

Plastics in the Circular Economy

Jan Jager



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Professorship Sustainable Plastics
Emmen (0,6 fte)

Professorship Circular Plastics
Leeuwarden (0,2 fte)

CIV DC Tech (Drenthe College)
Secondary Vocational Education
Sustainable Chemical Technology
Emmen (0,2 fte)



NHL Stenden University of Applied Sciences: history

- Formerly Hogeschool Drenthe (with locations in Emmen, Meppel, and Assen).
- Merger (01-01-2008) with CHN, Christelijke Hogeschool Nederland (Leeuwarden).
- Formation of Stenden University of Applied Sciences.
- Merger (01-01-2018) with NHL, Noordelijke Hogeschool Leeuwarden (Leeuwarden).
- Formation NHL Stenden University of Applied Sciences.



NHL Stenden: some key data



24000
STUDENTS

CA 15%
INTERNATIONAL
STUDENTS



MULTI
CAMPUS
UNIVERSITY

90+
STUDENT
NATIONALITIES

2000
ACADEMIC
STAFF



DESIGN
BASED
EDUCATION



14
ACADEMIES
44
PROFESSOR-
SHIPS



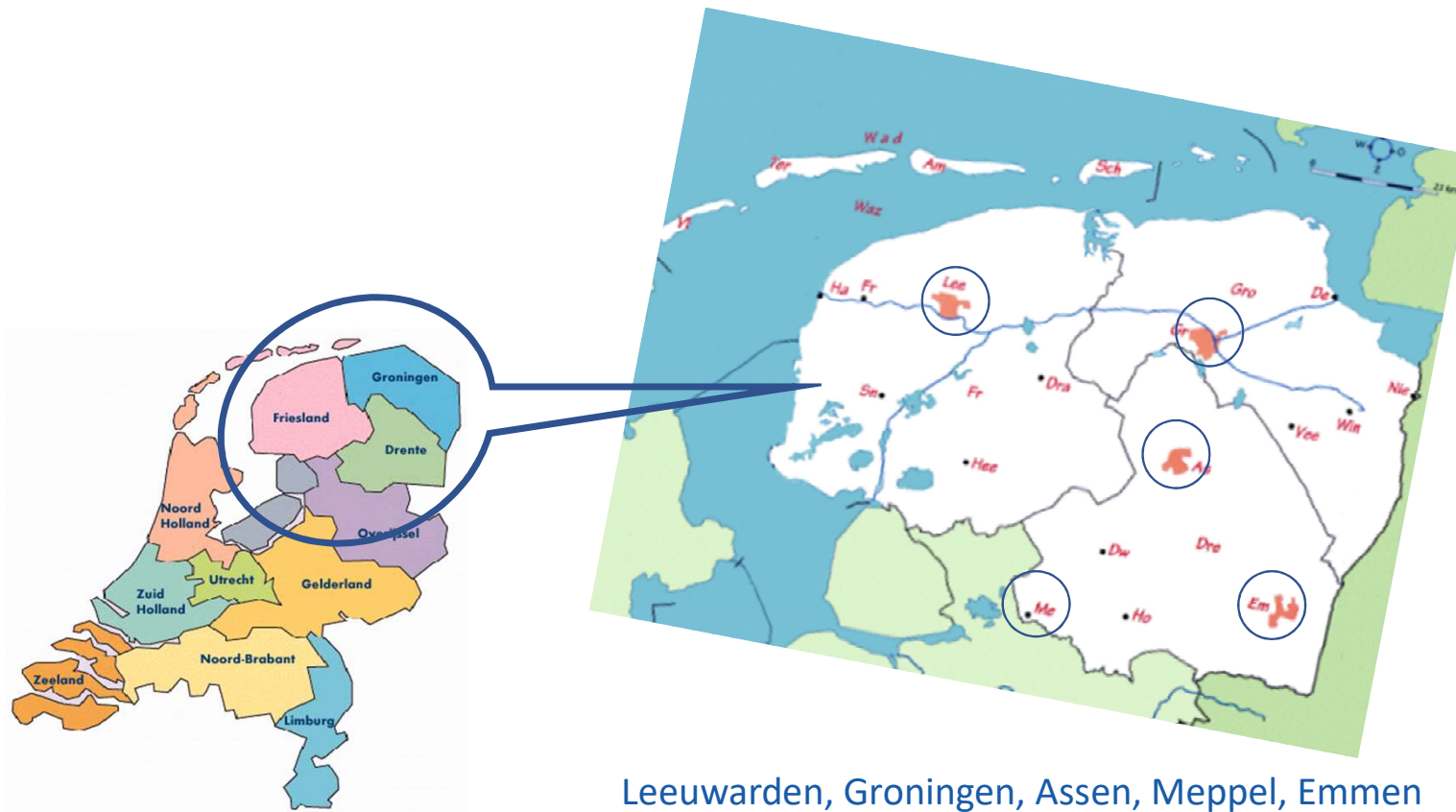
12
ASSOCIATE'S
DEGREES

73
BACHELOR'S
DEGREES

51
MINORS

17
MASTER'S
DEGREES

NHL Stenden University of Applied Sciences: locations



Leeuwarden, Groningen, Assen, Meppel, Emmen

NHL Stenden: locations abroad

NHL Stenden has branche campuses abroad (International Hospitality Management, International Business Administration, Tourism Management, and Disaster Management).

Bali:



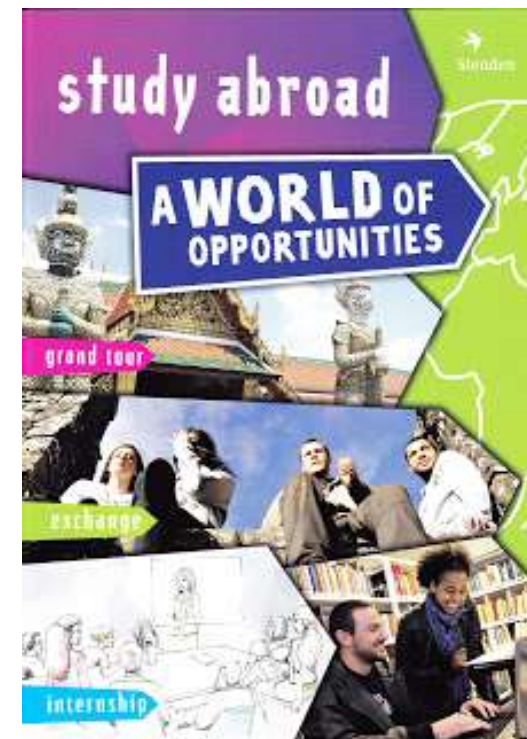
Bangkok:



Quatar:



Zuid-Afrika:



Green PAC: Center of Expertise (CoE)

- Cooperation with [Hogeschool Windesheim](#) (Zwolle): **Green PAC** (CoE).
- Applied and practice-oriented research .
- Topics:
 - **Composites and biocomposites.**
 - **3D printing (FDM en SLA).**
 - **Bioplastics (biobased and /or biodegradable).**
 - **Fibers and yarns.**
 - **Recycling (mechanical- or chemical recycling of plastics).**
- [iLAB](#), Innovation Laboratory in Zwolle (located on the [Polymer Science Park](#)) and in Emmen (located on the [Emmtec Industry & Business Park](#)).
- [COCI](#), Centre of Open Chemical Innovation in Emmen (located on the Emmtec Industry & Business Park).

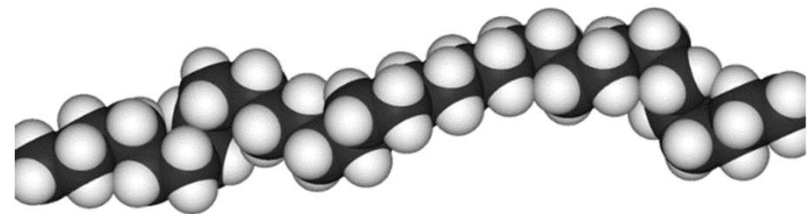
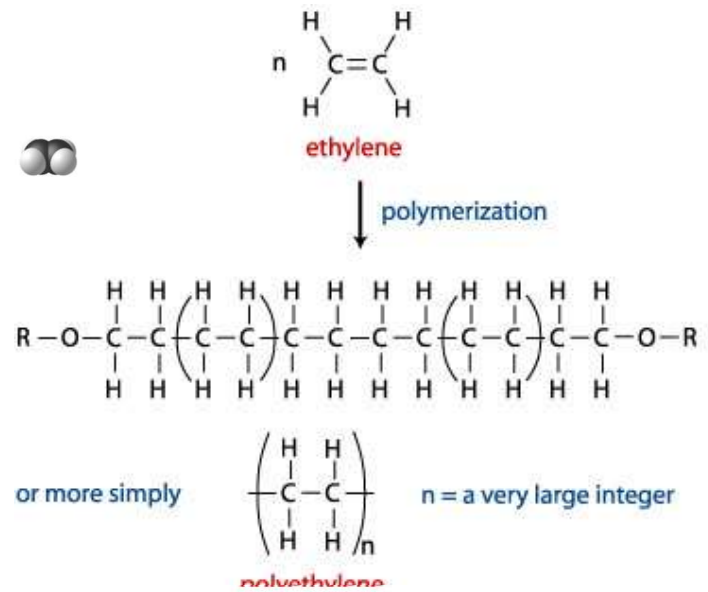
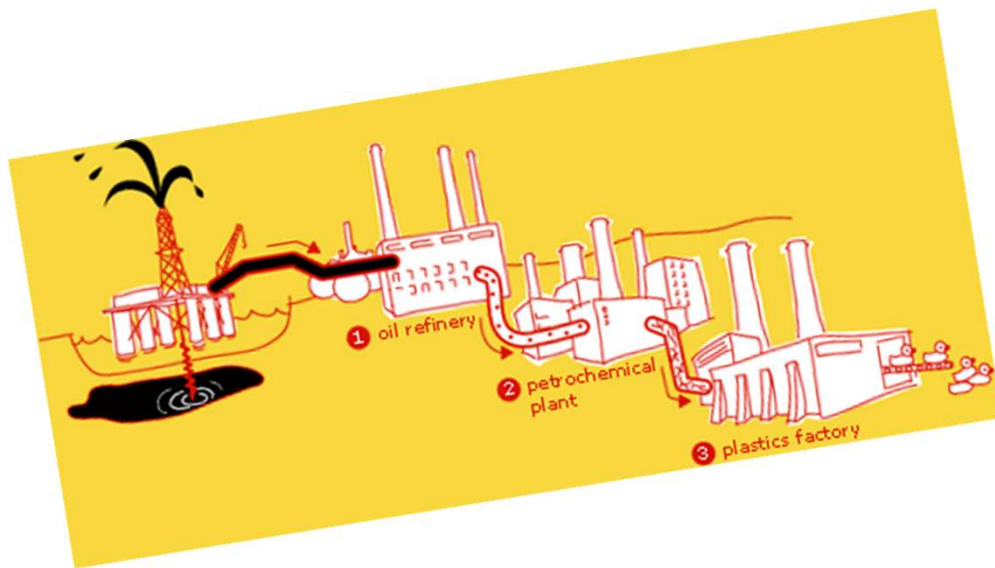


Origin of plastics

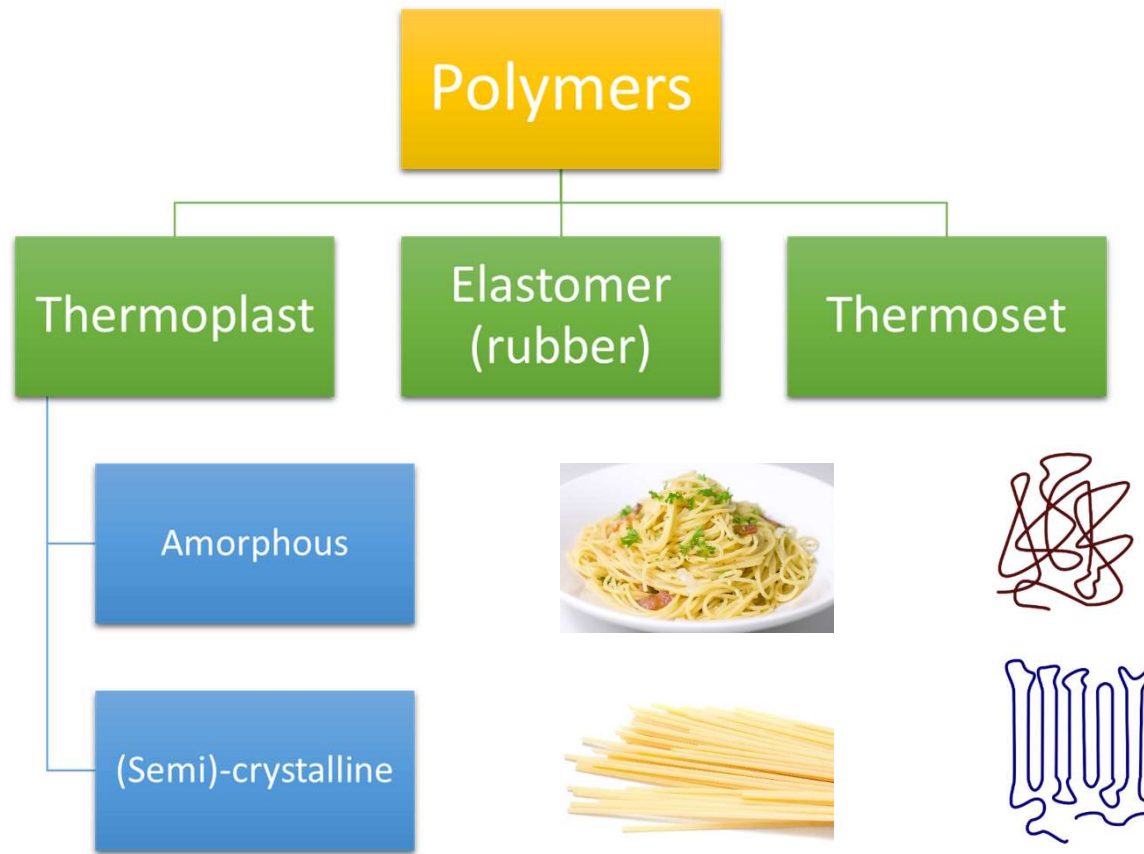
Plastics are made from oil.



Plastics and polymers

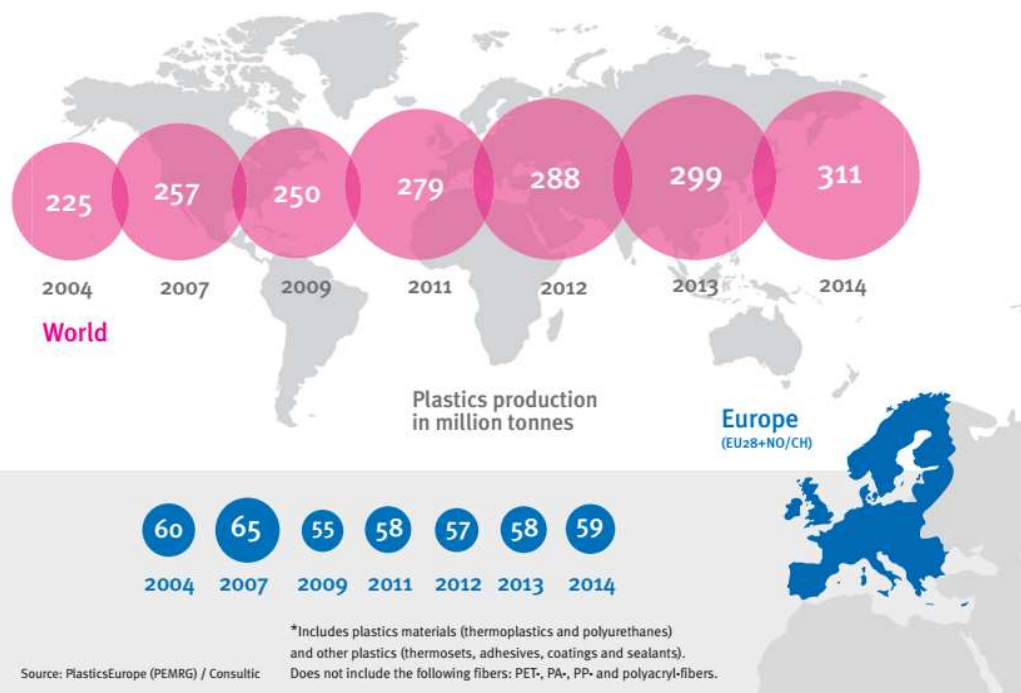


Amorphous vs. crystalline



PlasticsEurope – plastics: global production

Plastics* production is stable in Europe and grows globally



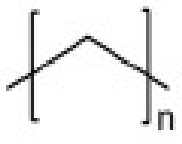
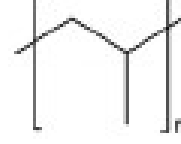
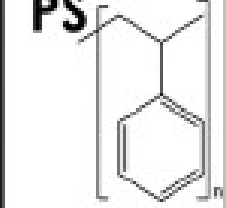
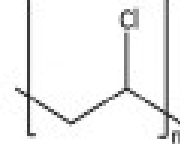
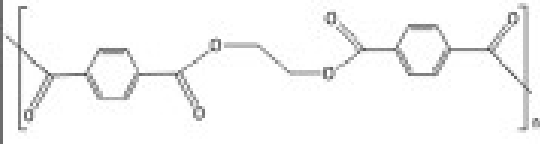
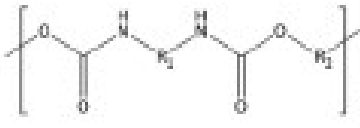
Weight Titanic:
52,310 ton

5945 Titanics!!!

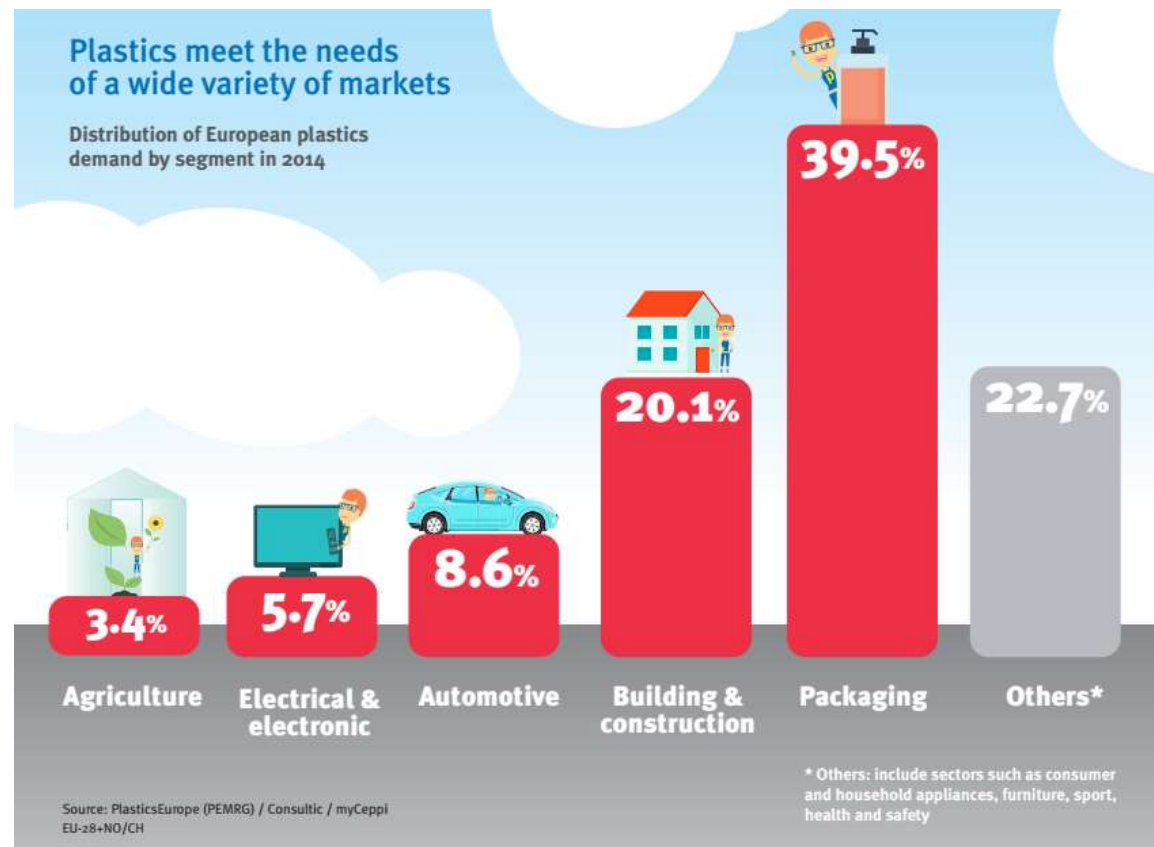


Structure of polymers

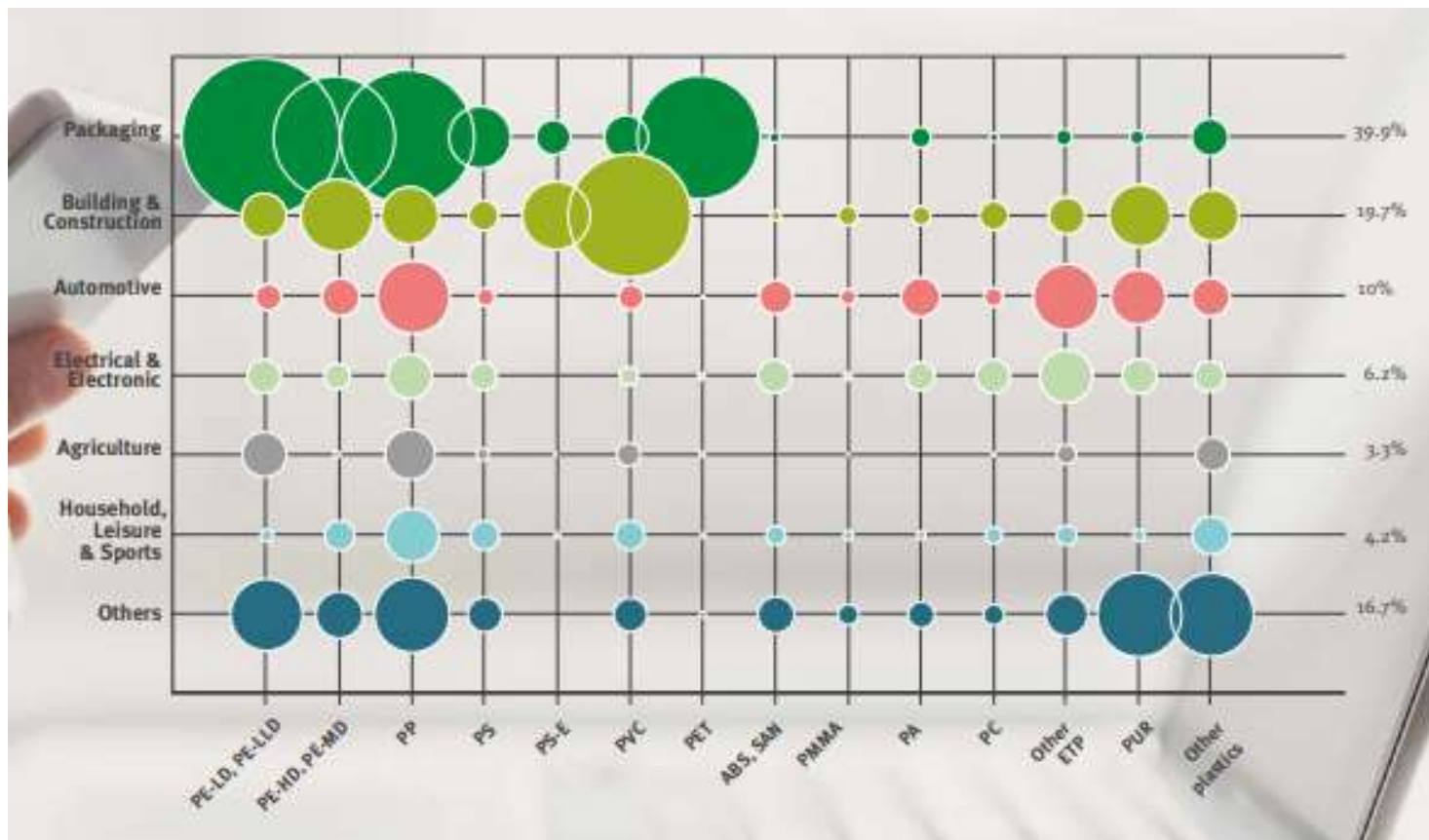
All carbon backbone vs. heteroatom backbone

Plastics					
C-C backbone				Heteroatoms in backbone	
PE 	PP 	PS 	PVC 	PET 	PU 
29.6	18.9	7.1	10.4	6.9	7.4
fraction of total European demand [%]					

PlasticsEurope – plastics: applications



PlasticsEurope – Plastics – the Facts 2017



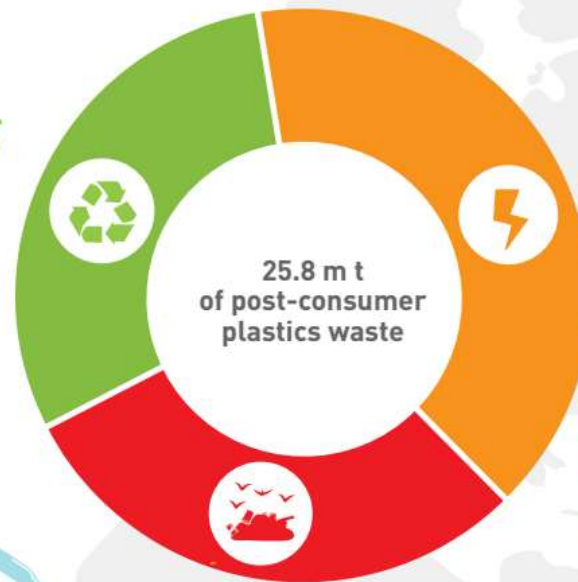
European plastics converter demand by segments and polymer types in 2016
Data for EU28+NO/CH.

PlasticsEurope – plastics: recycling

In 2014 plastics recycling and energy recovery reached 69.2%

In 2014, 25.8 million tonnes of post-consumer plastics waste ended up in the waste upstream. 69.2% was recovered through recycling and energy recovery processes while 30.8% still went to landfill.

Recycling
29.7%



Energy recovery
39.5%

Landfill
30.8%

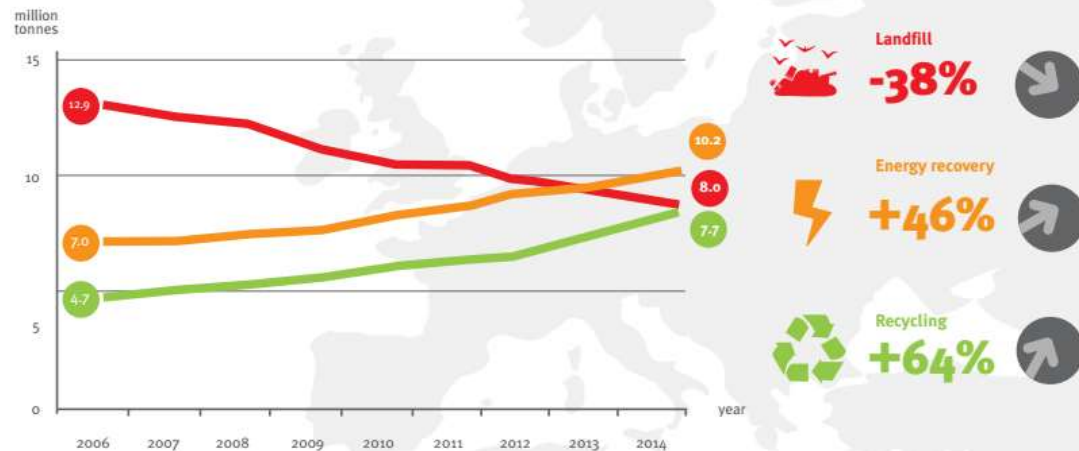


Treatment for post-consumer plastics waste in the EU28 + Norway and Switzerland
Source: Consultic

PlasticsEurope – plastics recycling trends

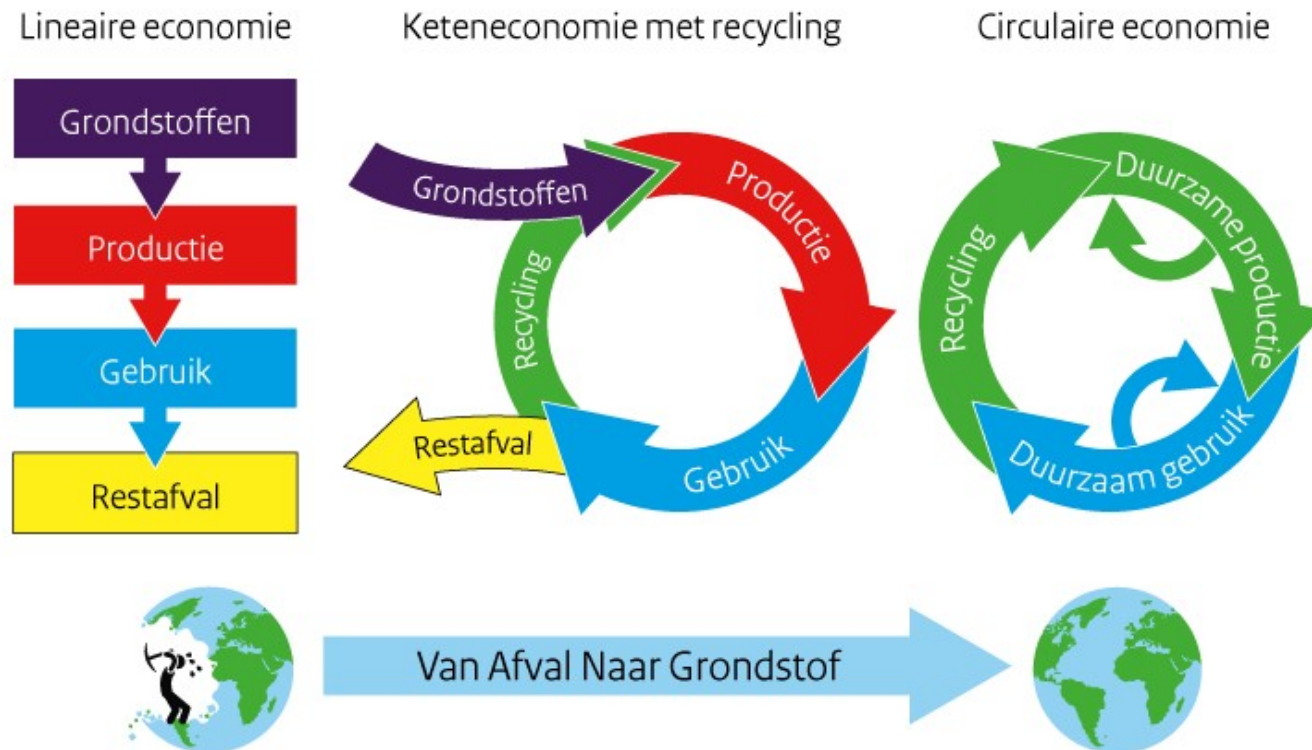
Since 2006 recycling and energy recovery have increased

The annual average of post-consumer plastics waste generation from 2006 to 2014 is 25 million tonnes



2006-2014 progress of recycling and energy recovery
Source: Consultic

Linear economy vs. circular economy



[Invulling programma Van Afval Naar Grondstof \(Mansveld, 28 januari 2014\)](#)

Ellen MacArthur Foundation



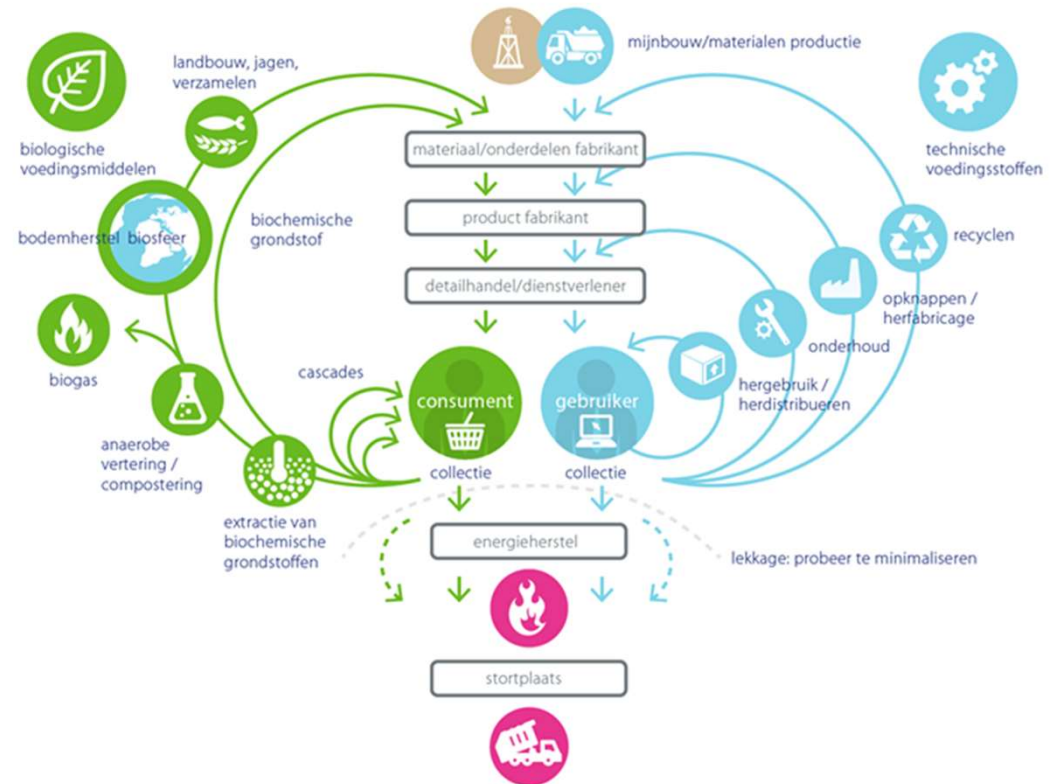
**ELLEN
MACARTHUR
FOUNDATION**
Rethink the future



The linear 'Take - Make - Dispose' system, which depletes natural resources and generates waste, is deeply flawed and can be productively replaced by a restorative model in which waste does not exist as such but is only food for the next cycle

— Ellen MacArthur —

AZ QUOTES

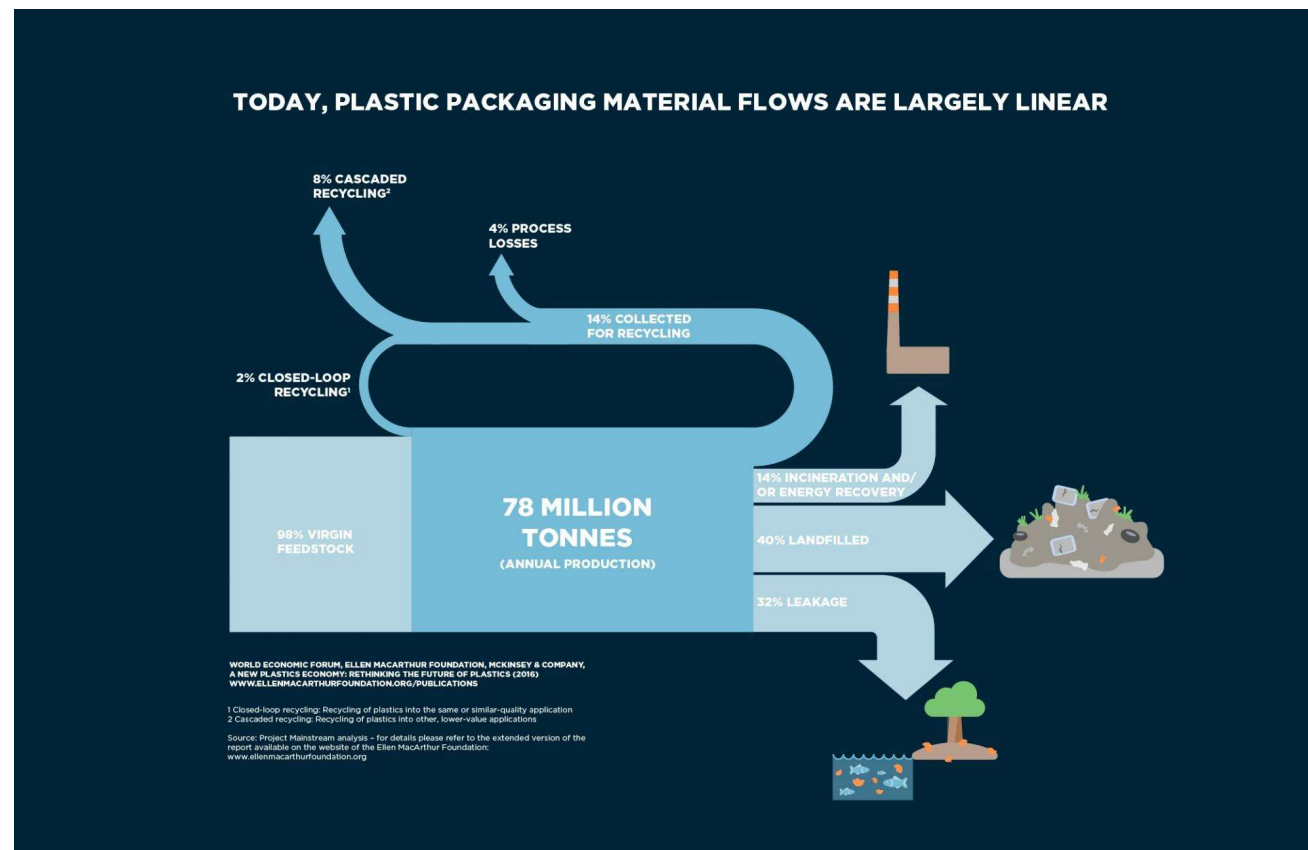


The New Plastics Economy

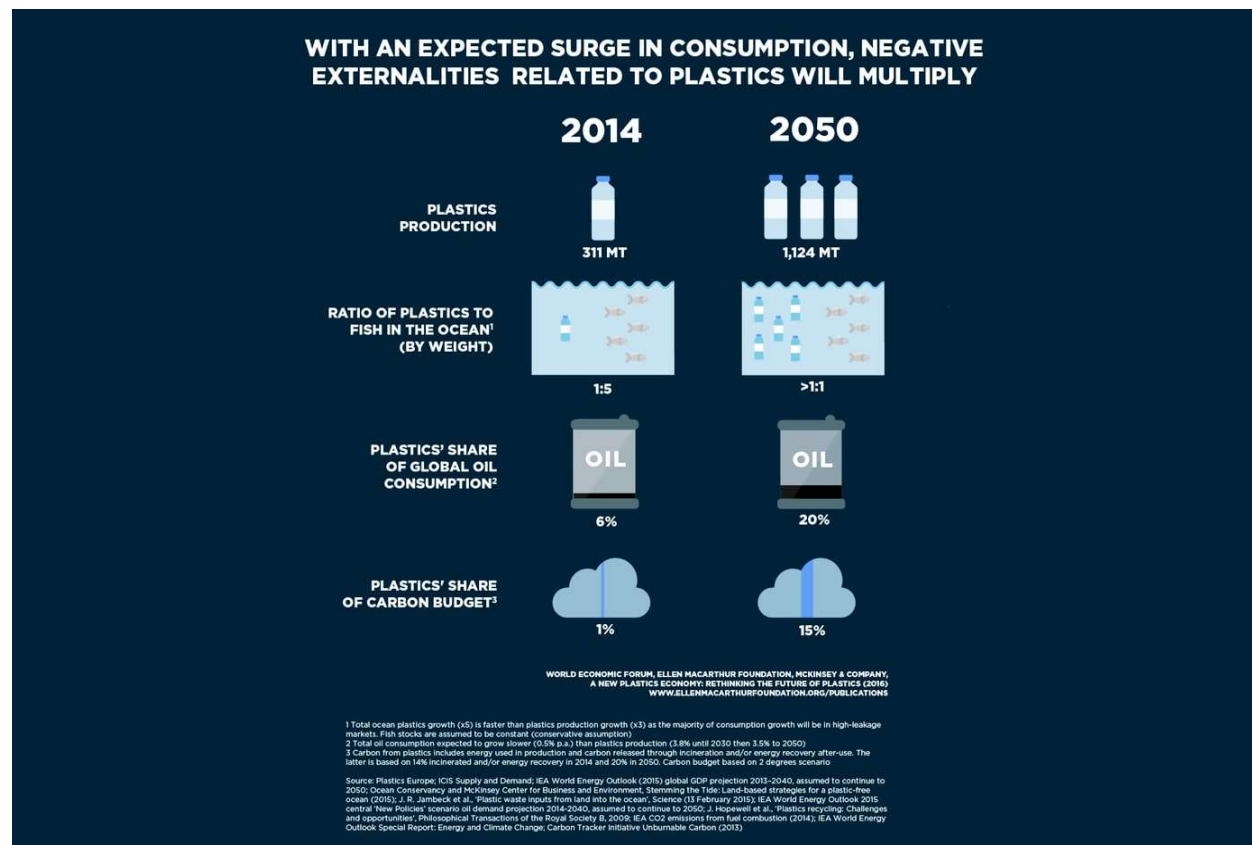
Ellen MacArthur Foundation
World Economic Forum
McKinsey & Company



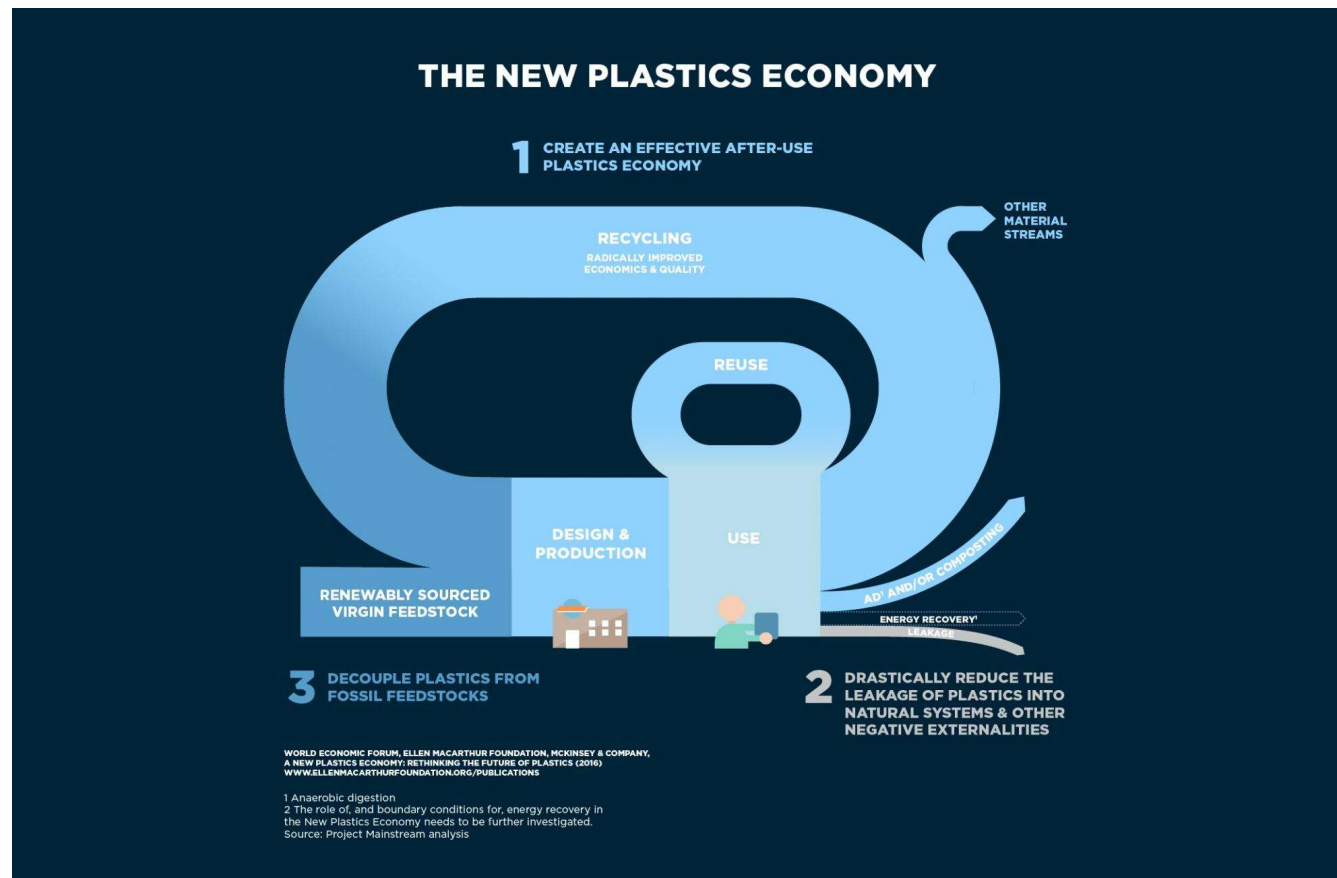
The New Plastics Economy: huidige situatie



The New Plastics Economy: situatie 2050



The New Plastics Economy: situatie 2050 (2)



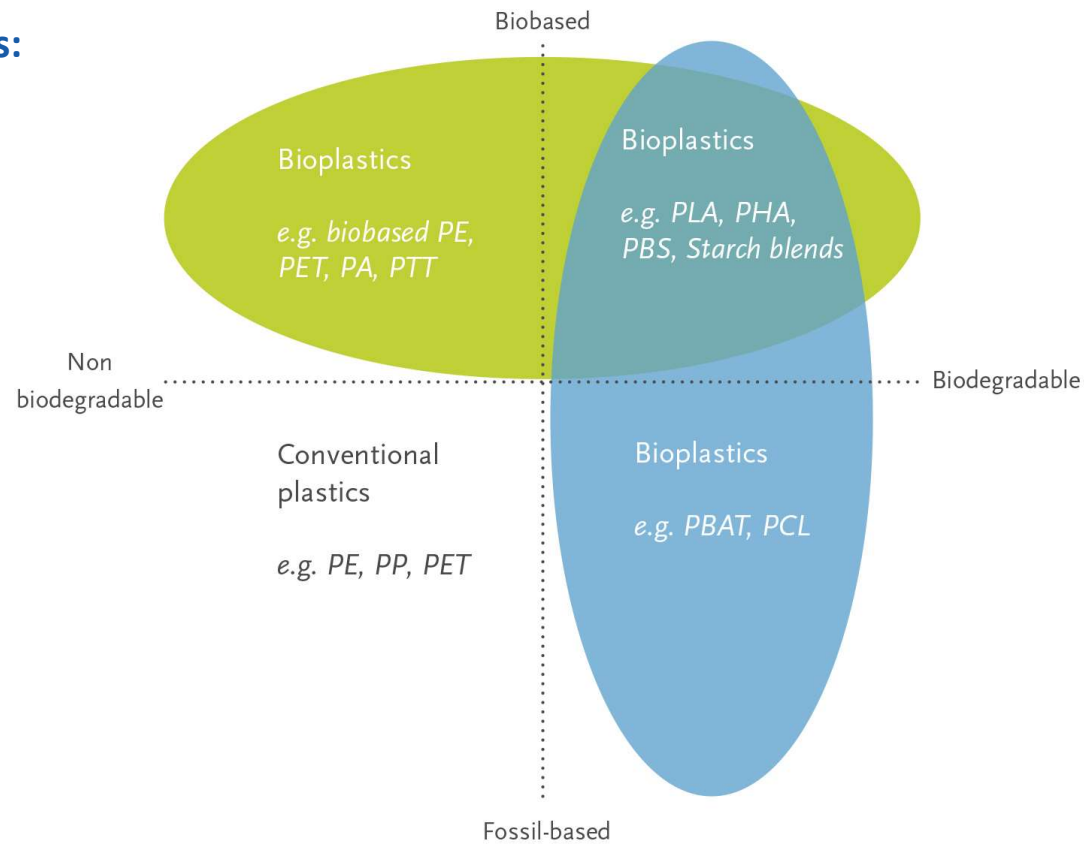
Out of the plastic trap: saving the Mediterranean from plastic pollution

WWF Publication 2018



European Bioplastics

Bioplastics:



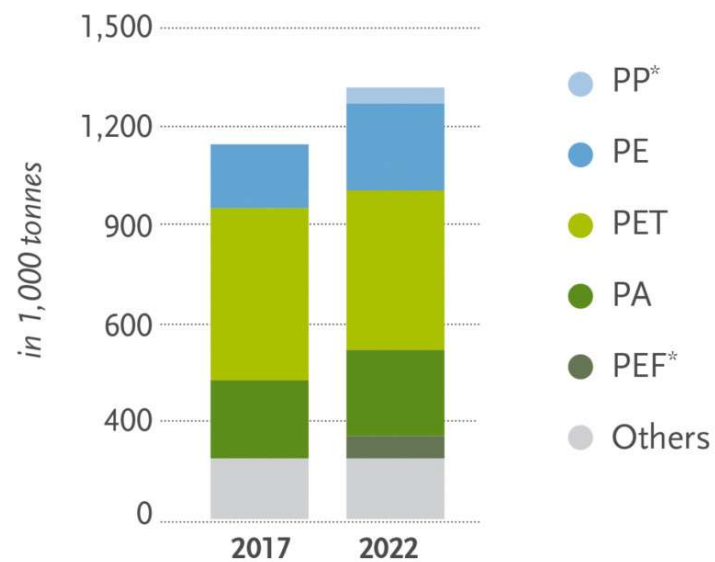
European Bioplastics

Biobased plastics

Biobased or partially biobased durable plastics, such as biobased or partially biobased PE, PET or PVC, possess properties, which are identical to their conventional versions. These bioplastics are technically equivalent to their fossil counterparts; yet, they help to reduce a product's carbon footprint. Moreover, they can be mechanically recycled in existing recycling streams.

European Bioplastics

Bio-based & durable bioplastics 2017 vs. 2022



**Bio-based PP and PEF are currently in development and predicted to be available in commercial scale in 2020.*

Source: European Bioplastics, nova-Institute (2017).

More information: www.bio-based.eu/markets and www.european-bioplastics.org/market

European Bioplastics

Biobased content

Companies with biobased bioplastics can either indicate the ‘biobased carbon content’ or the ‘biobased mass content’ of their products. As these units of measurement differ, the typical numeric percentage value will differ, too, and must be taken into account, especially when drawing comparisons.

A well-established methodology to measure the biobased carbon content in materials or products is the 14C-method (EU standard: [CEN/TS 16137](#), corresponding US-standard: [ASTM 6866](#)). Certification schemes and derived product labels based on the European and the U.S. standard are available – for example by the Belgian certifier [Vinçotte](#) or German certifier [DIN CERTCO](#).



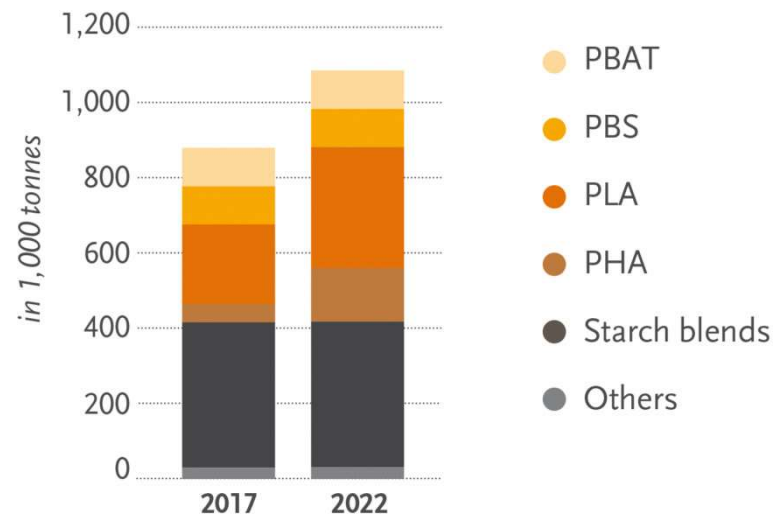
European Bioplastics

Biodegradable plastics

The property of biodegradation does not depend on the resource basis of a material. This feature is directly linked to the chemical structure of the polymer and can benefit particular applications, in particular packaging. Biodegradable plastic types offer new ways of recovery and recycling (organic recycling). If certified compostable according to international standards such as the [EN 13432](#) (preferably by an independent third party), these plastics can be composted in industrial composting plants.

European Bioplastics

Biodegradable bioplastics 2017 vs. 2022

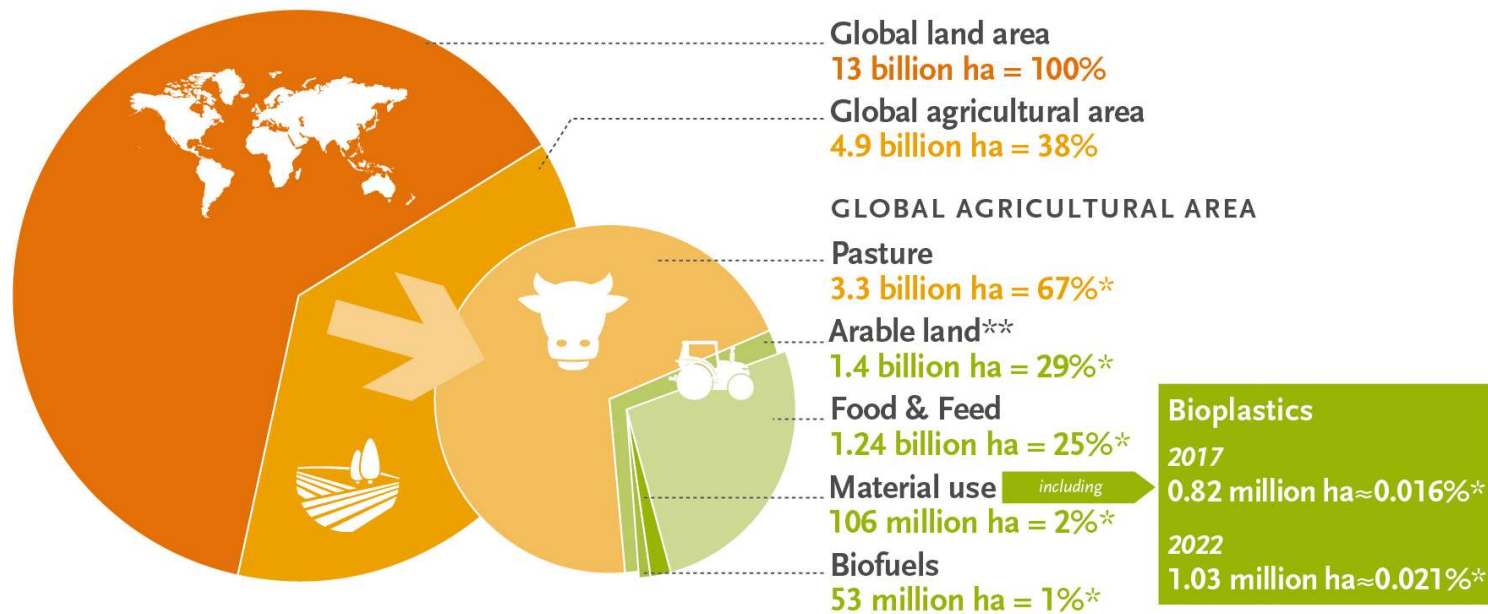


Source: European Bioplastics, nova-Institute (2017).

More information: www.bio-based.eu/markets and www.european-bioplastics.org/market

European Bioplastics

Land use estimation for bioplastics 2017 and 2022

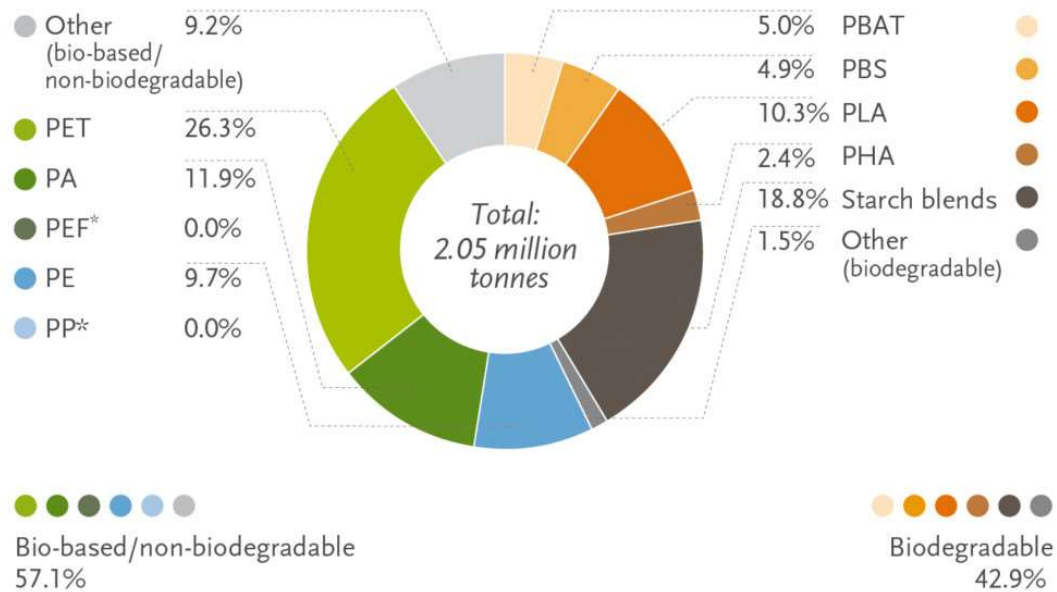


Source: European Bioplastics (2017), FAO Stats (2014), nova-Institute (2017), and Institute for Bioplastics and Biocomposites (2016). More information: www.european-bioplastics.org

* In relation to global agricultural area
** Including approx. 1% fallow land

European Bioplastics

Global production capacities of bioplastics 2017 (by material type)



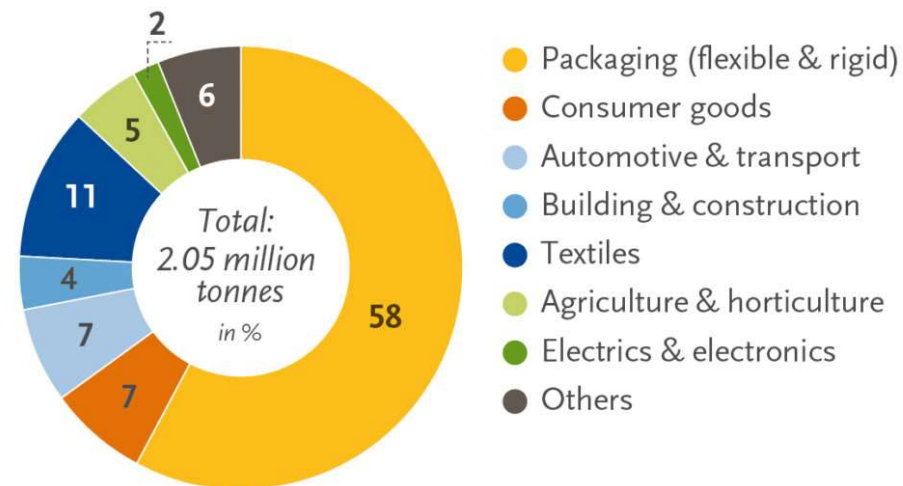
*Bio-based PP and PEF are currently in development and predicted to be available in commercial scale in 2020.

Source: European Bioplastics, nova-Institute (2017).

More information: www.bio-based.eu/markets and www.european-bioplastics.org/market

European Bioplastics

Global production capacities of bioplastics in 2017 (by market segment)



Source: European Bioplastics, nova-Institute (2017). More information:
www.bio-based.eu/markets and www.european-bioplastics.org/market

European Bioplastics

Global production capacities of bioplastics in 2017 (by region)



* Production in Australia/Oceania is a small proportion relativ to the global production capacity.

Source: European Bioplastics, nova-Institute (2017).

More information: www.bio-based.eu/markets and www.european-bioplastics.org/market

Bioplastics: biobased PE



Green Polyethylene Cycle



Sugarcane

Sugarcane metabolizes CO₂ to produce sucrose



Ethanol CH₃ – CH₂OH

At the mill, sugar juice and molasses are fermented and then distilled to produce ethanol



Ethylene CH₂ = CH₂

Through the process of dehydration, ethanol is transformed into ethylene



Green PE CH₂ = CH₂

Ethylene is polymerized in polyethylene in shared polymerization units



Final Products

I'm Green™ Green Polyethylene is transformed into final products by the same processes and machinery of fossil PE

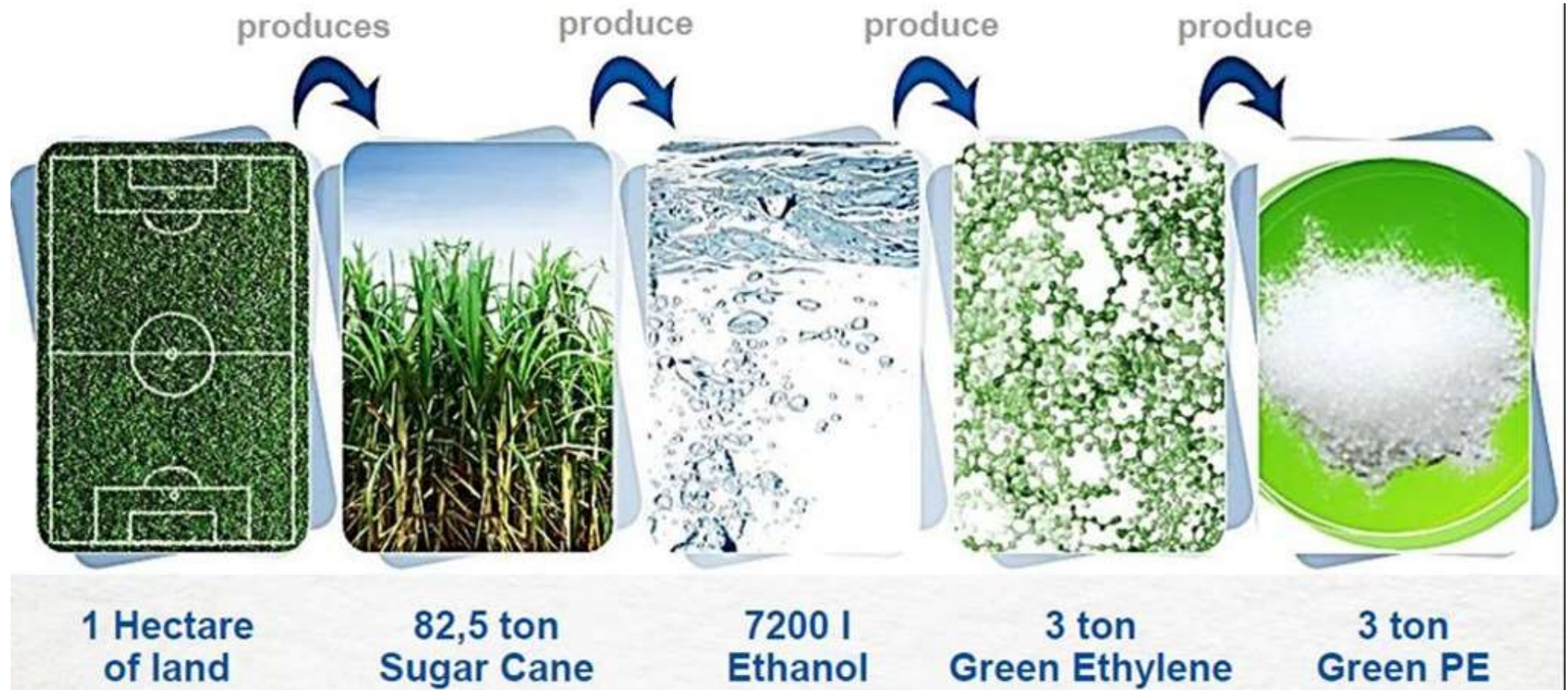


Recycling

I'm green™ is recyclable in the same chain established for fossil PE (mechanics / incineration)



Bioplastics: biobased PE

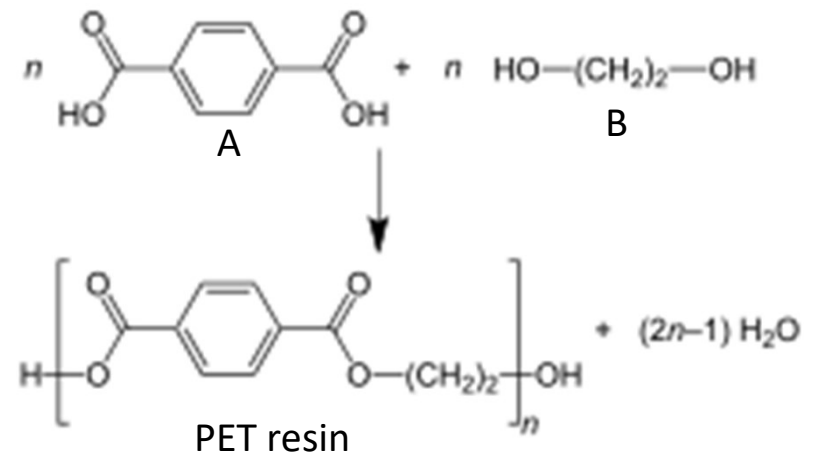
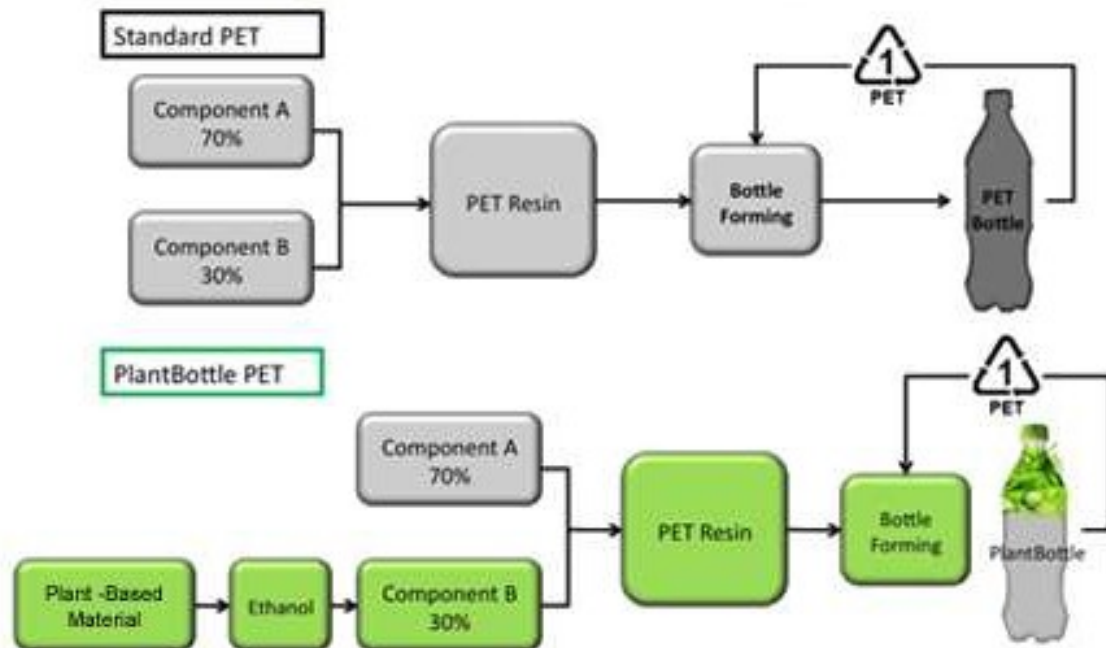


Bioplastics: biobased PE



Bioplastics: biobased PET

How is plantbottle™ PET Manufactured?



Bioplastics: biobased PET



The advertisement is divided into two main sections. The left section features the PlantBottle logo, which consists of a green recycling symbol with a bottle shape inside, and the text "plantbottle™" in green and grey. Below this, it states "up to 30% plant-based" and "100% recyclable bottle" in green and grey, followed by "redesigned plastic, recyclable as ever." in grey. The right section shows a real Coca-Cola bottle with a red label and a red cap, partially encased in a green leaf. To the right of the bottle is a tree whose trunk is a clear plastic bottle filled with green leaves and a small white flower, with a tire swing hanging from a branch. The text "A Bottle of Hope" is written in grey next to the tree. At the top right of the right section, there is a small green recycling symbol and the text "The PlantBottle™ is a better bottle—made up of 30% plant-based materials. It's the first of its kind to be 100% recyclable. Learn more about our journey to create a 100% renewable bottle at livepositively.com". The Coca-Cola logo is in the bottom right corner.

plantbottle™

up to 30% plant-based
100% recyclable bottle

redesigned plastic,
recyclable as ever.

Coca-Cola

The PlantBottle™ is a better bottle—made up of 30% plant-based materials. It's the first of its kind to be 100% recyclable. Learn more about our journey to create a 100% renewable bottle at livepositively.com.

A Bottle of Hope

Coca-Cola

Bioplastics: biobased PET



plantbottle™ packaging at a glance
 The journey of Coca-Cola's greenest bottle yet
www.coca-cola.co.uk/plantbottle

1975
 We first introduce our lightweight plastic bottle

1978
 The first recyclable PET (polyethylene terephthalate) plastic Coca-Cola bottle is launched

1991
 Coca-Cola launches the first plastic bottle made with recycled materials

2009
 We launch PlantBottle packaging in Copenhagen - the first ever recyclable bottle made partially from plants

2010
 Coca-Cola put over 2.5 billion PlantBottle packages on the market around the world

2011
 PlantBottle packaging launches in Great Britain and, globally, Coca-Cola will distribute well over 5 billion PlantBottle packages across 20 countries

By 2020
 By 2020 we intend that all PET bottles will be made from a combination of recycled PET and plant-based materials

100% RECYCLABLE

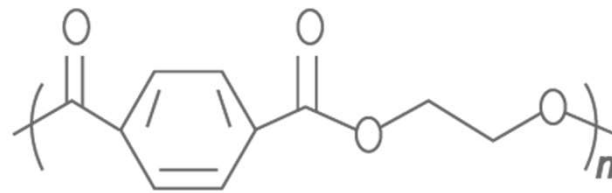
2015+
 We aim to be using plant waste like fruit peel, bark and stems to make PlantBottle packaging

OUR RESPONSIBLY SOURCED BRAZILIAN SUGARCANE IS ENDORSED BY WWF

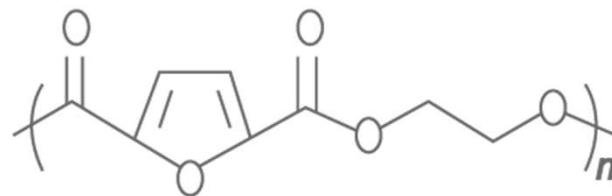
Where you come in:

1. Look for the PlantBottle logo on our packaging in stores
2. Recycle your empty bottles so they can be used again and again
3. Wonderful things can happen when we recycle. A plastic bottle can become another plastic bottle, or a bag, an umbrella, a chair...

Bioplastics: biobased PEF

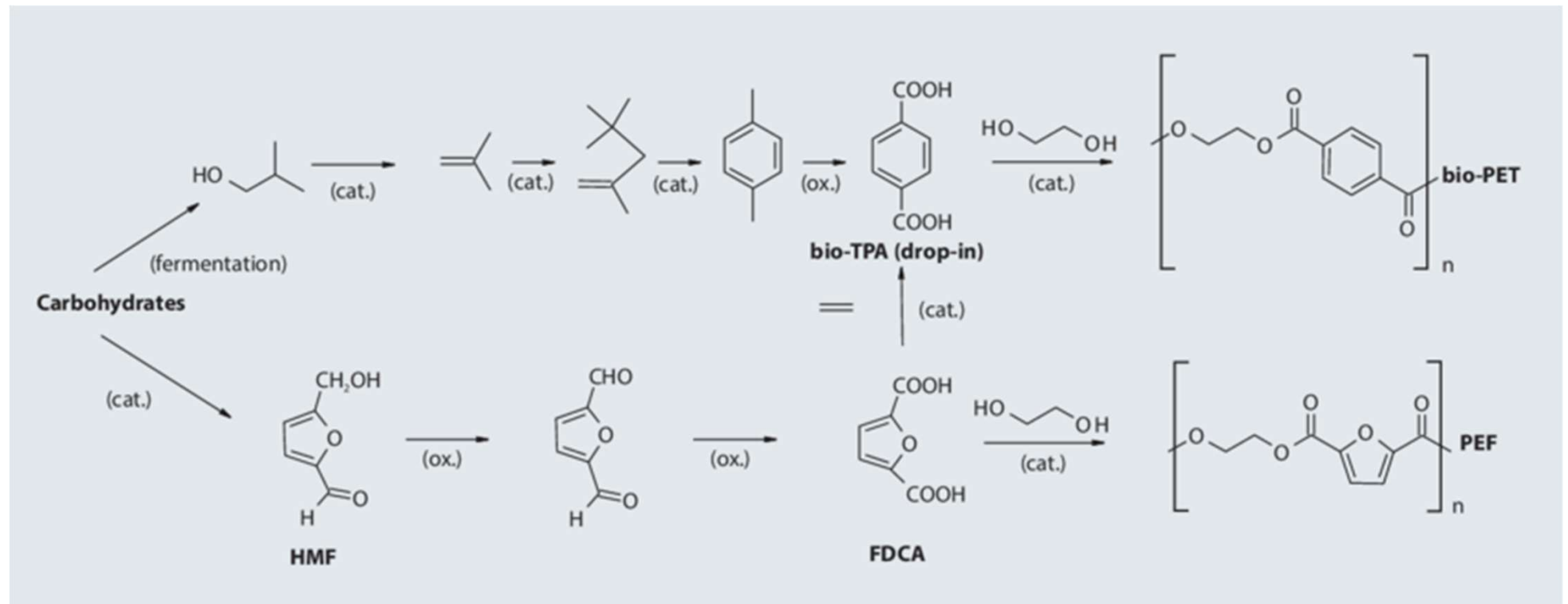


Polyethylene terephthalate (**PET**)



Polyethylene Furanoate (**PEF**)

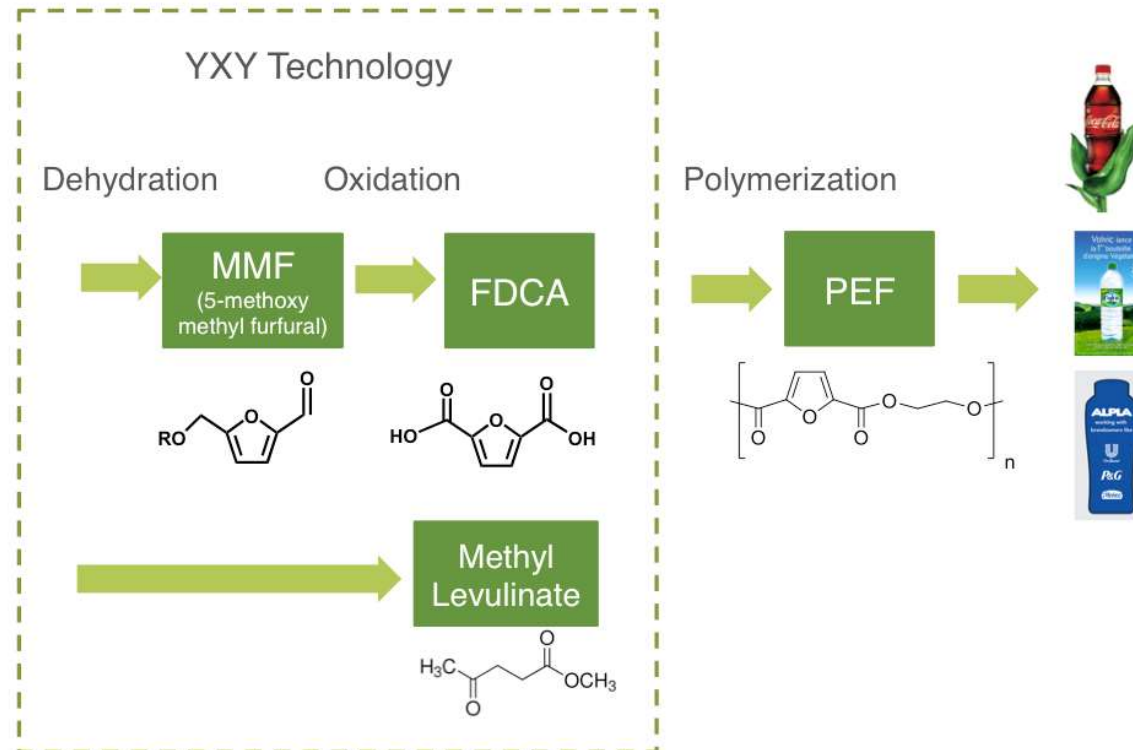
Bioplastics: biobased PET and PEF



Bioplastics: biobased PEF



Plant based
Feedstock

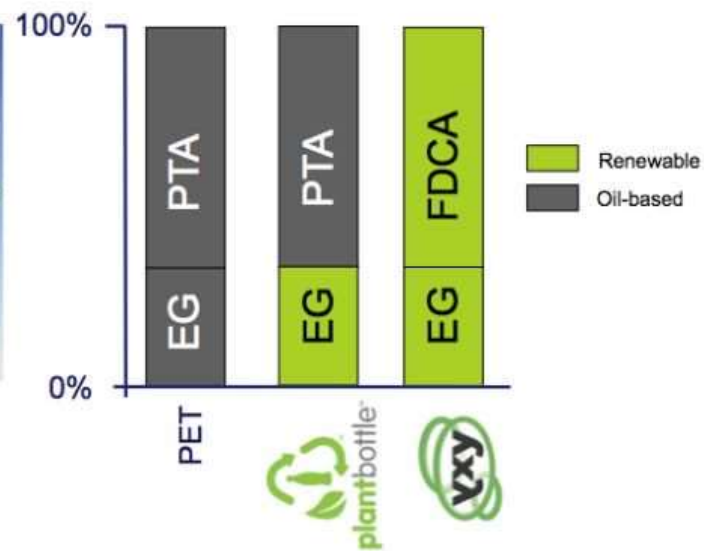


Bioplastics: biobased PEF

Moving to 100% green

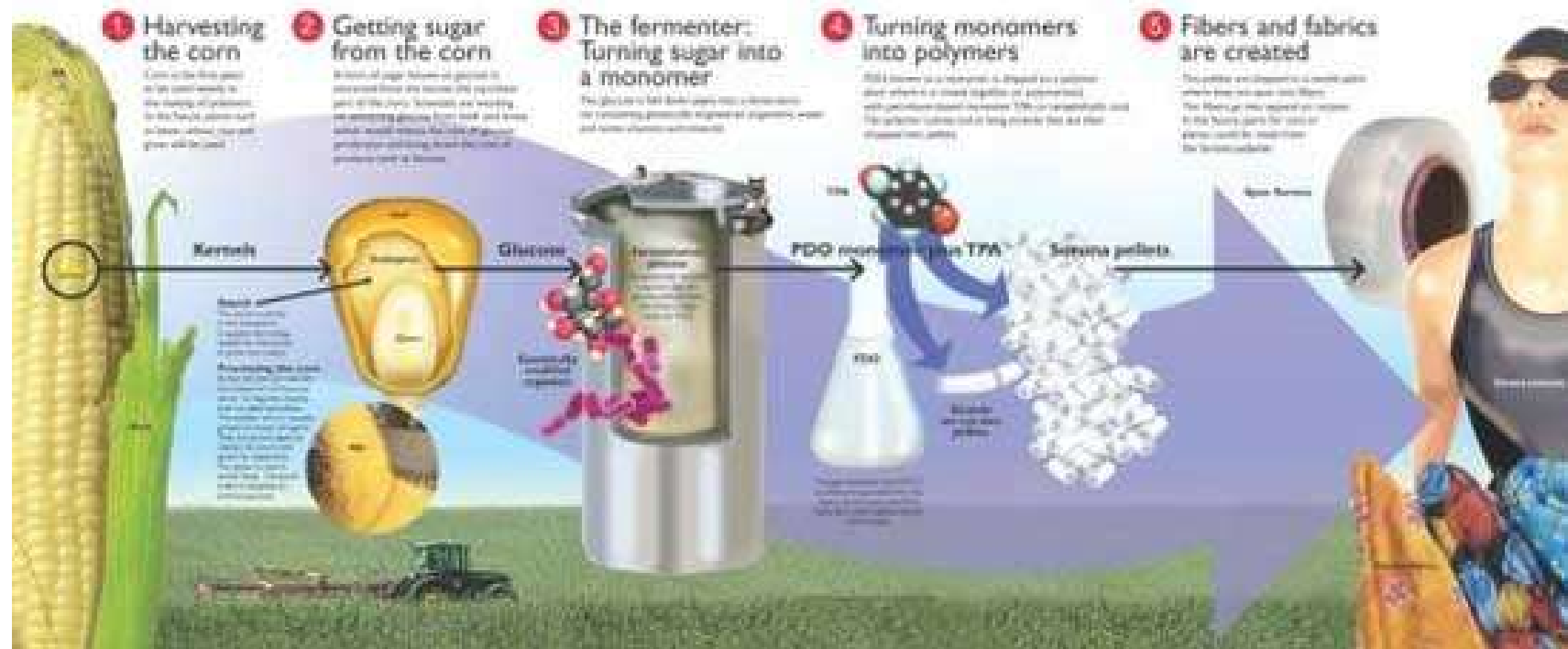


- PET is the most widely used polyester made of PTA and EG
- Plantbottle launched in 2010 - PET with biobased EG and oil-based PTA
- PEF by Avantium: biobased FDCA + biobased EG = 100% green



From corn to polymers and fibers

DuPont™ Sorona® is made from naturally occurring starch in the kernels of corn. In the next five years, researchers plan to find ways to use starch from the entire plant.



Bioplastics: biobased PTT



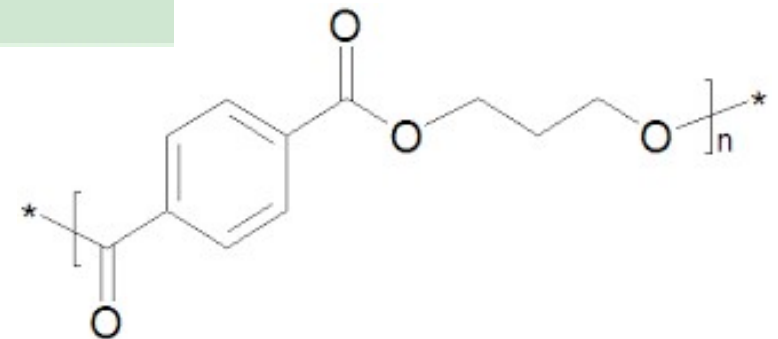
MOHAWK
SmartStrand
with DuPont Sorona® renewable content polymer

- Easy-care: Remarkable resistance to spots and soil
- Soft: Tender touches of supreme comfort
- Durable: Exceptional wear with long-lasting resiliency
- Eco-smart: Preserves limited natural resources

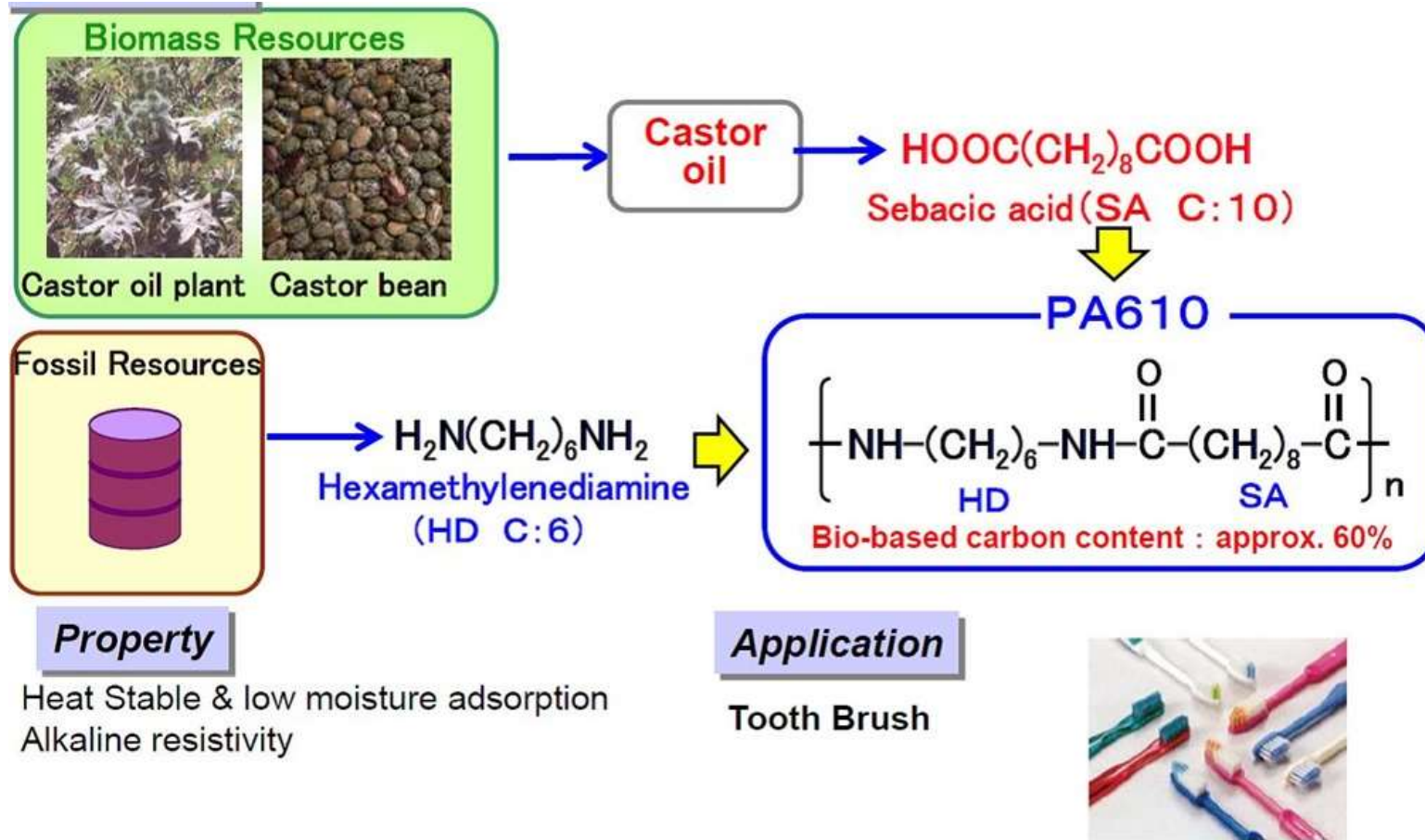
DUPONT



Don't worry. It's
SmartStrand
with DuPont Sorona® renewable content polymer



Bioplastics: biobased PA6,10



Bioplastics: biobased PAs



VESTAMID® Terra
High Performance Naturally

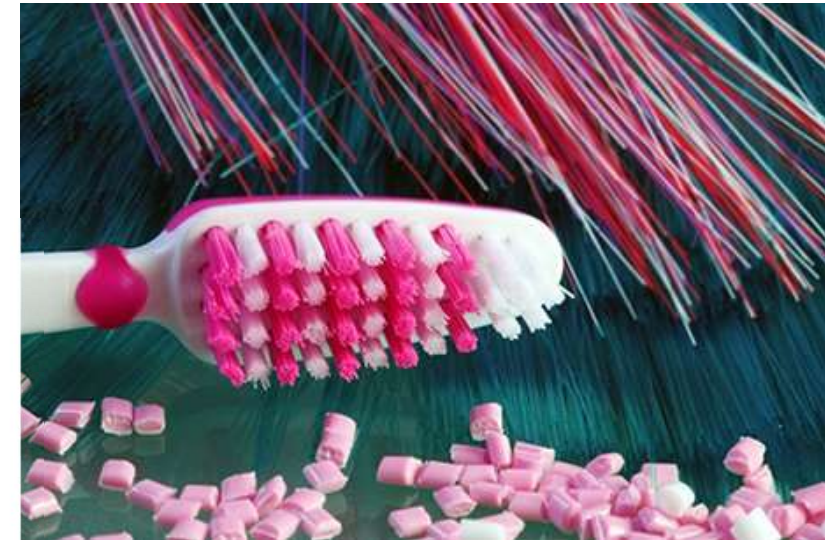


Technical biobased polyamides which achieve performance by natural means

VESTAMID® Terra DS (- PA1010) 100% renewable
VESTAMID® Terra HS (- PA610) 62% renewable
VESTAMID® Terra DD (- PA1012) 100% renewable

- Outstanding mechanical and physical properties
- Same performance as conventional engineering polyamides
- Significant lower CO₂ emission compared to petroleum-based polymers
- A wide variety of compound solutions are available

www.VESTAMID.com

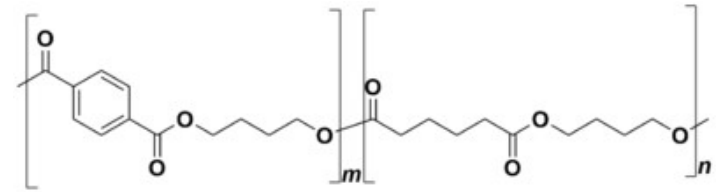


Evonik. Power to create.



Mit den fisher greenline Produkten ist fisher weltweit der erste Hersteller, der ein Sortiment an biobasierten Befestigungssystemen anbietet. Damit richten wir uns an Kunden, die während dem Bauen, Renovieren und Dekorieren auch beim Thema Befestigen großen Wert auf Nachhaltigkeit legen.

Bioplastics: compostable PBAT



Bioplastics: compostable PBAT



BASF has made a **fundamental breakthrough** in **plastics**



Bioplastics: compostable PBAT



European standard EN 13432,
Australian standard AS 4736



European standard
EN 13432



American standard
ASTM 6400



Japanese standard
GreenPla

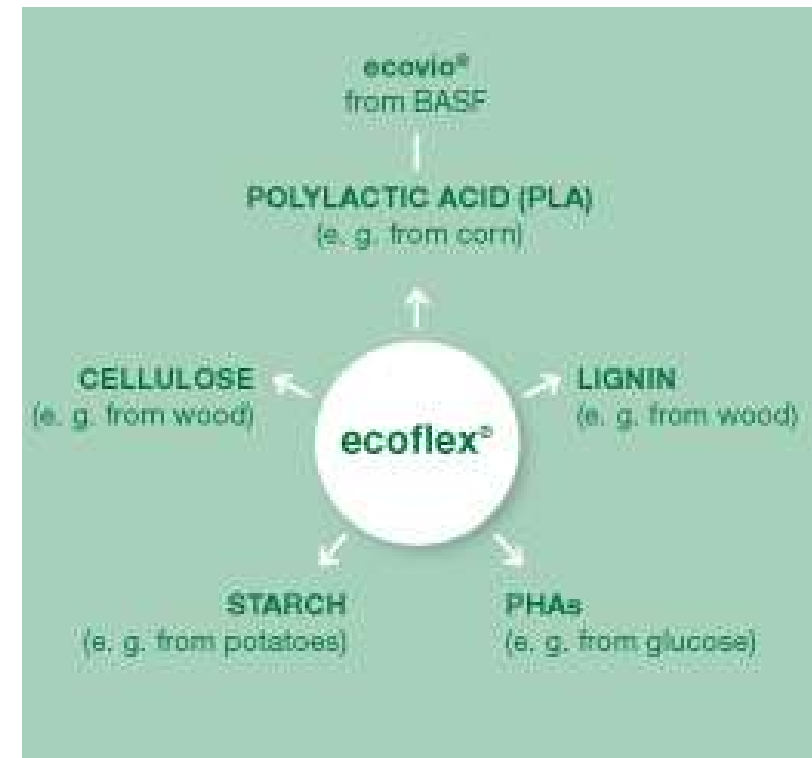


Home composting



Chinese standard
GB/T

Bioplastics: compostable PBAT



Bioplastics: compostable PBAT

ecoflex® and ecovio®



■ ecoflex®

- Based on fossil carbon
* partially renewable grades
- Compostable
- Compound Enabler for renewable materials

■ ecovio®

- ecoflex® and PLA Compound
- Compostable
- 10-75% Renewable Content
- Large range of properties and applications.

Original



2 weeks
composting

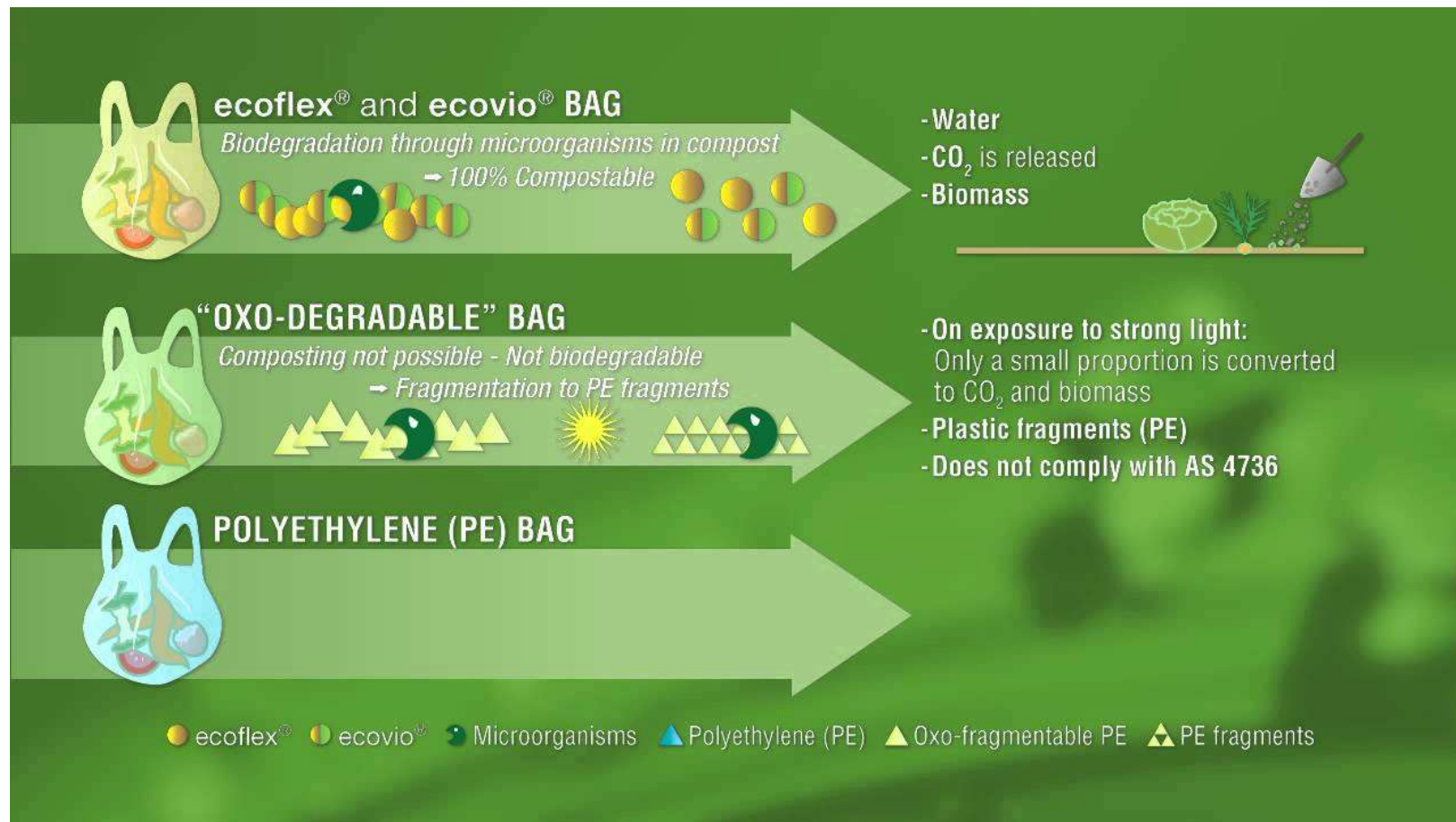


4 weeks
Composting

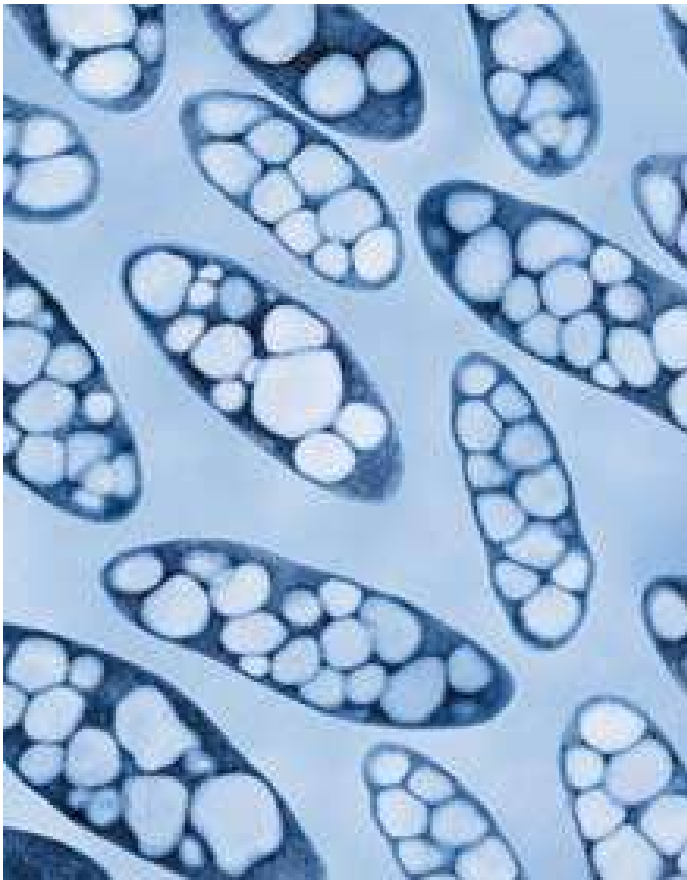


 **BASF**
We create chemistry

Bioplastics: compostable PBAT

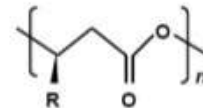


Bioplastics: biodegradable PHA



PHA

- Bioplastic from the family of polyesters (e.g. PET)
- Good moisture and gas barrier
- Excellent film forming and coating properties
- Good biodegradability



PHA

PHB
PHV
PHBV

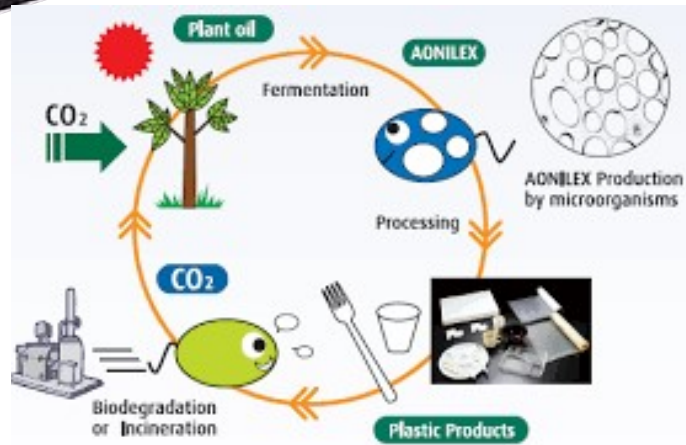
PHBHx
PHBO
PHBD
etc.

R group

-CH₃
-CH₂CH₃
-CH₃, -CH₂CH₃
-CH₃, -CH₂CH₂CH₃
-CH₃, -(CH₂)₄CH₃
-CH₃, -(CH₂)₆CH₃



Bioplastics: biodegradable PHA



Bioplastics: biodegradable PHA

KANEKA biopolymer
AONILEX®
 Bio-based biodegradable polymer

AONILEX is a novel biopolymer which has excellent biodegradability, flexibility, hydrolysis stability and heat resistance.

Life cycle of AONILEX
 AONILEX is produced by microorganisms in a specified fermentation condition using plant oils as the carbon source.

Certifications

	EUROPE	USA	CHINA
Biobased	✓	✓	Biobased or B
Compost	✓	✓	Certified by NTA (NEN-ISO 17088)
Biodegradable	✓	✓	Biodegradable or B
Sea Water	✓	✓	✓

Biodegradability
 AONILEX shows excellent biodegradability under aerobic, anaerobic, aquatic and composting conditions which proves to be an environmental-friendly plastic.

Microaerobic conditions

Anaerobic conditions

Aquatic conditions

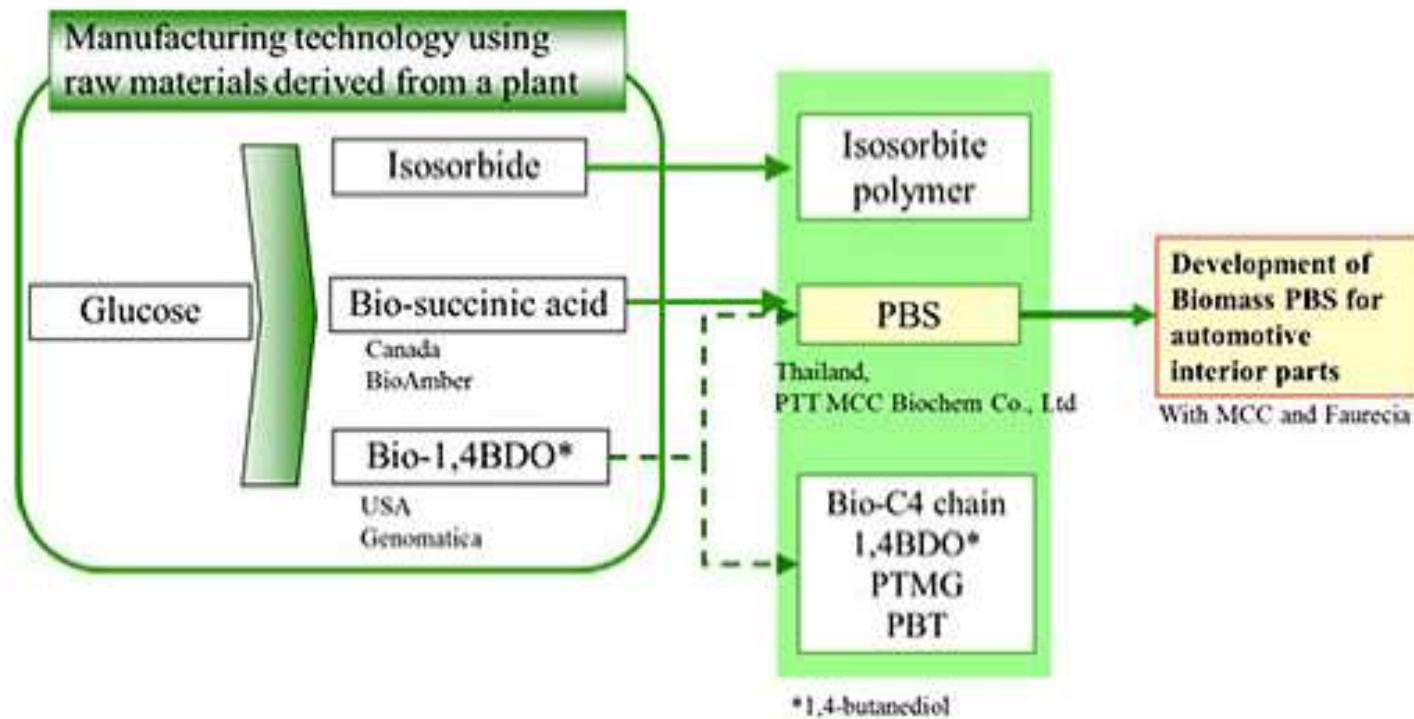
Composting conditions

KANEKA



Bioplastics: biodegradable PBS

About MCCs Sustainable Resource Business



PBS: The Lone Ranger of thermoplastics



It's tough. It performs. But it's biodegradable too. It leaves town when the job's done. A real bio-based silver bullet, kemosabe.

Reverdia, Wageningen UR Food & Biobased Research in hook-up to advance on biobased PBS.

Bioplastics: biodegradable PBS

BioPBS. RENEWABLE. BIODEGRADABLE.
THE EASY WAY TO CLEAN UP.



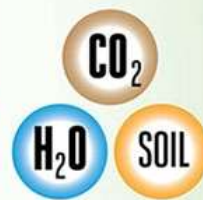
SUGAR CANE

BioPBS

MADE FROM SUGAR,
BioPBS IS RENEWABLE
AND BIODEGRADABLE.



But unlike most biodegradable plastics,
it degrades at room temperature. So there's
no need for special composting facilities.
It's an easy solution to a complex problem.



BioPBS™

Renewable . Ambient Compostable . FCN Approved

BioPBS™, solution for Compostable &
Recyclable paper cups!

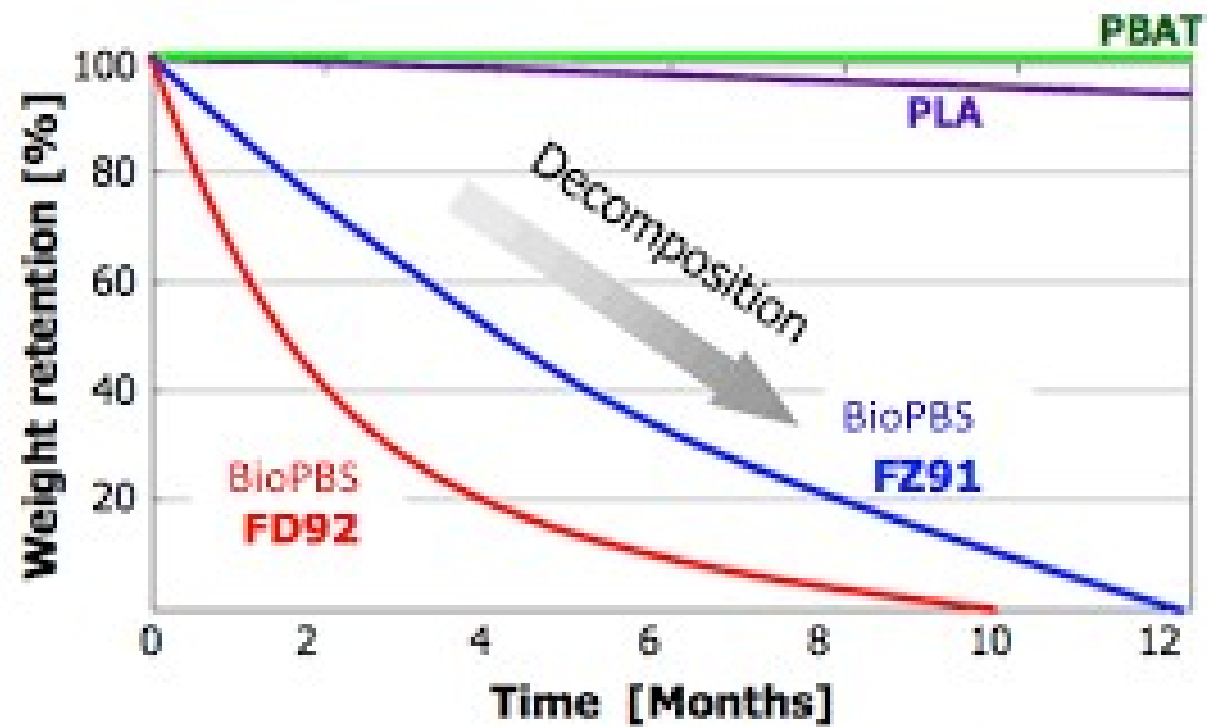
BioPBS coated paper samples
(1 side & 2 side coating) are
certified as recyclable by PTS
(Papiertechnische Stiftung)
according to PTS method
RH021/97



*Full certificates are available upon request

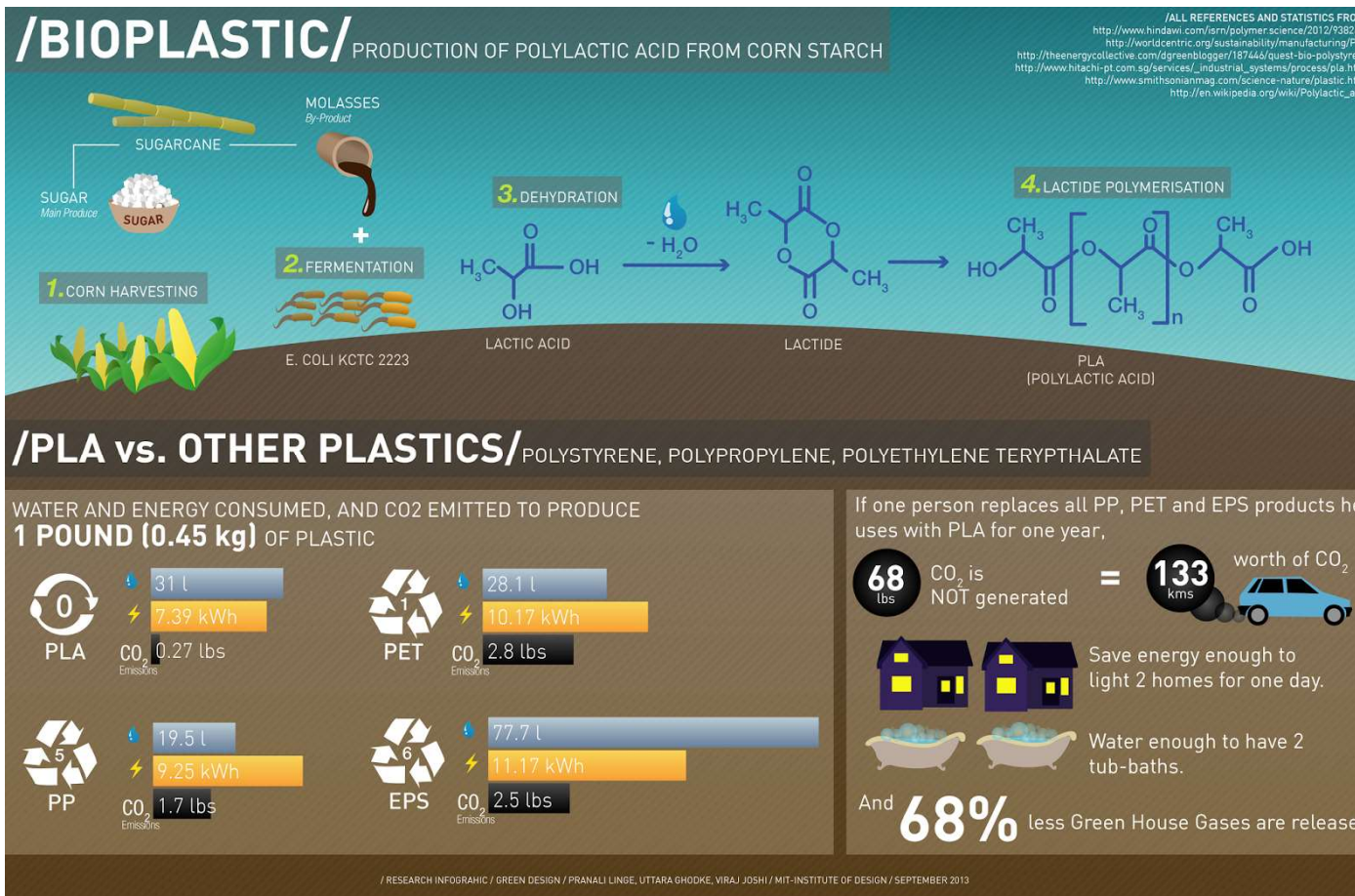


Bioplastics: biodegradable PBS

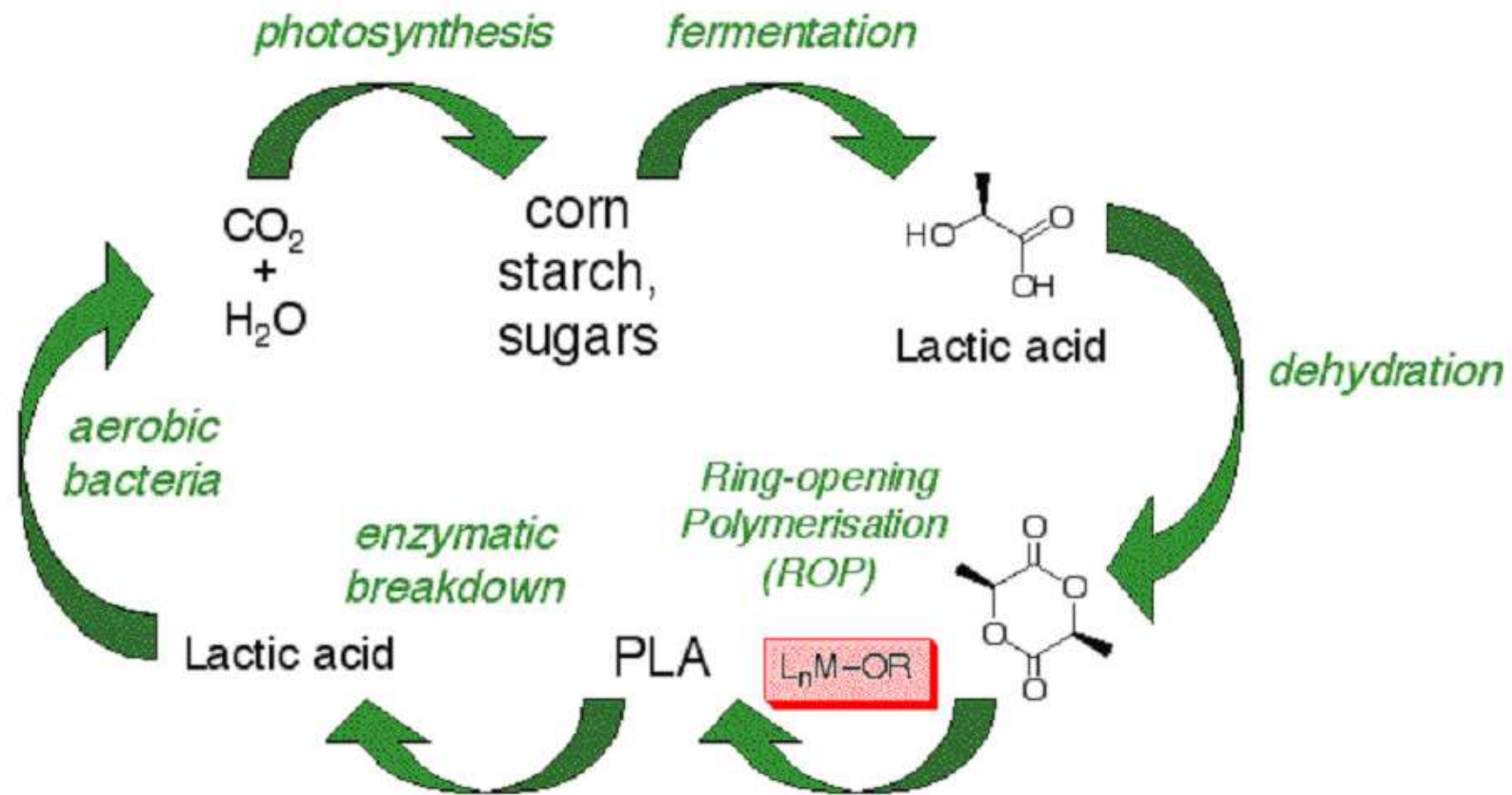


200 microns sheet sample in soil at 30°C/50%RH

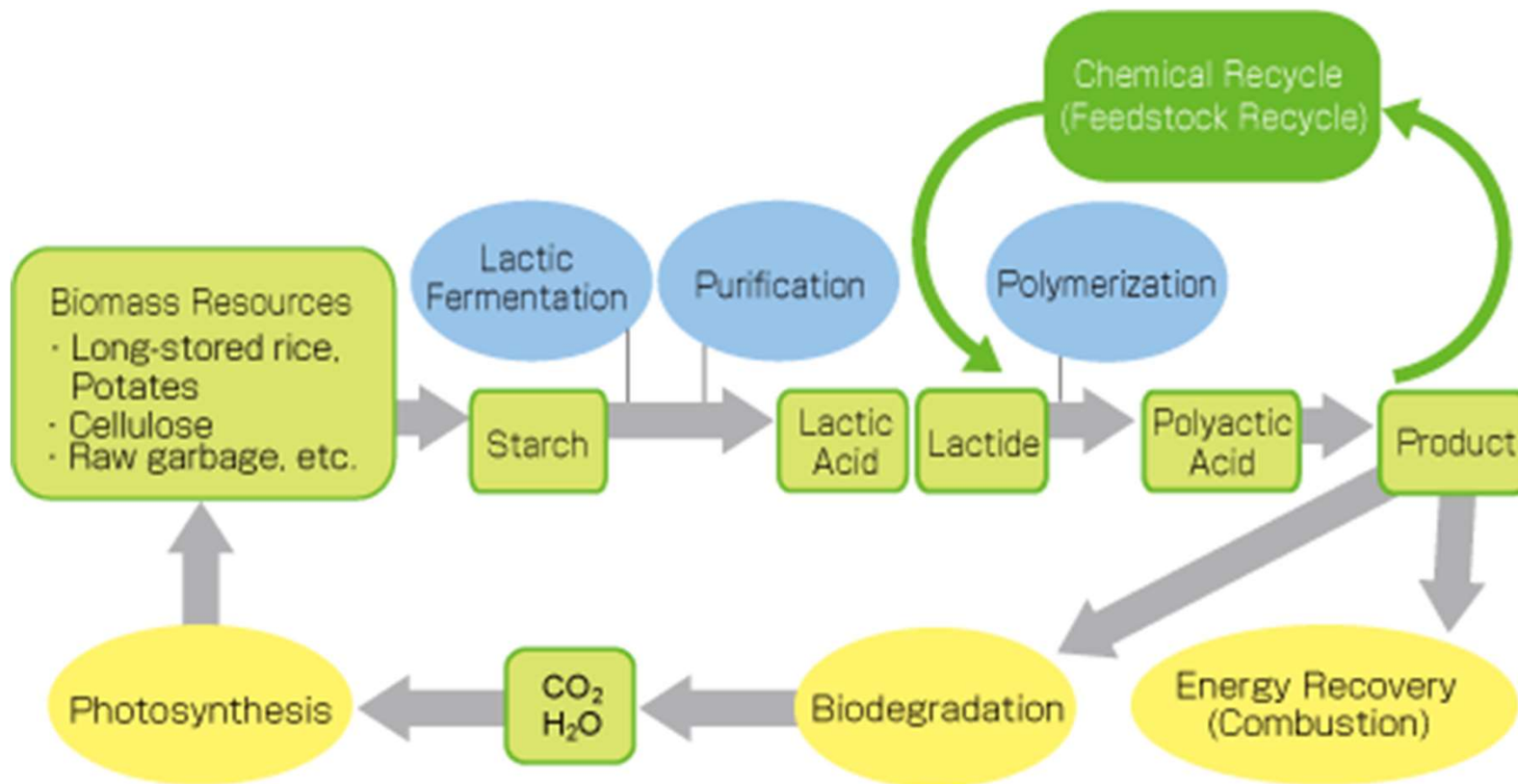
Bioplastics: compostable PLA



Bioplastics: compostable PLA



Bioplastics: compostable PLA



Bioplastics: compostable PLA



Bioplastics: compostable PLA



BOTTIGLIA ECO-SOSTENIBILE
Prima al mondo al mondo nel formato 1,5 l.

Sant'Anna[®]

sorgente Rebruant

Bio Bottle

NATURALE

L'unica al mondo che sparisce in soli 80 giorni (e l'ambiente ringrazia)*.

Dai vegetali arriva la prima bottiglia eco-sostenibile al 100%, la prima e unica al mondo nel formato 1,5 l.

Sant'Anna Bio Bottle è compostabile: mentre si conserva come le bottiglie di plastica tradizionale, si biodegrada completamente in 80 giorni negli appositi siti di compostaggio. Inoltre, a differenza delle plastiche più comuni, è riciclabile chimicamente: una Bio Bottle nuova nasce da una Bio Bottle usata, **senza usare petrolio e senza inquinare l'atmosfera**, 650 milioni di bottiglie Sant'Anna Bio Bottle permettono **un risparmio di 176.800 barili di petrolio con cui scaldare per un mese una città di 520.000 abitanti e riducono le emissioni di CO₂ pari a un'auto che compie il giro del mondo per 30.082 volte in un anno**. Per questo, oltre a scegliere un'acqua minerale naturale dalla riconosciuta, eccezionale leggerezza, con Sant'Anna Bio Bottle fai una scelta decisa in favore della sostenibilità dell'ambiente. Mettila nei contenitori per la raccolta differenziata della plastica: sarà compito degli enti preposti avviarla agli impianti di compostaggio industriale se disponibili.

Sant'Anna Bio Bottle. Plastica vegetale Ingeo™ al posto del petrolio.
Disponibile prossimamente nei formati da 0,5 e 1,5 l.

*nel formato 1,5 l biodegradabile in 80 giorni negli appositi siti di compostaggio industriale.