futerro

PLA, A DURABLE AND SUSTAINABLE POLYMER FOR A GREENER FUTURE

WHITE PAPER

2025

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INTRODUCTION

PLA AS A VALUABLE SOLUTION FOR OUR ENVIRONMENT

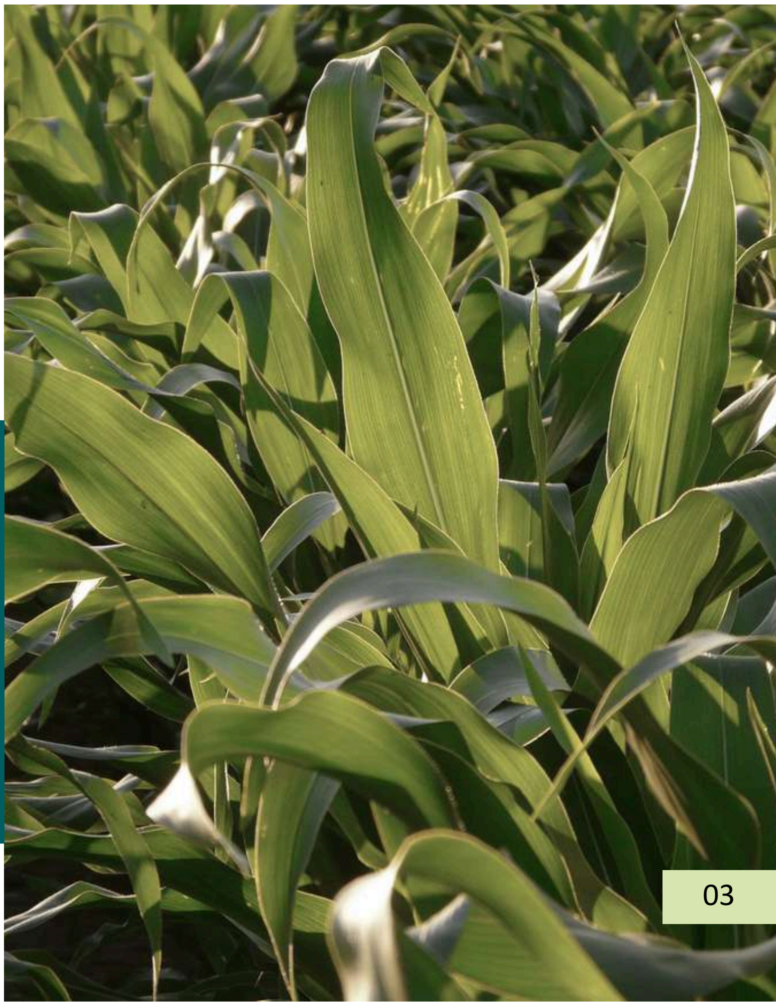
In a world where sustainability and environmental preservation have become major concerns, choosing carbon sources for the chemical and plastic industry is crucial. Lactic acid, lactide and polylactic acid (or PLA) are promising solutions to those challenges.

Plastics occupy a dominant part of our modern economy. It encompasses a wide range of applications, from food packaging to personal care products, pharmaceuticals, textiles, and more. However, the predominance of traditional petroleum-based materials has led to growing concerns about their impact on the environment and human health, due to their slow (or non-) degradation, poor recyclability, high carbon footprint, challenging end-of-life management, and potential eco-toxicity on animals, plants, and human organisms.

Against this backdrop, PLA bioplastic is emerging as a promising alternative to traditional plastics. PLA is a polymer that can be recycled and composted under certain conditions and is 100% bio-based, so it is manufactured from renewable and sustainable resources such as wheat, corn or sugarcane. Given these sustainable features, PLA can be considered as a fully circular product, also called and defined by Futerro as a biorenewable product.

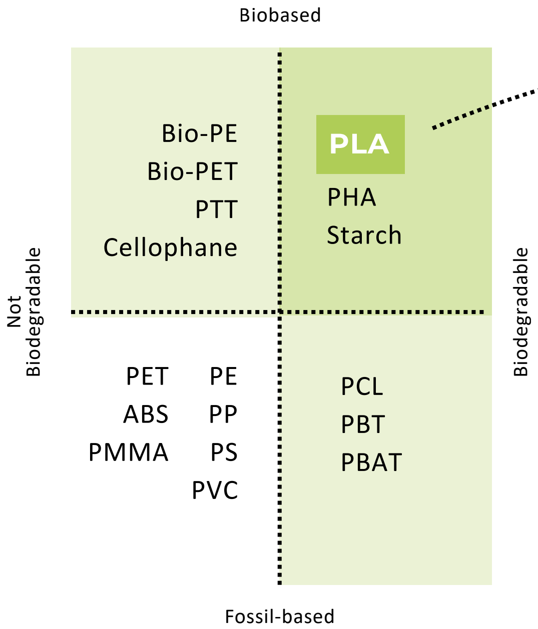
In addition to its ecological credentials, PLA can be used in a wide range of applications thanks to its versatile physical and mechanical properties, such as transparency, high strength, and high stiffness.

Furthermore, PLA is compatible with existing processing and manufacturing techniques, making it easy to integrate (drop-in solution) into existing production lines of standard commodity plastics such as PS, PP or PET.



WHAT ARE BIOPLASTICS?

Bioplastics encompass a diverse family of materials, as defined by the European Bioplastics Association. They include plastics that are either biobased, biodegradable or possess both attributes, as presented in Figure 1. For instance, polylactic acid (PLA) stands out as a bioplastic that is both derived from plant sources and biodegradable (industrially compostable).



	PLA	Fossil-based & non biodegradable polymers
Feedstock	Renewable ressources	Fossil ressources
Cradle-to-gate CO_2 Emissions	Limited	Significant
Compostable	Yes, under industrial conditions	No
Non-toxic when incinerated	Yes	No
Recyclable	Yes	Limited*
Non-persistant in the environment	Yes	No

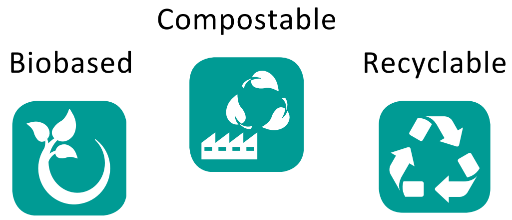
*depends on the type of plastic (e.g. PET and polyolefins are already recycled in Europe, whereas this is not the case of PS).

Figure 1: Bioplastics definition and focus on PLA vs. fossil-based polymers. © Futerro

Biobased plastics, a significant fraction of the bioplastic family, are manufactured from naturally renewable resources such as corn, sugarcane, or wheat. Some emerging sources of renewable raw materials include algae and fungi. However, these have not yet reached industrial-scale production and are not considered for now economically viable feedstocks for bioplastics manufacturing.

In contrast, fossil-based plastics, often referred to as conventional plastics, originate from non-renewable resources like oil or gas. These resources, categorized as non-renewables, stand in stark contrast to the sustainable and renewable nature of biobased plastics.

BIO-RENEW-ABILITY CONCEPT



PLA'S MAIN CHARACTERISTICS

- Low Carbon Footprint
- Produced from sustainable raw materials
- Responsible Production
- Generally recognized as safe
- Multiple end of life options
- Food contact approved
- Versatility of applications

FUTERRO'S PLA CERTIFICATIONS

Biobased Products :
DIN EN 16785-1:2016-03
ISO 16620-2_2016
Industrially Compostable Products :
DIN EN 13432:2000-12

Food contact approved :
(US) FDA 21 CFR 175:300
(EU) No 10/2011 & (EU) 2020/1245
(CN) GB 4806.7-2016

LACTIC ACID & PLA'S BIO-BASED ORIGINS

PRODUCTION FROM WHEAT

1 **Photosynthesis**: During photosynthesis, light energy is harnessed to transform carbon dioxide into organic compounds such as proteins, oils, and starches. These compounds, which are valuable biological products, vary depending on the chosen feedstock, which can include wheat, corn, sugar cane, sugar beet, and others.

2 **Starch extraction from wheat**: When the feedstock growth is completed, it can be harvested and stored for several months. Processing wheat involves cleaning and milling the grains to separate components like bran (fiber), endosperm (starch and gluten), and germ (dry feed). Starch is extracted by washing, and gluten is isolated through kneading. The extracted starch and gluten are usually dried and packed for industrial and food/feed applications. Wheat bran can be added back to enrich products with dietary fiber, mainly for the feed industry.

3 **Starch hydrolysis**: The extracted starch goes through a hydrolysis process, during which the starch molecules are broken down into smaller sugar molecules (carbohydrates). This is generally done using natural enzymes, that are naturally occurring substances capable of breaking down starch into glucose.

4 **Fermentation**: Wheat glucose fermentation into lactic acid is a natural and biological process in which, sugars, typically glucose or other carbohydrates, are converted into lactic acid by natural microorganisms. This fermentation process occurs under anaerobic conditions. Once produced, the lactic acid is purified using different processes to reach high-purity lactic acid grade required for the PLA polymerization.

5 **Cyclisation**: The transformation of lactic acid into lactide involves several chemical reactions like cyclisation where two molecules of lactic acid create a ring called lactide. The lactide is then collected and purified through different processes.

6 **Polymerization**: Once purified, lactide can be polymerized through a process called ring-opening polymerization, in which the lactide molecules open their cyclic structure and react together, forming long-chain polymers known as PLA.

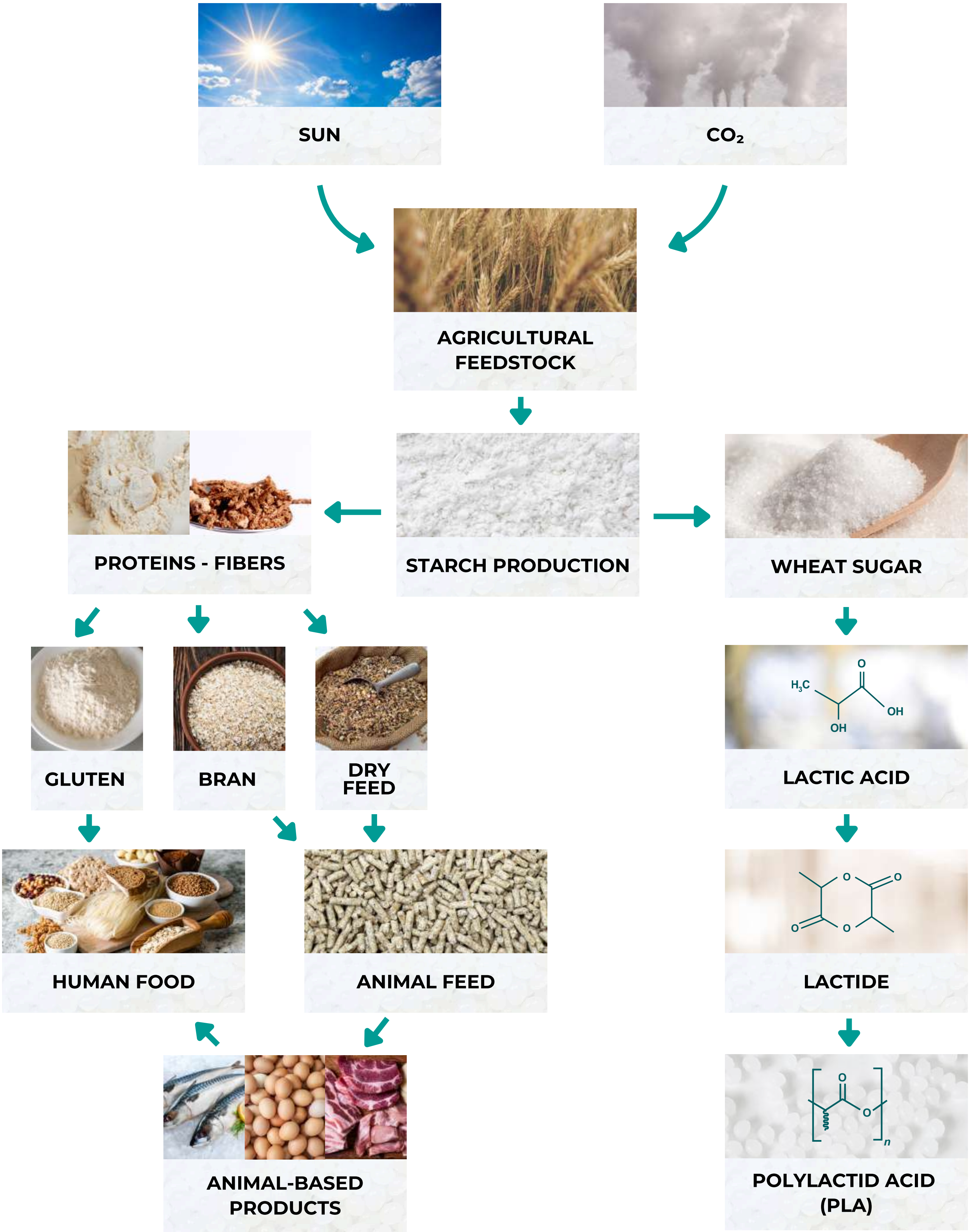


Figure 2: PLA production principle starting from wheat as biobased feedstock © Futerro

SWITCHING CARBON RESOURCES

Decrease in carbon demand expected in all sectors, except for chemicals & materials.

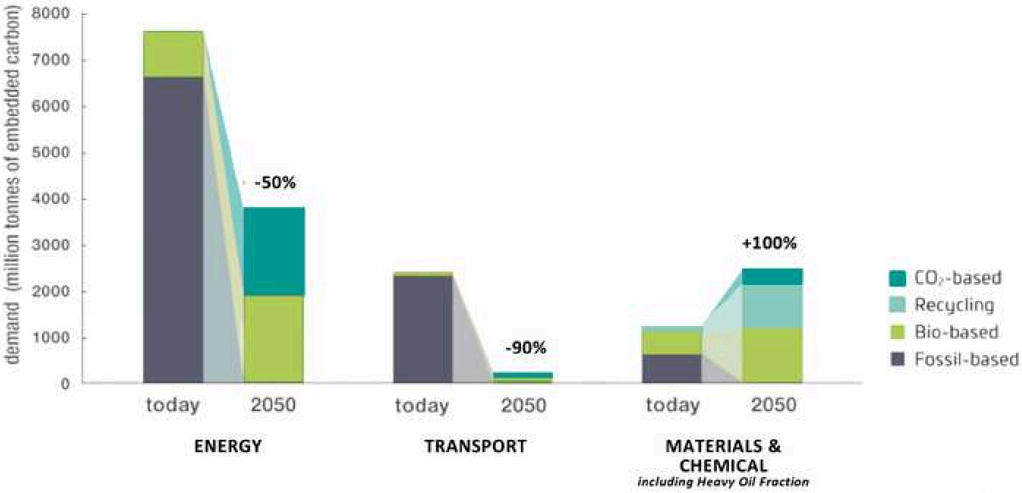


Figure 3. Embedded Carbon Demand for Main Sector. © Nova-Institute [1]

The use of renewable carbon as feedstock is one of the key conditions to achieve carbon neutrality by 2050. According to previsions from Nova-Institute [1], the only sector where the use of carbon sources will increase is the one of chemicals and materials. Indeed, such products are, by nature, produced from and containing carbon molecules; it is, therefore, impossible to switch them to non-carbon base molecules. The only way to mitigate their impacts on our environment is to use respectful and sustainable alternative carbon feedstocks including biobased, recycled, or CO_2-based.

By 2050, the global plastic production could reach 1,200 million tonnes worldwide. In order to reach carbon neutrality, scientists estimate that 135 million tonnes of plastics must be biobased, 315 million tonnes will be CO2-based and the remaining portion, 750 million tonnes, will be derived from recycled carbons [3].

Therefore, the only available solution for the chemical and material sector to reach carbon neutrality is to use and promote non-fossil-based carbon feedstocks as raw materials. PLA is a unique solution, being both 100% biobased and 100% recyclable using multiple end-of-life solutions like mechanical or chemical recycling. PLA can be considered as one of the most trustable solutions to defossilize the plastic industry.

Switch to sustainable alternative carbon sources.

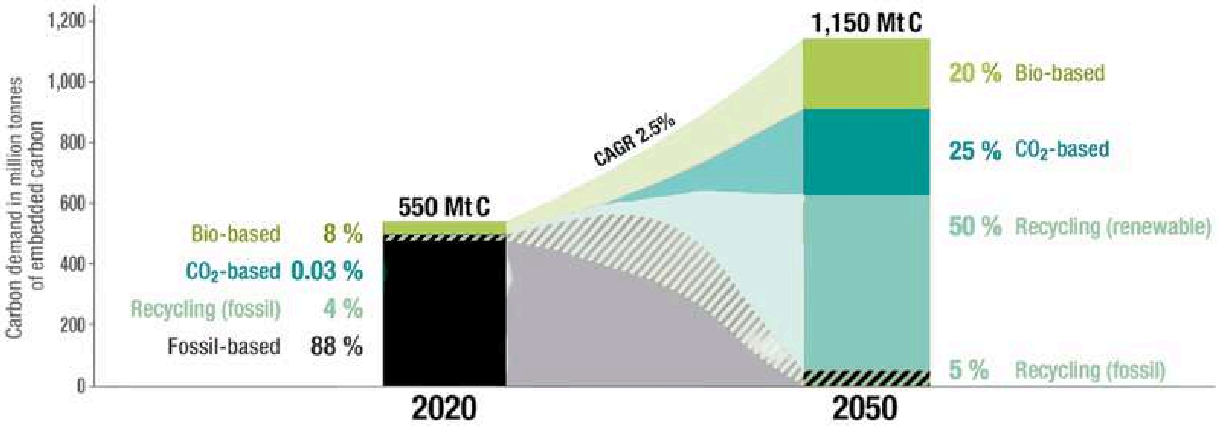


Figure 4. Carbon embedded in Chemicals and Derived Materials (inc. Plastics). © Nova-Institute [2]

SUSTAINABLE ORIGIN

BIO-BASED PLASTICS: LESS THAN 0,02% OF LAND USE TO DATE

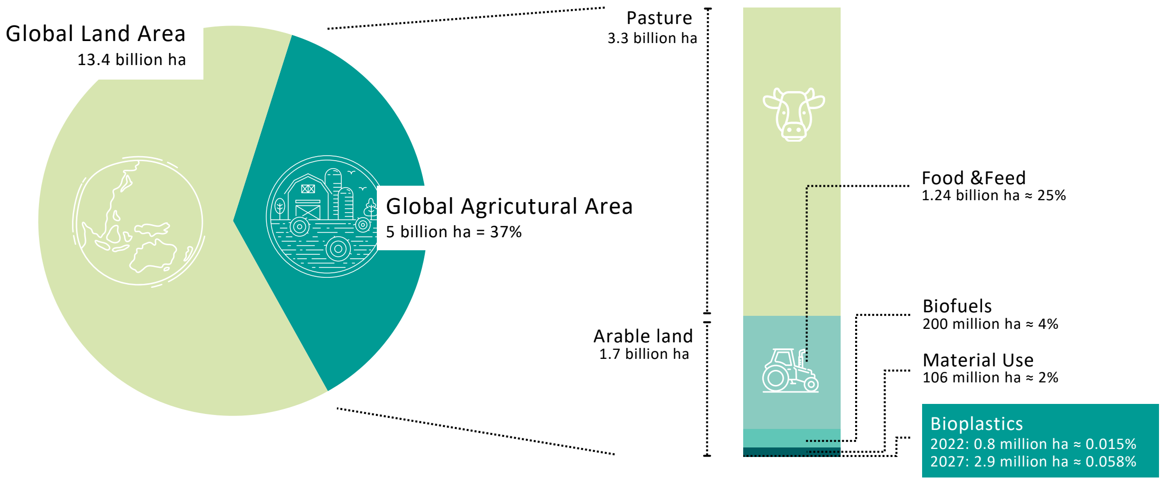


Figure 5: Land use estimation for bioplastics in 2022 and numbers estimated for 2027. [4]

In 2022, as presented in Fig. 5, the arable land dedicated to growing renewable feedstocks intended to produce bioplastics amounted to approximately 0.8 million hectares [4]. This figure remains remarkably modest, representing only 0,015 per cent of the entire global agricultural landscape spanning 5 billion hectares. Looking ahead, as global bioplastics production is poised for significant expansion over the next five years, the arable land used for bioplastics production will indeed rise, albeit conservatively, to a level below 0.06 per cent. These statistics underscore the compelling fact that there is no immediate competition between the resources allocated to renewable feedstocks for sustenance, animal feed, and the thriving bioplastics industry.

On the other hand, the sustainable sourcing of feedstock is a prerequisite for more sustainable and durable biobased products. Using non-sustainable feedstocks could impact negatively our environment like through massive deforestation. The same applies to social criteria and human rights. The selection of feedstocks harvested with good agricultural practices and covered by social standards is a part of Futerro's sourcing strategy.

PLA, ONE OF THE MOST EFFICIENT CARBOHYDRATE USAGE FOR THE BIOECONOMY

PLA production has the advantage of using less sugar per unit of product than bioethanol, bio-PET, and bio-PE. PLA proves to be the least land-intensive biobased product (Fig. 6.).
This production efficiency reduces pressure on resources and contributes to more sustainable use of raw materials while offering a versatile bioplastic with attractive environmental properties for a broad range of applications.

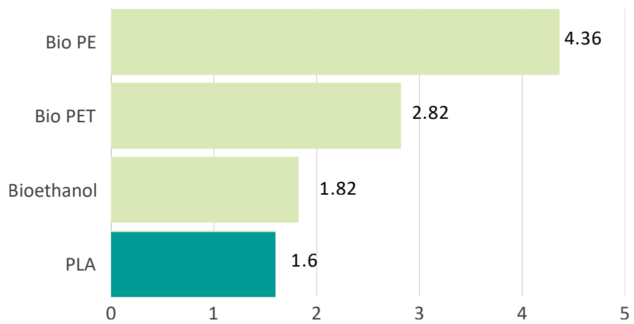


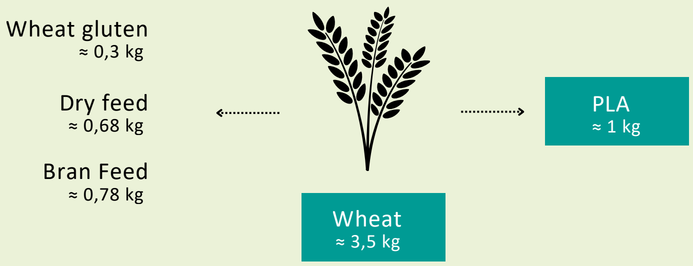
Figure 6: Sugar consumption per type of biomaterials (kg.eq) [5]

FEEDSTOCKS SELECTION

WHEAT AS RENEWABLE FEEDSTOCK

Agricultural yields per hectare of arable land vary according to crop type and geographic region. As the world's population grows and demand for resources increases, the availability of arable land could become limited. It is therefore crucial to use the most effective and versatile crops available.

PLA from wheat: extracting the maximum of each grain



Please note, this estimate is provided as an example and the actual values may fluctuate yearly. This variation is due to factors such as grain quality, weather conditions during growth, and numerous other environmental influences impacting harvests.

Figure 7: Production of valuable side-products during PLA production from wheat. © Futerro

As presented in Fig. 7., for 1 KG of PLA, many different valuable side-products can be extracted from the feedstock. From wheat, dry feed, bran feed, and gluten are extracted. The PLA is then produced with the less valuable portion of the plant, starch (sugar portion), which is mainly used today for bioethanol production or cardboard for example.

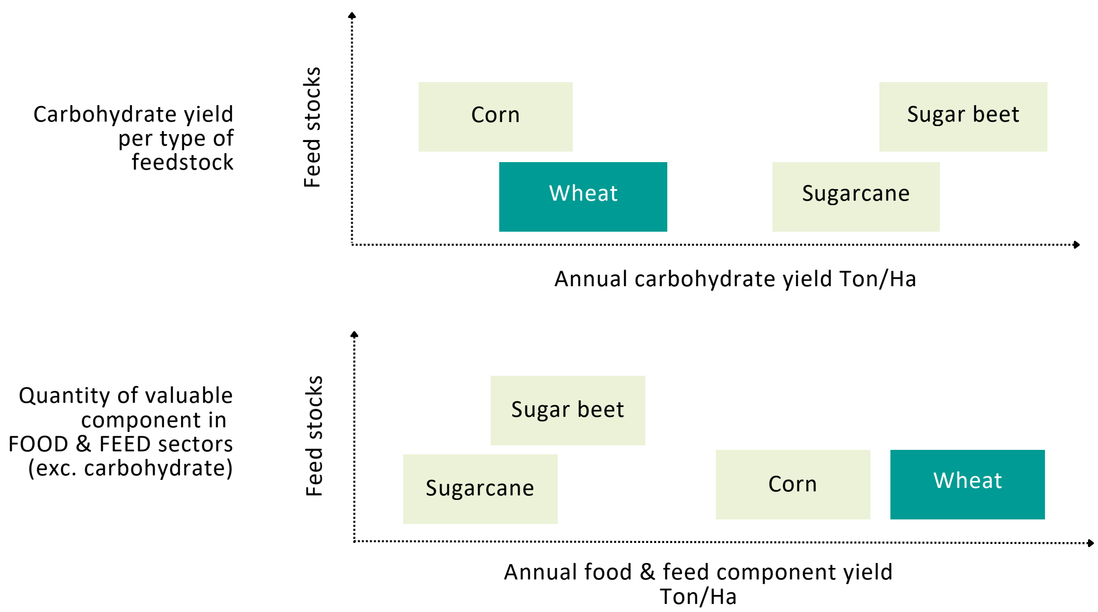


Figure 8: Ranking of the main sugar producing crops by carbohydrates and food/feed component productivity [6]

For its future biorefinery in France, Futerro has chosen locally grown French wheat as the primary feedstock for PLA production. Unlike sugarcane or sugar beet, wheat cultivation yields a diverse range of high-value co-products, particularly relevant to food and feed sectors (see Fig. 8).

ADVANTAGES OF A BIOBASED FEEDSTOCK

According to a recent study from Nova Institute [6], the use of biomass for industrial applications has the potential to replace fossil feedstocks and thus contribute to the urgent reduction of fossil carbon emissions in the atmosphere to fight against climate change. While not denying the direct need to fight world hunger, the report argues that using food and feed crops for chemicals and materials will not exacerbate food insecurity.

In fact, selecting an annually renewable feedstock for bio-based materials production offers several advantages, especially in the context of sustainability and environmental considerations:

SUSTAINABILITY

Annually renewable feedstocks are derived from plants, crops, or other natural resources that can be replanted and harvested on an annual basis. This ensures a continuous and sustainable supply of raw materials without depleting finite resources.

REDUCED ENVIRONMENTAL IMPACT

Using annually renewable feedstocks often results in a lower carbon footprint compared to fossil fuels or non-renewable resources. The growing and harvesting of these sustainable feedstocks typically involve fewer greenhouse gas emissions and less environmental degradation.

FOOD & FEED SECURITY

Due to the high value of the protein-rich or oil-rich co-products of food and feed crops, the overall availability of edible crops that can be stored and re-distributed in times of crisis (emergency reserve), actually mitigates risks of supply-cycle triggered regional hunger events.

ECONOMIC BENEFITS

The growing and processing of annually renewable feedstocks can create jobs and stimulate local economies in rural areas. This can have a positive economic impact on communities and regions that rely on agriculture and natural resources.

MARKET STABILITY

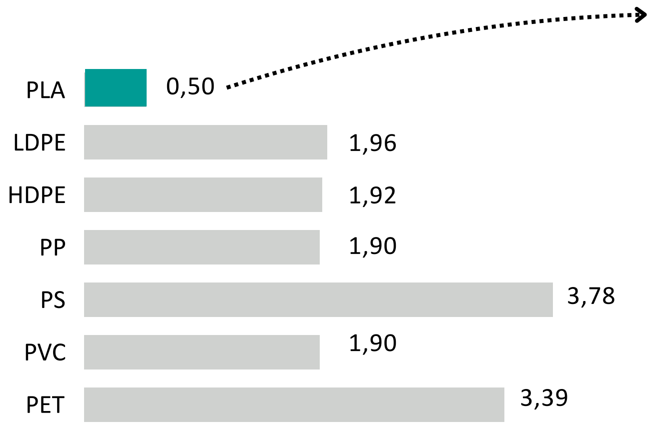
The risk of shortages and speculation peaks is reduced by the increased global availability of food and feed crops.

GMO-FREE PRINCIPLE

Futerro's technologies are not based on GMO micro-organisms. Therefore, Futerro does not select GMO-based feedstocks as raw material for PLA production. Indeed, GMO-crops can have unintended environmental consequences, such as the development of resistant pests or a decrease in terms of biodiversity. Non GMO-feedstocks are seen as a way to mitigate these risks and ensure sustainable agriculture for the coming decades in Europe and France.

CARBON FOOTPRINT

PLA represents a promising and sustainable alternative to fossil-based plastics, as it drastically lowers carbon footprint and hence becomes a trust partner in the transition towards more eco-friendly plastic solutions.



- Renewable feedstocks boast limited emissions during PLA's production process (inc. CO2 uptake)
- Energy is one of the main sources of GHG emissions in the PLA production process, thus carbon footprint is reduced through increased adoption of renewable and nuclear energy

Carbon emissions of virgin PLA (inc. CO2 uptake) are much lower than those of virgin fossil-based plastics

This benchmark analysis could only be considered as a reference, because results from different studies are not comparable due to the different methods, assumptions and so on. Official future LCA of PLA produced in our new plant in France will be published once the biorefinery will be running.

Figure 14: Average CO_2 foot print of main fossil-based plastics compared to average LCA market data for virgin PLA © Futerro. (Source: TÜV Rheinland - BAFA, Probas, Materia Nova).

In order to guarantee a sustainable supply of raw materials, it is crucial for our society to explore alternative resources for manufacturing vital goods. Using biobased plastics, such as PLA derived from renewable sources, offers a promising path to reduce dependency on finite fossil resources, which starkly contrasts with conventional plastics produced from non-renewable crude oil, having a high environmental impact as presented in Fig. 14.

Unlike fossil-based polymers, PLA derived from renewable origins offers the advantage of absorbing more CO_2 during its production process. However, it is important to note that the production of PLA still relies on energy, contributing to a non-neutral CO_2 balance. The potential for achieving carbon neutrality lies in the ability to use renewable energy sources during the production process, as well as the inclusion of recycled content. This presents an opportunity for Futerro with its future project in France, where at least 10% of the energy could be sourced directly from biogas produced on-site through wastewater treatment, and the implementation of the first European chemical recycling facility for PLA based products to decrease again the carbon footprint of the products and so further defossilize the biorefinery.

Furthermore, PLA stands out as one of the most prevalent and commercially viable biobased polymers, particularly for numerous applications where reducing the high CO_2 footprint of traditional plastics is essential. PLA's renewable nature positions it as a key player in the pursuit of sustainability in material production.

FULLY INTEGRATED BIOREFINERY PROJECT INTRODUCTION

Futerro's biorefinery project aims notably to to produce 75.000,00 tons of PLA per year, using technologies developed and patented by Futerro.
The production is set to occur on a site spanning 26.5 hectares, located within the Port-Jérôme II industrial port zone in the commune of Saint-Jean-De-Folleville, Normandy, France.The estimated investment is about 500 million euros and would create 250 direct and 900 indirect jobs locally. The PLA produced by the plant would primarily be destined for the European markets.

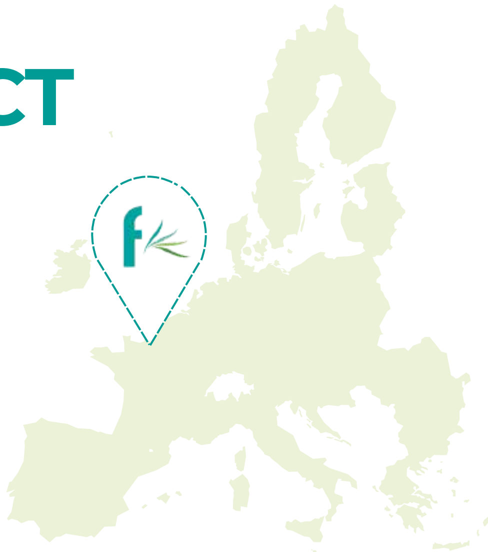


Figure 12. Localisation of future Futerro's biorefinery. © Futerro

The Futerro's biorefinery would include 3 main, distinct, and complementary units (ISBL):

- A fermentation unit in which sustainable wheat sugar would be transformed into lactic acid,
- A polymerization unit to transform lactic acid into lactide and PLA,
- A PLA recycling unit which, thanks to the patented LOOPLA® technology, will allow production of virgin quality PLA by recycling post-industrial and post-consumer PLA waste.

Support facilities are also planned to ensure the smooth operation of the site (OSBL):

- • A wastewater treatment plant producing biogas for direct on-site consumption,
- A gas-fired boiler to supply the site with energy from natural gas and biogas,
- Storage areas for raw materials and finished products,
- Administrative offices and parking lots for staff and visitors.

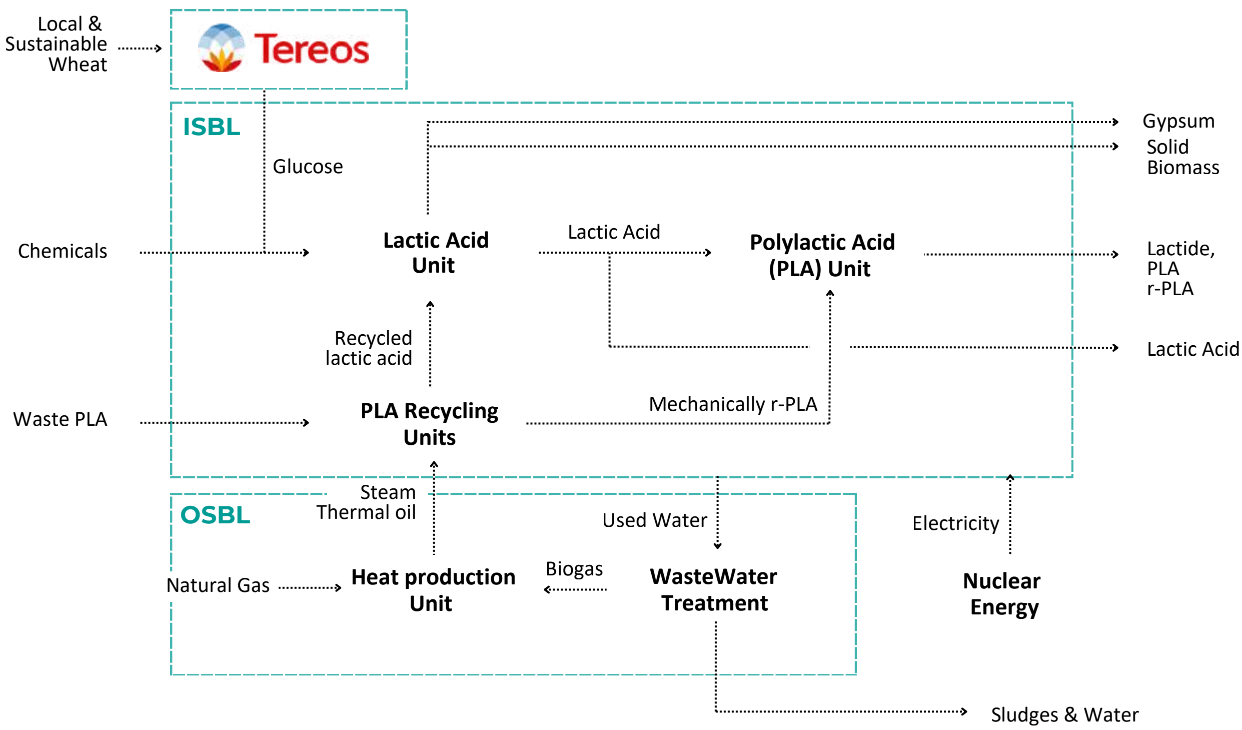


Figure 13. Schematic view of Futerro's future biorefinery. © Futerro

SUSTAINABLE FEEDSTOCK FOR OUR PROJECT

With its new project in France, Futerro is committed to developing the French and European bioeconomy sectors while respecting the local environment and agricultural sector. The Seine ports are at the heart of Europe's largest wheat-producing region. The diversity of production territories and yields, which are among the best in the world, guarantee a regular supply in terms of quantity and quality. Therefore, Futerro decided to source its biofeedstock directly from French and local producers (Fig. 9.).

A PLA COMBINING FRENCH QUALITY, SUSTAINABILITY AND LOCAL SOURCING

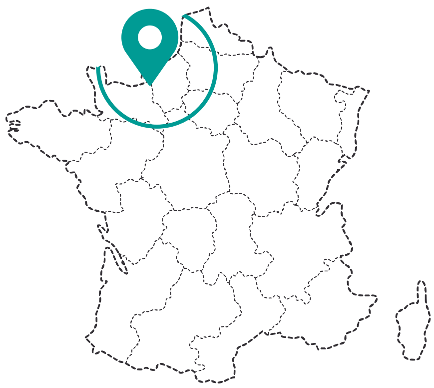


Figure 9. Wheat's origin for our future biorefinery. © Futerro

Futerro decided to externalize its wheat sourcing, storage, and processing into carbohydrates to an external and local service and product provider: the agricultural cooperative Tereos.

Tereos follows a strict CSR policy based on five major values: (1) sustainable agriculture, (2) protection of the environment, (3) preservation of resources, (4) responsible consumption, and (5) local development.

Tereos is granted the 2BS certificate [7], enabling it to demonstrate, via independent audit, compliance with the sustainability criteria set out in European Directive 2009/28/EC, amended by Directives, 2013/18/EU of the Council of May 12, 2013, and 2015/1513 of the European Parliament and of the Council of September 9, 2015. Even if those regulations and directives applied to the bioethanol sector, PLA being manufactured with the same raw materials follows the same scheme (Fig. 10.).

The scheme defines requirements and imposes compliance with several types of quantitative and qualitative criteria.

- Wheat must not come from land with "high value" in terms of biodiversity or carbon storage, or from peatlands that have been drained.
- Raw materials must comply with the Environment section of CAP cross-compliance and Good Agricultural and Environmental Conditions (GAEC).
- Implementation of a mass balance for each logistics unit.
- Implementation of a control system for each actor in the chain.

This approach makes it possible to certify as sustainable, within the meaning of the directive, the biomass used as a raw material and the starch produced from it. Therefore, Futerro's feedstock in France and its derived products (lactic acid, lactide and PLA) are considered as sustainable.

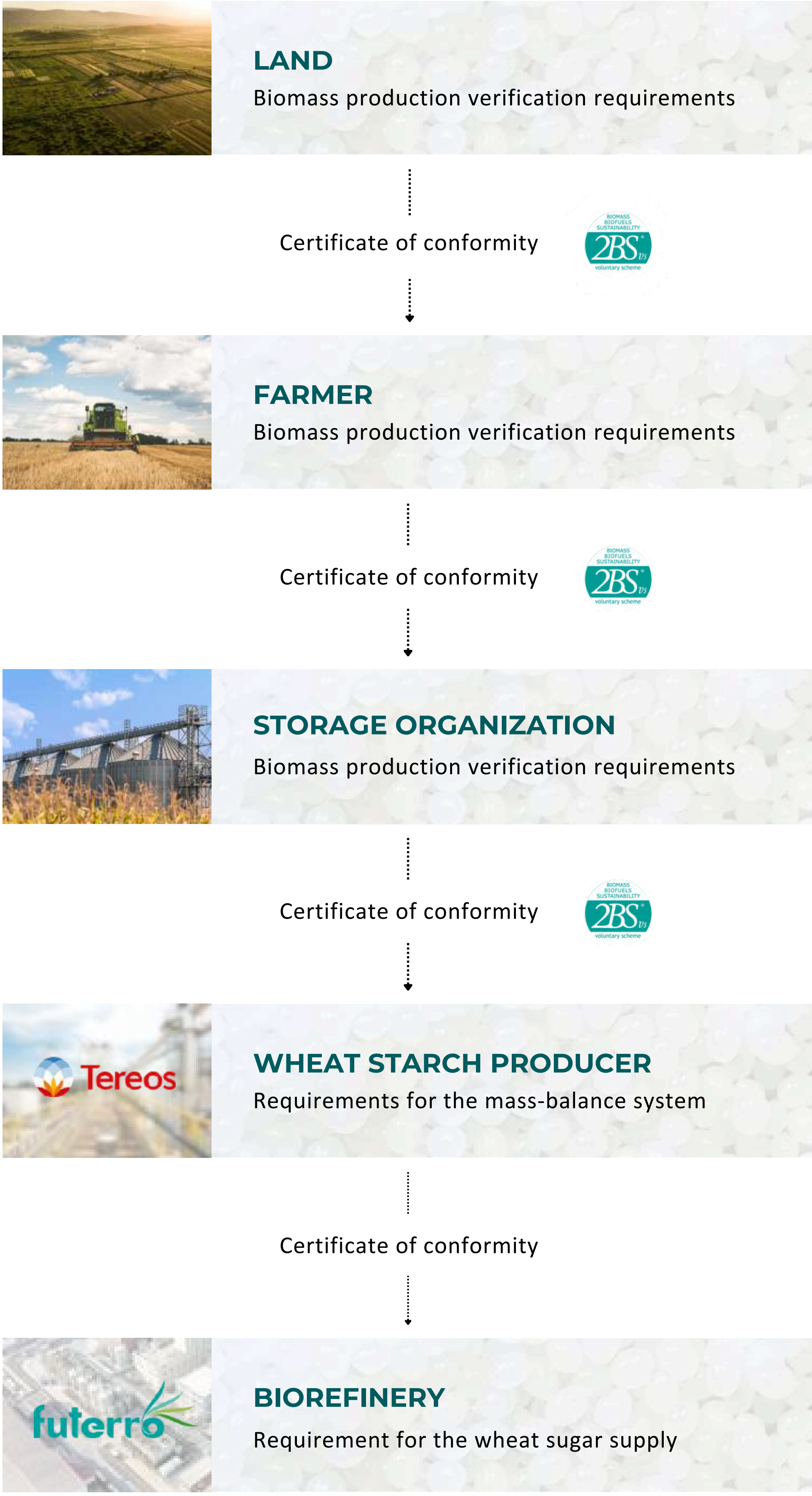


Figure 10. Sustainable principle in future Futerro's plant in Normandy. © Futerro

LINK WITH THE FRENCH AGRICULTURAL SECTOR

Wheat is mainly composed of starch representing 65 to 70% of its mass. Gluten, the protein fraction, accounts for 10 to 12%, and the remaining portion is fiber. Therefore, according to Futerro's estimates, the future biorefinery would use approximately 300.000,00 tons of wheat grain when the plant is at 100% production capacity.

Considering recent French wheat production reported by France AgriMer [8] during the 2021/2022 production campaign, total wheat production in France (38,5 Mtpa - 100%) is valorized as follows:

- 45,05 % is exported, mainly to Europe
- 20,17 % is used for animal feed
- 10,48 % is processed for human consumption
- 7,28 % is stocked for next year
- 7,18 % is used for starch or gluten production
- 4,32 % is used for bioethanol production
- 4,98 % is used for various purposes, including food and non-food, seeds, and shrinkage
- 0,55 % depends on importation

Drawing from the average wheat production capacity in France between 2010 and 2020, with an estimated wheat productivity of 7.1 T/ha per hectare, it can be inferred that Futerro's requirements will consume less than 0.80% of the total French wheat capacity. This equates to utilizing less than 0.1% of the total land area of continental France (Fig. 11.).

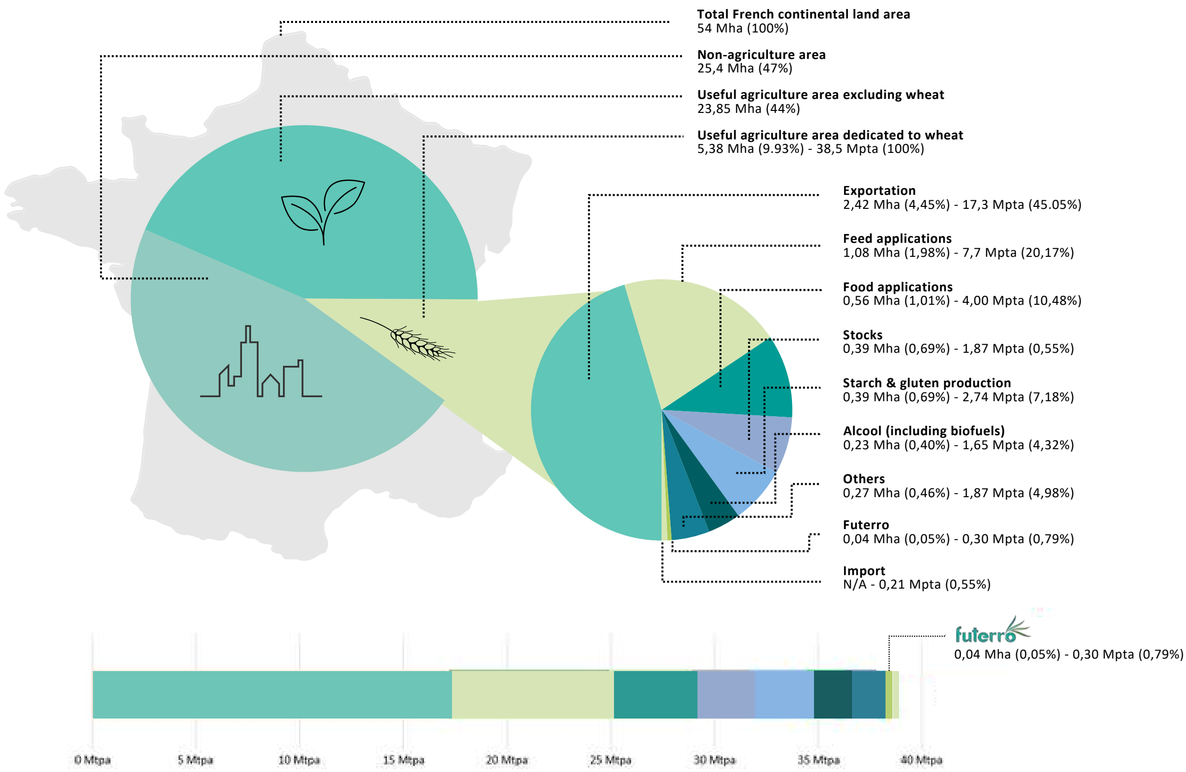


Figure 11. Wheat usage per applications in France in 2021/2022, and considering the needs from future Futerro's factory in Normandy. (Mha Million Hectare, Mtpa Million tons per annum). © Futerro (based on France AgriMer 2021/2022 [8])

ENVIRONMENTAL IMPACTS OF OUR PROJECT

The future biorefinery will be an installation classified for environmental protection (ICPE) and will have to undergo an environmental authorization procedure. The aim of this procedure is for Futerro to demonstrate the project's conformity with identified risks and impacts.

The French Environment Code precisely lists the elements that must be included in the environmental authorization application file. It must include technical information, such as a description of the project, manufacturing processes, materials and substances used, and the means of monitoring and surveillance. It must also make it possible to identify the issues at stake through a non-technical presentation note, a hazard study, and, above all, an impact study. Carried out on the basis of a comprehensive environmental assessment, this is the most important part of the dossier, covering the project's overall effects.

Futerro's project is designed and built to respect the following approach (Tab. 1.) :

Environmental Impacts	Actions
Fauna & Flora	A fauna/flora study has been completed. The project will incorporate all necessary measures to preserve local fauna and flora in consultation with the local authorities and taking into account neighboring projects. Futerro is committed to compensating by rehabilitating an area equivalent to 1.5 times that impacted by the project. In other words, it is an area of approximately 40 ha which will be sanctuaries to preserve nature.
Agricultural Sector	Although the site is in an industrial zone, part of the plot of land planned for the biorefinery is currently used for agricultural purposes and is therefore eligible for agricultural compensation. Futerro is committed to compensating for its impacts by providing a public fund dedicated to promoting the development of local and sustainable agriculture.
Population	To avoid any negative impact on the local population, several actions are considered : • An acoustic modelling is included in the study to assess and limit the impact of the project. Futerro will monitor noise emissions following current regulations and will implement noise reduction measures on most noisy equipment(s). • All substances likely to generate odours will be stored in closed, ventilated and filtered areas to avoid any nuisances.
Water	The project calls for the consumption of drinking water for sanitary purposes and industrial water from local providers for process and fire-fighting. Domestic wastewater will be treated in an autonomous plant, before discharge into the natural environment, monitoring will follow current local regulations.

Table 1: Futerro's commitments to decrease project's environmental impacts. © Futerro

FUTERRO'S COMMITMENTS ON A LOCAL VIEW

Preserving flora & fauna

Supporting agriculture

Appropriate water management

Maintaining the quality of life

FUTERRO AND THE EUROPEAN TAXONOMY

The EU taxonomy serves as a fundamental pillar of the EU's sustainable finance framework and plays a vital role as a tool for enhancing market transparency. Its primary purpose is to guide investments towards economic activities essential for the transition, following the objectives outlined in the European Green Deal. This classification system sets forth criteria for economic activities that are in alignment with achieving a net-zero trajectory by 2050, as well as broader environmental objectives beyond addressing climate-related issues.

Our project in France adheres to the minimum social safeguards outlined in existing conventions and UN guidelines to be considered "green" under the EU Taxonomy:

Criteria	**Futerro's answers**
Climate change mitigation	Being biobased, with a low-CO_2 footprint, the impact of PLA is limited compared to fossil-based plastics
Climate change adaptation	PLA has the potential to replace several fossil-based plastics that are recognized as harmful to our environment and planet
Sustainable use and protection of aquatic and marine resources	An assessment on Futerro's project impacts is carried out as part of the environmental authorization process subject to an impact study
Transition to a circular economy	PLA with its multiple end-of-life options, contributes to the circularity of the plastic industry and reduces our dependency on virgin fossil-based plastics
Pollution prevention and control	PLA is considered as non-persistent in the environment, industrially compostable and recyclable
Protection and restoration of biodiversity and ecosystems	PLA is manufactured with recognized sustainable feedstocks, its production doesn't impact biodiversity and ecosystems. Regarding impacts of plant erection, compensative and restorative measures are planned

PLA : A HIGH VERSATILITY OF APPLICATIONS

PLA is a versatile material that can be used in various industries and applications, thanks to its properties. PLA can be pure or modified, depending on the desired characteristics, performances and targeted applications, some examples are presented below:

Processing · Aesthetics · Mechanical properties · Other properties · Certification · End-Of-Life

PACKAGING & DISPOSABLES

Coffee cups, yogurt pots, bottles

- Colorable
- Transparent
- Barrier to aroma
- Sealable to prevent leakage
- Reusable
- Food contact approved
- Compostable
- Recyclable

FIBERS & NON-WOVENS

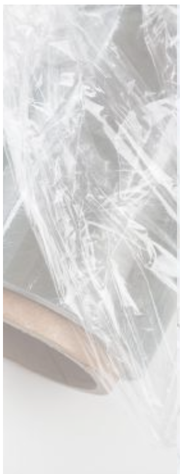
Diapers, duvets, apparel

- Colorable
- Good tenacity
- Breathable
- Good absorption
- Soft feel (like cotton)
- Compostable
- Recyclable

ROTOMOLDED PRODUCTS

Bins, Automotive

- Low processing temperature
- Good fluidity / flowability
- Transparent
- Stiffness
- Strength
- High dimensional stability



FILMS

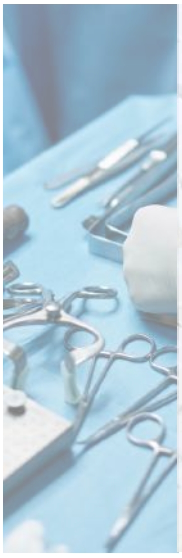
Transparent films, agricultural films

- Transparent
- Colorable
- Moderated barrier properties
- Sealable to prevent leakage
- Food contact approved
- Compostable
- Recyclable

CONSUMER PRODUCTS

Injection molded or 3D printing parts

- Low processing temperature
- No toxic fumes during the 3D printing process
- Good surface aesthetics
- Printable
- Good mechanical properties
- Good dimensional stability



MEDICAL & SURGERY

Filters, suture wire, gowns,implants, microcapsules

- Processability
- Functionalization
- Biocompatibility
- Bacteriostatic
- Non-persistent

OVERVIEW OF PLA'S MECHANICAL PROPERTIES

PLA has good mechanical strength and stiffness, making it suitable for producing rigid products such as cups, bottles, and packaging materials.

Moreover, PLA has excellent printability and can be easily molded into different shapes and forms, making it an ideal material for 3D printing and injection molding. PLA also has good barrier against aroma, moderated oxygen barrier and low vapor barrier, which makes it suitable for food packaging.

PLA can be limited by its low heat resistance: having relatively low glass transition temperature, it can start to deform or even melt when exposed to heat. As a solution, some additives can be used (e.g., nucleating agent) to increase its crystallinity, or a PLA-based compound can be selected for applications requiring high operating temperatures, such as in automotive, electronics, and appliances.

Key Features	Value Proposition & Target Applications
High Rigidity	Down gauging
High Transparency – Gloss	Aesthetics - Cosmetic – Food packaging
High water permeability	Breatheable textile or packaging
Aroma and oil barrier	Packaging
High Surface Energy	Easy Printing vs. PP/PE
Excellent Twist Retention	Cellophane alternative for film applications
Very Low Shrinkage	Dimensional Precision
Low Heat Seal initiation temperature	Heat seal films
Colorability	Easy to colorate with masterbatch
Mechanical Recycling	End-of-life option for pure materials
Chemical Recycling	Food Contact applications – end-of-life option for multilayers applications, additivated or composites materials
Industrially compostable	Interest for specific applications (e.g., Tea bags, coffee pods, diapers, etc.).

Table 2: PLA's key features. © Futerro

PLA AS A SUBSTITUTION TO FOSSIL-BASED PLASTICS

Overall, while pure PLA has many key features, its medium heat resistance, brittleness, and sensitivity to moisture are limitations that must be held in mind when considering its use in different markets and applications. The development of PLA-based compounds and the use of a broad range of additives/ fillers allow the improvement of physical properties (Table 3.).

Limitations of pure PLA	Solutions
Brittleness	Impact Modifiers – Plasticizers
Low Crystallization Rate /Crystallinity	Nucleating Agent
Poor Heat Resistance	Fillers, nucleating agents, blends
Low Hydrolysis Resistance	Anti-hydrolysis agent, Functionalization

Table. 3. PLA technical limitations and solutions. © Futerro

Table 4. shows a general comparison between main traditional plastics and pure PLA in terms of properties. Pure PLA as a stand-alone resin can compete with PET and PS. Regarding HDPE, PP, rigid PVC, PS (choc), PA, ABS, and PC, PLA would need to be additivated and/or processed into a compound to achieve similar physical performances depending on the targeted application.

	Pure PLA	Comments
HDPE	● (orange)	Need to soften PLA, attention to rheology in extrusion using additive route or compounds
LDPE	● (red)	Too flexible to be substituted by pure PLA
PP	● (orange)	Need to soften PLA using additive route or compounds
Rigid PVC	● (orange)	Need to improve impact and thermal resistance using additive route
Flexible PVC	● (red)	Too flexible to be substituted by pure PLA
PET	● (green)	No major difficulties to substitute by formulation
PS	● (green)	No major difficulties to substitute
PS (choc)	● (orange)	May require the addition of impact modifiers or blending pure PLA with another flexible bio-polyester
PA	● (orange)	Need to improve impact and thermal resistance using additive route or compounds
ABS	● (orange)	Need to improve impact and thermal resistance using additive route or compounds
PC	● (orange)	Need to improve impact and thermal resistance, using additive route or compounds

● (green) Easy to substitute ● (orange) Need modification to substitute ● (red) Impossible to substitute

Table 4 : PLA comparison with traditional fossil-based plastics. © Futerro

PLA END-OF-LIFE OPTIONS

To fight climate change, the world needs to reduce significantly its dependence on fossil fuels and do it urgently. While this means decarbonization in the energy sector, this strategy is not feasible for chemicals and plastics, which are for most manufactured from fossil-based carbon molecules. As a result, other strategies are needed to transform these industries and materials into ecologically responsible alternatives. Biobased materials can and will play an important role in supporting these efforts.

The end-of-life option of a plastic-made product is the key chain for closing the loop. PLA is one of the few plastics being at the same time biobased, recyclable through multiple technologies, industrially compostable, and depending on the application also reusable (Fig. 15.).

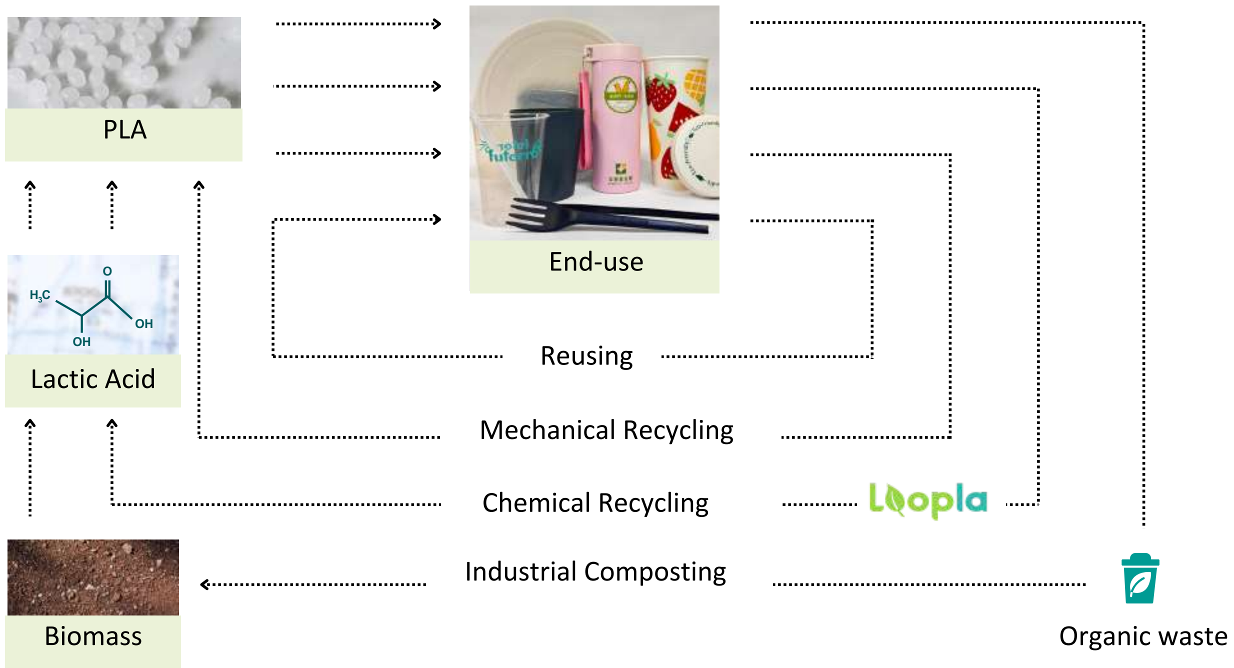


Figure 15: End-of-life options of PLA-based products. © Futerro

INDUSTRIAL COMPOSTING

Industrial composting of PLA involves processing PLA waste on a large scale in specialized facilities. These facilities are designed to create optimal conditions for the biological degradation of PLA, enabling it to be transformed into high-quality compost by breaking down PLA into CO_2 and H_2O. Industrial composting of PLA offers numerous advantages, as recently demonstrated by the "Projet Minéral" supported by the University of Montpellier, AgroParisTech, and the CoPack Chair [9], although it doesn’t represent the best end-of-life option and can be preferred for specific applications with high content of organic material (e.g., tea bags, diapers, coffee caps, films, etc.).

MECHANICAL RECYCLING

Mechanical recycling of PLA follows the same processes as for fossil-based plastics. Plastics that have been sorted and cleaned to remove contaminants such as dirt, labels, or food residues are ground into flakes and/or melted to form recycled plastic granules [10].

CHEMICAL RECYCLING

Chemical recycling of PLA using LOOPLA® technology enables Futerro to depolymerize pure PLA as well as non-pure PLA waste back into lactic acid, the monomer unit, from which, Futerro can manufacture virgin quality PLA from sourced waste. According to a recent study from Materia-Nova [11], PLA chemical recycling can be considered as one the most effective chemical recycling technology for plastic depolymerization.

PLA SORTING

Sorting PLA-based plastic waste is an essential step in efficient waste management and in promoting sustainable waste management practices. PLA can be recycled through different processes, but to ensure maximum efficiency, it is crucial to sort it correctly.

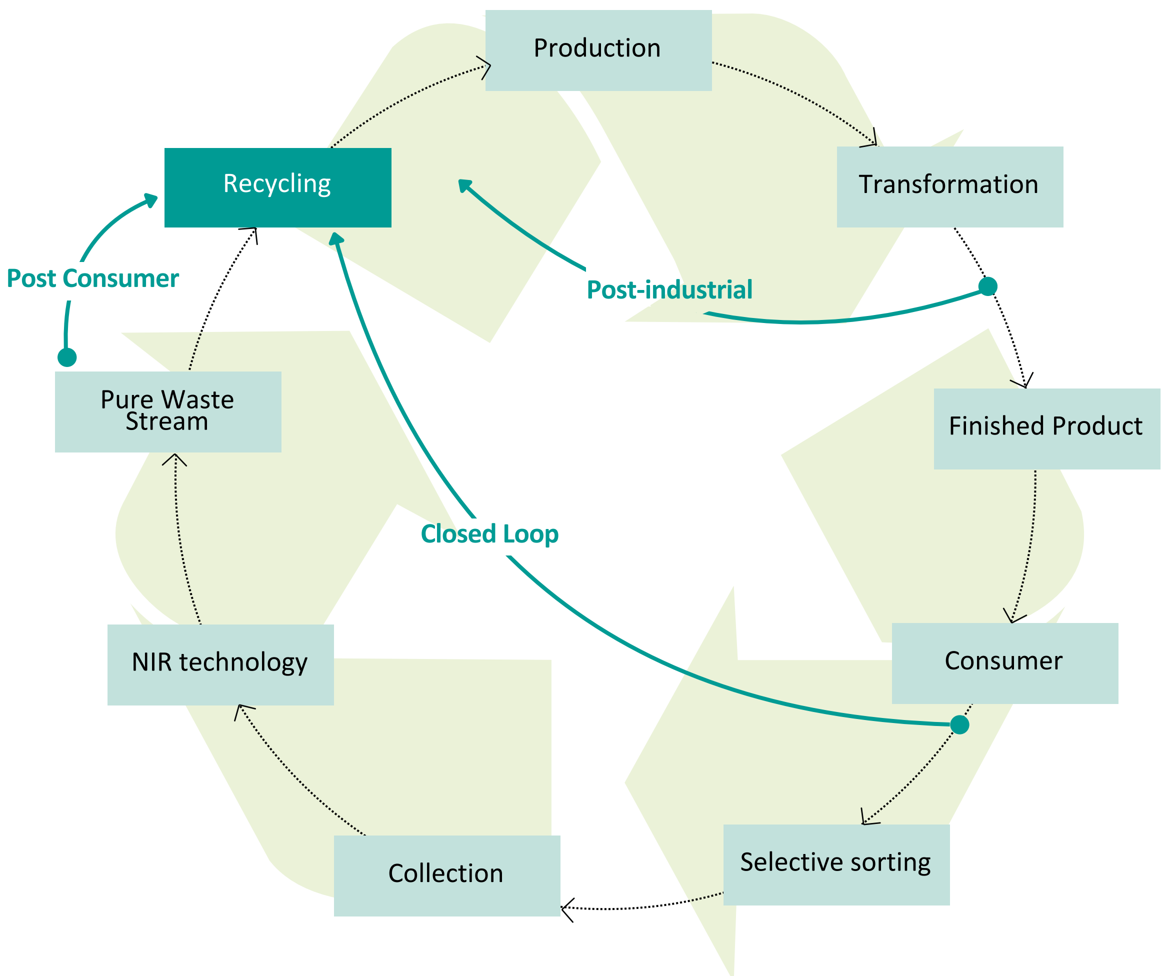


Figure 16: PLA collection & Sorting principle. © Futerro

PLA, like all plastics, face some challenges in waste management and recycling. If PLA contaminates other plastic streams, or if other plastics contaminate the PLA stream, it could degrade the quality of recycled materials. Therefore, it is important to separate PLA from other plastics before recycling.

One of the most common methods for sorting plastics is near-infrared (NIR) spectroscopy, which uses infrared light to identify the chemical composition of different materials. NIR technology can easily distinguish PLA from other plastics such as PET, PS, and HDPE, based on their different absorption spectra. By using NIR sensors and cameras, the sorting machine can separate PLA from mixed plastic waste and direct it to a specific bin or conveyor belt. This way, PLA can be isolated and collected for further processing.

This sorting principle for PLA has already been demonstrated at an industrial scale [12, 13, 14, and 15]. Therefore, to be implemented at a higher level, the volume of PLA based waste must be increased in the mixed plastic waste stream, or sorted directly in over-sorting facilities.

PLA INDUSTRIAL COMPOSTING

Industrial composting of PLA involves processing PLA waste on a large scale in specialized facilities. These facilities are designed to create optimal conditions for the biological degradation of PLA, enabling it to be transformed into compost by breaking down PLA into simple organic components.

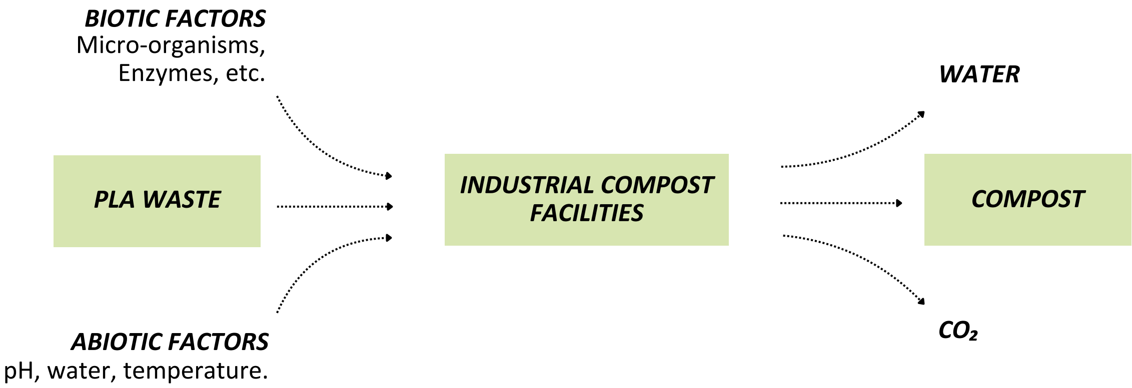


Figure 17. PLA composting principles. © Futerro

Industrial composting of PLA-based materials offer numerous advantages, as recently demonstrated by the "Projet Minéral" supported by the University of Montpellier, AgroParisTech, and the CoPack Chair [9].

This recent study demonstrates that the presence of compostable materials such as PLA in a batch of biowaste sent for industrial composting increases the composting yield and has no negative impact on the agronomic, microbiological, and toxicological quality of the obtained final compost.

This type of end-of-life solution reduces the amount of plastic waste sent to landfill or incineration, thus helping to preserve the environment. However, it should be noted that industrial composting of PLA requires specialized facilities and a rigorous control process to ensure effective degradation.

In addition, we recommend promoting this type of end-of-life only when recycling is not optional and for some specific applications where this type of end-of-life may be of interest if no other recovery route is feasible (e.g. agricultural mulch film, coffee capsules, tea bags, diapers, etc.).

RECOMMENDED END-OF-LIFE OPTION FOR THE FOLLOWING PLA-BASED PRODUCTS:




PLA MECHANICAL RECYCLING

Mechanical recycling of plastic waste is the process of transforming plastic waste into new, usable raw materials. Plastics that have been sorted and cleaned to remove contaminants such as dirt, labels, or food residues are ground into flakes or melted to form recycled plastic granules. This process is the same for most plastics, whether bio-based or fossil-based.

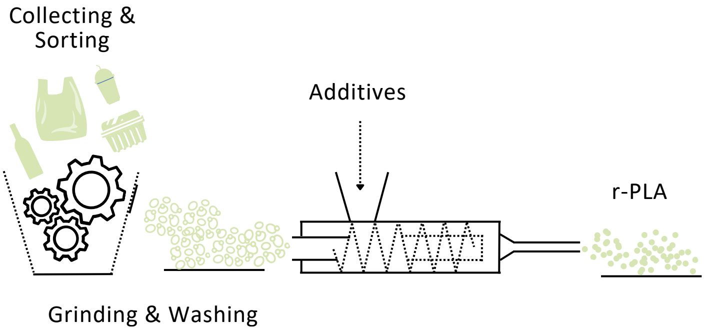


Figure 18. PLA mechanical recycling principle. © Futerro

Mechanical recycling, while beneficial, does come with its own set of technical challenges. To begin with, not all types of plastics are suitable for mechanical recycling. Certain plastics, like expanded polystyrene (commonly known as "Styrofoam") or complex multi-material plastics, may pose difficulties or might even be impossible to recycle mechanically due to their unique chemical composition or structure. During the thermomechanical treatment process, the polymer may experience a degradation of its chains, which may require the use of additives.

Furthermore, the quality of mechanically recycled plastics often falls short when compared to virgin plastics, which can result in the loss of food-contact certificates. Recycled plastics may contain residual impurities or may lose some of their properties during the recycling process. This can restrict their usage in high-demanding applications such as food packaging, fibres, and non-woven materials. Therefore, the sorting of pure plastic waste stream becomes a critical step in the mechanical recycling process.

For example, in 2023, the initial conclusions of the BIOLOOP project [10], developed by CNRS and INSA, clearly demonstrated the economical and ecological benefits of PLA mechanical recycling, but also its technical limitations, supported by a report from Materia Nova (Fig. 19.).

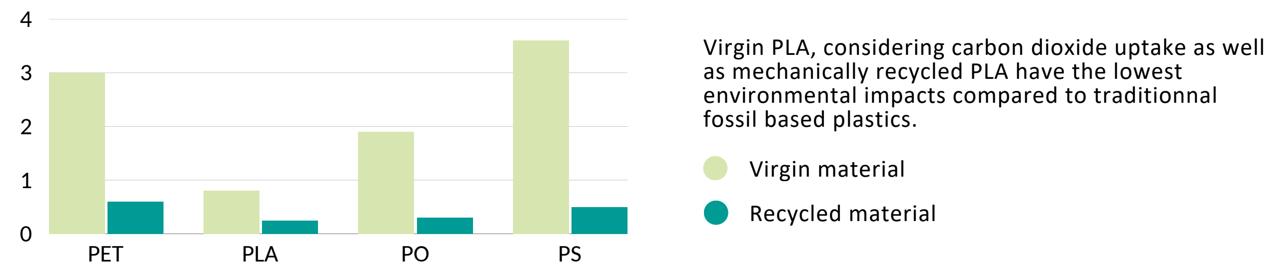


Figure 19. Comparison of the average climate change impacts between the production of secondary polymers from mechanical recycling and their virgin equivalents. © Materia Nova [11]

RECOMMENDED END-OF-LIFE OPTION FOR THE FOLLOWING PLA-BASED PRODUCTS:

PLA CHEMICAL RECYCLING

Chemical recycling of PLA, pioneered by the LOOPLA® technology developed by Futerro back in 2009, is a promising technology and an alternative to composting or mechanical recycling processes.

The LOOPLA® technology is based on solvolysis and depolymerization principles and involves breaking down the polymer chain into its monomer units using heat, low pressure, and natural solvents/alcohols. This process can restore the original quality of PLA and remove any impurities or additives to reach until 90% recovery of the original material.

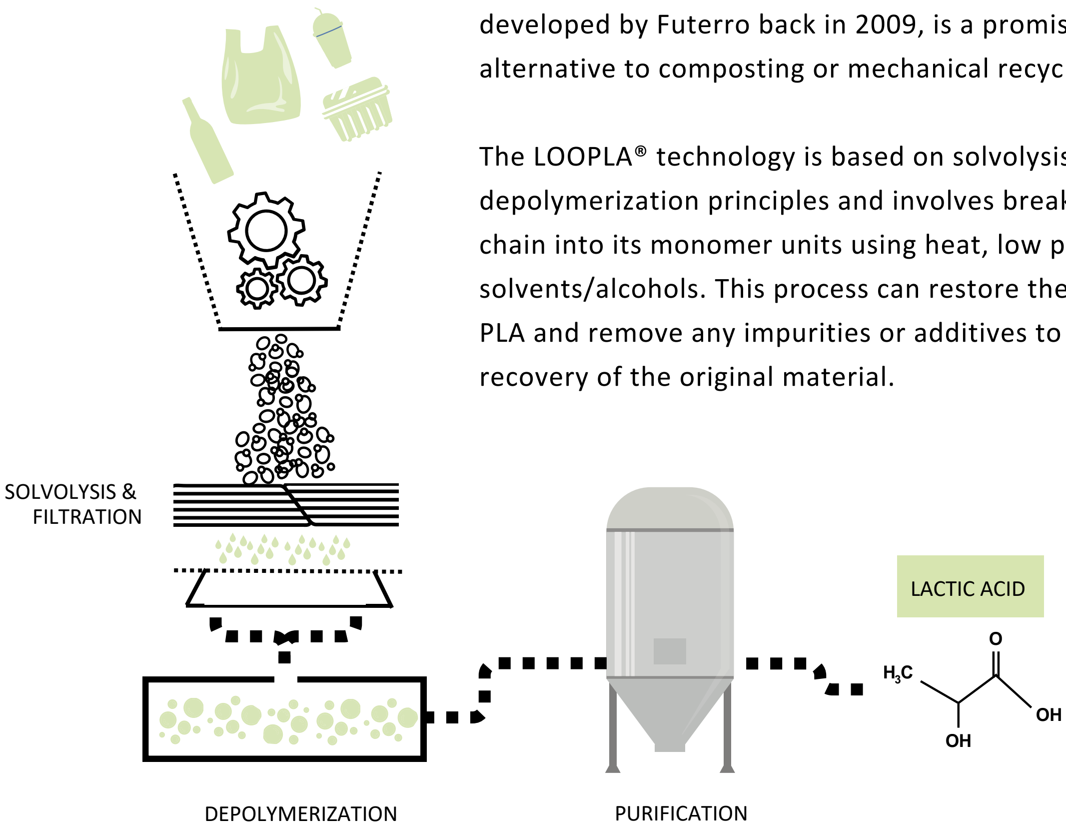


Figure 18. PLA chemical recycling principle. © Futerro

The process operates on an entirely circular and responsible principle. PLA-containing waste is first solubilized in a natural organic solvent. At this stage, non-PLA materials are filtered out and can be recycled in other channels. The solution obtained after solubilization undergoes a depolymerization step of PLA to come back to lactic acid. Finally, the solution obtained is purified, and the lactic acid monomer can be repolymerized into virgin-quality PLA.

In other words, the chemically-recycled PLA obtained has exactly the same properties as the virgin one derived from biofeedstocks, enabling it to be reproduced directly in particularly demanding applications such as food packaging (e.g., chemically-recycled PLA keeps food contact application certificates), automotive, textile, etc.

RECOMMENDED END-OF-LIFE OPTION FOR THE FOLLOWING PLA-BASED PRODUCTS:




PLA DEGRADATION IN THE ENVIRONMENT

WHAT ARE MICROPLASTICS?

Primary microplastics are small plastic particles that are directly released into nature during the manufacturing, use, or maintenance of large plastic objects. Examples of primary microplastics include the erosion of tyres while driving, microbeads in cosmetics, and the abrasion of synthetic textiles during washing.

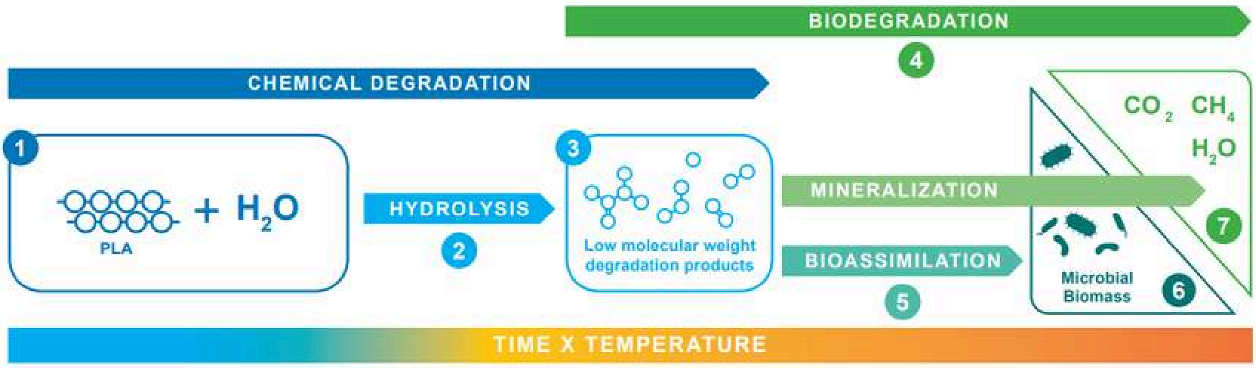
Secondary microplastics are smaller plastic fragments that originate from larger plastic items that degrade once exposed to the environment. This includes mismanaged plastic waste and fishing nets.

PLA DEGRADATION COMPARED TO OTHER MATERIALS IN THE ENVIRONMENT

All materials undergo decomposition in the environment due to natural fragmentation processes (abiotic factors) and biodegradation (biotic factors). While the degradation process remains consistent across soil, freshwater, and marine environments, the rate can differ based on environmental conditions.

PLA, a biodegradable plastic, decomposes through natural processes akin to organic materials like leaves or wood. Its molecular structure is vulnerable to chemical attack by water (hydrolysis), leading to complete hydrolysis and biodegradation, without leaving any persistent plastic particles in the environment as soon water or humidity is present [16].

On the other hand, non-biodegradable plastics such as PE, PP, or PS, lacking low energy degradation pathways like hydrolysis, can release harmful molecules into the environment. PLA degradation produces lactic acid, a naturally occurring molecule that serves as a carbon source for numerous micro-organisms and which is naturally produced and bioassimilated by the human body, whereas non-biodegradable plastics can inflict long-term environmental harm. Hence, materials like PLA, with their temporary environmental presence, have temporary impacts and allow for environmental recovery.



In the presence of water (1), PLA undergoes hydrolysis (2) as a pure chemical process of polymer degradation during which low molecular weight intermediates (3) such as oligomers and lactic acid monomers are produced. These become soluble and can be biodegraded (4). Microbes take up these oligomers and monomers as food (5) and use them to build up biomass (6) and as energy for metabolism. Ultimately, this leads to mineralization (7) of the original polymer carbon into carbon dioxide, methane, and water

Figure 21. Mechanisms for PLA degradation. © Hydra Marine Sciences [16]

IN ANY CASE, LITTERING IS NEVER THE RIGHT OPTION

Littering is never a suitable disposal method for any products we use daily, regardless of their composition or the non-persistent nature of them. All items, whether a paper napkin, compostable cup, or plastic bottle, should be disposed of properly. Materials meant for composting should be collected and processed in local composting facilities, not littered. Any environmental degradation claims on products must not imply that littering is an acceptable alternative to correct waste disposal.

PLA END-OF-LIFE DECISION TREE

Figure 22 presents the PLA end-of-life decision tree, which helps to understand the different options for disposing of PLA products.

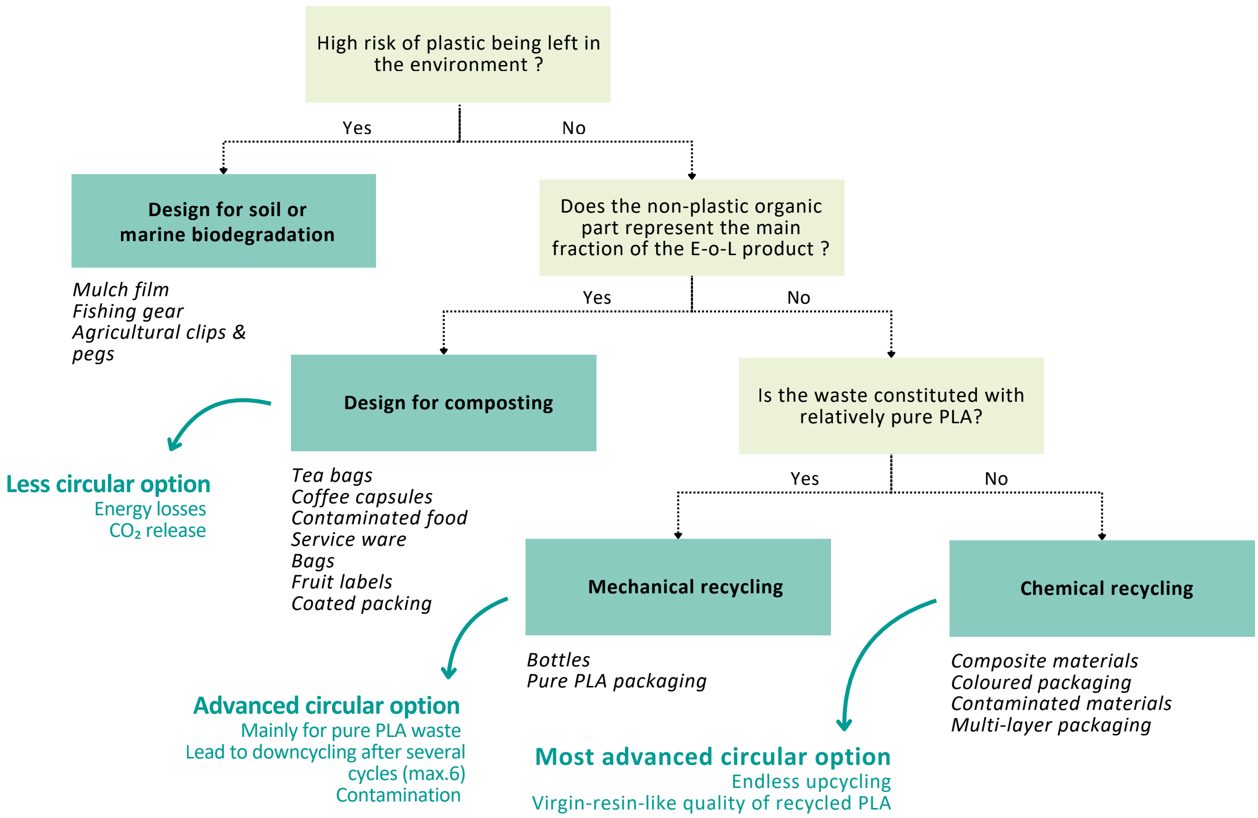


Figure 22. PLA end-of-life decision tree. © Futerro

The decision tree is based on the following criteria:

- **The risk of plastic leaching into the environment:** Some PLA products, such as agricultural films or fishing gear, are designed to biodegrade in soil or water, reducing the risk of plastic pollution (PLA must then be mixed with additives or other biodegradable polymers).
- **The non-plastic organic fraction of the product:** Some PLA products, such as tea bags, coffee capsules, or fruit trays, contain organic materials that can be composted along with the PLA. These products can be sent to industrial composting facilities, where they will break down into carbon dioxide, water, and biomass.
- **The purity of the waste stream:** Some PLA products, such as bottles, packaging, or textiles, are relatively pure and can be mechanically recycled. These products can be collected and sorted by waste management systems, and then processed into pellets or flakes that can be used to make new PLA products. Mechanical recycling reduces the need for virgin PLA and saves energy and resources. If the products aren't pure enough or mixed, chemical recycling offers a unique circular solution to produce recycled PLA products with the same quality as the virgin PLA (made from biofeedstocks).

By following the PLA end-of-life decision tree, you can ensure that your PLA products are disposed of according to the most environmentally friendly way possible. PLA is a bioplastic that offers a circular and sustainable solution for a variety of applications.

PLA RECYCLABILITY VS FOSSIL-BASED PLASTICS

Recycling encompasses a variety of technologies used to reprocess plastics that have reached their end of life. Different ways of recycling have been presented in various reports and studies. They can be categorized as follows:

- Mechanical recycling
- Chemical recycling
- Thermo-chemical recycling

Based on publicly available information, a recent study from Materia Nova [12] prepared a qualitative comparison between the 3 processes.

		Yield	Selectivity	Quality	Energy Demand	Climate Change Footprint
Mechanical Recycling	PET	🟢	🔴	🟠	🔴	🟠
	PLA	🟢	🔴	🟠	🟢	🟢
	PE/PP	🟢	🔴	🟠	🟢	🟢
	PS	🟢	🔴	🟠	🟢	🟡
Chemical Recycling	PET	🟢	🟠	🟢	🔴	🔴
	PLA	🟢	🟠	🟢	🟠	🟢
Thermochemical Recycling	PE/PP	🔴	🟡	🟢	🟠	🟠
	PS	🔴	🟡	🟢	🟠	🟠

Table 5: Qualitative comparison of recycling processes of plastics. © Materia Nova [12]

Table 5. compares the recycling processes for five different types of plastics: PET, PLA, PS, PE and PP. The recycling processes are evaluated based on five criteria: yield, selectivity, quality, energy demand, and climate change footprint. Yield measures the efficiency of the recycling process in terms of how much usable material is produced compared to the amount of input waste. Selectivity refers to the ability to treat low-quality waste streams, meaning non-pure materials products. Quality refers to the preservation of the material properties and performances once recycled by the technology. Energy demand is the amount of energy required to carry out the recycling process. Climate change footprint refers to the greenhouse gas emissions associated with the recycling process and the material.

The table shows that PLA can be considered as one of the best materials designed for recycling, whether it is mechanical or chemical recycling technology. Therefore, considering thermo-chemical recycling (inc. pyrogaseification and pyrolysis principles), which converts the polymer into a mixture of gases, liquids and solids, having a lower quality and value than the original material doesn't make sense. Thermochemical recycling technologies require higher temperatures and pressures than mechanical and chemical technologies, which increases the energy demand and greenhouse gas emissions of the recycling process.

CONCLUSION

The journey of PLA from its sustainable sourcing to its circularity showcases its pivotal role in the quest for a more environmentally friendly and sustainable future. PLA, as a bioplastic, embodies the essence of sustainability by being bio-based, recyclable, and industrially compostable; making it a viable and unique alternative to conventional fossil-based plastics.

The sustainable aspect of PLA begins with its raw material sourcing from renewable and certified sustainable resources, which are not only abundant but also versatile in their applications, therefore minimizing competition with food and feed supplies. This approach supports the principles of sustainability by reducing the carbon footprint, promoting local economies, and ensuring a continuous and sustainable supply of raw materials.

Furthermore, PLA production stands as a beacon of hope in reducing carbon emissions in the chemicals and materials sector. As the world seeks carbon neutrality, PLA is 100% biobased and its recyclability offers a trustworthy solution for defossilizing the plastic industry. It fits seamlessly into the EU Taxonomy's criteria for green investments, aligning with the goals of the EU Green Deal and the broader environmental objectives.

Moreover, PLA's applications span across various sectors and industries, demonstrating its technical and functional performance. PLA can be used for food packaging, injection moulded parts, additive manufacturing, medical devices, textile fibers, and many more products and applications. PLA properties are comparable or even superior to those of conventional plastics thanks to its high strength, stiffness, transparency, biocompatibility, compostability, and recyclability. PLA can also be blended with other polymers, additives and fillers to enhance its functionality and versatility. PLA's wide range of applications and technical capabilities make it a real technical and circular alternative to traditional plastics.

PLA's circularity further enhances its sustainability profile. Its end-of-life options, including industrial composting as well as mechanical and chemical recycling, make it a versatile and responsible choice. These processes not only reduce waste but also contribute to the reduction of carbon emissions, further validating PLA as a sustainable and durable alternative to fossil-based plastics.

In a world where climate change requires urgent and ambitious actions, the adoption of biobased materials like PLA represents a significant step towards mitigating the environmental impact of plastics. PLA's renewable origins and circular practices make it a key player in the pursuit of a greener and more sustainable future. It embodies the spirit of innovation and responsible resource management that our planet urgently needs.

At Futerro, we are committed to producing PLA that is sustainable and circular, from the certified biofeedstock grown in France to the recyclable end-products. Our future EU made PLA will offer a viable and responsible solution to the environmental challenges of plastic waste and fossil-based carbon dependency.

GLOSSARY

Abiotic factors
Non-living physical and chemical conditions, such as temperature, moisture, pH or oxygen can affect the breakdown of organic matter or substances like PLA into simpler substances. Abiotic factors can affect the rate and extent of biodegradation by influencing the activity and survival of microorganisms, as well as the degradation mechanisms, such as oxidation, hydrolysis or photodegradation.

Amorphous phase
A state of PLA in which the polymer chains are randomly arranged and not organized into crystals. Amorphous PLA can be moulded using low mould temperatures (room temperature) and no nucleating agent. Amorphous PLA has higher transparency and higher ductility than crystalline PLA.

Biobased plastics
Plastics that are made from renewable biological resources. They are not necessarily biodegradable or compostable, but they can reduce the use of fossil fuels and greenhouse gas emissions.

Biodegradation
The process of breaking down matter or substances into smaller and simpler substances by the action of biotic (e.g., microorganisms, enzymes, etc.) and abiotic factors (temperature, pH, water, etc.) which can be totally assimilated by the environment without impacting negatively.

Biomass
Biomass is any living or recently dead material that is not part of fossils or rocks. It can be organic matter from plants and animals, such as wood, crops, grasses, leaves, algae, and dung. Some biomasses can be used to make bioplastics.

Biotic factors
Living organisms, such as bacteria, fungi and yeast, that are involved in the breakdown of organic matter or substances like PLA into simpler substances. Biotic factors can affect the rate and extent of biodegradation by producing enzymes, metabolizing substrates, and adapting to environmental conditions.

Bran / Bran Feed
Bran is the outer layer of cereal grains such as wheat that is removed during milling. Bran is rich in fiber, minerals, and vitamins; so it can be used as a food ingredient or as animal feed.

Carbohydrates
A class of organic compounds that consist of carbon, hydrogen and oxygen atoms, Carbohydrates are formed by green plants from carbon dioxide and water during photosynthesis. Carbohydrates can be classified into one major group: Sugars.

Crystalline phase

A state of PLA in which the polymer chains are aligned and packed into ordered structures called crystals. Crystalline PLA can be moulded by using high mould temperatures (90-110°C) and nucleating agents. Crystalline PLA is usually opaque and has higher stiffness and heat stability than amorphous PLA.

ESG

Acronym for environmental, Social, and Governance. It refers to the three main criteria that measure the sustainability and ethical impact of an investment in a business or company.

Fossil based carbon

Carbon is derived from fossil fuels, such as coal, oil and natural gas. Fossil based carbon is extracted from the geosphere, where it has been stored for millions of years. Fossil based carbon is used to produce energy and various products, such as plastics, synthetic fibers, and fertilizers. Fossil based carbon increases the amount of carbon dioxide in the atmosphere, contributing negatively to global warming and climate change.

Fossil based plastics

Plastics that are made from petrochemicals, which are derived from fossil fuels such as oil, gas, or coal. They are usually non-biodegradable and can accumulate in the environment, causing pollution and being harmful to the wildlife.

Gluten

A wheat flour protein material that has been separated from starch and other flour components, and then dried carefully to preserve its properties. Vital wheat gluten is used as a protein supplement, a dough improver, and a meat alternative.

Hydrolysis

A chemical reaction in which a molecule is broken down into smaller components by reaction with water. The molecule changes its structure as new bonds are formed. Hydrolysis can occur in natural and artificial conditions, and it can affect the properties and biodegradability of plastics.

Renewable Carbon

All carbon sources avoid or substituting the use of fossil carbon from the geosphere. Renewable carbon circulates between the biosphere, atmosphere and technosphere, creating a carbon circular economy.

Solvolysis

A type of chemical reaction in which a substance is broken down into smaller components by the liquid it is dissolved in. The liquid acts like a pair of scissors that cuts the bounds between the atoms in the substance. Solvolysis can happen with different kinds of liquids, such as water (referring to hydrolysis).

Sustainable feedstock

Raw materials with low environmental impacts are used to produce plastics or other products.

Thermo-chemical recycling

Recycling technology for petro-based plastics in which wastes are converted into fuels, chemicals, or monomers by using high heat and catalysts. Thermo-chemical recycling can be done by methods such as pyrolysis, gasification or hydrogenation.

Wheat starch

The starch is extracted from wheat kernels. Wheat starch is a white and powdery substance finding applications in non-food applications such as papermaking, textile, and bioethanol production.

ABOUT US

FUTERRO – PIONEERING SUSTAINABLE BIOPLASTICS SOLUTIONS

At Futerro, we are at the forefront of sustainable bioplastics innovation, driven by a vision of a cleaner and more environmentally responsible future. Our commitment to sustainability and cutting-edge technology has positioned us as a strong leader in the bioplastics industry.

Our Mission: Revolutionize the way plastics are produced and consumed by providing sustainable alternatives that reduce the environmental impact. We are dedicated to developing and delivering bioplastic solutions that not only meet the demand of today but also pave the way for a greener and more sustainable tomorrow.

Our Difference: What sets Futerro apart is our unwavering dedication to three core principles:

- Innovation: We believe that innovation is essential to address the world's pressing environmental challenges. Our team of talented scientists and engineers continually pushes the boundaries of bioplastics technology, ensuring that our solutions are at the cutting edge of sustainability.
- Sustainability: We are committed to reducing the carbon footprint of plastic production by harnessing the power of renewable resources. Our bioplastics are derived from natural, plant-based feedstocks, promoting through LOOPLA®recycling technology a circular economy and reducing our reliance on fossil fuels.
- Partnerships: We understand that no single company can tackle global sustainability challenges alone. That's why we actively seek partnerships and collaborations with like-minded organizations, researchers, and industries. Together, we can drive positive change on a larger scale.

Our Expertise: Spans the entire bioplastics value chain, from research and development to production and application. Our cutting-edge technology and state-of-the-art facilities enable us to develop customized bioplastics solutions tailored to the unique needs of our partners and customers across various industries.

Our Commitment to Sustainability: Futerro is committed to sustainable practices throughout our operations. We actively seek to minimize waste, energy or water consumption as well as emissions in our production processes, striving for a cleaner, more sustainable future for all.

Join Us in Shaping a Sustainable Future: At Futerro, we believe that a sustainable future is within reach. We invite you to join us on this transformation journey towards a greener world where plastics are part of the solution, not the problem.

Explore our range of innovative bioplastics solutions and partner with us to make a difference. Together, we can build a better greener and healthier tomorrow.

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FUTERRO S.A.
Headquarters: Rue du renouveau 1, 7760 Escanaffles Belgium
Sales Office: Allée de la recherche 4, 1070 Brussels Belgium
+ 32 2 616 23 00 - info@futerro.com