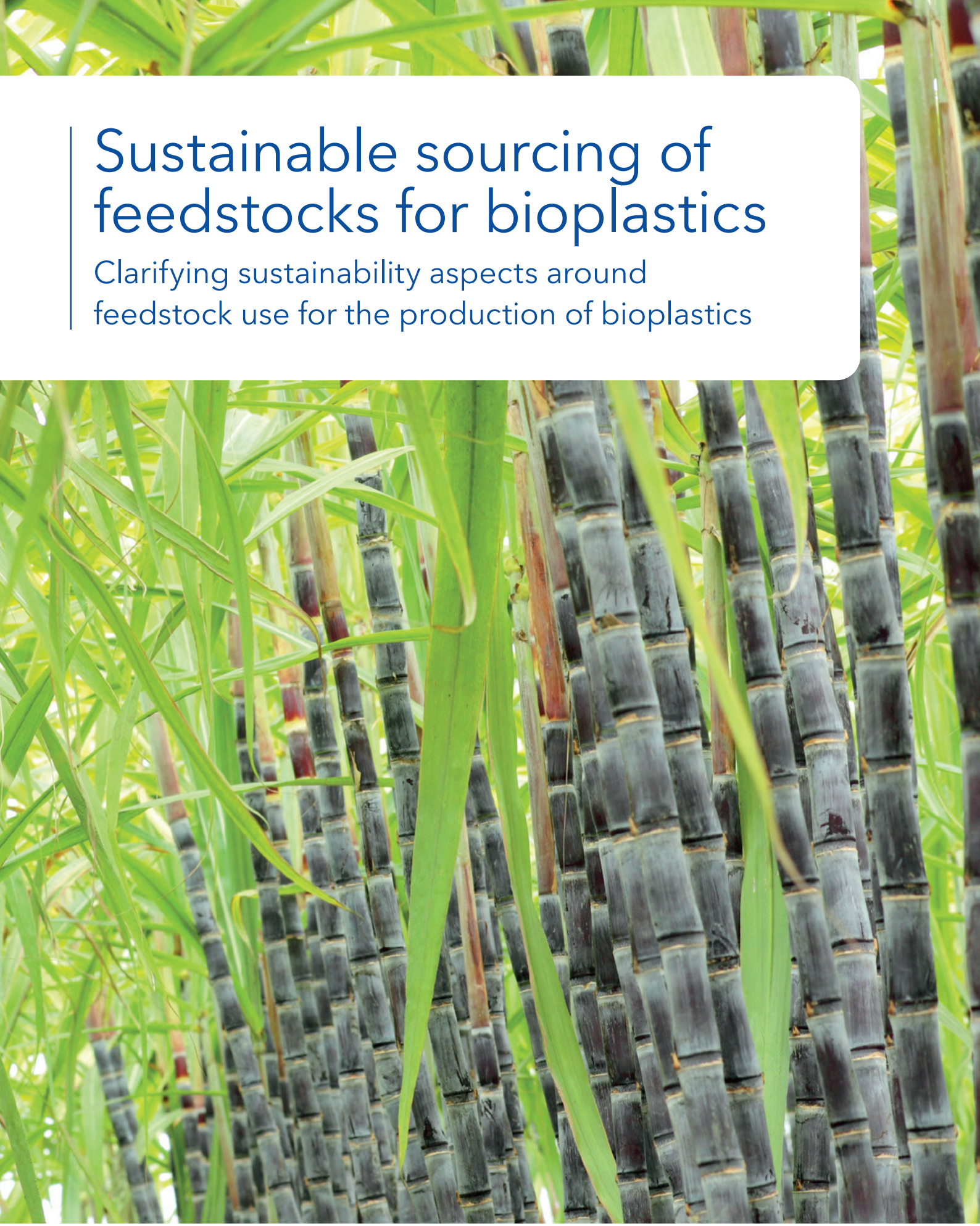
Sustainable sourcing of feedstocks for bioplastics

Clarifying sustainability aspects around feedstock use for the production of bioplastics



TotalEnergies Corbion

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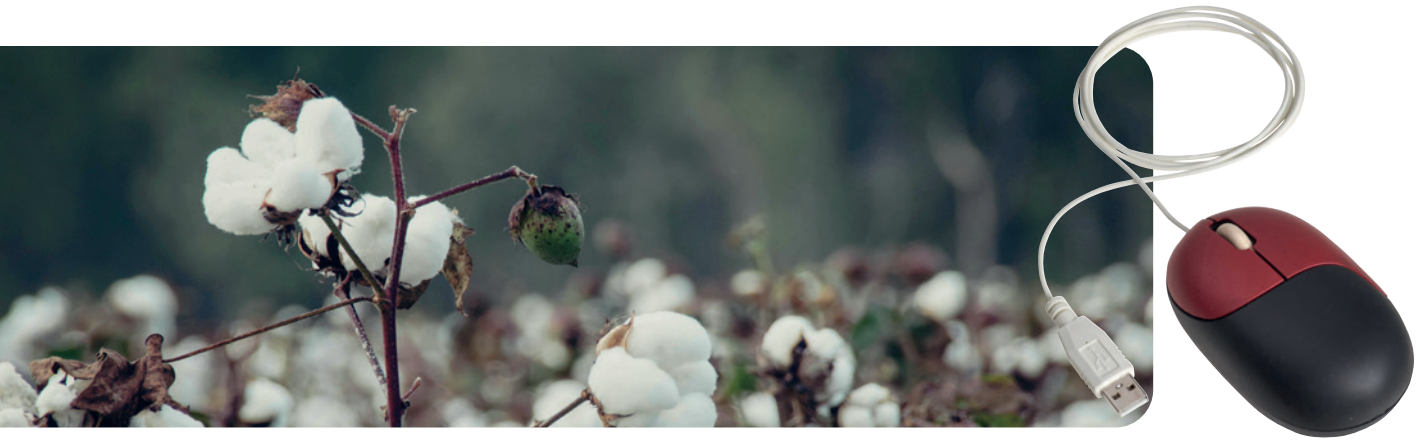
Introduction:
using renewable raw materials for the production of bioplastics

Historically, mankind has always relied upon natural grown resources to make higher added value products. Originating from nature, these grown resources - often referred to as renewable resources, biobased feedstocks or biomass - include a vast range of plants and trees, including some well-known agriculturally grown crops like cotton, rubber trees, sugarcane, corn and rapeseed, to name a few.



Typical examples of biobased products – products originating from these renewable resources - include wooden furniture, cotton shirts, paper, medicine, etc., but also lesser known products such as glue for the cardboard industry, chemical binder in car tires[1] and dextrin for firework production, all made from corn starch, as well as biobased plastic items like IT hardware made from sugarcane[2]. The scale on which such biobased products are used for industrial purposes today is considerable: for example, it is estimated that about 5 million tons of starch are currently used by the world paper industry alone: that is about 1.5% starch by end-product weight including all grades of paper and paperboard[3]. In 2015 in the EU alone, starch consumption was 9.3 million tons, of which 38% in non-food applications, primarily paper making[4]. Looking at the total chemical industry - with global sales of $2,820 billion in 2012 - around 9%, or $252 billion, came from biobased chemicals according to a report by McKinsey & Co[5].

Biobased plastics and biobased chemicals offer an alternative solution to traditional, comparable products made from fossil oil and its derivatives. Biobased plastics and chemicals often offer sustainability benefits over their fossil-based counterparts, like a reduced CO_2 footprint, reduced dependency on fossil resources and/or additional end-of-life options. Bioplastics can also offer improved product functionalities and performance in many cases, for example in 3D printing filaments[6].

Today, bioplastics such as PLA (Poly Lactic Acid) are made from renewable, biobased carbohydrate-rich feedstocks like sugarcane, corn, sugar beet and cassava. In this paper some facts and figures related to these feedstocks, alongside some alternative feedstocks, will be presented. The selection and the subsequent sustainable sourcing of these feedstocks is driven by a number of sustainability aspects. In this paper, Corbion and TotalEnergies Corbion team up to share their views and vision related to the selection and sustainable sourcing of feedstocks for bioplastics.

The TotalEnergies Corbion supply chain:
from raw materials to final article

Today's supply chain for PLA resins produced by TotalEnergies Corbion is demonstrated in Figure 1. Corbion liaises with various local sugar suppliers across the globe for each of its production plants, including for example Mitr Phol for their plant in Rayong, Thailand. Corbion converts these sugar feedstocks to lactic acid through a fermentation process.

Figure 1 TotalEnergies Corbion supply chain for PLA bioplastics

The lactic acid is then converted by TotalEnergies Corbion to lactide monomers, in our 75 KTpa production facility located adjacent to Corbion's lactic acid plant in Rayong, Thailand.

TotalEnergies Corbion has recently announced the intention to build a new, 100 kTpa PLA production plant in Grandpuits, France. This will be the first plant of its kind in Europe.

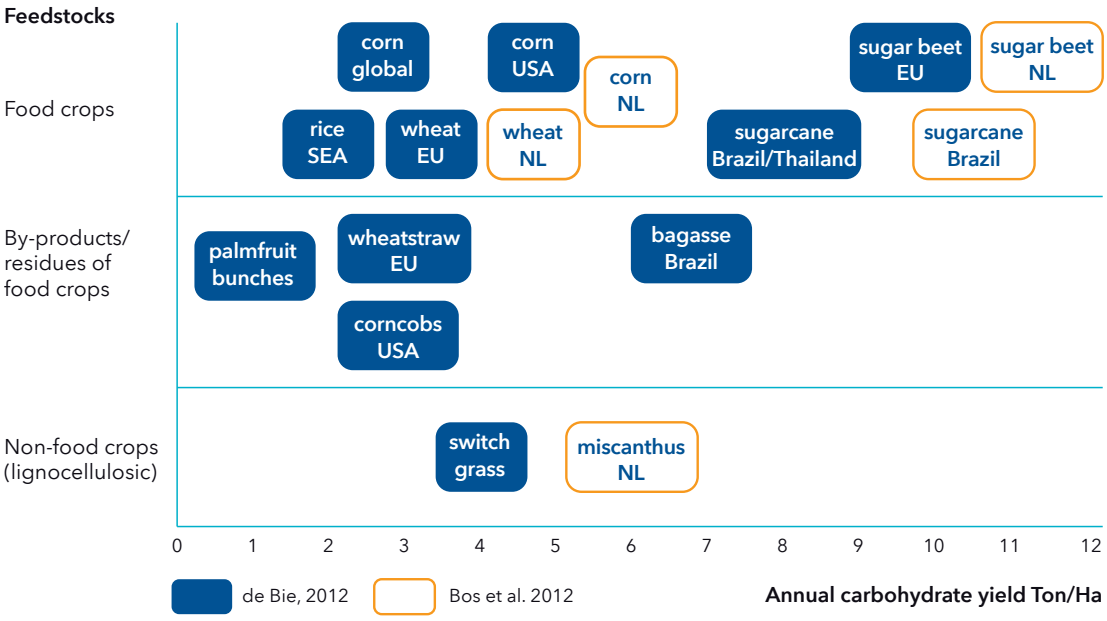
Sugar: today's most sustainable feedstock

Raw sugar extracted from sugarcane or sugar beet, or dextrose from corn starch or cassava starch, are the main feedstocks used today to produce lactic acid and its derivatives. The raw sugar is usually sourced locally based on the most readily available feedstock for a particular global region. This, in turn, is based on agricultural factors such as climate and soil conditions, as not all feedstocks can be grown effectively in all regions. Thailand and Brazil boast excellent conditions for growing sugarcane, the USA is one of the global leaders in growing corn (maize), whilst Europe has excellent farmland for growing sugar beet. 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 the feedstocks with the highest yields

As our population and our demand on global resources increases, arable land could become scarce and it is therefore of utmost importance to use the most efficient crops available. Agricultural yields per hectare of arable land vary based on 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



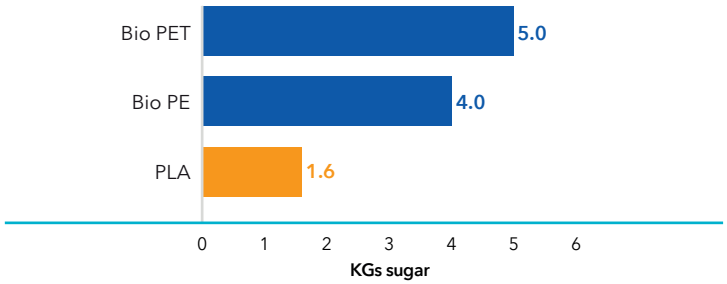
Nova 2013, based on de Bie 2012 & Bos et al. 2012

TotalEnergies Corbion sources its lactic acid from 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 USA and raw sugar from sugar beet is used by its factories in Spain and the Netherlands. In time of shortage, the plants can run on imported or other feedstocks; the factory in Thailand could, for example, also run on cassava starch. In addition to bioplastics production, the 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 efficient conversion from raw sugar to product. 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 the production efficiencies. This means that different types of bioplastics, produced using different production processes, 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

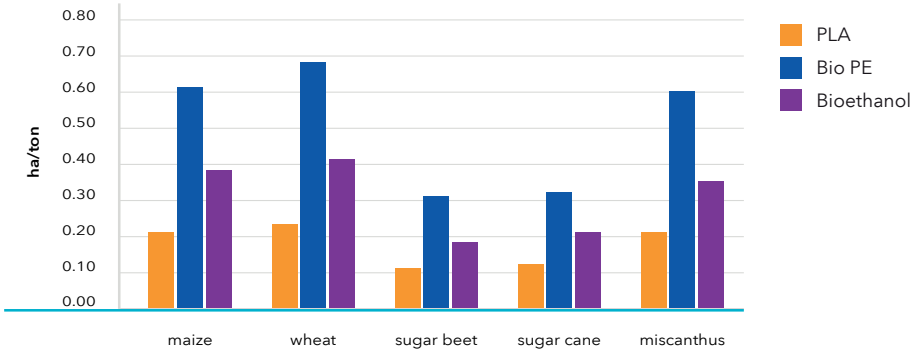


A number of institutes and universities have analyzed and combined crop yields with feedstock efficiencies for various biomaterials. See for example reports from IfBB[9] and Wageningen University and Research Centre (WUR)[10]. Figure 4 compares a few of the possible options and shows that when land use is a concern, PLA made from sugar beet or sugarcane is an efficient choice[11].

Ultimately, feedstock efficiency has a positive impact on land use and, in addition, 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 5 crops valid for both current agricultural practice and if all residues/co-products are used



TotalEnergies Corbion predominantly produces PLA bioplastic made from raw sugar from cane in Thailand. Over the years, both Corbion and TotalEnergies Corbion have significantly improved the internal process yields and is, as mentioned above, able to produce 1.0 kg of PLA using just 1.6 kg of raw sugar[12].

Sustainable agricultural practices for growing feedstocks

If the levels of consumption that the most affluent 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 [13]. In order, therefore, to produce biobased products in a responsible and sustainable way, for people today as well as for generations to come, companies should ensure that their feedstocks are grown using sustainable agricultural practices and that their supply chains are regulated in a sustainable way. A responsible and sustainable supply chain is essential for the communities in which we operate and should include the entire chain: from farmers to the companies that produce the final finished products used in daily life.

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 that is grown in Thailand, and to a lesser extent, sugar beet grown in Europe.

Corbion's Cane Sugar Code

TotalEnergies Corbion sources lactic acid from Corbion, and its Cane Sugar Code has been developed to describe the expectations it has of its cane sugar suppliers to fulfill its responsible sourcing commitment. The code is based on the definitions for sustainable sugarcane and derived products as set out by Bonsucro. Bonsucro is 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, which is applicable to all Corbion suppliers, as well as specific extensions directly related to sugarcane farming in Thailand and Brazil. Corbion's Supplier Code and the Cane Sugar Code are publicly available[14].

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

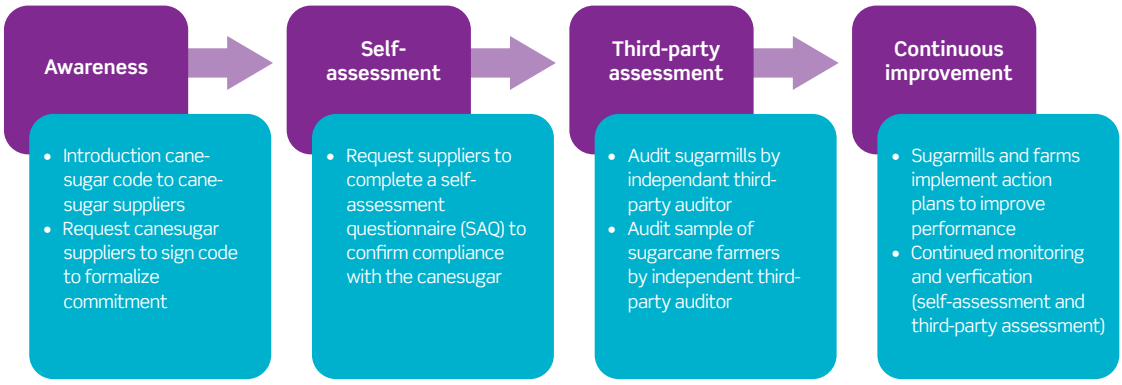
Corbion's Cane Sugar Code

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/sourcing

Corbion's Cane Sugar Code is applicable to all of its cane sugar suppliers. To validate that suppliers meet these requirements, verification procedures have been implemented, leveraging a combination of tools such as self-assessment questionnaires, third-party verification and Bonsucro certification. As of 2017, Corbion has been actively auditing cane sugar suppliers.



Bonsucro

Bonsucro has over 280 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; and through its unique metric-based certification scheme - The Bonsucro Production Standard – the organization is now laying down a clearly defined roadmap to help the industry improve. The Bonsucro Production Standard covers the following 5 key principles: obey the law, respect human rights and labor standards, manage input, production and processing efficiencies to enhance sustainability, actively manage biodiversity and ecosystem services and lastly, continuously improve key areas of the social, environmental and economic sustainability.

In addition to complying with the Corbion Cane Sugar Code, Corbion requires all of its cane sugar suppliers to become members of Bonsucro and expects them to work towards 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 is identifying with its suppliers the areas where improvement is needed to enable them to meet the standard – giving them an opportunity to make the changes necessary to achieve the standard, which includes answering questions and lending expertise wherever possible [15].

In recent years, Bonsucro certified sugar has become more readily available. Corbion, who committed to sourcing part of its sugar demand from Bonscro certified sources, has now started to source Bonsucro certified sugar. Corbion and TotalEnergies Corbion are both Bonsucro chain of custody certified. In 2017, TotalEnergies Corbion became the first company to offer Luminy® PLA bioplastic resins made from Bonsucro ceritified sugar to the market [16].

Throughout the years TotalEnergies Corbion as sold Bonsucro certified PLA to a broad range of customers and over the years the share of Bonsucro soruced sugar as % of overall sourced sugar has steadily increased. In 2021 the use of Bonsucro certified sugar will further increase.

GMO-free feedstocks

It is not a technical requirement to use genetically modified crops or feedstocks (in short, referred to as GM or GMO) for the production of 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.

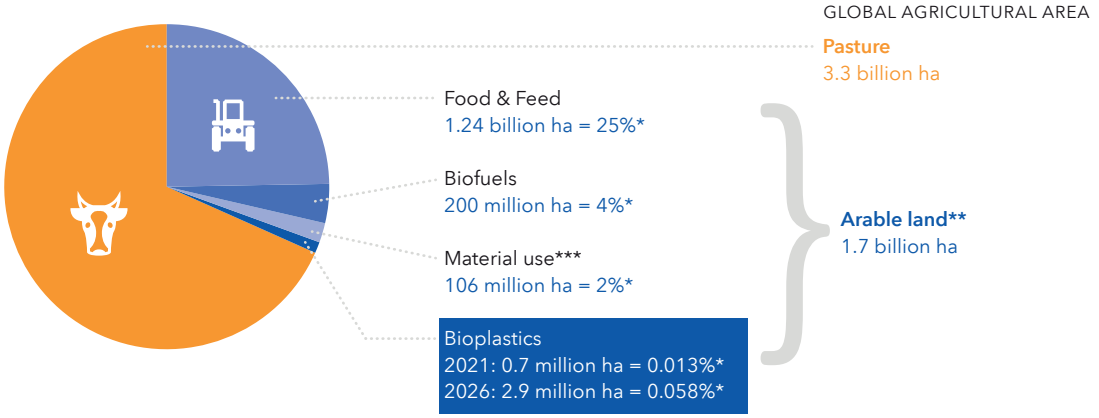
Within different world regions and industry segments, diverse views and regulations regarding products containing GMO exist. Whether driven by regulatory requirements or consumer preference, some of our customers look for ways to have their products produced from non-GMO raw materials. As a result, the Corbion portfolio includes products made from GMO and non-GMO feedstocks to enable the choices our customers need or desire.

At TotalEnergies Corbion, European sugar beet and Thai sugarcane are used as feedstocks for the production of PLA bioplastics. These are always GMO-free crops, which is why we can offer our customers PLA produced from GMO-free feedstocks.

Land used for bioplastics does not compete with food

Today's feedstocks for bioplastics are grown on arable land. For both today and projections up to 2026, we can demonstrate that land use for bioplastics production is minimal and in no way competing with food (see figures 5 below). The European Bioplastics Association publishes market size data for the existing and future years on an annual basis. Using these growth rates one can estimate the overall total impact that the bioplastics market has on land use. The data shows that, for example, in 2026 land used for growing feedstocks for bioplastics will account for only 0.058% of global agricultural area, a number which leads to the conclusion that bioplastics are in no way competing with land used for food [17]. This conclusion is supported by various independent reports, including those from the nova-Institute [18], Wageningen University and Research Centre[19] and IfBB[20].

Figure 5 Land use estimation for bioplastics 2021 and 2026



Source: European Bioplastics (2021), FAO Stats (2020), nova-Institute (2021) and Institute for Bioplastics and Biocomposites (2019). More information: www.european-bioplastics.org

* *In relation to global agricultural area*
** *Also includes approx. 1% fallow land*
*** *Land-use for bioplastics is part of the 2% material use*

Thai raw sugar production is in the range of 12,900,000 tons/year[21]. To produce 75,000 tons of PLA, TotalEnergies Corbion in Thailand uses a maximum of 115,000 tons of raw sugar annually, around 0.9% of Thai sugar production. Thailand has 16,810,000 ha of arable land, of which just under 10.5% (1,751,000 ha) is used for growing sugarcane[22]. This means that in Thailand, 7.4 tons of raw sugar are produced per hectare of land used for growing sugarcane. Therefore the 115,000 tons of raw sugar used annually by TotalEnergies Corbion require an estimated 15540 ha or 0.092% of the available arable land in Thailand.

Alternative feedstocks for bioplastics

Although the area of land used for growing crops for bioplastics today is minimal, and projected to remain so in the years to come, there remains a concern amongst certain parts of our society about the use of food crops for other applications than food and feed. Over the next decades, world population will grow and global demand for biomass for food and industrial applications is expected to increase.

Non-food biomass feedstocks

Currently, sugar-based feedstocks are the most efficient and sustainable crops. However, R&D teams continue to work on new production processes that support the production of biochemicals and bioplastics made from alternative feedstocks.

Options for alternative feedstocks include non-food biomass crops, agricultural by-products and waste streams. Specific examples include miscanthus, wheat straw, bagasse, corn stover and wood chips. These feedstocks are also often referred to as 'cellulosic feedstocks' or 'second generation feedstocks'.

In general, significant R&D efforts and investments are still needed in order to commercialize bioplastics made from alternative feedstocks. Within the bioplastics industry, many small and large companies are working on this topic; however a lot of effort and time is still needed to deliver economically viable technology.

In 2015, TotalEnergies Corbion became the first company to successfully produce, on lab scale, PLA from alternative feedstocks – and therefore the first to make PLA from non-food biomass [23].

Going circular: PLA waste as feedstock for new PLA

In addition to using virgin materials to create bioplastics, recent developments have now enabled the use of PLA-waste as a feedstock for new PLA resin. This process not only closes the loop and retains valuable materials in the use cycle, but also reduces the amount of mismanaged waste entering undesirable steams.

TotalEnergies Corbion recently announced the launch of Luminy® rPLA, a product that includes recycled content from chemically recycled feedstock and boasts the same properties, characteristics and regulatory approvals as virgin Luminy® PLA. TotalEnergies Corbion also posed the open invitation for any parties in the value chain to get in contact should they wish to make use of this circular approach for their new or used PLA applications: at the start- or end-of-life.

The benefits of using biobased plastics in consumer goods

This paper has outlined many aspects related to feedstocks used for bioplastics. Consumer awareness and interest in environmentally sustainable and ecologically sound products is increasing and continues to drive the demand for bioplastics.

Over the last 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. Biodegradable bioplastics can convert back to CO_2, water and harmless substances at the end of their useful life. This is a good option in case mechanical recycling of the end product is not (or no longer) feasible. TotalEnergies Corbion has recently published a whitepaper that outlines the preferable end of life options for PLA bioplastics. A copy of that paper can be found on our website in our download center.

PLA from TotalEnergies Corbion is both biobased and biodegradable, and offers a reduced carbon footprint. A detailed LCA to support these claims can be found on our website in our download center'. Furthermore, the compostability of PLA allows for increased organic waste collection and so helps to divert organic waste from landfill. For example due to recycling and composting of waste in compostable bioplastic bags, the Seattle Mariners baseball stadium diverted two million pounds of waste from landfill, saving $128,000 in waste disposal costs[24].

The use of bioplastics reduces our dependency on fossil fuels and supports a circular, local-for-local economy thanks to the multiple end-of-life options available.

'At TotalEnergies Corbion, we believe that the concerns of using biobased feedstocks for plastics can be successfully identified and managed, and that the many benefits of these biobased, renewable feedstocks far outweigh their challenges'.

Glossary

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.

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.

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.

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.

Beet sugar
The raw 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.

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

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

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.

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

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[25].

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[26].

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About us

About TotalEnergies Corbion

TotalEnergies Corbion (formerly known as Total Corbion PLA) 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 many 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 and has recently announced the intention to build a second plant in Grandpuits, France. The company is a 50/50 joint venture between TotalEnergies and Corbion. www.totalenergies-corbion.com

About TotalEnergies

TotalEnergies is a global multi-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, cleaner, more 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 the global market leader in lactic acid and its derivatives, and a leading supplier of emulsifiers, functional enzyme blends, minerals, vitamins, and algae ingredients. We use our unique expertise in fermentation and other processes to deliver sustainable solutions for the preservation of food and food production, health, and our planet. For over 100 years, we have been uncompromising in our commitment to safety, quality, innovation and performance. Drawing on our deep application and product knowledge, we work side-by-side with customers to make our cutting-edge technologies work for them. Our solutions help differentiate products in markets such as food, home & personal care, animal nutrition, pharmaceuticals, medical devices, and bioplastics. In 2020, Corbion generated annual sales of € 986.5 million and had a workforce of 2,267 FTE. Corbion is listed on Euronext Amsterdam. www.corbion.com