1.0

Planting the future with PLA

Sustainability aspects and advantages of renewable feedstocks in bioplastics production

Authors

Francois de Bie
TotalEnergies Corbion

Maelenn Ravard
TotalEnergies Corbion

Paolo La Scola
TotalEnergies Corbion

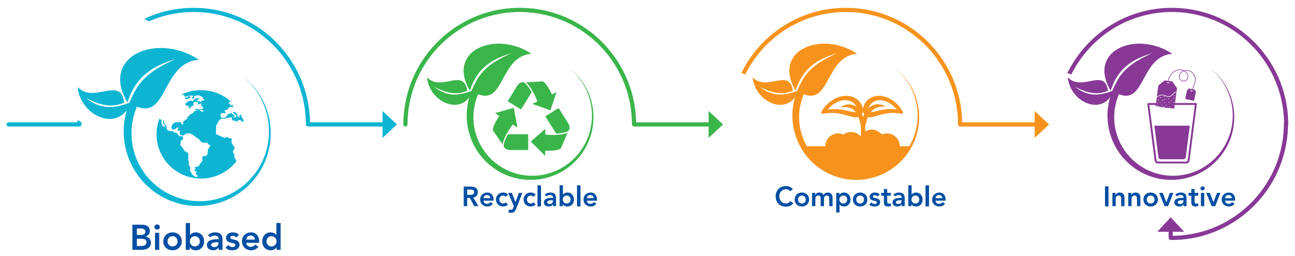
Rui Veras
TotalEnergies Corbion

TotalEnergies Corbion

www.totalenergies-corbion.com

Contents

Luminy® PLA
Beyond conventional plastic



Introduction

Using renewable raw materials for the production of bioplastics

Humans have always relied on naturally grown resources to create useful products, like cotton clothing, wooden furniture, and paper. Today, we often call these natural resources renewables, biobased products, or biomass.

Advancements in technology have allowed us to transform these natural resources in ways we have never thought possible: glue for the cardboard industry[1] and chemical binder in car tires[2] made from corn starch[3], and plastic made from sugarcane[4]. As humans continue to research and develop new ways to transform renewables into even more useful materials for daily life, we will see these items become increasingly prevalent.

Currently, bioplastics represent less than one percent of the more than 390 million tonnes of plastic produced annually. However, according to the latest market data compiled by European Bioplastics (EUBP) in cooperation with the nova-Institute, global bioplastics production capacities are set to increase from around 2.2 million tonnes in 2022 to approximately 6.3 million tonnes in 2027. This represents a significant potential reduction in atmospheric CO_2.[5]

What does bioplastics and biobased mean?

The term 'bioplastics', as defined by European Bioplastics, refers to the group of plastics which are plant-based (biobased), biodegradable or both. Polylactic acid (PLA) is one of the few bioplastics that is both biobased and biodegradable. [5]

Biobased plastics are produced from naturally renewable resources, including corn, starch, sugarcane, or wheat. Also emerging as a new source of renewable raw materials are algae and fungi. However, as these are not yet being produced on an industrial scale, they do not represent an economically viable feedstock for the production of bioplastics.

In contrast to biobased bioplastics, fossil-based plastics, also called conventional plastics, are produced from fossil-based resources like oil or gas. These resources are classified as non-renewables.

In line with the relevant standards, Luminy® PLA is tested and certified to be 100% biobased

In this paper, we examine facts and figures pertinent to the selection and sustainability aspects of sourcing common feedstocks such as sugar for PLA production, we share TotalEnergies Corbion's views and vision on how we sustainably source feedstocks for bioplastics.

We will also show that PLA bioplastics made from sustainably grown feedstocks are a more environmentally friendly alternative to many fossil-based plastics.

Biobased plastics benefits

- Reduces carbon footprint of products and packaging
- Leverages sustainable production methods
- Produces materials from renewable sources
- Complements sustainable food production and land use
- Enables material supply security for generations to come
- Generates versatile materials for multiple applications

The biobased origin of PLA

PLA Production process

Thailand is the second largest global exporter of sugarcane, a crop that flourishes in the region's climate conditions. Planting sugarcane is the starting point for Luminy® PLA production. After growing and harvesting the sugarcane, it is brought to a sugar mill to extract the sugar. The sugar obtained is then fermented using microorganisms to produce lactic acid, an organic acid also produced by the human body.

TotalEnergies Corbion converts the lactic acid into PLA, a biopolymer that manufacturers can use in multiple applications from packaging to 3D printing to electronics.

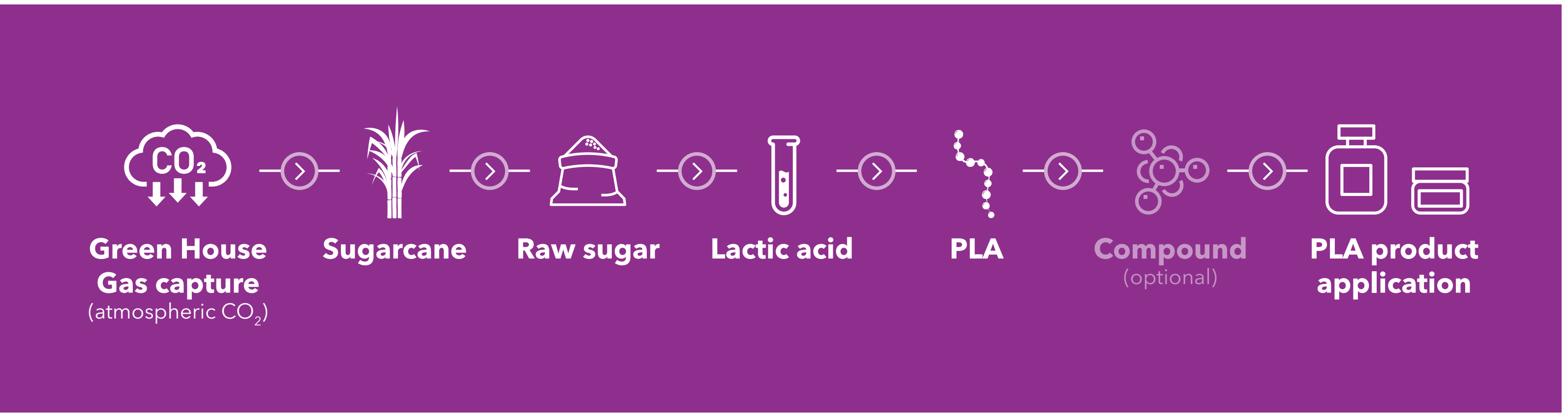


Figure [1]

PLA is a 100% biobased polymer, meaning its feedstocks are from a biobased origin.

Different regional and international standards exist to measure biobased content in plastic materials. Typically, these rely on the carbon dating technique [6] known as C14, which determines the origin of the carbon in the material. Carbon is the key building block of our planet, and roughly two sources of carbon exist: carbon from renewable resources or carbon from fossil resources. Biobased materials have a C14 activity of 100%, and fossil-based materials have an approximate 0% C14 activity.

In Europe, EN16875 is a regulation that specifies a method of determining the biobased content in products using the C14 method. In the United States, the US Department of Agriculture's BioPreferred program strictly monitors third-party certifications and manufacturers' claims regarding biobased content.

Luminy® PLA s certified 100% biobased according to EN16785 and USDA bioprefered program.

Today in the market, there is an emergence of bioplastics with "bio-attributed" or "bio-allocation" claims. These claims refer to the use of the mass balance method for renewable raw material consideration.

TotalEnergies Corbion sees a clear need to distinguish between the communication about the use of renewable feedstock for segregated biobased plastics (C14 measurable) and for plastics with bio-attributed feedstock using mass balance. The term 'bio-attributed' indicates that the use of renewable feedstock has been ascribed using the mass balance approach. While final biobased products and plastics based on C14 content measurement could be labelled as 'biobased', mass balance products and plastics cannot be considered biobased.

biobased

Biobased origin and sustainability

Sustainability of PLA feedstock

Raw sugar, from sugarcane or sugar beet, and dextrose, from corn starch or cassava, are the main feedstocks used in producing lactic acid and its derivatives today. The raw sugar is typically sourced from whichever feedstock is most readily available locally. Sugarcane grows well in Thailand and Brazil. On the other hand, The United States of America (USA) is the leading producer of corn while wheat and sugar beets grow in Europe. These feedstocks are often grouped under the term 'sugar/starch-based' feedstocks.

Raw sugar is an unrefined version of sugar and, as such, is generally not suitable for human consumption. Refining raw sugar results in sucrose also known as white sugar or table sugar.

Selecting feedstocks with the highest yields

As our population grows and global demand on resources increases, arable land will become scarce. It is, therefore, essential to use the most efficient crops available. Agricultural yields per hectare of arable land vary based on the type of crop and region. As shown in Figure 2 below, sugarcane and sugar beet provide the highest carbohydrate yields per hectare of land used [7].

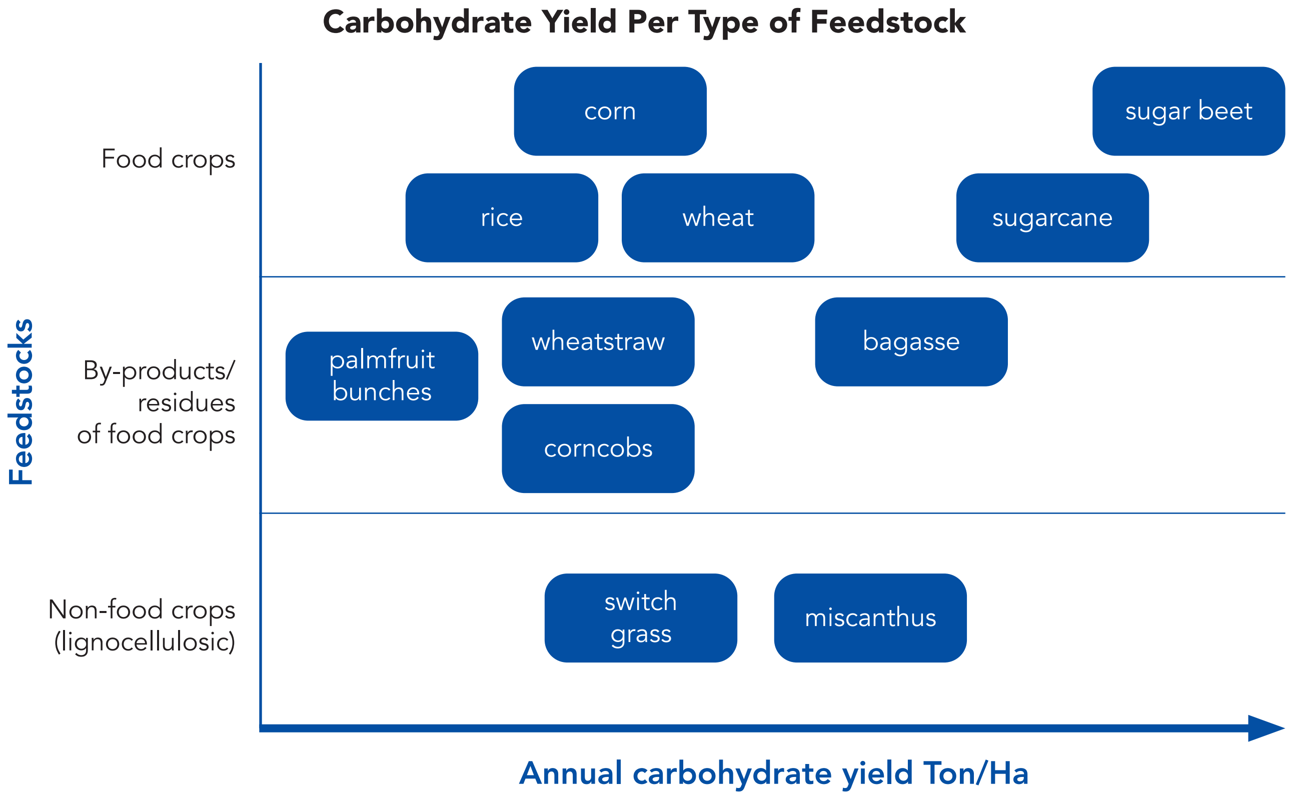


Figure [2]: Annual carbohydrate yield per hectare for different feedstocks [7]

TotalEnergies Corbion sources its lactic acid from fermentation specialists and global market leader in lactic acid Corbion. Corbion predominantly uses the highest-yielding feedstocks regionally available: raw sugar from cane is used by its factories in Thailand and Brazil, dextrose from corn is used by its lactic acid production plant in the USA, and sugar from sugar beet is used by its factories in Europe. In addition to bioplastics production, lactic acid produced in these factories is also used in food ingredients, biochemical ingredients, and medical biomaterials.

Feedstock efficiency scores highly for PLA

In addition to crop yields, it is important to have an energy-efficient conversion from raw sugar to polymer. The term 'feedstock efficiency' as used here describes the conversion ratio of feedstock weight to final plastic polymer weight and is a combination of a theoretical efficiency (which differs per type of bioplastic) in combination with production efficiencies. This means that different types of bioplastics, produced using different production processes, will require different amounts of feedstock. In terms of feedstock efficiency, PLA is one of the most efficient biopolymers: yielding 1.0 kg of PLA polymer for 1.6 kg of fermentable sugar feedstock. Other bioplastics can require 2.5 – 3 times more sugar feedstock to produce the same amount of plastic [8] (see Figure 3).

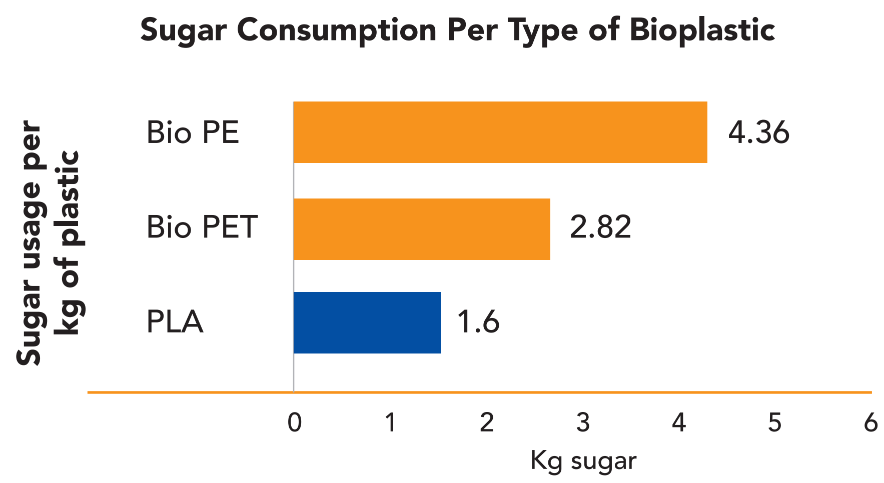


Figure [3]: Carbohydrate usage: kg sugar per kg plastic

A number of institutes and universities have analyzed and combined crop yields with feedstock efficiencies for various biomaterials. See, for example, reports from IfBB [8] and Wageningen University and Research Centre (WUR) [9]. Figure 4 compares a few of the possible options and shows that when land use is a concern, PLA made from sugar beet or sugarcane is an efficient choice [9].

Ultimately, feedstock efficiency has a positive impact on land use. Additionally, all environmental impacts related to agriculture are correlated with the amount of feedstock used.

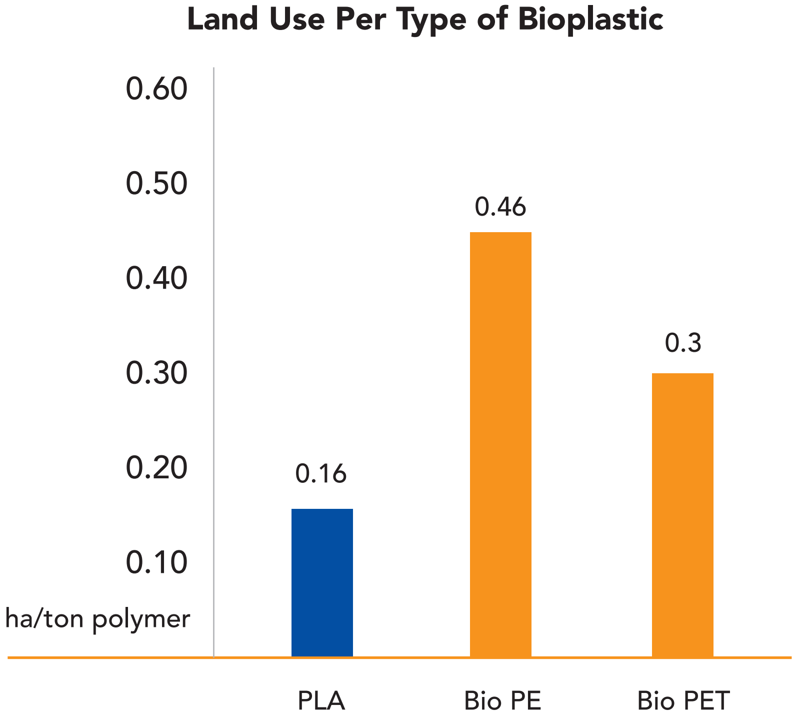


Figure [4]: Land use per ton of biobased PLA, biobased PE, and bioethanol from sugar cane. Valid for both current agricultural practice and if all residues/co-products are used [8]

TotalEnergies Corbion produces PLA bioplastic made predominantly from raw sugar from cane in Thailand. Over the years, both Corbion and TotalEnergies Corbion have significantly improved the internal process yields and as mentioned above, is able to produce 1.0 kg of PLA using just 1.6 kg of raw sugar.

Robust supply chains for ensuring sustainable agriculture

If the levels of consumption that the most wealthy people enjoy today were replicated across even half of the roughly 9 billion people projected to be on the planet in 2050, the impact on our water supply, air quality, forests, climate, biological diversity, and human health would be severe [10]. In order to maintain a healthy planet for generations to come, companies that produce biobased products must regulate and verify that their supply chains only utilize feedstocks grown using sustainable agriculture practices. Both companies and consumers need to know that opting for a sustainable product does not entail unintended consequences such as reduced diversity, deforestation, or compromised labor practices. A responsible and sustainable supply chain is, therefore, essential for the communities that companies operate in. It should include the entire chain: from farmers to the companies that produce the final finished everyday products.

TotalEnergies Corbion's approach to a sustainable supply chain and responsible sourcing extends through its suppliers, including Corbion, and is founded on principles of ethical business practices, human and labor rights, and environmental protection.

For the production of bioplastics, TotalEnergies Corbion's key agricultural material is raw sugar from cane grown in Thailand, and to a lesser extent, sugar beet grown in Europe.

Annually renewable feedstock

Unlike trees, for example, sugar cane used in the production of Luminy® PLA is an annually renewable crop. This means that the sugar cane harvest occurs every year, and new plants grow in the same land the following year.

Corbion's Cane Sugar Code

TotalEnergies Corbion sources lactic acid from Corbion, and Corbion's Cane Sugar Code [11] has been developed to describe our expectations of our cane sugar suppliers to fulfil its responsible sourcing commitment. The code is based on the definitions for sustainable sugarcane and derived products as set out by Bonsucro, a global, non-profit, multi-stakeholder organization founded by WWF in 2005 to advance a more economically, environmentally, and socially responsible sugarcane sector.

Corbion's code of conduct for cane sugar suppliers includes a general supplier code, applicable to all Corbion suppliers, as well as specific extensions directly relating to sugarcane farming in Thailand and Brazil. Corbion's Supplier Code and the Cane Sugar Code are publicly available [11] [12].

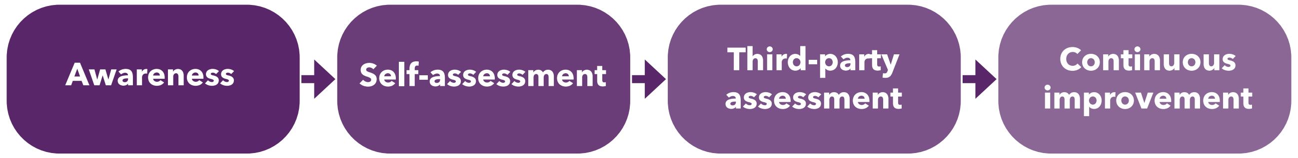
A benchmarking study indicates that Corbion's Code contains a broad set of robust principles and criteria that is well aligned with the principles and criteria laid down by Bonsucro and other relevant standards (RSB, ISCC, SMETA) for addressing raw materials, ethical and social compliance.

Corbion's Cane Sugar Code applies to all our cane sugar suppliers. Verification procedures are in place to confirm that a supplier meets these requirements. These include tools such as self-assessment questionnaires, third-party verification and Bonsucro certification. As of 2017, Corbion has been actively auditing cane sugar suppliers.

Corbion's Cane Sugar Code

Focus areas:
- Business ethics
- Human rights & labor conditions
- Environment
- Product quality & safety
- Intellectual property
- Land rights
- Biodiversity
- Good agricultural practices

Read more at:
www.corbion.com/Sustainability/Preserving-what-matters/Responsible-sourcing



The role of Bonsucro

Established to collectively accelerate the sustainable production and uses of sugarcane, Bonsucro is the leading global sustainability platform and standard for sugarcane. With 300 members in over 50 countries, from farmers to sugar mills to ingredient manufacturers like Corbion and TotalEnergies Corbion, to retailers and brand owners, the organization brings together all the players in the supply chain.

Since 2011 the organization has certified over 800 million tonnes of sugarcane, and over 55 million tonnes of sugar through its unique metric-based certification scheme, the Bonsucro Production Standard, a feature of which is the prohibited use of harmful chemicals.

The standard covers the following five key principles:
1. Obey the law
2. Respect human rights and labor standards
3. Manage input, production, and processing efficiencies to enhance sustainability
4. Actively manage biodiversity and ecosystem services
5. Continuously improve key areas of social, environmental, and economic sustainability.

In its strategic plan, Bonsucro aims to create value across the supply chain; improving the environmental impact of sugar cane production; and strengthening human rights and decent work in sugarcane and milling.

Regardless of whether a Corbion cane sugar supplier is Bonsucro Production certified, they must comply with the Corbion Cane Sugar Code, which mirrors the values and vision of Bonsucro. Corbion requires all its cane sugar suppliers to become members of Bonsucro and expects them to work towards the implementation of the Bonsucro Production Standard. As a Bonsucro member, Corbion is already working directly with its own network of industry suppliers – from Thailand to Brazil – to implement the standard. What this means in practice, is that Corbion, with its suppliers, identify areas where improvement is needed – giving them an opportunity to make the changes necessary to achieve the standard, which includes answering questions and lending expertise wherever possible.

Bonsucro-certified sugar is becoming more readily available. Globally, some 6% of the sugar cane growing areas are Bonsucro certified and for Thailand, this is just over 2%. Currently Corbion source part of its sugar demand from Bonsucro-certified sources, purchasing 21% of its sugar from Bonsucro's certified sugar in 2022. Corbion and TotalEnergies Corbion are both Bonsucro chain of custody certified.

Since 2017, TotalEnergies Corbion has offered Bonsucro certified Luminy® PLA as part of its portfolio [13]. All of our PLA grades conform to the Corbion Sugar Cane Code, the Bonsucro Production Standard or both. Customers can specifically request which grade they require.

More information on our sugar sourcing can be found in Corbion’s 2022 Annual Report. [14]

GMO-free feedstocks

It is not a technical requirement to use genetically modified crops or feedstocks (in short, GM or GMO) to produce bioplastics. If GMO crops are used in bioplastic production, the multiple-stage processing and high heat used to create the polymer removes all traces of genetic material in the end product. This means that the final bioplastic product contains no genetic traces.

At TotalEnergies Corbion, Thai sugarcanes are used as feedstocks for the production of PLA bioplastics. These are always GMO-free, which is why we can offer our customers PLA produced entirely from GMO-free feedstocks.

TotalEnergies Corbion plant certifications
TotalEnergies Corbion's production plant is certified ISO 14001-Environmental Management System, ISO 9001- Quality Management System and ISO 45001-Occupational Health and Safety Management System.

In 2023, the TotalEnergies Corbion PLA plant in Thailand was certified Platinum by EcoVadis. EcoVadis is a globally recognized assessment platform that rates businesses' sustainability based on four key categories: environmental impact, labor and human rights standards, ethics, and procurement practices.

TOTALENERGIES CORBION PLANTING THE FUTURE WITH PLA

Biobased and European environmental frameworks: Taxonomy

TotalEnergies Corbion Luminy® PLA produced in Thailand complies with EU Taxonomy regulations, meaning that it qualifies as a sustainable material within the framework of the delegated act on climate adaptation and mitigation defining criteria for reducing environmental impact and mitigating climate change in the region. For plastics users, this demonstrates that they can substantially reduce their Scope 3 GHG emissions by replacing fossil-based plastics with PLA.

What is the EU Taxonomy?
The EU taxonomy is a classification system with technical screening criteria for defining the specific requirements and thresholds for an economic activity to be considered as significantly contributing to a sustainability objective. This provides companies, investors, and policymakers with appropriate definitions of which economic activities are environmentally sustainable. It also helps the EU to scale up sustainable investment and to implement the European green deal.

The EU Taxonomy Regulation, which came into force on 12 July 2020, defines six environmental objectives:
1) Climate change mitigation
2) Climate change adaptation
3) The sustainable use and protection of water and marine resources
4) The transition to a circular economy
5) Pollution prevention and control
6) The protection and restoration of biodiversity and ecosystems

The first Delegated Act on climate change mitigation and adaptation (the 'climate taxonomy') adopted on 4 June 2021 established that a biobased plastic qualifies as contributing substantially to climate change mitigation if certain criteria were met.

These criteria and how TotalEnergies Corbion are complying with them are dealt with in the table below:

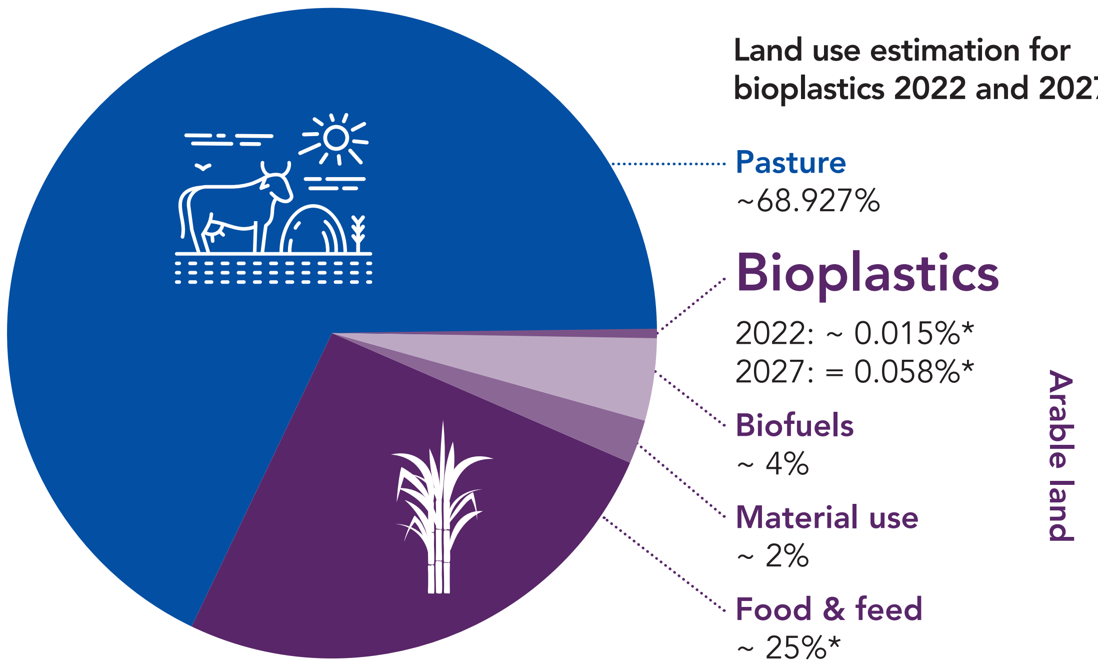
TotalEnergies Corbion: Leading the Way in Climate Change Mitigation and Adaptation, Meeting the EU Taxonomy Regulation [14]	
Qualifying criteria to meet	**Qualifying criteria to meet**
Biobased plastic is derived wholly or partially from renewable feedstock	Luminy® PLA is 100% biobased since it is produced entirely from sugar cane
Its life cycle GHG emissions are lower than the life cycle GHG emissions of fossil fuel plastics.	Regarding the GHG emission, TotalEnergies Corbion and Corbion conducted a third-party verified LCA for the production of Luminy® PLA bioplastics from lactic acid, (published in a scientific peer-reviewed journal in 2019. This shows that, when considering the biogenic carbon content, compared to the carbon footprint of fossil-based plastics, which are the best-performing alternatives available on the market, the carbon footprint of Luminy® PLA based on Corbion's lactic acid is substantially lower (69-78%). This enables plastics users to substantially reduce their Scope 3 GHG emissions by replacing fossil-based plastics with PLA.
The agricultural biomass used complies with the criteria laid down in Renewable Energy Directive Article 29, paragraphs 2 to 5: • paragraph 2 applies to residues and waste; • paragraph 3 provides that the biomass used shall not be made from raw material obtained from land with a high biodiversity value; • paragraph 4 requires that biomass does not come from land with high-carbon stock.	Article 2, paragraph 2 does not apply to the agricultural biomass (sugar cane) used by Corbion; Corbion evaluated compliance of their crop suppliers to the Renewable Energy Directive, which was validated by Global Risk Assessment Services GmbH: • none of these manufacturing sites and sugarcane plantation are located near biodiversity-sensitive, high-carbon stock and peatlands areas. • Corbion monitors land use change by using satellite images to demonstrate compliance.

Land use for bioplastics does not compete with food production

Today's feedstocks for bioplastics are grown on arable land. Land use for bioplastics production is minimal and does not compete with food productions in any way through 2027, as seen in Figure 5 below.

The European Bioplastics Association publishes annual market size data for the current and future years. Using these growth rates, one can estimate the overall impact of the bioplastics market on land use. The data shows that, for example, in 2027, land used for growing feedstocks for bioplastics will account for only 0.058% of global agricultural area, a figure from which we can conclude that bioplastics do not negatively impact food production [15], a conclusion also supported by various independent reports, including those from the nova-Institute [6], Wageningen University and Research Centre [9] and IfBB [8].

Food, Biofuel and Material Production Land Use



Source: European Bioplastics (2022), FAO stats (2020), nova-Institute (2022), and Institute for Bioplastics and Biocomposite (2019), University of Virginia (2016).
Info: www.european-bioplastics.org

* In relation to global agricultural area

Figure [5]: TBC Land use estimation for bioplastics 2021 and 2026

Thai raw sugar production is in the range of 12,900,000 tons/year [21]. Thailand has 16.81 million ha of arable land. In 2020/2021, the land used for sugarcane is estimated to be 1.75 million ha. This means that 10.41% of the arable land in Thailand is used for Sugar production. [16]
TotalEnergies Corbion has a production capacity of 75 kt of PLA. 1 kg of PLA requires 1.75 m² of land [22]. 75kt of PLA require 13 312 ha which is 0.08% of Thai arable land and 0.8% of Thai land used for sugar production.

Over 350 million tons of plastics are produced per year. If all fossil-based plastics currently produced were to become PLA, it would require 1.23% of the global agricultural land or 2.1% of the land suitable for crop production and still available [17]. In fact, around 40 million km² of land is suitable for crop production, and some 11 million km² are currently used meaning that there are 29 million km² of land still available for crops [18]. Assuming that a substitution of 10% of the total conventional plastic production by bioplastics is realistic, the bioplastic potential would be around 38 million tonnes. This would require 0.3% of the total agricultural land use for production (14.7 million ha).

If PLA represents 25% of the bioplastics, 10 million tons of PLA would be produced.

If 10 million tons of plastic is converted into PLA, their production will use 17 750 km² (=1.7 million ha). This production will use 0.03% of the total agricultural land.

The land use prediction above proves that land use requirements for bioplastics production are low and would not impact the availability of land needed for food production.

Furthermore, reducing food wastage would significantly increase the availability of arable land. Around one third of food produced is never consumed, yet its production requires 30% of the global agricultural land (1.4 billion ha) [19]. A 50% and 75% reduction of food losses would save respectively 14 and 21% of agricultural land. Reducing food losses and wastage by just 1% could save 14 million ha of land, enough to produce 79 million tons of PLA.

Production Steps for 1 kg of PLA

*** Conversion rates:** Fermt. Sugar - Lactic acid 85% Starch - Glucose 90%

Luminy® rPLA, a powerful value proposition

Since 2021, TotalEnergies Corbion has been offering a version of its Luminy® PLA grades with recycled content. Collected post-industrial and post-consumer PLA waste are depolymerized via hydrolysis producing lactic acid. The lactic acid is then reprocessed in the polymerization line to produce new PLA. Thanks to this advanced recycling technology, the new recycled PLA grades are of the same quality as the virgin material.

Recycling biobased plastics multiplies the environmental benefits. In fact, changing the feedstock from crops to waste avoids all the impacts linked to agricultural activity. Using PLA waste as raw material reduces almost 100% the land use impact.

For the production of virgin PLA, crops are used as raw materials. The crops absorb carbon from the atmosphere while growing and store it in their biomass. It is called biogenic carbon. This carbon is then transferred to the value chain to end up in the PLA final product. When incinerating the PLA plastic product, this biogenic carbon will be released back into the atmosphere, making the process neutral.

When recycling the PLA plastic product, the biogenic carbon is kept in the cycle and transferred to a new PLA item. This means that the carbon absorbed from the atmosphere is locked in for a longer period of time.

In the virgin PLA [20] life cycle assessment, agricultural activity and lactic acid production count as the most impactful areas of production. However, using PLA waste as a feedstock removes both of these stages. The process used for the recycling of PLA is a low-energy advanced recycling process which has a considerably lower impact than the virgin lactic acid production process.

TotalEnergies Corbion's estimates also indicates a reduction of 320 kg, CO_2eq/ton of PLA for a Luminy PLA with 30% recycled content compared to virgin PLA.

The benefits of using biobased plastics such as PLA

Reducing carbon footprint

Production of biobased Luminy® PLA has a 75% reduced carbon footprint, including biogenic carbon, compared to conventional plastics. Our peer reviewed LCA analyses contain a more detailed overview of the global warming potential and how Luminy® PLA performs in other environmental impact categories such as carbon footprint, water footprint and direct land use change. These analyses also reference a 2017 sustainability risk assessment for Corbion's main sugar supplier, which found no significant land transformation to sugar plantations in high- carbon stock or in high conservation value protected areas. Similarly, the water risk assessment results showed low risk for the sourcing areas where most water consumption occurs.

The enormous potential to further reduce the environmental impacts of PLA is also demonstrated in the analyses.

The starting point for the Global Warming Potential of PLA is the CO_2 absorption from the atmosphere by the growing sugarcane. According to the biomaterial storage approach, the amount of CO_2 fixated in the PLA material is 1833 kg CO_2/ ton of PLA.

Global net emissions from PLA production are 2334 kg CO_2/ton of PLA which makes the carbon footprint of PLA production 501 kg CO_2/ton PLA when deducting the carbon uptake. The biggest contributor to the GWP in the PLA production process is in the production of lactic acid. This is mainly due to the energy consumed and the chemical usage.
The emissions from TotalEnergies Corbion's PLA plant arise from natural gas and energy consumption.

The GWP of the sugar cane production is influenced by fertilizer usage, the plant burning, and the fuel used in machines and equipment. Finally, the sugar mill impact is negative due to the highest gain from heat and electricity produced from by-products.

PLA Cradle-to-gate Global Warming Potential

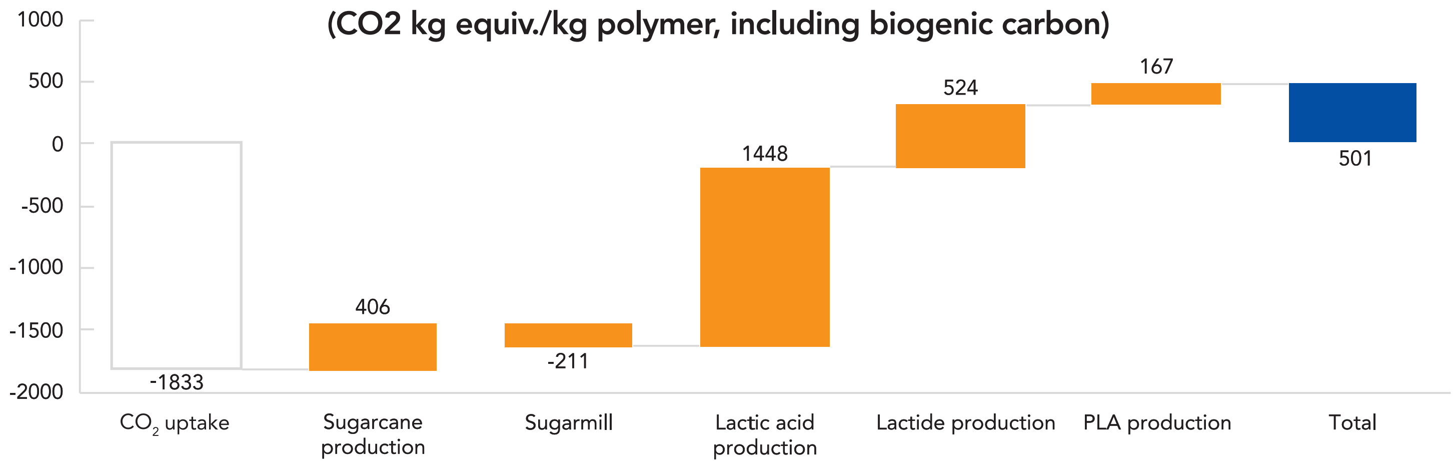
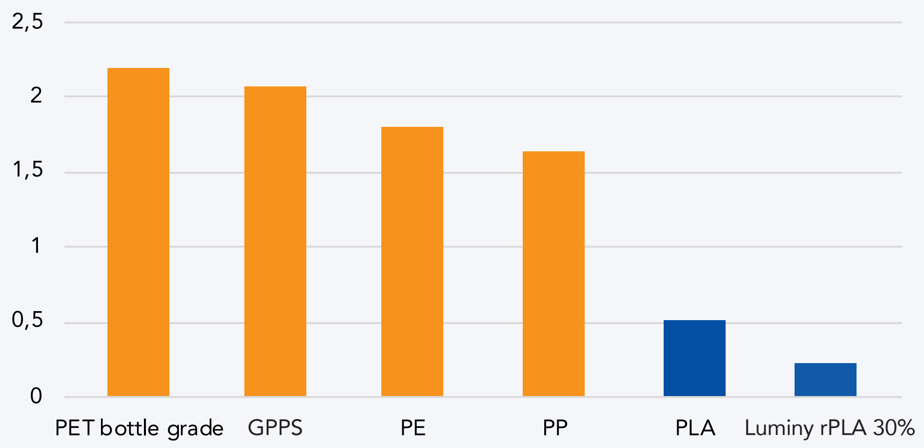


Figure [7]: LCA of PLA, Journal of Polymers and the Environment, (2019) [20]

Global Warming Potential, Cradle to Gate for various polymers

(CO2 kg equiv./kg polymer, including biogenic carbon)

Figure [8]: PlasticsEurope Ecoprofiles (2023); LCA of PLA, Journal of Polymers and the Environment, (2019) and internal sources. [20,21],



Our detailed Life Cycle Assessment, discussed above and supporting these claims can be found on our website in our download center: **www.totalenergies-corbion.com/downloads**

Decoupling from fossil resources

To ensure the sustainable availability of raw material, our society needs to find other resources to produce materials to make the items we all need. Using biobased plastics reduces dependency on finite fossil resources, whereas conventional plastics are produced from crude oil, which is not renewable.

Furthermore, fossil resources like oil for plastics are not readily available in all regions of the world, and this places great dependency in some parts of the world on others. Using biomass (plants) for the production of materials has the advantage of facilitating local production.

The exploitation of non-renewable fossil resources also has a negative economic, environmental, and social impact. Using them involves energy-intensive processes and also the emission of greenhouse gases. To reach global climate targets, the economy should partially switch to a bioeconomy. It's imperative that action is taken now.

End of life solutions

PLA bioplastics play an important part in our endeavors to reach a truly circular plastics economy by providing additional end-of-life options compared to traditional plastics.

In addition to being biobased, PLA can be organically recycled via industrial composting, creating valuable biomass, which in turn, facilitates plant growth and closes the cycle. Additionally, innovative biobased materials such as Luminy® can be transformed back into feedstock using established mechanical or advanced recycling methods. Advanced recycled Luminy® rPLA is sourced from used PLA and maintains the same certified characteristics, meaning that its product life cycles can be endless.

Further details on the end-of-life options for bioplastics are discussed in our whitepaper, which can be found in our download center.

Conclusion

This paper has outlined many aspects related to feedstocks used for biobased bioplastics. Consumer awareness and interest in environmentally sustainable and ecologically sound products is increasing and continues to drive the demand for bioplastics. Importantly, we have shown that the overall total impact that the bioplastics market has on land use does not pose a threat to food production. Considering all the different angles, we conclude Luminy® PLA is a more sustainable and environmentally friendly alternative to traditional plastics.

Over the last few years, many of the world's largest consumer brands have begun to employ bioplastics in the packaging of their products. Examples include Procter and Gamble's bioplastic shampoo packaging, Danone's PLA yoghurt cups and Coca-Cola's plant bottle. Highlighted benefits to consumers include their biobased origin, reduced carbon footprint and that they are made from renewable resources.

The use of biobased bioplastics reduces our dependency on fossil fuels and supports a circular, local-for-local economy thanks to the multiple end-of-life options discussed above. Luminy® PLA is a certified 100% biobased polymer that can be used in many applications replacing conventional plastics.

"At TotalEnergies Corbion, we believe the concerns of using biobased feedstocks for plastics can be successfully identified and managed. The many benefits of biobased plastics like Luminy® PLA far outweigh any misconceptions regarding their use."

TotalEnergies Corbion

Glossary

Beet sugar
The sugar derived from sugar beet, produced at the mill. This is sometimes used in Corbion's factories in Spain and the Netherlands where this feedstock is locally available.

Biobased product
A biobased product is a commercial or industrial product (other than food or feed) that is composed, in whole or in significant part, of biological products, including renewable domestic agricultural materials (including plant, animal, and aquatic materials), forestry materials, intermediate materials, or feedstocks.

Biomass
Material of biological origin excluding material embedded in geological formations and material transformed to fossilized material. Biomass includes organic material, e.g., trees, crops, grasses, tree litter, algae, and waste of biological origin e.g., manure. Biomass used for bioplastics is currently mainly derived from corn, sugarcane, or cellulose.

Cane sugar
The raw sugar derived from sugarcane, produced at the mill. At TotalEnergies Corbion, we produce PLA in Thailand via raw sugar from sugarcane.

Carbohydrate
Carbohydrates are organic compounds of carbon, hydrogen, and oxygen that are formed by plants and provide energy for animals. They include sugars, starches, celluloses, and gums. They may have twice as much hydrogen as oxygen and carbon.

Mass balance methodologies
Mass balance is a consideration of the input, output, and distribution of a substance between streams in a process or stage.

Refined sugar
This is the typical 'white' sugar that is used as table sugar for eating and cooking.

Raw sugar
One of the types of sugar produced at a mill (i.e., in addition to, and as a precursor to, refined white sugar). Raw sugar can be made of a number of feedstocks (sugarcane, beet, etc.). It is an unrefined version of sugar and as such is generally not suitable for human consumption. At TotalEnergies Corbion, we produce PLA in Thailand via raw sugar from sugarcane.

Second generation/alternative feedstocks
Cellulosic feedstocks from sources not intended for human consumption (such as bagasse, corn stover, wood chips, etc.).

Sugar
This can refer to raw sugar, cane sugar, beet sugar, sucrose, dextrose, etc.

Sugar beet
The crop, produced at the farm on arable land in, for example, Europe. The harvested sugar beet is sold to the sugar mill for further processing.

Sugarcane
The crop, produced at the farm on arable land in, for example, Thailand and Brazil. The harvested (cut and cropped) sugarcane is sold to the sugar mill for further processing.

Starch
This can refer to the starch feedstock from corn or cassava, for example, which can be further processed into dextrose as a sugar feedstock. In the USA, Corbion sources dextrose from corn.

References

1. Bajpai, D.P. (2015) Pulp and paper industry: Chemicals [p.85]. 1st edn. United States: Elsevier Science Publishing Co. https://www.elsevier.com/books/pulp-and-paper-industry/bajpai/978-0-12-803408-8 [Accessed: 3 May 2023]
2. Goodyear Corporate EMEA (no date) Life+: ECO2 Tyre tech. https://www.goodyear.eu/en_gb/consumer/why-goodyear/technology-and-innovation.html [Accessed: 3 May 2023]
3. Starch Europe (no date) EU starch market in figures. https://starch.eu/the-european-starch-industry [Accessed: 3 May 2023]
4. Nager IT (2016) The Faire Maus. https://www.nager-it.de/en/home [Accessed: 3 May 2023]
5. Bioplastics Facts and Figures https://docs.european-bioplastics.org/publications/EUBP_Facts_and_figures.pdf [Accessed: 3 May 2023]
6. OK biobased C14 dating method, Information Document 529 (EN) – 19.10, TÜV AUSTRIA Belgium, https://www.tuv-at.be/fileadmin/user_upload/docs/download-documents/ID/ID-529_C14_EN.pdf [Accessed: 3 May 2023]
7. Carus, M. and Dammer, L. (2013) Food or non-food: Which agricultural feedstocks are best for industrial uses? Nova Paper #2 on biobased economy. https://renewable-carbon.eu/publications/product/nova-paper-2-on-bio-based-economy-food-or-non-food-which-agricultural-feedstocks-are-best-for-industrial-uses-%E2%88%92-full-version/ [Accessed: 3 May 2023]
8. IfBB institute for bioplastics and bio composites, Biopolymers Facts and statistics [2018] production capacities, processing routes, feedstock, land and water use https://www.ifbb-hannover.de/files/IfBB/downloads/faltblaetter_broschueren/f+s/Biopolymers-Facts-Statistics-einseitig-2022.pdf [Accessed: 3 May 2023]
9. Bos, H.L., Meesters, K.P.H., Conijn, S.G., Corré, W.J. and Patel, M.K. (2012) 'Accounting for the constrained availability of land: A comparison of biobased ethanol, polyethylene, and PLA with regard to non-renewable energy use and land use', Biofuels, Bioproducts and Biorefining, 6(2), pp. 146–158 https://research.wur.nl/en/publications/accounting-for-the-constrained-availability-of-land-a-comparison- [Accessed: 3 May 2023]
10. Worldwatch Institute [2004] The state of consumption today http://www.adorngeo.com/uploads/2/7/3/5/27350967/the_state_of_consumption_today.pdf [Accessed: 3 May 2023]
11. Corbion Cane Sugar Code (2016) https://www.corbion.com/-/media/Corbion/Files/PLA-PDFs-12-of-24/corbion-cane-sugar-code_545064.ashx [Accessed: 3 May 2023]
12. Corbion Supplier Code (2018) https://www.corbion.com/-/media/Corbion/Files/Supplier-Code-PDFs/1418022-cor-supplier-code-vijf-talen_en_v3_764355.ashx [Accessed: 3 May 2023]
13. TotalEnergies Corbion (2017) https://www.totalenergies-corbion.com/about-pla [Accessed: 3 May 2023]
14. Corbion annual report 2022: On the road to sustainable sugar cane. https://annualreport.corbion.com/annual-report-2022 [Accessed: 3 May 2023]
15. European Bioplastics Association, Institute for Bioplastics and Biocomposites and nova-Institute (2016) Feedstocks. https://www.european-bioplastics.org/market [Accessed: 3 May 2023]
16. USDA Foreign Agricultural Service (2019) GAIN Report (Global Agricultural Information Network), Thailand sugar annual 2019, https://www.fas.usda.gov/data/thailand-sugar-annual-3 [Accessed: 3 May 2023]
17. Low carbon footprint of PLA confirmed by peer reviewed Life Cycle Assessment (2019) https://bioplasticsnews.com/wp-content/uploads/2019/10/191014-PR-Total-Corbion-PLA-LCA.pdf [Accessed: 3 May 2023]
18. Our World in data, Land use, Hannah Ritchie and Max Roser, September 2019 https://ourworldindata.org/land-use [Accessed: 3 May 2023]
19. FAO (2021) FAOSTAT: Arable land area Thailand in 2018. http://www.fao.org/faostat/en/#data/RL [Accessed: 3 May 2023]
20. Life Cycle Impact Assessment of Polylactic Acid (PLA) Produced from Sugarcane in Thailand (2019) https://www.totalenergies-corbion.com/media/ygiaoqq4/mora-o-bie2019_article_lifecycleimpactassessment.pdf [Accessed: 3 May 2023]
21. PlasticsEurope (2023) Ecoprofile.https://plasticseurope.org/sustainability/circularity/life-cycle-thinking/eco-profiles-set/ [Accessed: 3 May 2023]

About TotalEnergies

About TotalEnergies Corbion

TotalEnergies Corbion is a global technology leader in Poly Lactic Acid (PLA) and lactide monomers. PLA is a biobased and biodegradable polymer made from annually renewable resources, offering a reduced carbon footprint versus traditional plastics. The Luminy® PLA portfolio, which includes both high heat and standard PLA grades, is an innovative material that is used in a wide range of markets from packaging to consumer goods, fibers and automotive. TotalEnergies Corbion, headquartered in the Netherlands, operates a 75,000 tons per year PLA production facility in Rayong, Thailand. The company is a 50/50 joint venture between TotalEnergies and Corbion. www.totalenergies-corbion.com

About TotalEnergies

TotalEnergies is a broad energy company that produces and markets energies on a global scale: oil and biofuels, natural gas and green gases, renewables and electricity. Our 105,000 employees are committed to energy that is ever more affordable, clean, reliable and accessible to as many people as possible. Active in more than 130 countries, TotalEnergies puts sustainable development in all its dimensions at the heart of its projects and operations to contribute to the well-being of people. www.totalenergies.com

About Corbion

Corbion is a sustainable ingredients company dedicated to preserving what matters, including food and food production, health, and the planet. We specialize in lactic acid, lactic acid derivatives, food preservation solutions, functional blends, and algae ingredients, using our deep application and product knowledge to propel nature's ingenuity through science. With more than a century of experience, we continue working side-by-side with our customers to make our cutting-edge technologies work for them. Leveraging our advanced capabilities in fermentation and preservation technology, we help customers differentiate their products in diverse markets ranging from food and animal nutrition to home & personal care, pharmaceuticals, electronics, medical devices, and bioplastics. Corbion is listed on Euronext Amsterdam.
For more information: www.corbion.com

TotalEnergies Corbion

www.totalenergies-corbion.com