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Biochar Production and Use, and its Current Status in the World

D. Casini, F. Tozzi, A.M. Rizzo, D. Chiaramonti

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Introduction
RE-CORD

Who we are

RE-CORD is a private, not for profit, research center, whose members are:

We are a **multi-disciplinary team,** made of 23+ researchers, covering the disciplines of: engineering, chemistry, biotechnology, agronomy, etc.

we perform **independent research activities** to support Innovative Industries in the development of new sustainable processes for renewable energy and valuable materials recovery.

Headquarter
Laboratory & offices
Scarperia (FI)

REC PARK
Experimental Area
Scarperia (FI)

EC projects office @UNIFI
DepartmentofIndustrial Engineering
Firenze

Experimental area
AGRO-BIO
Agricultural field trials
S. Casciano Val di Pesa (FI)

REC-PARK
Thermochemical units

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- Slow Pyrolysis unit, rotary kiln
- Downdraft oxydative pyrolysis unit
- Intermediate (catalytic) pyrolysis unit
- Slow/intermediate pyrolysis unit, screw
- Hydrothermal microreactor system
- HydroThermal Liquefaction unit
- Downdraft Imbert-type gasifier
- Adapted Capstone Microturbine
- Fractional condensation unit
- Chemical leaching unit
- Lab-scale furnace for char activation

Biochar tailoring in Pilot & Industrial units, LAB assessment

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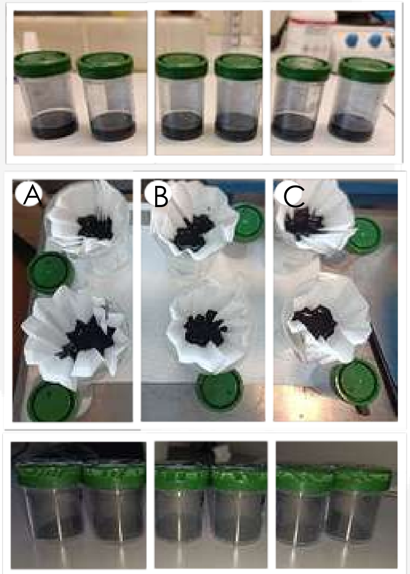
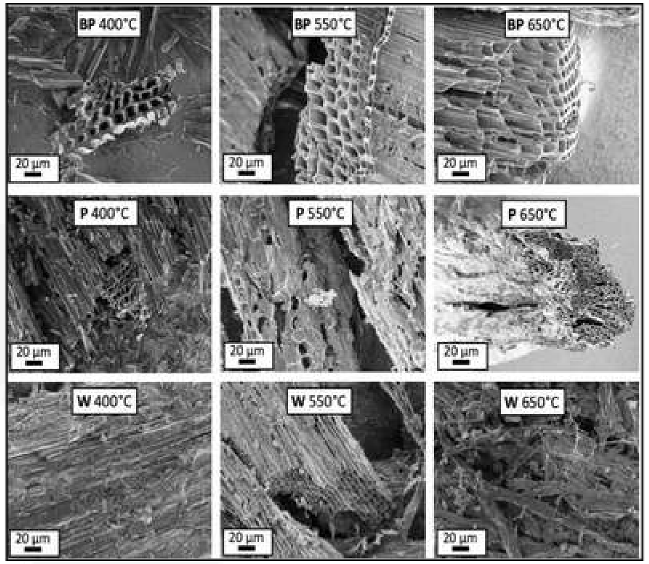
- **Tailored biochar production** for specific applications through feedstock and process parameters selection. Product performances evaluation and comparison.
- Development of **custom-made products**: drug delivery vector, additive for microbiological
- processes, sorption material, nutrient retention, etc.
- Post-production treatments to comply **specific quality standards** for different potential enduses (e.g., soil improver, nutraceutical and pharmaceutical grade, etc.)



Oxidation

Feedstock selection



Porosity investigation


Co-composting

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Section 1

Biochar

What is biochar?

<< Lehmann and Joseph (2009) distinguished biochar operationally from charcoal. Primarily, the difference betweenthese two terms liesinthe end use. The charcoal is a source of charred organic matter for producing fuel and energywhereas **thebiochar can be applied for carbon sequestration and environmental management**. >>

M.Ahmadetal.(2014).Biocharasasorbentforcontaminantmanagement in soil and water: A review. Chemosphere. Vol. 99. Pg. 19-33.

<< Biochar is a porous, carbonaceous material that is produced by pyrolysis ofplant biomasses and isapplied in such a waythatthe containedcarbon **remains stored as a long-term C sink or replaces fossil carbon in industrial manufacturing. It is not made to be burnt for energy generation**. >>

N.Hagemann,H.P.Schmidt - EBCCertificationofBiochar - TheEuropeanIndustryStandardCarbonSinkCertification.

Slow pyrolysis process

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Thermally induced chemical decomposition of organic materials in the absence (or limited presence) of oxygen is defined as pyrolysis.

FEEDSTOCK

HEAT

PYROLYSIS

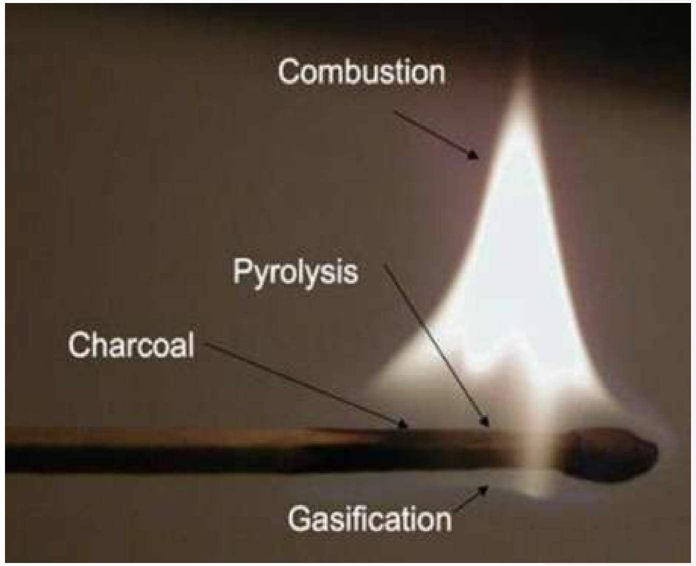
CHAR
(SOLID RESIDUE)

LIQUIDS
(CONDENSABLE GASES)

- BIO-OIL
- WOOD VINEGAR (AQUEOUS PHASE)

GASES
(NON CONDENSABLE)

- CO, CO2, CH4, H2, CXHY



Slow pyrolysis process

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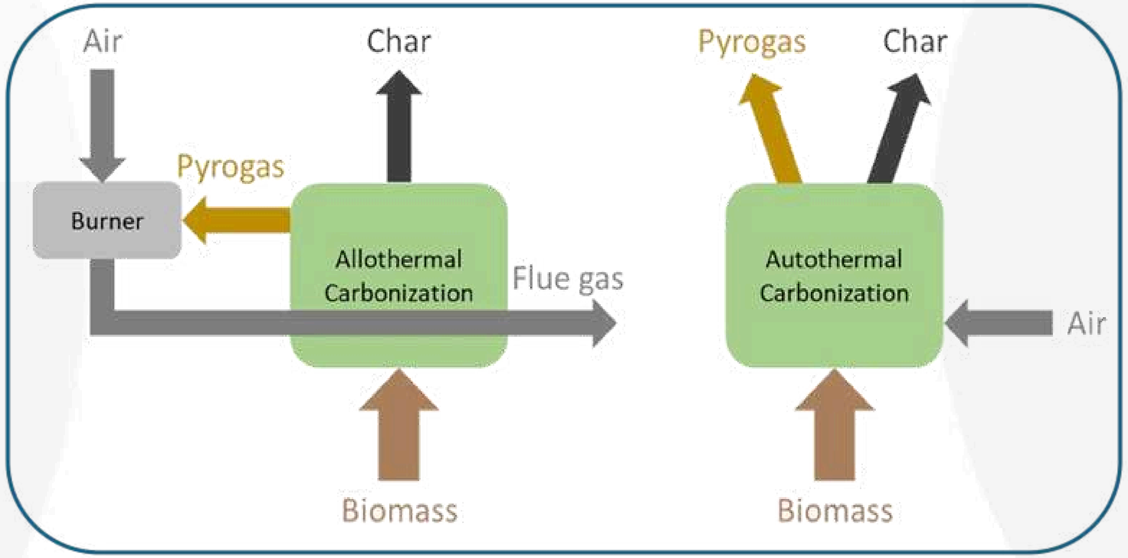
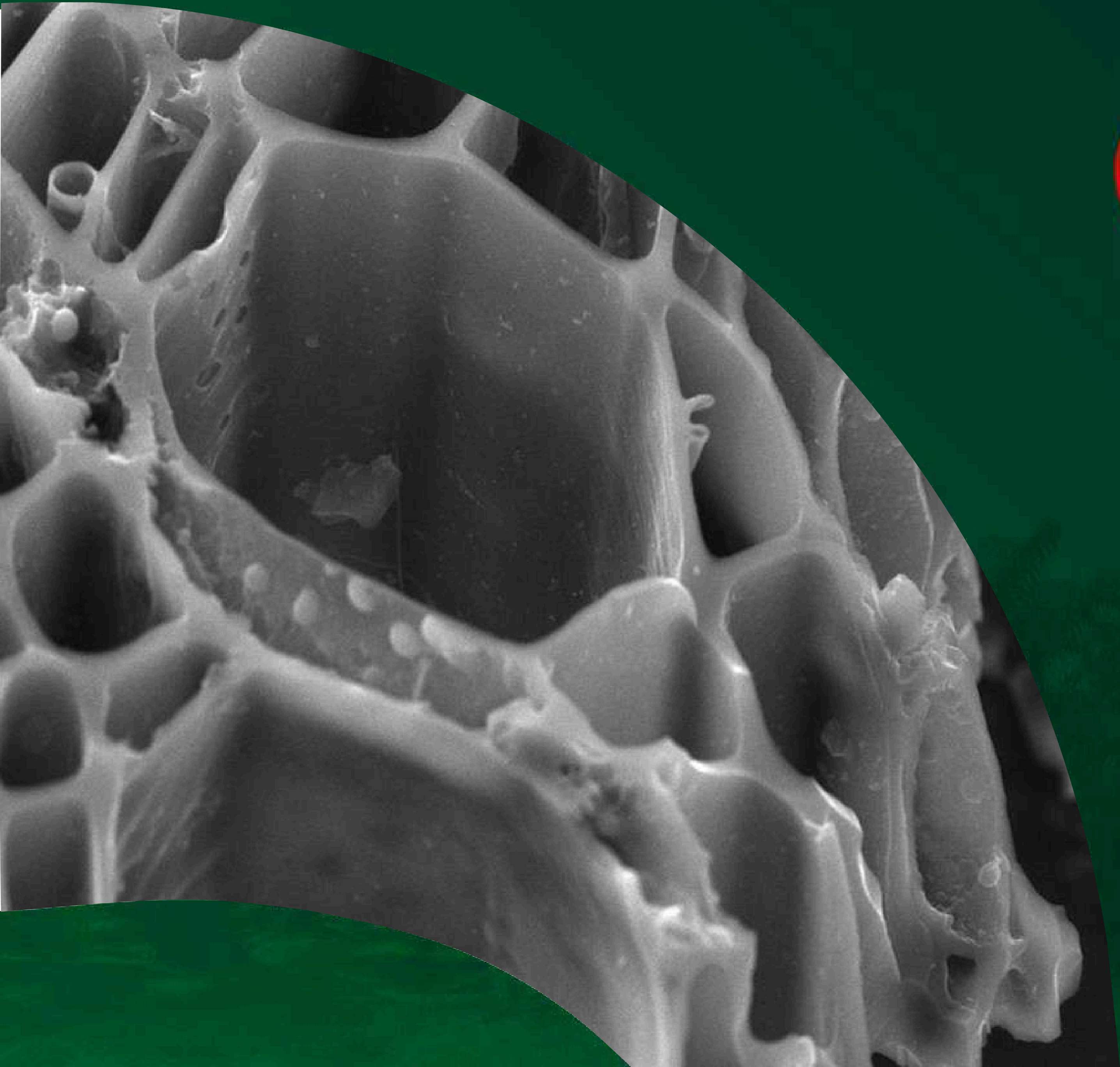
- **Solid residue maximization**, by weight. Productqualityandquantity depends on process parameters and feedstock properties
- Wide range of technologies at different scales. Heat recovery.
- **Self-sustained process**, as combustion of the syngas
- **Oxidative pyrolysis** of biomass is an **autothermal process** in which the energy can be provided by the combustion between oxygen and organic matter from biomass





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Section2

Biochar properties

Biochar stability

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Biomass and Bioenergy 203 (2025) 108365

Contents lists available at ScienceDirect

Biomass and Bioenergy

journal homepage: www.elsevier.com/locate/biombioe

Biochar and its impact on the carbon cycle

David Chiaramonti [a,*], Franco Berruti [b], Johannes Lehmann [c], Ondrej Masek [d], Henrik Ingermann Petersen [h], Manuel Garcia Perez [f], Hamed Sanei [e], Francesco Primo Vaccari [g]

Chiaramonti *et al. Biochar* (2024) 6:81
https://doi.org/10.1007/s42773-024-00366-7

Biochar

PERSPECTIVE Open Access

Biochar is a long-lived form of carbon removal, making evidence-based CDR projects possible

David Chiaramonti[1*], Johannes Lehmann[2], Franco Berruti[3], Paola Giudicianni[4], Hamed Sanei[5] and Ondrej Masek[6]

<< Carbonization reactions converts the organic matter into a **more durable form of carbon**, slowing down the return of a portion of this carbon to the atmosphere by microbial activity in soil and sediments. [...] at pyrolysis temperatures typically at 550–600 ◦C >>

Biochar Carbon Removal

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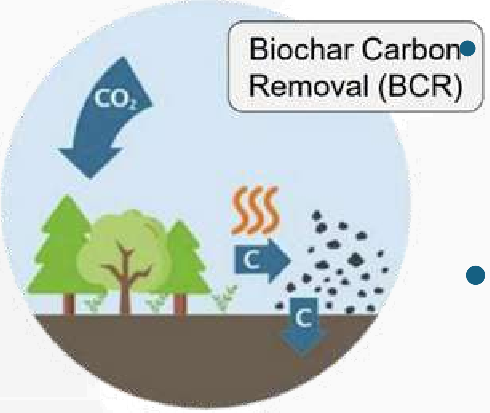
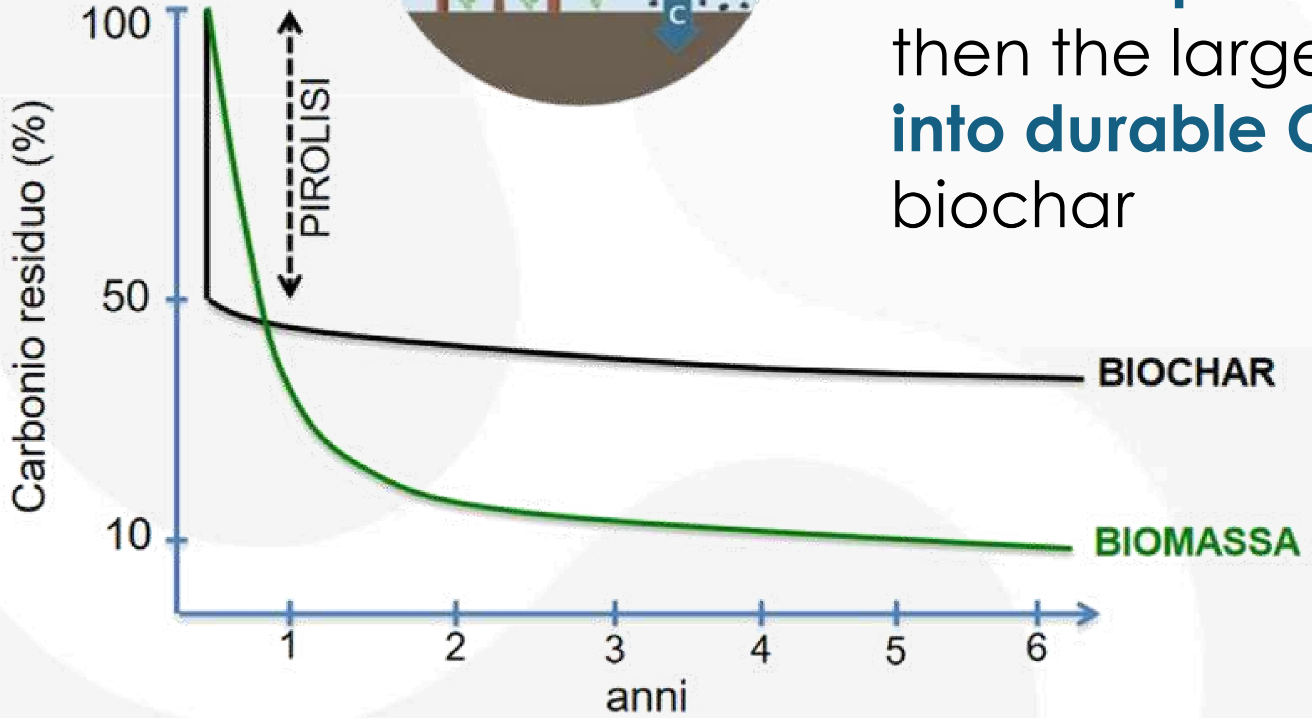


BCR enables the capture and sequestration of atmospheric C bycombiningphotosynthesisand carbonization of biomass

- **CO2 is captured** by plants through **photosynthesis**, then the largest share of carbon is converted into **into durable C** through pyrolysis and stored in biochar



BIOCHAR → STABLE C, RECALCITRANT FORM → **BCR**

BIOMASSA → LABILE C, DECOMPOSITION AND MINERALIZATION → CO_2 RELEASE

Inertinite assessment and random reflectance analysis

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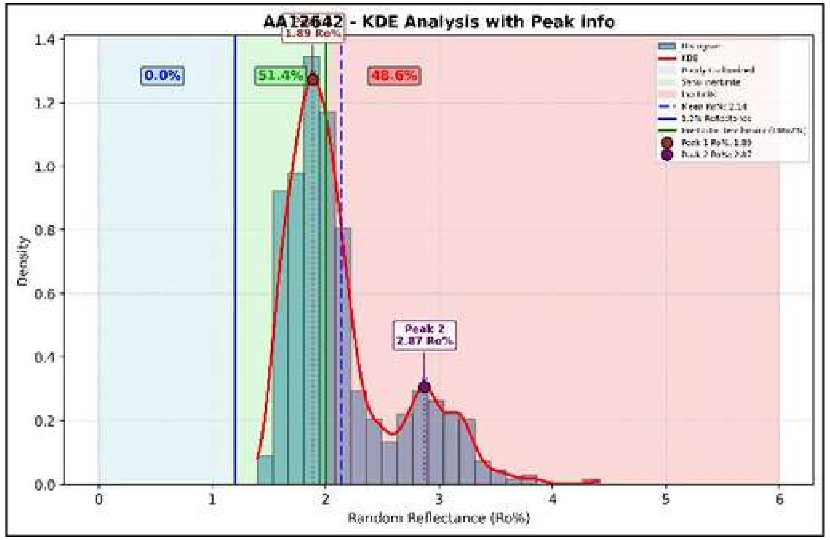
Inertinite is a group of inert organic components found in coal and other carbonaceous materials.
It is a highly durable form of carbon, making it very resistant to chemical and biological degradation (will not relevantly degrade in soils within climate-relevant periods).


International Journal of Coal Geology 281 (2024) 104409
Contents lists available at ScienceDirect
International Journal of Coal Geology
journal homepage: www.elsevier.com/locate/coal

Assessing biochar's permanence: An inertinite benchmark

Hamed Sanei [a,*], Arka Rudra [a], Zia Møller Moltesen Przyswitt [a], Sofie Kousted [a], Marco Benkhettab Sindlev [b], Xiaowei Zheng [a], Søren Bom Nielsen [a], Henrik Ingermann Petersen [c,*]

Random reflectance is a new method to determine the various C shares in biochar. The analysis recognizes these various Carbon forms in biocharvialightreflectance.



Porosity characterization

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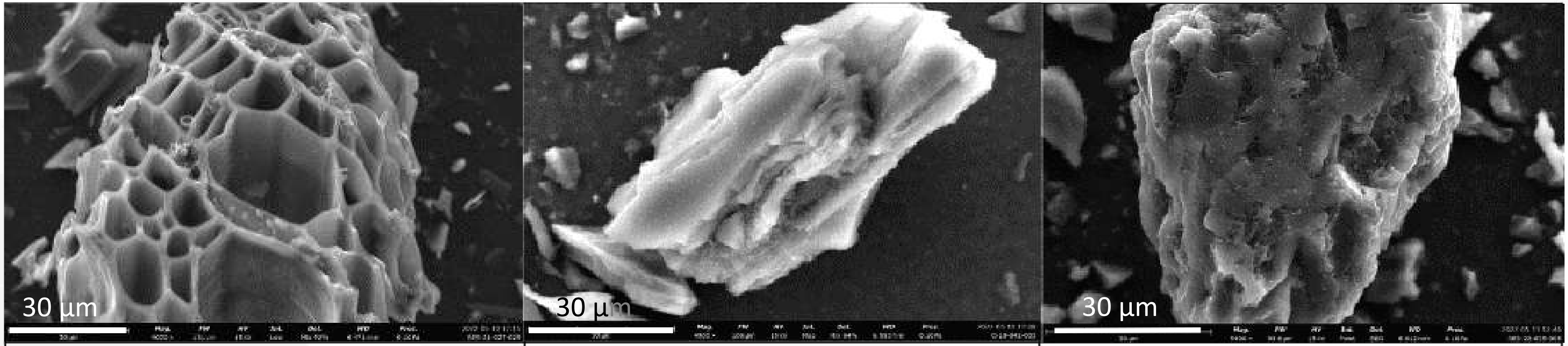
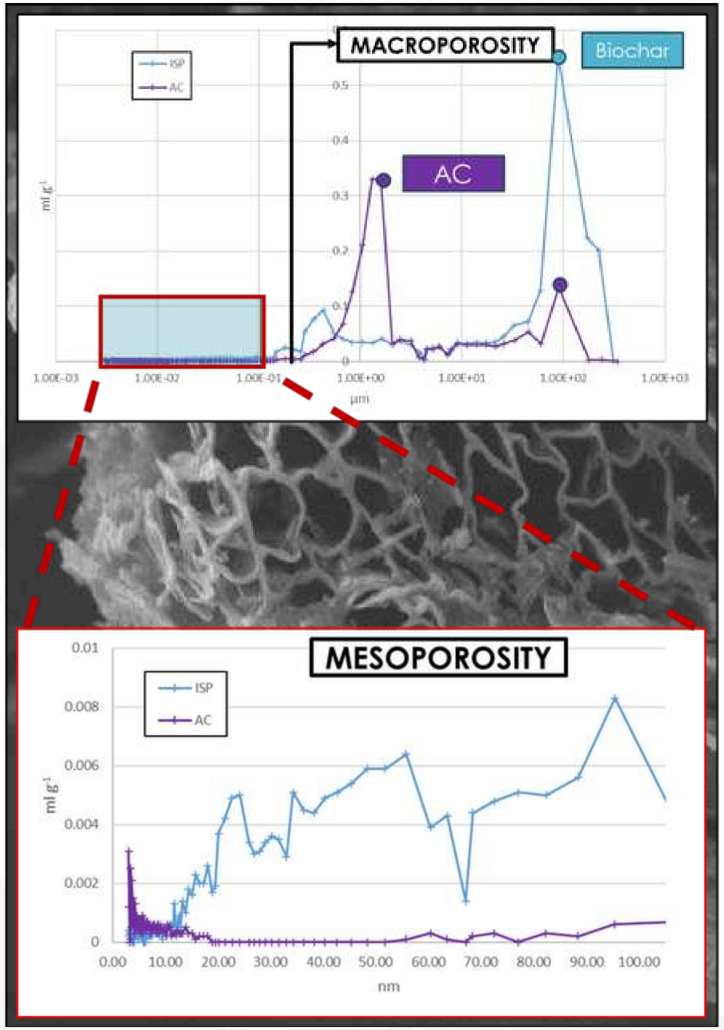


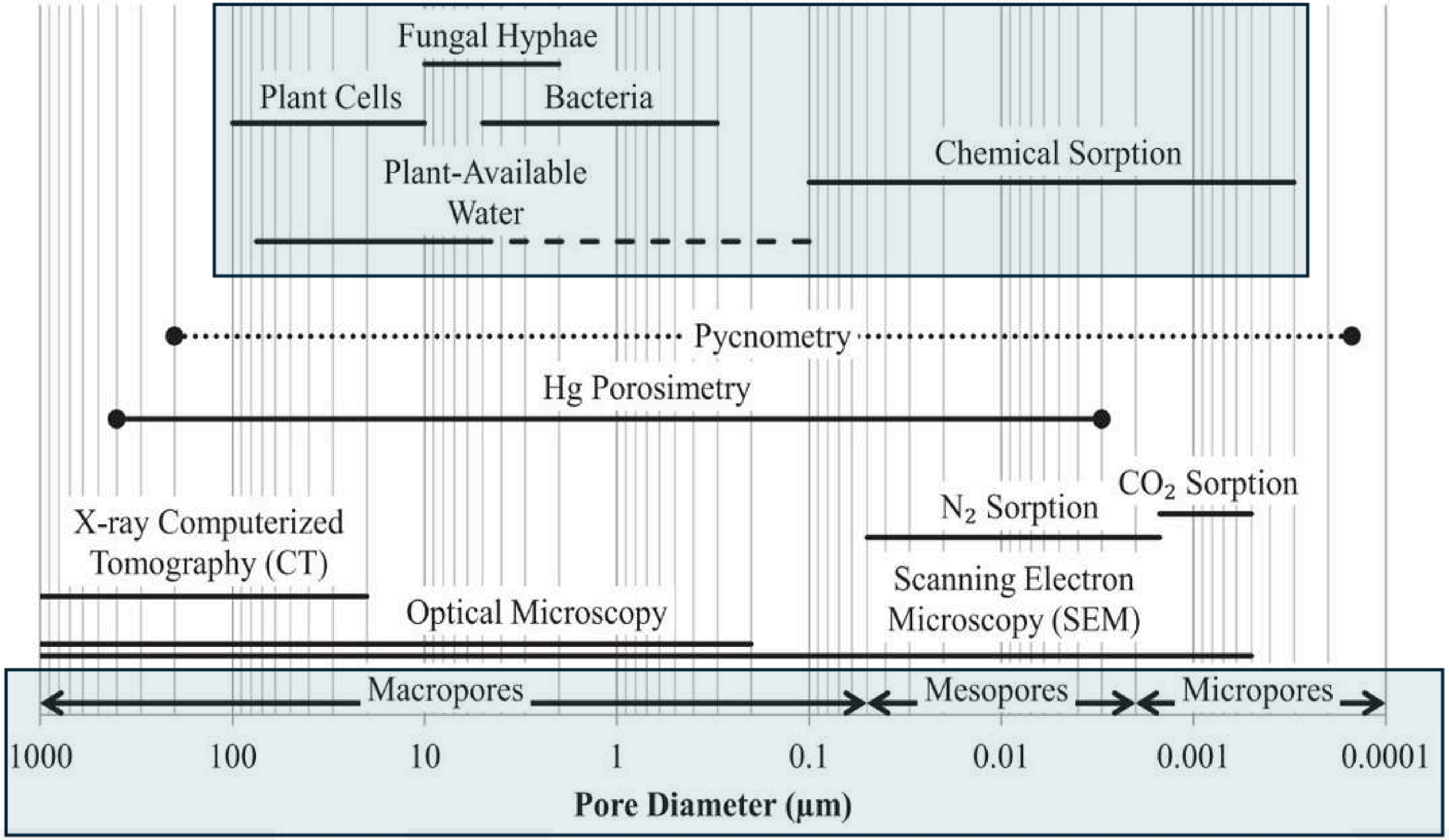
Alder biochar	Activated carbon 1	Activated carbon 2

Biochar can act as a **sponge**, a **carrier** or a **filter** depending on the pores size distribution of its carbonaceous structure.

That means it can increase soil water and nutrient retention ability, and CEC. It can be inoculated with microorganisms, etc.

Porosity study

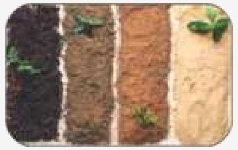




Soil improver

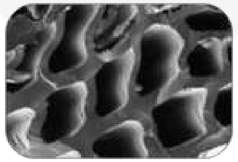
The effective results of biochar application to the soil are the outcome of the interplay of multiple factors:

Pedo-climatic characteristics



Soil properties

Crop



Biochar properties

* Water savings
*Improved fertilizationefficiency
* Improved soil fertility
* Increased crop yields
* Soil carbon sequestration
* pH buffering
et cetera

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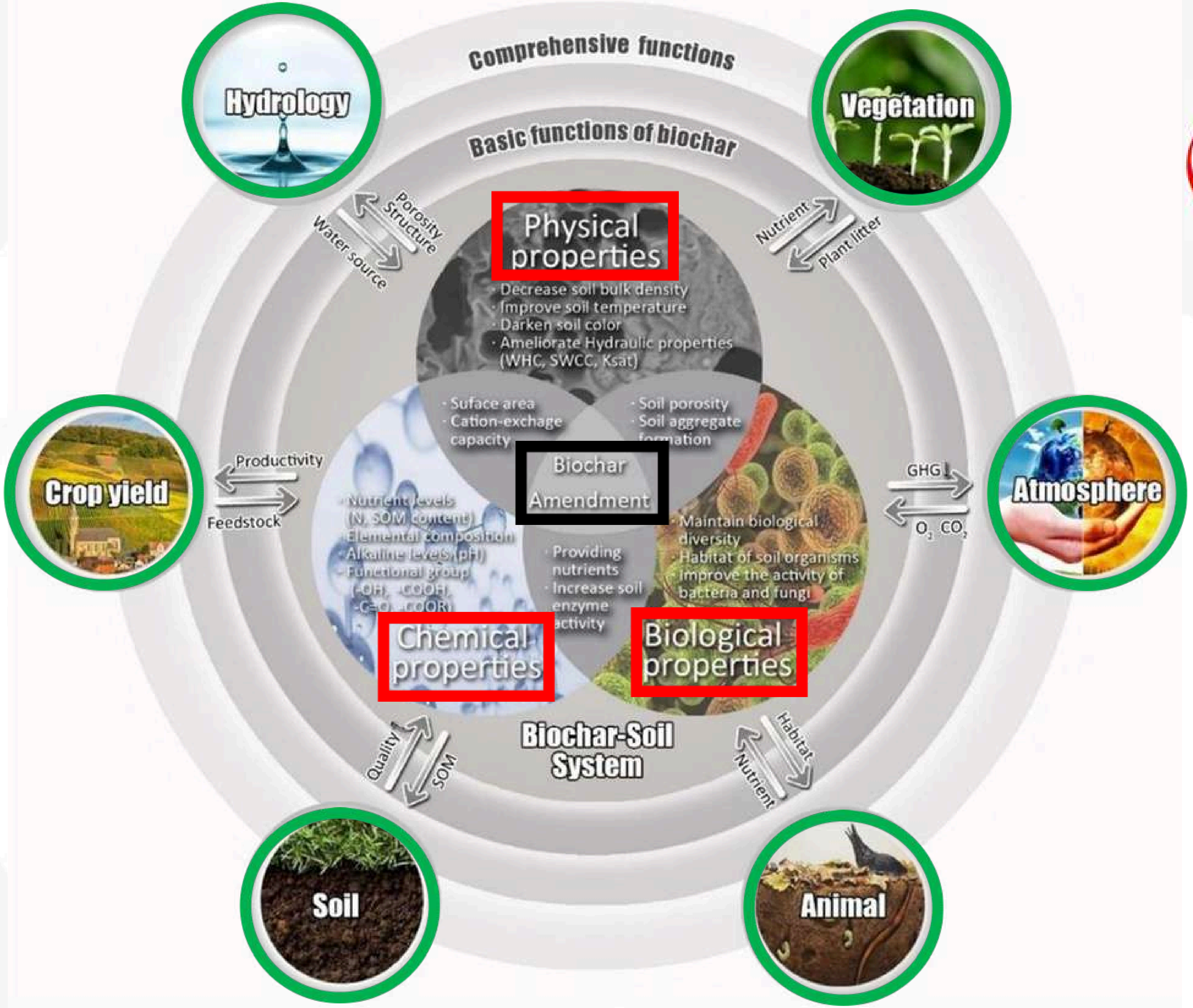

Benefits of biochar

There aremultiple benefitsofbiochar, that contribute to sustainability and resilience through multipleinteractions.

Source: Wani, I., Kushvaha, V., Garg, A.*et al.*Review on effect of biochar on soil strength: Towards exploring usage of biochar in geo-engineering infrastructure.*Biomass Conv. Bioref.*(2022). https://doi.org/10.1007/s13399-022-02795-5

Synergies with compost

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Biomass Conversion and Biorefinery
https://doi.org/10.1007/s13399-019-00482-6

ORIGINAL ARTICLE

Check for updates

Production and characterization of co-composted biochar and digestate from biomass anaerobic digestion

David Casini[1] · Tommaso Barsali[1] · Andrea Maria Rizzo[1] · David Chiaramonti[1,2]

Received: 30 March 2019 / Revised: 15 July 2019 / Accepted: 16 July 2019

Benefits of Co-composting:

* Biochar becomes enriched with nutrients and microorganisms.

* Biochar improves the quality and efficiency of the composting process.

* It shortens the process duration.

* It reduces greenhouse gas, ammonia, and odour emissions.

Chapter 3

Biochar statusinthe world

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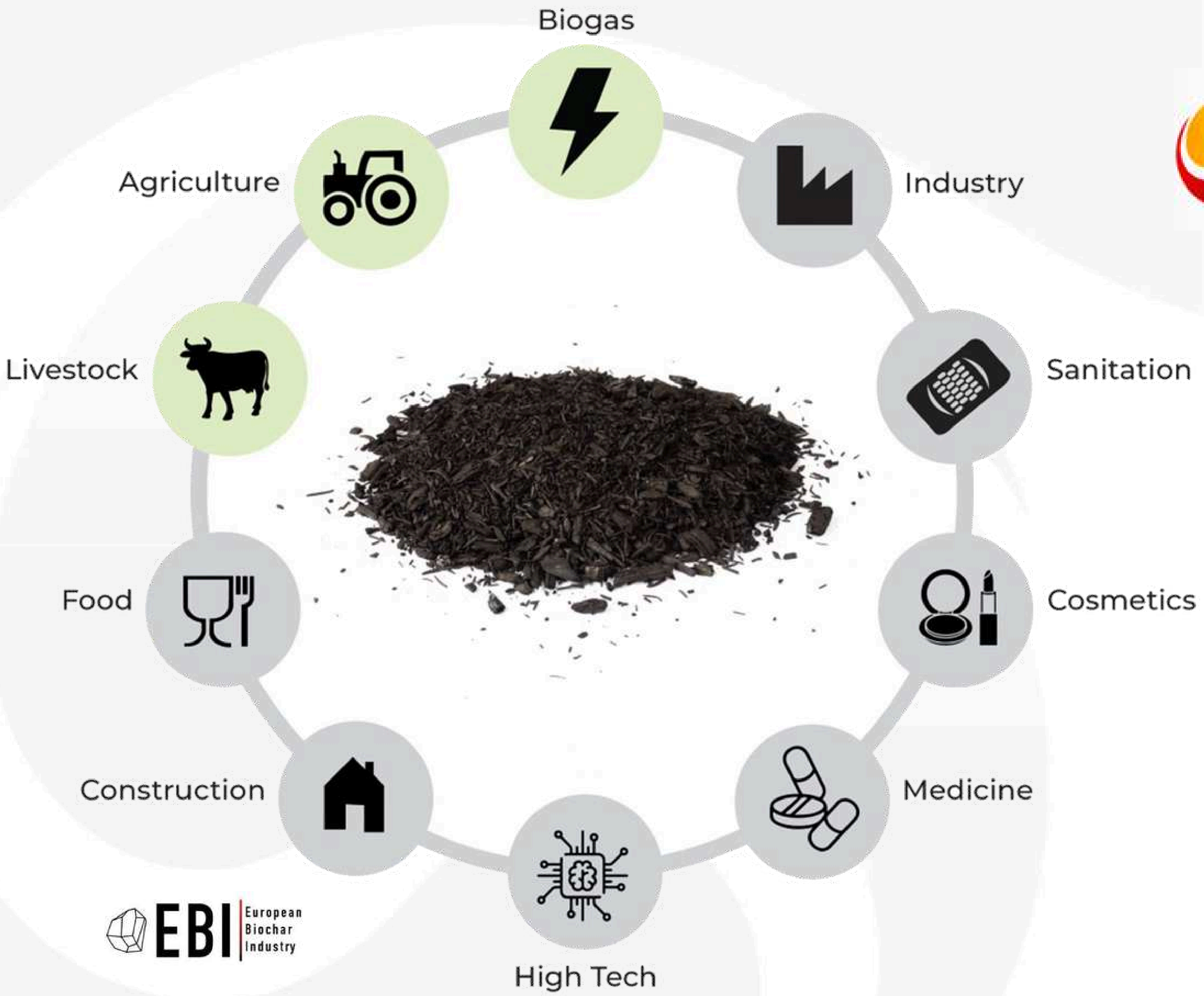
The broad applications of biochar



Biochar market & trends

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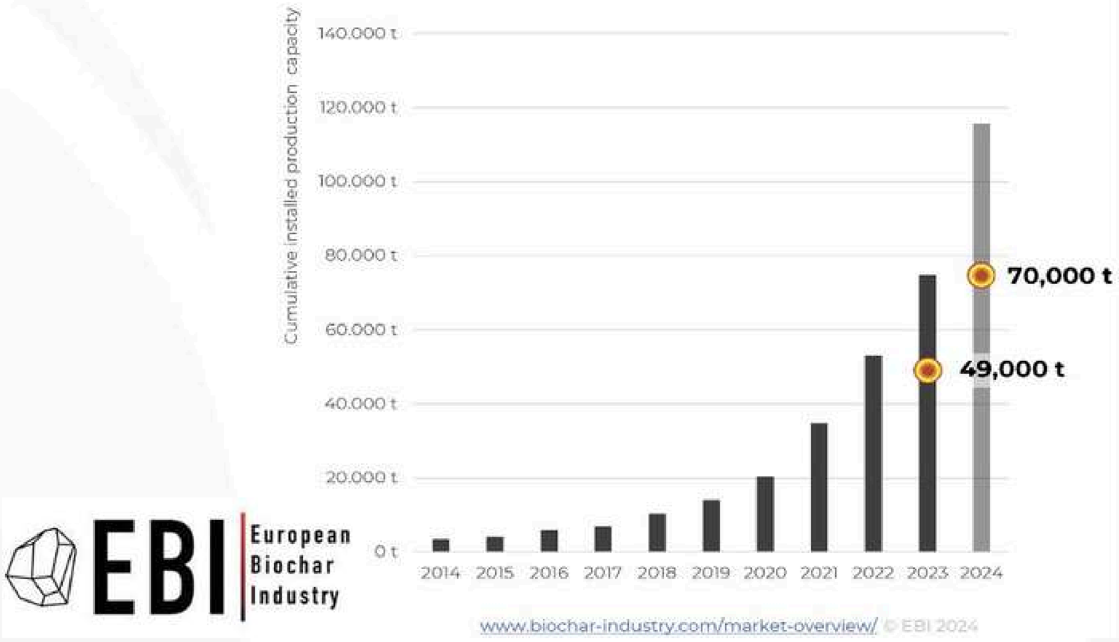
World biochar market

- **The expanding Market**: The biochar market is valued up to **$2.2 billion** in 2024, with estimates starting from **$221.79 million**.
- **Outlook**: Exponential growth, with an annual rate (CAGR) projected to be between **7.68%** and **16.2%** until 2032.
- **Applications**: Agriculture dominates the market, representing 79.1% of its total value in 2024.

European actual biochar production



Almost 80% of the production capacity end of 2023 is in the equipment categories between **200-5'000 t/y**

International Quality standards

International Biochar Initiative

CARBON STANDARDS international

CERTIFIED BIOCHAR WBC WORLD BIOCHAR CERTIFICATE

With the rapid expansion of the Biochar industry, Carbon Standards International (**CSI**) and the International Biochar Initiative (**IBI**) has announced their new partnership to create a higher caliber of standard to the production of Biochar.

CDR voluntary market

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- **A Leading Role in Carbon Dioxide Removal (CDR):** Biochar accountedfor **94%** of durable carbon credits sold in the **voluntary market** in 2023.
- The **New Frontier:** The Global South is emerging as a key player in the production of biochar credits.
- The "Manual for Biochar Carbon Removal: A Comparative Guide for the Certification of Biochar Production as a Carbon Sink", published by the International Biochar Initiative, identifies the **leading certification programs currently active in the market:**

VERRA Verified Carbon Standard

puro · earth

Gold Standard® Climate Security & Sustainable Development

BIOCHAR C-SINK

CLIMATE ACTION RESERVE

Biochar development in EU
Reg.1009/2019 andCRCF

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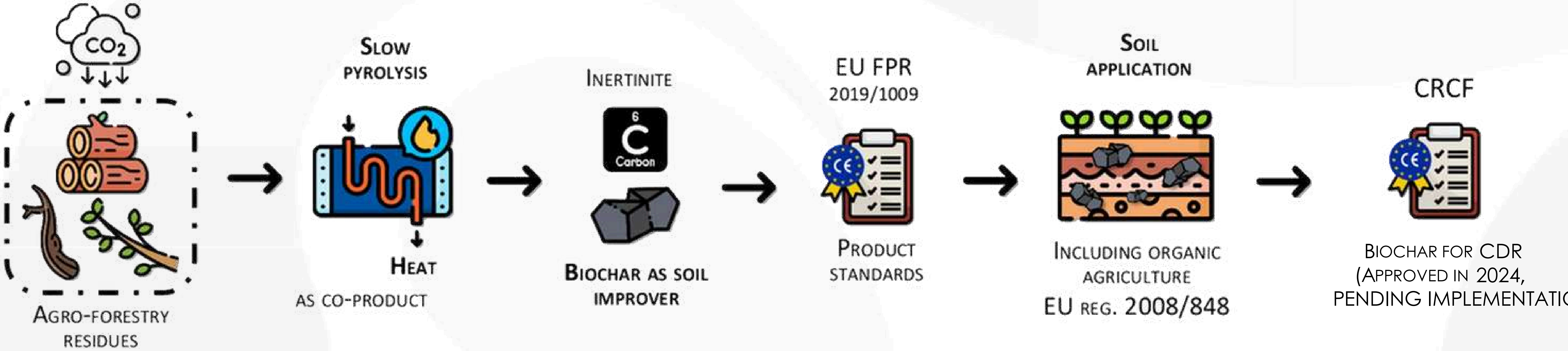

- Biochar is included in the EU Fertilising Products Regulation (**EU FPR**) as a
- component material (CMC 14) for producing fertilising products. It can
- be also used in **Organic Agriculture** The EU Carbon Removal Certification Framework (**CRCF**) will regulate all Carbon Direct Removal (**CDR**) activities, with biochar included as a permanent carbon removal mean.

Section4

Biochar-CPO mill synergies

SoA: available feedstock

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Mill residues

PKS – Palm kernel shell	● Energy generation
MF - Mesocarp fiber	● Energy generation
PKC – Palm kernel cake	● Feeding
POME–Palmoilmilleffluent	● Anaerobic digestion ● Composting ● Fertilization
EFB – Empty fruit bunch	● Composting ● Fertilization ● Energy generation

Plantation residues

OPF – Oil palm frond	● Fertilization
OPT – Oil palm trunk	● Fertilization

Common end-uses

- ● Energy generation
- ● Anaerobic digestion
- ● Composting
- ● Fertilization
- ● Feeding

Suitable feedstock

	Lignin content	Moisture	Pre-treatments
OPT – Oil palm trunk	=	↑	milling, drying
EFB – Empty fruit bunch	=	=	milling, (drying), (compaction)
PKS – Palm kernel shell	↑	↓	no need
MF – Mesocarp fiber	=	↓	(compaction)

Energy demand forpre-treatments → Electricity,Heat

for biochar production → Electricity

Biochar on-site production

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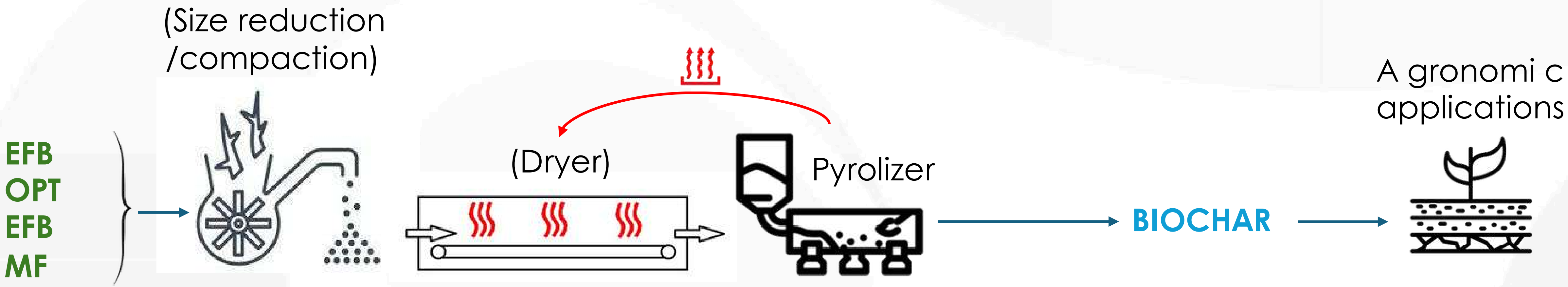
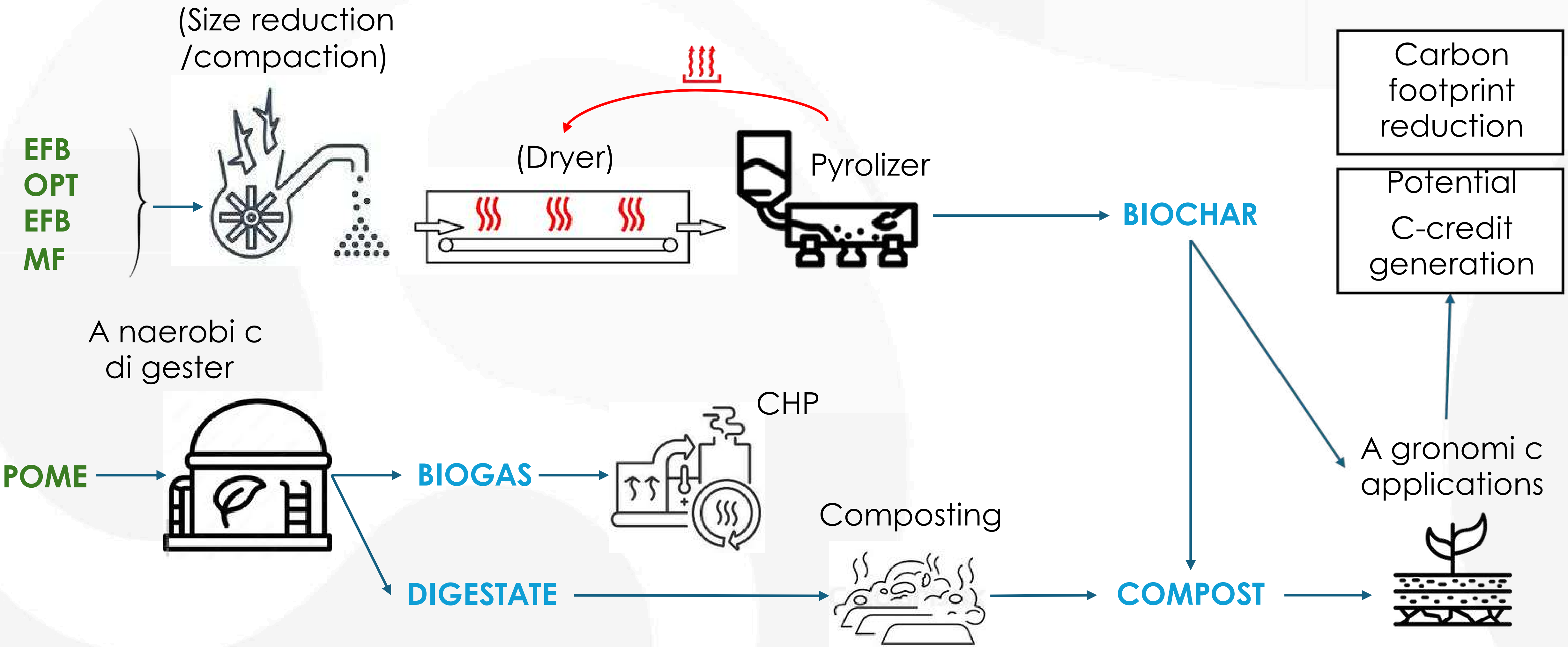


Biochar produced can be used for **agronomic applications**, such as:

- **Soil amendment** directly used in plantations
- **Substrate** in pots in nursery
- Used as **bed** in palm seedling transplantation
- **Additive** in co-composting and POME digestion

Synergies with biogas production



Synergies with biogas production

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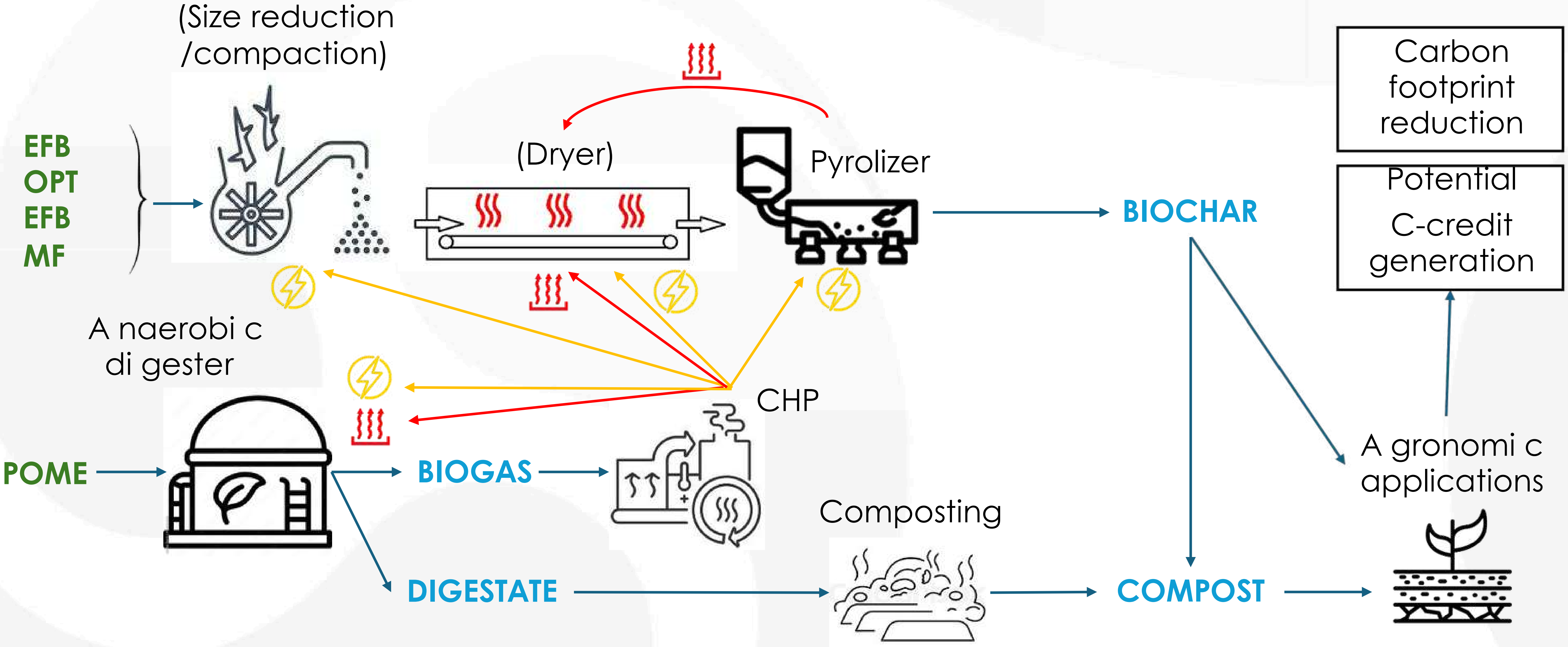

Final remarks

- The logistical potential is a key advantage. The **benefit is already available on the website**, and we can leverage our existing logistics. Only the OPT solution requires a new logistical approach.
- Utilizing low-temperature waste heat at the CPO mill for pre-treatment always yields a positive balance (**more heat is recovered than consumed**). We should note that this process can be very intensive when considering the OPT solution.
- While the agronomic benefits of using biochar in oil palm plantations are potentially high, there is a notable **lack of extensive scientific literature** on the subject.
- **Carbon footprint reduction** and potential C-credit generation.

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THANK YOU

contact: david.casini@re-cord.org

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