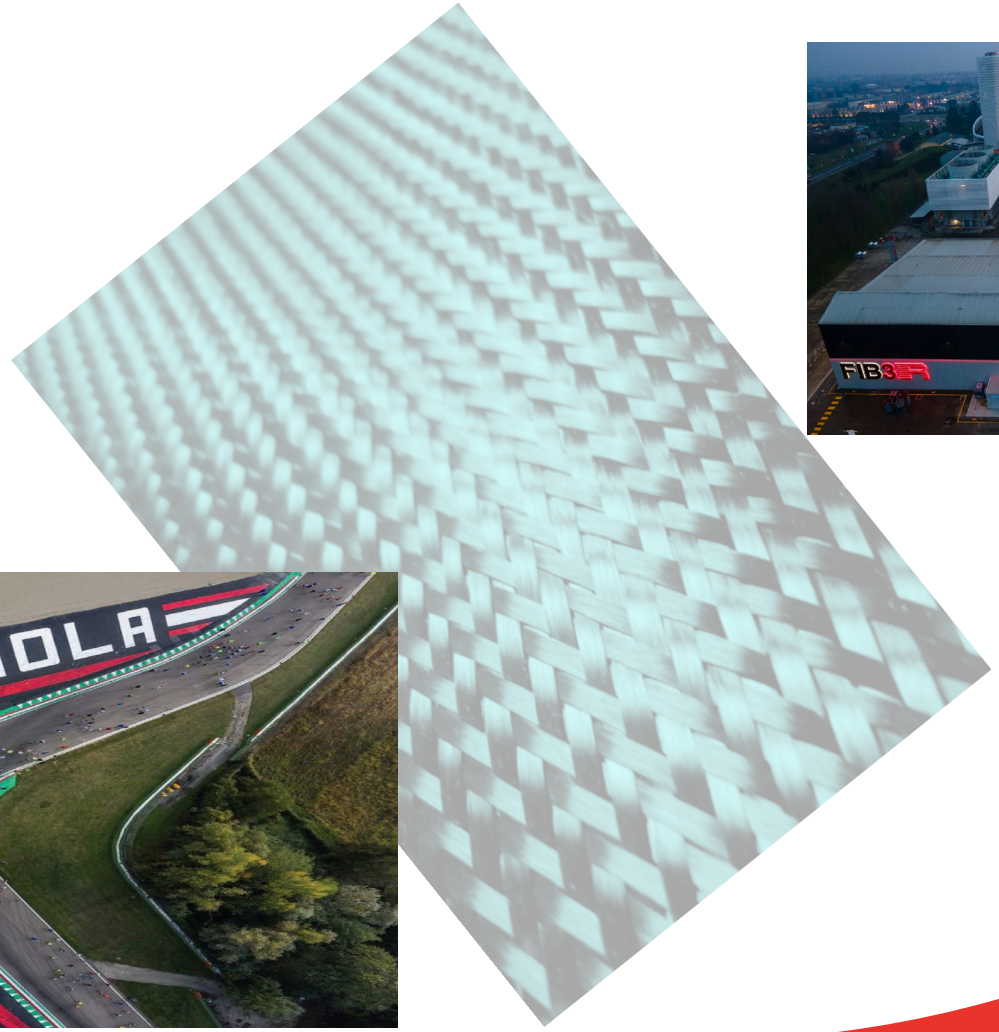
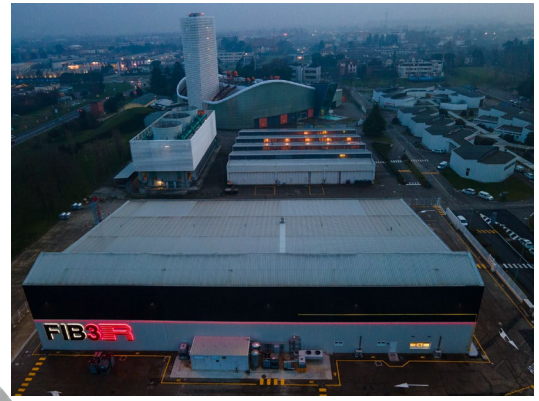
FIB3R

Recover Reduce Reuse
Carbon Fiber








# EUROPE'S FIRST INDUSTRIAL-SCALE RECYCLING PLANT

12/06/2025

HERAmbiente
Società del Gruppo Hera

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# HERA GROUP

Founded in **2002,** by the merger of **11 municipal companies in Emilia-Romagna.** Through a path of constant and balanced growth, it has become one of the **nation's largest multiutilities.** It works in the **environment, water and energy sectors,** by providing a variety of services mainly in the **Emilia-Romagna, Veneto, Friuli-Venezia Giulia, Marche and Toscana** regions.

**15 billion €**
revenue

**> 9,500**
employees


Since 2003, it is listed in the Italian Stock Exchange (Borsa Italiana). In 2019, it entered the FTSE Mib.

Included in the Dow Jones Sustainability Europe Index and in the Dow Jones Sustainability World Index.

Since 2021 in the MIB ESG Index, the first Italian blue-chip index, dedicated to ESG best practices.

FTSE

Dow Jones Sustainability Indexes

MIB ESG

*Market positioning*

**1°** ENVIRONMENT
7.7 million tonnes
of waste treated

**2°** WATER
283.4 million cubic metres
of water sold

**3°** GAS
10.7 billion cubic metres
of gas sold

ENERGY
14.5 TWh
of electricity sold

*2023 data*

# HERAMBIENTE GROUP

Established on July 1°, 2009, in order to concentrate the **Hera Group's extensive plant equipment** in a new company capable of better seizing the business development perspectives.

Herambiente is the **leader in Italy in the waste treatment and recovery of energy and material sectors.**

**1.1 billion €**
revenue

**> 2,000**
employees

**7.2 MILLION TONNES/YEAR**
of waste treated

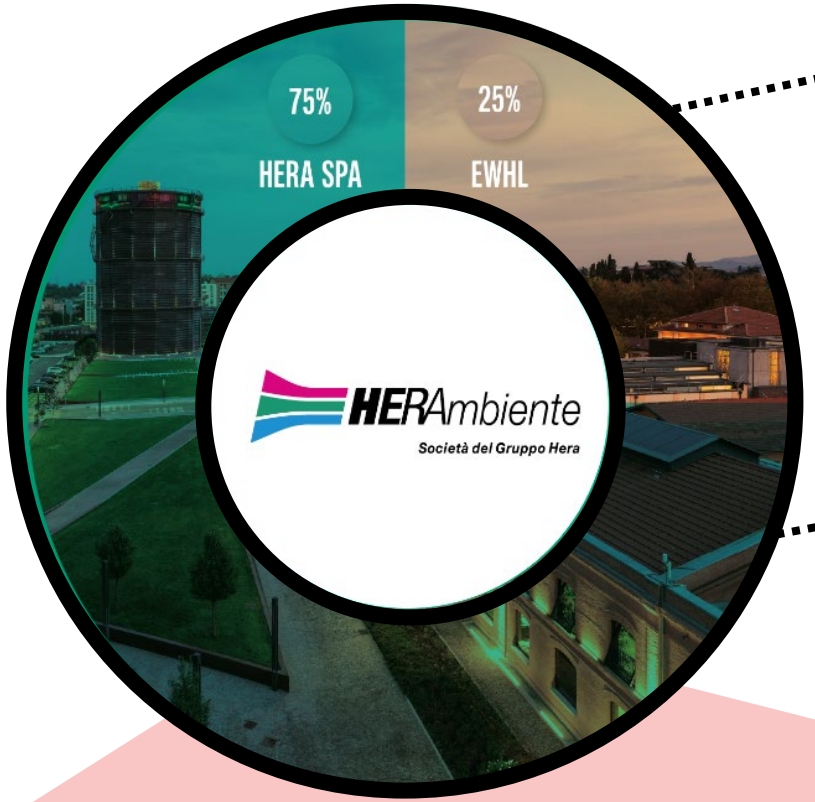
**5.2 MILLION TONNES/YEAR**
of special waste treated
- of which > 1.5 MILLION TONNES/YEAR
  C&I waste treated

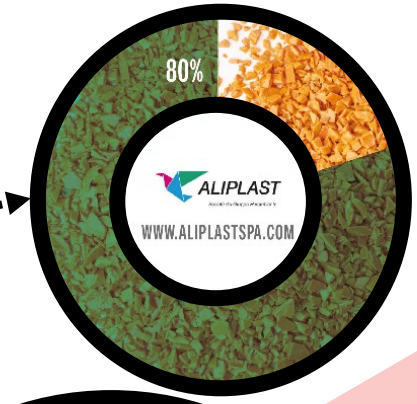
**2 MILLION TONNES /YEAR**
of urban waste treated


*2023 data*

# CORPORATE STRUCTURE

FIB3R
Recover Reduce Reuse Carbon Fiber





100% FERONIA
Finale Emilia (MO) landfill for non-hazardous waste

70% BIORG
Joint venture with Inalca for biomethane and compost production (MO)

70% HESTAMBIENTE
Trieste and Padua waste-to-energy plants

51% FEA
Granarolo (BO) waste-to-energy plant

51% ASA
Castelmaggiore (BO) landfill for special waste

50% ENOMONDO
Thermal and electricity production plants from biomass in Faenza (RA)

60% ACR REGGIANI
Leading operator in remediation services, industrial waste treatment, decommissioning of industrial plants and civil works related to oil & gas (MO)

31% TREMONTI
Bussi sul Tirino (PE) implementation of soil and groundwater remediation services

100% RECYCLA
Maniago (PN) industrial waste treatment/recovery platforms

80% VALLORTIGARA
Torrebelvicino (VI) industrial waste treatment/recovery platforms

70% TRS ECOLOGY
Multifunctional platform management for special waste Caorso (PC)

60% CIRCULARYARD
Partnership with Fincantieri on shipyards

50% HEA
Partnership with Eni Rewind for industrial waste treatment plant in Ravenna

31% SEA
Ancona industrial waste treatment/recovery platform

20% TEAM SRL
Treatment plant for industrial liquid waste in Pesaro

*2025 data*

Subsidiary  Participated

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# WHAT IS THE FIB3R PROJECT?

Partnership between Herambiente, Curti and the University of Bologna for the valorization of carbon fiber scraps through thermal regeneration.

CURTI

## Targets

- Collecting and recovering carbon fiber scraps, now destined as disposal waste...
- ...through the industrial-scale construction of a treatment and recycling plant...
- ...capable of producing semi-finished products for the fabrication of new carbon fiber manufactures with a circular economy perspective.

## Companies involved

All supply chain players and end users in automotive, marine, aerospace, furniture, etc.

- Weavers
- Impregnators
- Moulders
- Users



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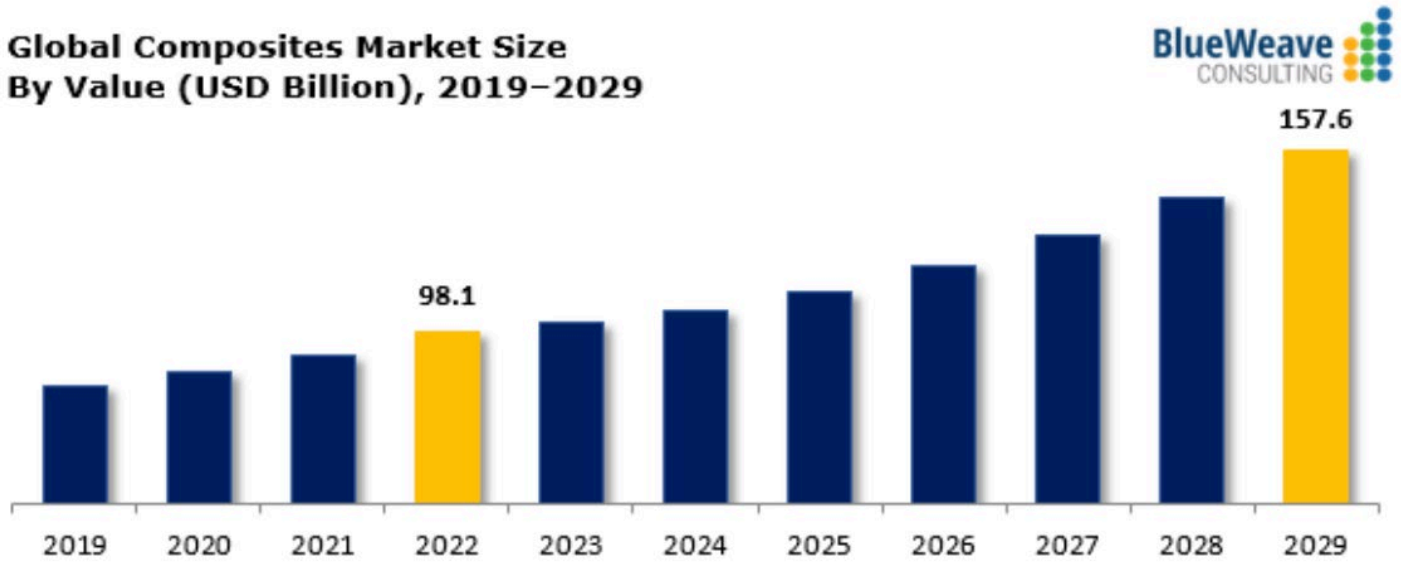
# THE DESIGN IDEA




*Demand for virgin carbon fiber and composite materials is estimated to increase to 2029, generating a gap between supply and demand that, with current industry capacity, will not be filled.*

- Growing focus of companies on reducing their impacts and sustainability of their business
- European legislation obliges many categories of manufacturers to use recycled components*
- Strong and steady growth in demand for virgin carbon fiber (over +9% per year)
- Demand for composite materials, formed from carbon fiber impregnated with glues and resins, follows the trend of virgin (10-12% per year)

**Production of recycled carbon fiber may fill the capacity gap between demand and virgin fiber production**

** E.g. 2015 EU directive mandates that 85% of end-of-life cars must be recycled/reused*

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# NEW LIFE TO CARBON FIBER SCRAPS

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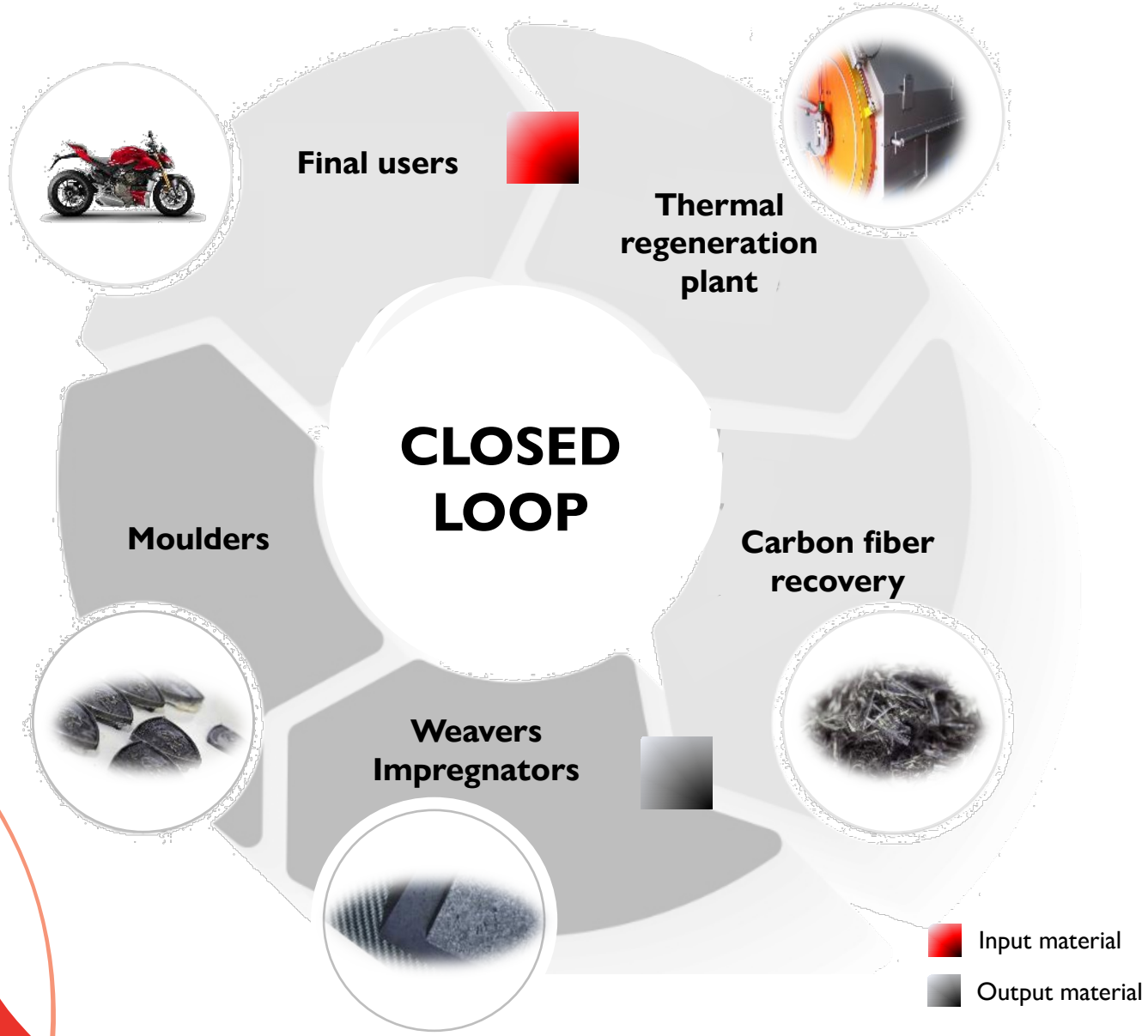


## INPUT CHARACTERISTICS

- Scrap
- Prepreg
- Cured and finished scraps
- End-of-life molds

## OUTPUT CHARACTERISTICS

- T300® (like)
- T700® (like)
- Mix T300®, T700® e high grade*

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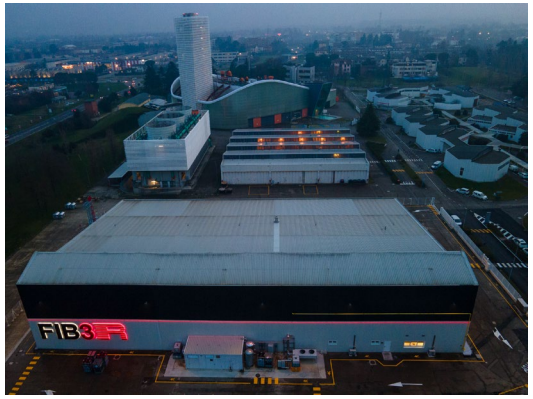



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Recover Reduce Reuse Carbon Fiber

# THE PLANT CURRENT STATE

**Plant building timelapse**

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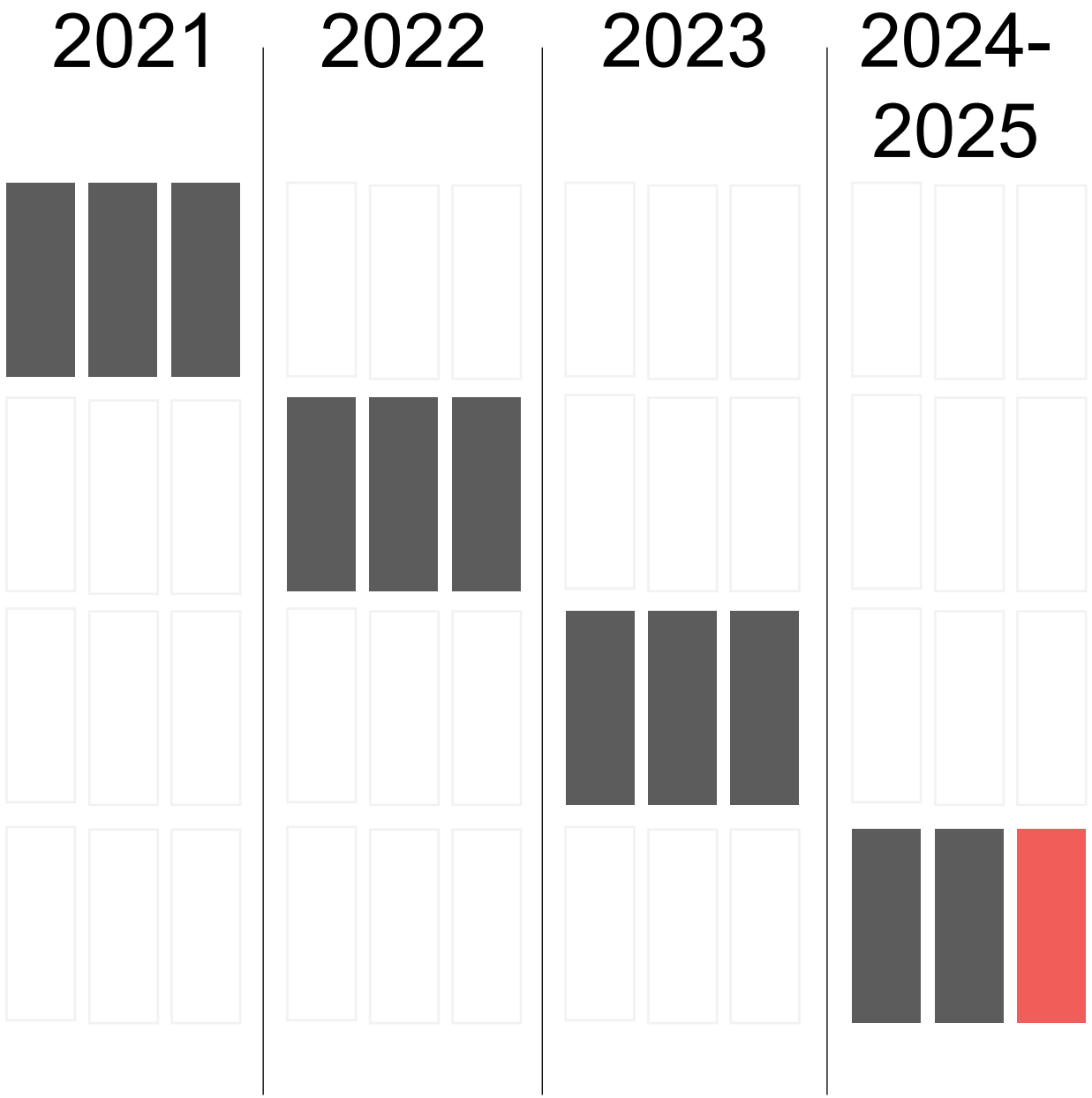
# TIMELINE

- Technical tests and environmental impact assessments with pilot plant
- Production campaigns for obtaining samples and test specimens
- Produced T300 TNT roll (200g/m$^2$ grammage, 1x20m).

- Approval process for construction of Imola plant started
- End of September obtained Unique Authorization

- Start of civil works
- End of the year, completion of civil works and start of construction of line 1

- **November 2024** start line 1
- **May 2025** start of testing line 1
- **June 2025 start of production line 1**



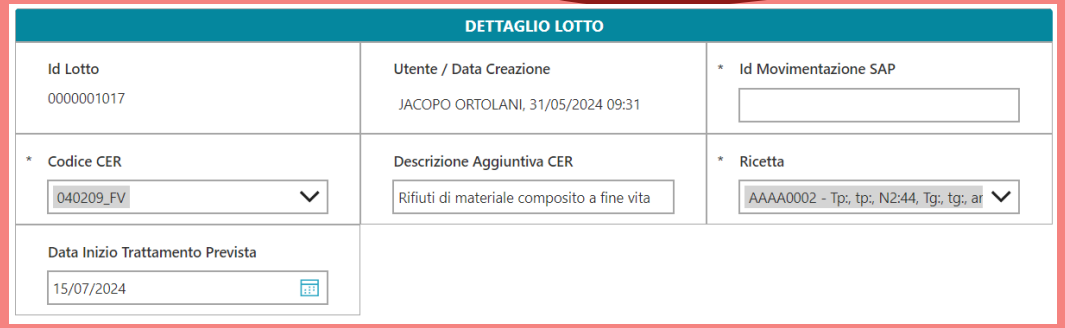
# DATA TRACEABILITY 1/2

1) Within the traceability app, the arrival of one or more lots at the plant is scheduled and planned. The waste delivered is then uploaded to the Hera portal, which provides the unique ID that identifies the entry of that waste. At this point, this screen appears in the "acceptance" section of the traceability app (1).

2) Then the ID is entered, so that there is a correlation between the HERA systems and those in the app. In addition, the app asks you to select the storage area: the first free storage area is automatically proposed.

3) Before waste can be sent for treatment, the app prompts to confirm whether or not (or even partially) the incoming batch is in compliance.

1




2


3

# DATA TRACEABILITY 2/2

4) When the first big bag is filled with recycled fiber (EoW), the application automatically creates a QR-code that identifies the processed batch (including the final storage area). The QR-code (and related information written on the side) is then printed and attached to each big bag, uniquely identifying it.

5) The big bag, labeled with all the information about the initial source, type of treatment, and location within the plant, can then be shipped to the final customer, which often coincides with the waste supplier upstream of the process. Shipment of the recycled carbon fiber is completed by a final quality check, carried out within the chemical laboratory, which is also located in the plant.

4

Id Mov. SAP: 0000052553
Numero: 1/1
Peso Big Bag: 3,000
Data Inizio Lavorazione Lotto: 05/06/2024
Data Fine Lavorazione Lotto: 05/06/2024
Data Fine Lavorazione Big Bag: 05/06/2024

5

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# DESCRIPTION OF THE PROCESS

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## 1 – PYROLYSIS

Incoming material is fed to the first reactor zone, consisting of the pyrolysis section, which operates in an inert atmosphere.

## 2 – GASIFICATION

The process is completed with the gasification section, which operates in an oxidizing atmosphere (air).

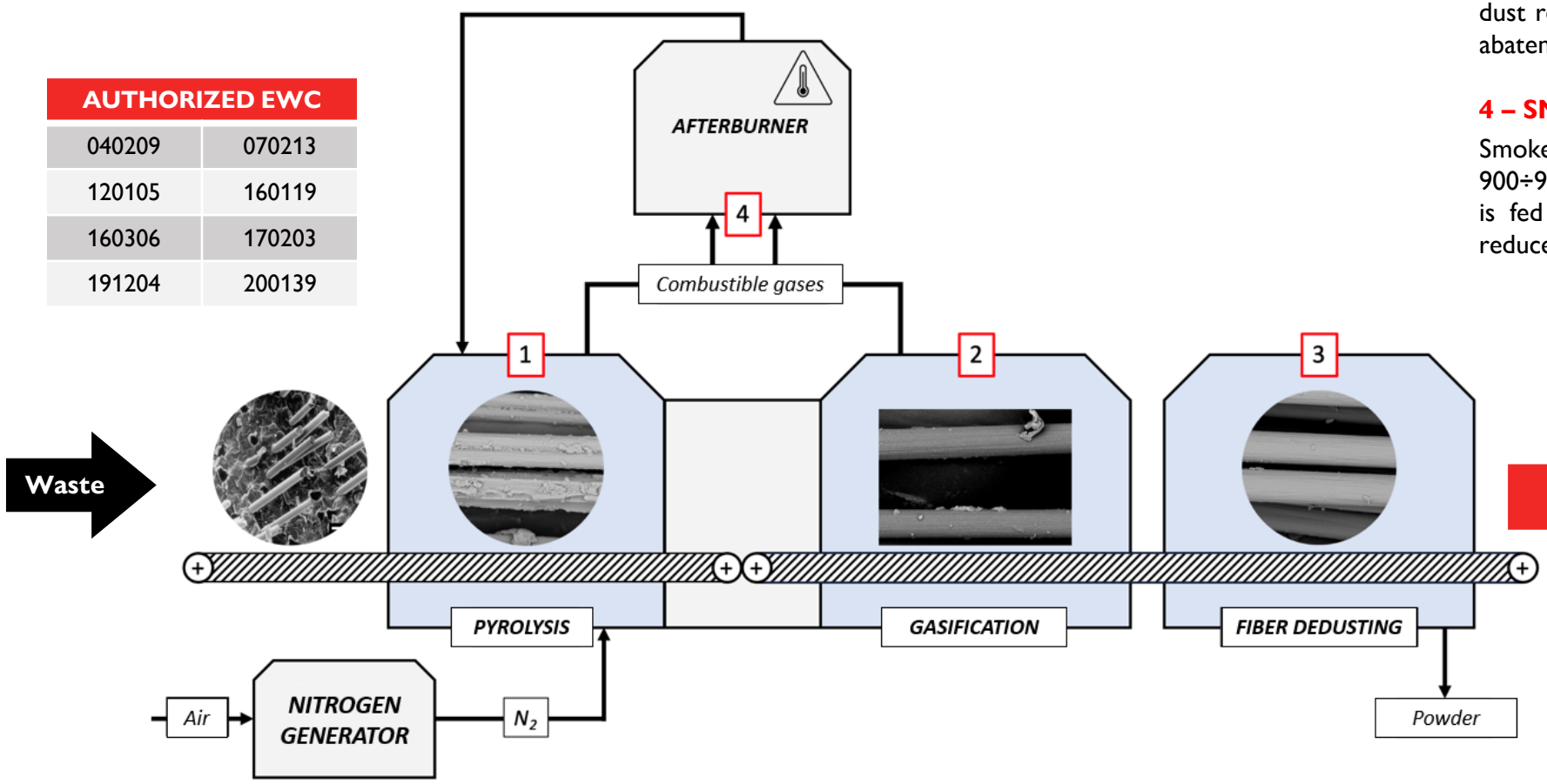
## 3 – FIBER DEDUSTING

The material is discharged onto the dedusting tape where the dust remaining in the fibers is vacuumed and sent to a special abatement system.

## 4 – SMOKE TREATMENT

Smokes from the afterburner, (having a temperature of 900÷920°C, thus ensuring complete combustion of pollutants) is fed to the burners of the pyrolysis section in order to reduce methane consumption.

| AUTHORIZED EWC | |
|---|---|
| 040209 | 070213 |
| 120105 | 160119 |
| 160306 | 170203 |
| 191204 | 200139 |




**Carbon Fiber EOW**

From 160 tons/year input per line, 80 tons/year of recycled material is obtained (efficiency about 50%)

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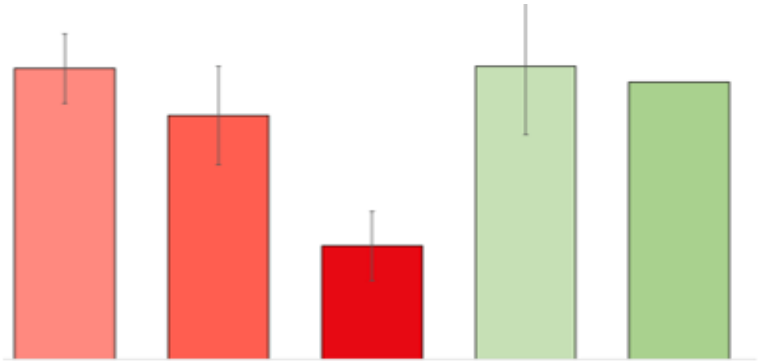
# MECHANICAL PROPERTIES OF CF AND RCF

## F AND rCF

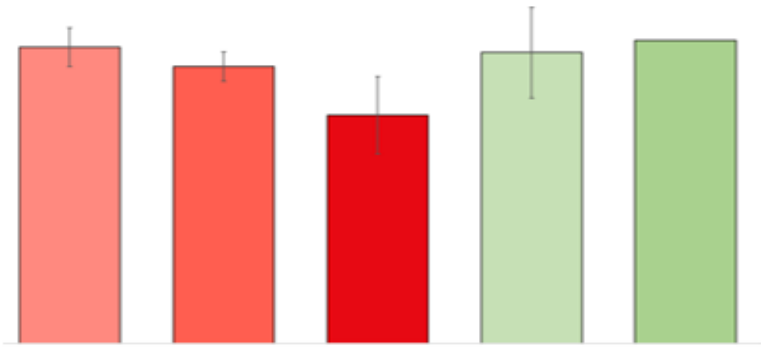
Strain at break [GPa]



- **Test 1**: Temperature ($T_1$); Residence time ($t_1$)
- **Test 2**: Temperature ($T_2$); Residence time ($t_2$)
- **Test 3**: Temperature ($T_3$); Residence time ($t_3$)
- **Virgin Fibers**: Experimental tests
- **Virgin Fibers**: Data Sheet

- $T_3 > T_2 > T_1$
- $t_3 > t_2 > t_1$

Elastic Modulus [GPa]



- **Test 1**: Temperature ($T_1$); Residence time ($t_1$)
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- **Test 3**: Temperature ($T_3$); Residence time ($t_3$)
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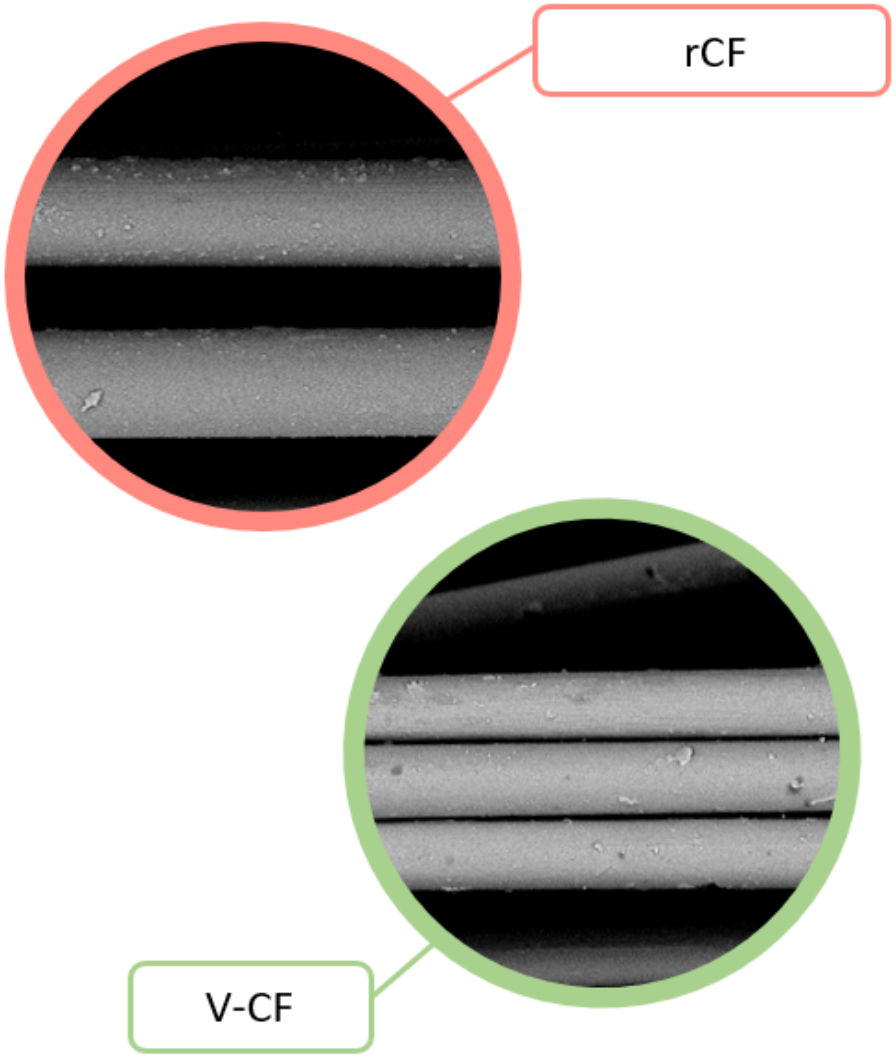
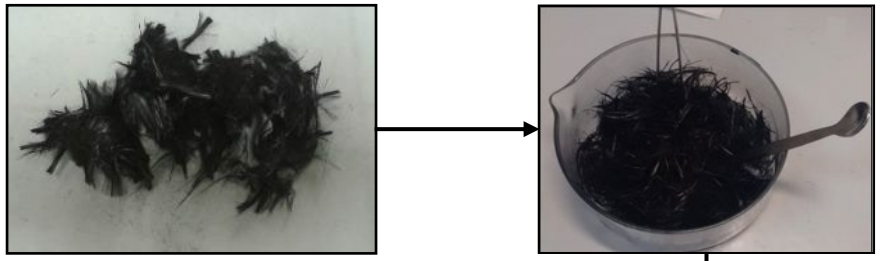
- $T_3 > T_2 > T_1$
- $t_3 > t_2 > t_1$



# REUSE OF CARBON FIBERS FOR THE PRODUCTION OF SHORT FIBER COMPOSITES

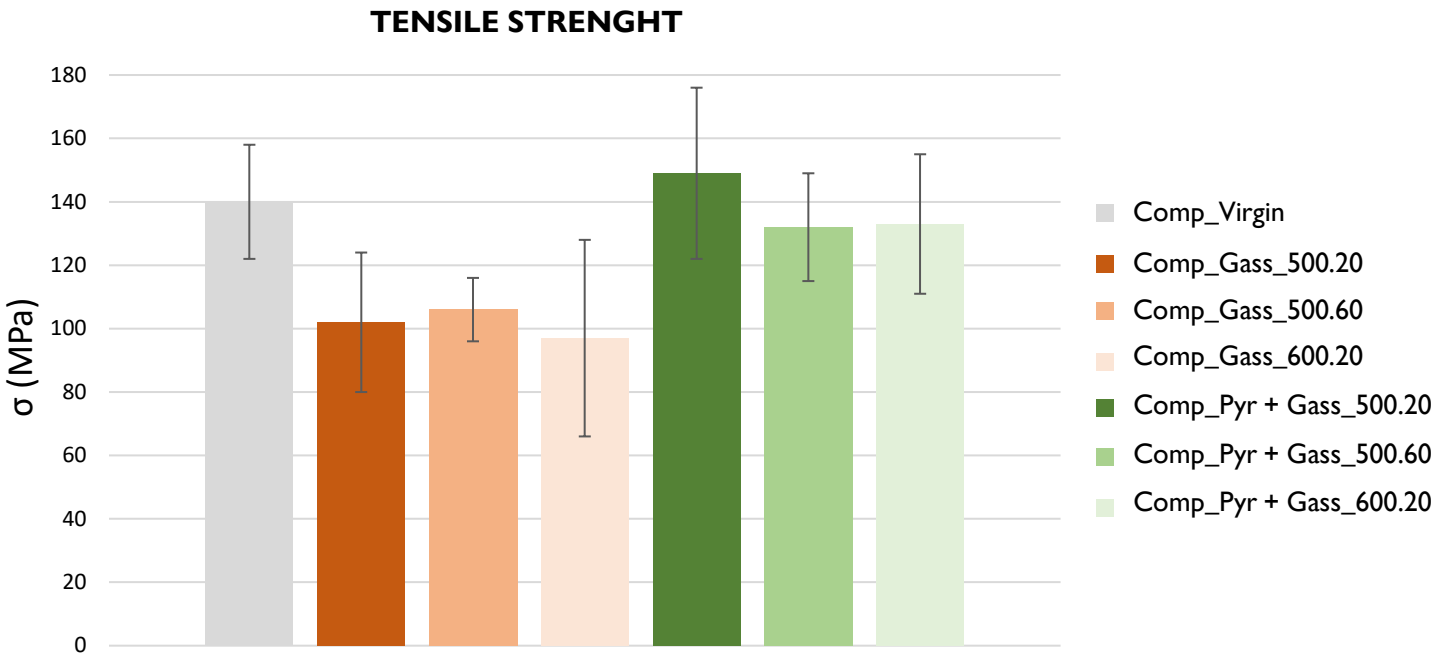
2cm-length and disentangled CFs

Fiber:Resin = 60:40





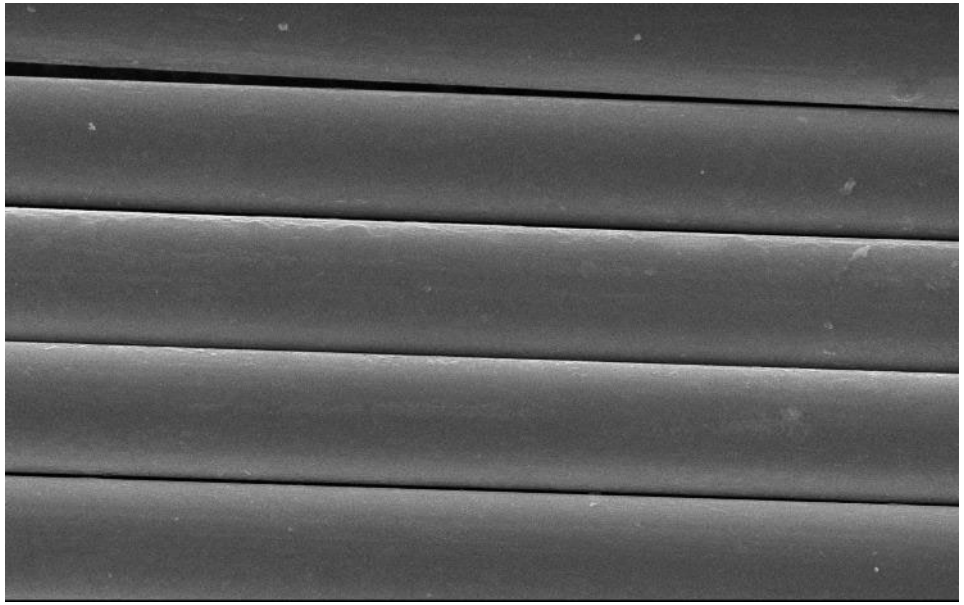
Hot-press cured for 30 min. a 90° C and 45 min. a 110° C




Composites obtained using carbon fibers from pyrogasification show excellent mechanical properties, similar to those of the composite obtained from untreated virgin fiber.

*Source: L. Giorgini et al. , Composite, Part A, 112, 504-514 (2018).*

# APPEARANCE AND PROPERTIES OF TREATED FIBERS



| PARAMETERS - TREATED FIBERS | VALUE | STD. DEV. |
|---|---|---|
| ELASTIC MODULUS (GPa) | 210 | 12 |
| STRENGTH AT BREAK (GPa) | 3,8 | 0,3 |
| ELONGATION AT BREAK (%) | 1,68 | 0,10 |

| PARAMETERS - VIRGIN FIBERS | VALUE | STD. DEV. |
|---|---|---|
| ELASTIC MODULUS (GPa) | 209 | 6 |
| STRENGTH AT BREAK (GPa) | 4,4 | 0,4 |
| ELONGATION AT BREAK (%) | 2,02 | 0,14 |

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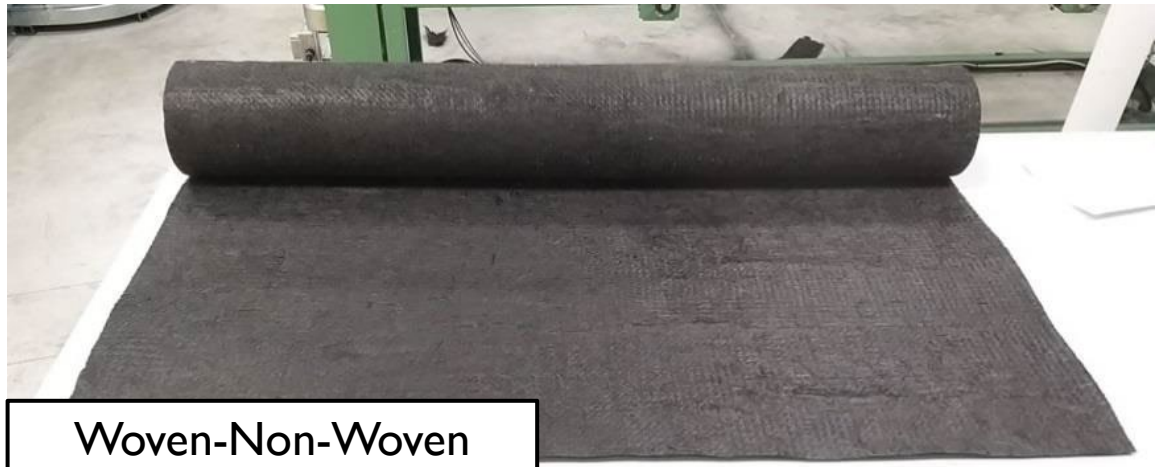
# APPEARANCE OF THE TREATED MATERIAL

Pre-treatment

Post-treatment



Woven-Non-Woven

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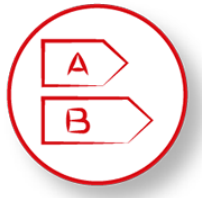
# WHY CHOOSE RECOVERED CARBON FIBER?




## 75% SAVING ON ENERGY CONSUMPTION

compared to that used in production of virgin fibres

## INFINITE RECYCLING POTENTIAL

## TECHNICAL FEATURES AND SIMILAR PERFORMANCE

to that of virgin carbon fibre

## ENVIRONMENTAL IMPACT OF THE ENTIRE LIFE CYCLE REDUCED BY 74%

in terms of greenhouse gas emissions

Our recovery technology solution has **50%* lower LCA impacts** than common ways of treating and disposing of carbon fiber waste

## REDUCTION OF WASTE DISPOSAL IN LANDFILLS

** Impacts of reCFs are reduced by about 42% for climate change and 57% for resource impact categories for human health and ecosystem quality.*

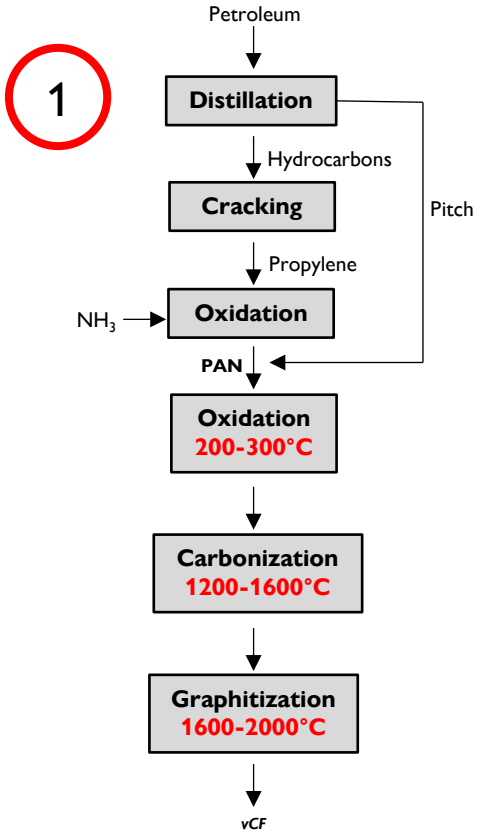
# LCA ANALYSIS 1/3

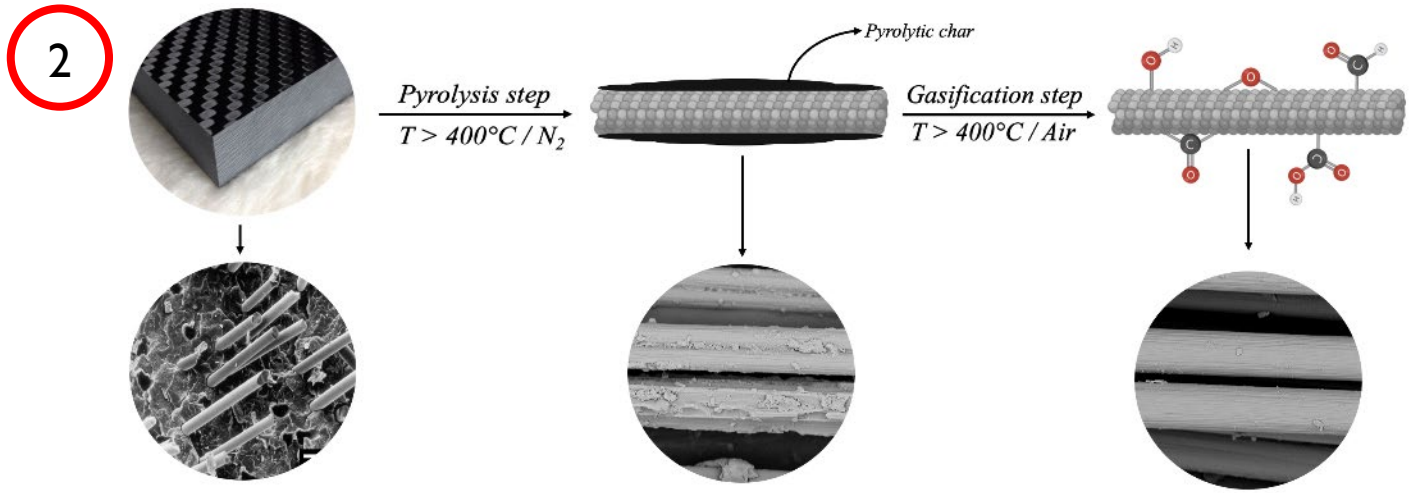
Life-cycle assessment (LCA) is a structured and internationally standardized method for quantifying the potential environmental and human health impacts associated with a good or service from its respective resource consumption and emissions.

The present study is taken from the article [1] concerning the pyrogasification process on composite scrap in a semi-industrial plant in order to recover and recycle carbon fibers, as shown in the diagram below.

*[1] Cacci, L.; Zattini, G.; Tosi, C.; Berti, B.; Passarini, F.; Giorgini, L. Carbon Fibers Waste Recovery via Pyro-Gasification: Semi-Industrial Pilot Plant Testing and LCA. Sustainability* **2022**, *14 (7), 3744.*

## *PRODUCTION OF VIRGIN FIBERS (1) vs. PROCESS FOR PRODUCTION OF rCF (2)*




The energy demand for producing 1 kg of recycled fiber is **75 percent less than that required to obtain the same amount of virgin fiber.**

From the thermic process, an End of Waste (EoW) product, i.e., a second raw material, is obtained to be re-introduced within the production cycle.

# LCA ANALYSIS 2/3

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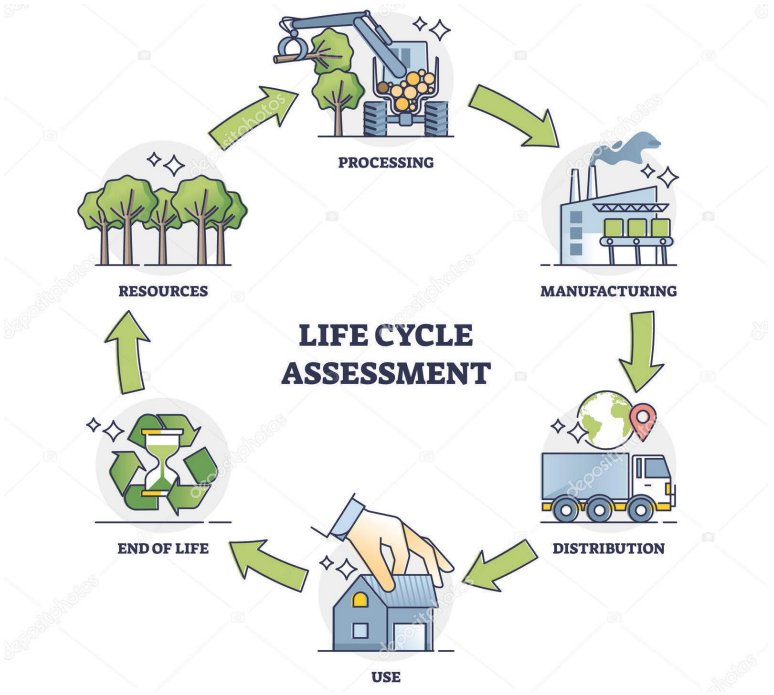
In collaboration with the University of Bologna, we are carrying out two types of LCA analysis:

- **PROCESS LCA**: allows to assess the impact of the plant in its entirety
- **PRODUCT LCA**: allows an assessment of the environmental impact, in terms of energy and emissions, of the recycling operation versus disposal, in relation to a specific product

**The first results will be available by the end of 2025.**

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA



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# LCA ANALYSIS 3/3

The first preliminary estimates already offer significant values:

## Methods

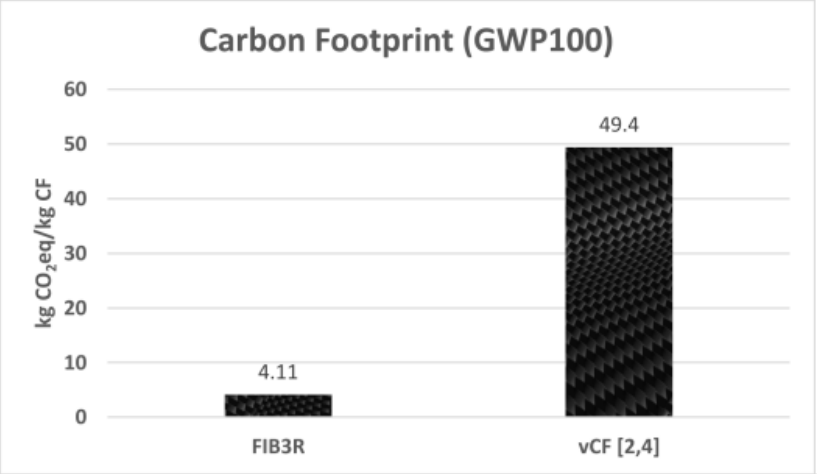
ISO 14040 ISO 14044

LCA is the preferred methodology for the quantitative evaluation of the environmental impacts of a product system throughout its life cycle.

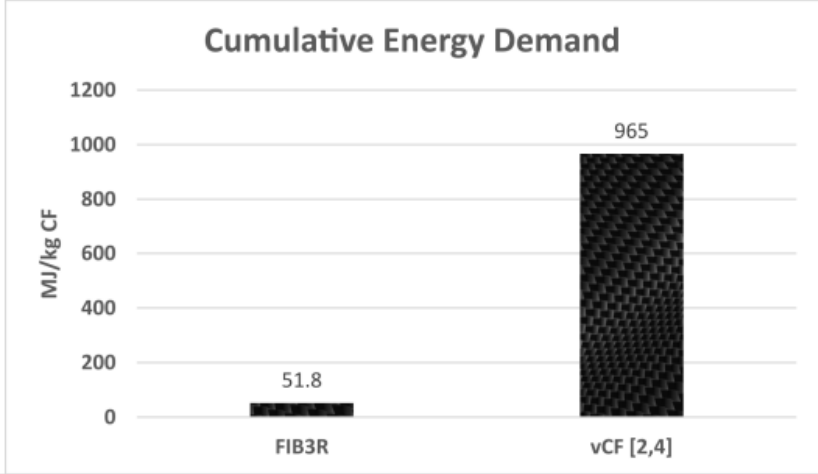
- **Functional unit and reference flow:** 1 kg of carbon fiber (CF).
- Primary data from FIB3R plant.
  - Mass and energy inputs.
  - Wastes and emissions.
- **Life Cycle Impact Assessment:** single-issues analyses for preliminary results.
  - IPCC Global Warming Potential (100-year time horizon).
  - Cumulative Energy Demand (CED).

## Results & Discussion

From a preliminary estimation, the GHG emissions amount to **4.11 kg $CO_2$ eq/kg CF**. A significant **reduction of 91.7%** compared to the virgin CF (vCF) production. The main contributor to this category are the direct emission of $CO_2$ from the chimney (46%) and the electricity required (43%).




The CED for the process amounts to **51.8 MJ/kg CF**, corresponding to a **reduction of 94.6%** relative to the primary production.
These reductions can be viewed as a "budget" that will be spent on the waste treatment steps (collection, transport, separation) of the composite materials.



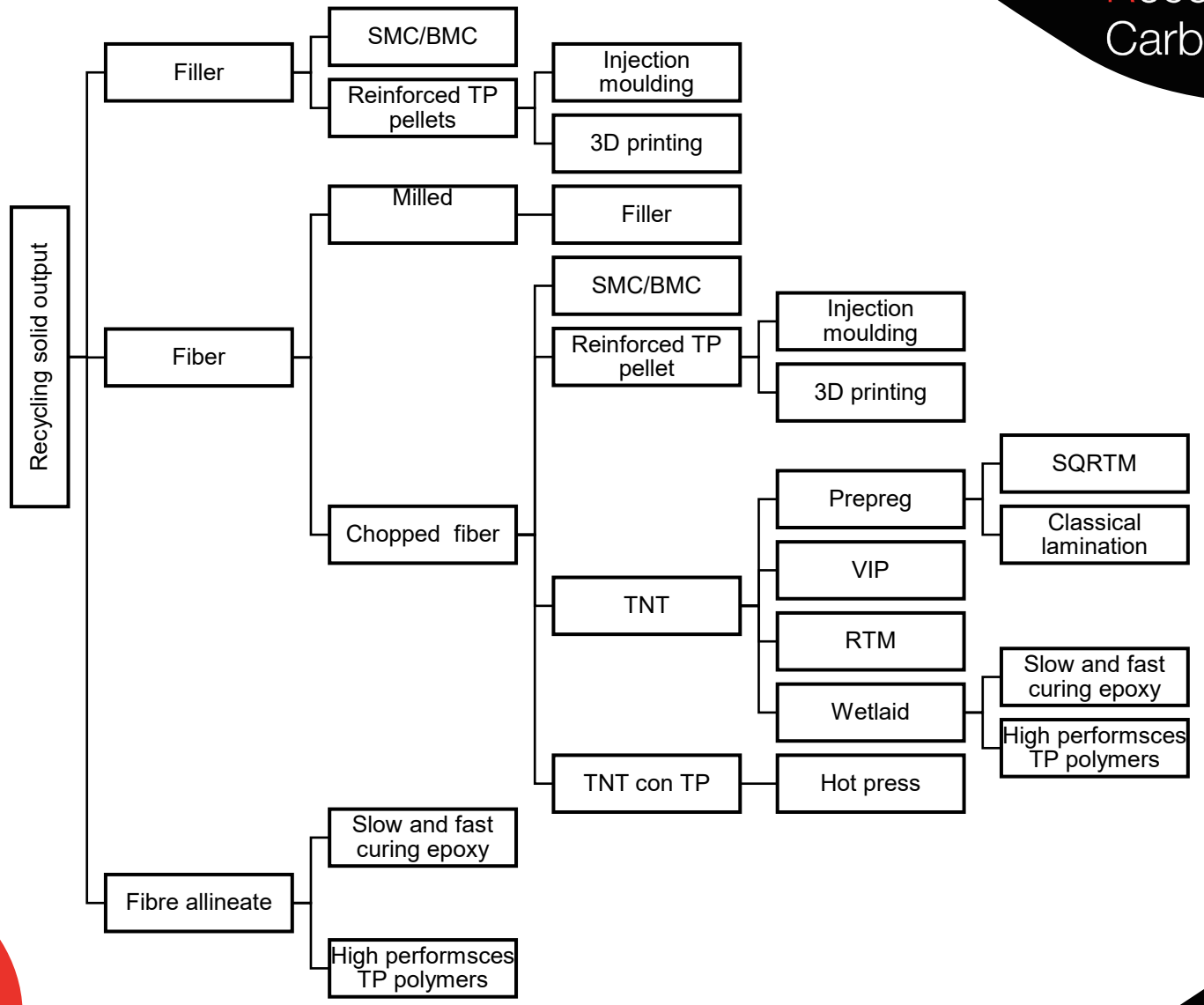
# SUMMARY

- HERA GROUP – HERAMBIENTE GROUP
- THE FIB3R PROJECT
- THE DESIGN IDEA
- NEW LIFE TO CARBON FIBER SCRAPS
- THE PLANT – CURRENT STATE
- TIMELINE AND DATA TRACEABILITY
- DESCRIPTION OF THE PROCESS
- MECHANICAL CHARACTERIZATION OF CF AND RCF
- PROJECT BENEFITS AND LCA
- POSSIBLE RCF APPLICATIONS

FIB3R
Recover Reduce Reuse
Carbon Fiber

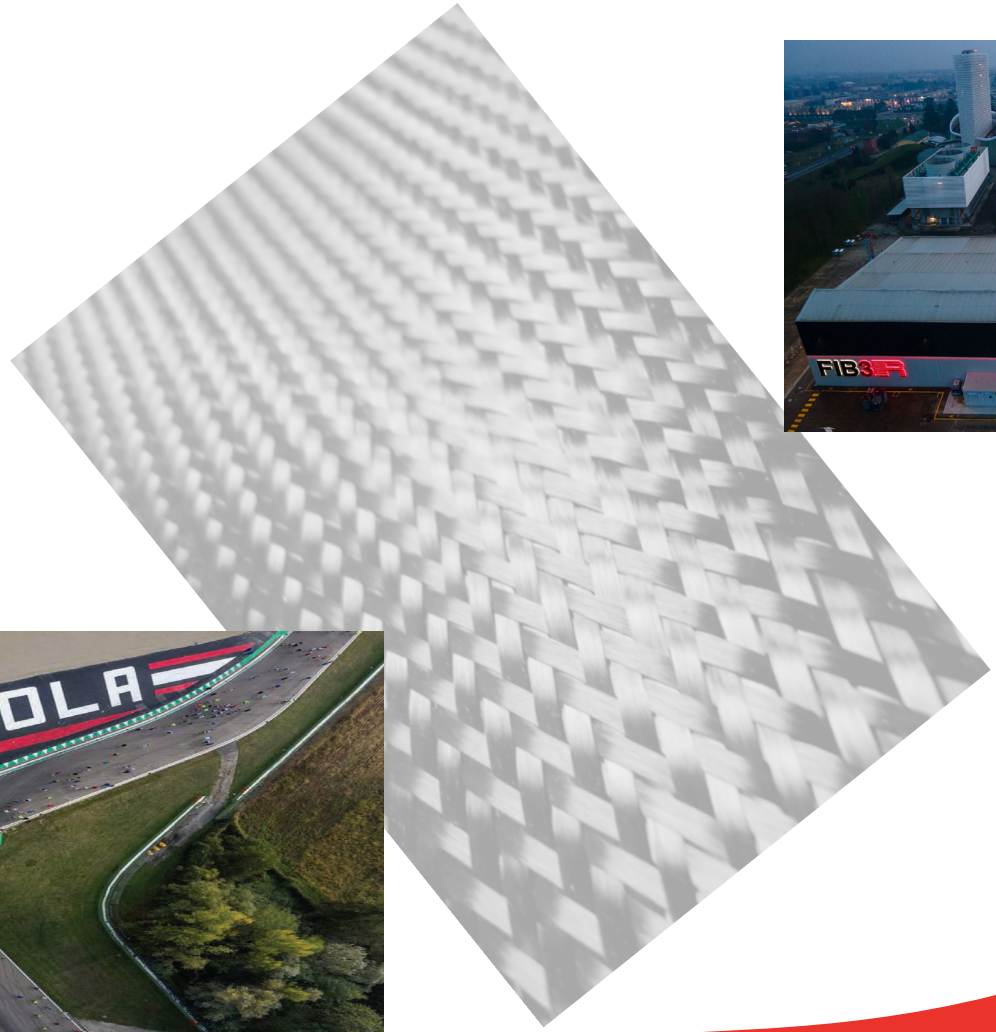
# POSSIBLE RCF APPLICATIONS

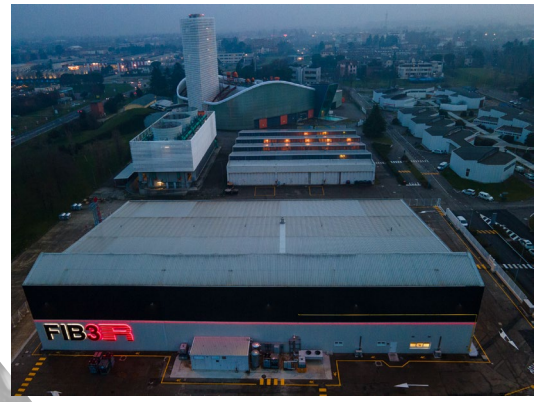
FIB3R
Recover Reduce Reuse
Carbon Fiber



# FIB3R

Recover Reduce Reuse
Carbon Fiber








**FOR MORE INFORMATION ABOUT THE PROJECT**

www.herambiente.it/recovery/new-life-to-carbon-fiber

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Società del Gruppo Hera