Report on the sustainability of the wood fiber production chain and its use as a component of growing media in horticulture

GENERAL INFORMATION

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1. Preamble

PROMECO S.p.A., a leading company in the construction of bio-treatment machines and plants, promoted an initiative to measure the environmental performance of wood fiber for horticultural use and to compare it with the main raw materials used in the production of growing media, primarily peat.

Among the primary environmental indicators deemed appropriate to define the sustainability of these materials were identified 1) the assessment of the carbon footprint (CFP) and 2) the water footprint (WFP) of the product.

Specifically, the carbon footprint is a life cycle analysis that evaluates greenhouse gas (GHG) emissions directly and indirectly related to the production of a good allowing producers (and consumers) to understand the impact of processes on climate change and giving them the opportunity to reduce it (and / or compensate) over time.

The water footprint is an indicator of the fresh water consumption, defined as the total volume of the same resource used directly and indirectly to produce goods and services. It is measured in terms of water consumed (evaporated or incorporated in a product) and polluted per unit of time in the specific collection point.

ENERION RENEWABLES S.r.l. is an Italian company that operates internationally in the sustainability sector by developing strategies to increase the environmental category of products and organizations based on the accounting and analysis of specific environmental indicators.

The company was commissioned by PROMECO S.p.A. to carry out the necessary procedures to support the study drawn up on the basis of primary data collected from the company FIBRA DI LEGNO S.r.l. in the reference year 2020. Fibra di Legno srl is an Italian company that manufactures wood fiber using Promeco technology.

This document summarizes the results of the assessment and the considerations that arise on the sustainability of the wood fiber production chain and its use as a component of substrates in the horticultural field.

2. Introduction

Over the last fifty years, the use of substrates in horticulture has notably increased due to the greater availability and improvement of the quality characteristics of the products on the market.

These materials have become technical means of primary importance for the fruit and vegetable sector, so much so that their production and marketing have significantly differentiated, this given the increasingly specific needs of the end user, professionals or simple amateurs.

Italy, with more than 5 million cubic meters, is the second European country, after Germany, in terms of growing media consumption, but the first in terms of economic value, estimated at about 260 million Euros against a total of 1.3 billion Euros on a continental level.

Starting from the early seventies, the introduction and subsequent development on the market of ready-to-use substrates coincided with the beginning of the exploitation for this purpose of peat, until then used exclusively as a fossil fuel.

Although peat is still today to be considered the reference material in the substrate industry, over the years various raw materials, whether organic, inorganic or synthetic, have been tested with the aim of partially or totally replacing the peat; however, in the face of the studies undertaken and the results obtained, peat remained predominant in the constitution of mixtures. Nevertheless, the emergence of a new awareness on the part of the consumer on the repercussions connected with the exploitation of non-renewable resources and the opportunity to use more sustainable raw materials, has led to limiting the extraction of peat in order to preserve important natural ecosystems that are indispensable for the survival of animal and plant species.

In the last decade, there has been no shortage of official positions on this dispute: since several years England has almost cancelled the use of peat in the production of flowers and potted plants, as well as Switzerland, which has moved in this direction by inviting producers and users to place "peat-free" products on the market. The Ecolabel System, on the other hand, one of the environmental and industrial policy instruments of the European Union aimed at encouraging the presence on the market of products with a lower environmental impact, has been attributing its label only to substrates that do not contain peat or derivative products.

Last in order of time, but very significant in terms of future market orientation, is the case of Bord na Móna, a well-known Irish bog with public participation present on the market since 1946 with an estimated production per year of several million tons of peat, as well as one of the first companies globally to promote the use of peat in growing media, which on January 15, 2021 announced that it had formally concluded peat exploitation and completed the full transition to new activities focused on fighting climate change, energy supply from renewable sources, biodiversity and on the circular economy.

3. Carbon footprint of wood fiber

In recent years, consumer awareness has grown remarkably in relation to the ability to influence market logic through a "positive selective pressure" towards products with a lower environmental impact, thus overcoming the concepts underlying international initiatives for the reduction of greenhouse gases such as the Kyoto Protocol or the Emissions Trading System (EU).

In parallel, producers have begun to see in the environmental performance a concrete opportunity to achieve an advantage in a competitive global context towards consumers increasingly oriented towards "green" and "conscious" consumption through products or services with lower emissions.

In this context, the calculation of the carbon footprint (CFP) has established as environmental indicator that quantitatively expresses the effects produced on the climate by the greenhouse gases generated by a person, an organization, an event or from a product (good or service).

The calculation of the product CFP includes the quantification of the emission (and absorption) of climate-altering gases (GHG - greenhouse gases) along its life cycle, hypothetically from the extraction of the raw materials that constitute it up to its final disposal ("from the cradle to the grave").

The CFP represents a subset of data deriving from a Life Cycle Assessment (LCA) study, however limited to the impacts that have an effect on the phenomenon of climate change, therefore easier to communicate and understand by the public. The calculation of CFP is therefore establishing itself as a marketing tool used by manufacturers to demonstrate their commitment to reduce the environmental impact and highlight the sustainability of their products.

The calculation is increasingly accompanied by the reduction (mitigation) of the impact, where mitigation means all those direct actions implemented by the producer to limit the project or process emissions (e.g. renewable energy, energy saving, low impact production factors, good agricultural practices, biochar, process innovations).

It is then always possible to offset the resulting emissions, intended as the financial support to third-party projects capable of reducing greenhouse gas emissions in the short or long term.

3.1. Product carbon footprint: methodology

The calculation of products carbon footprint is based on the use of internationally recognized official standards and methodologies.

1) ISO 14067:2018

As part of the ISO 14000 family of standards, ISO 14067:2018 specifies the principles, requirements and guidelines for quantifying and communicating the carbon footprint of products (CFP) in accordance with international standards on life cycle analysis (LCA) (ISO 14040:2006 and ISO 14044).

2) The Carbon Neutral Protocol

The Carbon Neutral Protocol, developed by The Carbon Neutral Company, is a voluntary tool that allows companies and organizations to define guidelines to develop a reliable program for the reduction and / or neutralization of greenhouse gas emissions generated by their activities and processes, within defined operational and temporal boundaries.

The Carbon Neutral Protocol[1] was used to establish the inventory limits of the carbon footprint of the product, that is define as the activities whose emissions were included in the calculation.

[1] https://carbonneutral.com/pdfs/The_CarbonNeutral_Protocol_Jan_2021.pdf

3.2. Limits of inventory

3.2.1. Functional unit and reference flow

For the purposes of the analysis of the carbon footprint, the functional unit of reference was defined as equal to one (1) ton by weight of wood fiber (product), a measure to which the product carbon footprint is generally related.

The values can then be converted into volume, a measure to which the quantity of a substrate and its components is commonly expressed, by means of the average bulk density of the product.

3.2.2. Type of inventory

Quantification of emissions was carried out on the basis of a "cradle to door" perimeter, which includes two phases of the product life cycle: (1) the possible extraction, processing and transport of raw materials, including packaging materials; (2) the production process before the distribution.

3.2.3. GHG of inventory

The greenhouse gases (GHGs) considered in this study, which come from both controlled and uncontrolled processes by the company, are listed in the following table.

For these gases, in accordance with the criteria of the Intergovernmental Panel on Climate Change (IPCC) [2], the values of the global warming potential for a period of 100 years were considered, that is the time horizon of their permanence in the atmosphere.

Other gases such as hydrofluorocarbons, fluorocarbons or sulfur hexafluorides were not considered as they are unrelated to the process.

GHG	Formula	Applicability
Carbon dioxide	CO_2	Yes (Combustion of hydrocarbons, biogenic emissions, leaks)
Methane	CH_4	Yes (Combustion of hydrocarbons, leaks)
Nitrous oxide	N_2O	Yes (Combustion of hydrocarbons, leaks)

For the purposes of the calculation, the global warming potentials defined according to AR5 and published by the IPCC in 2013[3] were used.

3.2.4. Limits of inventory

In accordance with the Carbon Neutral Protocol and with the limits of products inventory, the following emission sources were taken into consideration:

[2] https://www.ipcc.ch
[3] https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_all_final.pdf

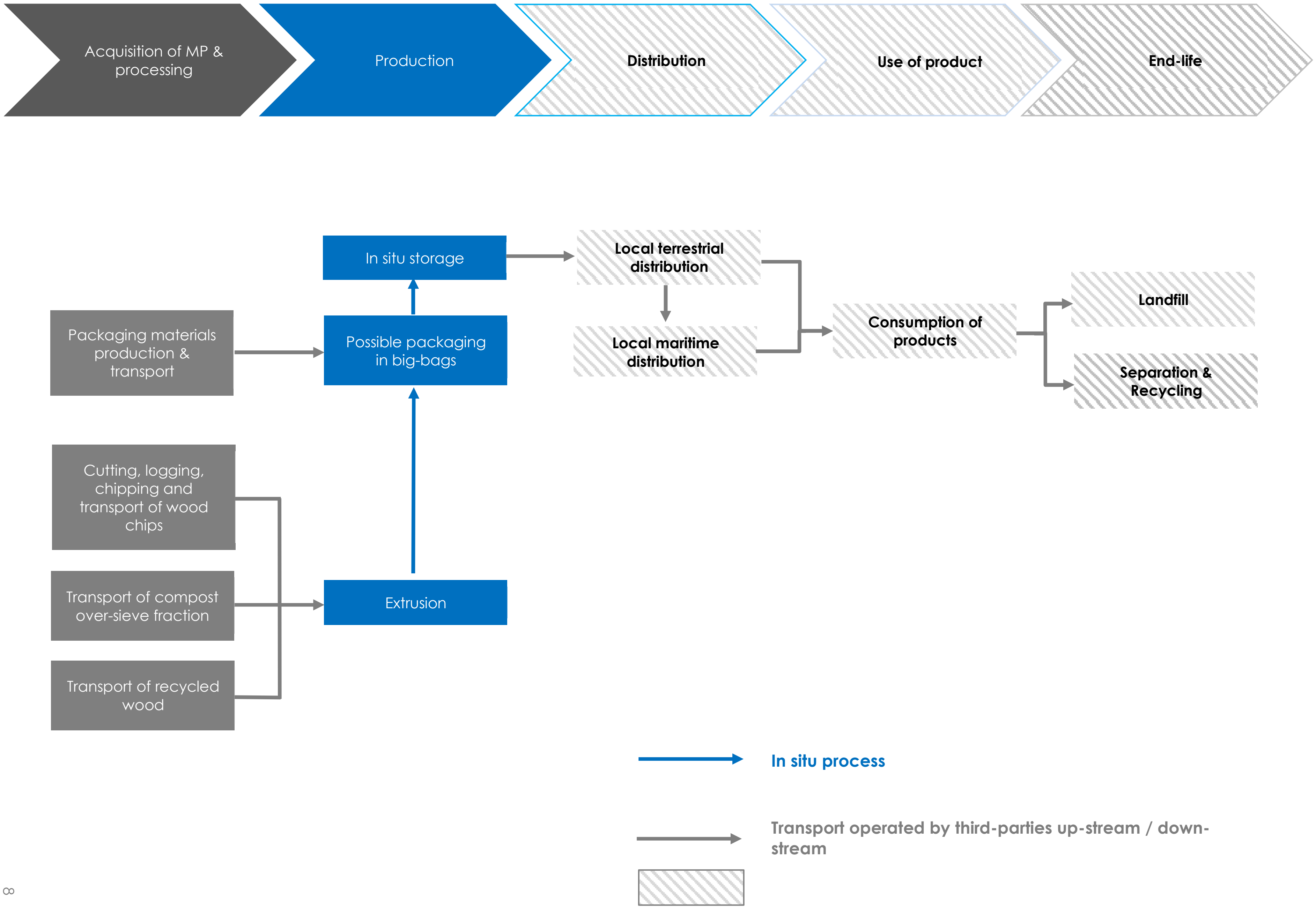
Category	Emission sources	Carbon Neutral Protocol criteria	Used criteria
Extraction, processing and transport of raw materials, including packaging materials	Cradle-to-grave or cradle-to-customer emissions of raw materials and other production inputs	Requested	Considered
	Transportation of raw materials and other production inputs	Requested	Considered
Production, packaging and storage of products	Direct emissions due to the use of fossil fuels in situ and fugitive emissions	Requested	Considered
	Electricity consumption in situ	Requested	Considered
	Emissions from waste disposal or process wastewater	Requested	Not-Considered

3.2.5. Product life cycle

The UNI EN ISO 14067:2018 standard indicates, as part of the life cycle of a product, five different phases, starting from the extraction process of raw materials up to its disposal.

Based on the life cycle of the product and the limits of its inventory, the following figure illustrates the flow diagram of the process, including the main phases of the life cycle and specifying the contribution of the main raw materials, as well as transport.

The following diagram summarizes the phases and processes at the base of the analysis, which, as illustrated, only considers the emissions produced from the "cradle-to-door".



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3.3. Inventory data

Inventory data includes primary, secondary data and emission factors.

Primary data is derived from specific product lifecycle processes and includes direct measurements, such as data recorded within the company's producing or purchasing area (amount of energy and fuel, volume of raw materials, ...).

Secondary data, unlike the primary, does not come directly from specific processes of the product life cycle, but from external sources (databases, trade associations, ...) or other process / activity; they can be adapted to the process or used as they are.

The **emission factors (FE)** are secondary data that represent the emission referred to the unit of activity of the source, expressed for example as the quantity of pollutant emitted per unit of product, or as the quantity of pollutant emitted per unit of fuel consumed.

The choice of emission factors is a fundamental and particularly critical aspect of the analysis.

Emission factors can include one or more greenhouse gases (expressed as units of carbon dioxide equivalent - CO_2e), as well as one or more life cycle processes of a product.

In this case, the emission factors were taken from the BASE CARBONE database (basecarbone.fr), from the GHG Protocol (ghgprotocol.org) and from DEFRA (Department for Environment Food & Rural Affairs of United Kingdom), most of which derive from the IPCC.

Only emissions above 1% of the total were considered relevant for the analysis.

The following table shows the different emission sources used for the calculation of the carbon footprint, along with their bibliographic reference.

Emission source	M.U.	Value	Reference
Virgin wood	$kgCO_2e\ t^{-1}$	312.61	DEFRA. Greenhouse gas reporting: conversion factors 2020
Waste wood	$kgCO_2e\ t^{-1}$	38.54	DEFRA. Greenhouse gas reporting: conversion factors 2020
Diesel (mobile sources)	$kgCO_2e\ l^{-1}$	2.688	DEFRA. Greenhouse gas reporting: conversion factors 2020
Biodiesel	$kgCO_2e\ l^{-1}$	0.166	DEFRA. Greenhouse gas reporting: conversion factors 2020
Electricity from the Italian national grid	$kgCO_2e\ kWh^{-1}$	0.276	ISPRA. Fattori di emissione 2020
Land transport	$kgCO_2e\ tkm^{-1}$	0.227	World Resources Institute (2015). GHG Protocol tool for mobile combustion. Version 2.6.
Polyethylene (PE)	$kgCO_2e\ t^{-1}$	2,090	Base Carbone V5.8. Plastique (PEBD)

3.4. Calculation principles

The following equations illustrate how the amount of CO_2e per input, output or process was calculated based on process data, emission factors and GWP (Global Warming Potential).

Two cases were considered:

(1) Starting from process data

When process data was collected, the basic equation for calculating CO_2e for an input, output or process was:

$$kg\ CO_2e = \text{Process data} \times \text{Emission factor} \times GWP$$

Unit of measure: unit **x** *kg GHG/unit* **x** *kgCO₂e/kg GHG*

(2) Starting from direct emissions:

When direct emissions data were collected, not requiring emission factors, the basic equation to calculate the inventory results for an input, output or process was:

$$kg\ CO_2e = \text{Direct emissions} \times GWP$$

Unit of measure: kg GHG **x** *kgCO₂e/kg GHG*

3.5. Wood fiber emissions

The wood fiber emission factor was calculated on the basis of primary data collected at Fibra di Legno S.r.l., as well as the emission factors reported in the previous paragraph 3.3.
The following table explains the individual sources of GHG and their impact in terms of CO_2e emissions, as well as the percentage contribution of the same to the total carbon footprint.

Source of GHG	EF	tCO_2e	%
Virgin wood	312.61 $kgCO_2e\ t^{-1}$	119.56	59.87
Recycled compost over-sieve fraction wood	38.54 $kgCO_2e\ t^{-1}$	19.37	9.70
Big-bags (Polypropylene)	2,090 $kgCO_2e\ t^{-1}$	0.13	0.07
Transport (Wood & big-bags)	0.227 $kgCO_2e\ tkm^{-1}$	6.27	3.14
Diesel	2.688 $kgCO_2e\ l^{-1}$	4.62	2.31
Biodiesel[4]	0.166 $kgCO_2e\ l^{-1}$	0.01	0.01
Electricity from the grid	0.276 $kgCO_2e\ kWh^{-1}$	49.73	24.90

TOTAL (tCO_2e)	199.70
Total production (t)	1,060
EF ($kgCO_2e\ t^{-1}$)	**188.39**

The **wood fiber emission factor**, calculated on the basis of the collected inventory data, is equal to 188.39 $kgCO_2e\ t^{-1}$.
The analysis of the footprint highlights the dependence of the data on the type of wood used for the production of the fiber (in this case a 1:1 mix of virgin wood chips and recycled wood), being the emission factor of virgin wood by an order of magnitude greater than recycled wood.
In this regard it was possible to produce a projection of the hypothetical emission factor considering only the first or second. In the first case, the EF calculated on the same primary data would be equal to **319.92 $kgCO_2e\ t^{-1}$**, in the second **88.28 $kgCO_2e\ t^{-1}$**.

[4] With the European standard EN 590, the possibility of adding a part of biodiesel up to a maximum of 7% to the diesel fuel has been introduced. Biodiesel, or more properly FAME (Fatty Acid Methyl Esters), is a mixture of esters obtained through a trans-esterification process of fatty acids of vegetable origin with methyl alcohol. In 2019, the average percentage of biodiesel in diesel was 4.5%.

4. Carbon footprint of the other main organic raw materials

4.1. Peat emission factor

The peat emission factor was derived from a 2010 Dutch study[5] based on the 2006 IPCC[6] guidelines which describe a method for calculating emissions from the various phases of the supply chain of peat used in the horticultural sector.

The production cycle consists of three phases:

(1) **Preparation** - The peatlands are drained by excavating drainage channels that allow the lowering of the water table and consequently the extraction of the material (after eliminating the topsoil - trees, shrubs, sphagnum trees, etc.); in this phase the emissions mainly consist of CO_2 released following the removal of the organic matter and the mineralization of a part of the organic fraction of the peat. The standard value of the duration of the drainage phase is five (5) years; the emissions of the preparation phase are spread over thirty-five (35) years, the average time of exploitation of the peat bogs.

(2) **Extraction** - The peat is excavated and dried in blocks in the sun; carbon dioxide and nitrous oxide are released by the decomposition of part of the organic matter.

(3) **Subsequent uses** - The "exhausted" peatlands are used for other at the end of the extraction phase, thus remaining drained, with consequent greenhouse gas emissions.

The following table summarizes the CO_2e emissions per unit weight ($kgCO_2e\ t^{-1}$) of the phases / components of the peat production cycle (including road transport to destination for a distance of 1,600 km), as determined by the bibliographic study taken as reference.

Phases / components	M.U.	EF	%
Preparation	$kgCO_2e\ t^{-1}$	3.4	0.28
Extraction	$kgCO_2e\ t^{-1}$	66.0	5.47
Fuel consumption (extraction)	$kgCO_2e\ t^{-1}$	58.1	4.81
Carbon decomposition (off-site)	$kgCO_2e\ t^{-1}$	935.0	77.43
Nitrogen decomposition (off-site)	$kgCO_2e\ t^{-1}$	123.6	10.24
Transport	$kgCO_2e\ t^{-1}$	21.5	1.78
Total	$kgCO_2e\ t^{-1}$	1,207.6	100

The study returns EF equal to **1,208 $kgCO_2e\ t^{-1}$**.

4.2. Coconut fiber (coir) emission factor

The emission factor of coconut fiber was taken from a 2009 French study conducted by the Centre Technique Interprofessionnel des Fruits et Légumes – CTIFL[7] applying Bilan Carbone® developed by ADEME (Agence de l'environnement et de la maîtrise de l'énergie) with the aim of determining GHG emissions related to the production of coconut fiber in South Asia and its transport (by ship and by land) to its destination in Europe, as well as at the end of life.

[5] Blonk H., Kool A., Luske B., Ponsioen T., Scholten J., 2010. Methodology for assessing carbon footprints of horticultural products – A study of methodological issues and solutions for the development of the Dutch carbon footprint protocol for horticultural products, Blonk Milieu Advies BV, NL.

[6] 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 7, Wetlands

[7] Grasselly D., Hamm F., Quaranta G., Vitrou J., 2009. Empreinte carbone des substrats à base de fibres de coco, Infos-Ctifl, Paris, F

The calculation gives EF equal to **361 $kgCO_2e$ t^{-1}**.
The impacts of production cycle phases (including road transport from the port of arrival to the destination for a distance of 165 km) are shown in the following table.

Production cycle phases	% GHG
Naval transport	35.2
Packaging	25.6
Pressing	12.7
Plant	8.2
Infrastructure	5.1
Road transport in South Asia	5.1
Road transport in Europe	2.8
Palettization	2.5
End-life	0.1

4.3. Compost emission factor

In consideration of the heterogeneity of composting processes and incoming materials (wastes), past studies have demonstrated the variability of the carbon footprint value of compost.

In general terms, during the composting process, the microbial activity underlying the bio-oxidative reactions of organic matter generates CH_4 and N_2O which contribute to the net GHG emissions associated with the production of compost. The amount of these "**leaks**" depends on various factors, including the type of waste, the process typology (e.g. turning frequency), the shape, temperature and humidity of the pile, as well as the amount of oxygen.

For the purpose of quantifying these emissions, the United Nations under the Clean Development Mechanism (CDM) [8] has proposed a methodology that defines, in the absence of direct measurements, a predefined emission value for methane (CH_4) and nitrous oxide (N_2O) on the total production of compost. The method also establishes the "non-accounting" of emissions due to the presence of wastewater in the event of recirculation of such effluents as part of the composting process.

In the present case, two distinct values were taken into consideration by virtue of the aforementioned product heterogeneity.
For green compost the value was taken directly from the database "Greenhouse gas reporting: conversion factors 2020" published by DEFRA (UK Department for Environment, Food & Rural Affairs)[9] which attributes the emission of **113 $kgCO_2e$ t^{-1}**, moreover in line with what was directly measured by Enerion Renewables in similar studies conducted on the same materials which returned values between 115 and 170 $kgCO_2e$ t^{-1}.
For other types of compost, such as those containing sludge, a study conducted by an Italian manufacturer (Progeva S.r.l.) and co-financed as part of a public project launched in 2013 by the Ministry of the Environment and the Protection of the Territory and the Sea returns EF of **484 $kgCO_2e$ t^{-1}**.

[8] United Nation, Framework Convention on Climate Change, 2017. Clean Development Mechanism Methodological Tool 13: Project and leakage emissions from composting, Version 2.0

9 https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2020

5. Wood fiber and other main organic materials water footprint

5.1. Product water footprint

The product water footprint represents the potential environmental impact resulting from the use of fresh water and considers the water directly consumed and polluted for the production of a good.

The global calculation of the water footprint consists of two indicators:

Direct Water Scarcity Footprint: is the measure of the potential water scarcity due to the direct consumption of fresh water (surface and / or underground water) during the process that doesn't return downstream to the same collection point or returns there at different times.

Non-Comprehensive Direct Water Degradation Footprint: represents the volume of polluted water quantified as the volume of water needed to dilute the pollutants so that the water quality remains above the defined quality standards (legal and / or ecotoxicological).

The use of these two indicators allows to investigate how the product (in this case a material that constitute a growing media) affects the degradation of water resources both from a quantitative and qualitative point of view.

The main standard taken as a reference is the **UNI EN ISO 14046: 2016** and the impacts are assessed on the basis of the methodologies proposed by the WULCA (**Working Group on Water Use LCA**) and the **Water Footprint Network**.

The results, in cubic meters of fresh water, is referred to one ton of product.

The calculation of the water footprint consists of the following factors:

(1) Blue water (or water footprint) of each raw material (constituting the product), corresponding to the volume of surface or ground water taken from water bodies and used in its production process, which does not return to the same point from which it was taken, or comes back but at different times
(2) Grey water (or water footprint) of each raw material (constituting the product), corresponding to the volume of water that allows any contamination of the water body due to be brought under the legislative or eco-toxicological limits applicable to the production area
(3) Blue water (or water footprint) of the process, corresponding to the volume of surface or ground water taken from water bodies and used in the production process, which does not return to the same point from which it was taken, or returns there but at different times
(4) Grey production water (or water footprint) of the process, corresponding to the volume of water that allows any contamination of the water body due to pollutants used in the industrial process to be brought under the legislative or eco-toxicological limits applicable to the production area.

5.2. Calculation of wood fiber water footprint

The wood fiber water footprint is aimed at quantifying the volume of fresh water used directly and indirectly during production.

All values have been extrapolated from company documents (Fibra di Legno S.r.l.).

The blue component of the water footprint is calculated using the formula:

$$WF_{\text{raw mat, blue}} = \text{abstracted water volume} - \text{effluent (discharged) water volume}$$

The methodology used for the calculation of grey component allows to estimate the pollution load, in the case of a point source (in other words, when the pollutants are released directly into a water body in the form of wastewater disposal), by measuring the volume of the effluent and the concentration of a dissolved substances.

The grey component of the water footprint is calculated using the formula:

$$WF_{raw\ mat,\ grey} = \frac{L}{(c_{max} - c_{nat})} = \frac{(Effl \times c_{effl} - Abstr \times c_{act})}{(c_{max} - c_{nat})}$$

where:

- $WF_{raw\ mat,\ grey}$ is the grey component of the water footprint of each constituent material
- L is the polluting load
- c_{max} is the maximum concentration of the pollutant in the receiving water body fixed by law
- c_{nat} is the natural concentration of the pollutant in the receiving water body
- *Effl* is the volume of effluent (discharged) water per unit of time
- c_{effl} is the concentration of the pollutant in mass per volume
- *Abstr* is the volume of abstracted water per unit of time
- c_{act} is the actual concentration of the pollutant in the abstracted water in mass per volume

The grey component of the product water footprint is always calculated on the major contaminant, as it is clear that the resulting volume of water will be able to bring all other pollutants under the legislative or eco-toxicological limits.

c_{max} is taken from the Italian national legislation (Legislative Decree 152/2006, Table 3, Annex 5, third part).

c_{nat} and c_{act} are assumed to be zero from a conservative point of view.

Data	**Value**	**M.U.**
Total abstracted water	140	m^3
Total effluent water	0	m^3
Wood fiber total production (volume UNI EN 12580:2014)	9,860	m^3
Wood fiber total production (tons)	1,060	t
Total blue water	140	$m^3\ yr^{-1}$
Total blue water per unit of volume	14	$l\ m^{-3}$
Total blue water per un it of mass	132	$l\ t^{-1}$

The absence of effluent water makes the grey component of the footprint null.

The water footprint of wood fiber is equal to **0.132 m^3_{H2O} ton^{-1}** (**0.014 m^3_{H2O} m^{-3}**, if considered an average bulk density of 0.108 t m^{-3}).

5.3. Peat water footprint

Due to the impossibility of obtaining data relating to the production and transformation process, the water footprint values of the peat have been taken from the bibliography, which by virtue of the innovative nature of the measure are to be referred to studies still in progress, mostly preliminary and subject to partial revision.

In particular, a first study conducted at the University of Groningen (NL) was used as a reference for peat, presented during the "Symposium International Peatland Society 50 years" in September 2018[10].

[10] Gerbens-Leenes W., Schilstra A. J., 2018. The water footprint of peat from tropical and boreal locations, Book of Abstracts Symposium International Peatlands Society 50 years.

In this case, the water footprint of peat has been defined as equal to 15,000 $m^3{}_{H2O}$ t^{-1}d.m., which, considering the average humidity (40% v v^{-1}), returns a value of **9,000 $m^3{}_{H2O}$ t^{-1}** (equivalent to 1,620 $m^3{}_{H2O}$ $m^{-3}{}_{PEAT}$, if considered an average bulk density of 0.18 t m^{-3}).

5.4. Coconut fiber (coir) water footprint

Due to the impossibility of obtaining data relating to the production and transformation process, the water footprint values of the coconut fiber were obtained from the bibliography, which by virtue of the innovative nature of the measure are to be referred to studies still in progress, mostly preliminary, and subject to partial revision.
For coconut fiber, the data was derived from a 2011 Dutch study conducted at the University of Twente[11].
The average global water footprint of coconut fiber (Coconut - coir - fiber, processed) is defined as equal to **2,449 m^3 t^{-1}** (equivalent to 857 $m^3{}_{H2O}$ $m^{-3}{}_{COIR}$, if considered an average bulk density of 0.35 t m^{-3}).

5.5. Compost water footprint

In consideration of the heterogeneity of the composting processes, as well as of the starting raw materials, past studies have shown a certain variability in the water footprint value of compost. This aspect is almost always related to the different management of the percolation wastewater in the plant, which in some cases are collected and totally reused for the humidification of compost while in others they are removed as waste (landfill leachate) with consequent aggravation of the volume of polluted water (i.e. the volume of water necessary to dilute the pollutants so that the quality remains above the defined legal and / or ecotoxicological standards).

The water footprint of the compost can therefore vary from very low values of the order of a **few hundred liters of water per ton up to higher values**, however moderate, **of a few tens of cubic meters of water**.

[11] Mekonnen M.M., Hoekstra A.Y., 2011. The green, blue and grey water footprint of crops and derived crop products, Hydrol. Earth Syst. Sci., 15, 1577-1600.

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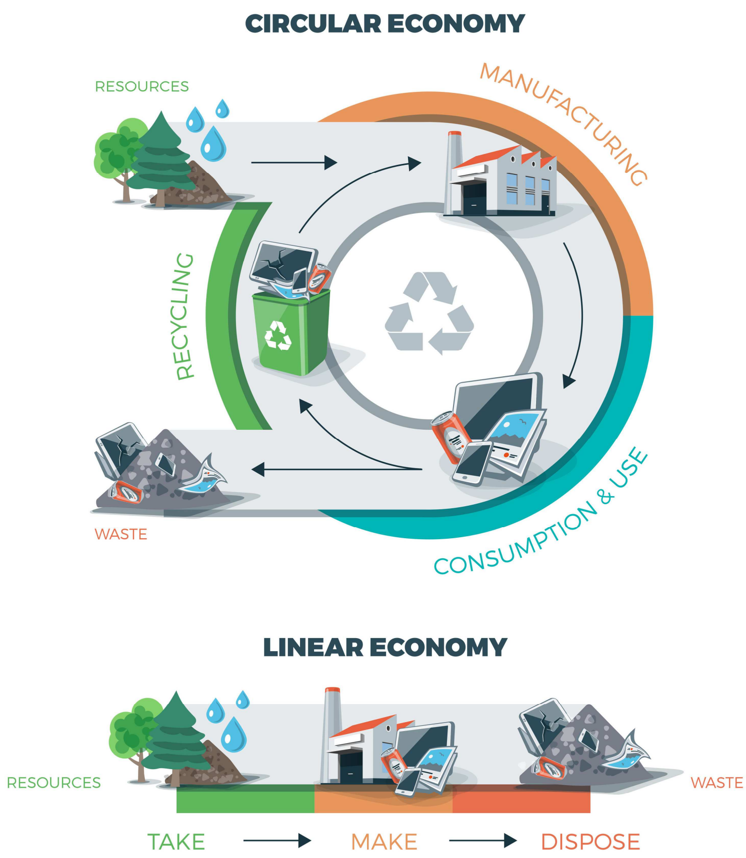
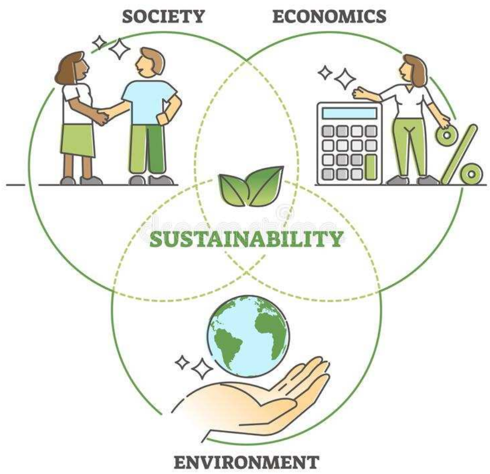
6. Analysis of results

The last few years have marked the spread of the innovative concept of circular bioeconomy which integrates the concept of bioeconomy into the classic definition of circular economy.

In the linear economy, the life cycle of products starts from the extraction of raw materials, continues with production and consumption, and then ends with the disposal of waste and the products that have become waste. The circular economy, on the other hand, is based on extending the life of products, on the use of raw materials according to usage rates compatible with their degree of regeneration and their reuse.



UNEP (United Nations Environment Program) defines the circular economy as "an economy that balances economic development with the protection of the environment and resources, emphasizes the more efficient use and recycling of resources, aims to low energy consumption, low emission of pollutants and high efficiency, involves the application of Cleaner Production and the development of Eco-Industrial Park for the development of industry, agriculture and urban areas" (UNEP, 2006). In other words, the circular economy is based on less dependence on non-renewable energies and fossil-based products, characterized by a high environmental footprint, taking into due consideration the three pillars of sustainability, 1) environmental quality, 2) economic prosperity and 3) social equity.



At the political level, the European Commission, in line with the climate neutrality goal of the Green Deal[12] by 2050, proposed in March 2020 a new action plan for the circular economy which aims to integrate sustainability into all phases of the value chain of a product, from design, to production, up to its consumption.

To define the bioeconomy, on the other hand, it is possible to refer to what was reported in the context of the Global Bioeconomy Summit in Berlin in 2015 (Helm, 2016), that is the "production based on knowledge and the use of biological resources, innovative biological processes and principles for supplying goods and services in a sustainable way to all economic sectors ". This definition emphasizes the need both to replace non-renewable resources and related products, and to further integrate the value of natural resources into economic development.

In the context of the circular bioeconomy, the forest sector and related products (such as wood fiber) will play a role of primary importance for the future economic development of the EU. In fact, the EUwood forecasting model has estimated that the potential of timber that can be harvested from European forests could be between 625 and 898 million m^3 in 2030, against a demand that is estimated to grow by over 70%. These data highlight the important role that the forest-wood supply chain and related products can play in the future in the circular economy of EU countries.

In Italy, the impact of the bioeconomy in reference to the year 2015 was estimated at about 251 billion euros, of which the forest-wood sector, including paper mills, represents about 15% of the total. In terms of employment, the bioeconomy employs over 1.7 million people, of which around 16% in the forest-wood sector (Intesa Sanpaolo, 2015). For this reason, forests were included in the final text of the "Italian Bioeconomy Strategy" (2017)[13] together with the marine bioeconomy, bioindustry and agri-food.

In the context of the bioeconomy, wood fiber and its use as a component of cultivation substrates in soilless agricultural systems offers an important opportunity for connection between the forest sector and the agri-food sector, where the decrease in arable land, the 'increased urbanization and the consequent localized demand for agricultural goods, the scarcity of water and other resources, as well as climate change exert a clear pressure on plant production.

One of the approaches that have always been considered the most virtuous to face the challenge

[12] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_it
[13] https://www.agenziacoesione.gov.it/lacoesione/le-politiche-di-coesione-in-italia-2014-2020/strategie-delle-politiche-di-coesione/strategia-italiana-per-la-bioeconomia/

of sustainability that combines an increase in production and respect for the ecosystem is soilless cultivation in a protected environment, the spread of which has now reached considerable dimensions in Europe (as in the Netherlands and in Spain), Canada and the United States, especially in the context of large horticultural industrial complexes.

The primary technical factors of soilless production certainly include growing media, i.e. "those materials different to the soil, consisting of one or more components, organic and / or inorganic, used to support plant development".

A good substrate must meet physical-chemical, mechanical and biological requirements which can be basically summarized in the following points:

- Ensure good anchoring to the root system and the stability of the pot-plant complex
- Have a good water retention capacity and good air availability even in correspondence with the maximum water capacity
- Be free of pathogens, parasites and phytotoxic substances
- Maintain physical characteristics unaltered for as long as possible and therefore resist compaction and volume reduction, maintaining good drainage capabilities
- Be homogeneous and uniform
- Have a competitive cost
- Be easy to find
- Be reproducible with consistent quality

Growing media therefore assumes a fundamental importance in soilless pot cultivation since the root system of the plants has a limited volume to explore and has greater needs for air, water and nutrients compared to agricultural soil.

For these reasons, also thanks to the progress of knowledge and production technologies, the substrate industry has placed on the market mixtures in which, in relation to the species and the cultivation system, different raw materials (organic, inorganic and additives) are added in different proportions.

Of all the constituent materials, peat is undoubtedly the most used. Derived from the decomposition of marsh grasses (mosses, sphagnums) in asphyxiated marshy environments, it has absolutely ideal characteristics for a cultivation substrate: homogeneity, high water retention capacity, good capacity for air, good structural stability (maintenance of the characteristics physical properties of the substrate), limited supply of nutritional elements, acid reaction that can be easily modified according to the cultivation needs with the use of calcination, absence of phytotoxic substances, absence of pathogens.

However, **peat is a limited resource** and **its extraction**, given the high demand, **causes very negative impacts on the environment**.

In fact, peatlands are habitat with a special ecological value, considered among the most important ecosystems in the terrestrial biosphere, capable of providing various environmental services, such as the preservation of biodiversity, the local regulation of water quality and hydrological conditions (including flood protection), as well as the maintenance of important long-term carbon sinks. Even though they represent only about 3% of the global surface, in fact, peatlands store a significant share of the terrestrial organic carbon (between 21 and 33%).

However, when these ecosystems are destroyed they no longer act as carbon sinks.

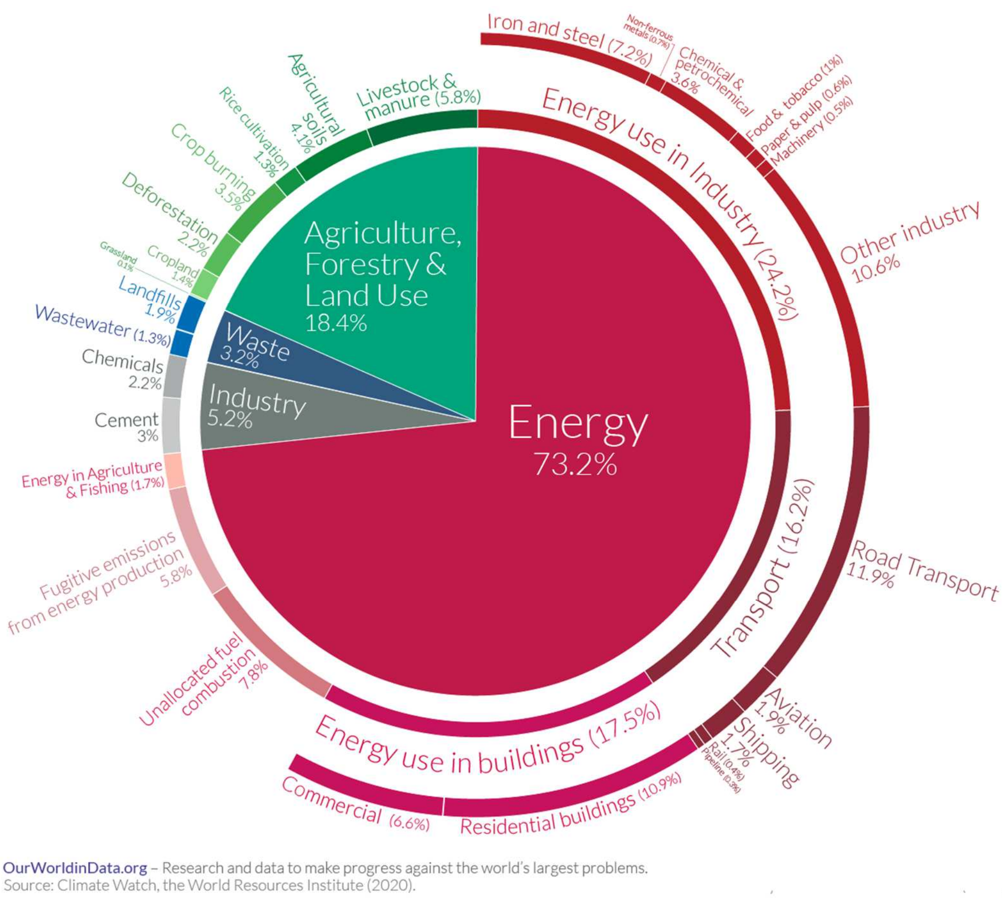
Degraded peatlands contribute disproportionately to global greenhouse gas emissions, **equivalent to around 15 million tons of carbon dioxide per year**, i.e. the emissions from around 750,000 cars each traveling 100,000 kilometers.

A study promoted by EPAGMA (European Peat and Growing Media Association) and prepared by the Swiss firm Quantis entitled "Comparative Life Cycle Assessment of Horticultural Growing Media Based on Peat and Other Growing Media Constituents 2012" clearly indicates that **peat has the greatest impact on "climate change" and "resources" among all the materials commonly used in**

the production of growing media.

Even inorganic materials are not free from environmental problems, as in the case of stone wool with which it is estimated that over 10,000 hectares are cultivated worldwide, including 6,000 hectares of greenhouses in Europe, mainly in the Northern countries. That material, obtained from the fusion at 1,500 ° C of aluminium, calcium and magnesium silicates and coke carbon, has a fibrous structure, is inert and has a high porosity (87%).
However, although some authors have shown some reuse options, the problem of its disposal has led to limitations of its current use. Analyzing its life cycle, Quantis reported that mineral wool reveals the greatest negative impacts on human health among all the materials commonly used in the production of growing media, without considering the relatively high transport costs.

In light of the foregoing, it is clear that carbon emissions and energy consumption in horticultural production systems are now increasingly in the public eye spotlight, therefore the consumer requires not only healthy and safe traceable products, but also "clean and green" products with a low carbon footprint. On the other hand, due to limited natural resources and waste recycling problems, environmentally acceptable solutions are needed for materials used as components of growing media.



Incidence of global greenhouse gas emissions by sector

In the last twenty years, numerous efforts have actually been aimed at identifying alternative materials to peat with the objective of its partial or total replacement and the development of mixtures to be used as growing media in nurseries with comparable physical-chemical characteristics. The results produced solutions already used in the preparation of substrates for growing in pots.

However, the many limitations that characterize some raw materials candidates for this replacement are not to be hidden, in the choice of which research has often indulged by combining organic materials (such as compost, coconut fiber and wood fiber) with suitable physical-chemical characteristics and possibility of effective use, with artificial materials, often recycled (as polystyrene, polyurethane foams, spent tire pellets), with severe limitations on use up to the actual phytotoxicity for the nursery crops.

Furthermore, the research activities have in some cases been directed to materials which, due to their characteristics, are intended to integrate the mixture and not to be used individually, if not in the face of particular cultivation techniques. This is the case, for example, of some aggregates, which in relation to the property of allowing the rapid removal of excess water are used to increase the porosity and the air capacity of the substrate. This kind of materials are used alone only in hydroponic crops, where, alongside the total inertia of the substrate, the rapid removal of the fertigation solutions is required.

The aim of this study was to compare the carbon emission of peat with that of the major candidates for its replacement, that is, quality compost, coir and wood fiber, all materials which have long been proven the possibility and opportunity of use in the face of agronomic characteristics defined and compatible with the soilless cultivation of plants.

In order to achieve the above, the carbon footprint was taken as a reference, i.e. that analysis of the life cycle that evaluates greenhouse gas emissions (GHG) directly and indirectly related to the production of a good and which allows producers (and consumers) to understand the impact of processes on climate change, giving them the opportunity to reduce it (and / or compensate it) over time.

The analysis, which took as reference bibliographic data and, limited to the wood fiber due to the absence of specific studies, primary data collected at a production plant (Fibra di Legno S.r.l.), highlighted a wide variability of the factors of emission, with presence of raw materials, including peat, very impacting, and others, just like wood fiber, much more respectful towards the environment.

The following table summarizes the emission factors of the materials taken into consideration.

Materials	**EF ($kgCO_2e\ t^{-1}$)**
Peat	1,208
Coconut fiber (coir)	361
Green compost	113
Other compost	484
Wood fiber	**188**

Peat, as already mentioned, is a fossil material containing plant residues, such as mosses and more or less decomposed sphagnum, present in natural deposits.
Fossilization is a very slow process and under anaerobic conditions the carbon fixed by plants in organic matter can remain stuck in the soil for thousands of years
The extraction and use of peat cause mineralization of a part of the organic matter with consequent release of carbon into the atmosphere in the form of carbon dioxide and other greenhouse gases; in addition, the process of extraction, processing, and transport from the places of origin to the sites of production (the latter generally carried out by road covering distances of thousands of kilometers) contribute, as energy-consuming, to significantly increase the emission factor of the material.

Finally, it should be noted that the extraction is often accompanied by the drainage of the peat bog, which makes the soil conditions aerobic by causing the emission of large quantities of nitrous oxide.

Unlike peat, coconut fiber, in addition to being renewable, is more sustainable by virtue of a significantly lower carbon emission, despite the fact that it is far away from the places of origin and consequently the incidence of shipping up to destination affect in terms of footprint.

With regard to green compost, the contribution on the total carbon footprint of fugitive emissions of methane and nitrous oxide during the composting process is substantial, resulting, in fact, the largest source of emissions.
It's worth remembering that the amount of these "leaks" depends on various factors, including the type of waste, the production technique (e.g. frequency of turning over), the shape, temperature and humidity of the heap, as well as the quantity of oxygen.
In general, green compost, also due to the localization of the resource and consequent low incidence of transport, is a very low carbon impact raw material.

The wood fiber, on the other hand, is very virtuous in terms of environmental performance by virtue above all 1) of the availability and widespread localization of the starting raw material (derived from the forest-wood supply chain or recycling) with a very low incidence of transport, 2) the substantial simplicity and cost-effectiveness of its production which translates into moderate electrical absorption during the material extrusion process, 3) the absence of process waste. It should be remembered the variability of the footprint in relation to the type of wood input, very limited in the case of use of recycled material, greater but still sustainable in the case of use of virgin wood directly derived from the forest supply chain.

The analysis was then completed by including the product water footprint assessment (WFP) among the environmental indicators deemed appropriate for defining the sustainability of different materials, which expresses the potential environmental impacts resulting from the use of fresh water and considers the water directly consumed and polluted for their production.

Also, in this case bibliographic data were taken into consideration and limited to the wood fiber, by virtue of the absence of specific studies in this regard, primary data collected from a producer (Fibra di Legno S.r.l.).

The following table summarizes the impacts on the water resource of the different materials.

Materials	Water impact ($m^3\ t^{-1}$)
Peat	9,000
Coconut fiber (coir)	2,449
Compost	< 100
Wood fiber	**0.13**

In general terms, the analysis highlights, as expected and already noted for the carbon footprint, wide variability of the sustainability performance of the different constituent materials analyzed, with the presence of some ones, such as peat and coconut fiber, which have been significantly more impactful unlike compost and wood fiber which are much more respectful of the water resource.

For peat the duration of the formation process (hundreds / thousands of years) in the humid places of origin affects the WFP, which results in a profound imbalance in the ratio between the evaporation rate in the bog and that of growth and consequently in the increase of the water footprint.

For the coconut fiber, the palm cultivation cycle and the production process of the material for "soilless" use, which involves, among other things, the washing of the coconut in order to reduce its salt content affects heavily the WFP. This impact is not related to the direct consumption of fresh water, which in most cases returns downstream of the production process at the same time and point of collection, but to the volume of polluted water.

For green compost, has already been reported the variability related to the different management methods of the percolation wastewater in the plant.

In terms of the significance of the reported data, it is useful to remember that the water footprint values of peat, coconut fiber and compost were taken from the bibliography due to the impossibility of taking them directly in the places of origin, therefore they are to be considered liable for future revision, also by virtue of the highly innovative nature of the measure.

Finally, the absolute compatibility in terms of safeguarding of water resource of wood fiber is evident.

This material therefore shows evident peculiarities in terms of environmental performance, fully responding to the concept of sustainability and to the three different "pillars" that characterize it, namely "environmental quality", "economic prosperity" and "social benefit".
The first is in fact amply demonstrated as a result of the limited carbon footprint (which becomes almost negligible in the case of the use of waste wood, as in the case of compost over-sieve fraction) and the marginal water footprint, both far inferior not only to peat (whose impact on climate change is reiterated), but also to materials already dedicated to its replacement such as coconut fiber and compost.
The "economic prosperity" is guaranteed, as well as by agronomic characteristics compatible with the cultivation in pots and in general with the soilless production that already today make it a substitute material for peat, by the dynamics of the current economy that see the sectors involved in the production and use of wood fiber in significant and constant growth. This is the case of the wood supply chain, which has already been considered strategic by the policies of promotion and development of the circular bioeconomy at national and European level, as well as of the agri-food production, today increasingly under pressure in terms of management and conservation of resources and its effect on climate change.
Lastly, the "social benefit" achieved above all in the face of the increase in the potential number of employees involved in the production chain and the distributed development of the territory should not be overlooked. It is in fact clear to everyone how wood (just think about forest) is by its nature a widespread, local, not very concentrated resource, the same is true for the production of wood fiber. Society and the community benefit from all this, with reference also to the economic effects on the territory and on the local community, as well as the landscape.

In terms of **wood fiber production processes**, it is worth noting the presence on the market of three different processes:

1) Mechanical treatment
2) Heat treatment
3) The sum of the first two (heat and mechanical treatment)

More specifically, mechanical treatment involves three different technologies:

1) Extrusion, that is, the fraying due to mechanical heating ("steam explosion") of the material;
2) Shredding by means of a hammer mill;
3) The "disc refiner", i.e. the action of two counter-rotating discs that reduce the wood into fibers.

With heat treatment, on the other hand, the sudden rise in temperature due to the entry of steam into a reactor causes "steam explosion", that is the "explosion" of the water contained in the wood.

Finally, with thermal and mechanical treatment, the wood is first treated with steam to make it softer and then extruded with a reduced use of energy.
This heterogeneity of production, linked to overall simple processes, will offer in the future the possibility of developing new systems and new technologies that can translate into a positive economic driving force for producers.

Moving on to analyze the **current size of the Italian wood fiber market**, a production of between 400,000 and 500,000 cubic meters per year is estimated to date, essentially related to the activity of only three different producers.

If this values are compared with the numbers of peat in Italy (equal to about 5 million cubic meters per year), the opportunity for the development of the wood fiber market appears clear, which shows good margins for growth even in the face of the partial reconversion of the current biomass plants now close to the expiry of the national contribution following a period of 15/20 years of activity as well as the possibility of differentiating the offer, producing fibers from different essences for specific garden and nursery needs.
On the other hand, in strictly productive terms, **the hypothesis of a partial or total replacement of peat with wood fiber is a widely achievable result**. Actually, assuming a production line capacity equal to 25 cubic meters per hour on a production cycle of 3,000 hours of work per year, about 30 plants (15 if we consider two lines per plant) would be enough to replace 50% of the peat and about 60 plants (30 from two lines) to cancel the imports of peat.

This reasoning allows to set the calculation of the hypothetical saving of greenhouse gas emissions following the partial or total replacement of peat with wood fiber.
In this regard, the calculations, elaborated on the basis of the emission factors established in this study and reported in the following table, estimate a lower impact (emissions avoided / saved) equal to about half a million tons of CO_2e in case of replacement of 50% peat with wood fiber and up to about one million tons of CO_2e in the case of total replacement (respectively equal to the emissions produced by about 25,000 and 50,000 cars each traveling a distance of 100,000 kilometers).

Materials	EF (kg CO_{2e} t^{-1})	Bulk density (t m^{-3})	EF (kg CO_{2e} m^{-3})
Peat	1,208	0.18	217
Wood fiber	188	0.11	20

Materials	Quantity (m^3)	Emissions (tCO_{2e})	Saving (tCO_{2e})
Peat	5,000,000	1,087,200	-
Wood fiber	0	0	
Total	**5,000,000**	**1,087,200**	

Materials	Quantity (m^3)	Emissions (tCO_{2e})	Saving (tCO_{2e})
Peat	2,500,000	543,600	**493,075**
Wood fiber	2,500,000	50,525	
Total	**5,000,000**	**594,125**	

Materials	Quantity (m^3)	Emissions (tCO_{2e})	Saving (tCO_{2e})
Peat	0	0	**986,150**
Wood fiber	5,000,000	101,050	
Total	**5,000,000**	**1,087,200**	

This extremely ambitious result opens up further consideration on the opportunity for the development of wood fiber in the horticultural sector. In terms of emissions avoided / saved, in fact, there has been much discussion in recent times about the introduction of a tax on products and services that involve CO_2 emissions, the so-called "carbon tax", accompanied by a second tax, the "border carbon tax ", which introduces a duty on imported products that have environmental standards lower than those established for those who produce internally, offsetting the negative effects of any competition based on less sustainability.
In fact, some important observers have argued for a long time that establishing a price for greenhouse gas emissions is essential to try to limit climate change, on which not even the partial block of industrial production caused by the Covid-19 pandemic and the general lockdown have

succeeded to affect.
To date, according to the OECD, the carbon tax of the forty-two major economies is worth an average of 8 USD per ton of CO_2, however the United Nations estimates it is necessary to reach an amount between 135 and 5,500 USD per ton by 2030, otherwise it will not be possible to contain the increase in global average temperatures to within 1.5 degrees centigrade compared to the pre-industrial era.
Regarding the value of this mechanism, cannot be referred the case of the countries of Northern Europe which, since the early 1990s, have introduced a carbon tax and today lead the ranking of the nations that have most reduced greenhouse gas emissions in relation to the gross national product, with percentages ranging between 45 and 55%.
The European Union has never adopted the carbon tax (also because taxation is a national matter), opting for the Emissions Trading Scheme (ETS), with the same goal, that of discouraging the use of fossil fuels and reorienting the productive system towards sustainable sources and processes.
However, the adoption of the ETS does not exclude a future carbon tax at the national level. On the other hand, the next international conference on climate change, COP26 in Glasgow, in November 2021, will be the deadline for nearly two hundred countries to update their emissions reduction commitments. If the meeting does not give the hoped-for results, the EU has already reiterated that it will proceed with unilateral measures and for this reason it is already developing a regulation that aims to penalize the imports of some goods from countries with weak pollution rules, thus helping to protect the competitiveness of local producers who meet the most stringent standards. The carbon border tax, in fact, as mentioned, can act in a double direction: rebalancing competition, avoiding relocation to "less virtuous" countries, and promoting a change in climate policy, guaranteeing a global increase in environmental sustainability standards.
In this context, it is likely that in the near future those who want to continue to use peat in horticulture will also necessarily have to bear the load of the carbon emissions related to it.

To conclude, cannot fail to note the economic sustainability of the wood fiber, whose production cost is much more competitive, of the other materials commonly used in the substrate industry as peat or coconut fiber to which the cost-effectiveness of transport due to the localization of its production must be added; the farther is the peat excavation site or coconut fiber origin, the more competitive is the wood fiber price.

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