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IfBB
Institut für Biokunststoffe
und Bioverbundwerkstoffe

Biopolymers

facts and statistics

HOCHSCHULE
HANNOVER
UNIVERSITY OF
APPLIED SCIENCES
AND ARTS
–
*Fakultät II
Maschinenbau und
Bioverfahrenstechnik*

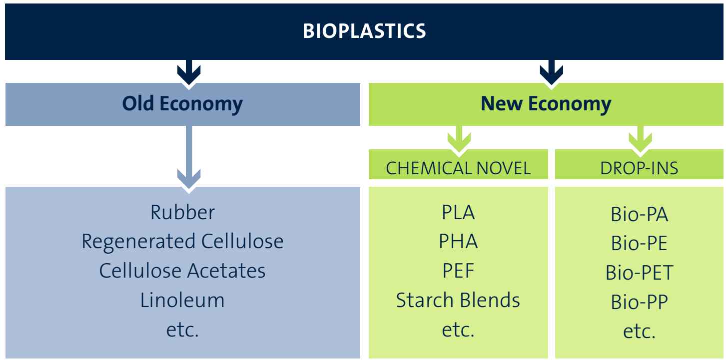
1 INTRODUCTION AND BACKGROUND

The IfBB – Institute for Bioplastics and Biocomposites is a research institute within the Hochschule Hannover, University of Applied Sciences and Arts, which was established in 2011 to respond to the growing need for expert knowledge in the area of bioplastics. With its practice-oriented research and its collaboration with industrial partners, the IfBB is able to shore up the market for bioplastics and, in addition, foster unbiased public awareness and understanding of the topic.

As a research-led expert institution for bioplastics, the IfBB is willing to share its expertise, research findings and data with any interested party via the Internet, online and offline publications or at fairs and conferences. In carrying on these efforts, substantial information regarding market trends, processes and resource needs for bioplastics is being presented here in a concise format, in addition to the more detailed and comprehensive publications "Technische Biopolymere[1]" and "Engineering Biopolymers[2]".

One of our main concerns is to furnish a more rational basis for discussing bioplastics and use fact-based arguments in the public discourse. Furthermore, "Biopolymers – facts and statistics" aims to provide specific, qualified answers easily and quickly for decision--makers in particular from public administration and the industrial sector. Therefore, this publication is made up like a set of rules and standards and largely foregoes textual detail. It offers extensive market-relevant and technical facts presented in graphs and charts, which means that the information is much easier to grasp. The reader can expect comparative market figures for various materials, regions, applications, process routes, agricultural land use or resource consumption, production capacities, geographic distribution, etc.

A large amount of additional information is also available on the IfBB website at *www.ifbb-hannover.de*.



In recent years, many new types of bioplastics have emerged and innovative polymer materials are pushing on the plastics market. All the same, bioplastics by no means constitute a completely new class of materials but rather one that has been rediscovered from among the large group of plastic materials.

The first polymer materials fashioned by human hands were all based on modified natural materials (e.g., casein, gelatine, shellac, celluloid, cellophane, linoleum, rubber, etc.). That means they were biobased since petrochemical materials were not yet available at that time. Ever since the middle of the 20th century however, these early biobased plastics, with a few exceptions (cellulose and rubber-based materials), have almost been fully replaced by petrochemical materials.

By now, due to ecological concerns, limited petrochemical resources and sometimes new property profiles, bioplastics have undergone a remarkable revival and are taken more and more into focus by the general public, politics, the industrial sector and in particular the research community.

Of particular interest today are new types of bioplastics, which were developed in the past 30 years. The publication presented here refers to the socalled “New Economy” bioplastics as opposed to “Old Economy” bioplastics which indicate earlier materials developed before petrochemical bioplastics emerged, yet still exist on the market today (e.g., rubber, cellophane, viscose, celluloid, cellulose acetate, linoleum).

New Economy bioplastics divide up into two main groups. On the one hand, there are those biopolymers which have a new chemical structure virtually unknown in connection with plastics until a few years ago (e.g., new biobased polyesters such as PLA), on the other hand socalled “drop-ins“, with the same chemical structure yet biobased. The most prominent drop-ins at this point are biobased PET (Bio-PET) and biobased polyethylene (Bio-PE).

2 PROCESS ROUTES

Process routes depict the manufacturing steps from the raw material to the finished product, specifying the individual process steps, intermediate products, and input-output streams. So they serve as a guide for all considerations and calculations around the production of bioplastics, in particular also with regard to their resource consumption.

The following methodical approach was chosen to establish the process routes:

The mass flows were first calculated using a molar method based on the chemical process, with the introduction of known rates and conversion factors. The routes so established were confirmed with polymer manufacturers and the industry generally as far as possible. In so far as no loss rates due to the chemical processes or the process stages were included, the calculations were made basically assuming no losses. The mass flows show feedstock and resulting land requirements in ha for the production of one metric ton of bioplastics.

Feedstock requirements were calculated for the use of different crops. For final land use calculation only the most commonly used crop was taken into consideration. Yield data from FAO statistics served as a basis for calculation (global, non-weighted average over the past 10 years). To calculate land use in this bottom-up approach, the producer-specific production capacities of a type of bioplastics were multiplied by the output data of the corresponding process routes.

Yields of the most important crops and renewable raw materials used for feedstock are shown in the chart below. Please note that the yields in this context refer to the crop itself, which contains the raw material for processing, and not to the harvested whole plant.

TYPE OF CROP	GLOBAL MEAN YIELD
Corn	*6,5 t / ha*
Sugar cane	*70 t / ha*
Sugar beet	*52 t / ha*
Wheat	*3,5 t / ha*
Potatoes	*21 t / ha*
Castor oil plant	*1 t seeds/ha = 0,4 t oil / ha, given one harvest per year*
Wood	*1,64 t atro / ha*

In all of the calculations no allocation was made, which means land use was fully, by 100 %, allocated to the raw materials for bioplastics and not split up between various parallel side products such as proteins or straw in wheat. So this approach leads to a rather conservative estimate.

Numbers in chapter headings, like "PET-30" for example, mean that 30 / 70 / 100 % of the material have a biobased origin / are biobased.

ABBRIVIATIONS USED:

bb = *Bio-based*

SCA = *Succinic Acid*

BDO = *Butanediol*

PDO = *Propanediol*

PTA = *Purified Terephthalic Acid*

MEG = *Monoethylene Glycol*

PMDA = *Pentamethylene Diamine*

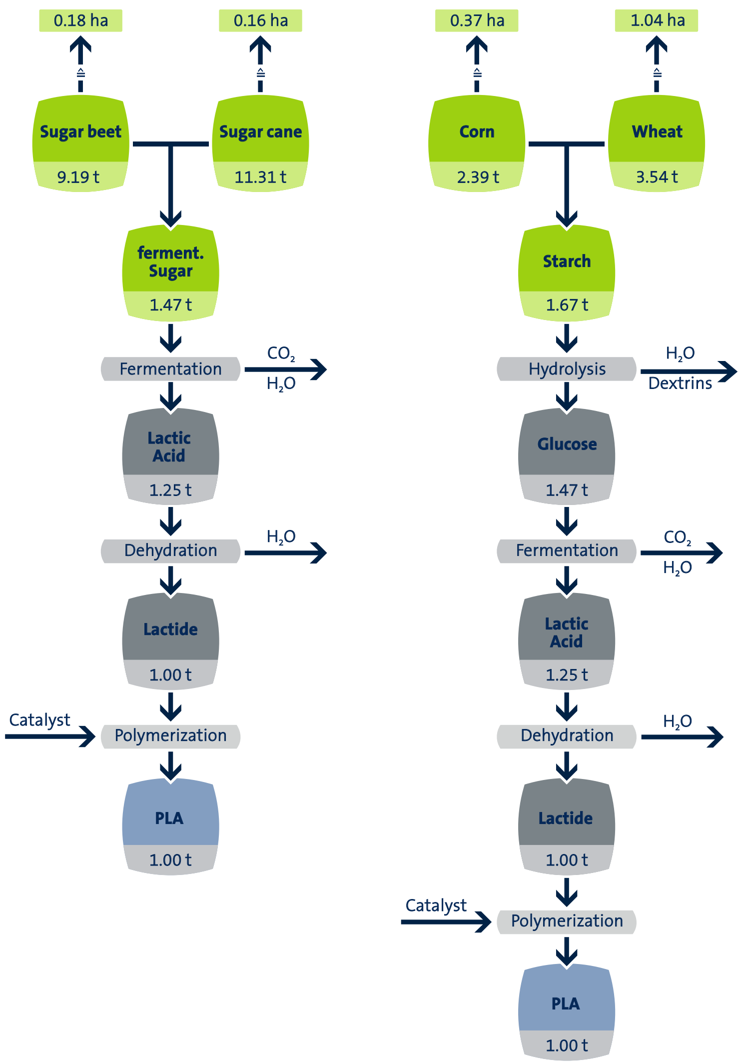
TMDA = *Tetramethylene Diamine*

HMDA = *Hexamethylene Diamine*

DMDA = *Decamethylene Diamine*

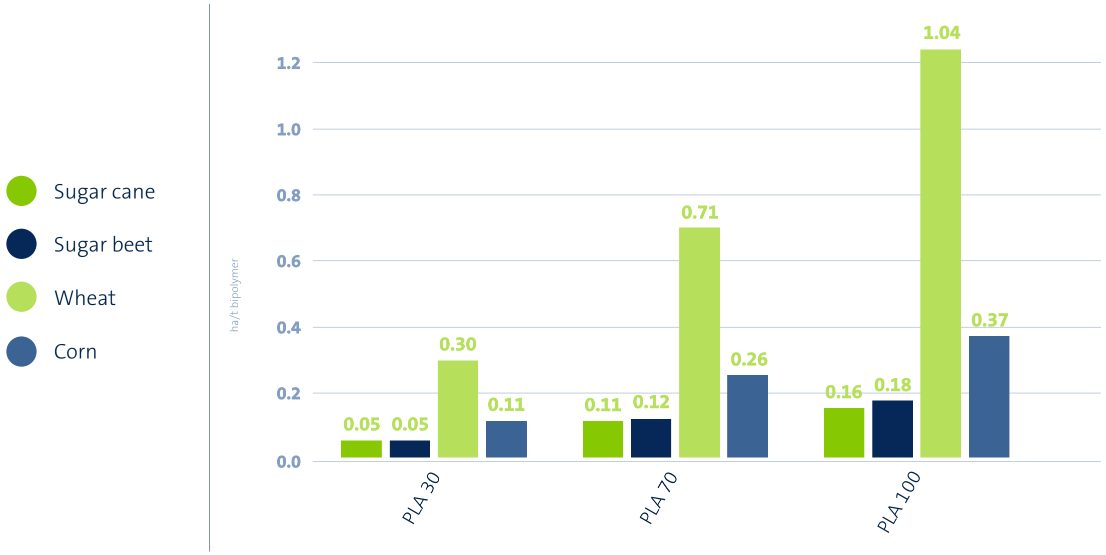
2.1 Bio-based polyesters

2.1.1 Polylactic Acid (PLA)

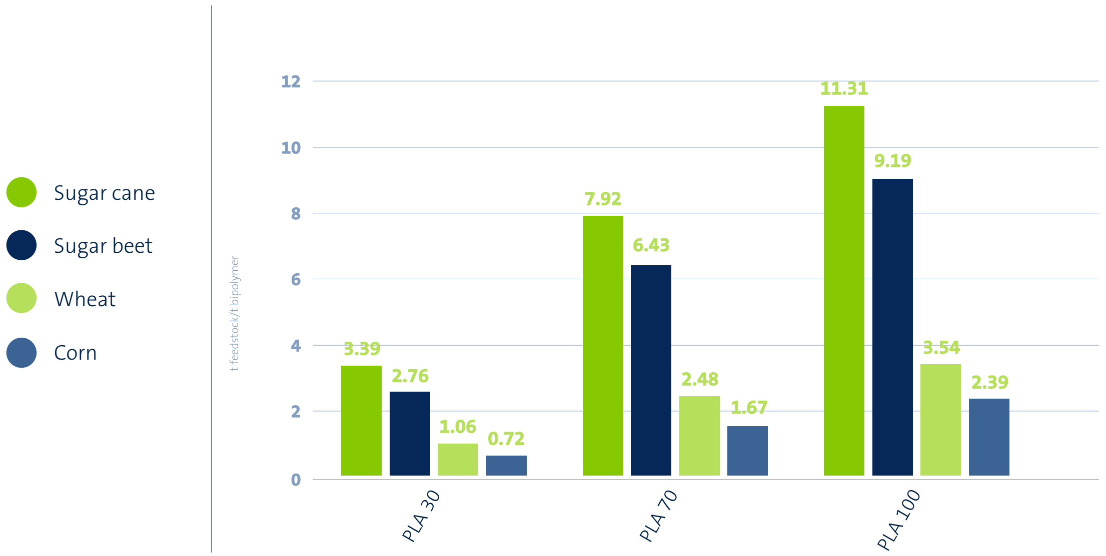


* **Conversion Rates:**
Sugar – Lactic Acid 85 %

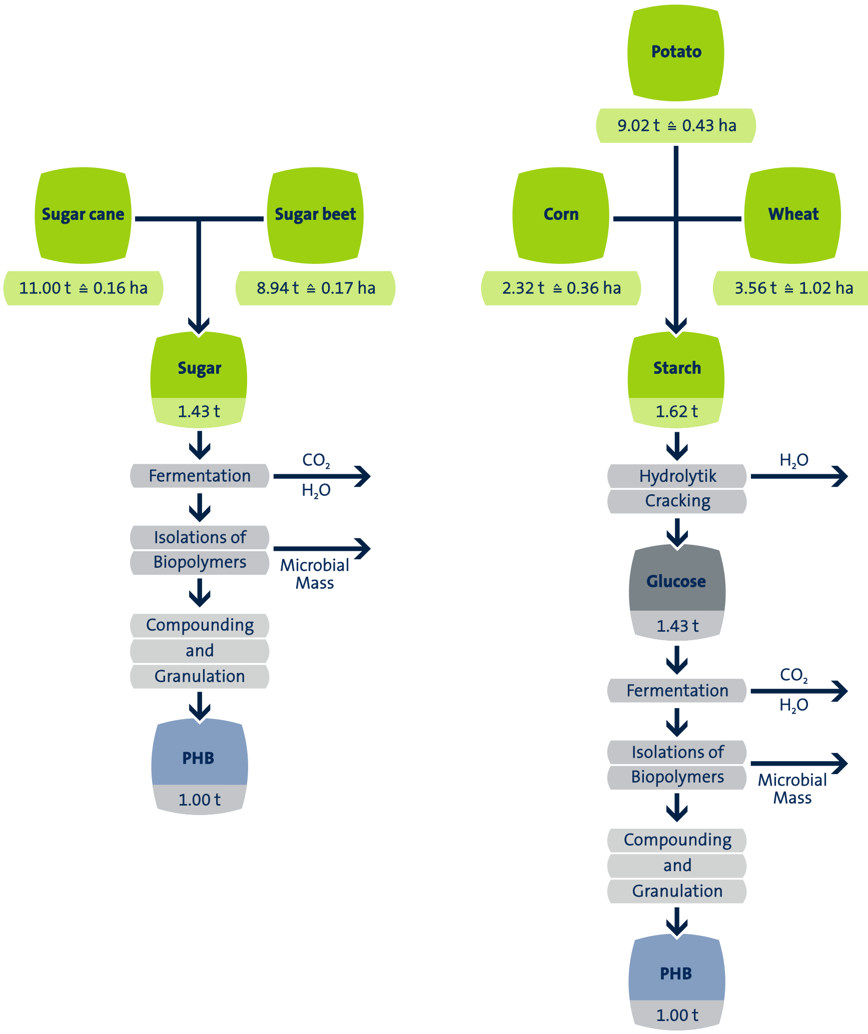
PLA and PLA blends – Land use in ha (different feedstocks)



PLA and PLA blends – Feedstock requirement (different feedstocks)

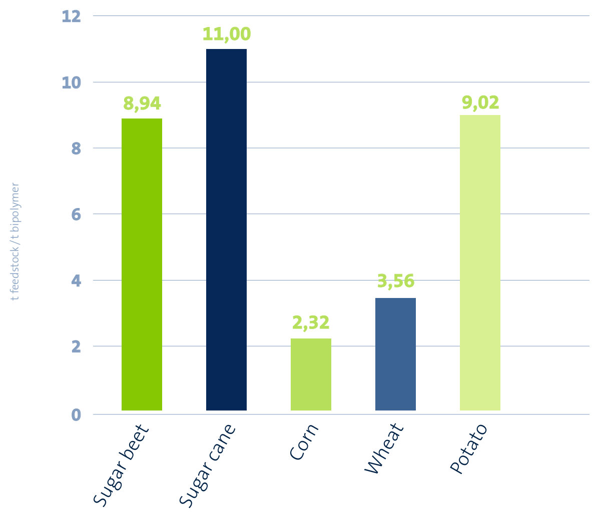


2.1.2 Polyhydroxybutyrat (PHB)

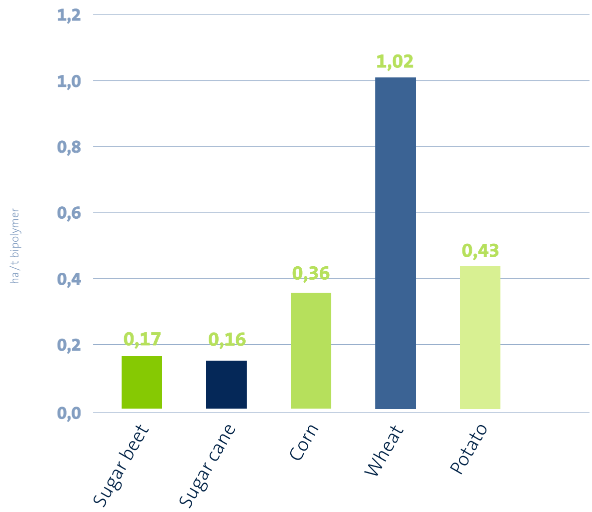


* **Conversion Rates:**
fermt. Sugar – PHB 70 %

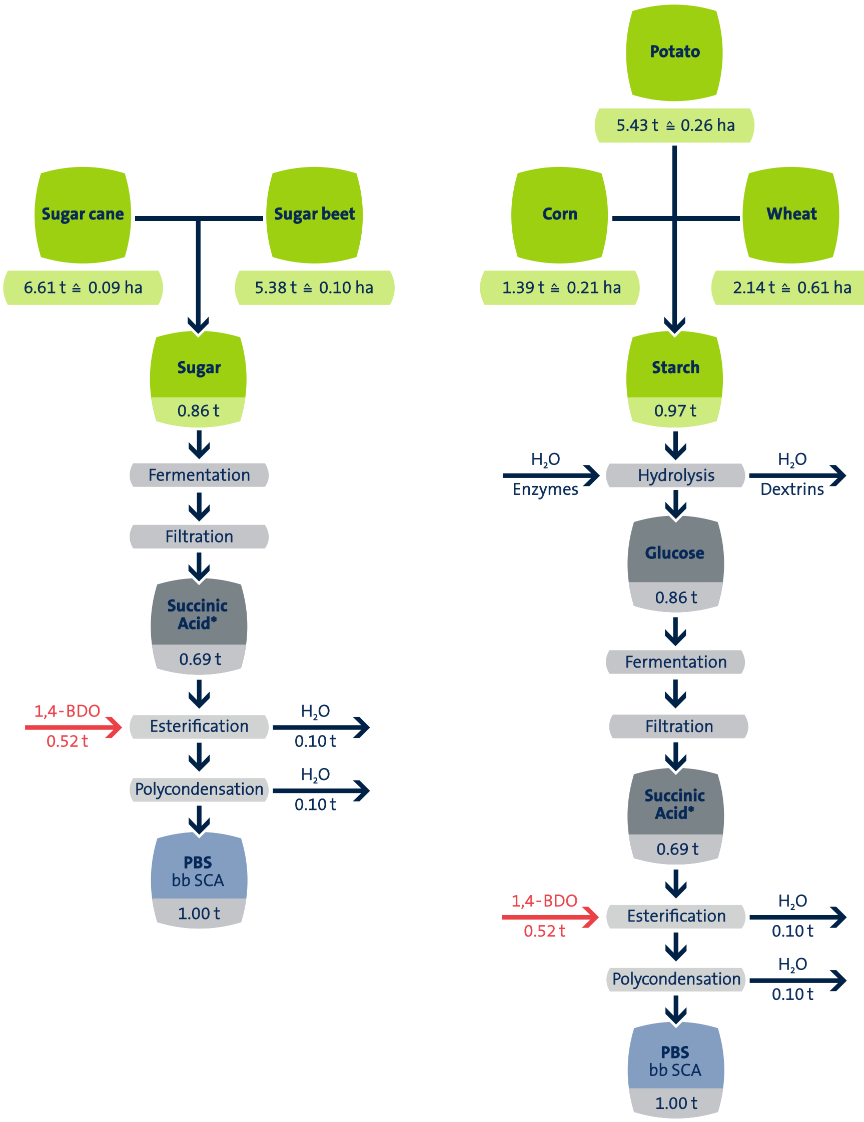
PHB – Feedstock requirements



PHB – Land use in ha (different feedstocks)

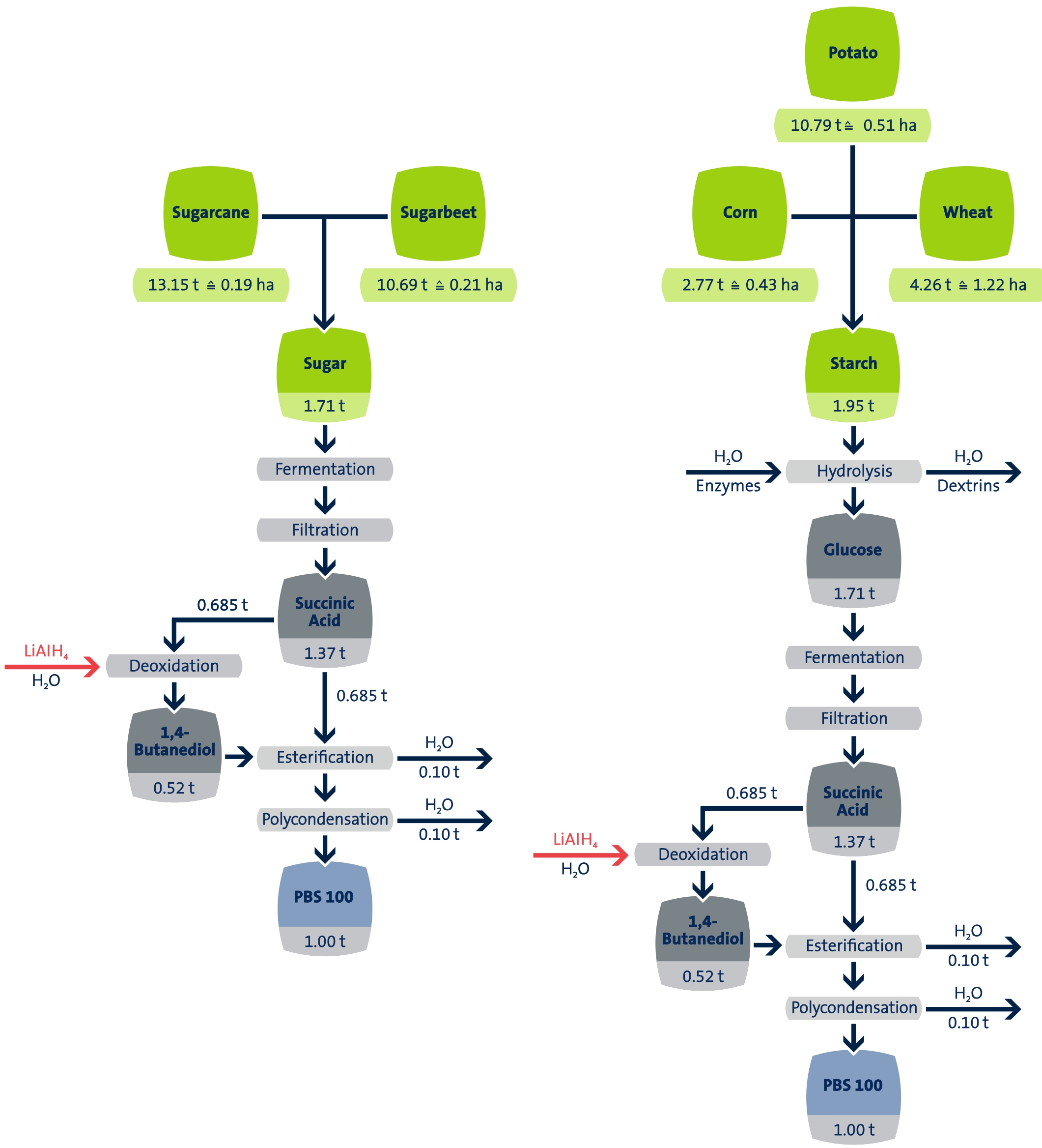


2.1.3 Polybutylensuccinate (PBS bb SCA)



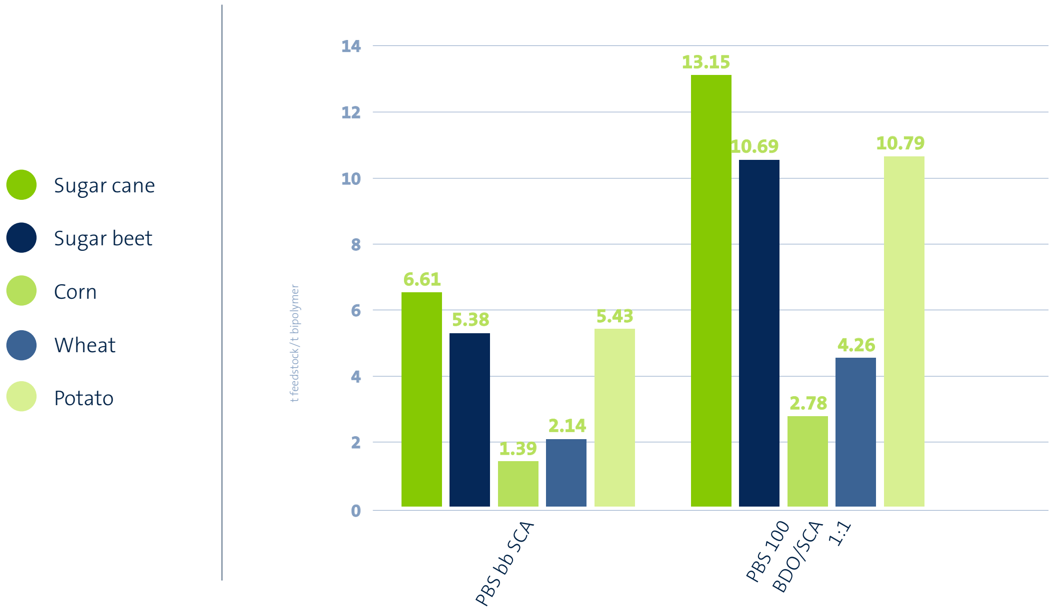
* **Conversion Rates:**
Starch – Glucose 90 %
fermt. Sugar – Succinic Acid 80 %

2.1.4 Polybutylensuccinate (PBS-100)

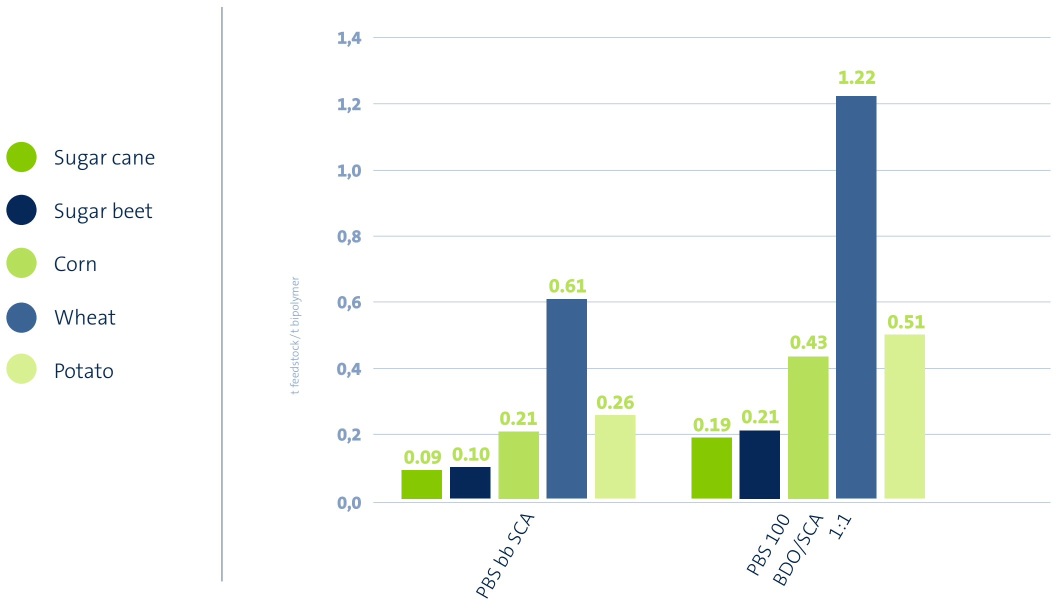


* **Conversion Rates:**
Starch – Glucose 90 %
fermt. Sugar – Succinic Acid 80 %

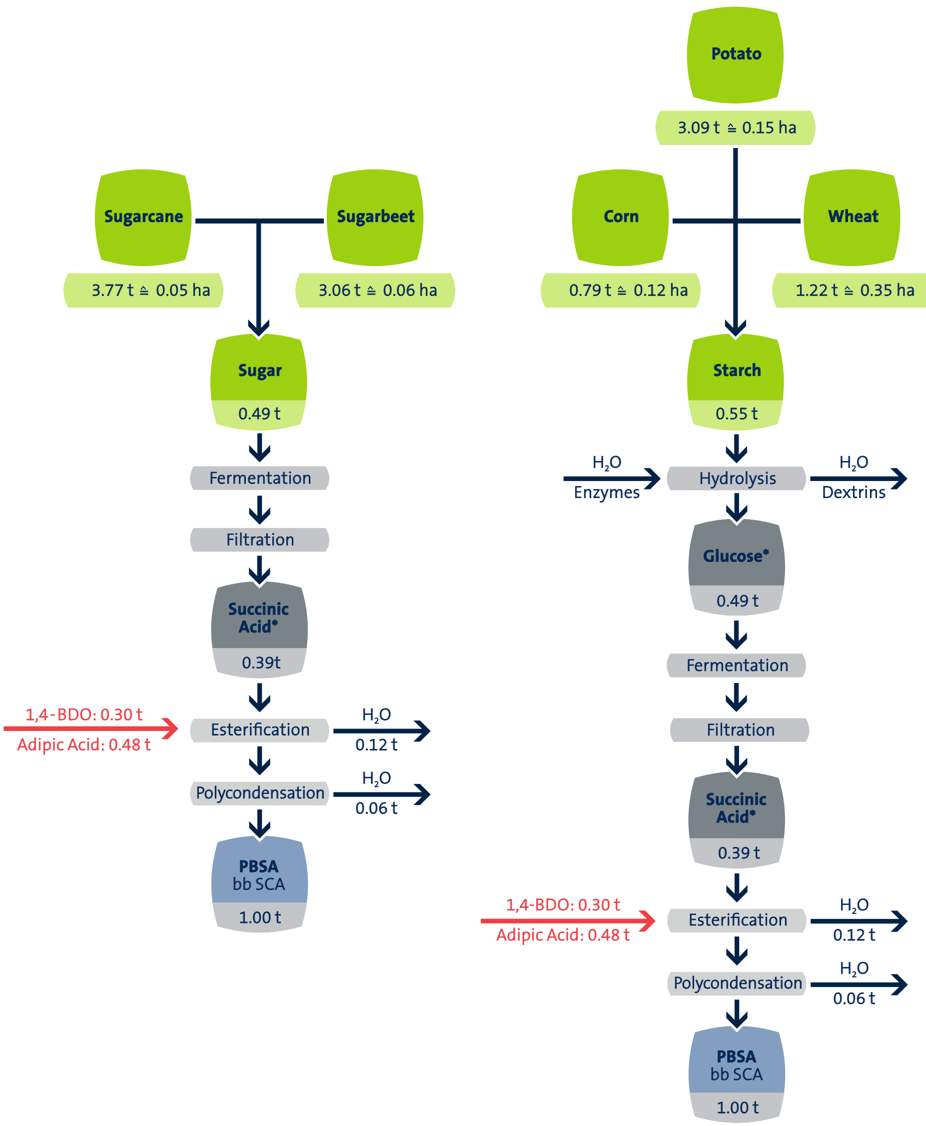
PBS variations – Feedstock requirements



PBS variations – Land use in ha (different feedstocks)

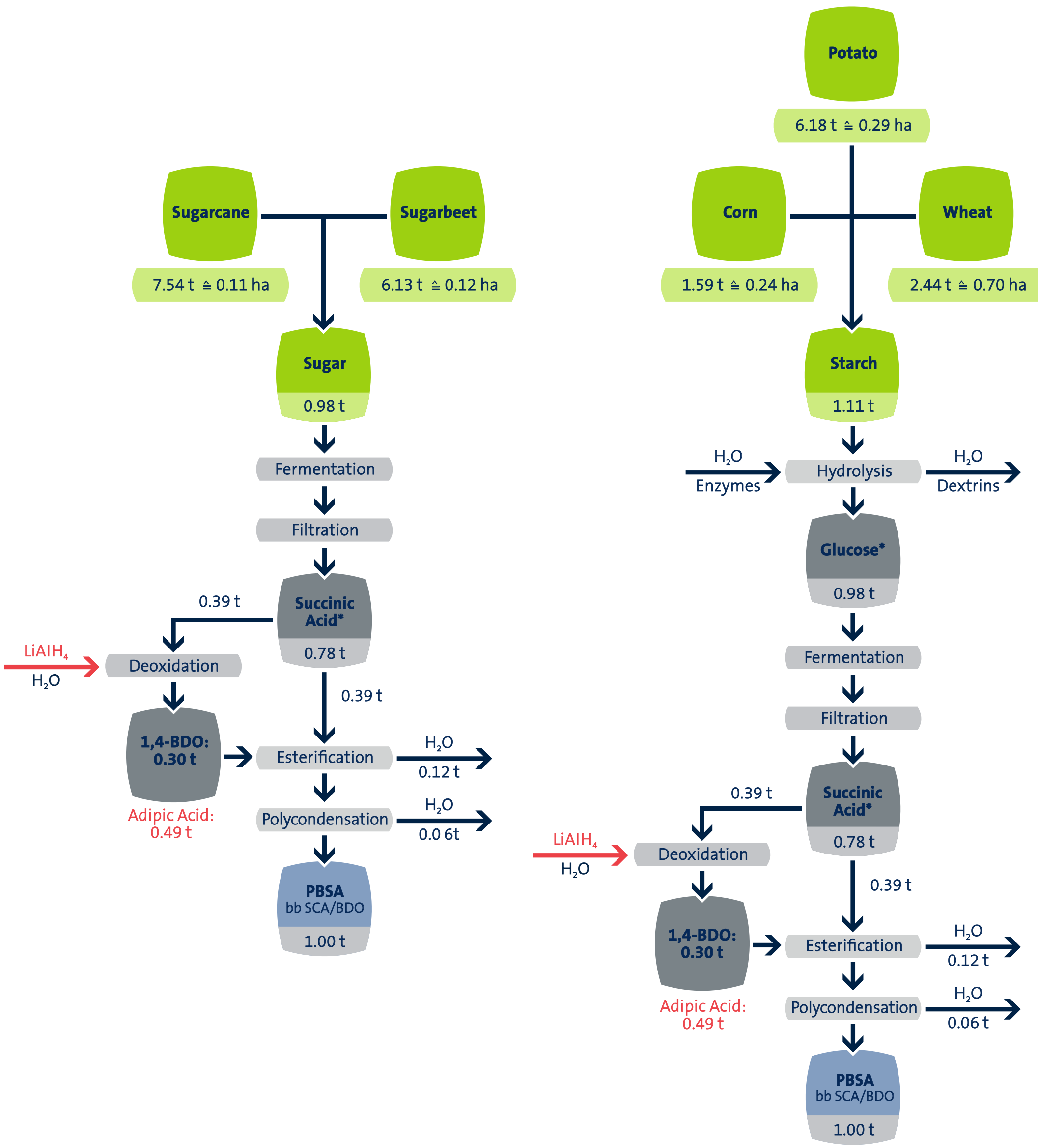


2.1.5 Polybutylensuccinate-adipate (PBSA-bb SCA)



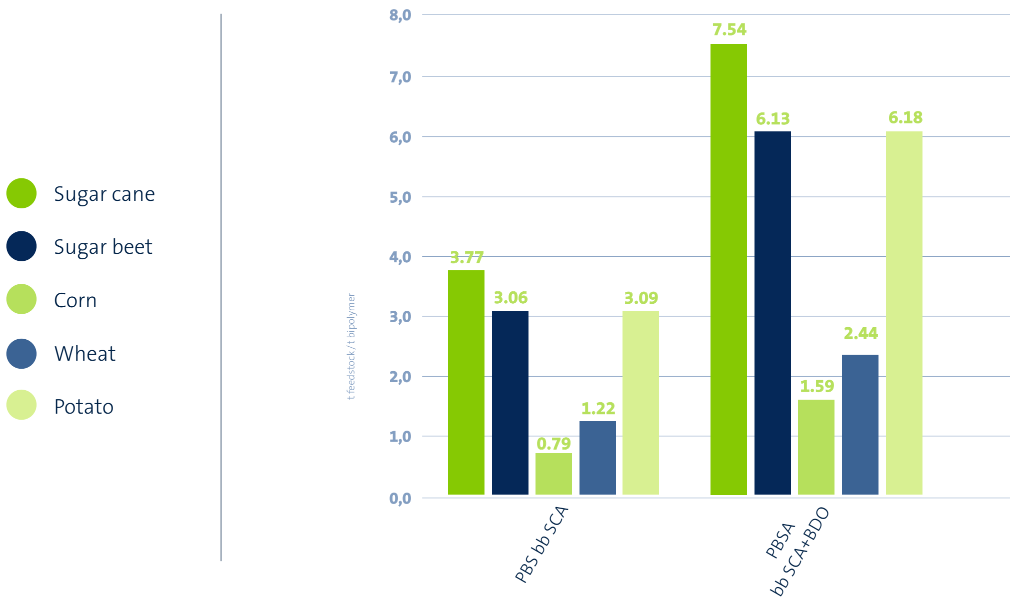
* **Conversion Rates:**
Starch – Glucose 90 %
fermt. Sugar – Succinic Acid 80 %

2.1.6 Polybutylensuccinate-adipate (PBSA - bb SCA and BDO)

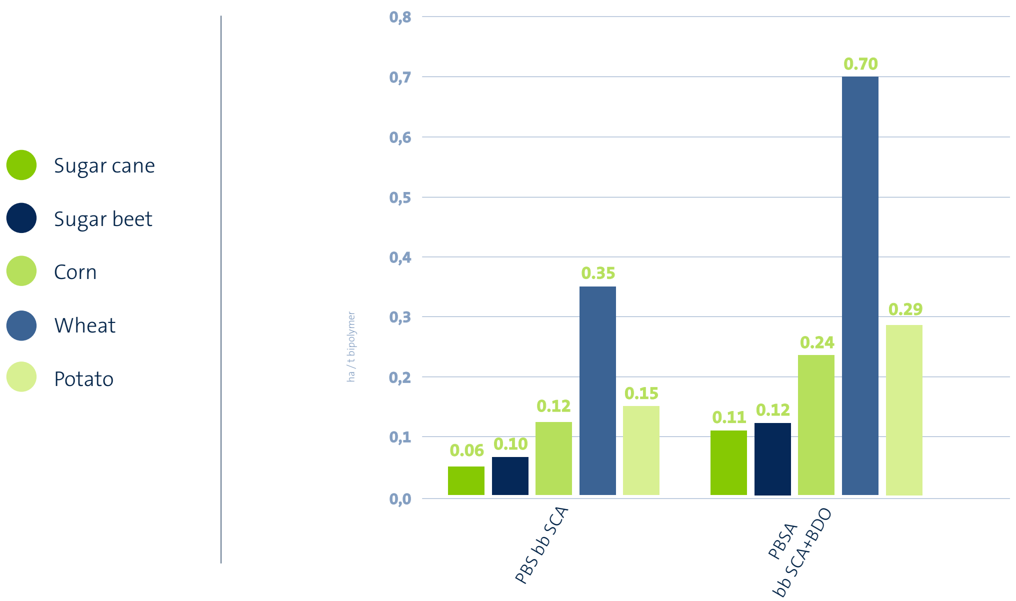


* **Conversion Rates:**
Starch – Glucose 90 %
fermt. Sugar – Succinic Acid 80 %

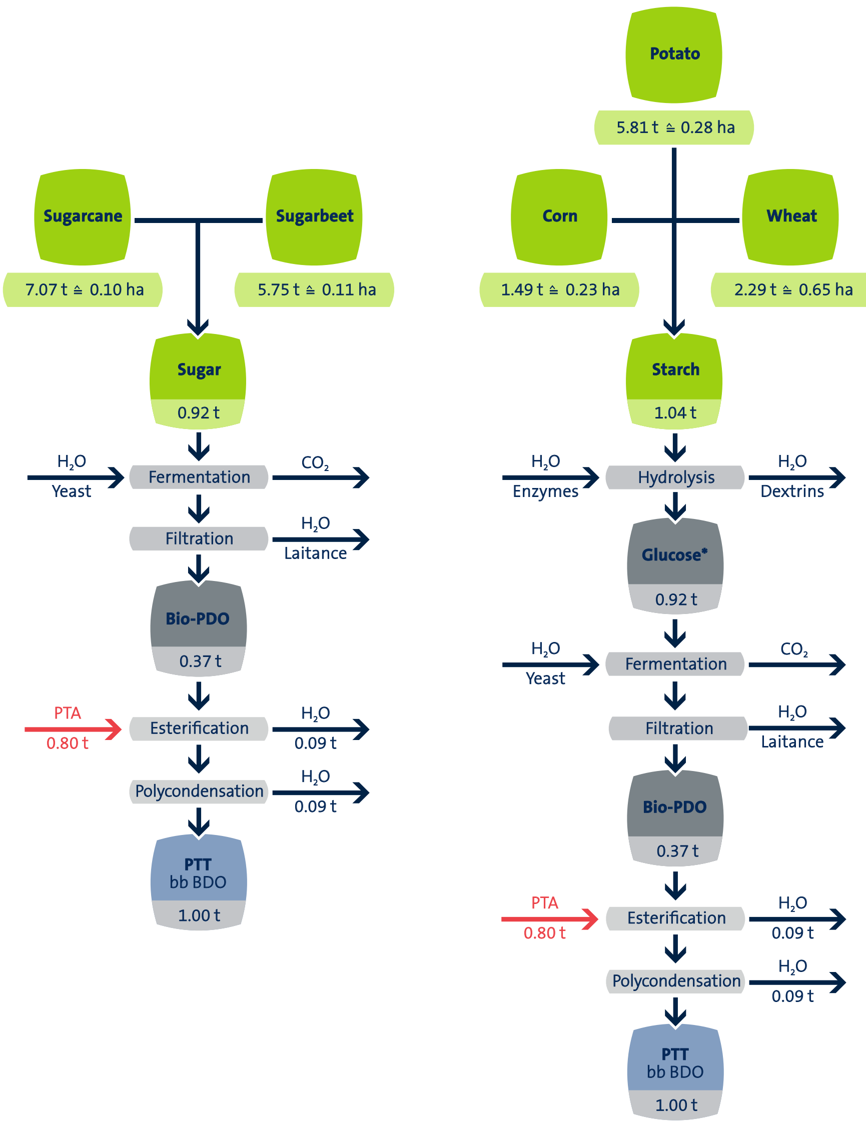
PBSA variations – Feedstock requirements (different feedstocks)



PBSA variations – Land use in ha (different feedstocks)

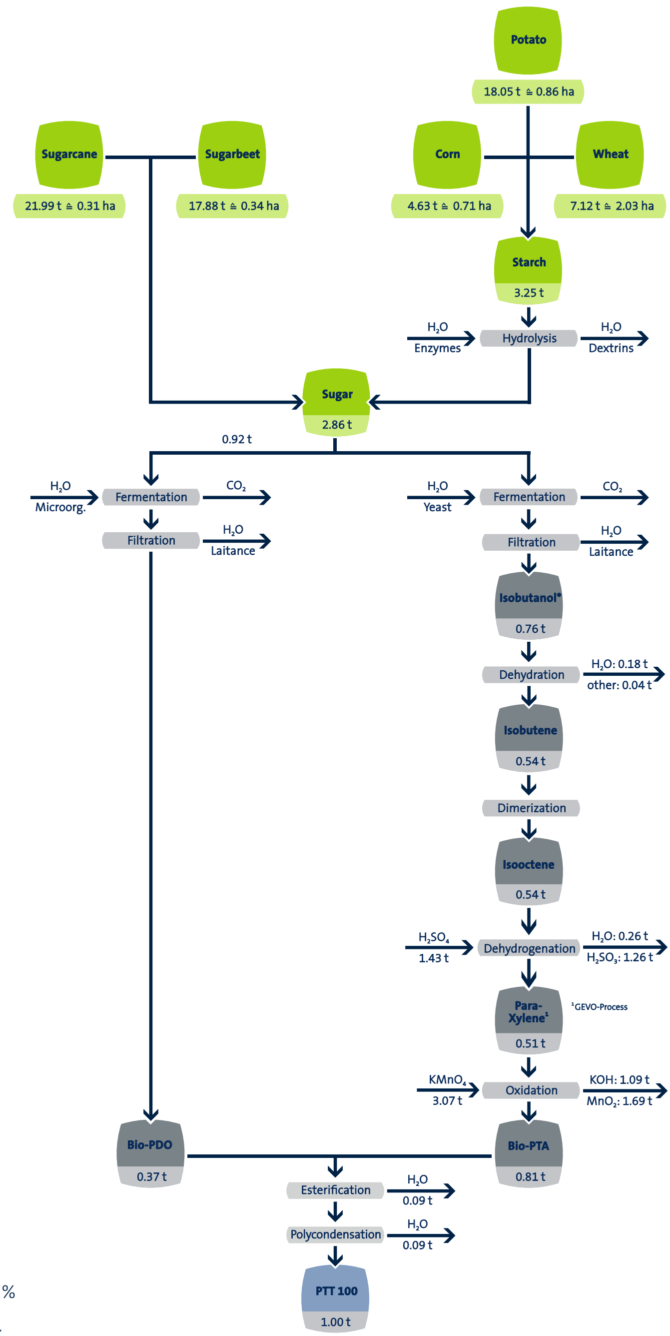


2.1.7 Polytrimethyleneterephthalate (PTT bb BDO)



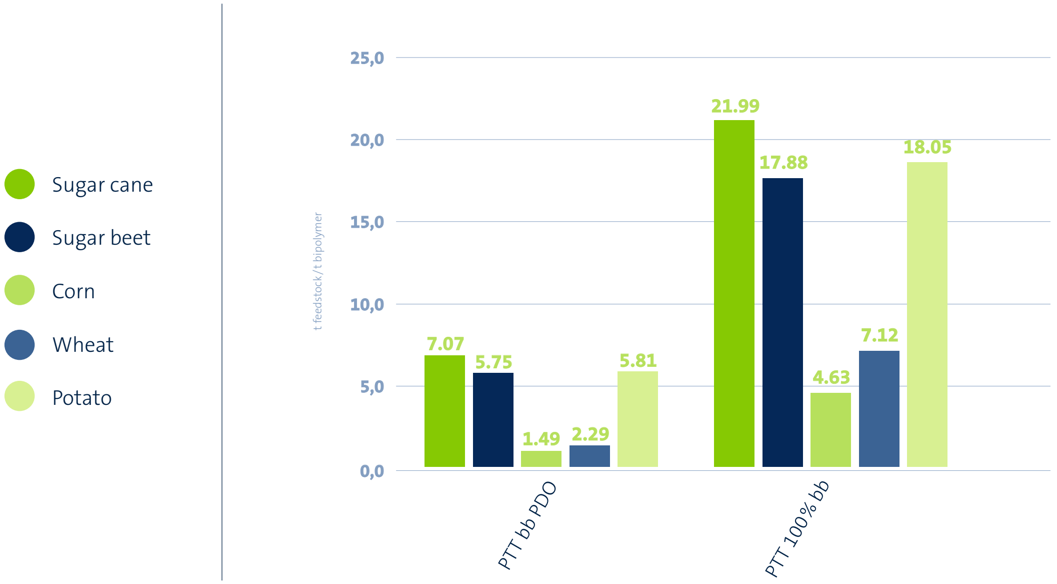
* **Conversion Rates:**
Starch – Glucose 90 %
fermt. Sugar – PDO 40 %

2.1.8 Polytrimethyleneterephthalate (PTT-100)

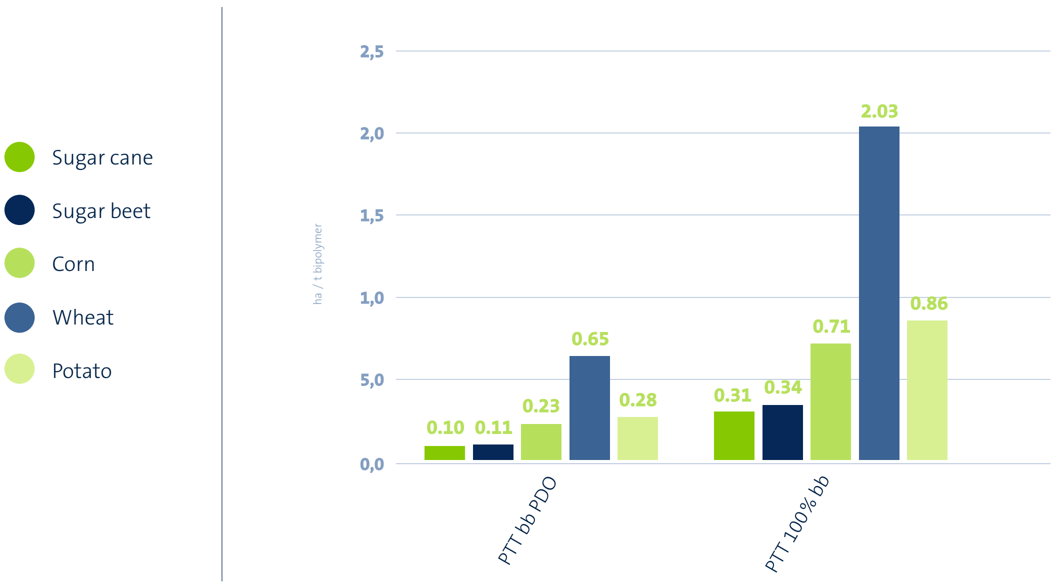


* **Conversion Rates:**
Starch – Glucose 90 %
Sugar – PDO 40 %
Glucose – Isobutanol 39 %
Ethanol – Ethen 48 %
Ethen – Ethenoxide 85 %

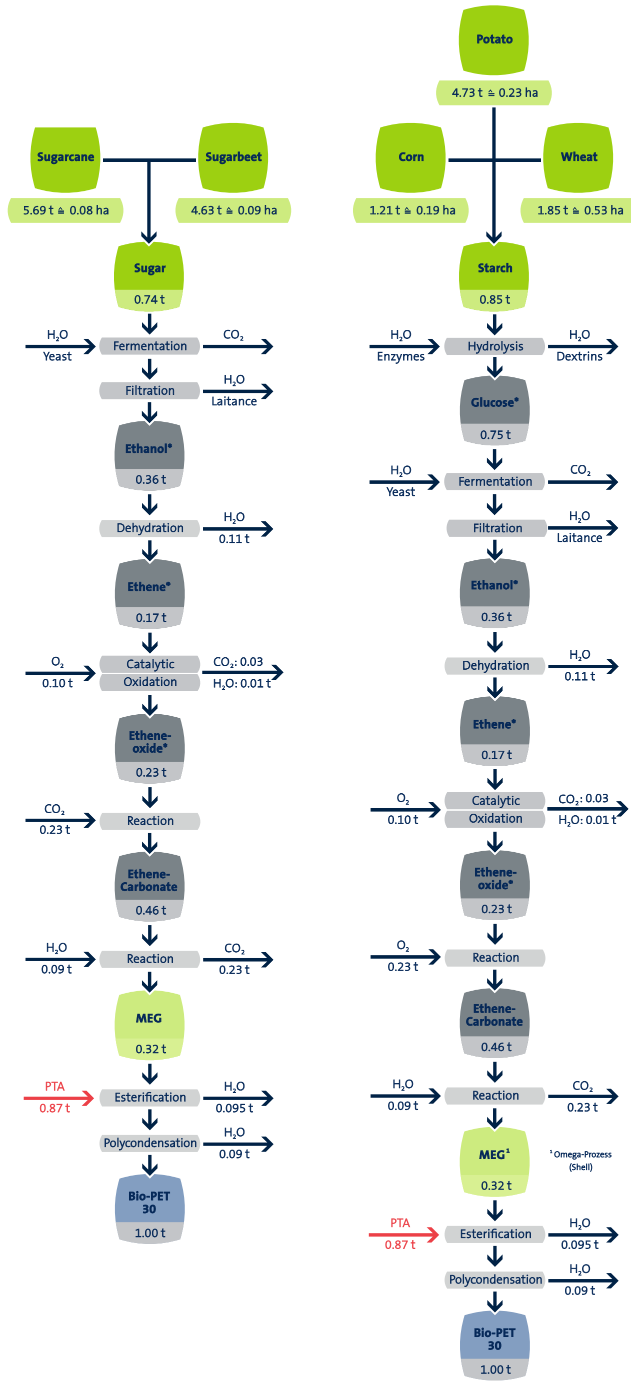
PTT variations – Feedstock requirements



PTT variations – Land use in ha (different feedstocks)

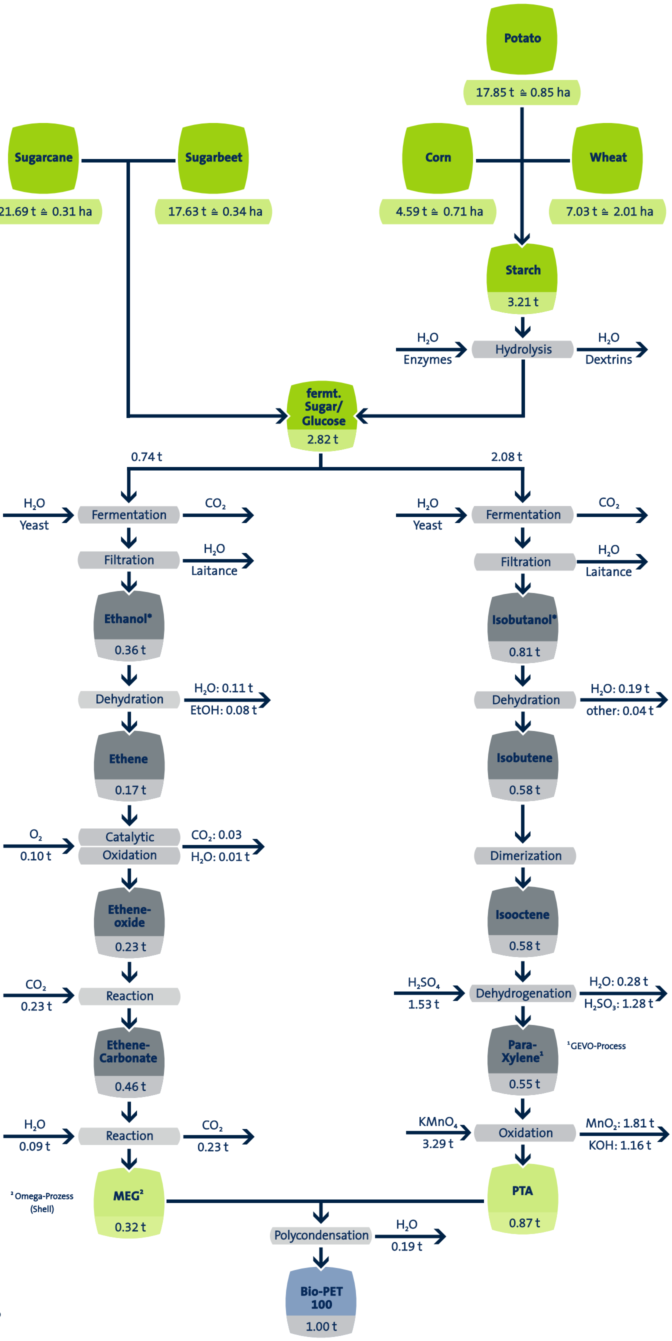


2.1.9 Polyethyleneterephthalate (PET-30)



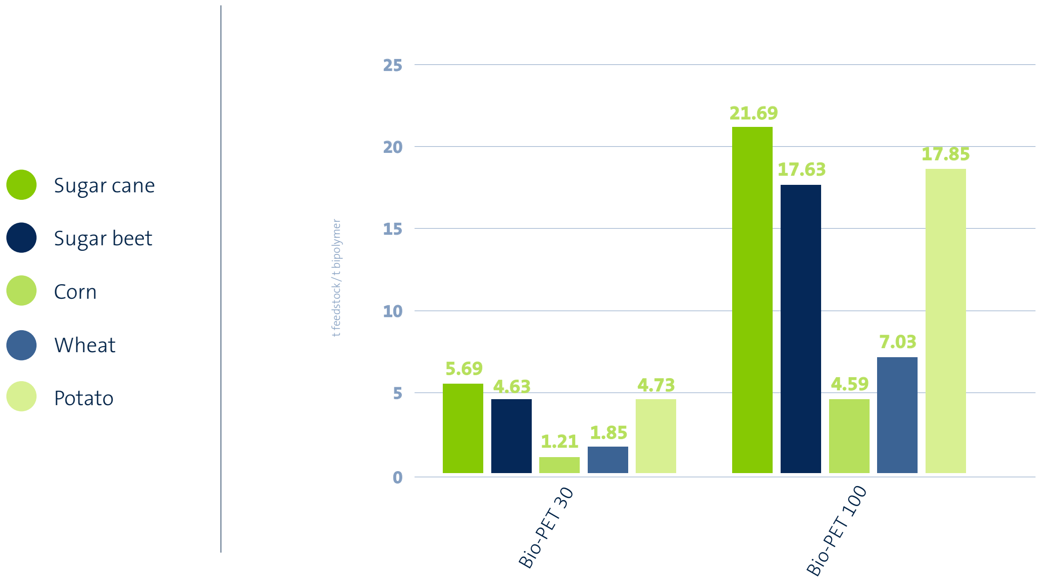
* **Conversion Rates:**
Starch – Glucose 90 %
Glucose – Ethanol 48 %
Ethanol – Ethen 48 %
Ethen – Ethenoxide 85 %

2.1.10 Bio-PET 100

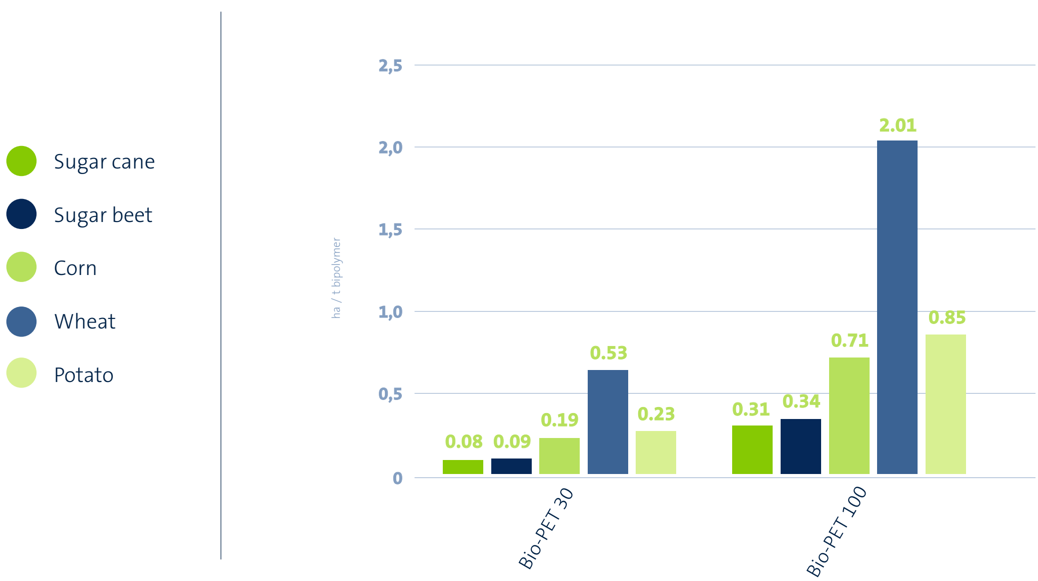


*** Conversion Rates:**
Starch – Glucose 90 %
Glucose – Ethanol 48 %
Glucose – Isobutanol 39 %
Ethanol – Ethen 48 %
Ethen – Ethenoxide 85 %

Bio-PET variations – Feedstock requirements (different feedstocks)

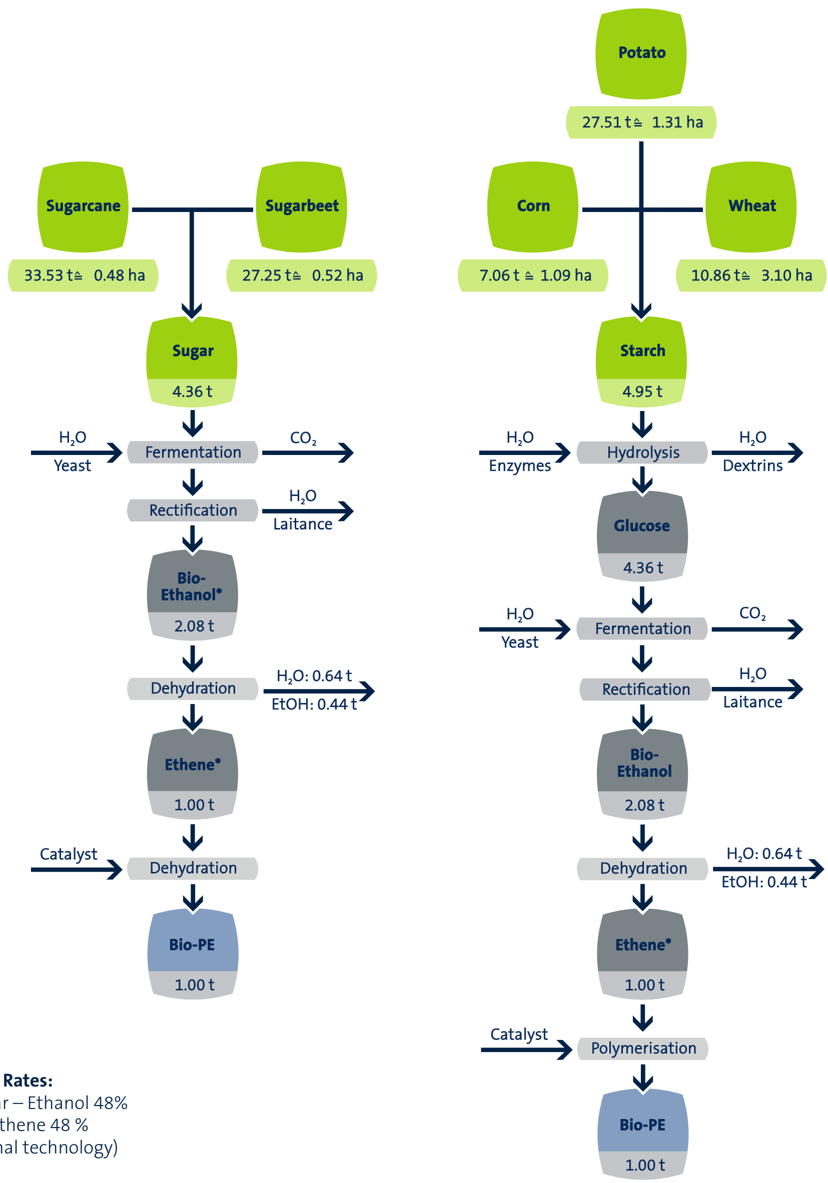


Bio-PET variations – Land use in ha (different feedstocks)



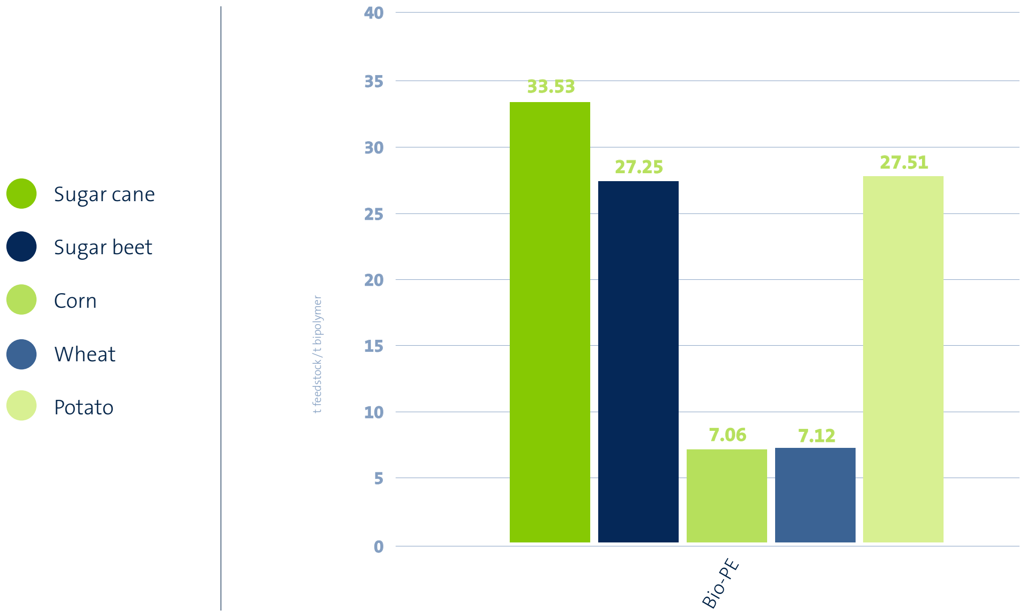
2.2 Bio-based polyolefins

2.2.1 Polyethylene (Bio-PE)

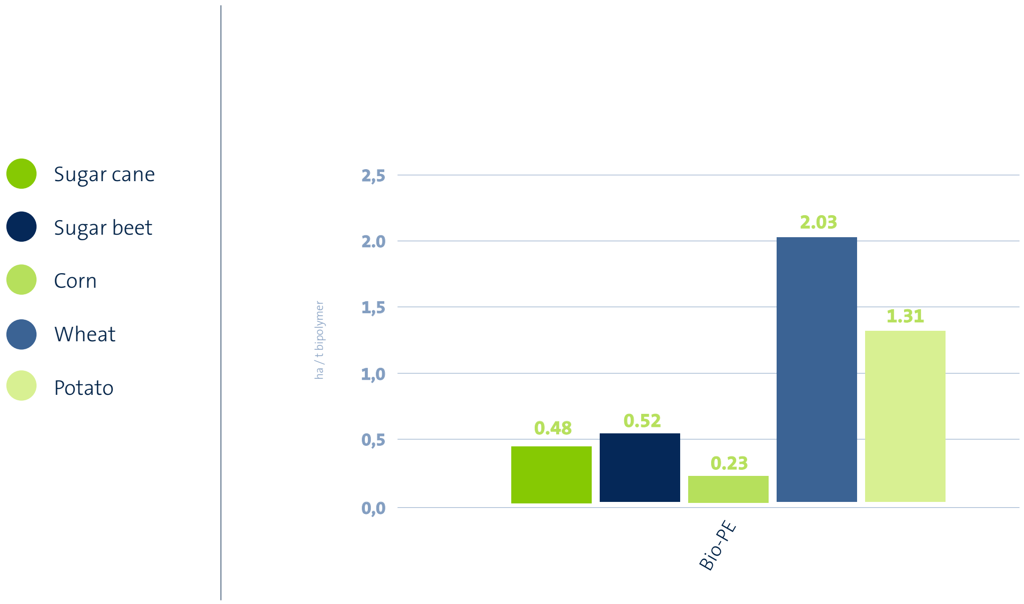


* **Conversion Rates:**
fermt. Sugar – Ethanol 48%
Ethanol – Ethene 48 %
(conventional technology)

Bio-PE – Feedstock requirements (different feedstocks)

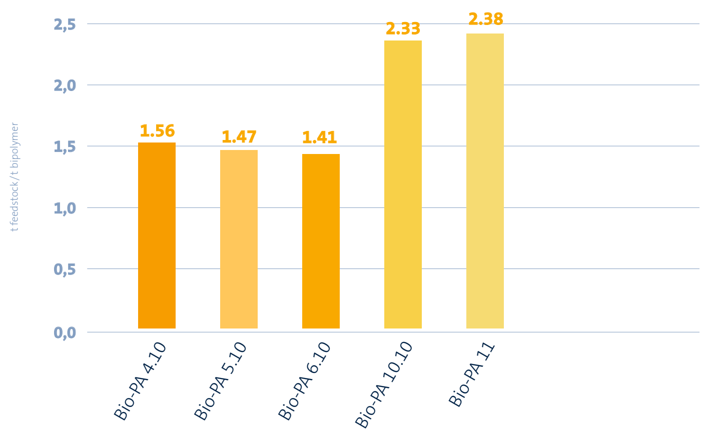


Bio-PE – Land use in ha (different feedstocks)

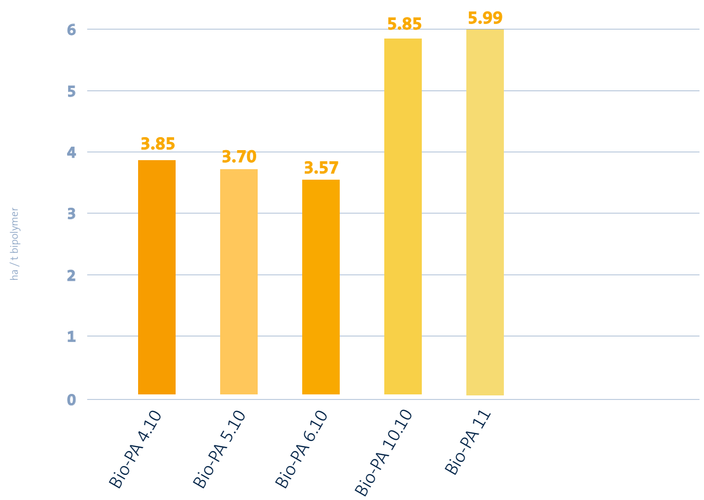


2.3 Bio-based polyamides (Bio-PA)

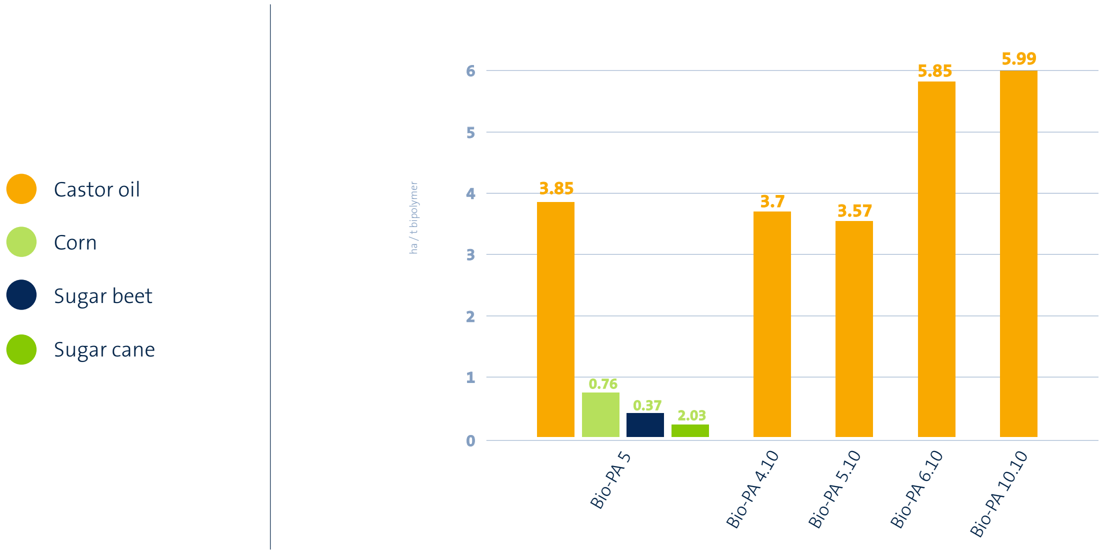
Bio-PA – Feedstock requirements (castor oil)



Bio-PA – Land use in ha (feedstock castor oil)

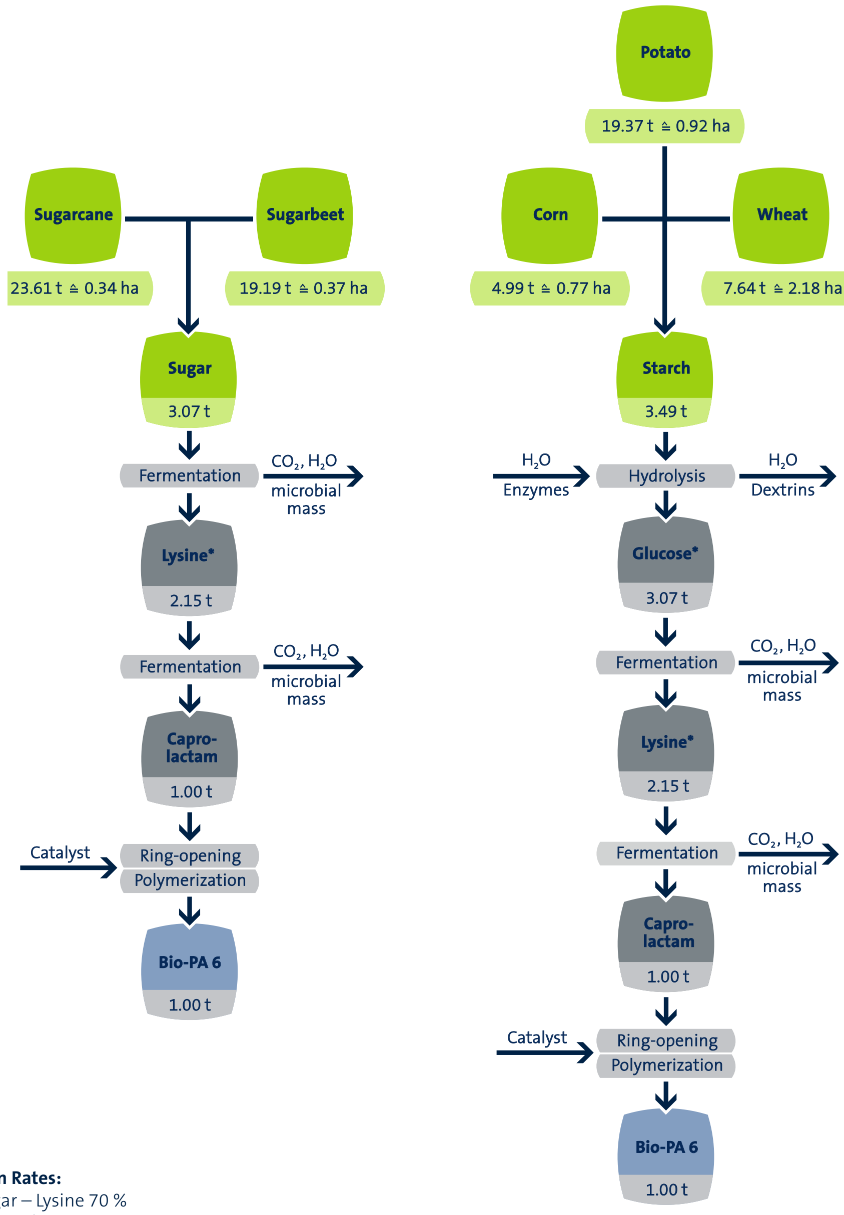


Bio-PA – Land use in ha (different feedstocks)



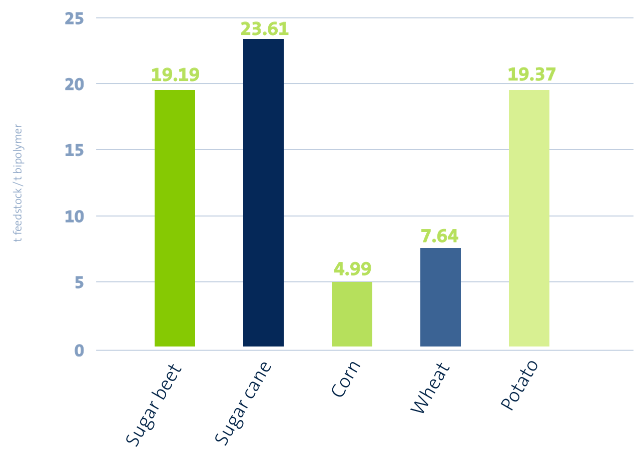
2.3.1 Homopolyamides

2.3.1.1 Bio-PA 6

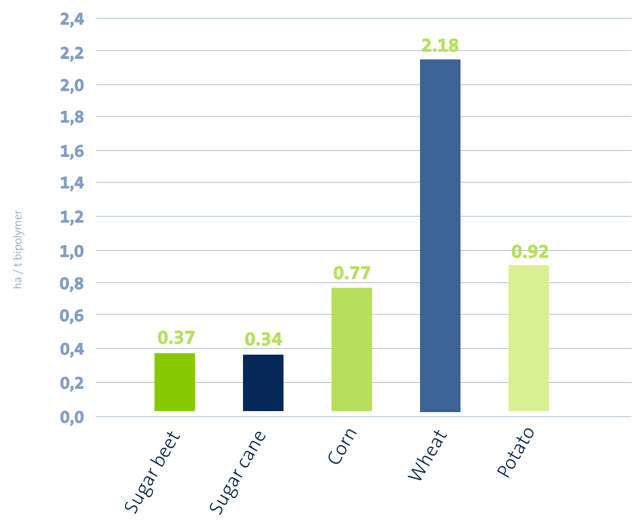


* **Conversion Rates:**
fermt. Sugar – Lysine 70 %
Lysine – Caprolactam 47 %

Bio-PA 6 – Feedstock requirements (different feedstocks)

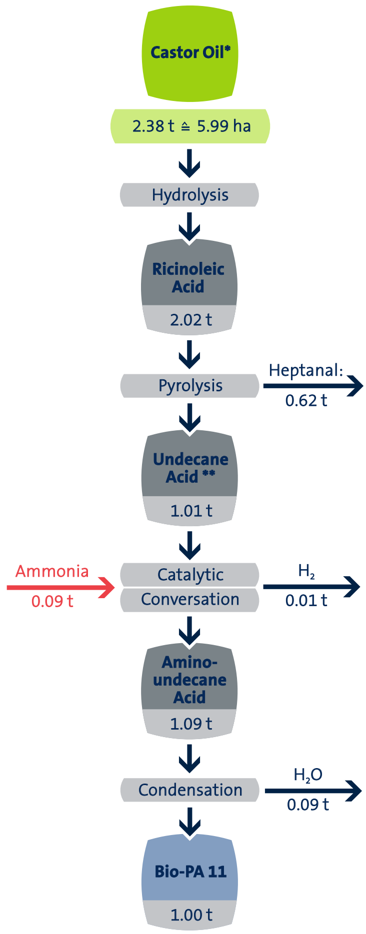


Bio-PA 6 – Land use in ha (different feedstocks)



2.3.1 Homopolyamides

2.3.1.2 Bio-PA 11

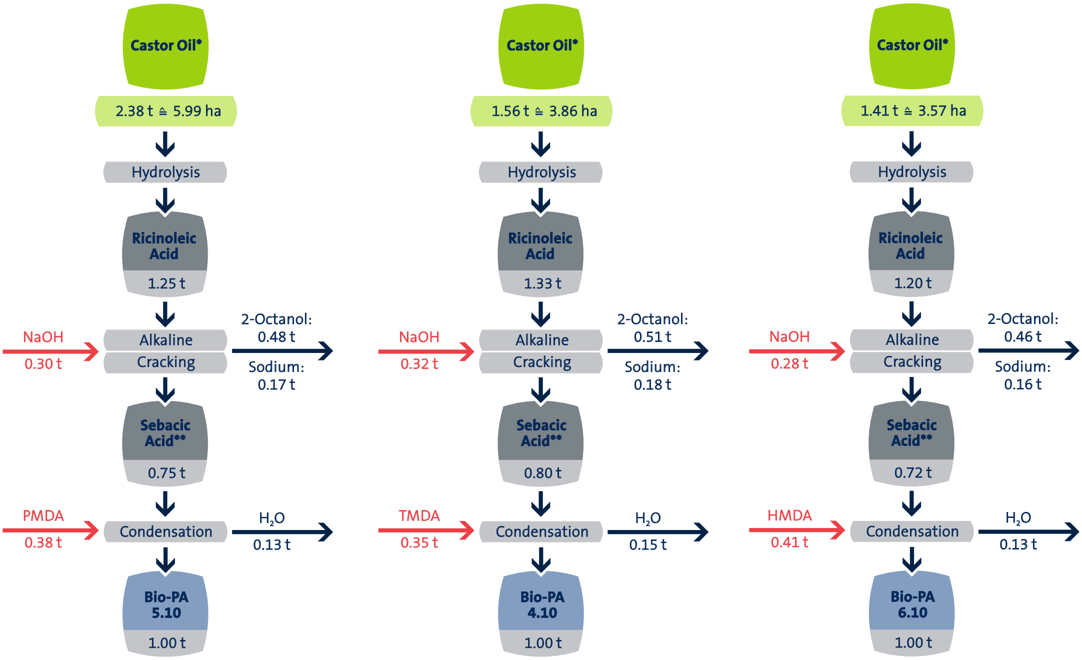


* one harvest per year

** **Conversion Rates:**
Ricinoleic Acid – Undecane Acid 50 %

2.3.2 Copolyamides

2.3.2.1 Bio-PA 4.10 – Bio-PA 5.10 – Bio-PA 6.10

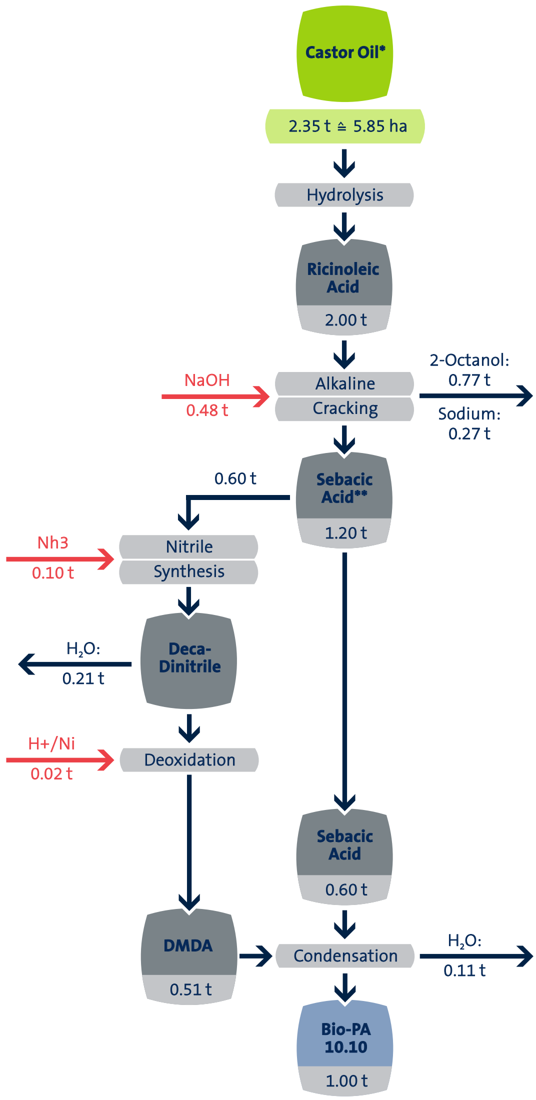


* one harvest per year

**** Conversion Rates:**
Ricinoleic Acid – Undecane Acid 50 %

2.3.2 Copolyamides

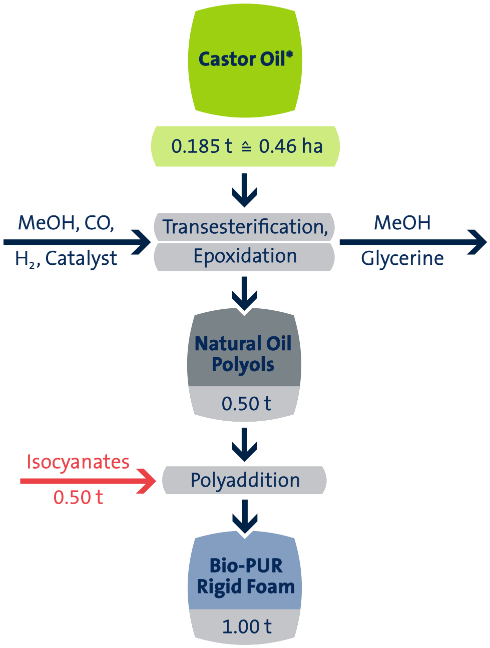
2.3.2.2 Bio-PA 10.10

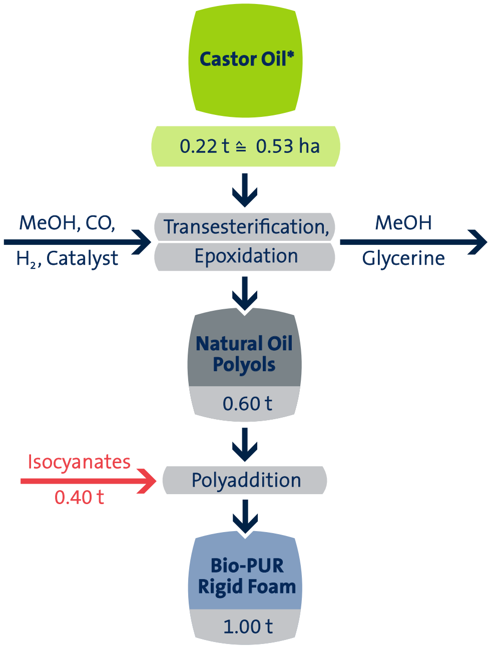


* one harvest per year

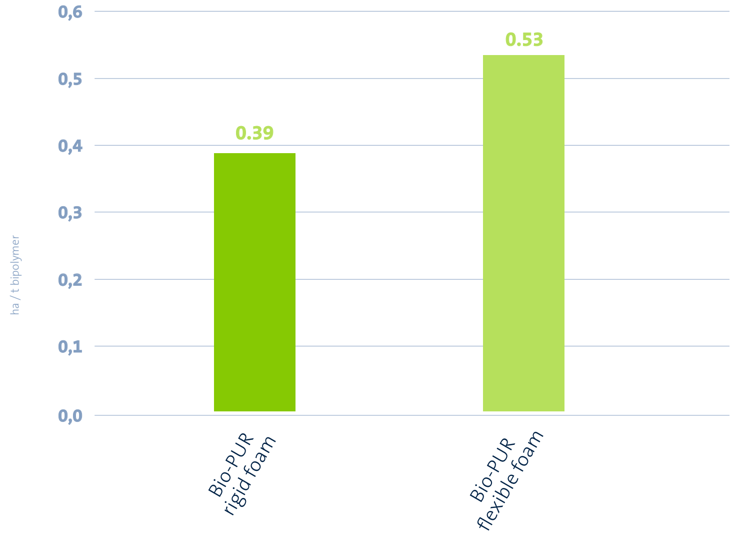
**** Conversion Rates:**
Ricinoleic Acid – Sebacic Acid 70 %

2.4 Polyurethanes

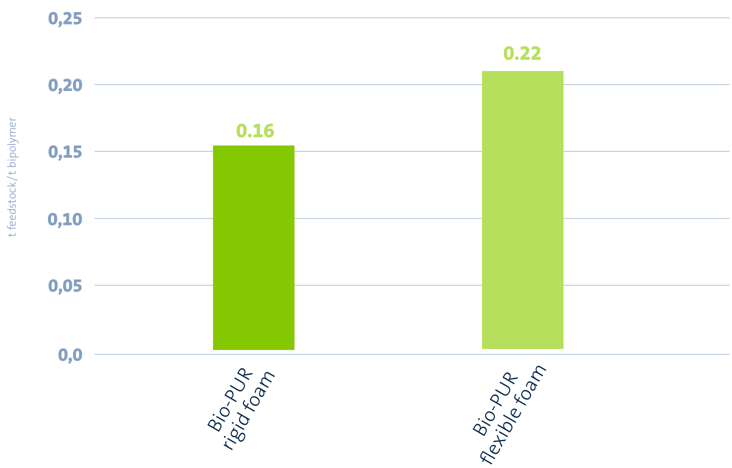




Bio-PUR – Land use in ha (feedstock castor oil)



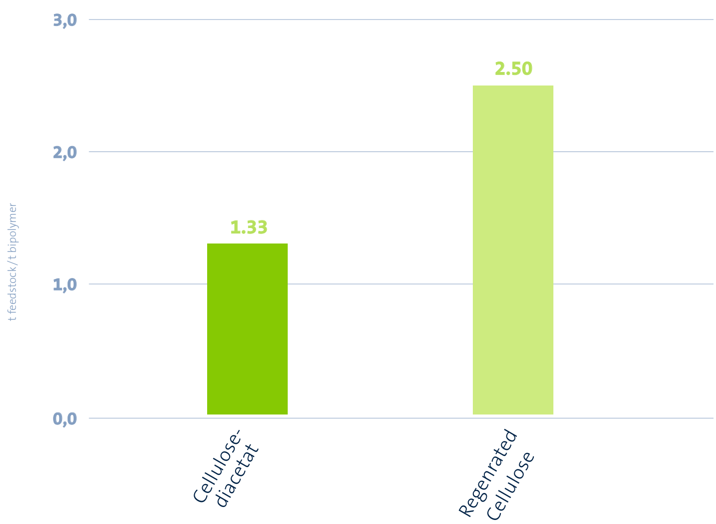
Bio-PUR – Feedstock requirements (castor oil)



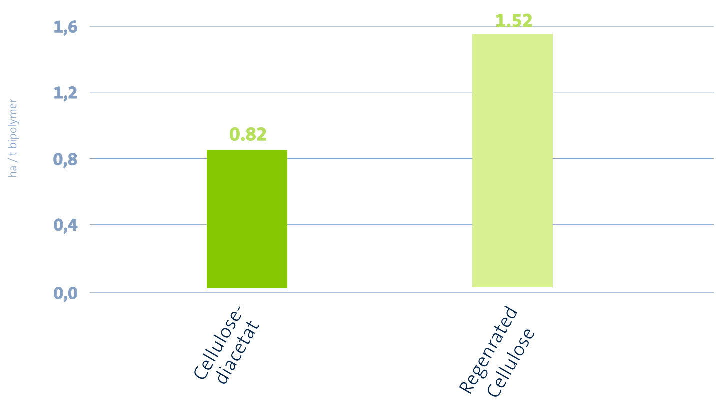
2.5 Polysaccharid polymers

2.5.1 Cellulose-based polymers

Feedstock requirements (feedstock wood)

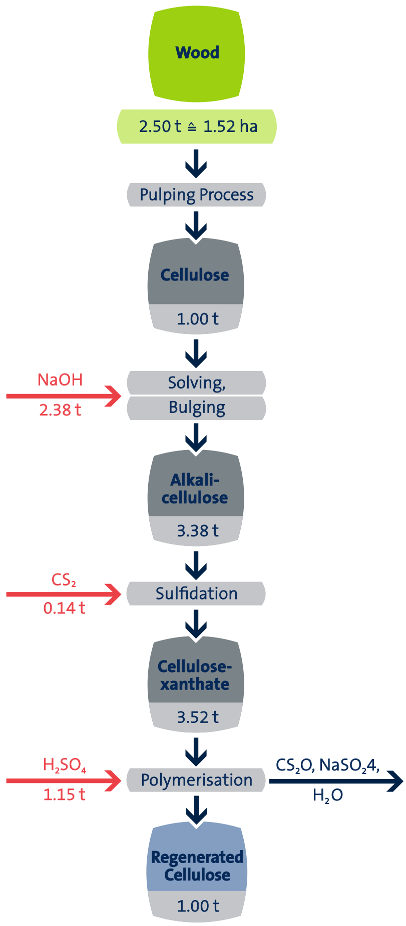


Land use in ha (feedstock wood)



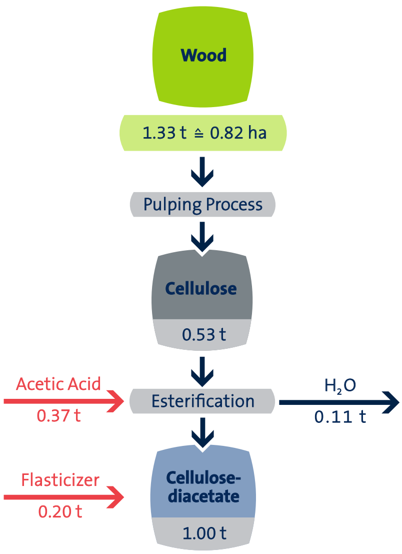
2.5.1 Cellulose-based polymers

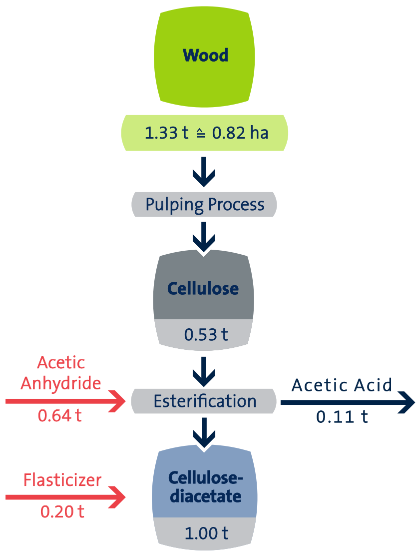
2.5.1.1 Regenerated cellulose



2.5.1 Cellulose-based polymers

2.5.1.2 Cellulose ester



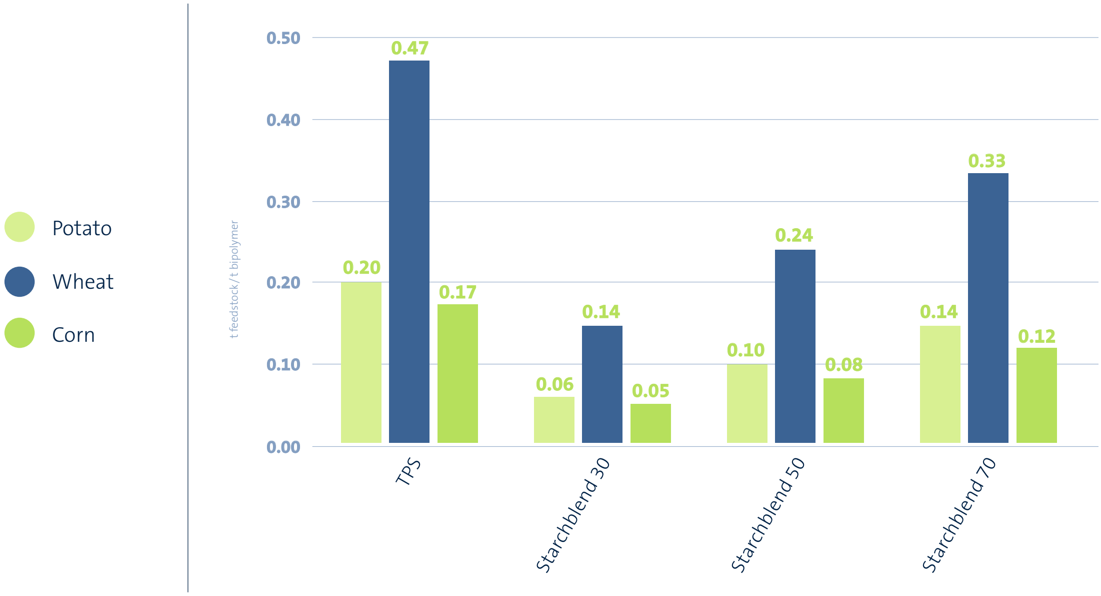


* one harvest per year

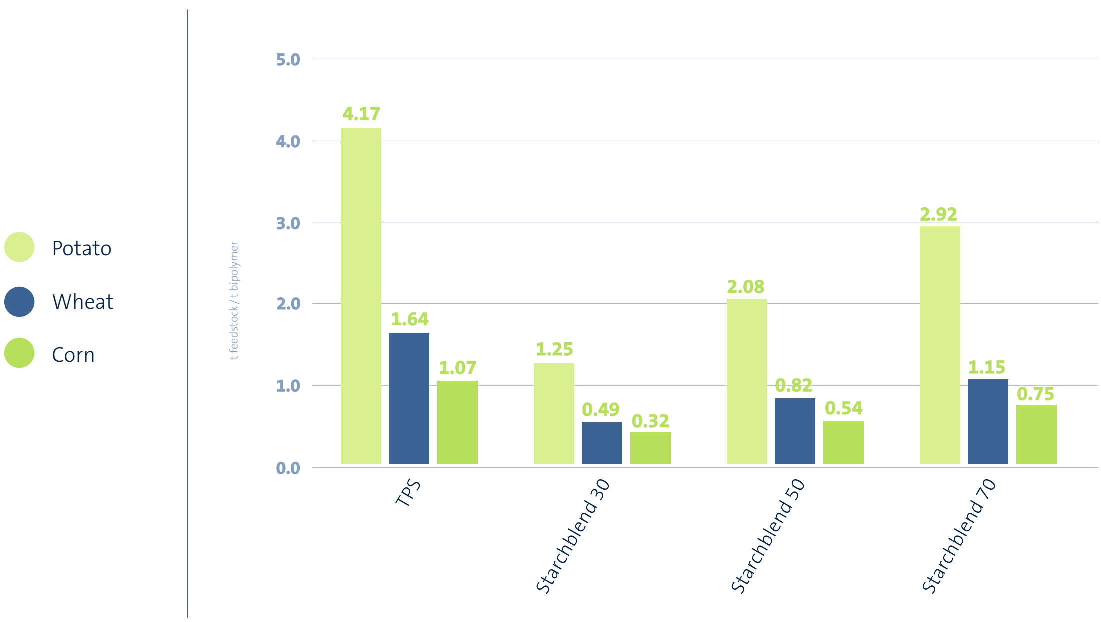
** **Conversion Rates:**
Ricinoleic Acid – Undecane Acid 50 %

2.5.2 Starch-based polymers

Starchpolymers – Land use in ha (different feedstocks)

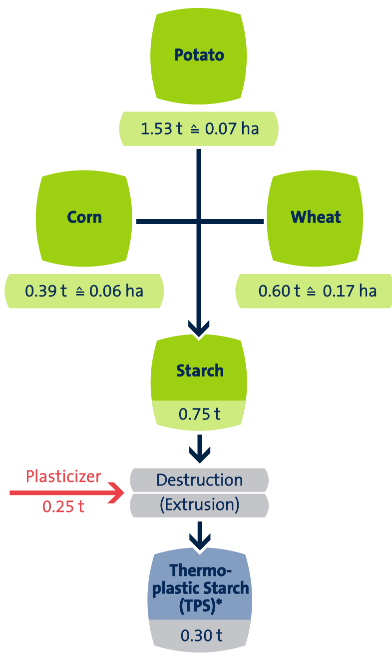


Starchpolymers – Feedstock requirements



2.5.2 Starch-based polymers

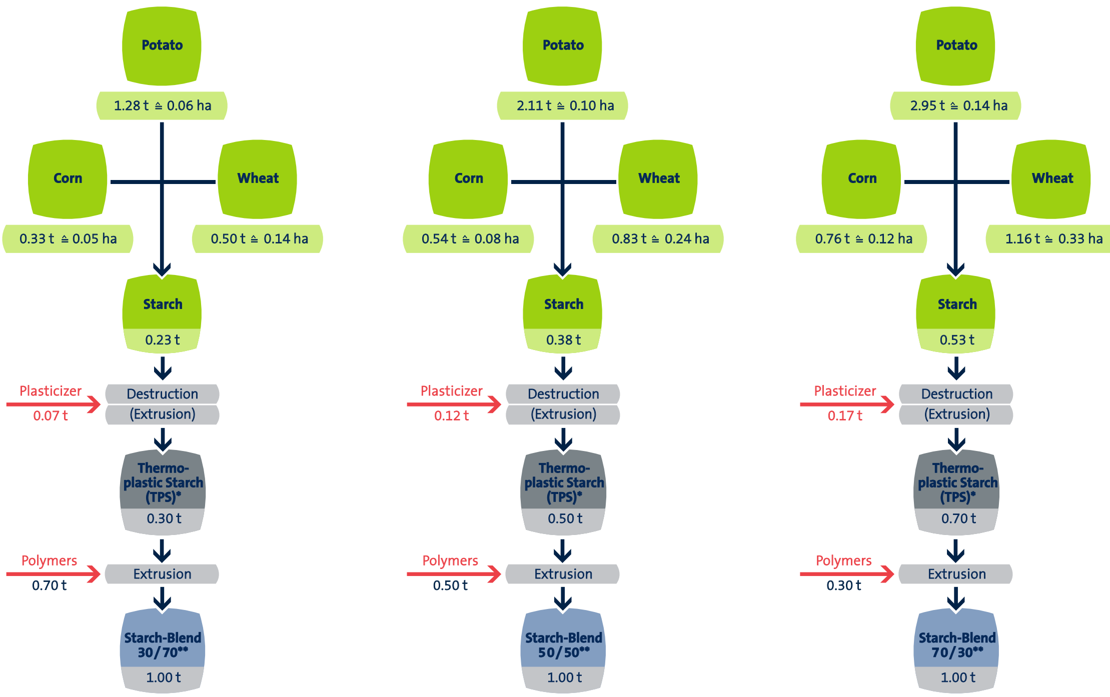
2.5.2.1 Thermoplastic starch (TPS)



* Starch content 70 %

2.5.2 Starch-based polymers

2.5.2.2 Starch blends



* Starch content 70 %

** Ratio TPS/Polymer

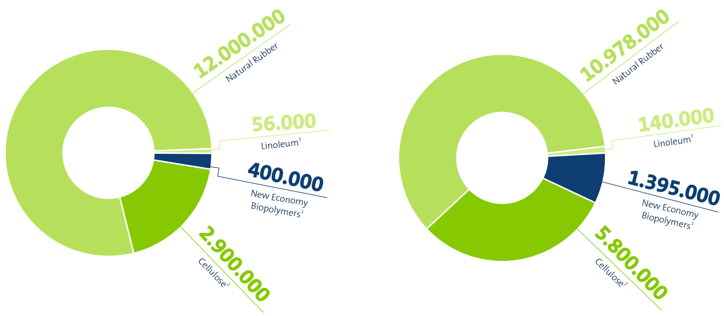
3 MARKET DATA AND LAND USE FACTS

As already mentioned in the introduction, the focus of attention is on New Economy bioplastics, including their position at the market. To give the reader an impression of the market share of these innovative and novel bioplastics:

when considering the most important Old Economy bioplastics with their global production capacity of 17 million tonnes annually, it turns out that the share of New Economy bioplastics is 10 times lower, i.e. 10 % of the market volume of all biobased plastics (including the Old Economy bioplastics), with rising tendency.

By and large, Old and New Economy bioplastics (about 18.5 million tonnes) have a combined share of presently 6 - 7 % of the global plastics market. Given the anticipated market growth, especially of New Economy bioplastics, over a 5-year period, the market share of Old and New Economy bioplastics is expected to reach a maximum of 10 % of the global market for plastics within the next 5 years. The corresponding land use of Old and New Economy bioplastics is currently at approximately 15.5 million hectares, which is equivalent to only 0.3 % of the global agricultural area or approximately 1 % of the arable land. Comparing these figures reveals that New Economy bioplastics, which tend to be the only focus of interest in land use discussions, use up only 4 % of the area required for all biobased plastics combined.

Production capacities and land use old and new economy



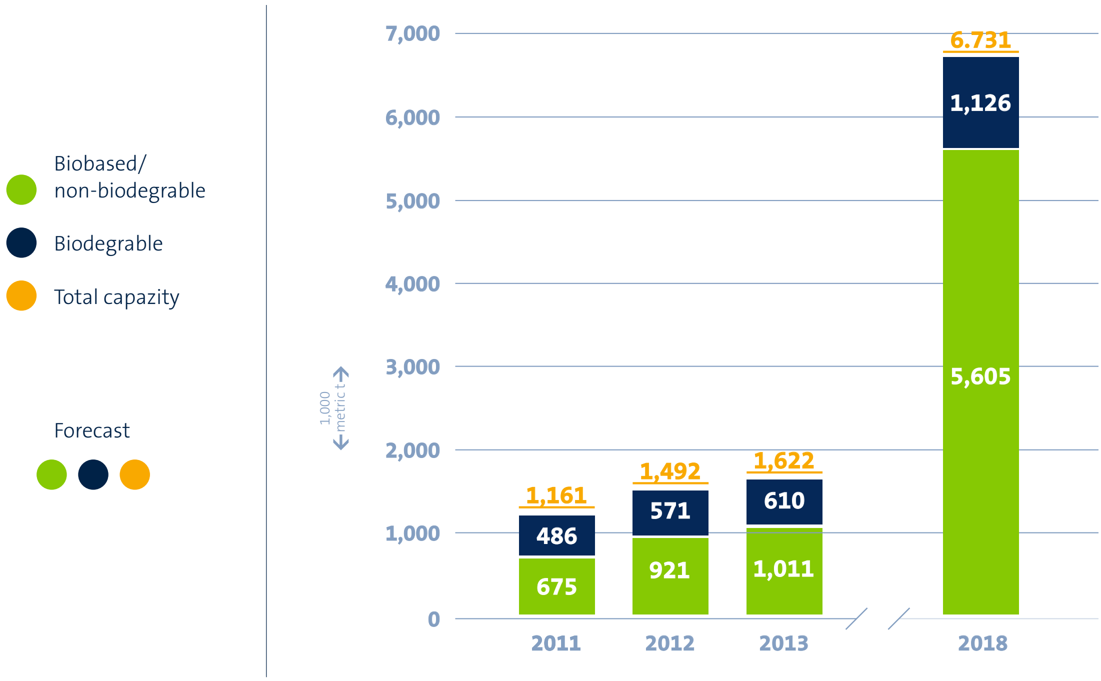
1 PLA, PHA, PTT,PBAT, Starch blends, Drop-Ins (Bio-PE, Bio-PET, Bio-PA) and other

2 material use excl. paperindustry

3 calculations include linseedoil only

Even though global forecasts predict a rapidly growing market for these novel bioplastics in the next few years, the need for agricultural areas will be kept at a very low level. While the market for new bioplastics has been growing by around 15 % annually during the last three years and a sustained growth is anticipated in the future, it can be assumed that land use for New Economy bioplastics by 2018 (6.7 million tonnes), for example, will be as low as 0.03 % of the global agricultural area or less than 0.1 % of the arable land. Regardless of the significant growth rates, it should be mentioned that the market share of these New Economy bioplastics is still hovering at less than 1 % of the global plastics market and is likely not to exceed 2 - 3 % in the near future. To make things even more compelling, it is a fact that biobased plastics, even after multiple material usage, can still serve as an energy carrier. This means that additional crop lands, which are currently used for direct energy production, could be set aside for the production of bioplastics. Prior material usage of biomass, as in the case of bioplastics, still permits subsequent trouble-free energy recovery, whereas direct incineration of biomass (and also crude oil based products!) precludes an immediate subsequent material usage. In this case, more arable land for plant cultivation is needed and consequently another photosynthesis process, in order to gain new resources once again as feedstock for material usage.

3.1 Global production capacities of bioplastics

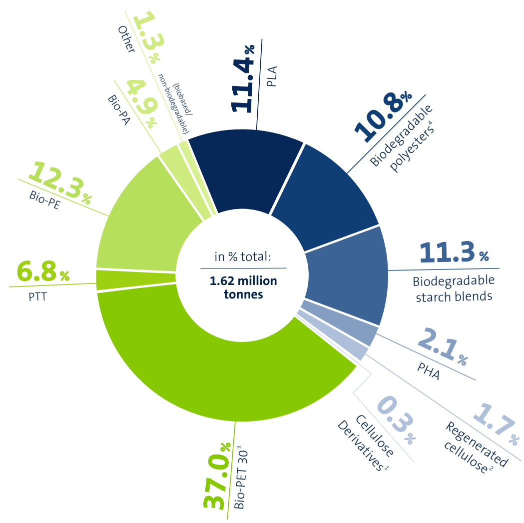


3.2 Bioplastics production capacities by material type

Bioplastics production capacities 2013 (by material type)

62.3%
Biobased/non-biodegradable

37.7%
Biodegradable

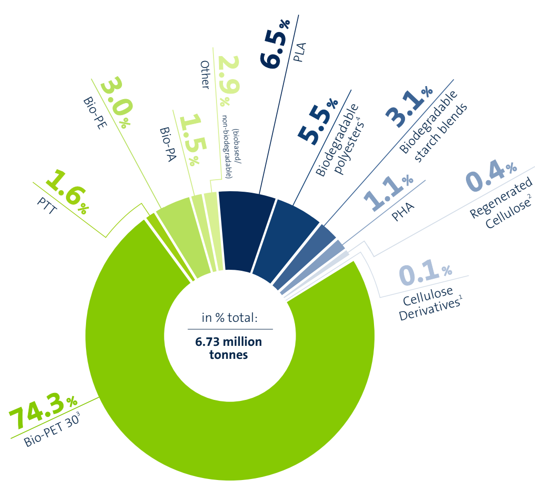


1 Biodegradable cellulose esters
2 Compostable hydrated cellulose foils
3 Biobased content amounts 30%
4 Contains PBAT, PBS,PCL

Bioplastics production capacities 2018 (by material type)

83.8%
Biobased/non-biodegradable

43.4%
Biodegradable



1 Biodegradable cellulose esters
2 Compostable hydrated cellulose foils
3 Biobased content amounts 30%
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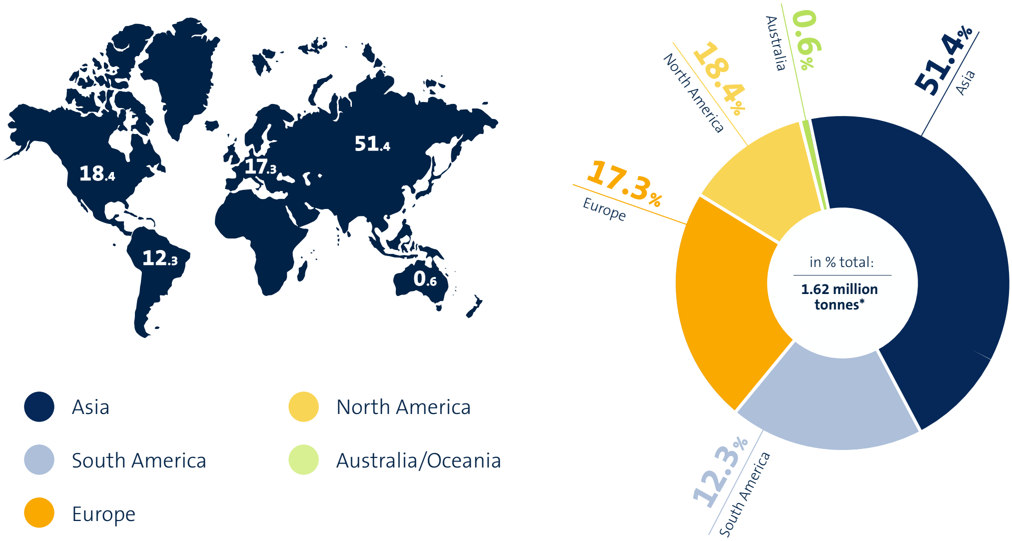
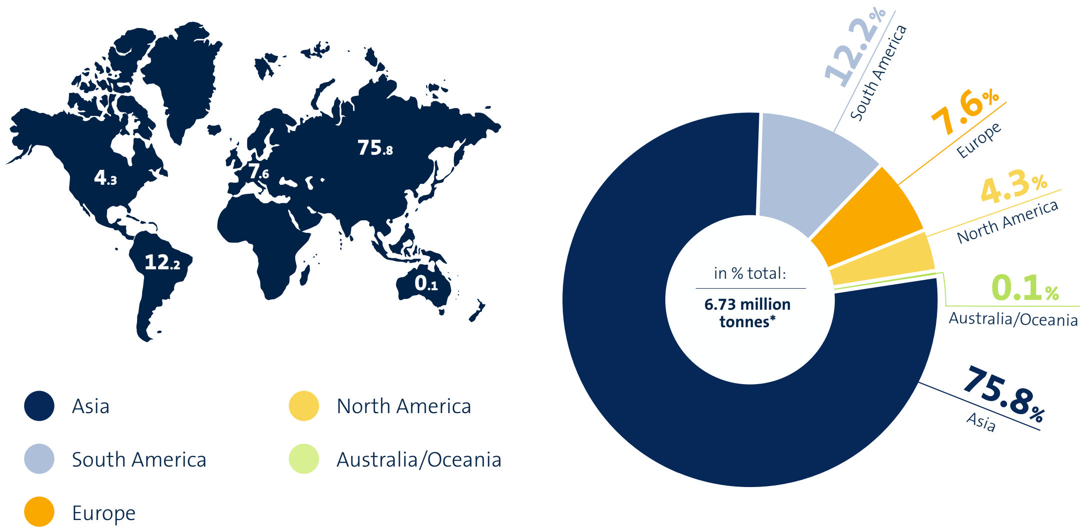
3.3 Bioplastics production capacities by region

Global production capacities of bioplastics in 2013 (by region)



Global production capacities of bioplastics in 2018 (by region)



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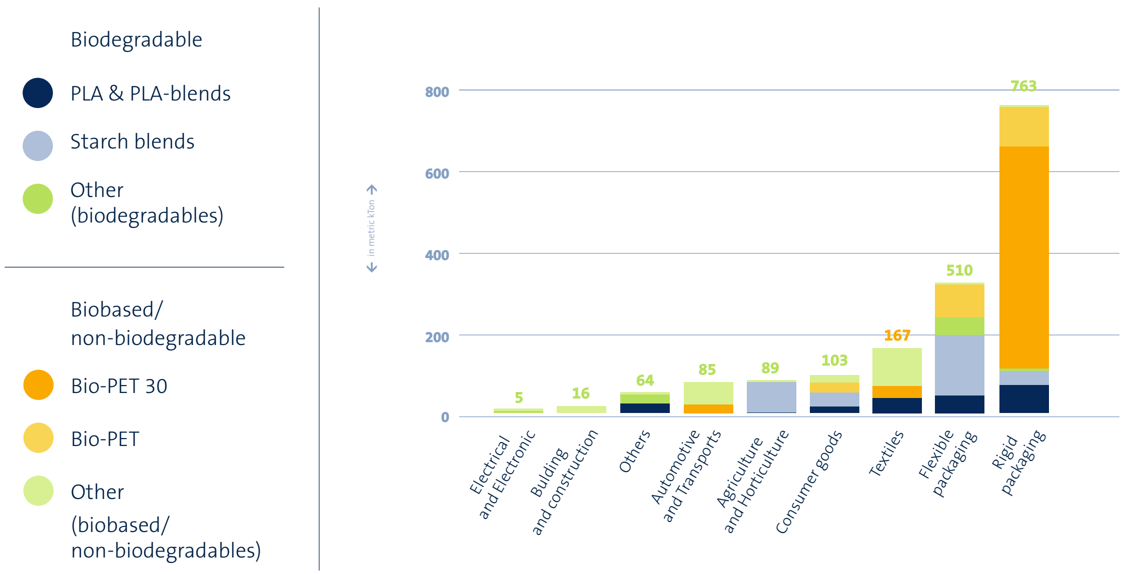
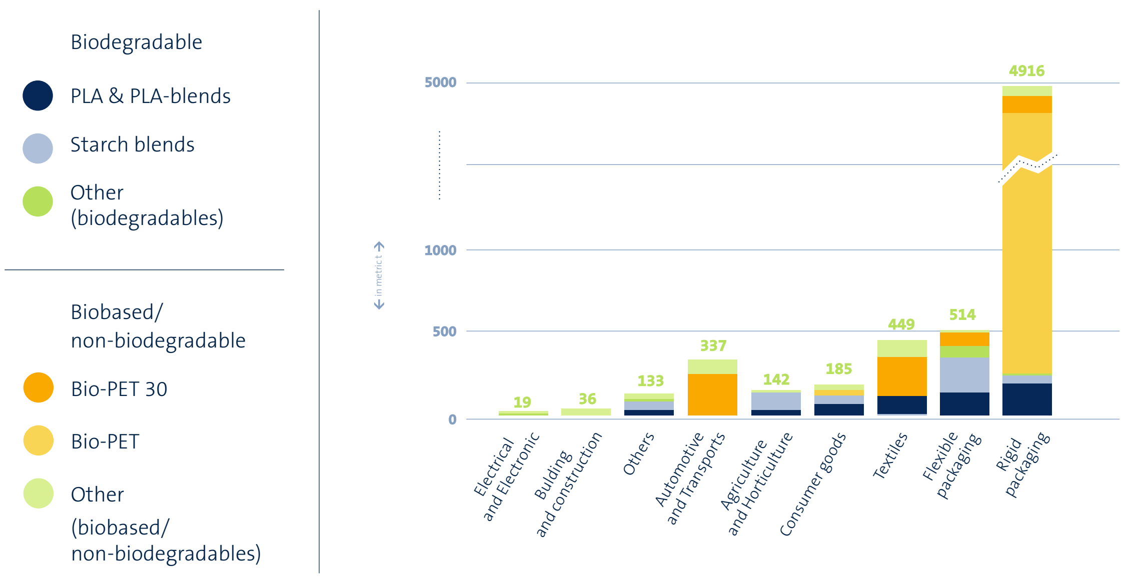
3.4 Bioplastics production capacities by market segment

Global production capacities of bioplastics 2013 (by market segment)



Global production capacities of bioplastics 2018 (by market segment)



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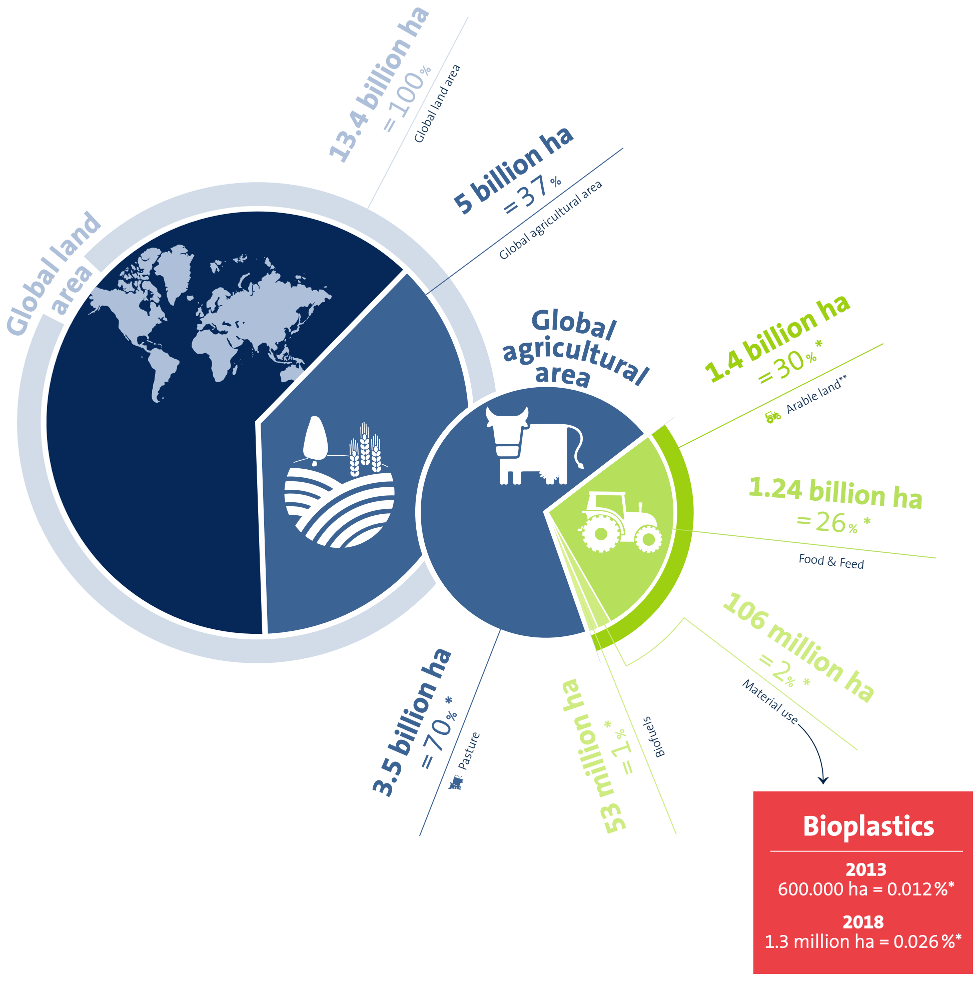
3.5 Land use for bioplastics 2013 and 2018



* In relation to global agricultural area 2011

** Also includes approx. 1% fallow land

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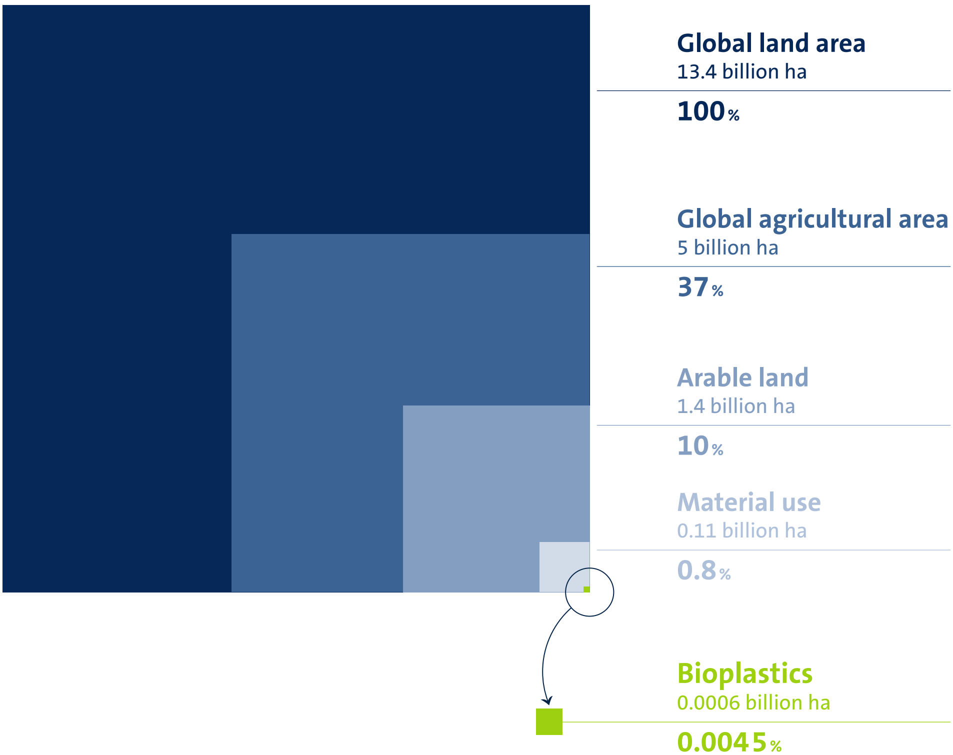
3.6 Land use for bioplastics 2013



Note:

Note:

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