material science and robotics

€51M
Raised to date

Quality blue chips partners

SELECTED RECYCLING CLIENTS

HEXCEL · SIEMENS · exel · DASSAULT AVIATION · TARMAC AEROSAVE

SELECTED SALES MATERIALS CLIENTS

DECATHLON · WITHINGS · FOCAL

MAIN SHAREHOLDERS

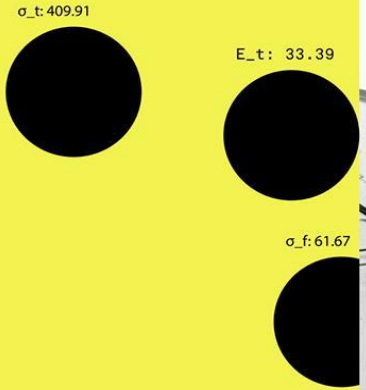
TEMASEK · Singular. · CNP · PICTET · THE FRIEDKIN GROUP

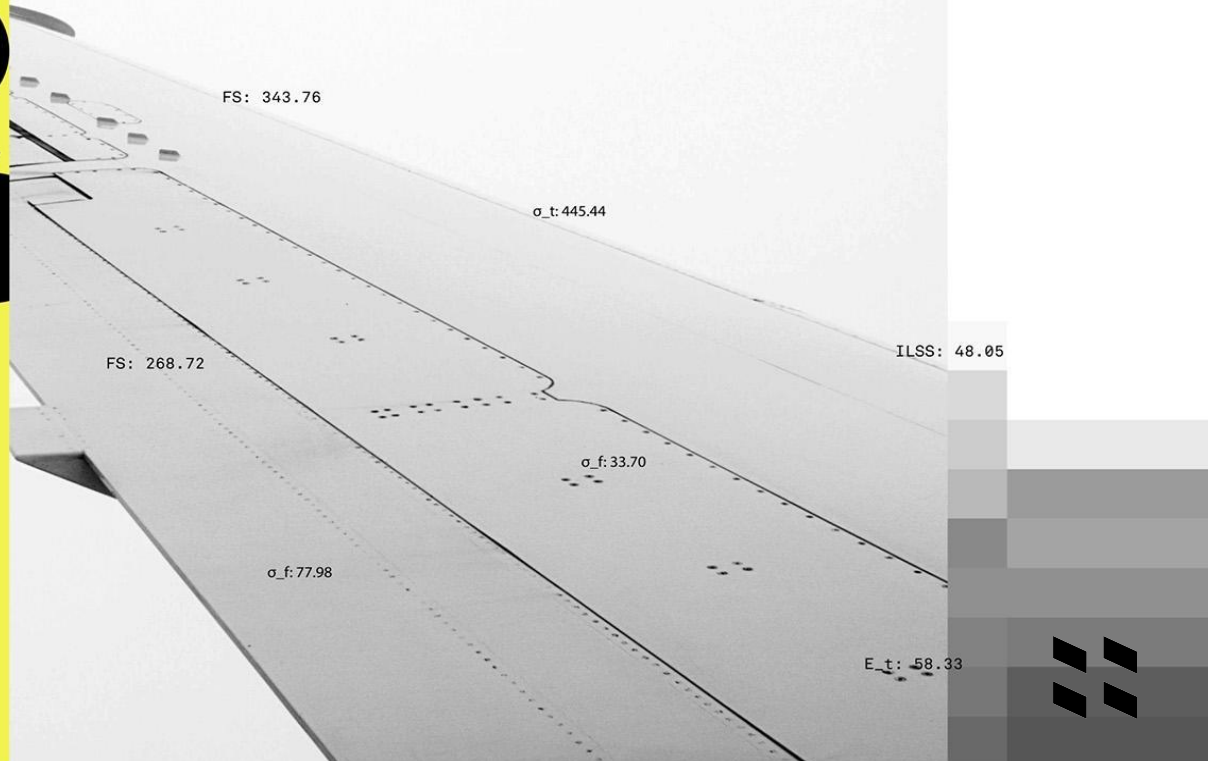
OTHER FINANCIAL PARTNERS

bpifrance · Région PAYS DE LA LOIRE

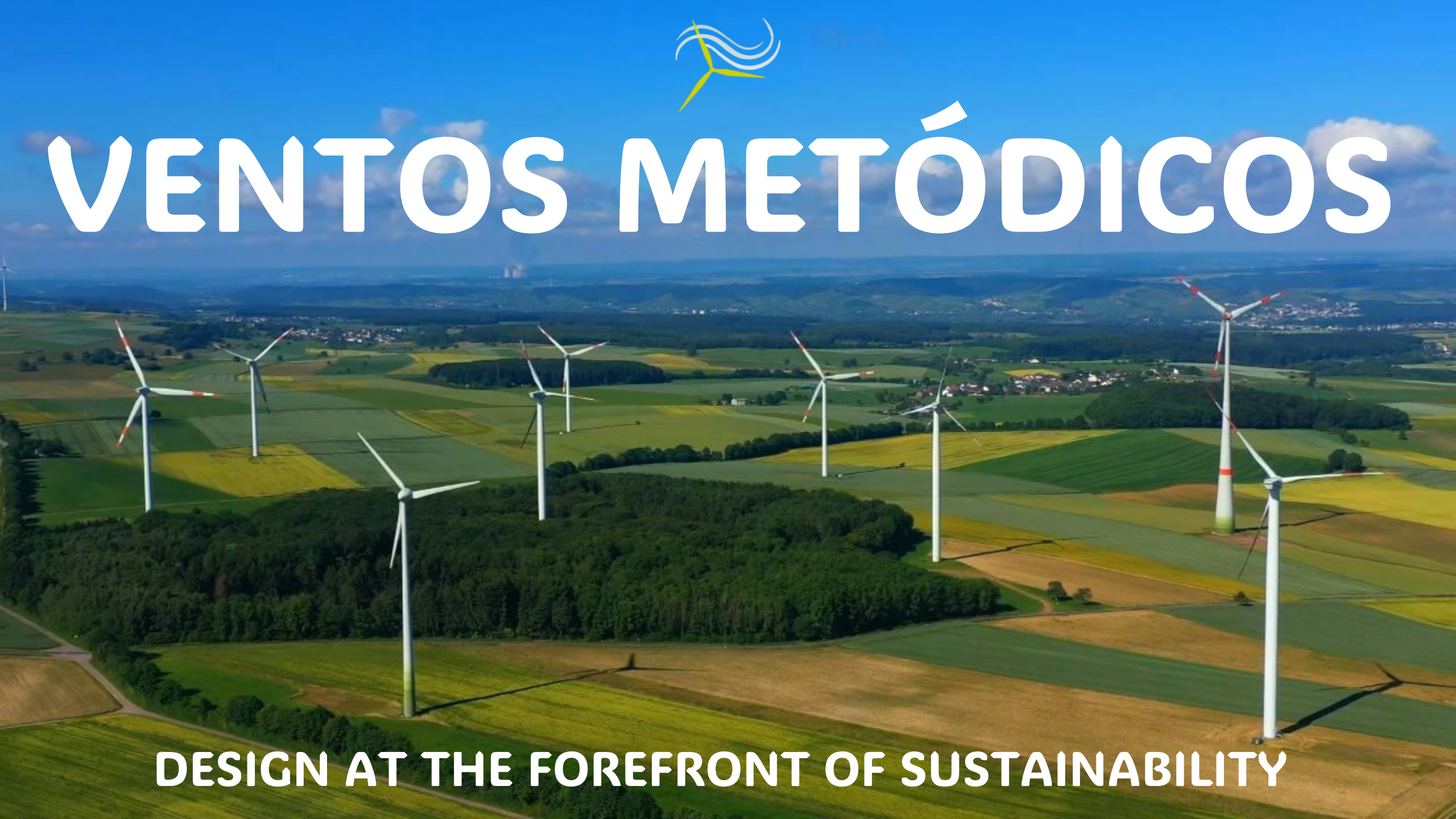
Closing the loop on carbon fiber, globally

Thank you.





FAIRMAT®

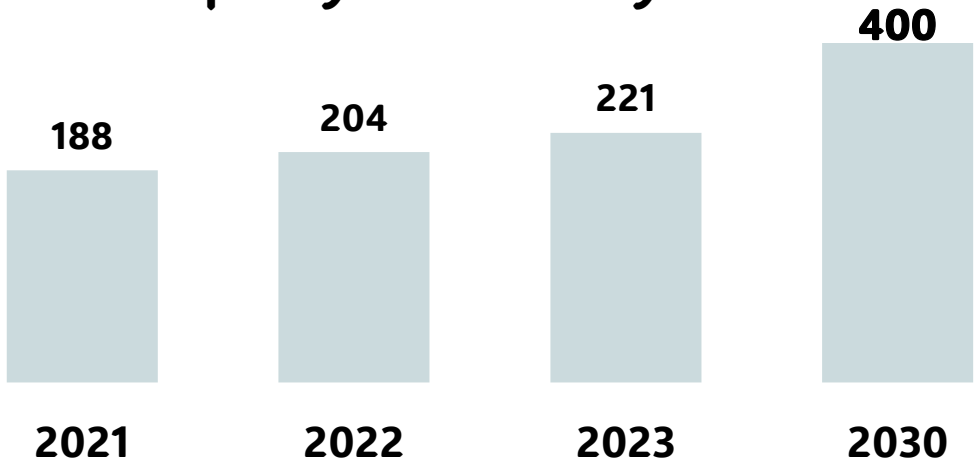

VENTOS METÓDICOS
DESIGN AT THE FOREFRONT OF SUSTAINABILITY

Current Outlook

90´s

“Boom” of wind farm installation

GW Capacity Produced by Wind in EU



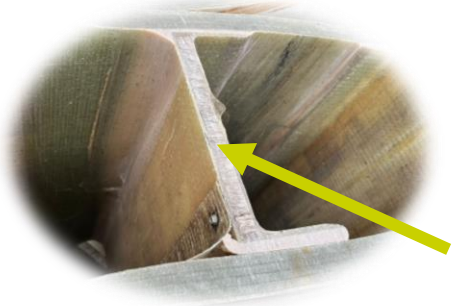
Life span

≈ 25 years

>1/3

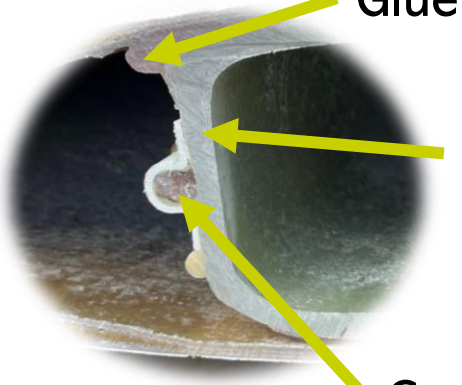
Ventos Metódicos

End of Life Approach



Carbon Fiber

Glue



Glass Fiber + Polymer

Copper

Balsa wood

Landfill

Incineration

Cement Industry

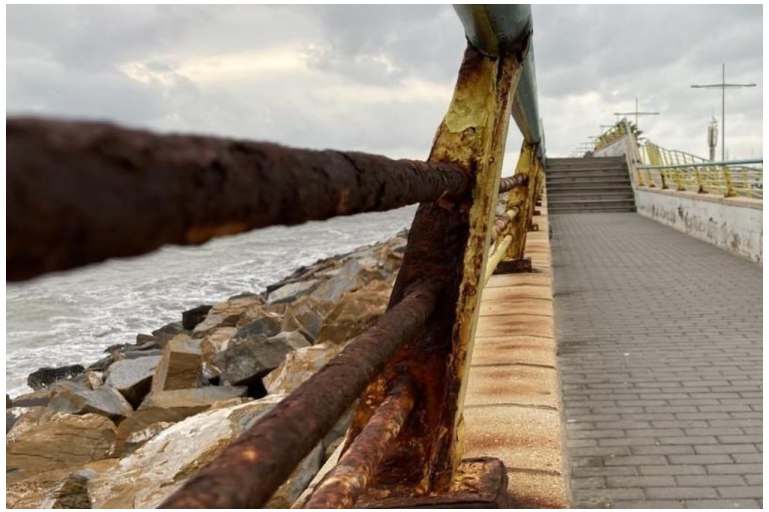
Our Operations

Ventos Metódicos

Our Advantage

With our materials we address common issues in urban/agricultural contexts

Non-Roasting material



Material Strength

Non-Organic material

Ventos Metódicos

Our Products

Urban

Home

Agriculture

Limited Edition

Ventos Metódicos

Our Products

Benches

Tables

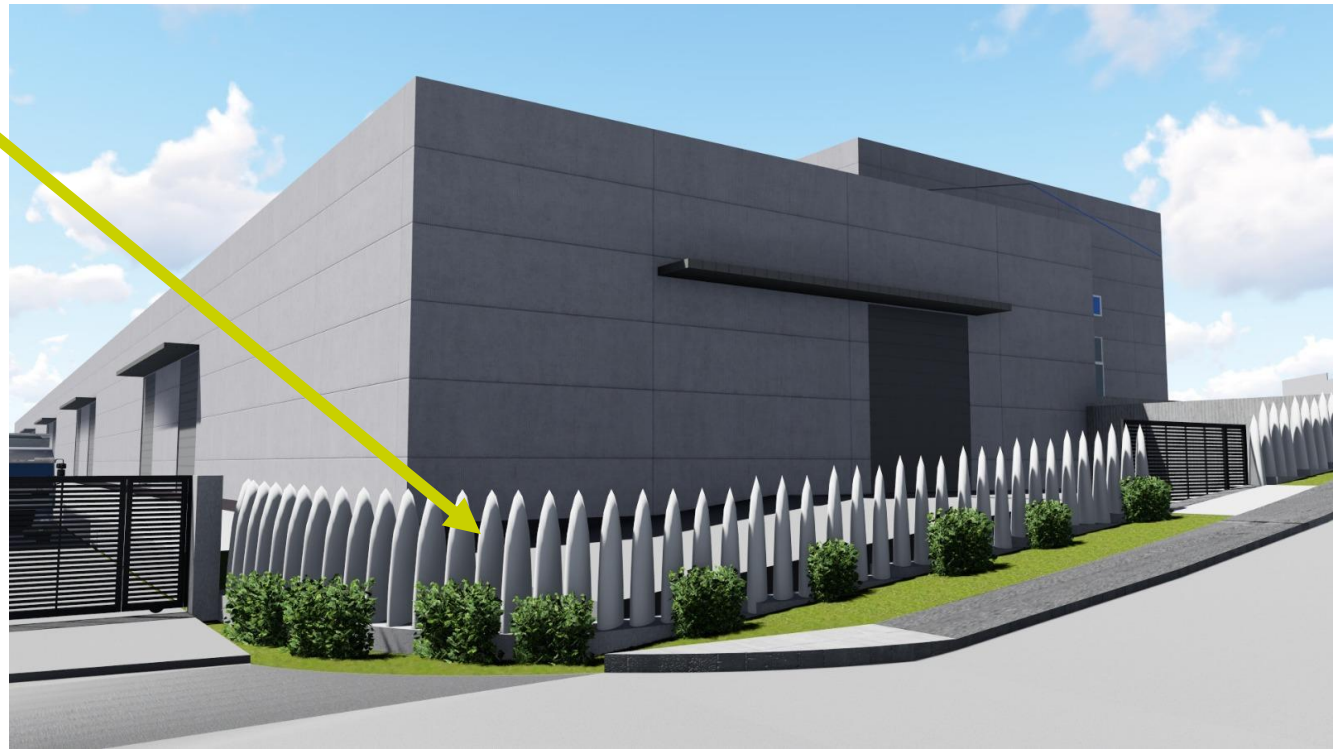
Our Products

Flower Pots

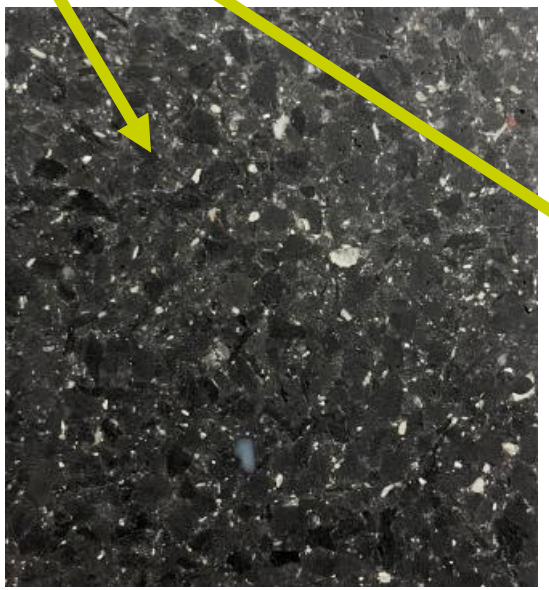
Full Sets

Next Steps

Factory Enclosure



Conglomerates



THANK YOU

Ventos Metódicos

WIND BLADES:

- Currently in Spain there are 1.5Mt of blade waste.

SERIOUS PROBLEM

AERONAUTIC SECTOR:

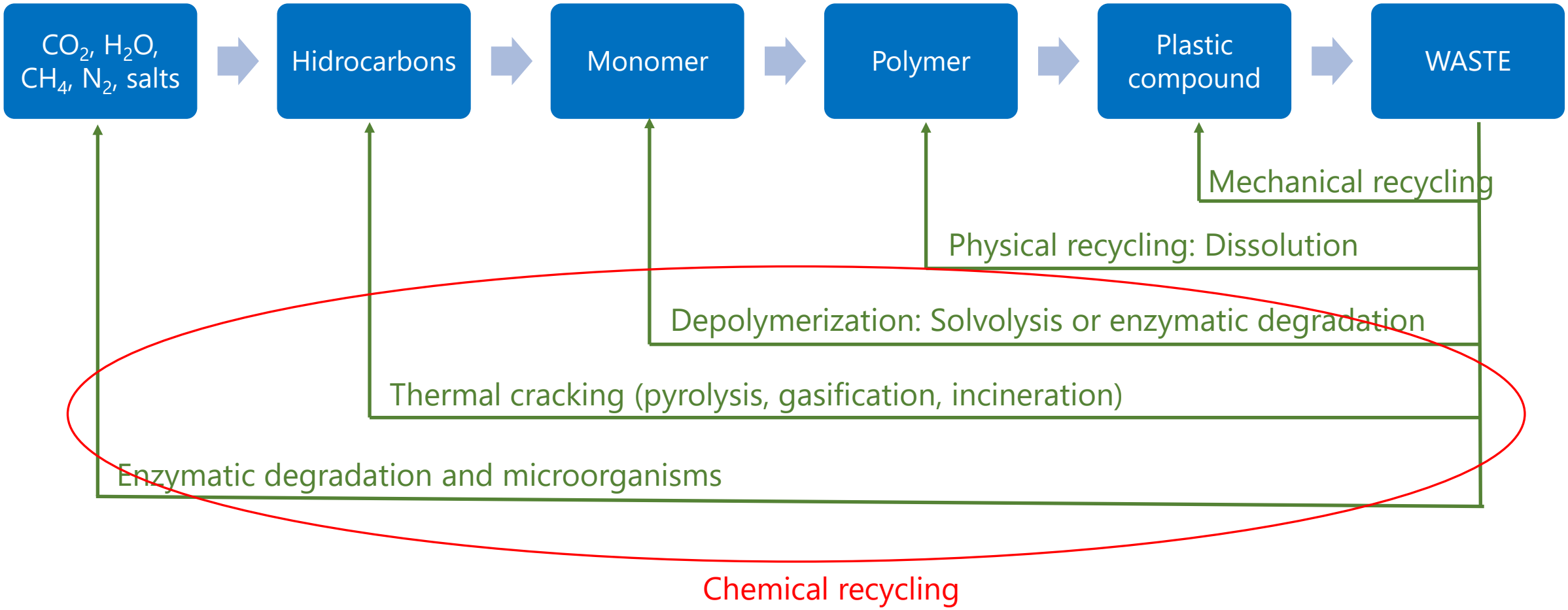
- 10.000 aircraft will be retired globally over the next 20 years

Chemical recycling of composites: a necessary and sustainable reality (EROS and ELIOT projects)

Nora Lardiés Miazza· Chemical recycling department AIMPLAS

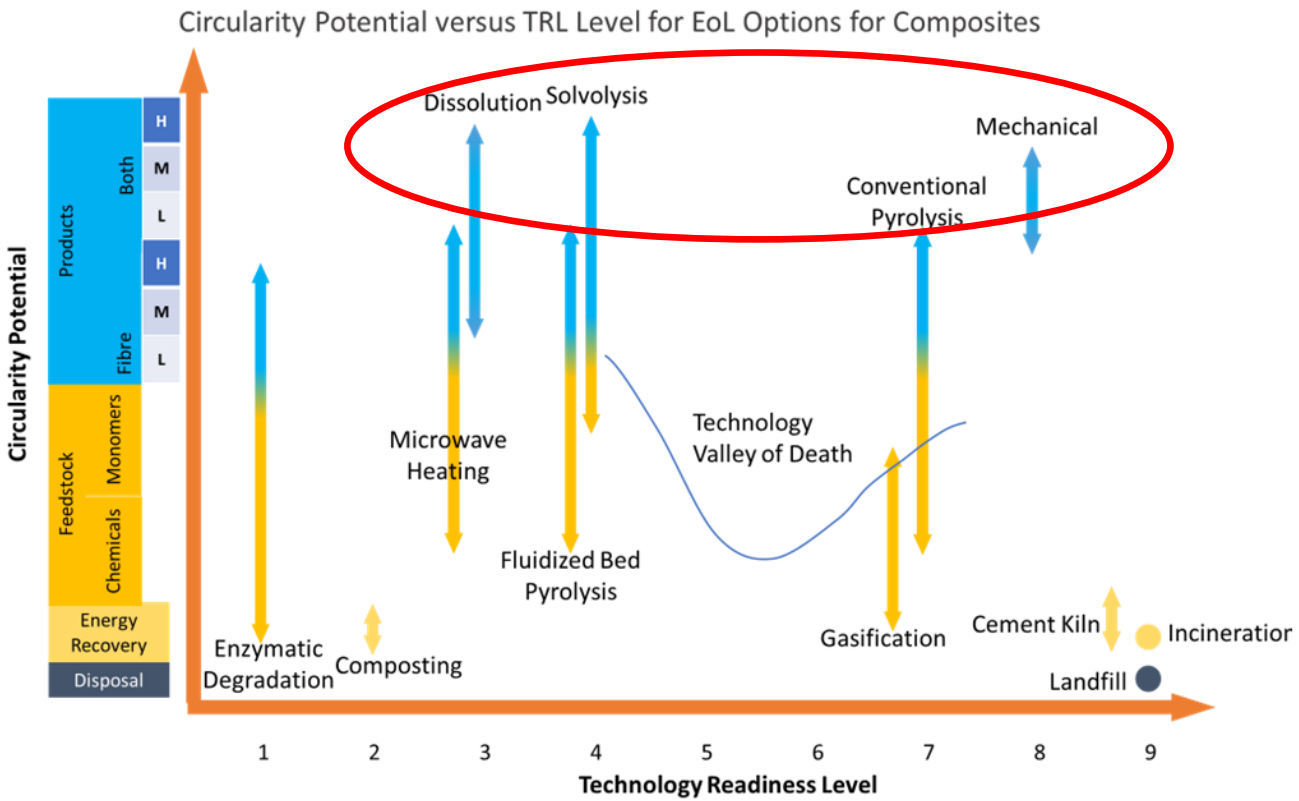
nlardies@aimplas.es

Recycling technologies

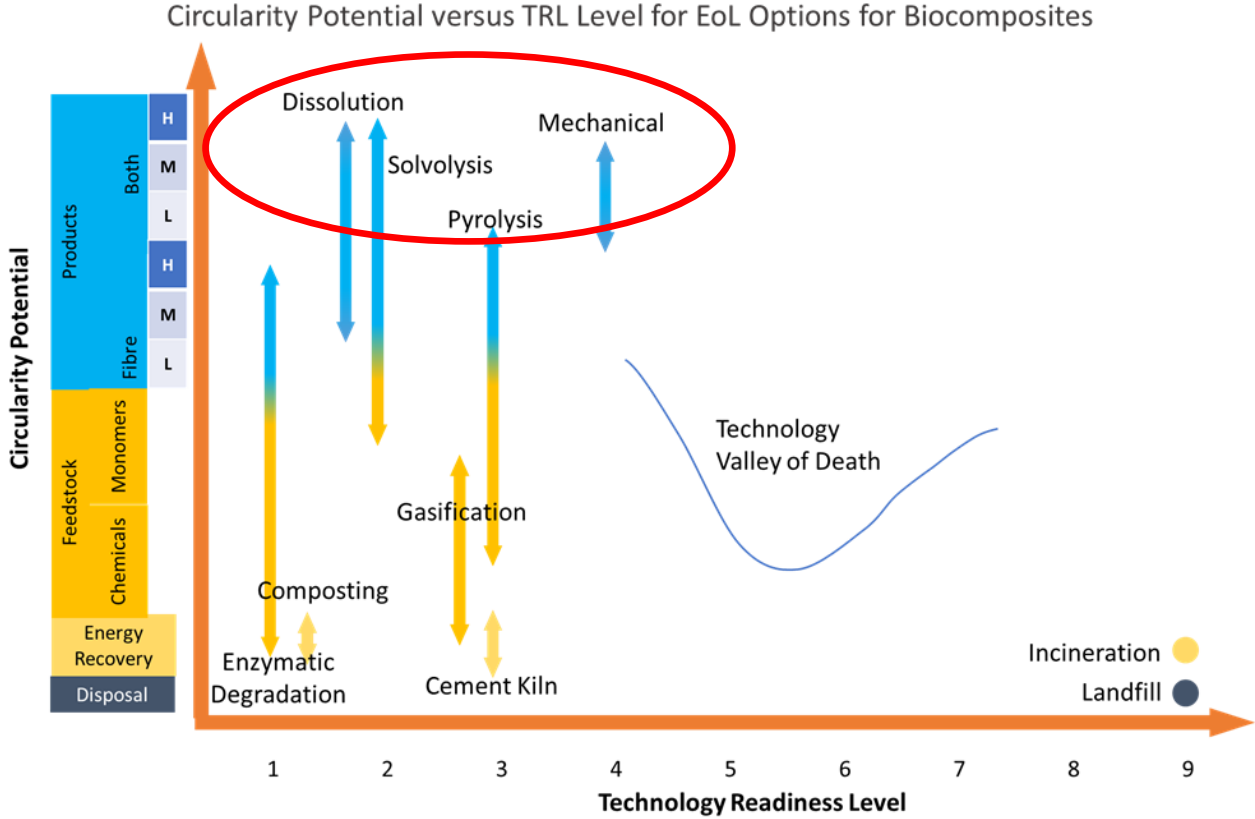


Assessment of all recycling technologies

Composites



Biocomposites

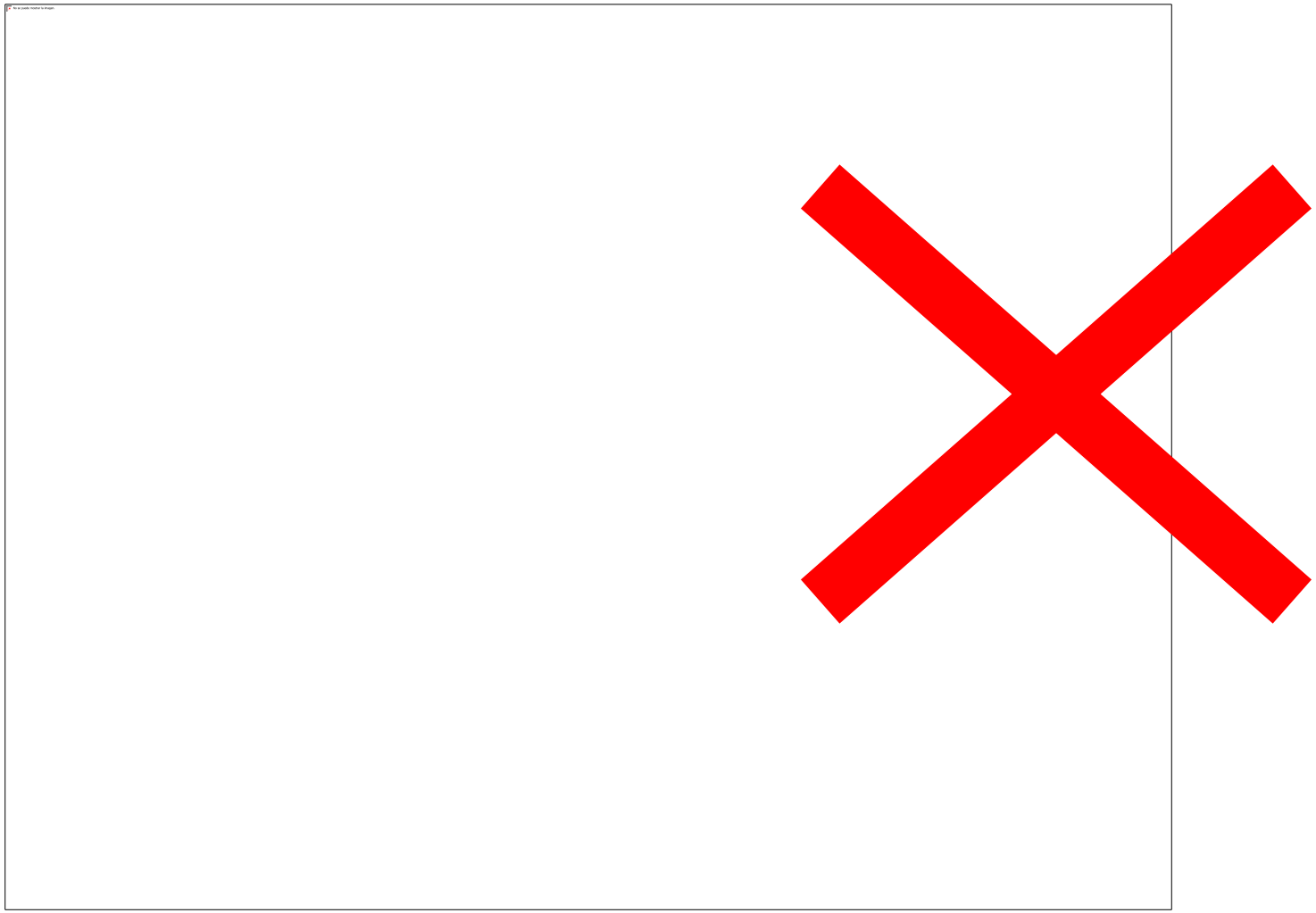


1) Mechanical recycling

Grinded biocomposites were introduced in new composites as fillers

Figure 1. *Sequence of the laminate's preparation by vacuum bagging process*

1) Mechanical recycicling



Mechanical properties REDUCED!

of the new biocomposites with the grinded fillers compared to the same biocomposite with a standard fillers

2) Physical recycling (dissolution)

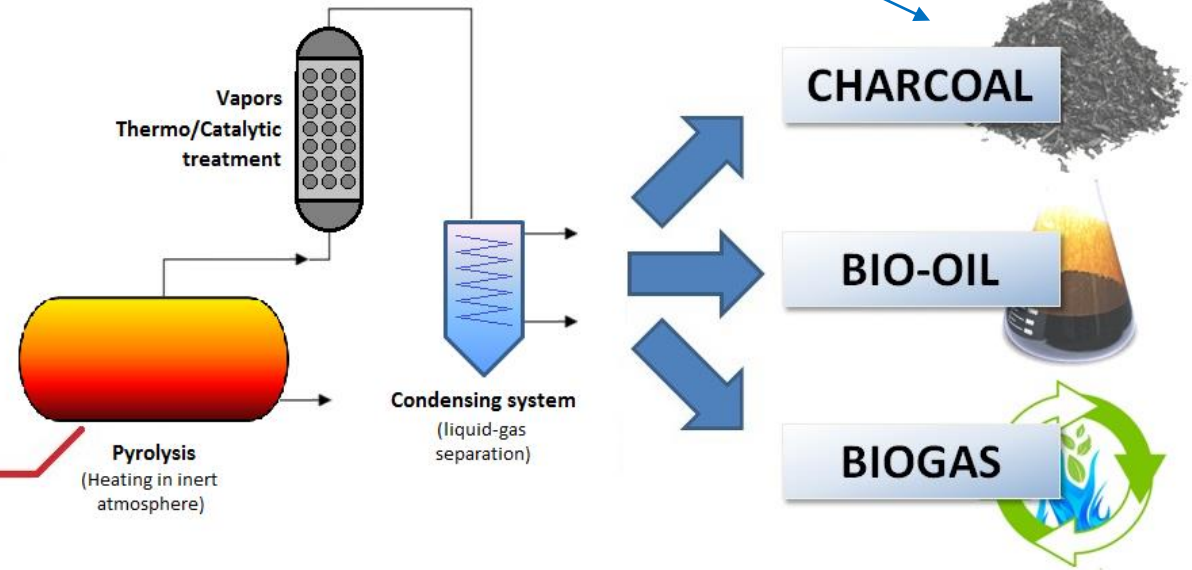
Broad range of solvent classes was tested but:
no suitable solvent (and dissolution conditions) were found for any of the studied materials

TNO innovation for life

3) Chemical recycling: PYROLYSIS

AIMPLAS´ pilot plant

- Temperature (>400 ºC)
- Inert atmosphere
- For mixed wastes
- Products: 3 fractions are obtained



3) Chemical recycling (pyrolysis)

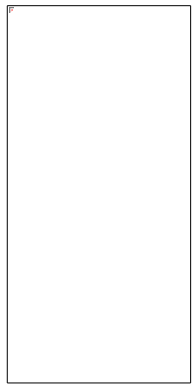
3) Pyrolysis with catalysts

	Tª (ºC)	Solid	Liquid	Gas
Control	500	5%	40%	45%
H-ZSM-5 100%	500	13%	33%	54%
H-ZSM-5 100%	450	35%	25%	40%
H-ZSM-5 50%	500	22%	32%	46%
Zeolita Y 100%	500	50%	32%	18%
Zeolita Y 100%	450	89%	1%	9%
Zeolita Y 50%	500	57%	15%	28%
Zeolita B 100%	500	44%	3%	52%
Zeolita B 100%	450	66%	24%	11%
Zeolita B 50%	500	55%	19%	26%

The use of catalysts:

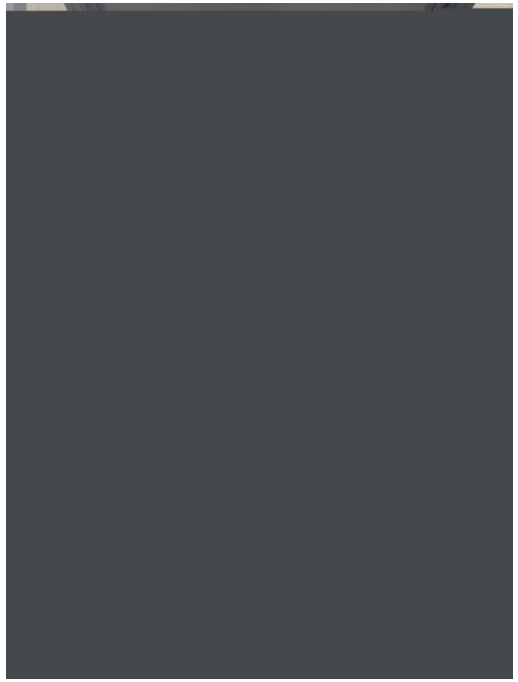
- Increase the amount of char over the fibre
- Reduce the amount of pyrolytic oil

4) Chemical recycling: SOLVOLYSIS



300ml reactor
(344 bar, 360ºC)

Reactors up to 100 litros



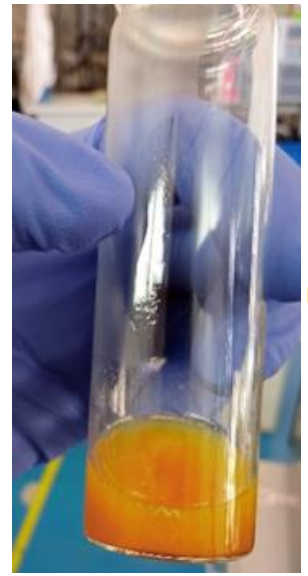
High pressure reactor 20 litros

High pressure reactor 100 litros

- Temperature (lower than pyrolysis)
- Solvents (in sub o super critic conditions)
- Option: pressure and catalysts
- Products obtained: fibres and monomers → To synthesize new polymers again

4) Chemical recycling (solvolysis)

Laboratory scale



Monomers

Pilot plant scale

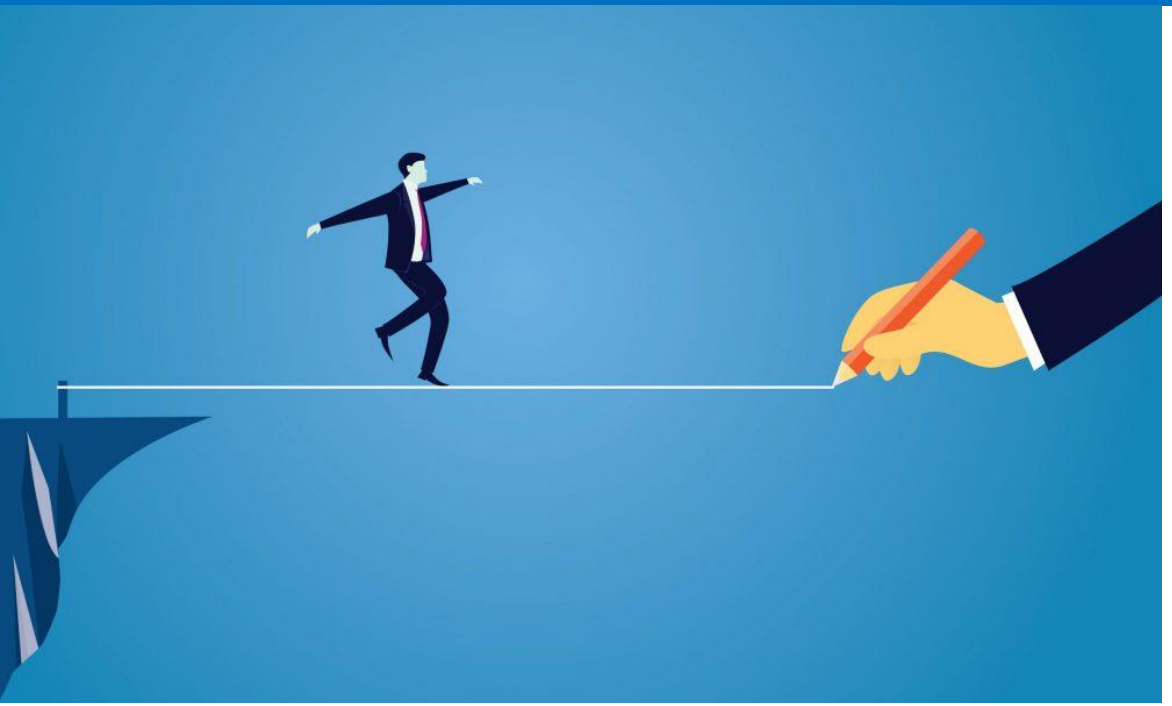
Fibres

4) Chemical recycling (solvolysis)

Solvolysis of an epoxy resin

Reaction	Reagents	Conditions	Yield (%)
1	Water	Subcritic	65
2	Ethanol and $ZnCl_2$	Subcritic	50
3	PEG200, NaOH	Subcritic	5
4	HOAc, H_2O_2	Subcritic	70
5	Acetone and water	Supercritic	85
6	Propanol, KOH	Supercritic	80

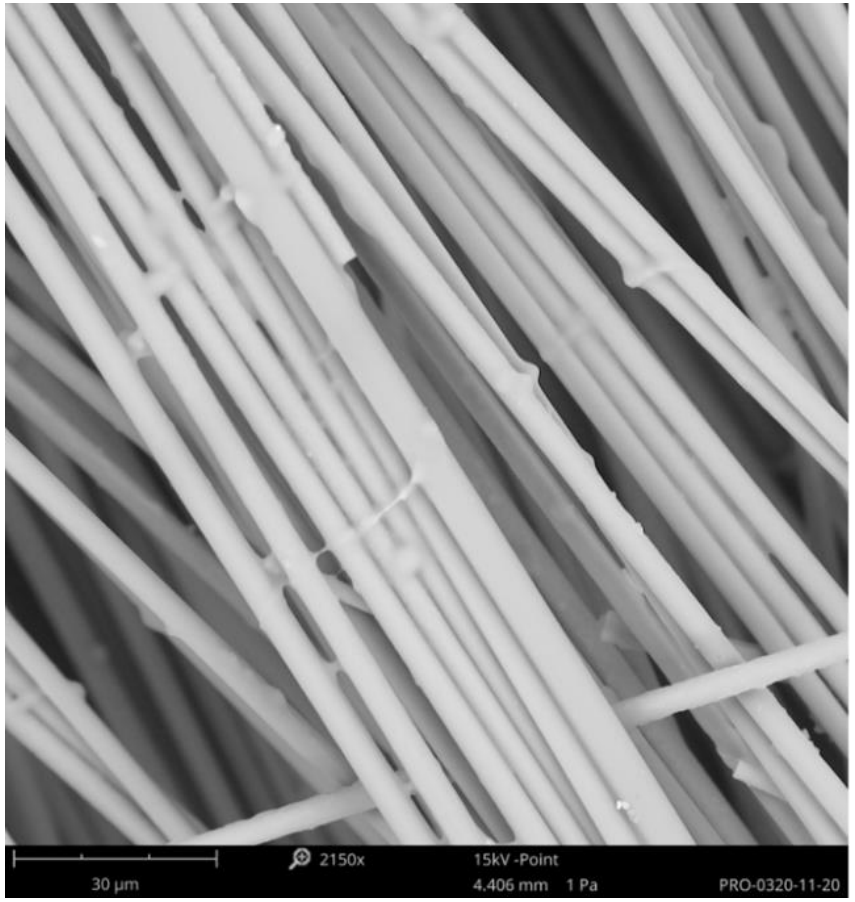
CHALLENGES

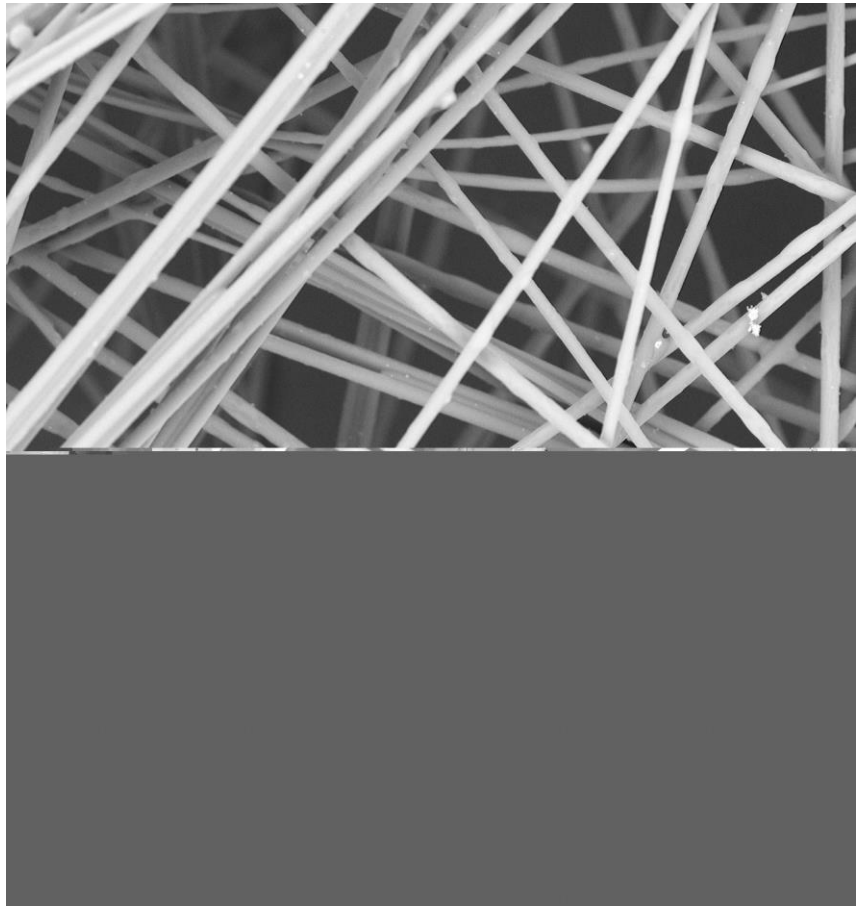


- ✓ Develop and apply a sizing to the recycled fibres obtained.
- ✓ Design recycling processes to maintain maximum fibre length for spinning and weaving the recycled fibre obtained.

- ✓ Synthesize new thermosetting resins from the monomers from the solvolysis liquid:
  - Recycled resins
  - 3R resins

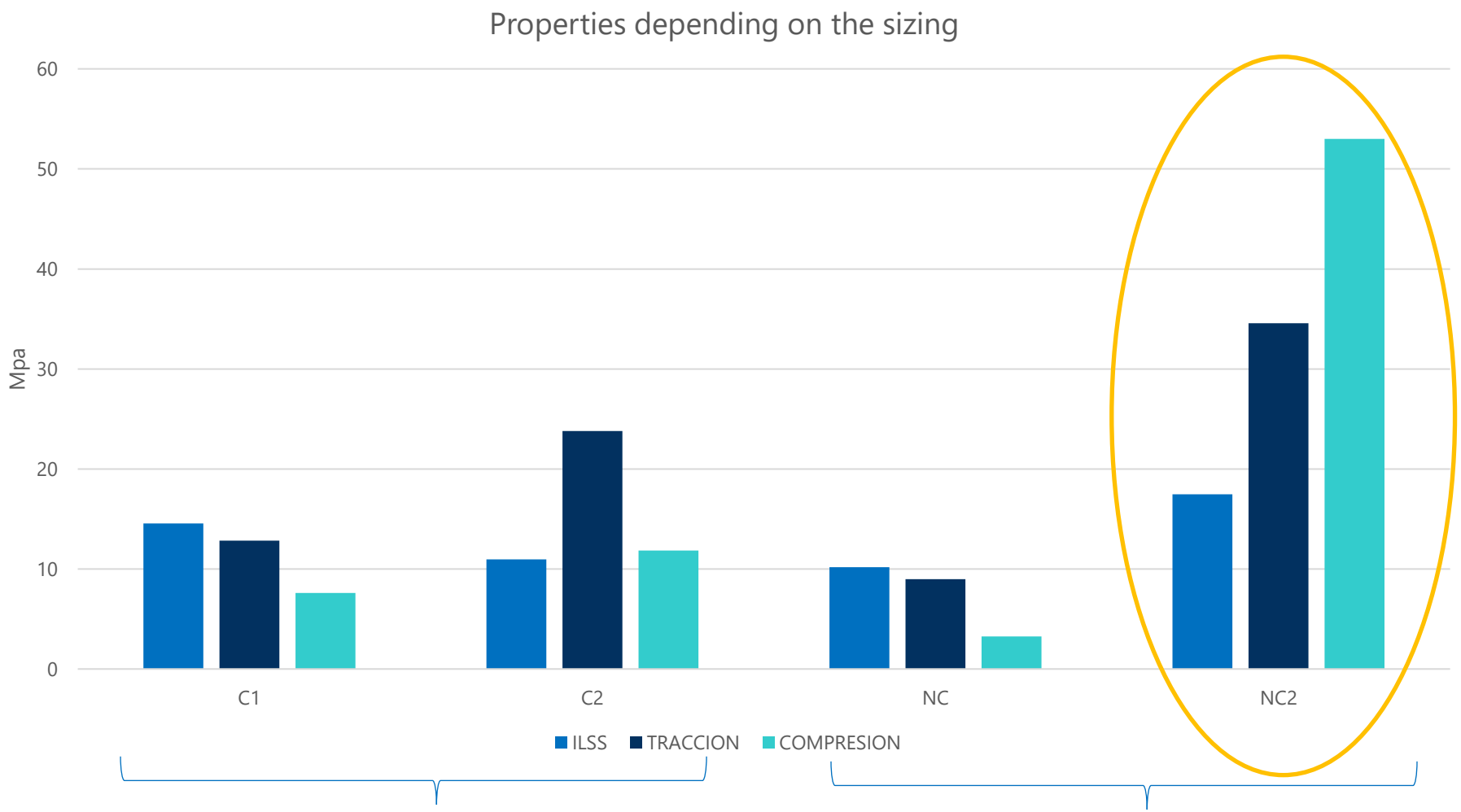
APLICATION OF SIZINGS





!Homogeneous sizing!

APLICATION OF SIZINGS

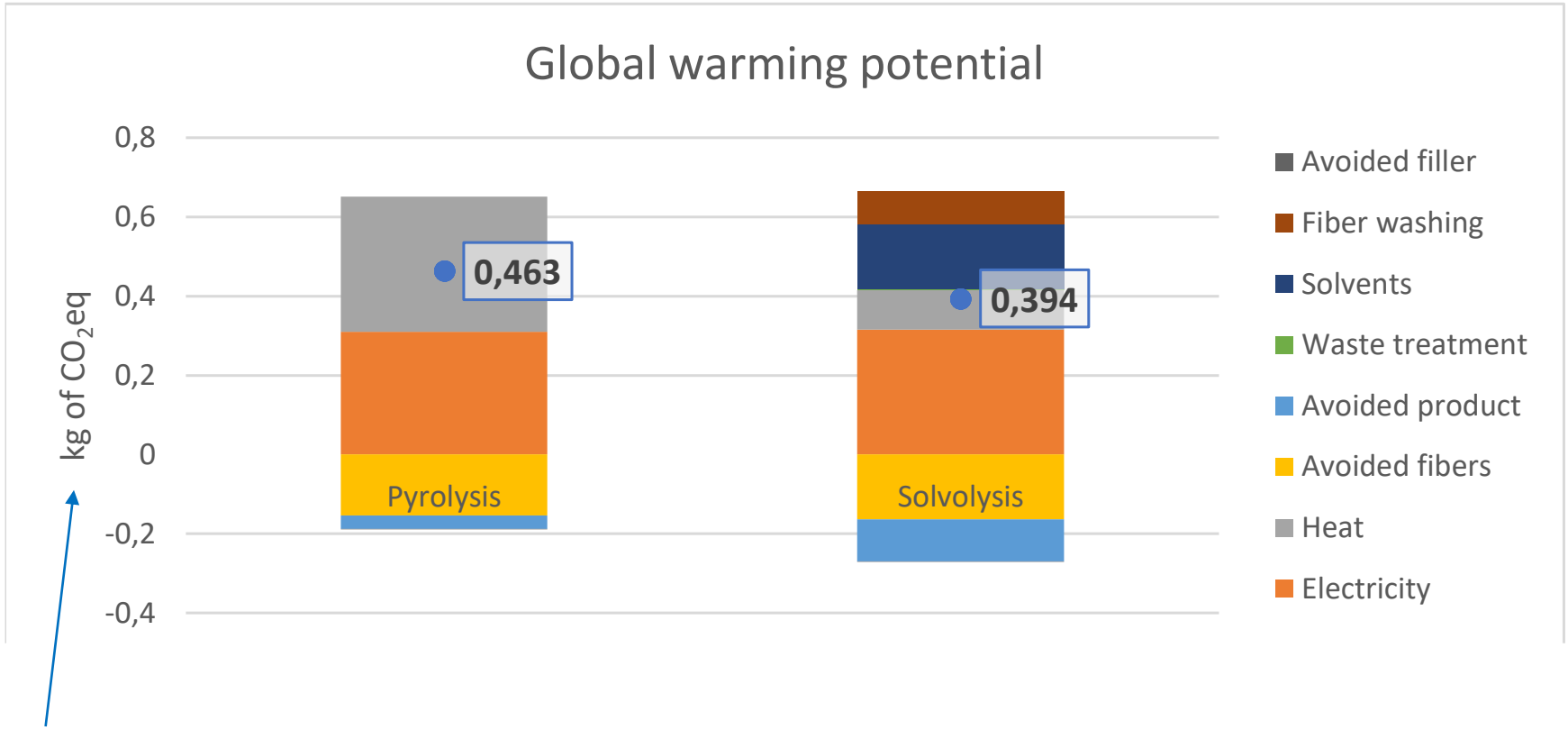


19


Chemical
recycling


Chemical recycling:
PYROLYSIS
SOLVOLYSIS
IS IT PROFITABLE?

LCA and economy assesment



Kg of CO_2 by kg of waste

- Solvolysis emits 17% less CO_2 than pyrolysis.
- Solvolysis uses solvents, which are recovered very efficiently and reused in the process.

- Solvolysis higher capital investment costs → associated with equipment

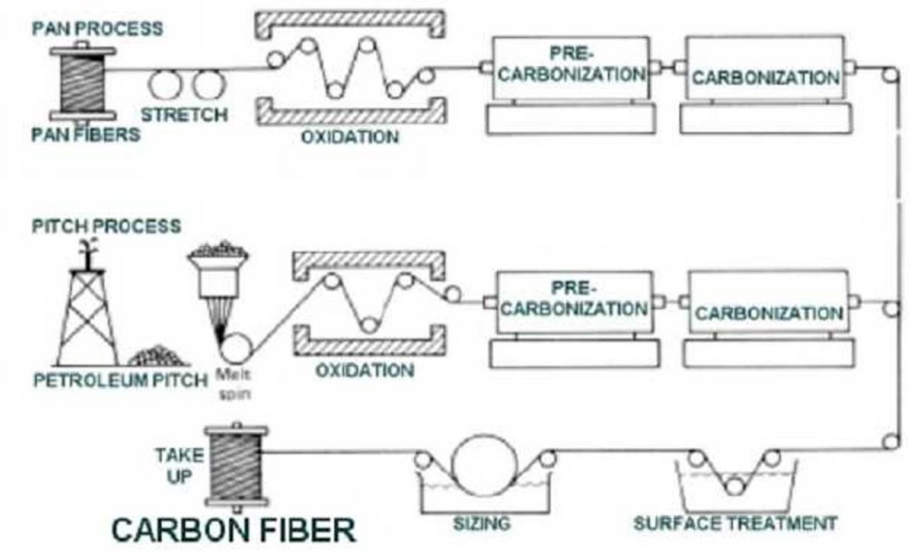
TNO innovation for life

AIMPLAS

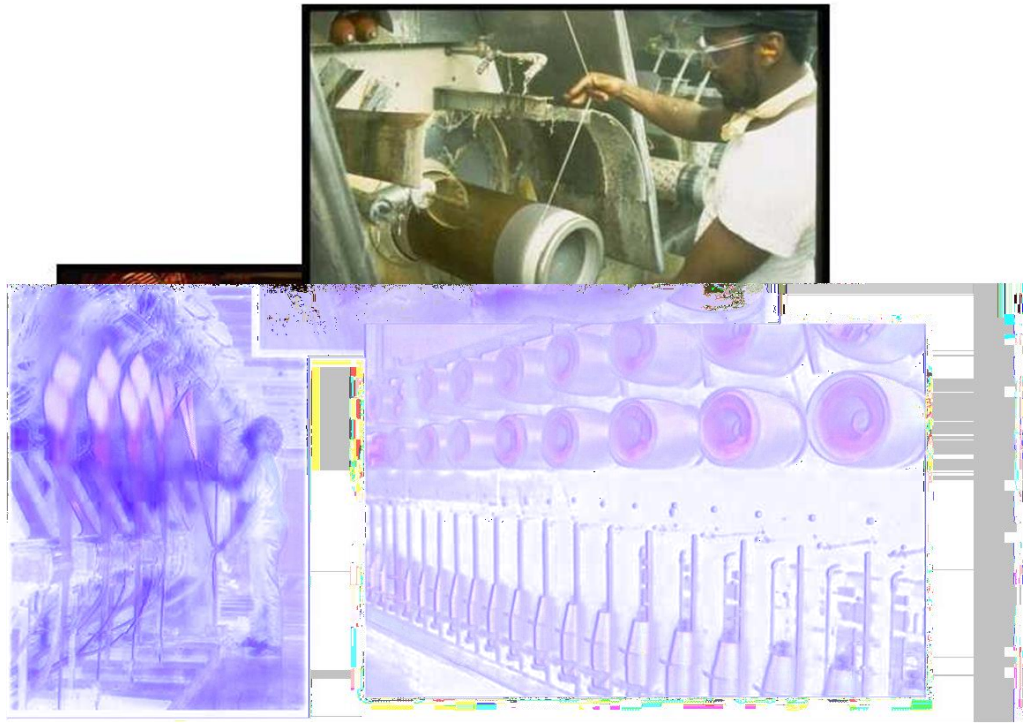
LCA and economy assesment

CO_2 emissions during the production process of commercial carbon and glass fibre?

Carbon fibre manufacturing process



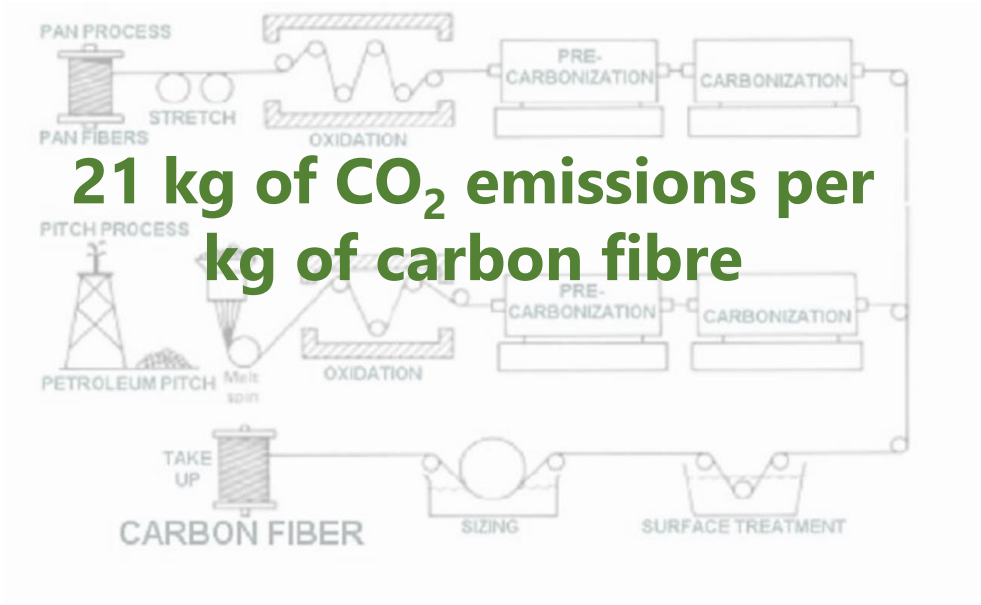
Glass fibre manufacturing process



LCA and economy assesment

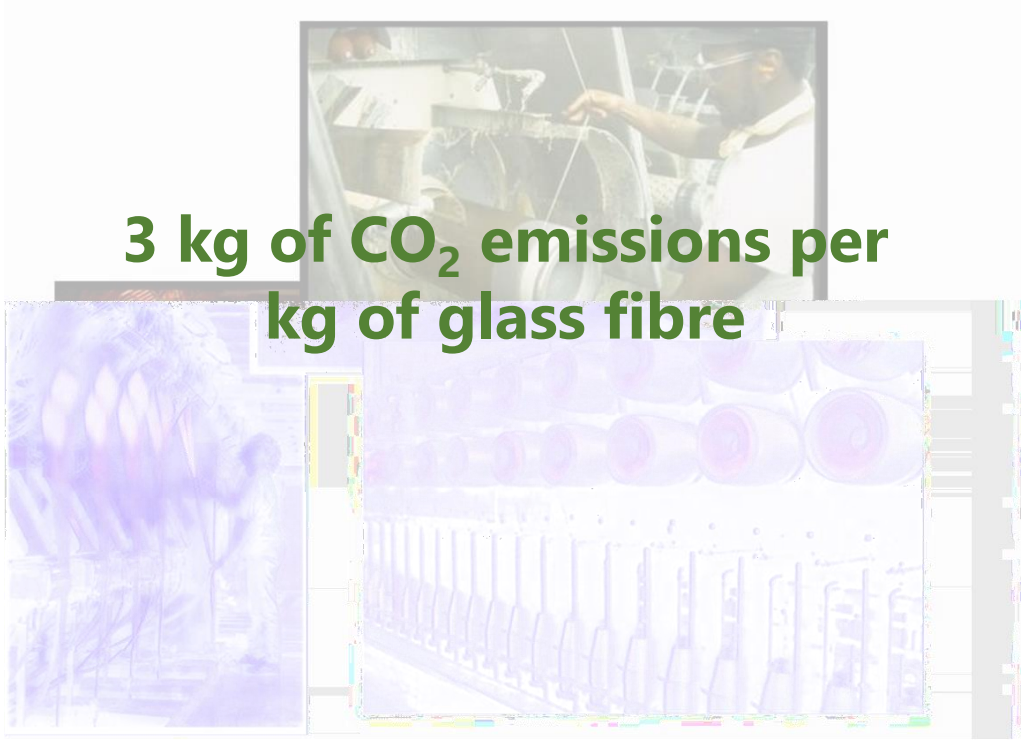
CO_2 emissions during the production process of commercial carbon and glass fibre?

Carbon fibre manufacturing process



21 kg of CO_2 emissions per kg of carbon fibre

Glass fibre manufacturing process

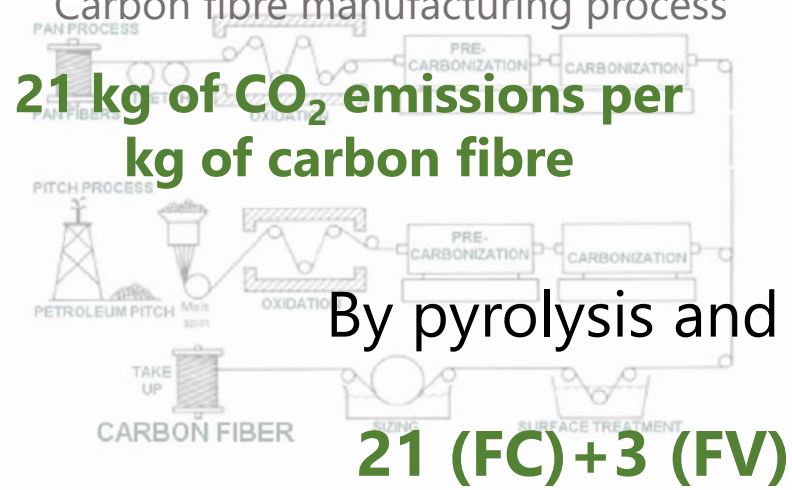


3 kg of CO_2 emissions per kg of glass fibre

LCA and economy assesment

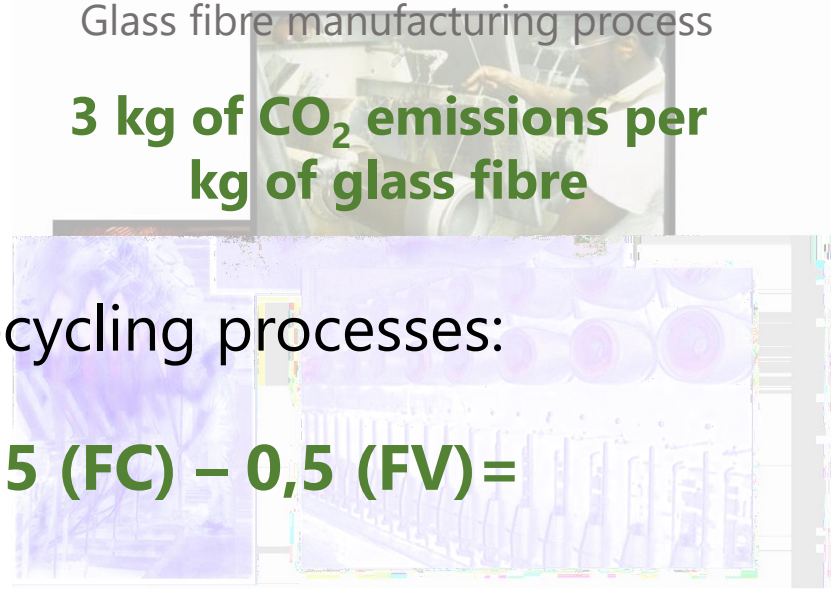
CO2 emissions during the production process of commercial carbon and glass fibre?

Carbon fibre manufacturing process



21 kg of CO_2 emissions per kg of carbon fibre

Glass fibre manufacturing process



3 kg of CO_2 emissions per kg of glass fibre

By pyrolysis and solvolysis recycling processes:

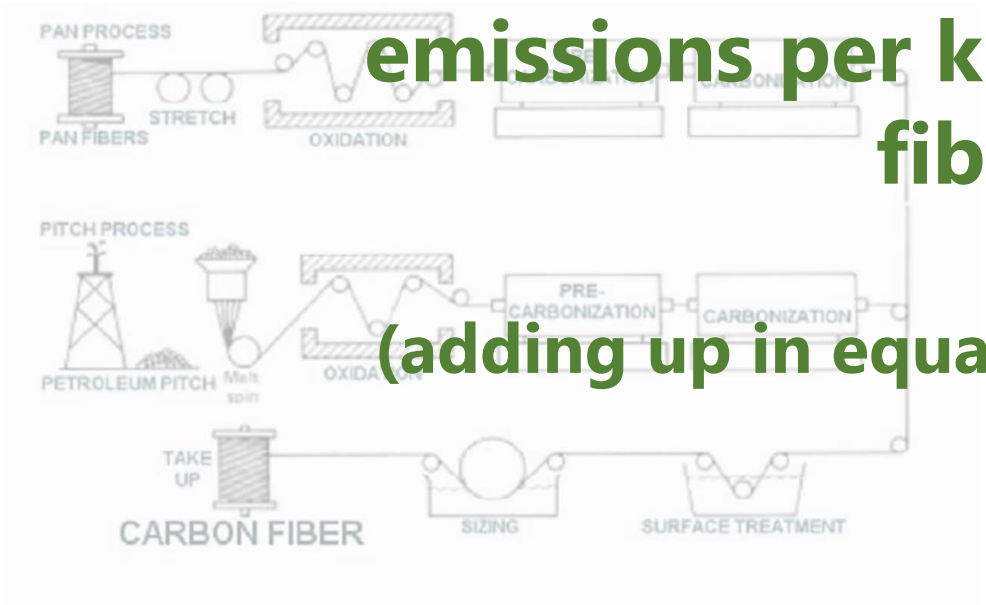
21 (FC)+3 (FV) = 24 kg -0,5 (FC) – 0,5 (FV)=

Reduction of 23 kg of CO_2 emissions per kilo of recovered fibre

LCA and economy assesment

By pyrolysis and solvolysis recyclilng processes:

Carbon fibre manufacturing process



Glass fibre manufacturing process

Reduction of 23 kg of CO_2 emissions per kilo of retrieved fibre

(adding up in equal parts CF and GF)

TNO innovation for life

AIMPLAS


Chemical recycling:
PYROLYSIS
SOLVOLYSIS
a necessary and
sustainable solution

!THANK YOU VERY MUCH FOR YOUR ATTENTION!

Nora Lardiés Miazza nlardies@aimplas.es

Chemical recycling area of AIMPLAS

Síguenos

Recycling solutions for creating value from EoL composites wind turbine blades

April 24th, 2024

ACCIONA & KEY FIGURES

Key Industries

Energy | Transport | water | Cities | Real Estate

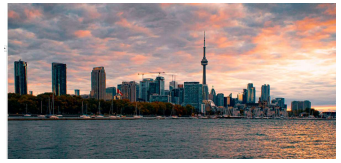
2023 HIGHLIGHTS

(Million Euro)	FY 2023	FY 2022	Chg.(€m)	Chg. (%)
Revenues	17,021	11,195	5,826	52.0%
Attributable Net Profit	541	441	100	22.6%

INNOVATION FOCUSED

ENERGY- PAMPLONA

CONSTRUCTION-MADRID



WATER- BARCELONA

INNOVATION IN CONSTRUCTION

+74
Research Engineers

14
Laboratories

1
Workshop for prototype

Technology and Innovation Division- Madrid

Optimization of Construction process

New Materials

Digitalization of Construction process

Reducing the Carbon footprint of Construction projects

Innovation areas

Recycling solutions for creating value from EoL composites wind turbine blades

Understanding First Generation Composite Wind Turbine Blades


tve1
1995
26 September
Tarifa is Spain's biggest wind farm.

Once a biggest wind farm with LATEST technology became OBSELETE in 24 years

REPOWERING

BEFORE

90 turbines of 330-kW generating 30 MW

AFTER

12 turbines (8 x 3 MW and 4 x 1.5 MW)

+ 16% output increase

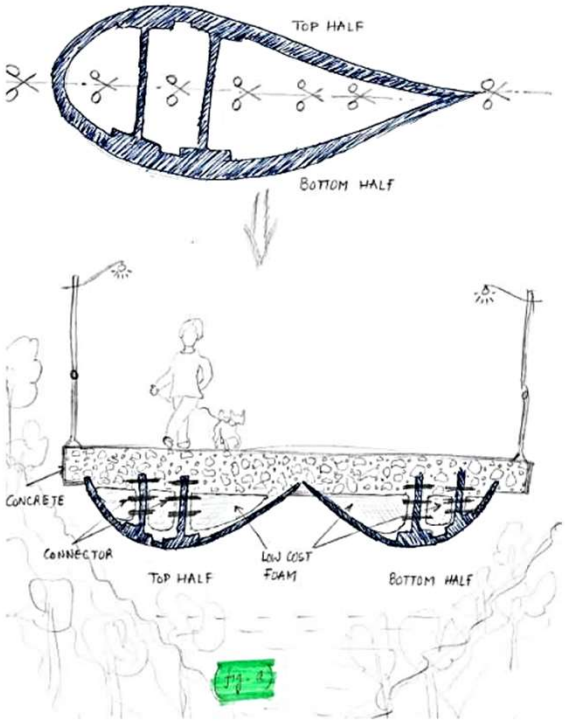
+ reduce impact on surroundings

What about the decommisioned/**EoS Blades?**

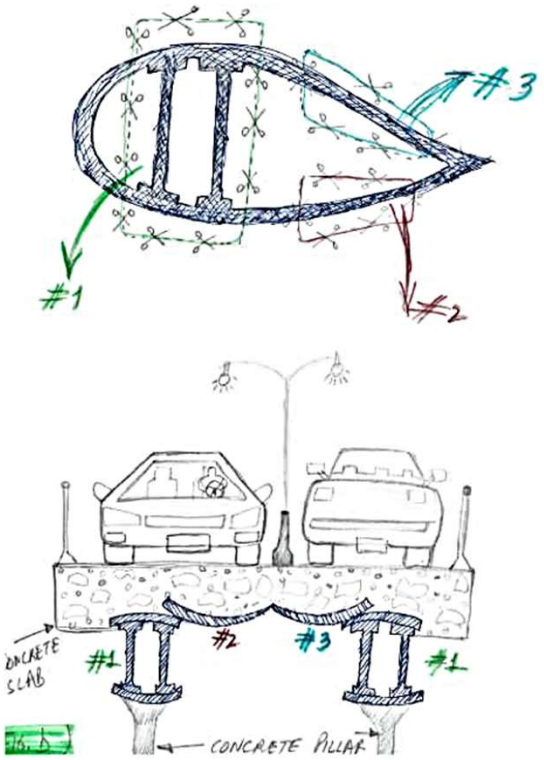
https://reneweconomy.com.au/six-factories-planned-to-recycle-end-of-life-wind-turbine-blades-in-europe/

https://www.downwindersatrisk.org/2017/08/why-cement-kilns-are-insatiable-and-why-you-care/

Stored for replacement of old Blades in other operational farms



FOOT/PEDESTRIAN BRIDGE



VEHICULAR BRIDGE

The PV panels supporting structures must withstand various types of climate (tropical, industrial,…) in different locations (sea shores, islands…) or geological soils (including the most aggressive)…

(https://industry.arcelormittal.com/market-segments/steel-for-energy/solar)

GI Profile:

- Corrosion
- Heavy and Costly installation (time & labour)

“Waste2Zero approach”

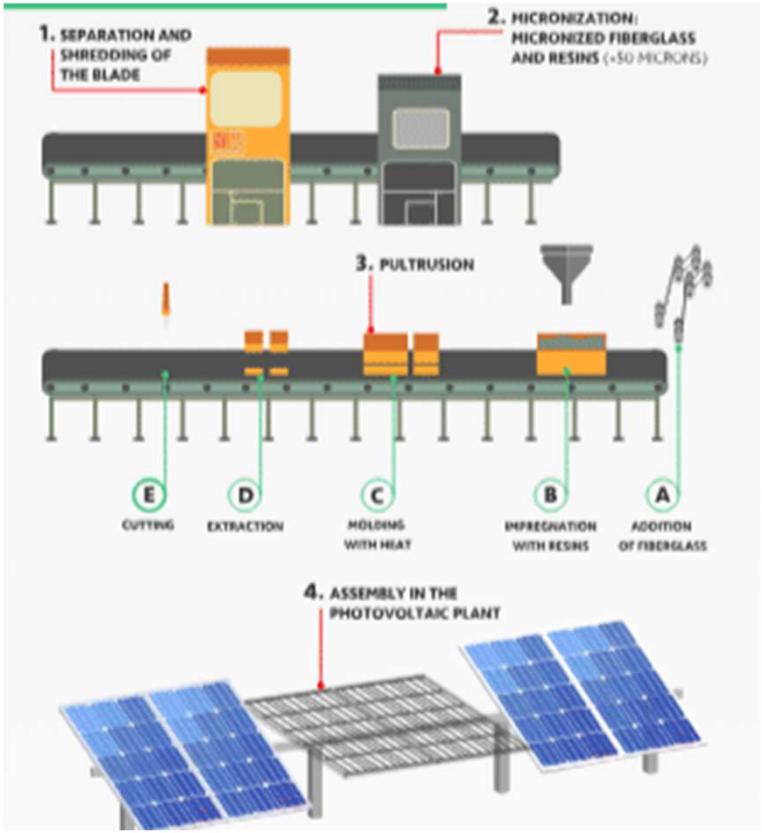
End-of-Service life composite Wind blade

Shredded blade

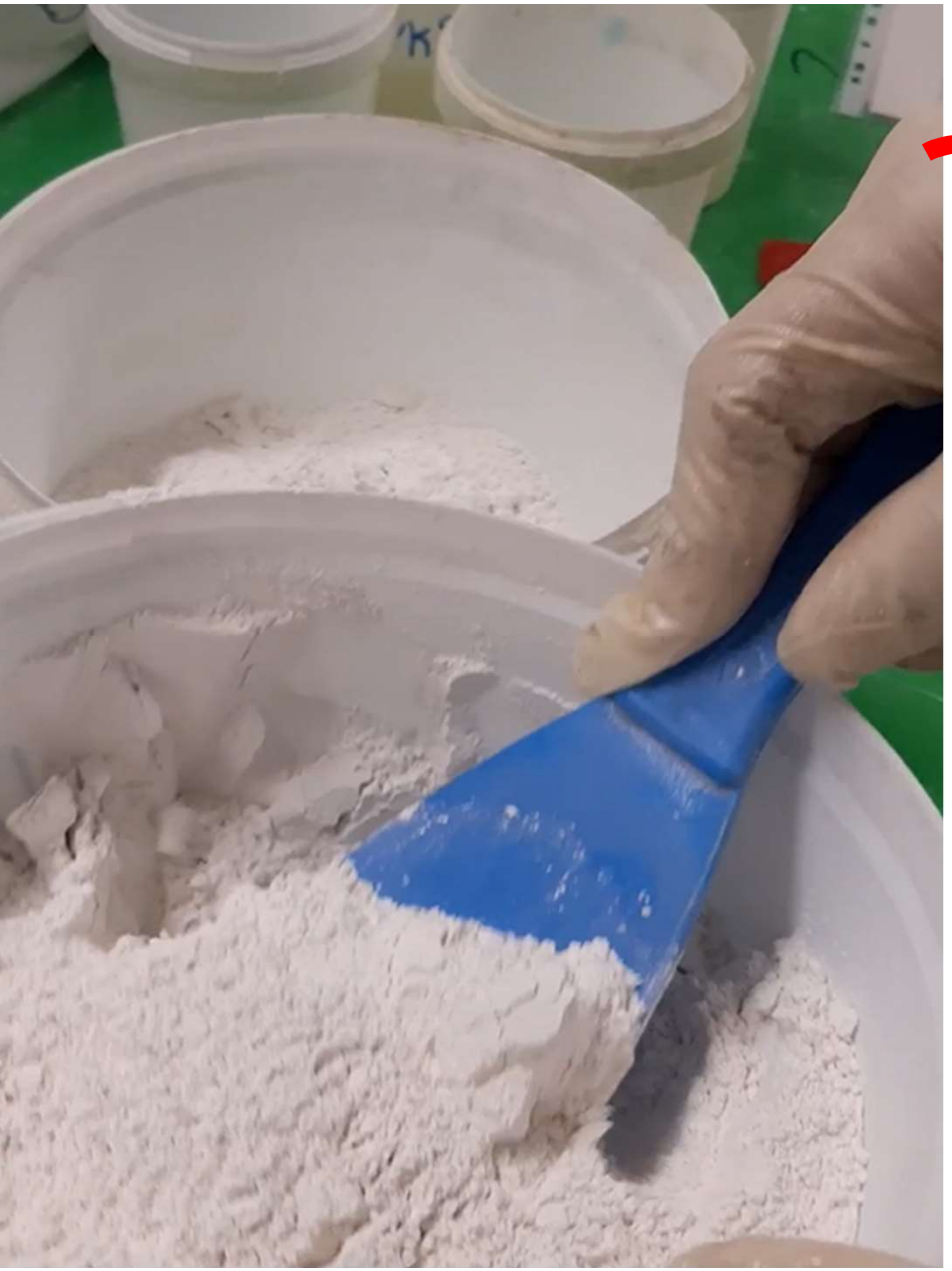
Composite Powder

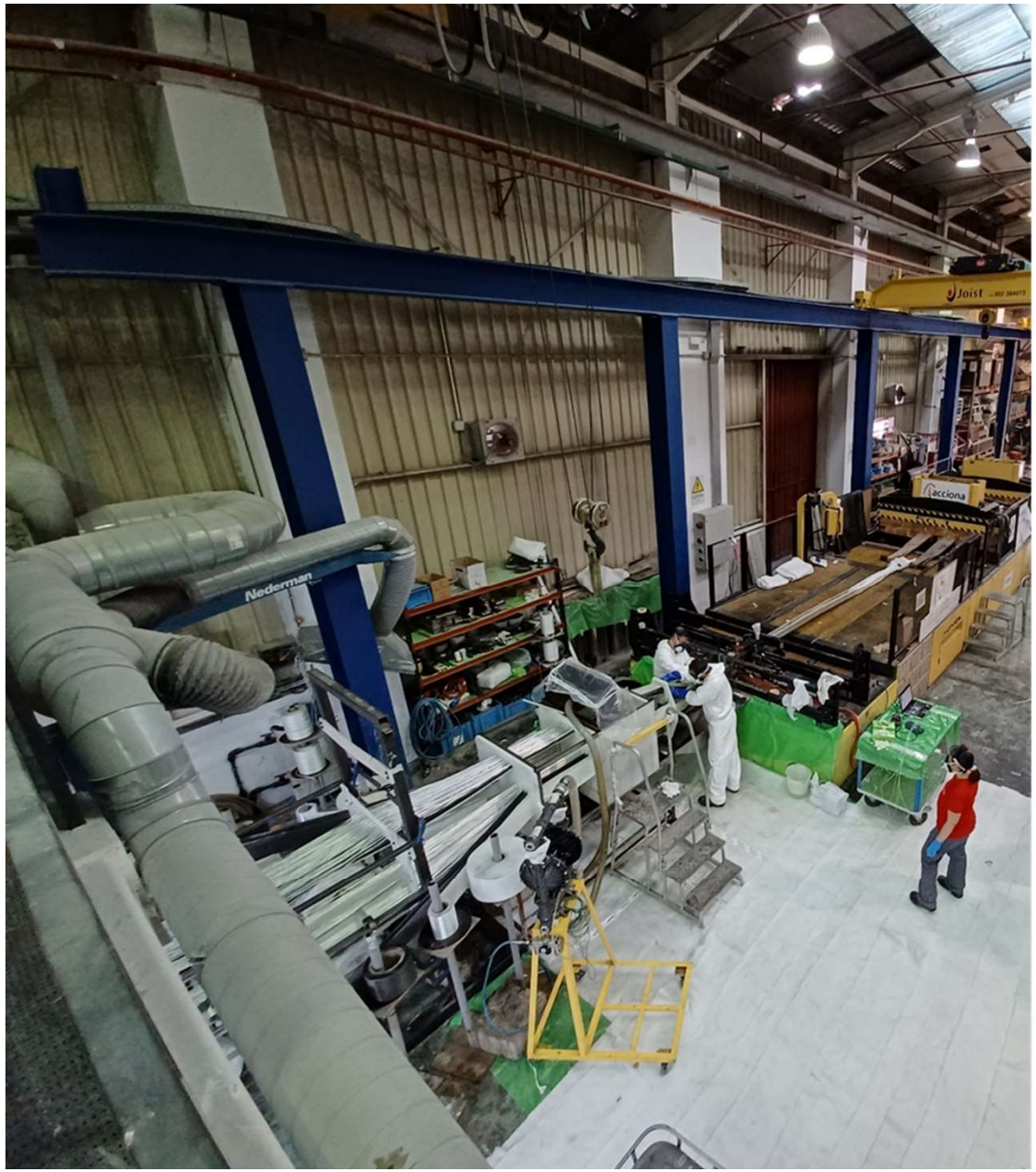
Composite Pultruded profile

Application: Structural profile for instlling Solar PV panels




Patent pending: PCT/ES2022/070841




Joist
acciona
Nederman


acciona


acciona

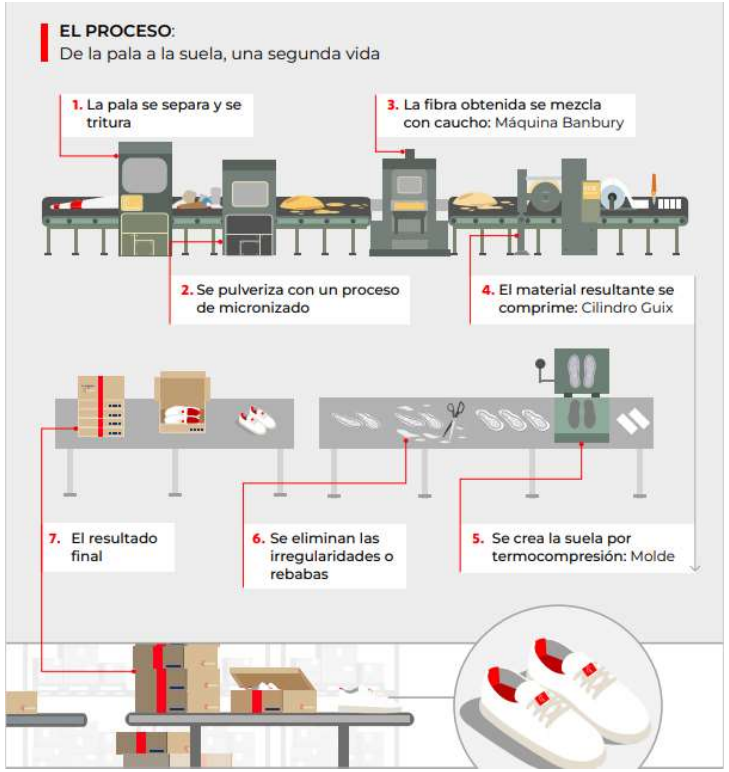
Use case-2 (Mechanical Recycling)

End-of-Service life (EoL) composite Wind blade

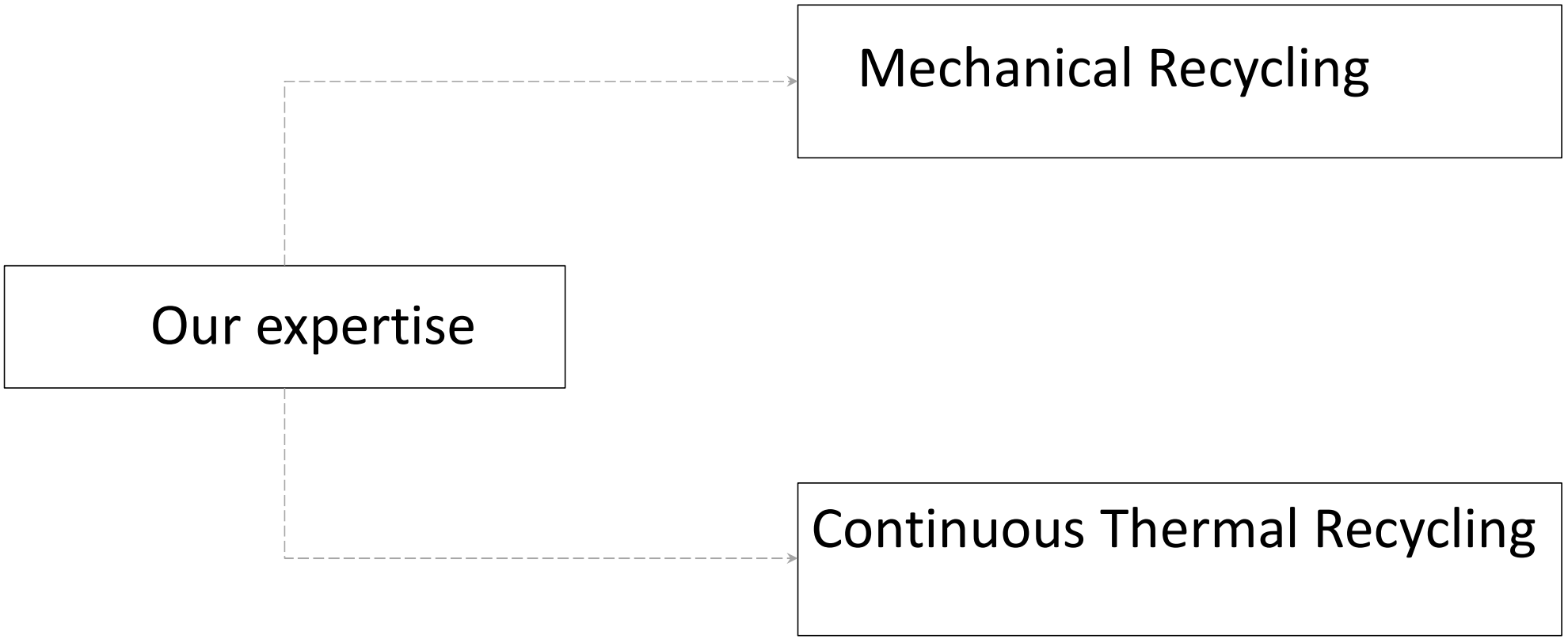
Shredded blade

Composite Powder

Application:
Wear resistance additive in Sports shoes sole



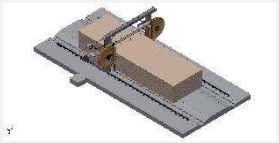
Steps from receiving a EoL Blade to cutting, shredding, grinding, through manufacturing of a shoe sole till a pair of shoes ready for use



SCHEMATIC DIAGRAM OF CONTINUOUS THERMAL RECYCLING

1. Reception, Cutting, Shredding, Segregation

Waste



Cutting system at ~1 meter.

Multistage shredding system ~ 5 cm.

Segregation system

2. Thermal treatment

Electric furnace

Patent pending: PCT/ES2022/070842

Glass fiber

Carbon fiber

Pyrolytic oils: for new raw materials/monomers.

Mechanical recycling
Grinded composite applications: loading in resins of the same family; short fiber with resin.
Advantage: mature technology, lower costs.
Disadvantage: Very specific and low value-added applications.

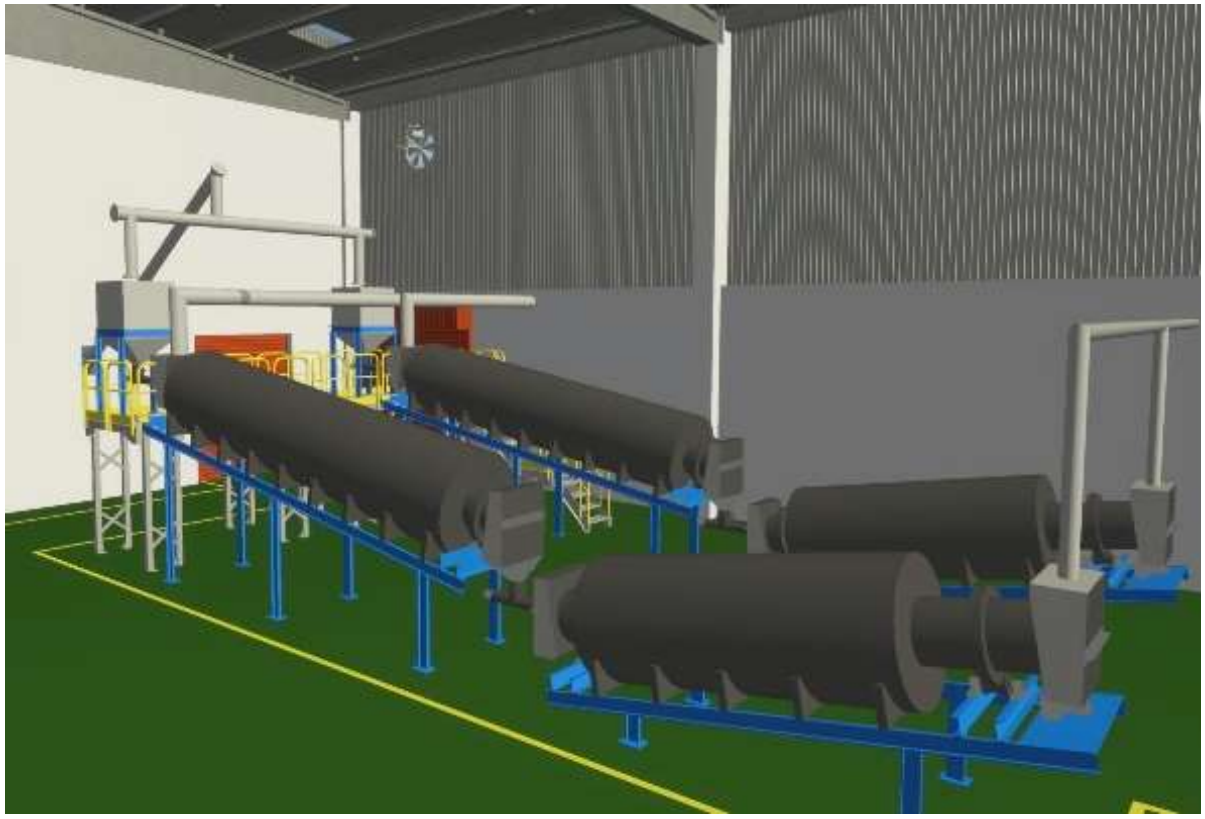
3. Transformation

Facility 1: 1000 tn/year

Full stage operation in May,2024

Facility2: 10,000 tn/year

Full stage operation in March,2026



FACILITY 2: 10,000 TN/YEAR

WALUE

WASTE TO VALUE

An initiative of ACCIONA towards sustainable planet

Anurag Bansal Bansal

Head of Strategic Innovations

ANURAG.BANSAL@ACCIONA.COM

+34 - 600409547

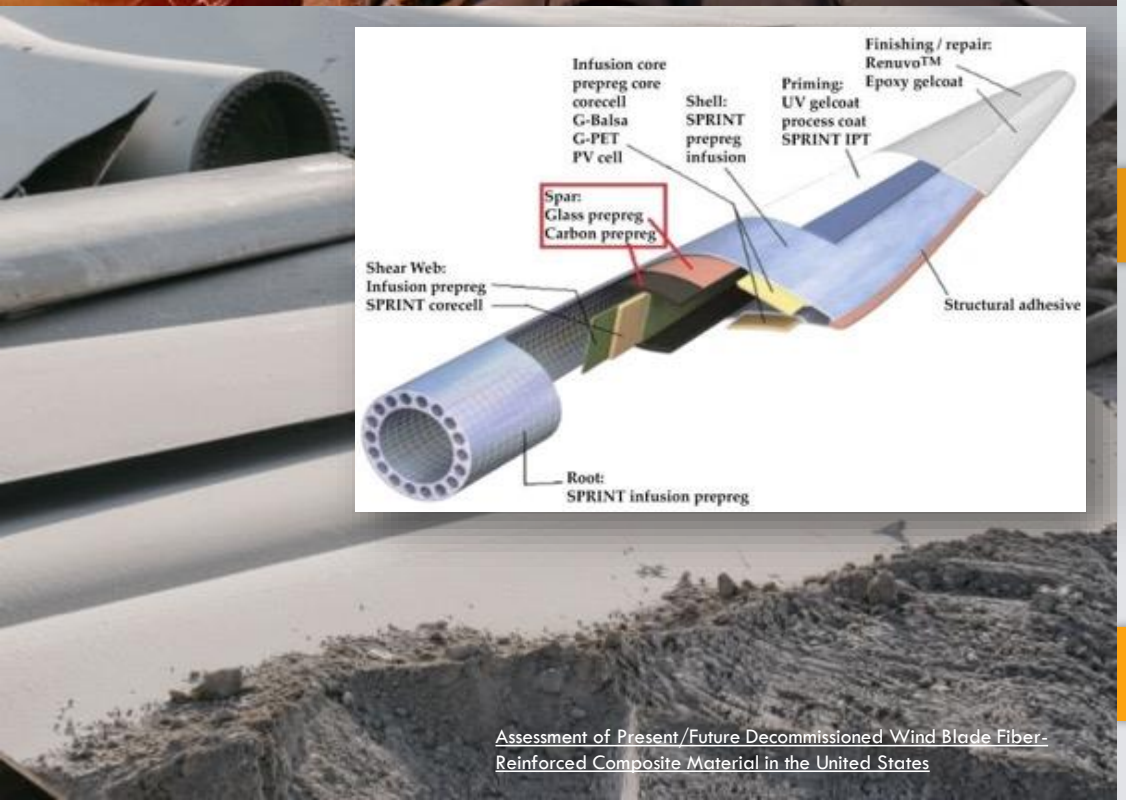
acciona

continuum

CIRCULAR COMPOSITES FOR A BETTER FUTURE

Confidential Company Presentation

A Transformational Investment Opportunity in Sustainability & the Circular Economy

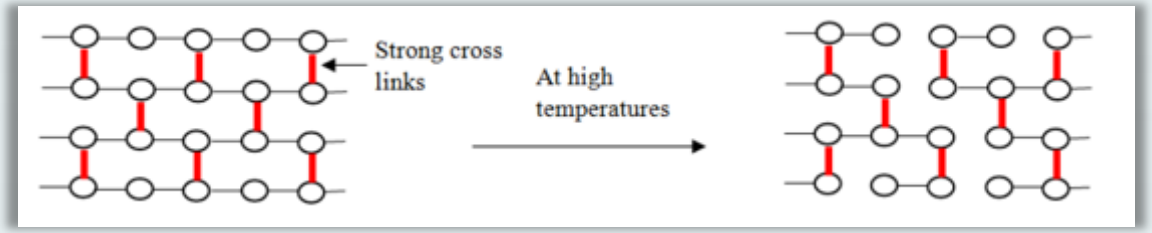


Assessment of Present/Future Decommissioned Wind Blade Fiber-Reinforced Composite Material in the United States

There is a problem with the problem.

And that is our challenge.

1. Chemical structure of resin



2. Composition of blades

Material	Blade part	Mass %
Glasfiber	Blade shells, beam, root section	61
Epoxy resin	Blade shells, beam, root section	21
PVC foam	Blade shells, Web	4
PUR adhesive	Leading edge, trailing edge, beam to blade shell	6
Aluminium	Root section, lightning protection system	4
Epoxy gelcoat	Outer surfaces	3

3. Increasing amounts of GFR waste and lack of sustainable recycling technologies

continuum

Continuum, a Danish company backed by over 20 years of R&D, have developed the most advanced mechanical composites transformation technology in the world.

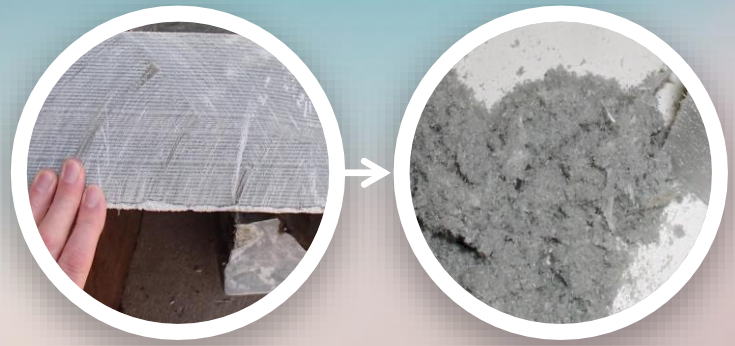
We are solving one of the worlds greatest recycling challenges and enabling a multi-million Euro, global business.

Our patented circular technology allows us to sustainably turn end of life wind turbine blades, composite materials and composite manufacturing waste into high value end products that can be transformed into new products **over and over again**.

We are the ONLY TECHNOLOGY in the world capable of taking ALL the composite back to original material and small particles…

clean FIBRE recovery

clean RESIN (epoxy or polyester) recovery



clean PU recovery

clean METAL (Cu & non-ferrous) recovery

Our mechanical, non-toxic methodology.

Feedstock in…

The Continuum Process

Reclamation of raw materials

Creation of new composites

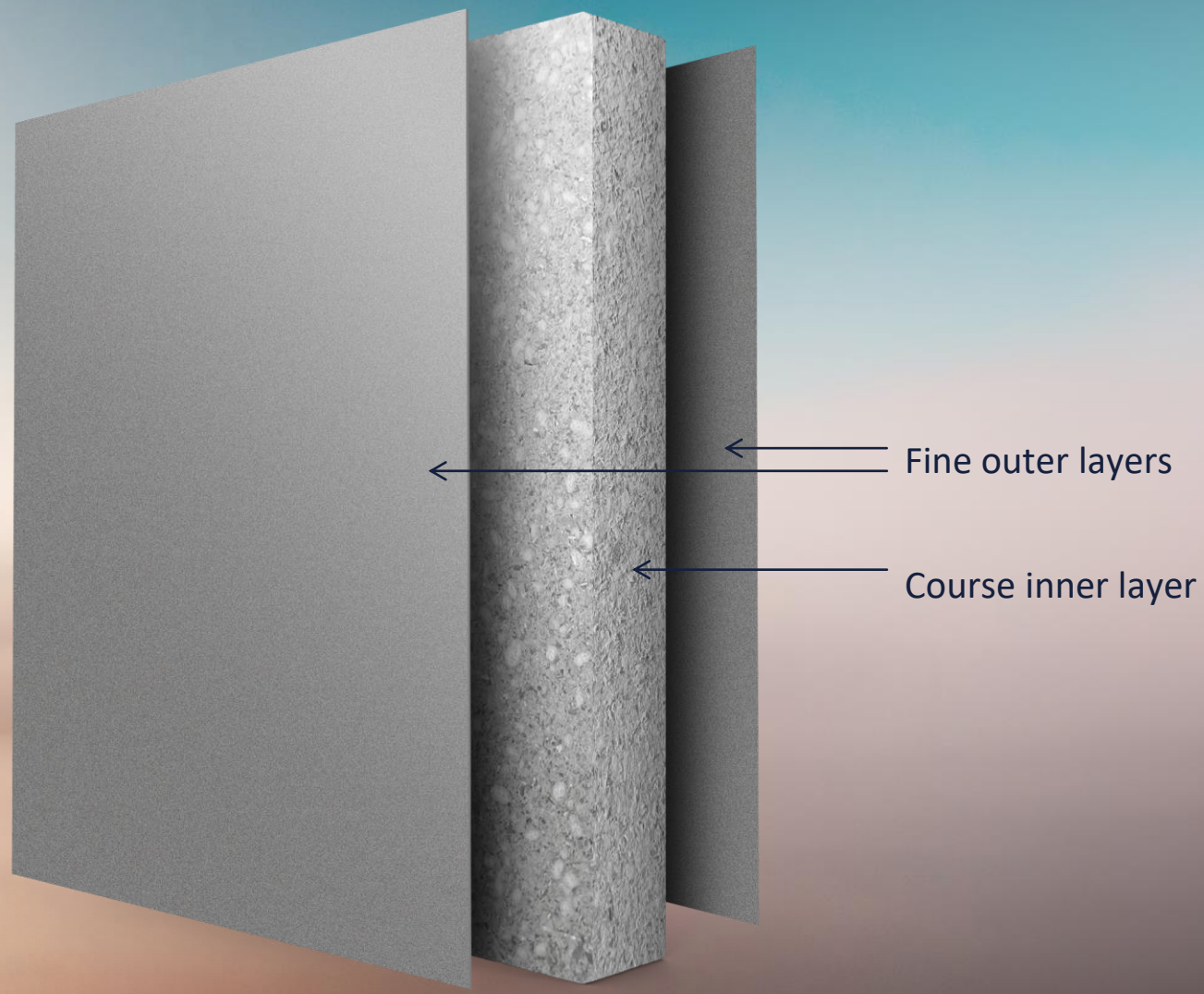
Production of new panels

…new panels out

continuum

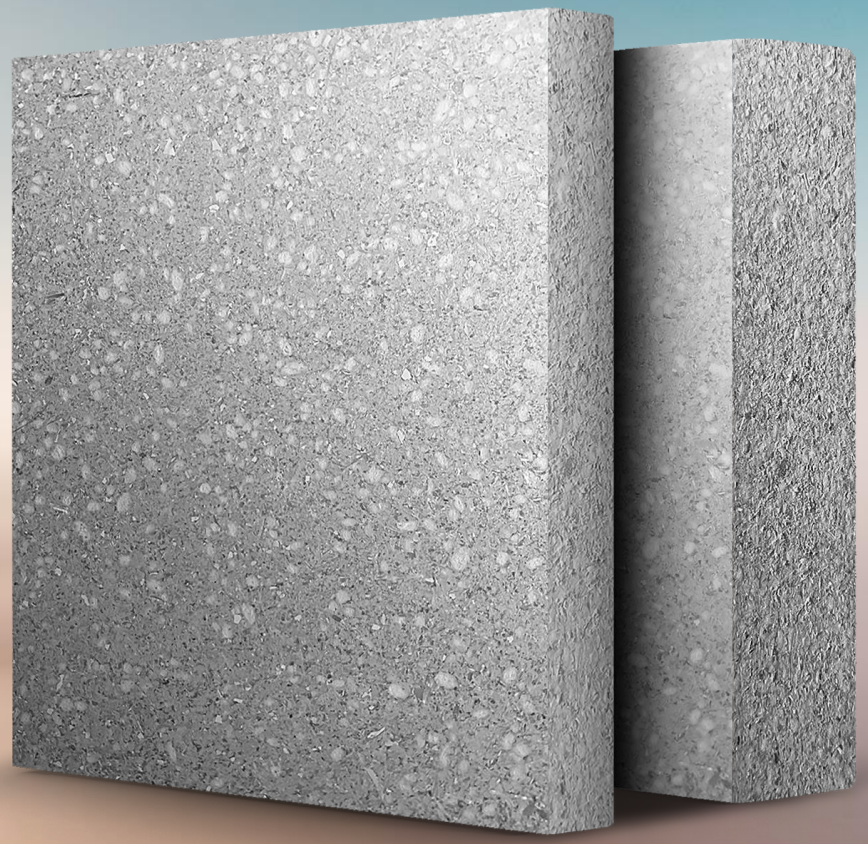
High performance, high value 3-layer composite panels

Greener, higher performing and made from up to 92% reclaimed materials. Infinitely recyclable ♺.



High performance, high value single layer composite panels

Greener, higher performing and made from up to 92% reclaimed materials. Infinitely recyclable ♺.



Panels can be finished in almost any material or finish you require

Some examples of high volume, high potential end-product applications

Ongoing talks with CXO level decision makers from major EU companies

Interior construction to replace traditional gypsum (drywall) panels whenever drywall no longer suitable

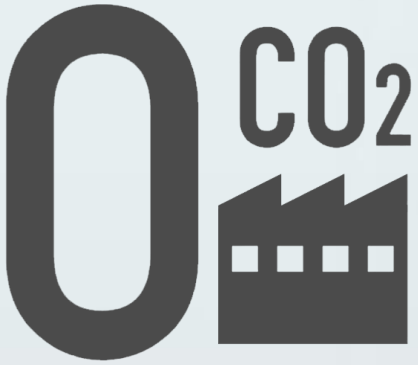
Interior/exterior construction in areas exposed to heavy water or risk of flooding

Facades that are directly exposed to the weather

Solid veneered- or laminated industrial doors

Compact Secondary Substations for wind/solar farms, mobile construction sites, etc.

Formwork



Almost zero CO_2 Emissions Factory

NOW IT'S A REALITY!

No stack
no air emissions

No dryer
no VOC's,
no HAP's, no NOX

No combustion
no oil, no gas,
no flame

Energy source
100 % (green)
electricity

No dust emissions
100% filtration air
systems

No waste-water
no effluent
process water

There is a new word for circular composite. It's called Continuum

continuum

Up to
800% CO2 emissions reduction
vs traditional disposal methods

Our panels have a leading CO2 footprint in the market of **<150 kg CO2/m3***

continuum

EuReComp – M24 Meeting & Workshop

Authorities and Regulations for used AC Parts

24.04.2024, Vigo

Alexander Knorr / Elbe Flugzeugwerke

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EFW
A company of ST Engineering and Airbus

Content Overview

Aviation

Customs

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The customs status of an aircraft depends on its registration

➤ EU-Aircraft

- No restrictions under customs law
- Everything can be used, scraped or passed on

➤ Non-EU-Aircraft

- Goods that have been removed must be sent with a customs document
  - Within the EU: T1
  - Outside of the EU: ABD
- Goods can be scraped
  - Burden of proof lies with the disposal company
- No private transfer of parts possible
- No customs clearance by dismenling company possible
  - Customs clearance only by the owner
- Regulated by our approval, can‘t be changed due to EU laws

Any violation of applicable customs law may result in the immediate loss of all approvals.

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Aviation Authorites

- The so-called Design Organizations (DOA) are responsible for the development of an aircraft, which also includes the qualification of materials and the approval of components. The EASA regulations are applicable.
- Organizations that manufacture components are referred to as Production Organizations (POA), which operate within the regulations of both the higher-level authorities EASA and the national authorities such as the LBA (monitors on behalf of EASA) in Germany.
- Maintenance work on aircrafts has to be carried out by maintenance organizations, including those authorized under Part 145 LBA. Maintenance organizations are therefore subject to national aviation law within the regulations of the respective national authorities.

Authorities:
Design Organisations | EASA (europa.eu)
Federal Aviation Administration (faa.gov)
Luftfahrt Bundesamt – LBA (lba.de)

Acronyms:
EASA European Aviation Safety Agency
LBA Luftfahrt-Bundesamt / federal aviation Administration:
FAA Federal Aviation Administration
AMC Acceptable Means of Compliance
Form 52 EASA/LBA Formblatt 52

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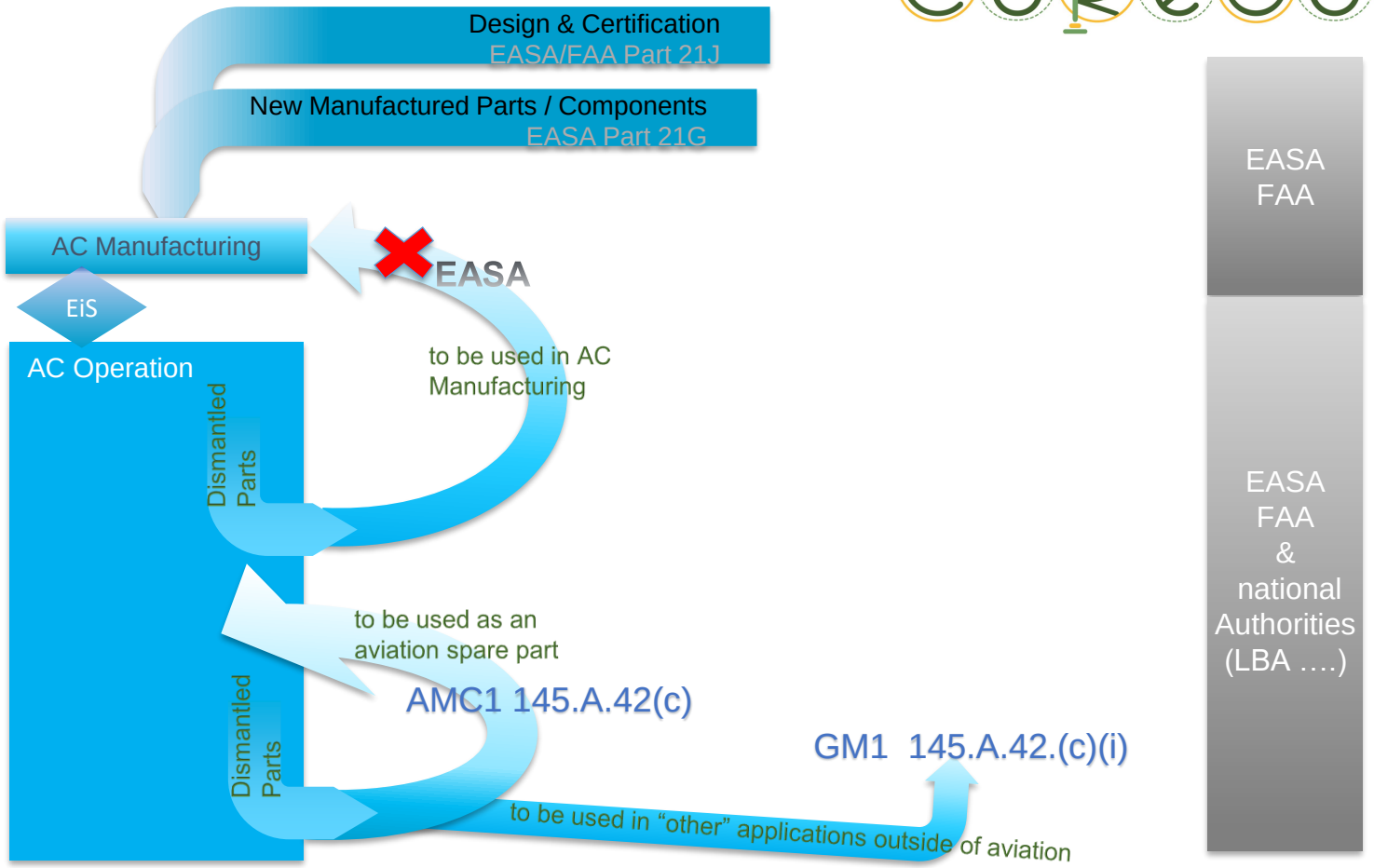

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First of all, let's take a look at the maintenance organization. It acts in accordance with procedural instructions specified by a DOA or an authority.

When we talk about the reuse of used components, components are usually removed in a maintenance organization or inspected as part of the inspection.

If there are no complaints, the component is reinstalled. If there are defects in the component and it cannot be reused, further use in the aircraft is no longer permitted! Further use of the component would then only be possible outside of aviation or recycling or disposal would also be an option.

If components are removed as part of modifications to an aircraft and are no longer required and have no defects, the situation is different. These components can be reused as spare parts in other aircrafts as long as they are identical in form and function and the DOA documents approve them.

The use of components which have already been used in an aircraft for new construction is not permitted in accordance with Regulation Part 21 /G Part 21 No. (EU) 748/2012

LBA

Verwendung gebrauchter Teile bei der Herstellung von Luftfahrtgerät

1. Zweck und Anwendungsbereich

Bei der Herstellung von Luftfahrtgerät dürfen grundsätzlich keine gebrauchten Bau-und Ausrüstungsteile verwendet werden. Allgemeine Festlegungen zur Verfahrensweise für Ausnahmefälle sind in diesem Merkblatt beschrieben.

2. Abkürzungen

AMC	Acceptable Means of Compliance
EASA	European Aviation Safety Agency
Form 52	EASA/LBA Formblatt 52
LBA	Luftfahrt-Bundesamt
Teil 21/G	Teil 21 Hauptabschnitt A Abschnitt G der Verordnung Nr. (EU) 748/2012

3. Festlegungen

I. In Ausnahmefällen kann auf Antrag bei entsprechender Begründung die Verwendung gebrauchter Teile durch das LBA genehmigt werden. Näheres hierzu bleibt einer Regelung im Einzelfall vorbehalten. Im Besonderen sollte bei wiederkehrenden Ereignissen gleichen Umfangs diese Regelung in Form einer vom LBA zu genehmigenden Verfahrensanweisung erfolgen.

Der Antrag ist bei der für den Herstellungsbetrieb zuständigen LBA-Außenstelle einzureichen.

II. In Bezug auf Heißluftballone wird die Verwendung gebrauchter Bau-und Ausrüstungsteile (Korb, Brenner) generell akzeptiert. Einer Genehmigung im Einzelfall bedarf es nicht.

III. Bei Verwendung lebensdauerbegrenzter Bau- und Ausrüstungsteile ist die verbleibende Zeit in die Lebenslaufakte aufzunehmen.

Diese Regelung betrifft nicht die Instandhaltung nach Herstellung eines neuen Luftfahrzeugs innerhalb des Genehmigungsumfanges eines nach Teil 21 Abschnitt G genehmigten Herstellungsbetriebes (Instandhaltung nach Abschluss der Herstellung und Ausstellung der Übereinstimmungsbescheinigung (EASA Form 52) bis zur Übergabe in die Verantwortung des zukünftigen Halters gemäß AMC 21A.163(d)).

In diesem Fall dürfen Motoren, Propeller und Bau- oder Ausrüstungsteile auch von einem genehmigten Instandhaltungsbetrieb instandgehalten und als „gebraucht" eingestuft und freigegeben werden, bevor sie wieder in das neue Luftfahrzeug eingebaut werden (vgl. AMC 21A.163(d)).

Dieses Merkblatt ersetzt das Rundschreiben RS 02-07/04-3 vom 04.02.2004.

Im Auftrag

Plehn

Ausgabe 1 vom 15.01.2020 Seite 1 von 1

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For the lifetime extension of components, the two regulations (AMC from EASA and GMC from EASA) are applicable.

The AMC1 145.A.42(c) provides the following information:

Segregation of components

1. Unserviceable components should be identified and stored in a secure location that is under the control of the maintenance organization until a decision is made on the future status of such components. The organization that declared the component to be unserviceable may transfer its custody after identifying it as unserviceable to the aircraft owner provided that such transfer is reflected in the aircraft logbook, or engine logbook, or component logbook.
2. “Secure location under the control of an approved maintenance organization” refers to a secure location whose security is the responsibility of the approved maintenance organization. This may include facilities that are established by the organization at locations different from the main maintenance facilities. These locations should be identified in the relevant procedures of the organization.
3. In the case of unsalvageable components, the organization should:
    4. Retain such component in the secure location referred to in paragraph b);
    5. Arrange for the component to be mutilated in a manner that ensures that they are beyond economic salvage or repair before disposing it; or
    6. Mark the component indication that it is unsalvageable, when in agreement with the component owner, the component is disposed of for legitimate non-alight uses (such as training and education aids, research and development), or for non-aviation applications, mutilation is often not appropriated. Alternatively to marking, the original part number or date plate information can be removed or a record kept of the disposal of the component.

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The GM1 145.A.42(c)(i) refers to:

Mutilation of components

a) Mutilation should be accomplished in such a manner that the components become permanently unusable for their originally intended use. Mutilated components should not be able to be reworked or camouflaged to provide the appearance of being serviceable, such as by replating, shortening and rethreading long bolts, welding, straightening, machining, cleaning, polishing, or repainting.

b) Mutilation may be accomplished by one or a combination of the following procedures:

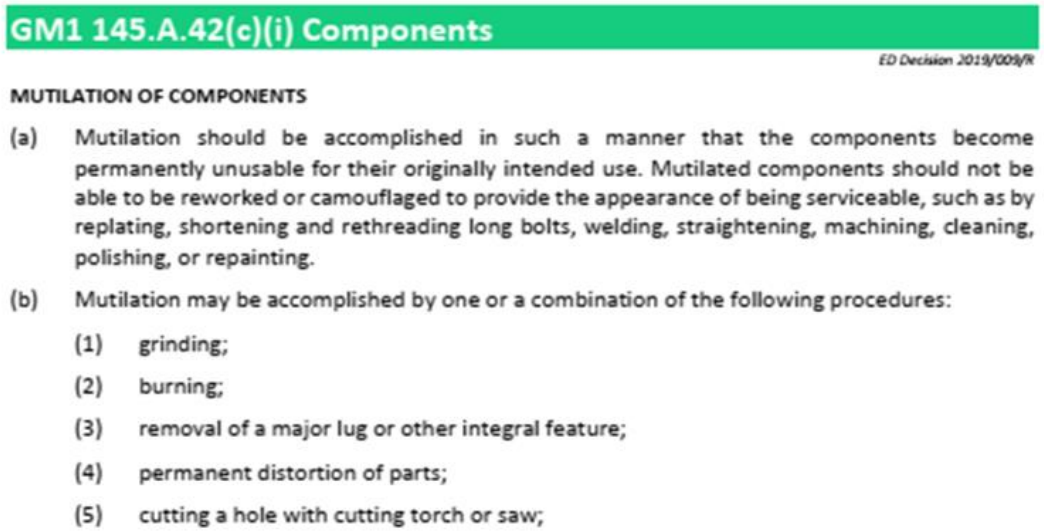
1) Grinding;

2) Burning;

3) Removal of a major lug or other integral feature;

4) Permanent distortion of parts;

5) Cutting a hole with cutting torch or saw.



GM1 145.A.42(c)(i) Components

ED Decision 2019/009/R

MUTILATION OF COMPONENTS

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(4) permanent distortion of parts;

(5) cutting a hole with cutting torch or saw;

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Conclusion

- End-of-life scenario for an "undamaged" component → use as an aviation spare part
- If this usecase isn´t feasible for a variety of reasons, the use of the components outside of aviation, whereby the two regulations, AMC from EASA and GMC from EASA, are mandatory. It must be ensured that the component cannot be reinstalled in an aircraft.
- Finally, the only remaining option → material recycling

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Thank you!

Alexander Knorr

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Elbe Flugzeugwerke GmbH

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AMC1 145.A.42(c) Components

ED Decision 2019/009/R

SEGREGATION OF COMPONENTS

(a) Unserviceable components should be identified and stored in a secure location that is under the control of the maintenance organisation until a decision is made on the future status of such components. The organisation that declared the component to be unserviceable may transfer its custody after identifying it as unserviceable to the aircraft owner provided that such transfer is reflected in the aircraft logbook, or engine logbook, or component logbook.

(b) 'Secure location under the control of an approved maintenance organisation' refers to a secure location whose security is the responsibility of the approved maintenance organisation. This may include facilities that are established by the organisation at locations different from the main maintenance facilities. These locations should be identified in the relevant procedures of the organisation.

(c) In the case of unsalvageable components, the organisation should:

(1) retain such component in the secure location referred to in paragraph (b);

(2) arrange for the component to be mutilated in a manner that ensures that they are beyond economic salvage or repair before disposing it; or

(3) mark the component indicating that it is unsalvageable, when in agreement with the component owner, the component is disposed of for legitimate non-flight uses (such as training and education aids, research and development), or for non-aviation applications, mutilation is often not appropriate. Alternatively to marking, the original part number or data plate information can be removed or a record kept of the disposal of the components.

GM1 145.A.42(c)(i) Components

ED Decision 2019/009/R

MUTILATION OF COMPONENTS

(a) Mutilation should be accomplished in such a manner that the components become permanently unusable for their originally intended use. Mutilated components should not be able to be reworked or camouflaged to provide the appearance of being serviceable, such as by replating, shortening and rethreading long bolts, welding, straightening, machining, cleaning, polishing, or repainting.

(b) Mutilation may be accomplished by one or a combination of the following procedures:

(1) grinding;

(2) burning;

(3) removal of a major lug or other integral feature;

(4) permanent distortion of parts;

(5) cutting a hole with cutting torch or saw;

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Acknowledgment

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Consortium

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Non-Destructive Testing Techniques

2nd Workshop

April 24th, 2024, O Porriño, Spain

Miguel Gómez Fernández

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101058089.

Active Thermography

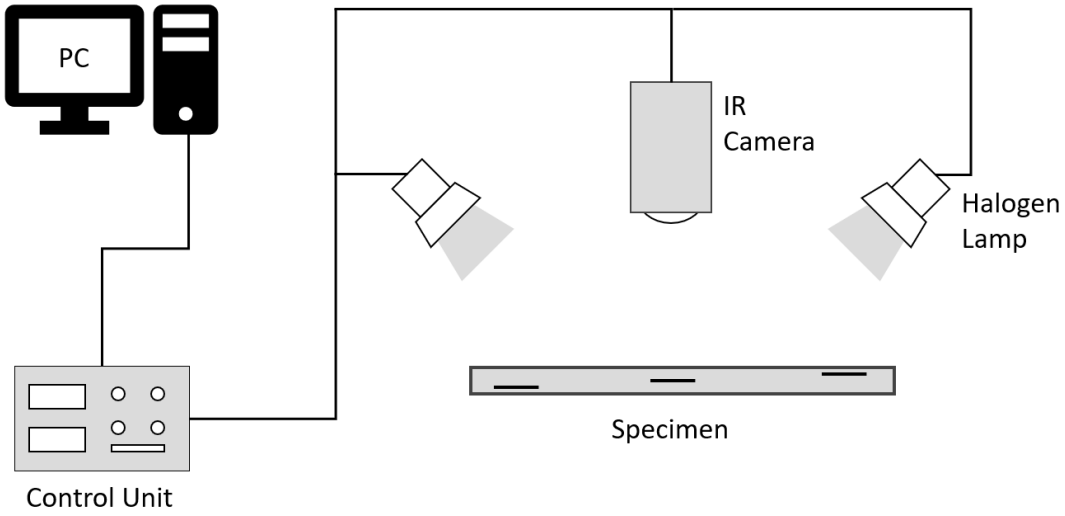
Active Thermography involves the use of a heat source to stimulate an object with a heat pulse. An infrared camera records a video of the object to measure the heating and cooling process on the object's surface.

Advantages:

- To be in real time
- Provide two-dimensional thermal images

Problems:

- Non-uniform surface heating
- Lateral heat difusion
- Environmental noise



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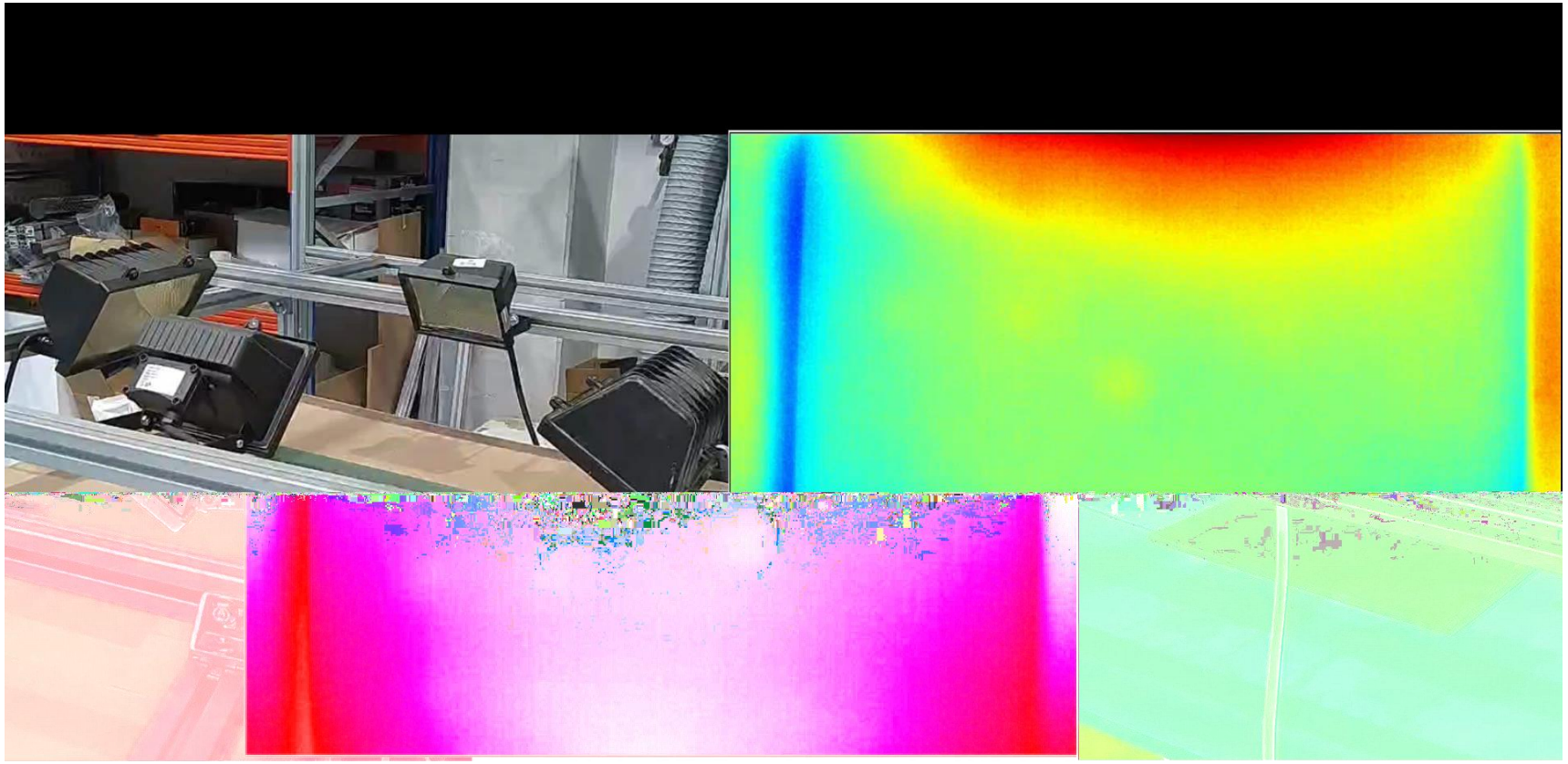
Active Thermography



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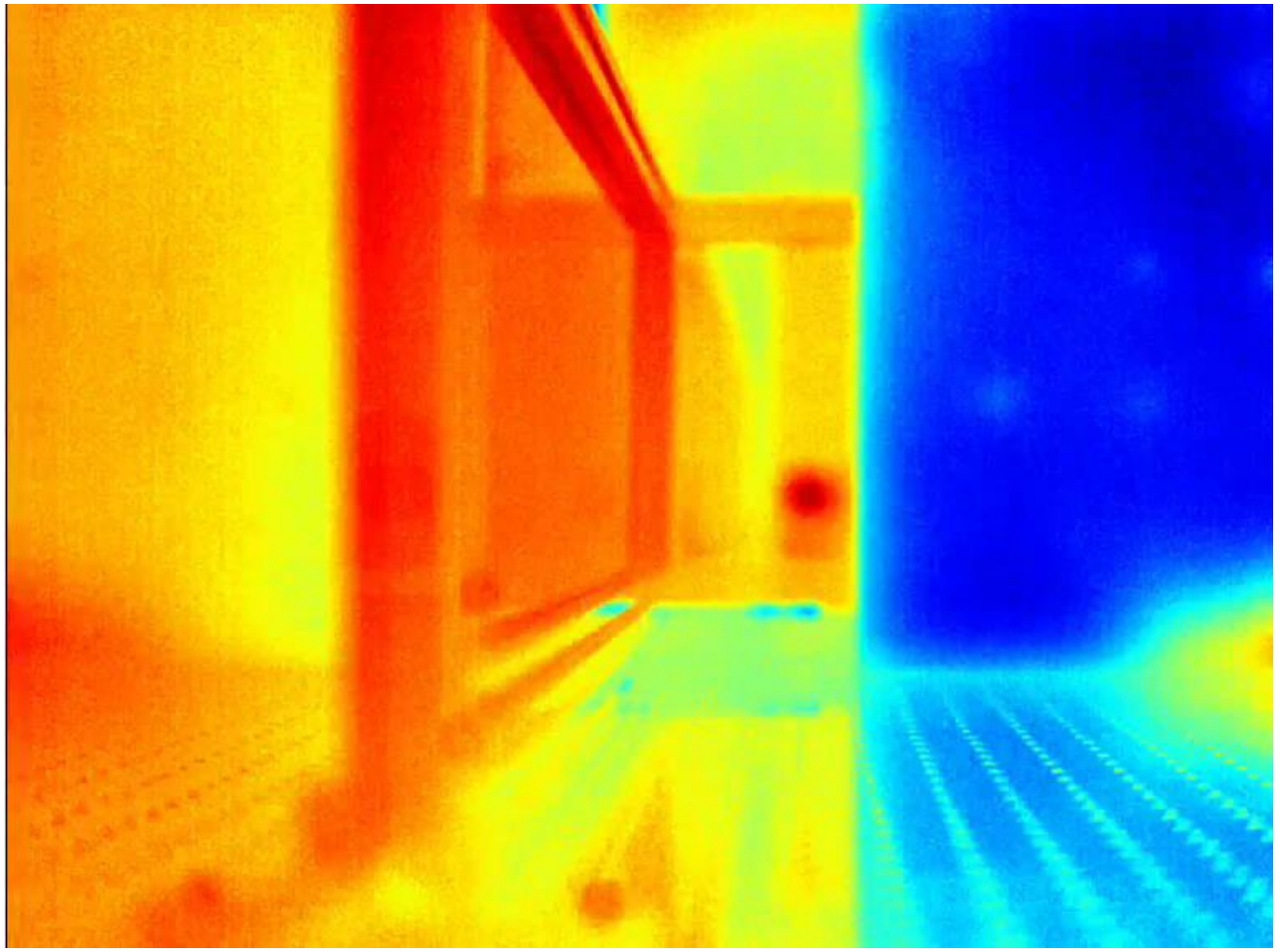
Active Thermography with Laser



Advantages

- Homogeneous illumination
- Adjustable beam shape and size
- Modulable warming curve
- Selective analysis area
- Allow scanning procedure

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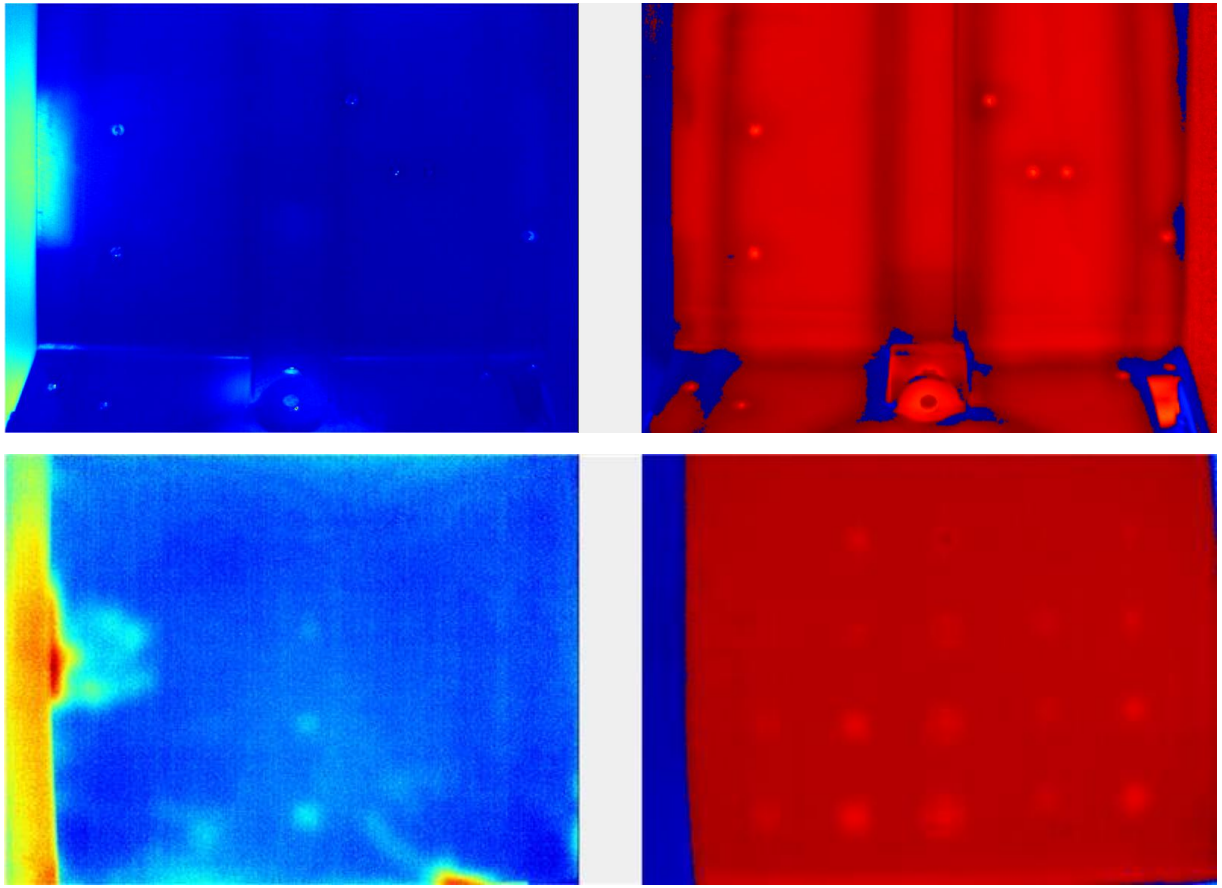
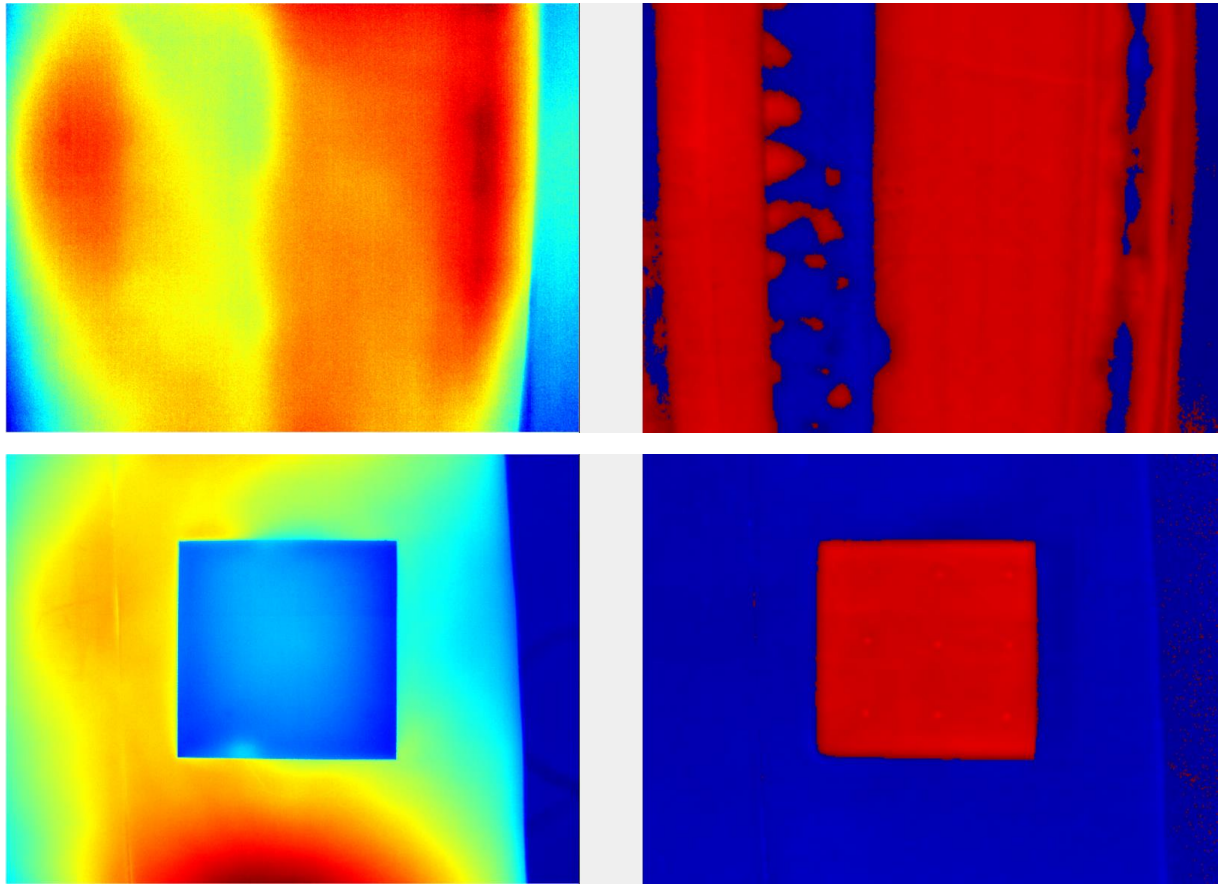
Pulsed Phase Thermography

A thermal image sequence post-processing method that involves the calculation of the phase of a thermal image sequence using a Discrete Fourier Transform.





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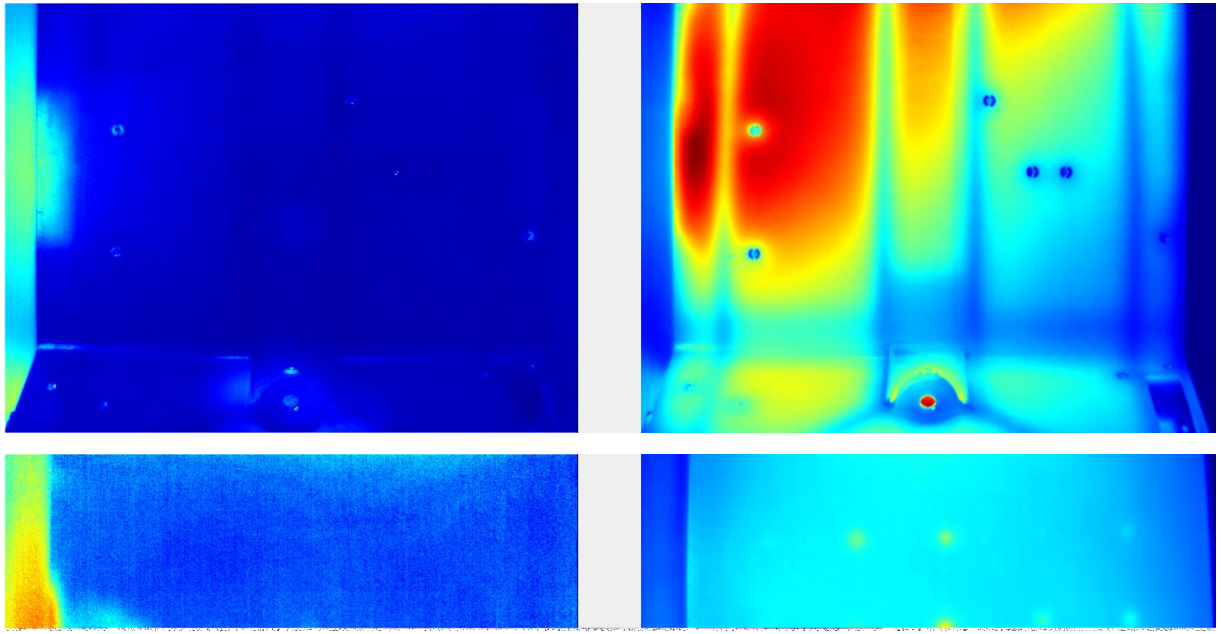
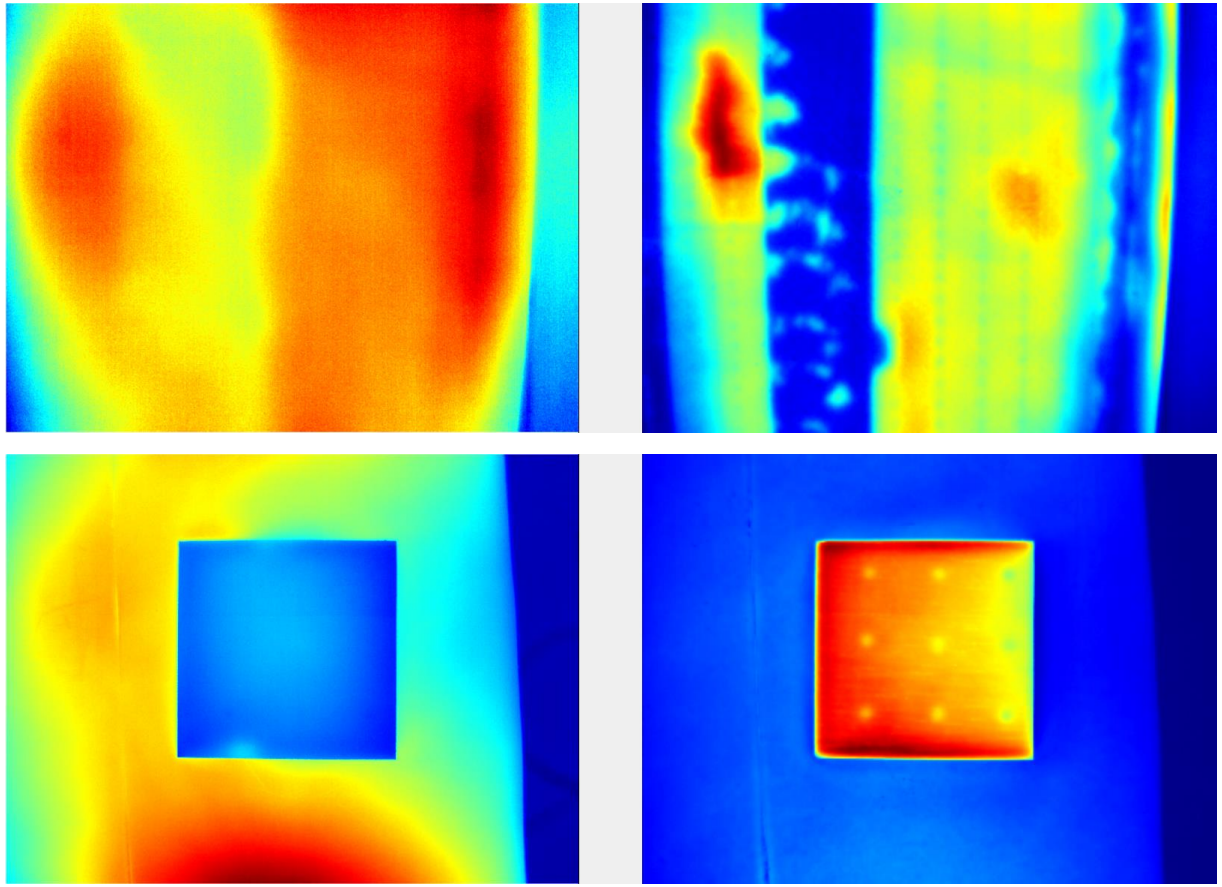
Principal Components Thermography

A statistical technique used to identify specific patterns in large datasets containing a high number of features per observation and analyze them to enable the depicting of similarities and differences of specific patterns





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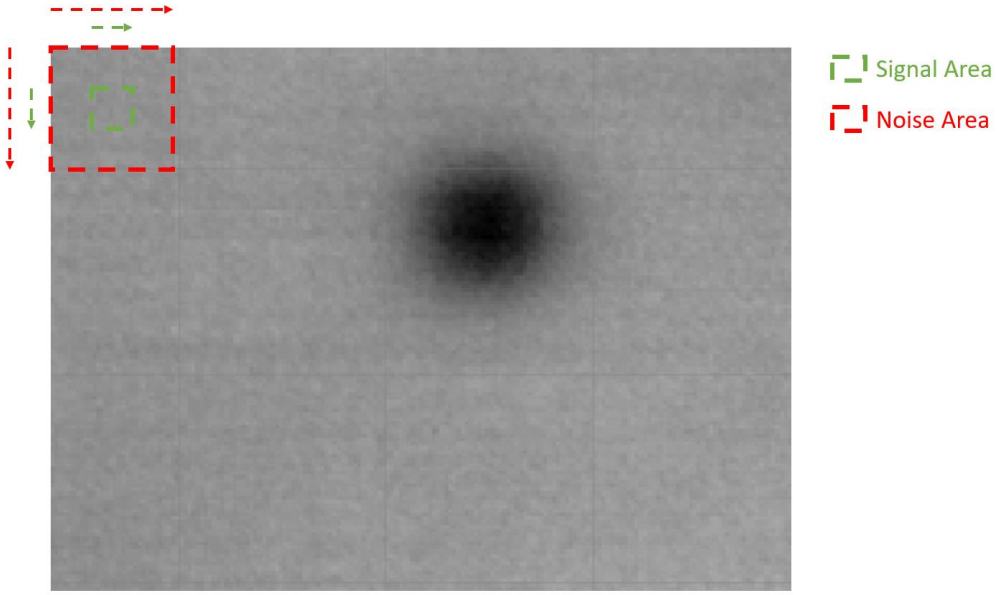
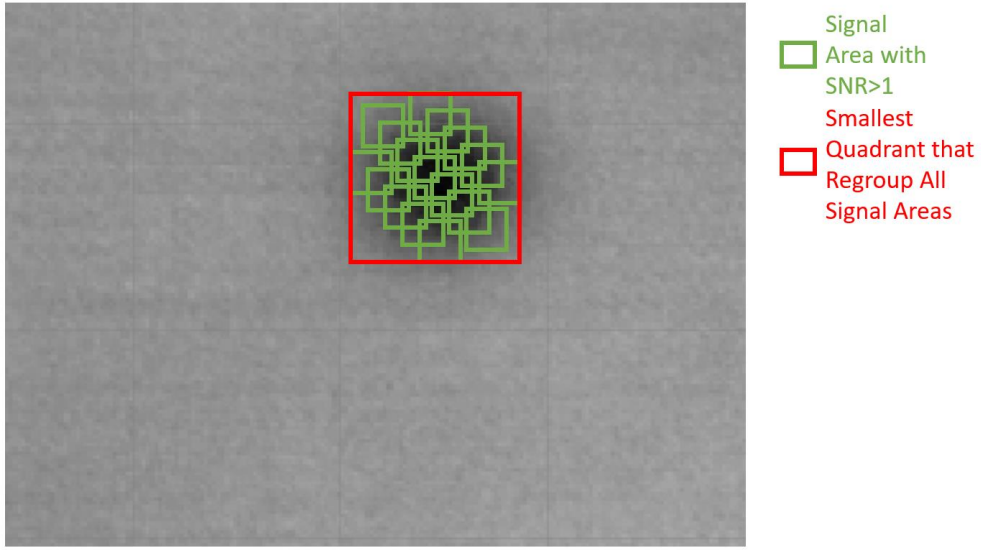
Automatic Detection of Defects

After the post-processing techniques a measure needs to be applied for the automatic detection of defects

Signal to Noise Ratio (SNR)

- Compares the level of a desired signal to the level of background noise
- Used to refer to the ratio of useful information to irrelevant data





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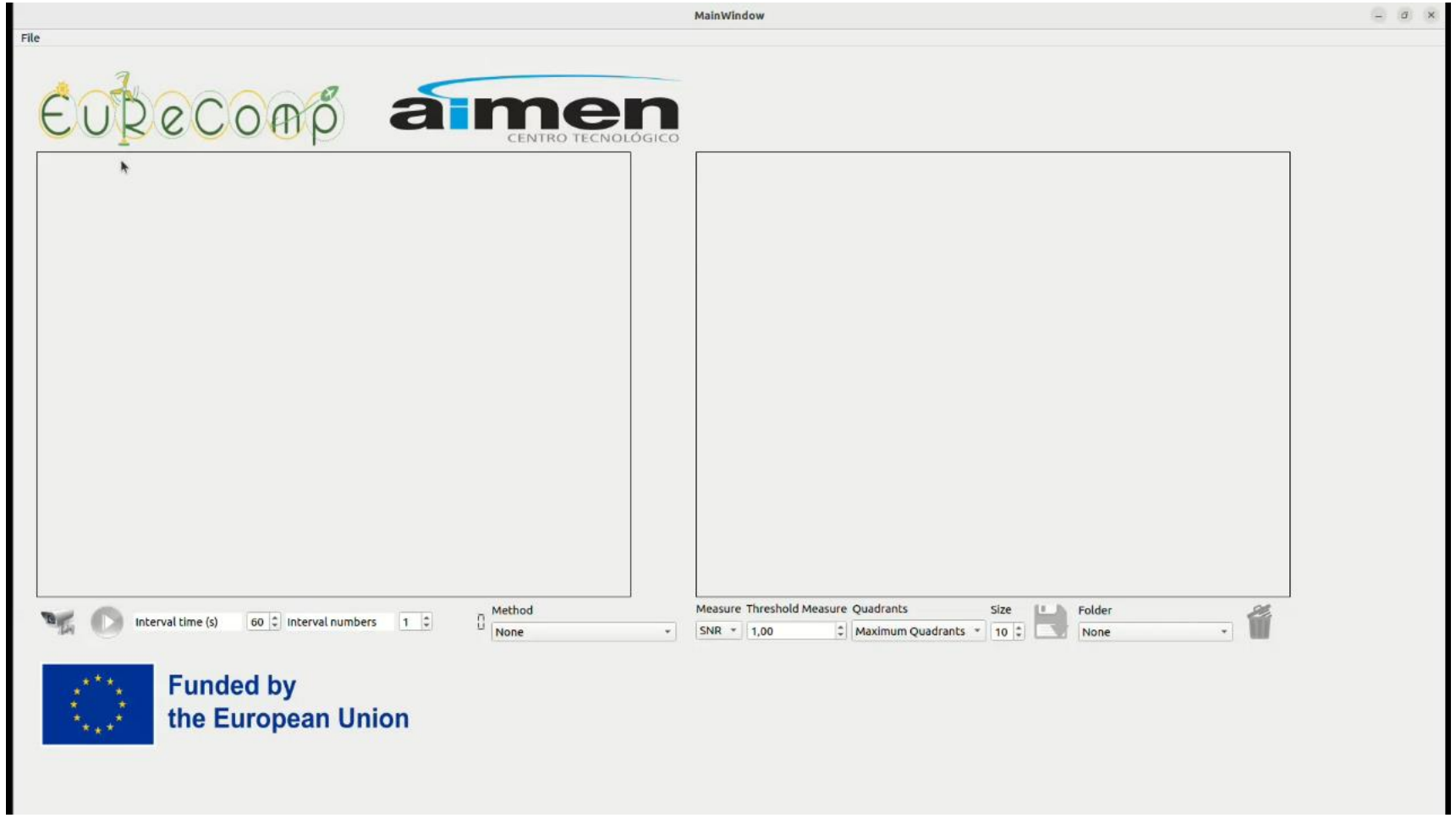
Thermography Application



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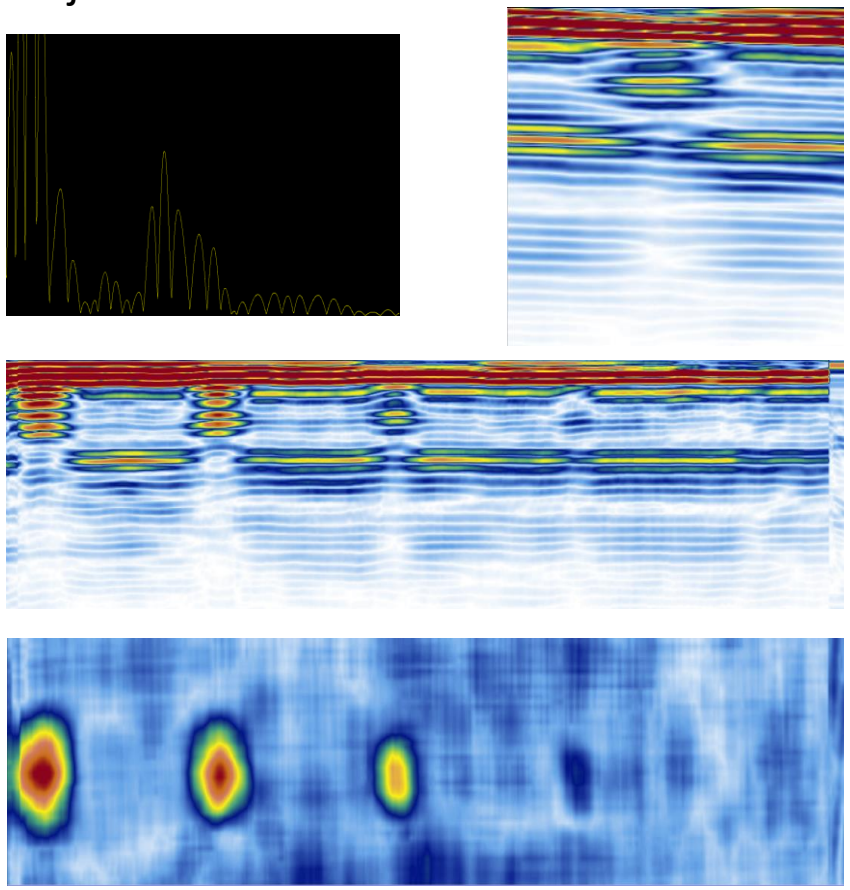
Ultrasound Testing

The ultrasound testing is based on the detection and the feature extraction of the ultrasonic waves reflected by defects. UT works by sending ultrasonic waves through an object or material.

- **A-Scan:** Is a radio-frequency waveform presentation showing the time and amplitude of an ultrasonic signal
- **S-Scan:** Is an image that represents a cross-sectional view derived from a series of A-scans that have been plotted with respect to time delay and refracted angle
- **B-Scan:** Is an image showing a cross-sectional profile through one vertical slice of the test piece
- **C-Scan:** Is a two-dimensional presentation of data displayed as a top view of a test piece



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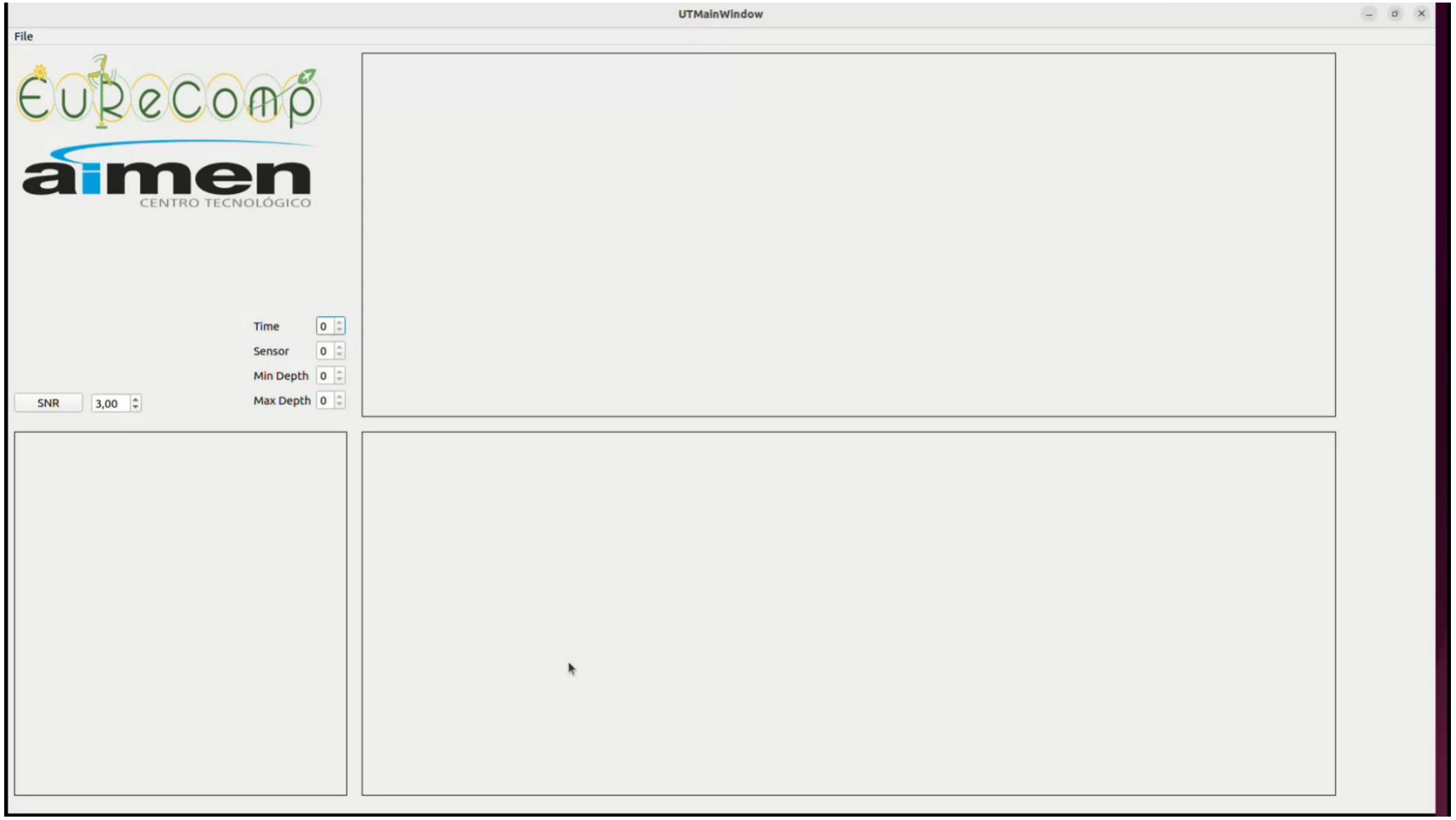
UT Application



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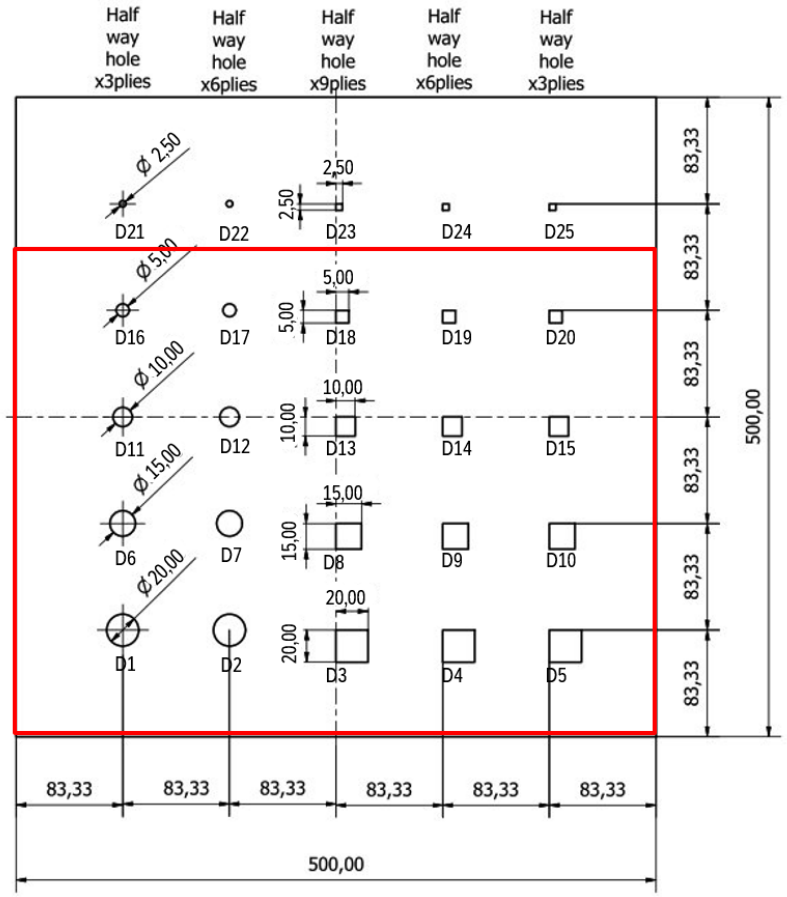
Results



	PPT	PCT	UT
TP	19	19	20
FP	6	1	4
FN	1	1	5
Total Detections	25	20	24
Total Defects	20	20	25
Accuracy	0.76	0.95	0.83
Recall	0.95	0.95	0.8

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Results

	PPT	PCT	UT
D1	4.21	2.97	5.59
D2	4.49	4.67	4.04
D3	5.89	4.89	5.24
D4	5.15	2.96	5.51
D5	5.25	5.20	5.53
D6	4.54	3.90	5.81
D7	5.21	5.84	5.51
D8	4.77	6.15	5.57
D9	5.88	4.84	6.21
D10	5.95	5.94	5.88
D11	3.86	1.37	6.40
D12	6.06	7.36	6.26

	PPT	PCT	UT
D13	1.52	7.28	6.52
D14	4.25	7.40	4.77
D15	6.35	6.01	6.82
D16	4.67	1.96	6.88
D17	6.23	6.97	6.52
D18	4.04	7.51	5.97
D19	0.42	0.31	-1.24
D20	5.50	3.50	2.27
D21	NAN	NAN	-12.84
D22	NAN	NAN	5.14
D23	NAN	NAN	5.68
D24	NAN	NAN	-0.91
D25	NAN	NAN	0.51

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Thank you!

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AIMEN

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Consortium

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Spectroscopic techniques for material characterization

EURECOMP M24 Workshop

24/04/2024

Camilo Prieto (AIMEN)

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101058089.

Outline

Motivation

Laser Induced Breakdown Spectroscopy (LIBS)

- Introduction to technique and system
- LIBS spectra and data analysis
- Application examples: resin and composite identification

Hyperspectral imaging (HSI)

- Introduction to technique and system
- HSI data: optical characterization and analysis
- Application examples: resin and composite characterization

Conclusions and ongoing work

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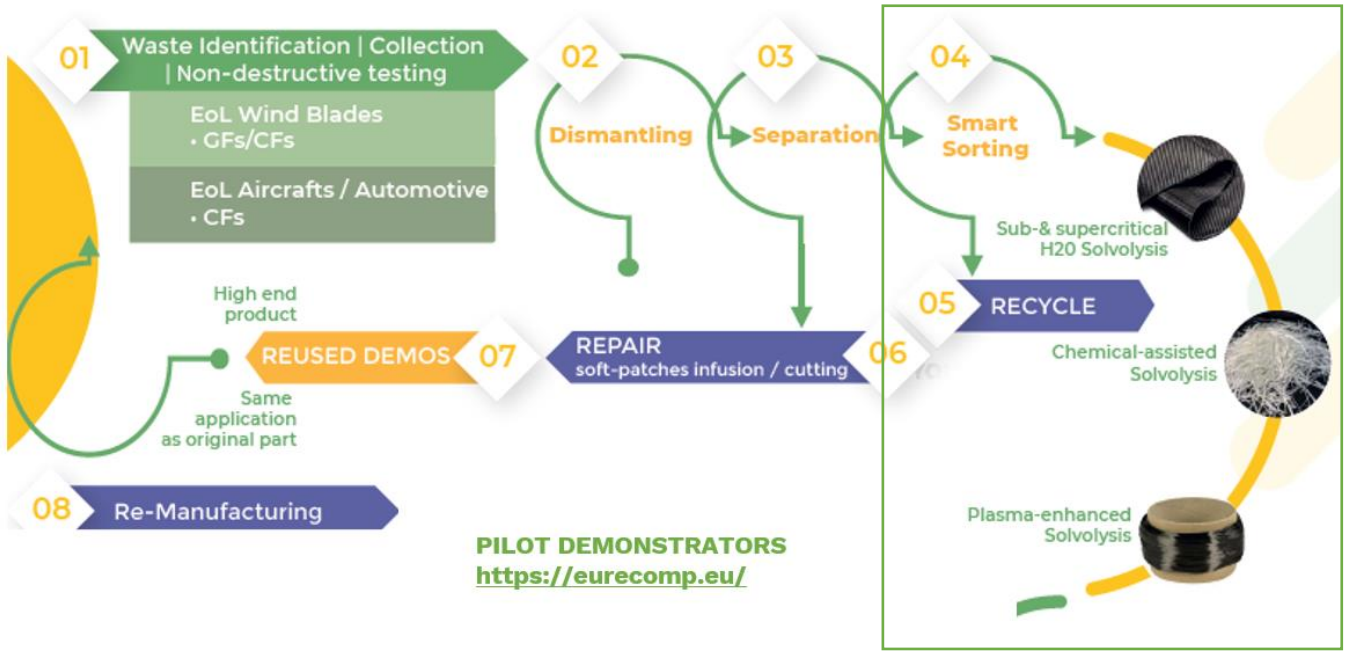
Motivation: EURECOMP project



Chemical recycling of fiber-reinforced polymer matrix composites

In-situ material identification is one the challenges

OBJECTIVE: To develop innovative identification systems enabling reuse and recycling of complex composite materials by means of spectroscopic and machine learning techniques: Laser Induced Breakdown Spectroscopy (LIBS) and Hyperspectral Imaging (HSI)

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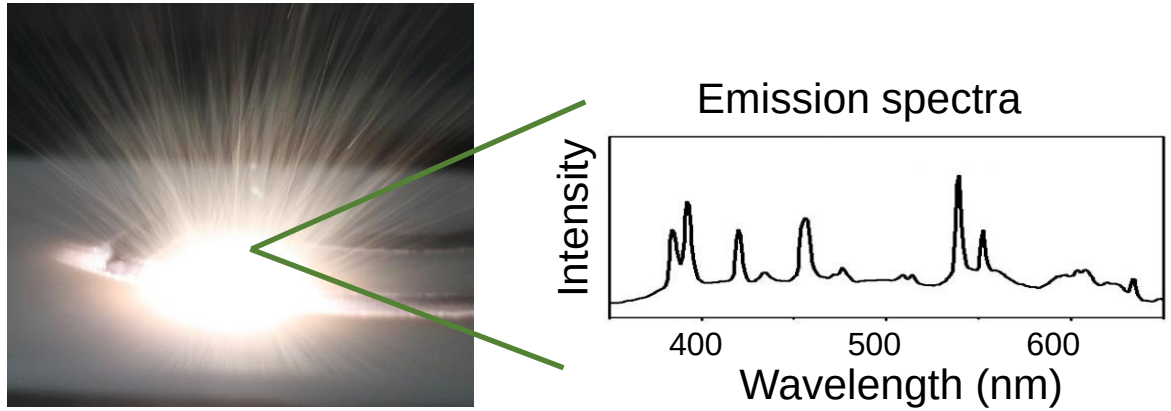
LIBS: Laser Induced Breakdown Spectroscopy

Atomic emission spectroscopic technique for elemental analysis

Analysis of plasma generated during laser ablation -> provides information about chemical composition of sample



Laser ablation

FEATURES:

- No sample preparation
- Multiple element detection
- In-situ and fast analysis
- Surface / depth-profiling technique
- Solid or liquid samples

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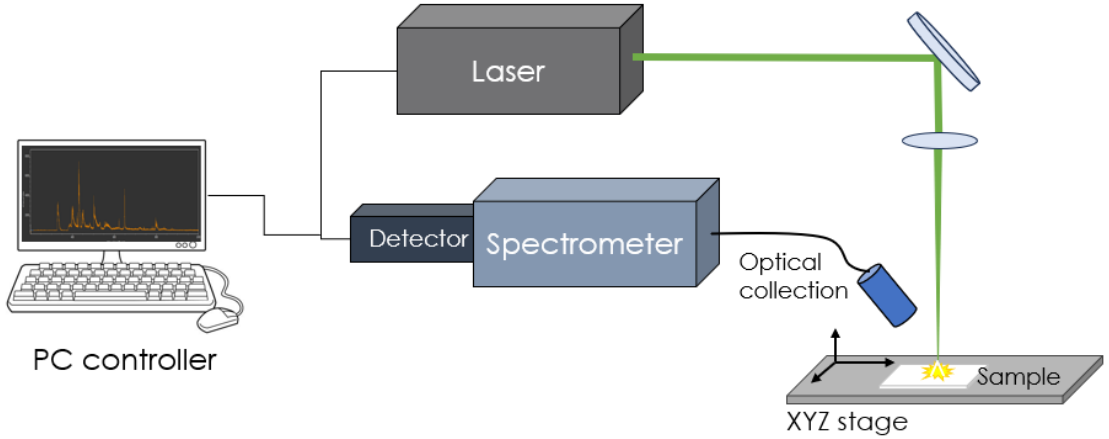
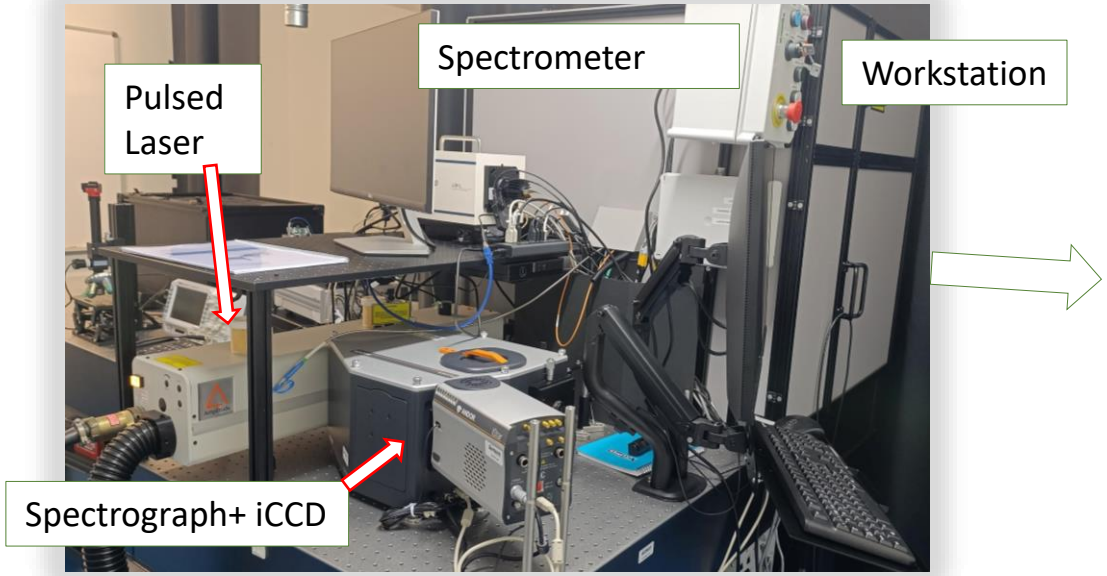
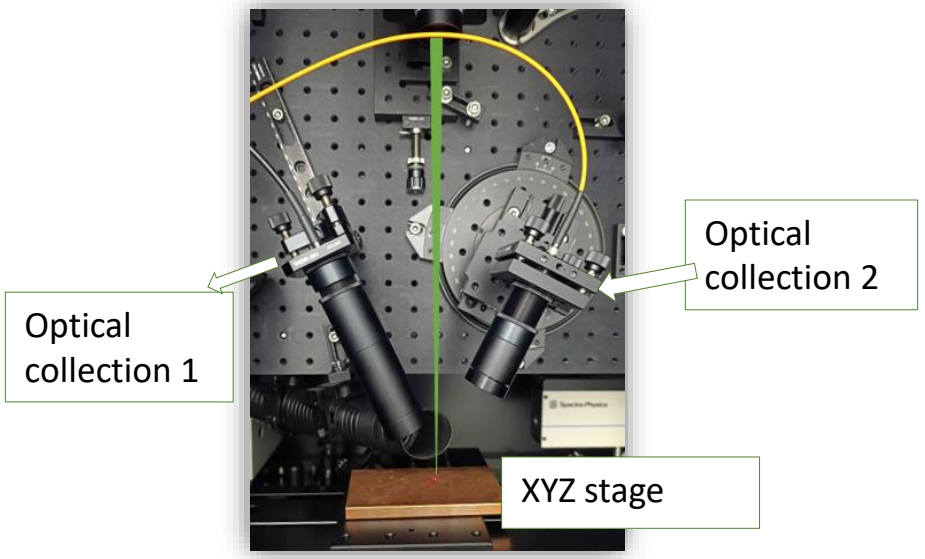
LIBS system



- Pulsed Laser
- Focusing optics
- Optical collection
- Spectrometer and detector





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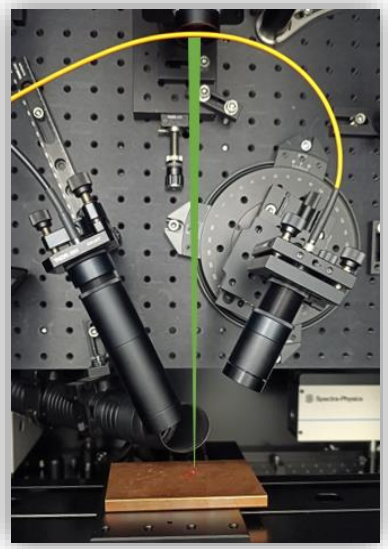
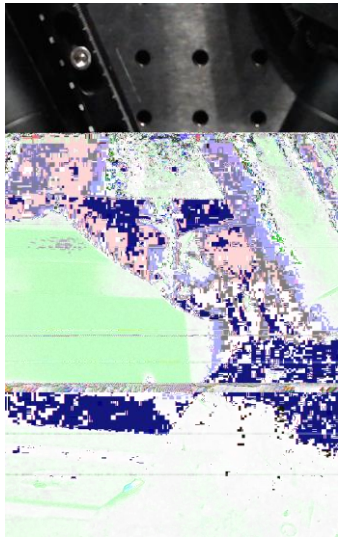
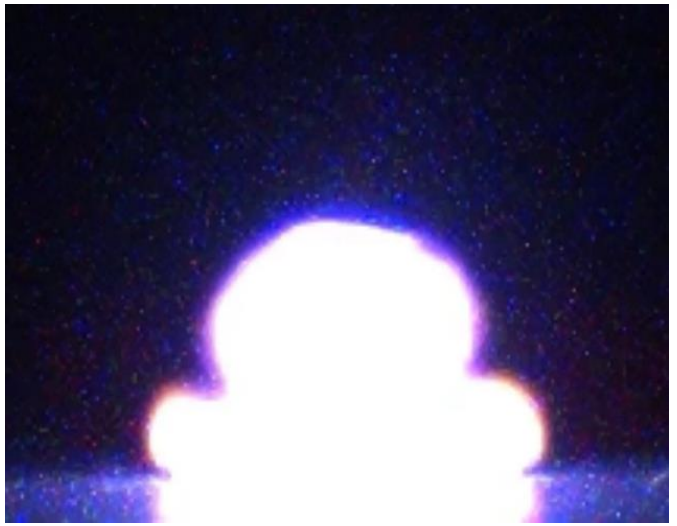
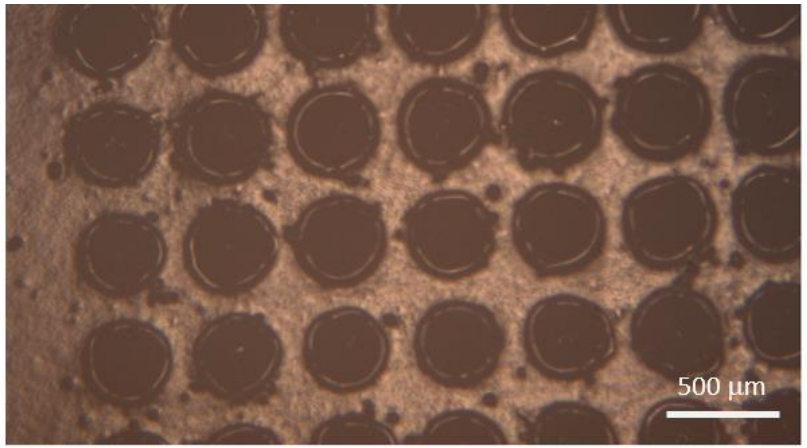
LIBS measurement

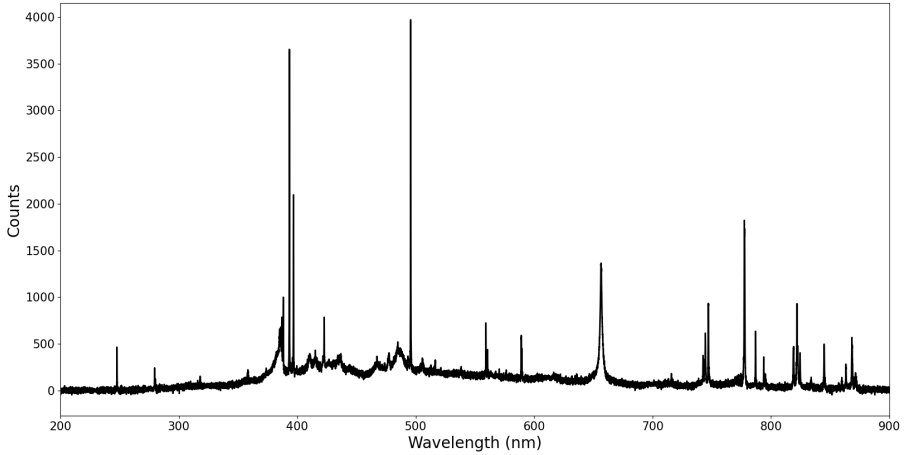






- Plasma duration?
- Plasma size?
- Spectral range and resolution?





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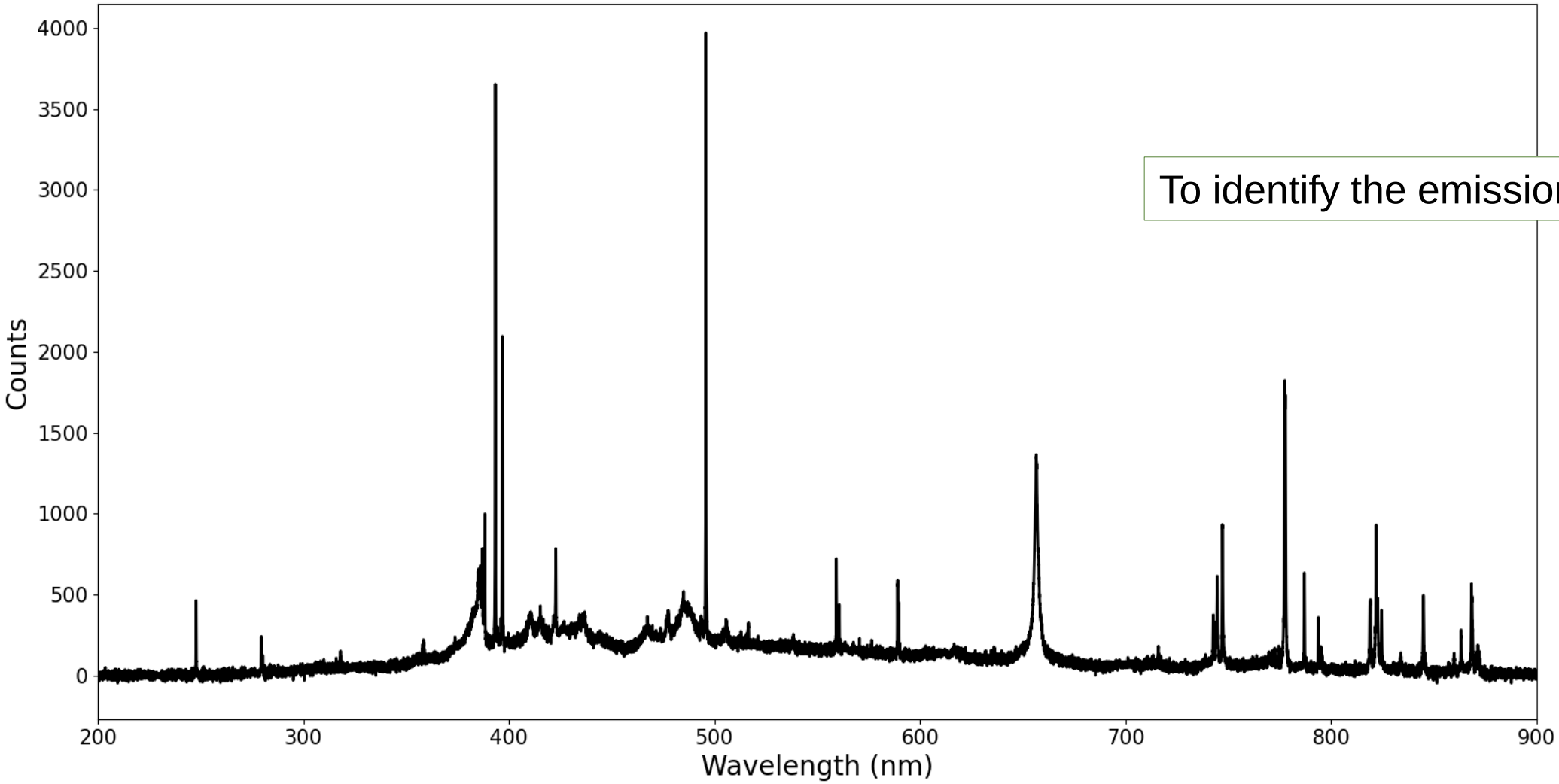
LIBS spectra on thermoset resins



To identify the emission lines

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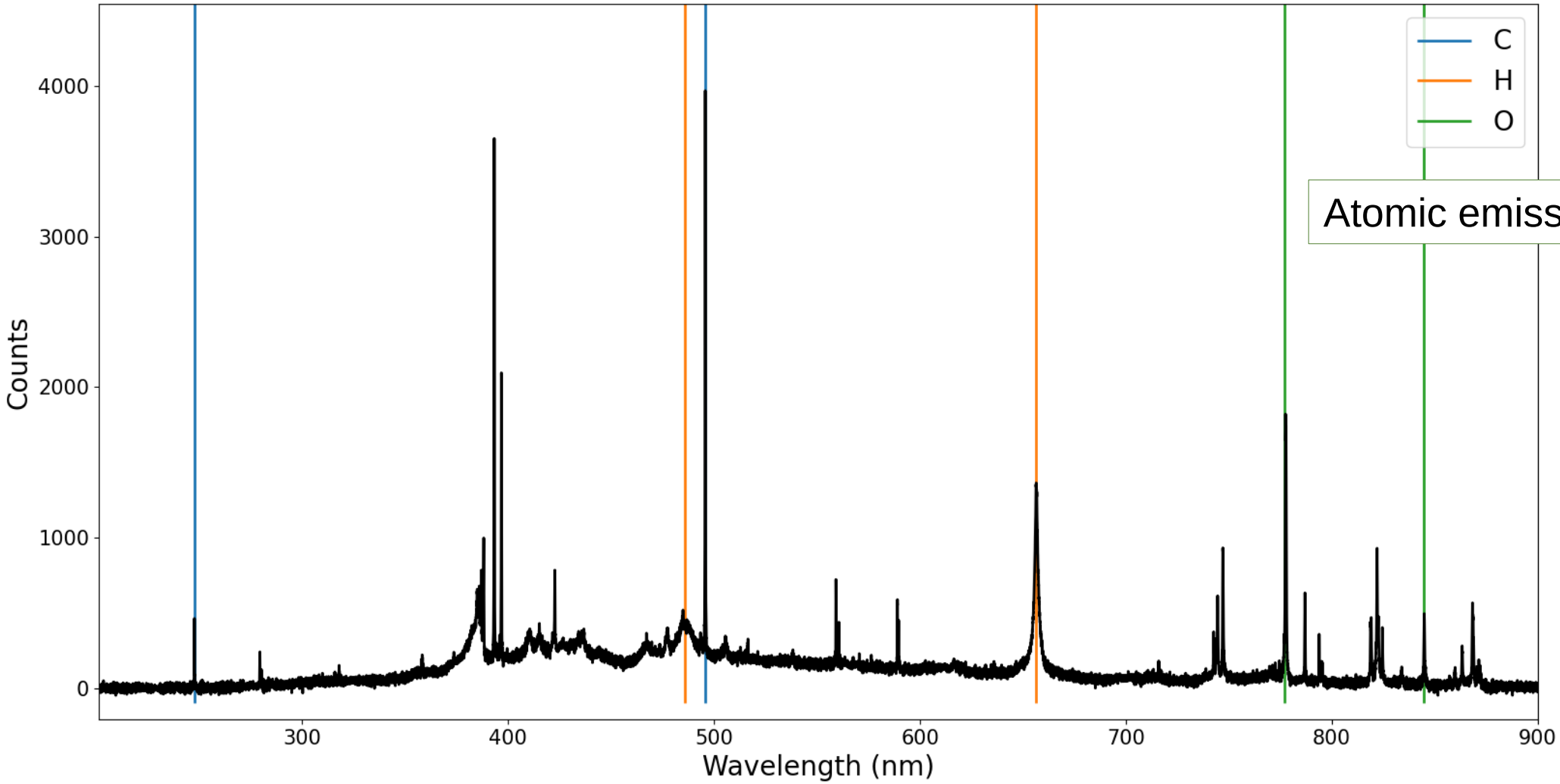
LIBS spectra on thermoset resins



Atomic emission lines

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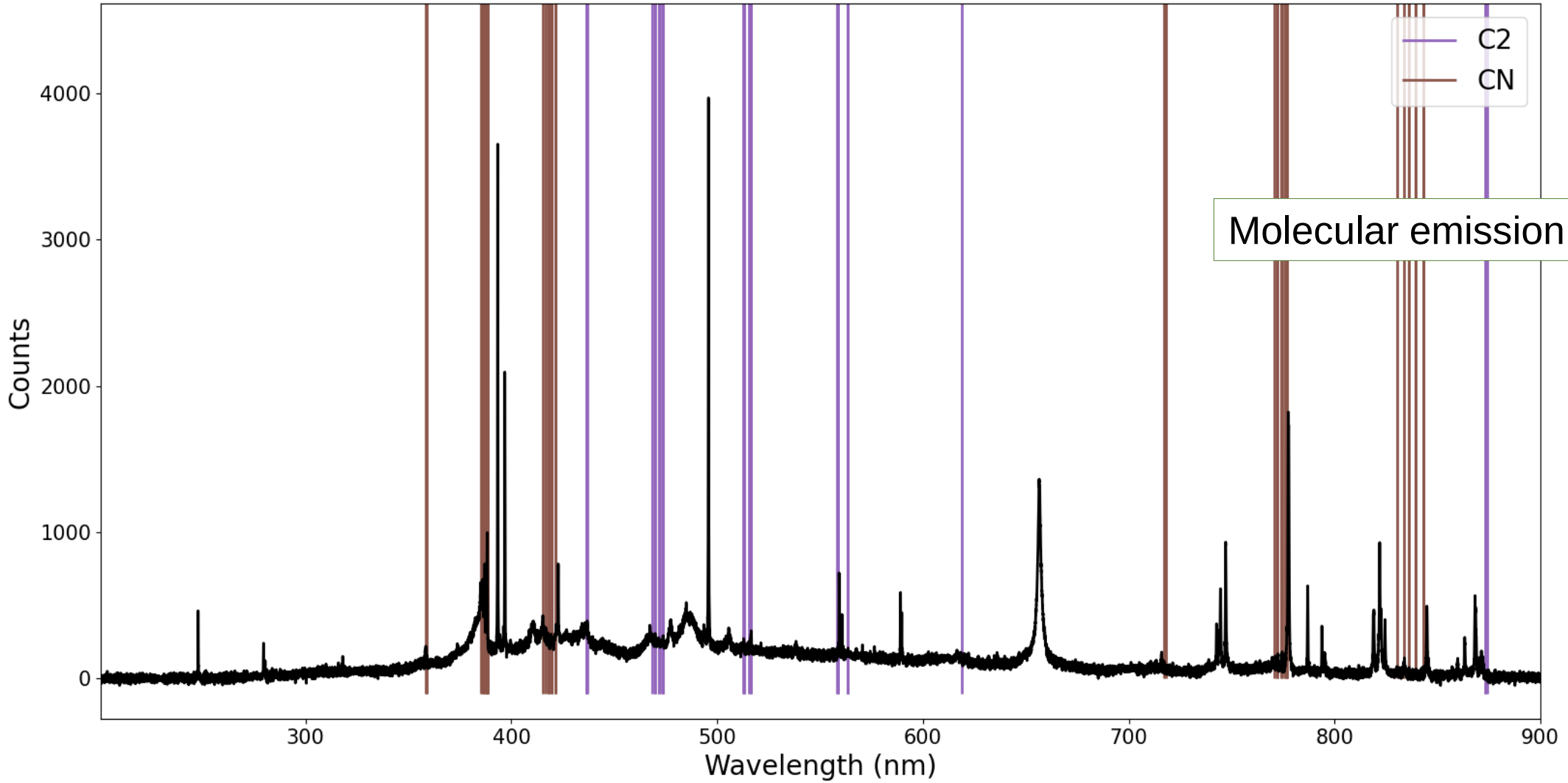
LIBS spectra on thermoset resins



Molecular emission lines

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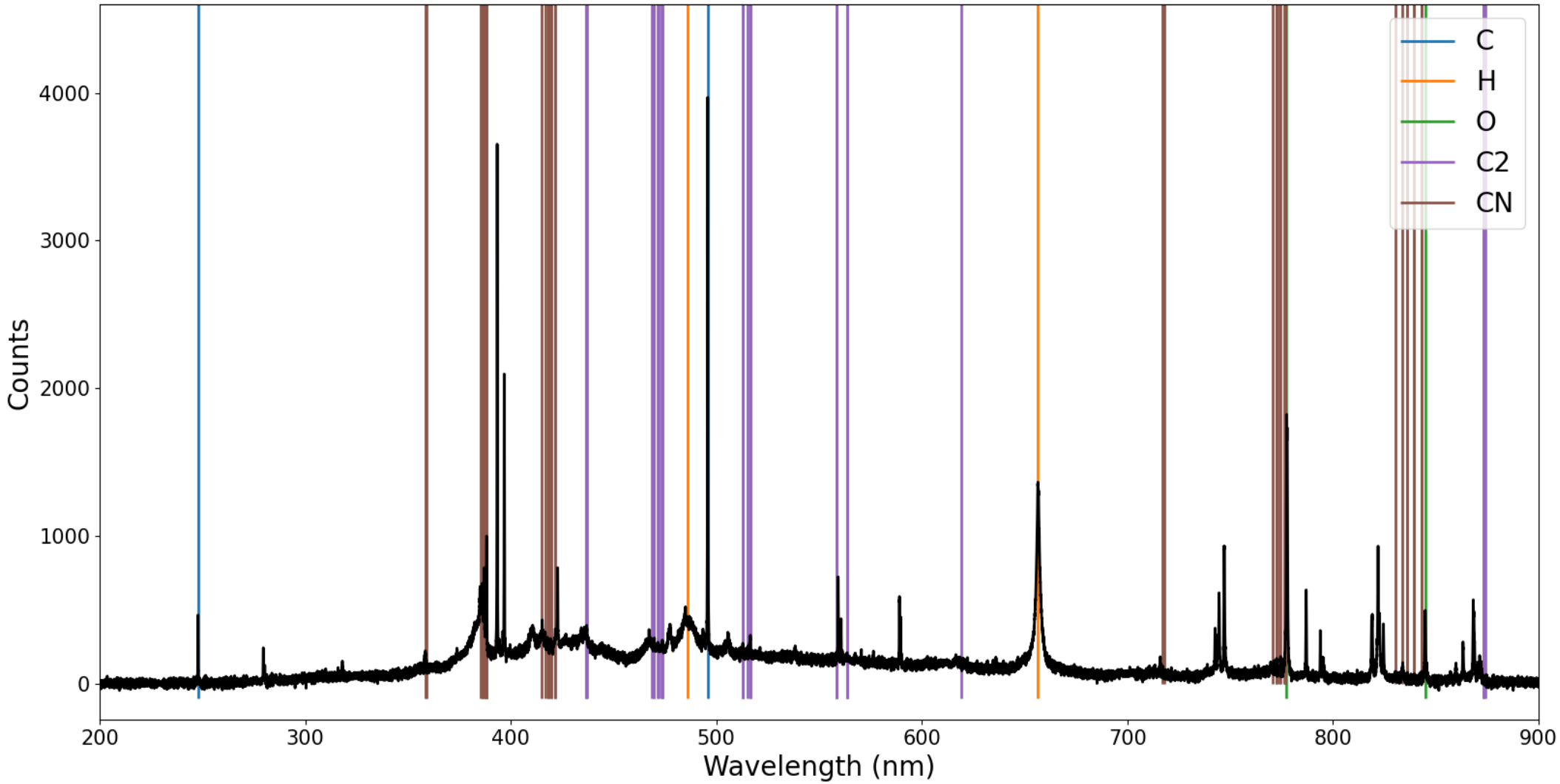
LIBS spectra on thermoset resins



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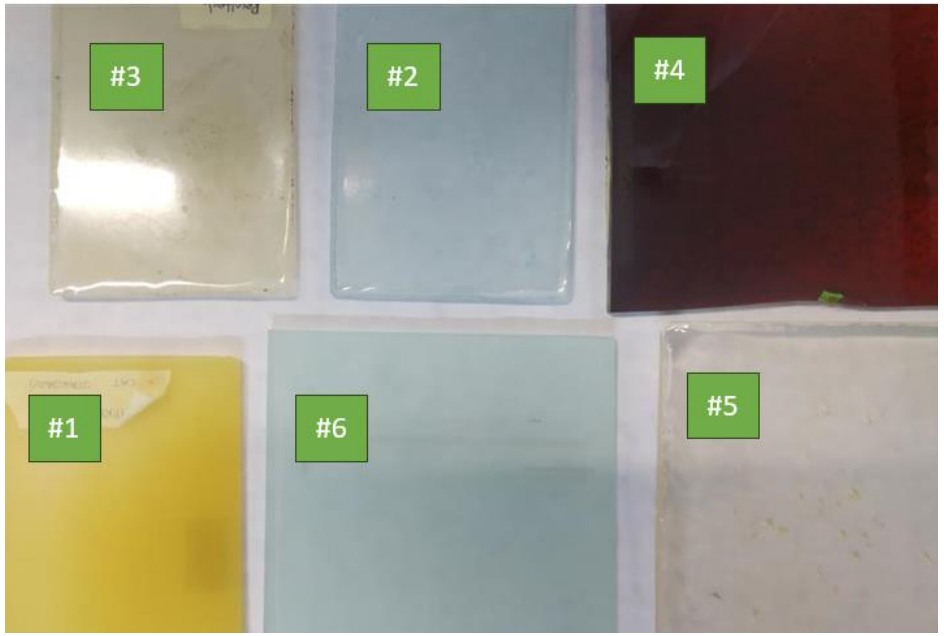
LIBS: resin classification

Can we classify/identify thermoset matrixes using LIBS spectra?

ID	Resin	Hardener/curing agent
1	Ampreg 30 resin	Ampreg™ 3X
2	EPIKOTE™ Resin MGS RIMR 135	MGS RIMH 137
3	Resoltech 1800	Resoltech 1808
4	EPIKOTE™ Resin MGS RIMR 135	4-Aminophenyl disulfide
5	SR Infugreen 810	SD 3304
6	EPIKOTE™ Resin MGS™ RIMR 135	EPIKURE™ Curing Agent MGS™ RIMH 134–RIMH 137



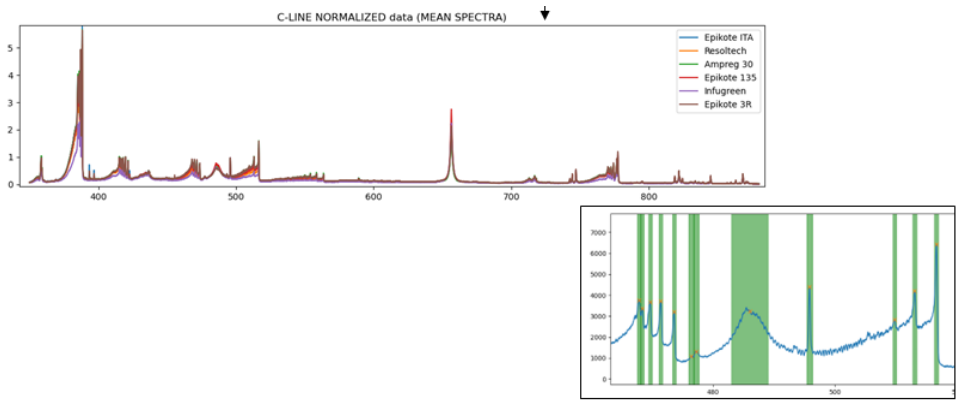
System and experimental protocols optimization -> Dataset 500 measurements per resin

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101058089.

LIBS: resin clasification

RESINS CLASIFICATION

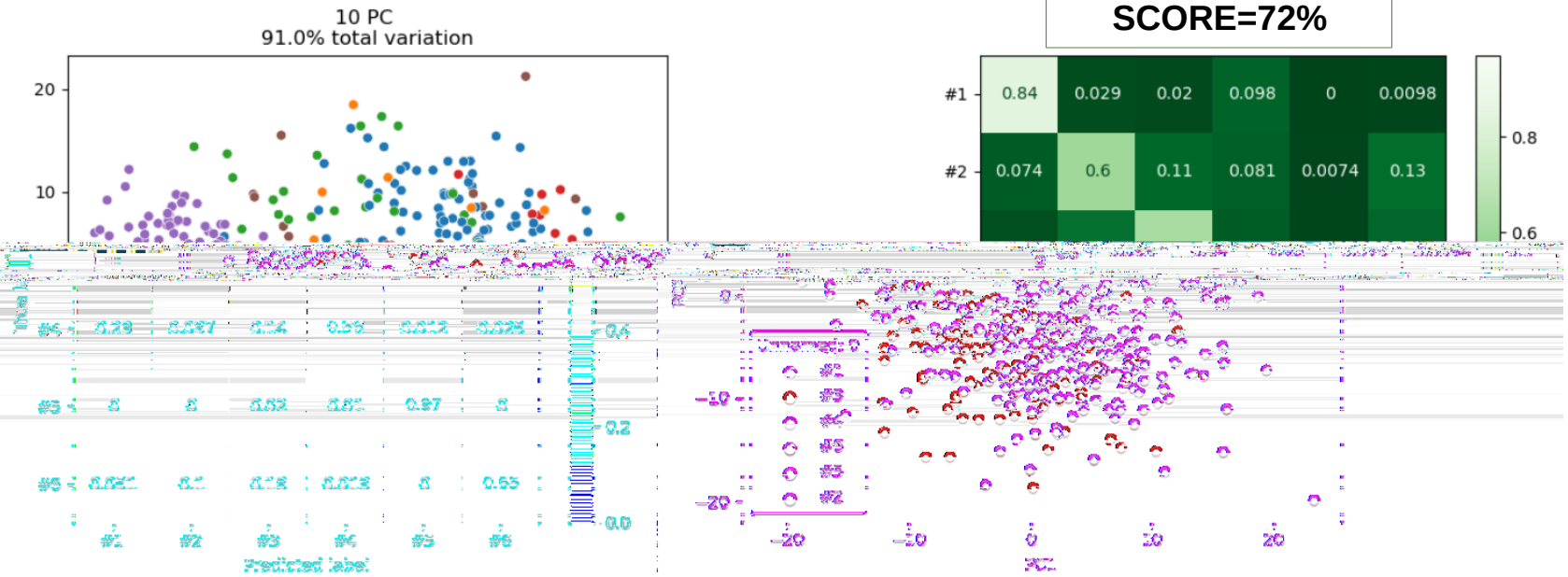
- **LIBS spectra**
- **Preprocessing**
  Normalization
  Table of features
- **Feature selection dimensionality reduction**
- **Classification algorithms**



$$X = \begin{pmatrix} x_{11} & x_{12} & \dots & x_{1d} \\ x_{21} & x_{22} & \dots & x_{2d} \\ & & \dots & \\ x_{s1} & x_{s2} & \dots & x_{sd} \end{pmatrix} \quad Y = \begin{pmatrix} y_1 \\ y_2 \\ \dots \\ y_r \end{pmatrix}$$

spectra

Size: s x d



SCORE=72%

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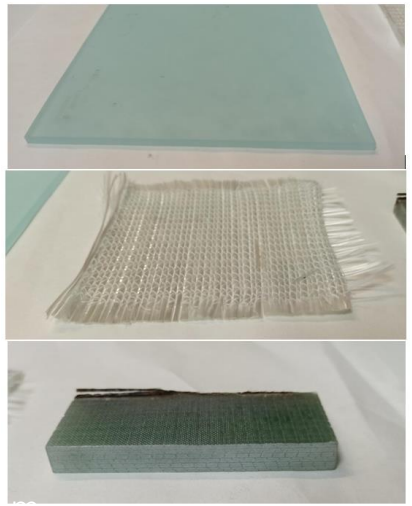
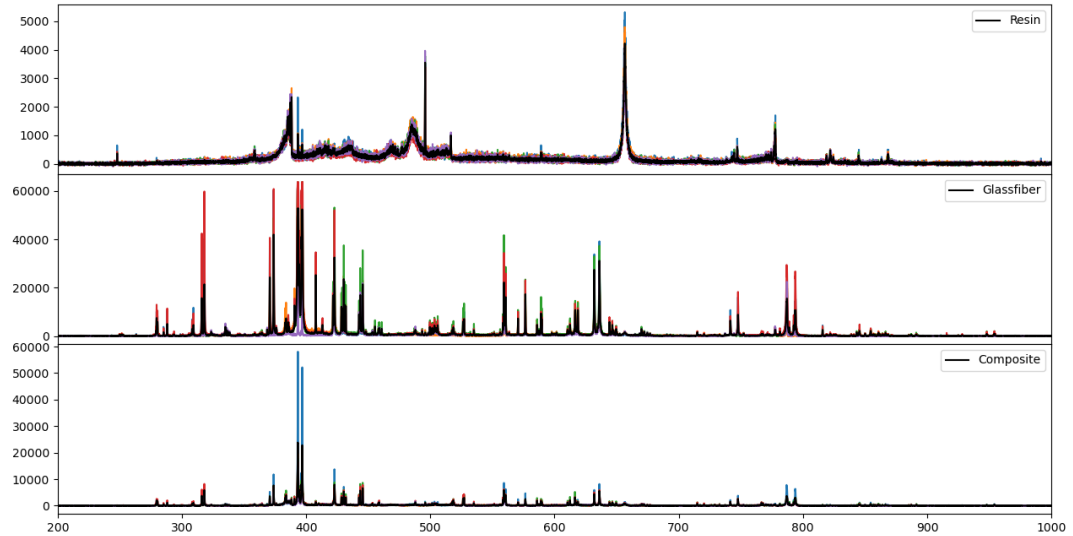
LIBS: GFRP and CFRP identification



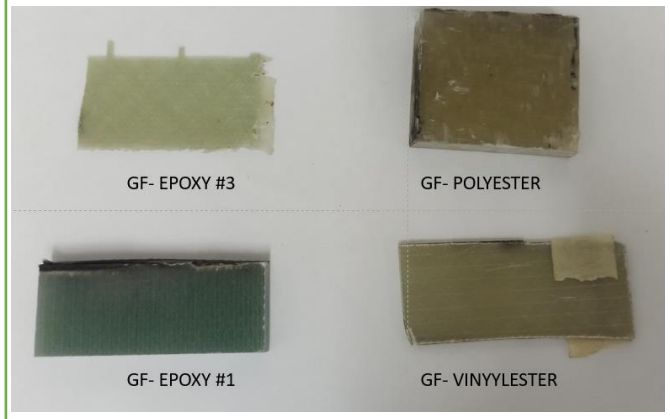
Matrix

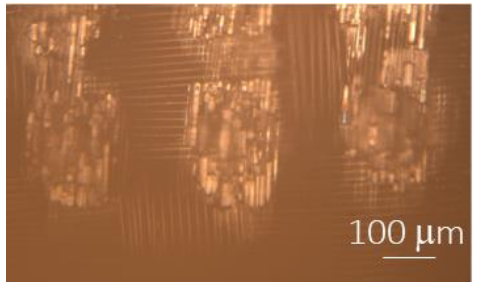
Glass fiber

Composite

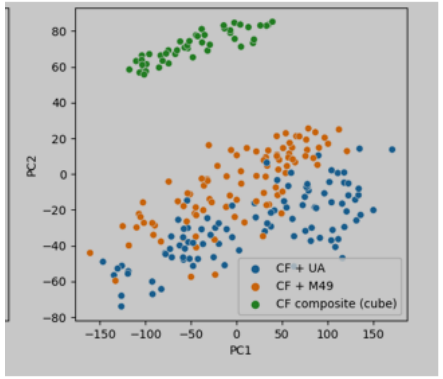


GFRP





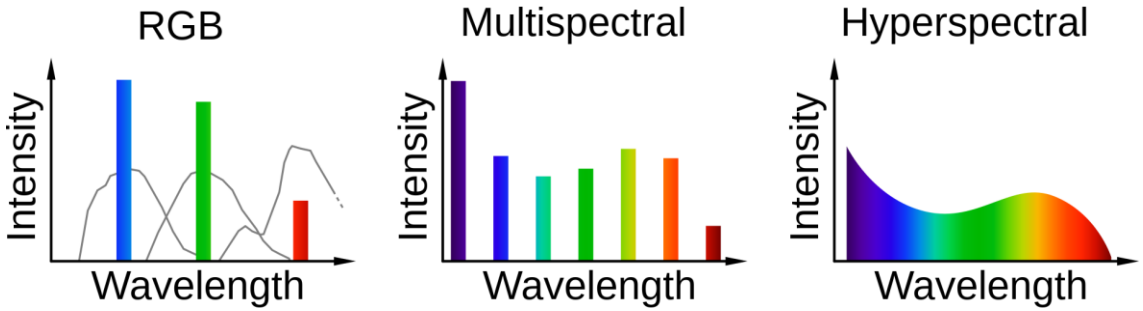
CFRP

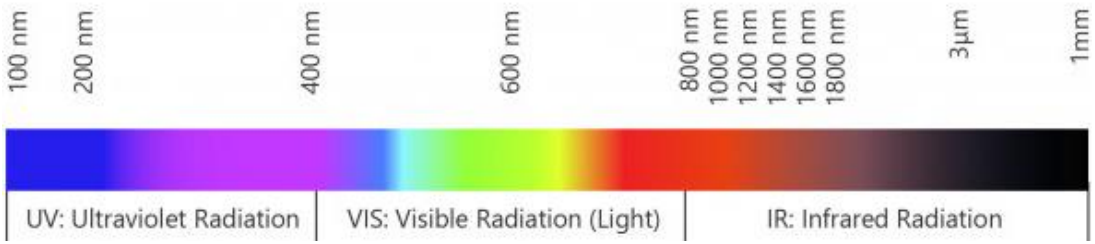


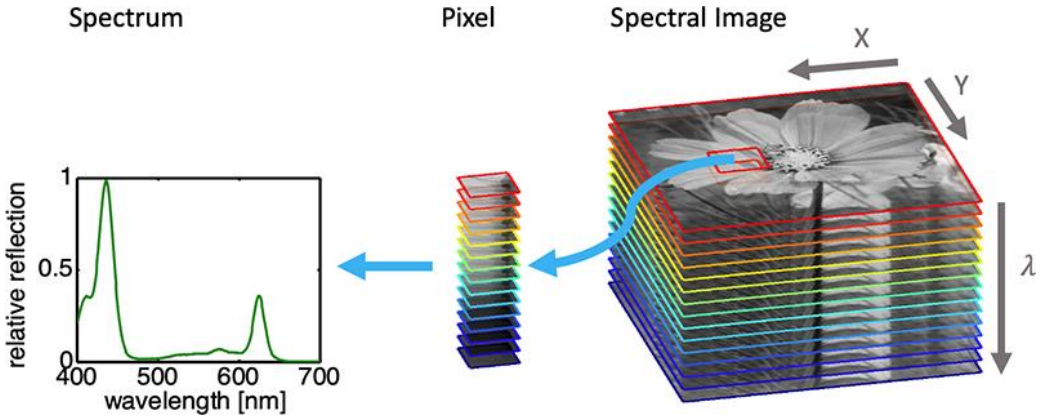
This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101058089.

Hyperspectral imaging

It combines digital imaging and spectroscopy







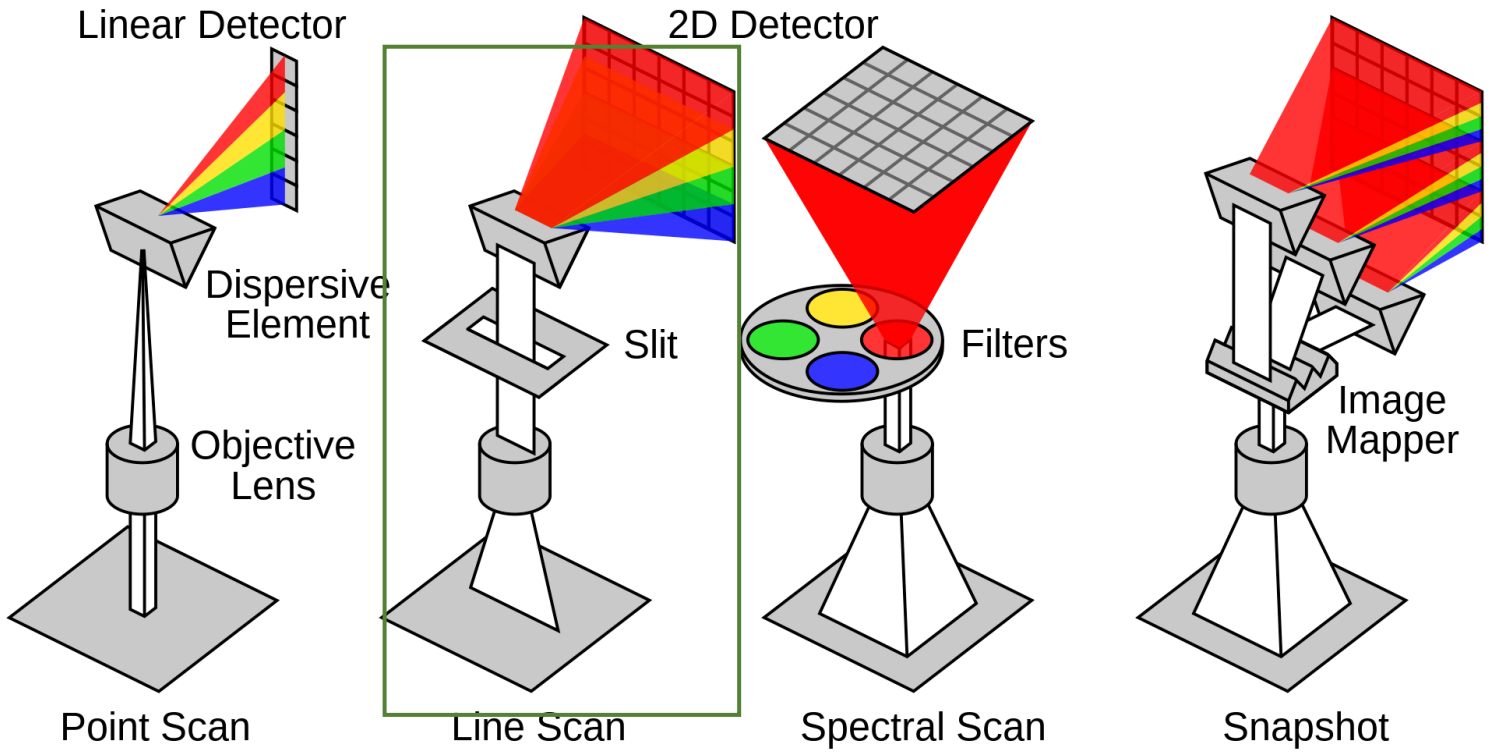
Every pixel in the image provides local spectral information across a large number of spectral bands.

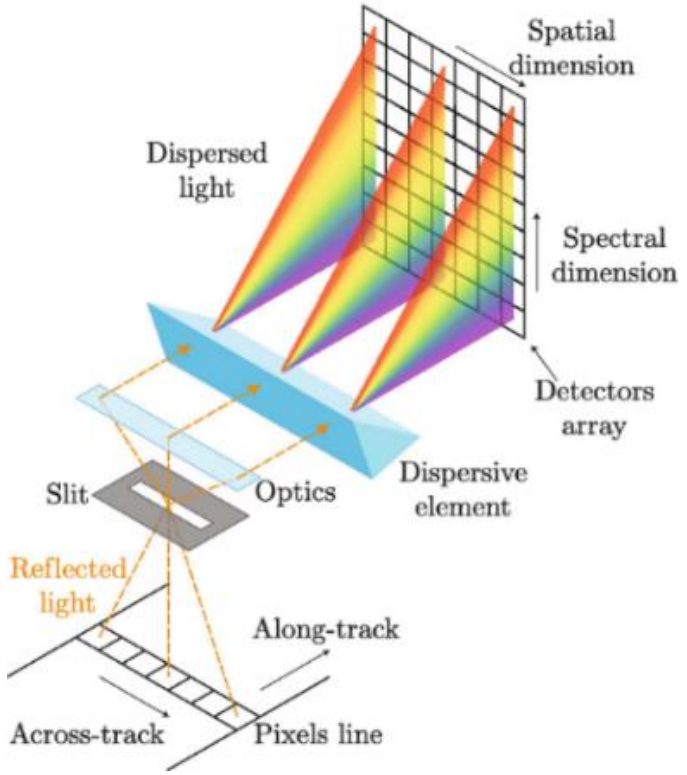
HYPERSPECTRAL: 3D data structure

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101058089.

Hyperspectral imaging

Scanning strategies for multi/hyperspectral imaging





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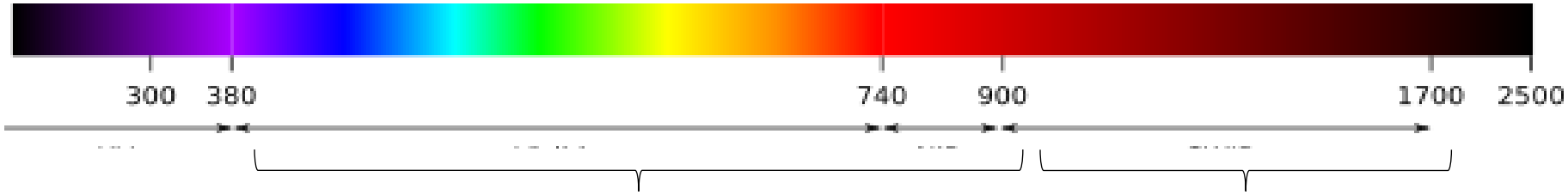
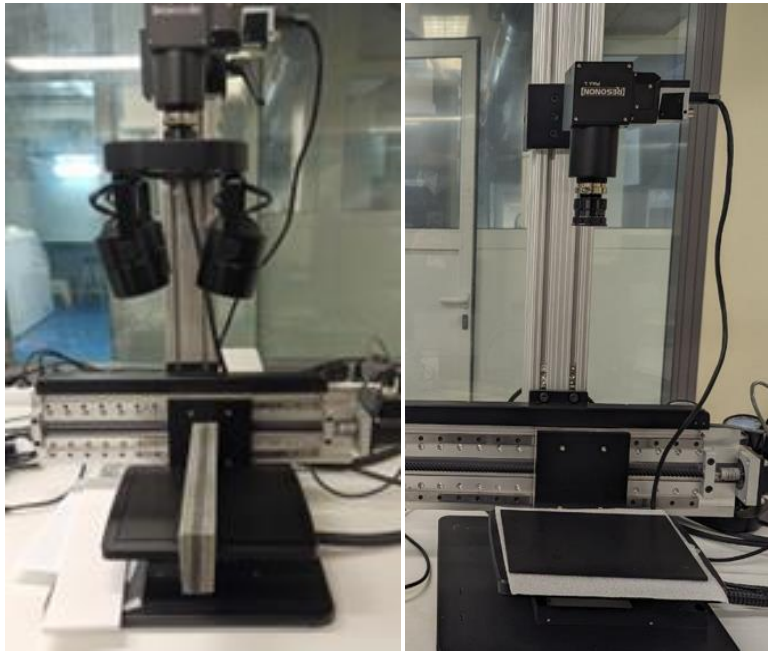
Hyperspectral imaging systems



Sensor technology: **Silicon** | **InGaAs**

400 – 1000 nm
2.1 nm resolution
300 spectral channels
900 spatial channels



Reflection / transmission

Reflection

900-1700 nm
4,5 nm resolution
180 spectral channels
900 spatial channels

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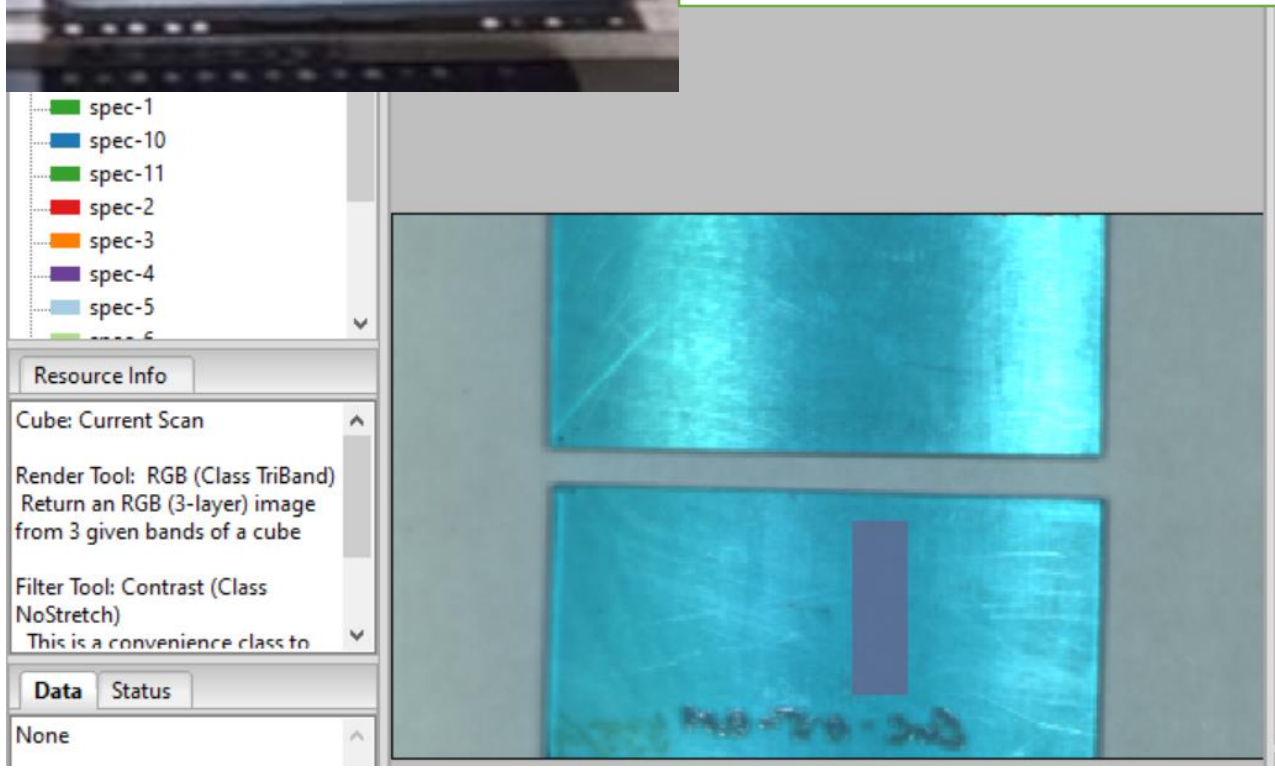
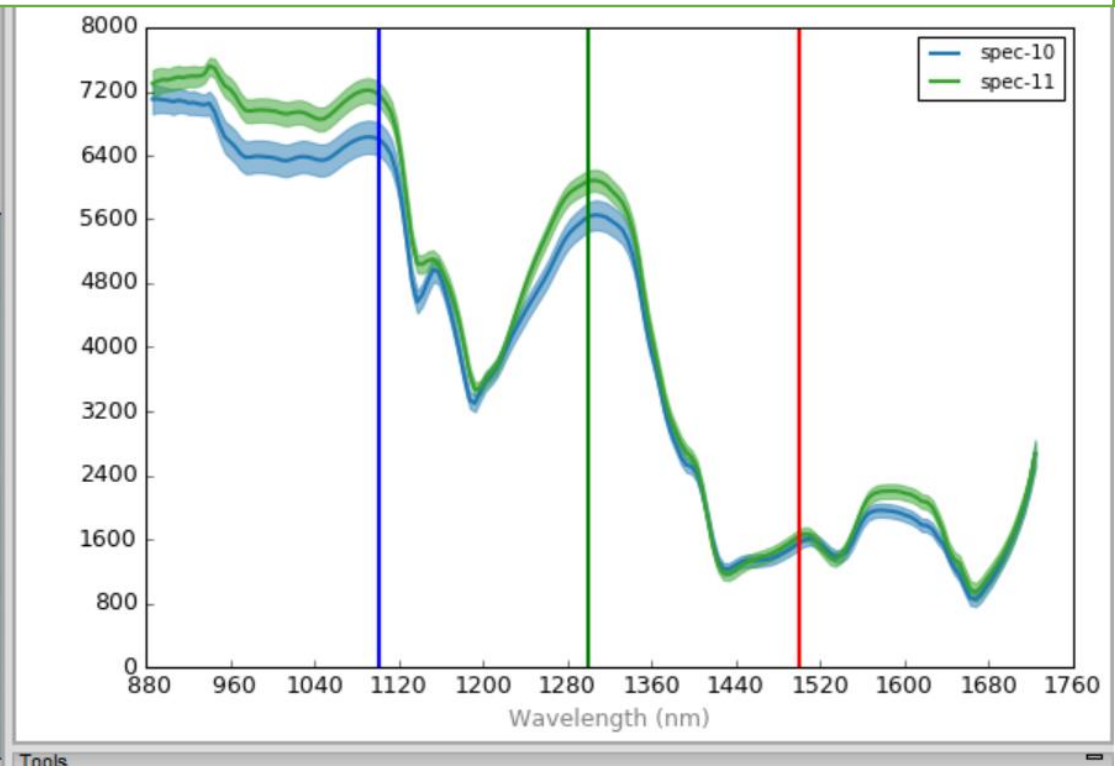
HSI: Resin identification: optical characterization

Epikote Resin RIMR 135	EPIKOTE Curing Agent RIMH 134
Epikote Resin RIMR 935	EPIKOTE Curing Agent RIMH 936





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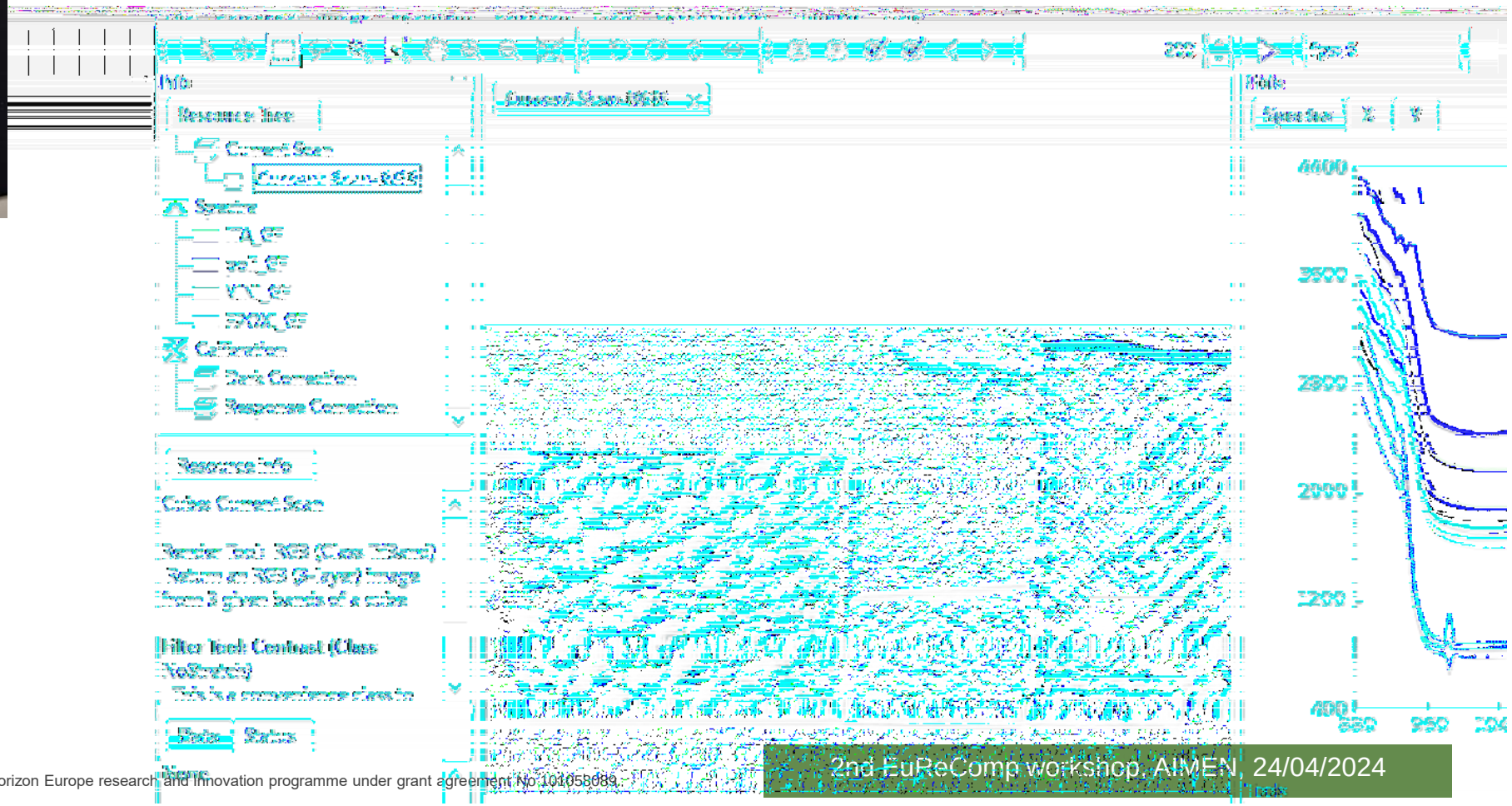
HSI: composite characterization

Fiber amount and distribution impact NIR reflectivity %



This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101058089

Conclusions and ongoing work

- ✓ LIBS system: experimental protocols developed and coupled with machine learning techniques -> capable of identifying composite resin matrix -> recyclers to make decisions about the chemical process conditions
- ✓ HSI technique investigated as potential method for resin identification and fibre-reinforced composites -> sorting EoL composites -> enabling informed decisions for material circularity pathways

Ongoing development

- ➢ LIBS: Extended range of matrixes and composites being investigated.
- ➢ LIBS: Explore and transfer ML algorithms from resins to EoL composites
- ➢ HSI: Characterize ground-truth materials to continue machine learning models development

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101058089.

Thank you!

Camilo Prieto
(camilo.prieto@aimen.es)

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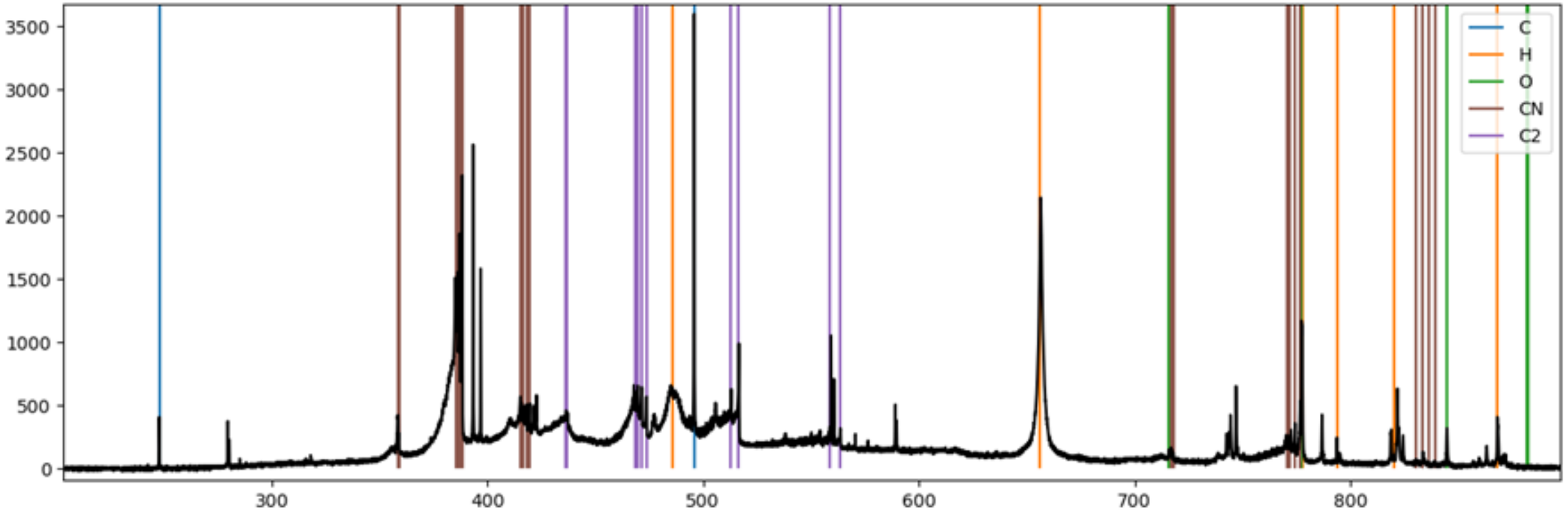
Back up slide



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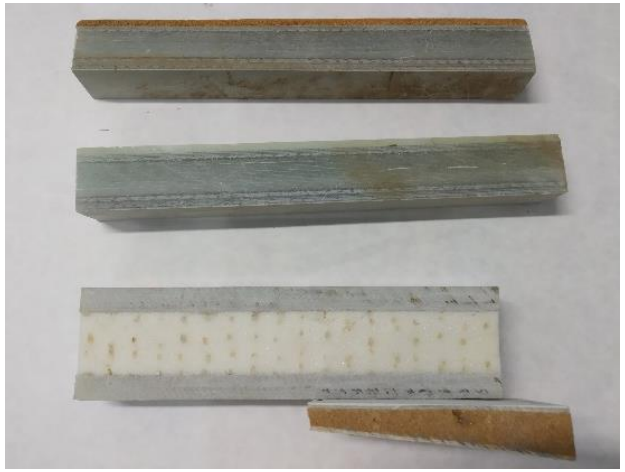
Back up slide

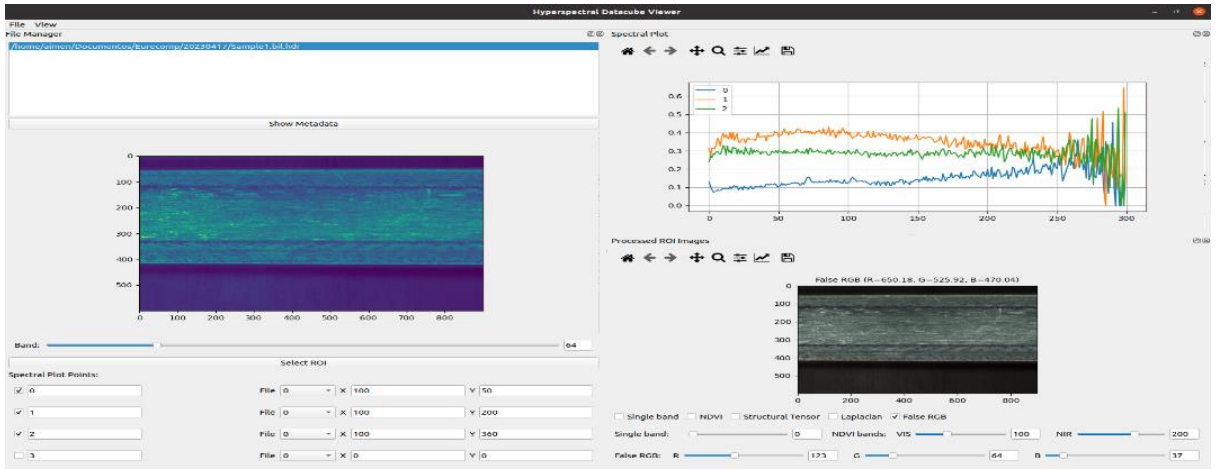
COMPOSITE LAYER IDENTIFICATION

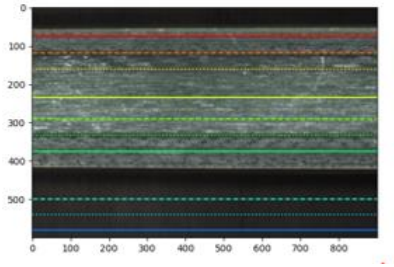
Experimental/ data
- HSI spectra: optical characterization
- Exploratory analysis
- Preprocessing: normalization

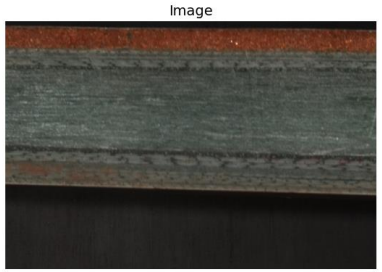
Dimensionality reduction
- Spectral distance and spectral angle

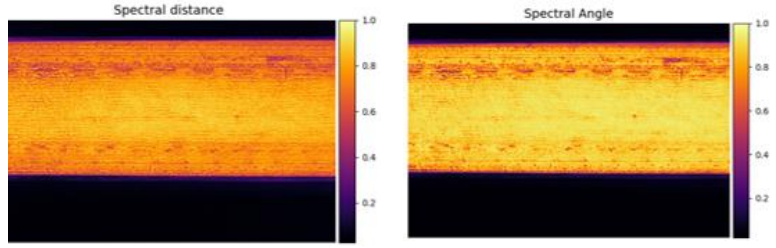
Clustering algorithm

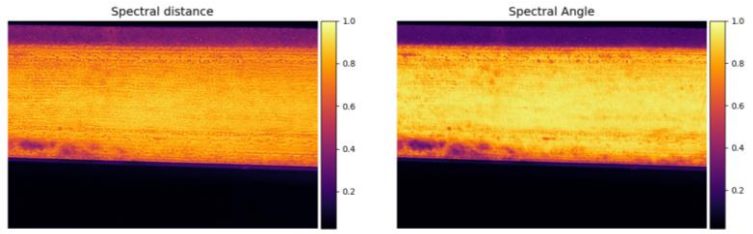


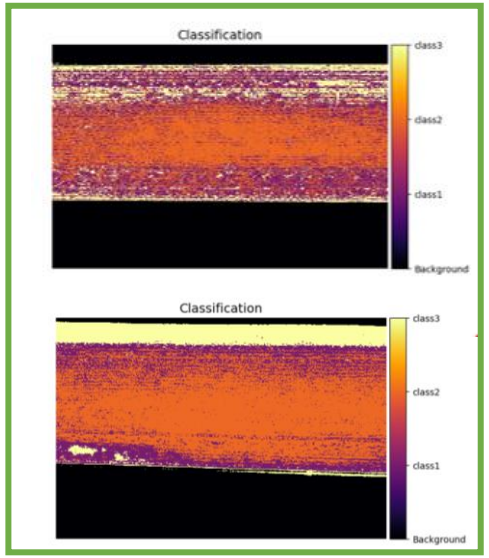












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Back up slide

RAW DATA

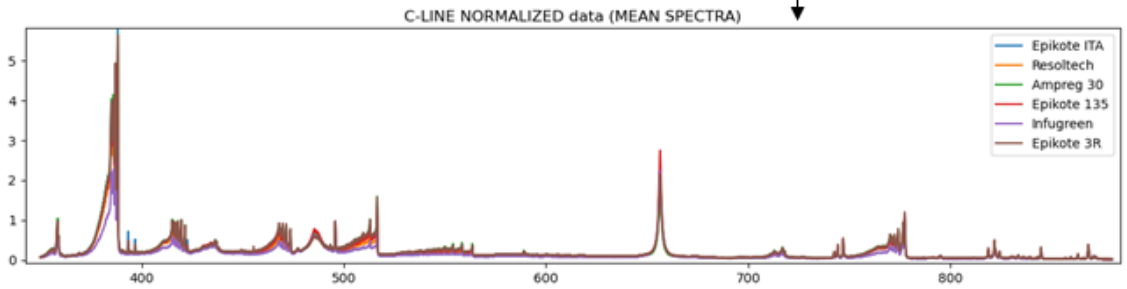
EXPERIMENTAL DATA ANAYSIS

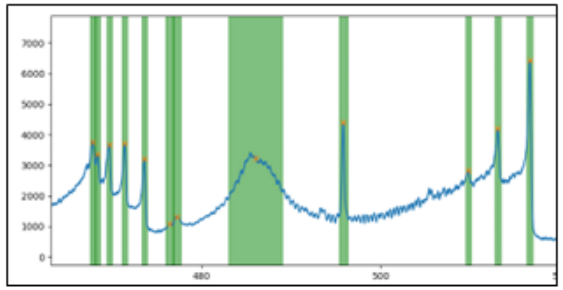
PREPROCESSING

1. Dark current subtraction
2. Spectra Normalization

DESCRIPTORS CALCULATION

DESCRIPTOR MATRIX





descriptors

$$X = \begin{pmatrix} x_{11} & x_{12} & \dots & x_{1d} \\ x_{21} & x_{22} & \dots & x_{2d} \\ & \dots & & \\ x_{s1} & x_{s2} & \dots & x_{sd} \end{pmatrix} \quad Y = \begin{pmatrix} y_1 \\ y_2 \\ \dots \\ y_r \end{pmatrix}$$

spectra

Size: s x d

d → descriptor (spectral line peak ratios)
s → experimental normalized spectrum
r → resin type

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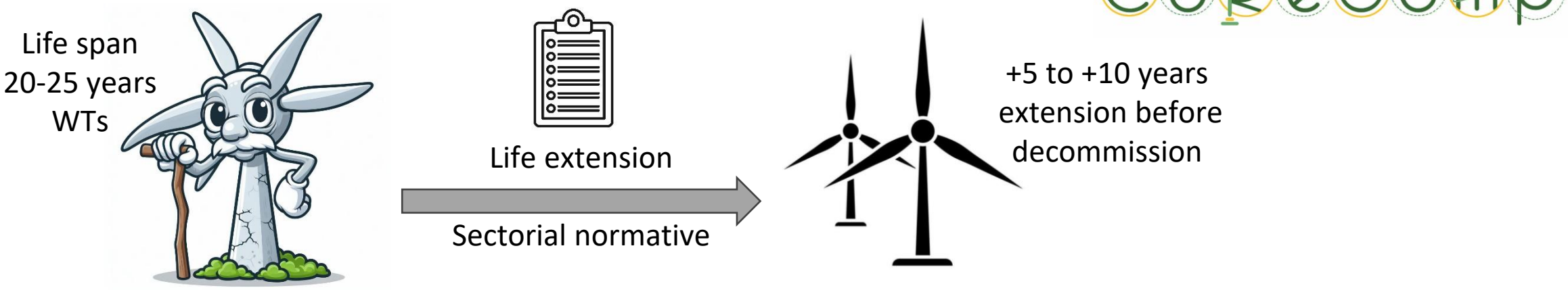
Reuse and Repurpose of EoL high performance composite parts: Methodologies for fatigue life extension, damage assessment and redesign

M24 Workshop - April 24, 2024 | Vigo

Andreia Araújo – INEGI
Francisco Lahuerta – Itainnova

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101058089.

Lifetime extension and End-of-Life normative for WTB



- **Lifetime extension of wind turbines** applies to all types of wind turbines and provides principles, technical requirements and guidance for the lifetime extension of both onshore and offshore. This extension is considered technically and economically when a wind turbine reaches its original design lifetime (20-25 years)
- The sectorial normative which applies to wind turbines and in particular for WTB:
  - **DNVGL-ST-0262:2016 – Lifetime extension of wind turbines**
  - **DNVGL-SE-0263:2016 – Certification of lifetime extension of wind turbines**
  - **DIN SPEC 4866:2020** document that specifies the framework conditions for the sustainable and efficient dismantling, disassembly, recycling and recovery of onshore wind turbines
  - **WindEurope – Decommissioning of Onshore Wind Turbines (2020)** is an Industry Guidance Document
  - **DIN IEC/TS 61400-28 (VDE V 0127-28)** is a technical specification (TS) related to wind energy generation systems

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101058089.

Brief breakdown of the life-extension process

Data collection | Life extension assessment (Risk management) | Implementation

- Site info
- Historical data
- Maintenance and inspection reports
- SCADA data
- Site permissions
- Condition monitoring data if available

Load modelling

- Analyze RUL (remaining useful life) assesment
- WTBs and structural components

End-of-life inspections

Assessing the current condition thorough inspections

Report & Certification

- Documenting and certifying of findings and formulating life extension strategy

Apply strategy

- Condition monitoring system
- Fleet optimization
- Maintenenance
- Repairs

Continuous monitoring (data collection & regular inspections)

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Repair techniques

Erosion repair and protection

- **Anti-erosion coating repair** is usually the first and most recurrent repair performed in wind turbine blades.
    - **Risks:** lead to crack progression through the laminates, water penetration into the material
- Repair solutions for eroded blades include anti-erosion:
    - Protective coatings of epoxy and polyurethane **fillers**. The application of filler is a highly labour intensive and usually not automate
    - Protective coatings in the form of protection **tapes** from durable, abrasion-resistant polyurethane elastomers. The tapes, typically made of polyurethane, provides a ductile layer to dampen the initial impact of the raindrops.
    - Shells or **shields** of either rigid or semi-flexible materials. Using either rigid or semi-flexible materials. Manufactured in controlled productions environments. Positioned straight onto the leading edge by means of adhesives

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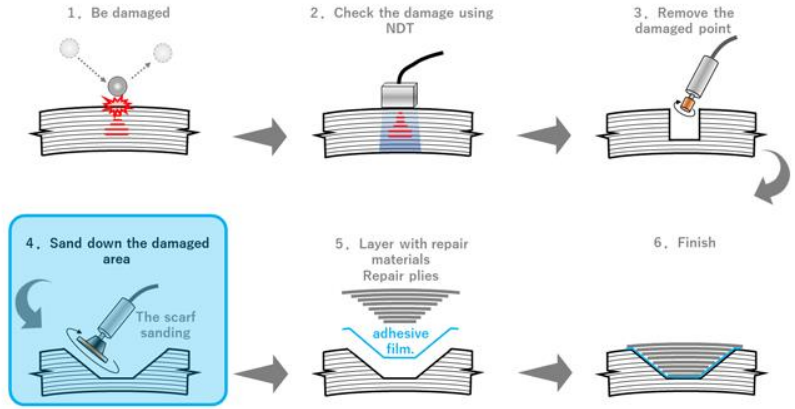
Repair techniques

Structural repair, patches and scarfs

- The most suitable and used technique is **flush repair**. That is, forming a joint between the prepared area to be repaired and a repair patch. The procedure includes,
  - the removal of the damaged region known as scarfing (conical or stepped) the preparation of a patch
  - bonding between the patch and the host structure (pre-pregs, adhesive films or infusion)
  - manufacturing technique of the patches:
    - Soft patch: When the composite patch is co-cured
    - Hard patch: When the patch is previously manufacture in an autoclave and then bonded (not very usual, require close tolerances between the patch and the part)
  - in all cases the final surface does not match the finishing criteria and require of a re-work with fillers or coatings



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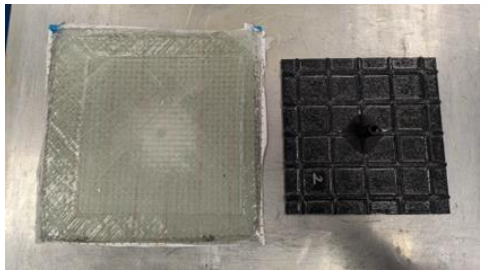
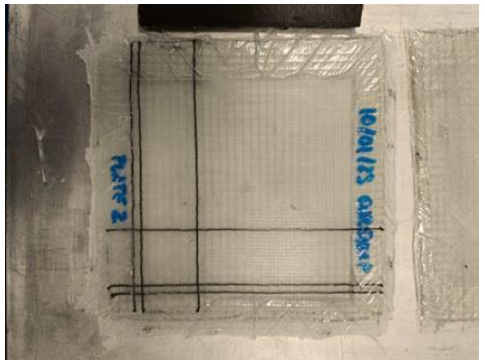
Repair techniques in EuReComp

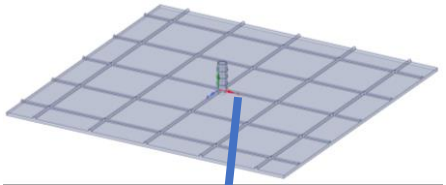
Evaluation of surface and structural repair strategies based on 3D AM printed caul plates tools

- Evaluation of surface and structural repair strategies based on 3D AM printed caul plates tools
  - Avoid secondary finishing processes like grinding and improve superficial tolerances
  - 3D printed tool shapes tailored to specific geometries (collaboration with BioG3D)
  - Applicability to drones works

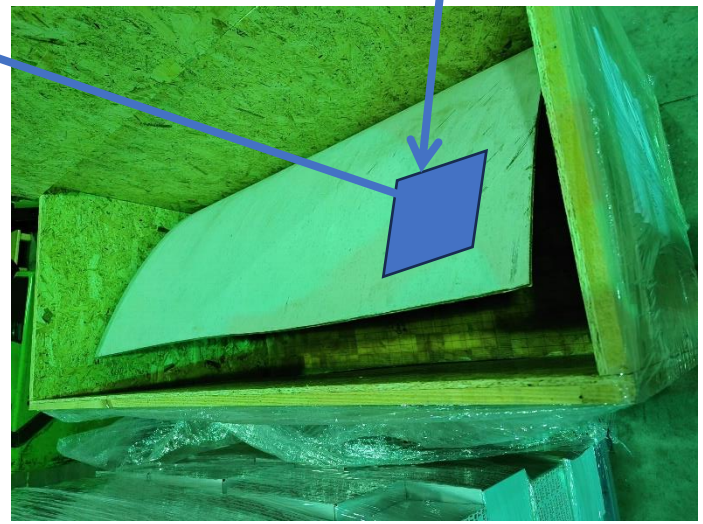




Demonstrator trials
- Evaluation of finishing
- Evaluation of processability



Patch repair with 3D printed caul plate adapted to the blade wrapping. To be develop



Identifications of damages and repairs suitable for this technique
- Bibliographic review on WTB damages and repairs

Demonstrator specifications
- 3D printing tool
- Materials definitions
- Repair process specification

Demonstrator trials
- Evaluation of finishing
- Evaluation of processability

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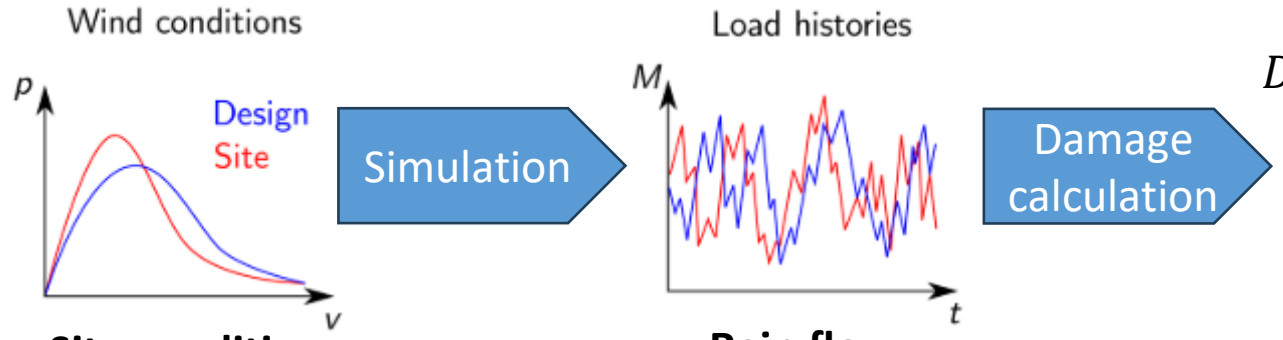
WTB fatigue life extension

Methodologies for fatigue damage assessment in WTBs

- Sectorial WTs guidelines: DNVGL-ST-0262, DNVGL-ST-0263, E DIN IEC/TS 61400-28 VDE V 0127-28:2022-05. And evaluation of the RUL (remaining useful life, DIN IEC/TS 61400-28)
- Damage ratios above 1 are required to justify possible WTBs life extension



Site condition

Design vs Real site

Rain flow

Design vs Real site

$$Damage_{ratio} = \frac{D_{Site}}{D_{Design}} = \left(\frac{M_{eq}^{a,s}}{M_{eq}^{a,d}}\right)^{m} = \frac{\sum_i \left(n_i^s \cdot \left(M_i^{a,s}\right)^m\right)}{\sum_i \left(n_i^d \cdot \left(M_i^{a,d}\right)^m\right)}$$

Saathoff, M., & Rosemeier, M. (2020)

$$\begin{cases} M_{eq}^{a,s}, M_{eq}^{a,d}: \text{equivalent moment for each WTB section} \\ n_i^s, n_i^d: number\ of\ rain\ flow\ ocurrences\ i \\ M_i^{a,s}, M_i^{a,d}: moment\ i\ of\ rain\ flow \\ m: fatigue\ slope \end{cases}$$

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EoL WTB – Alternatives pathways

What to do when Life Extension is not possible?

R1 | Reuse

R2 | Repair

R3 | Refurbish

R4 | Remanufacture

R5 | Repurpose

R6 | Recycling

“Waste” reduction

High-added value products

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EoL WTB – Redesign for repurpose

Case Studies

Wikado one-off playground with a similar cost but a smaller ecological footprint using 5 of 30 m blades.

Willemsplein public seating: urban seating using 9 of 6 m WTBs was designed and installed in a Rotterdam square

REWIND ALMERE (Bus shelter): convert 30 m blades into pieces of the functional urban architecture

Pedestrian bridge: using 2 8.5 m WTBs as side girders that transfer the loads from a concrete deck to the supports

Zhang, Z., et al. *BladeBridge - Design and Construction of a Pedestrian Bridge using Decommissioned Wind Turbine Blades*. in *ICSA 2022*

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EoL WTB – Redesign for repurpose

Case Studies

Conceptual architectural housing for underdeveloped countries

Bank, L.C., et al., *Concepts for Reusing Composite Materials from Decommissioned Wind Turbine Blades in Affordable Housing.* Recycling, 2018. **3**(1): p. 3.

- using straight, slender panels, such as the blade's shear webs as doors, window shutters, flood barriers, structural insulated panels and facades;
- top and bottom airfoil sections as roof frames;
- severely curved parts, such as the leading edge, as a concept for an interlocking shingle system for roofing as well;
- the root section is also given functionality as an elevated foundation system in areas where flooding is bound to occur.

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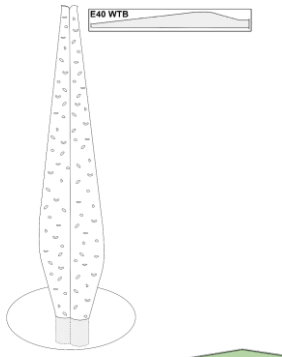
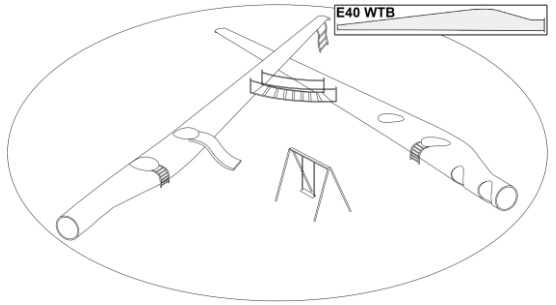
EoL WTB – Redesign for repurpose

Approaches



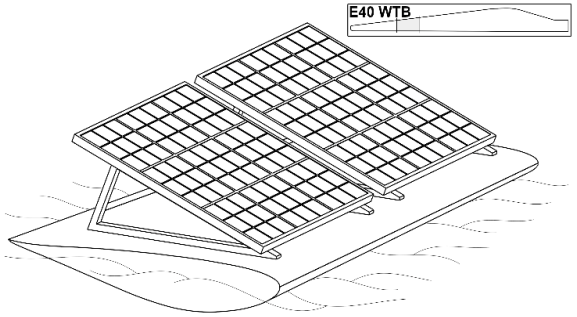
1- High-loaded complete structure

- e.g. a climbing tower from an EoL WTB



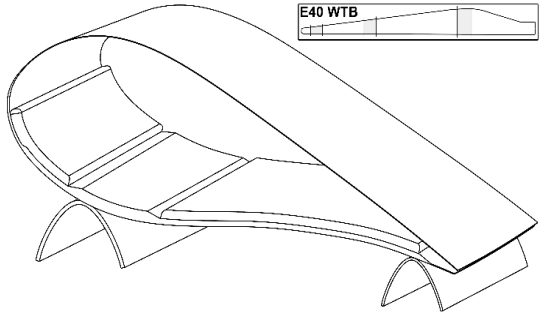
2 - Low-loaded complete structure

- e.g. a playground from an EoL WTB



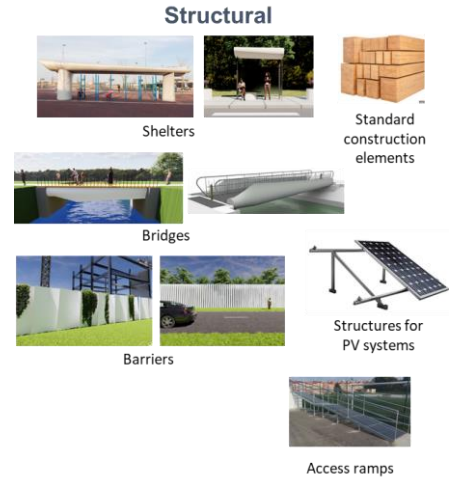
3 - High-loaded segmented structure

- e.g. PV-floating system from an EoL WTB



4 - Low-loaded complete structure

- e.g. lounger/furniture from an EoL WTB



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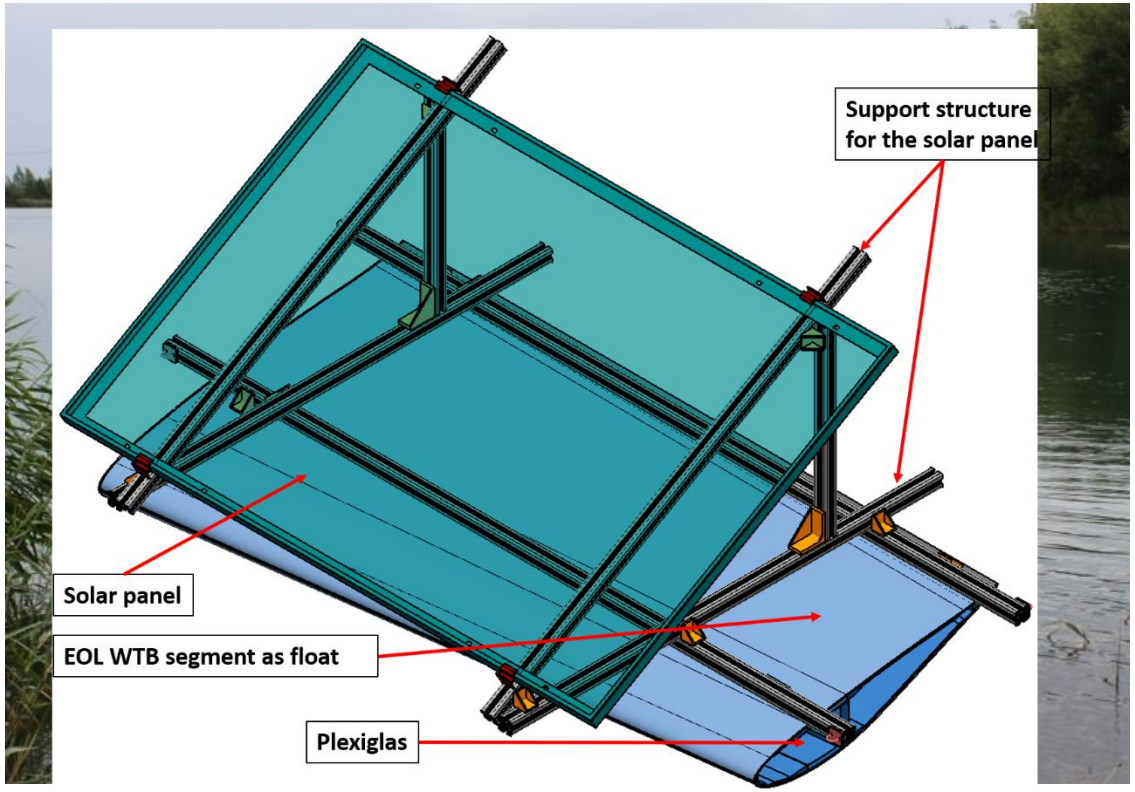
EoL WTB – Redesign for repurpose

Structural demo case: Floating PV structure

- ✓ **Small-scale**: for tests and to gain knowledge for the larger demo
  - Initial proof of concept.
  - Develop a methodology to close the ends.
  - Evaluate flotation capacity (closing of ends, sealing methodologies).
  - Test connections to the WTB.
  - Load application *via* spar cap.

(1) Concept small-scale platform



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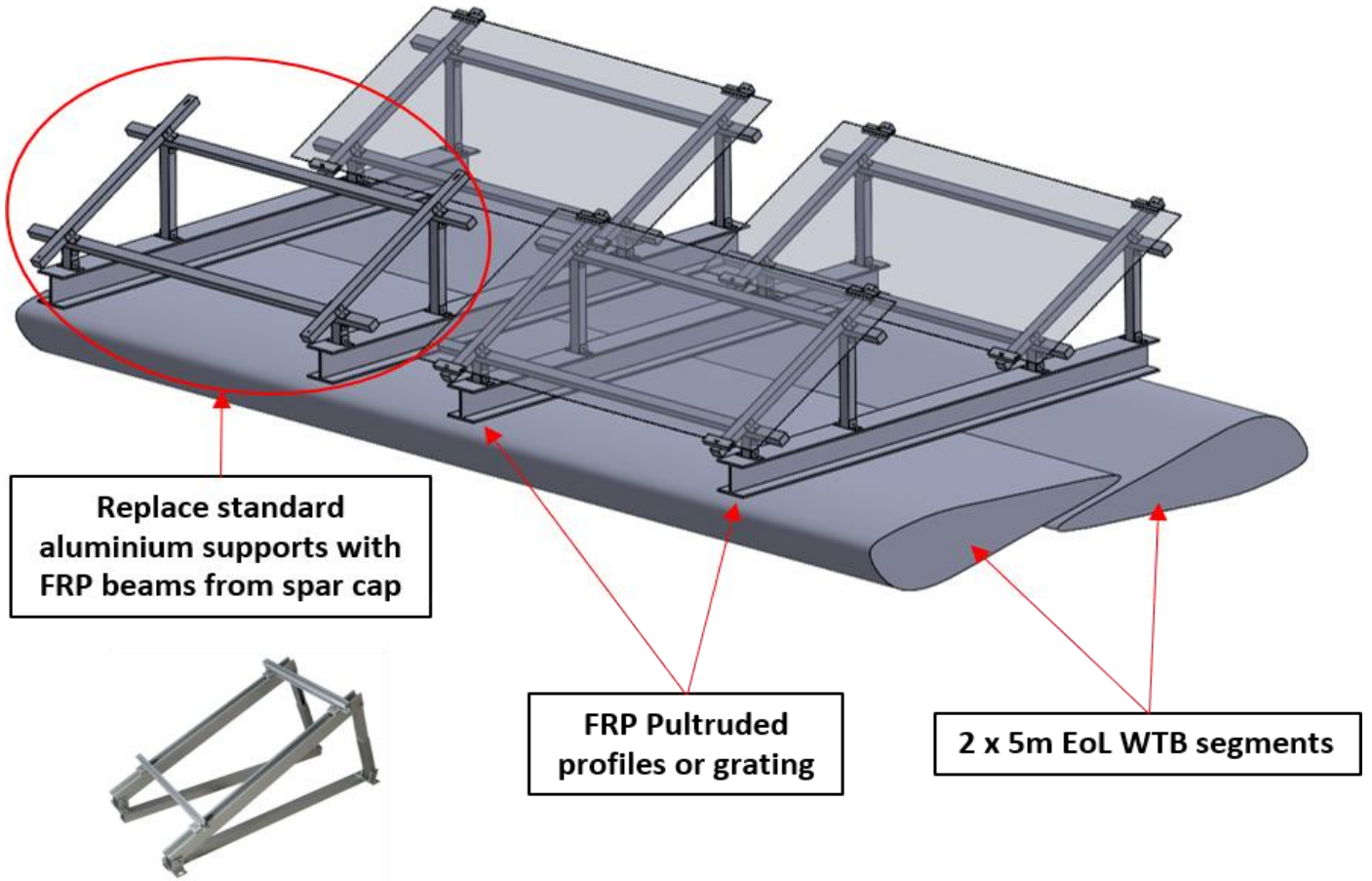
EoL WTB – Redesign for repurpose

Structural demo case: Floating PV structure

- ✓ **Large-scale:** to implement constructive solutions in a larger scale



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Thank you!

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ITA, INEGI

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