UNIVERSITÀ DEGLI STUDI DI MILANO
University of Milan

"BIOPLASTICS for food packaging: better biobased or biodegradable ?

Luciano Piergiovanni

PackLAB UNIMI Food Packaging Laboratory

DEFENS DEPARTMENT OF FOOD, ENVIRONMENTAL AND NUTRITIONAL SCIENCES

Organized by ISEKI - Food Association

European FooD-STA WEBINAR

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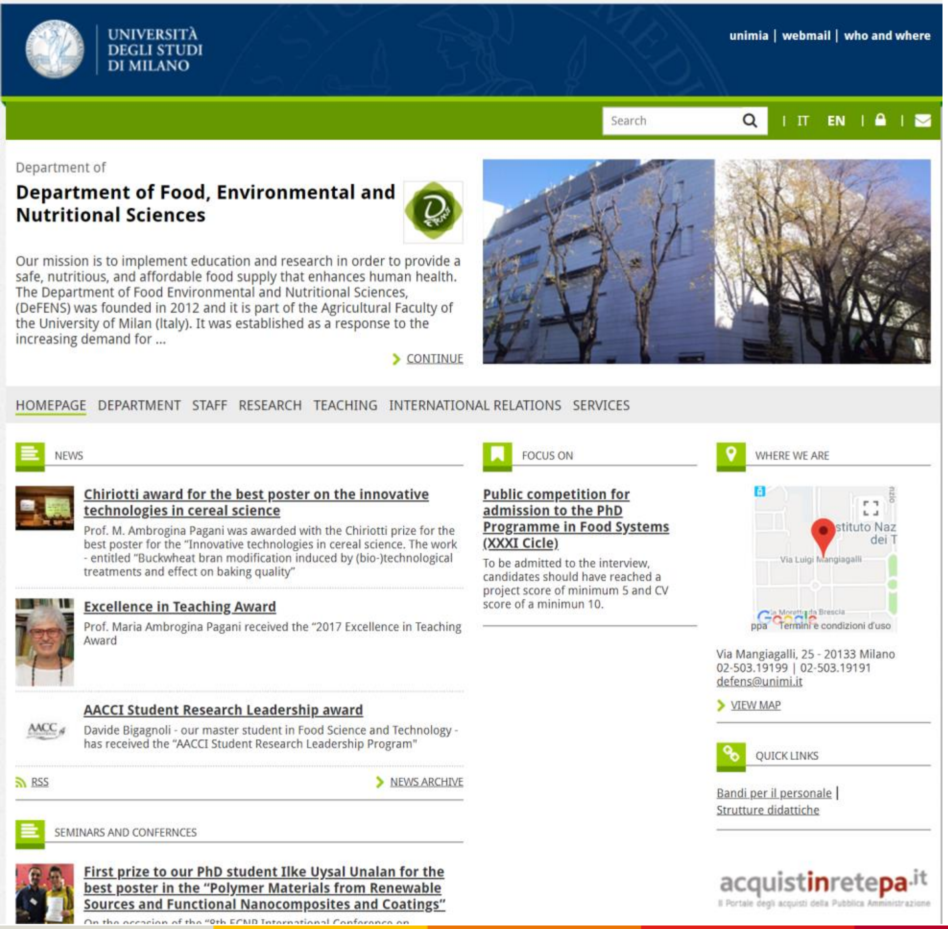

PackLAB
UNIMI Food Packaging Laboratory

Packlab is the only laboratory in the University of Milan exclusively devoted to food packaging science.

We are engaged in research, teaching and testing in the specialistic field of Food Packaging.

UN World Environment day 2018: «Beating plastic pollution»

UN environment

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UN ENVIRONMENT EVENT

World Environment Day 2018

5 June 2018
India

Overview

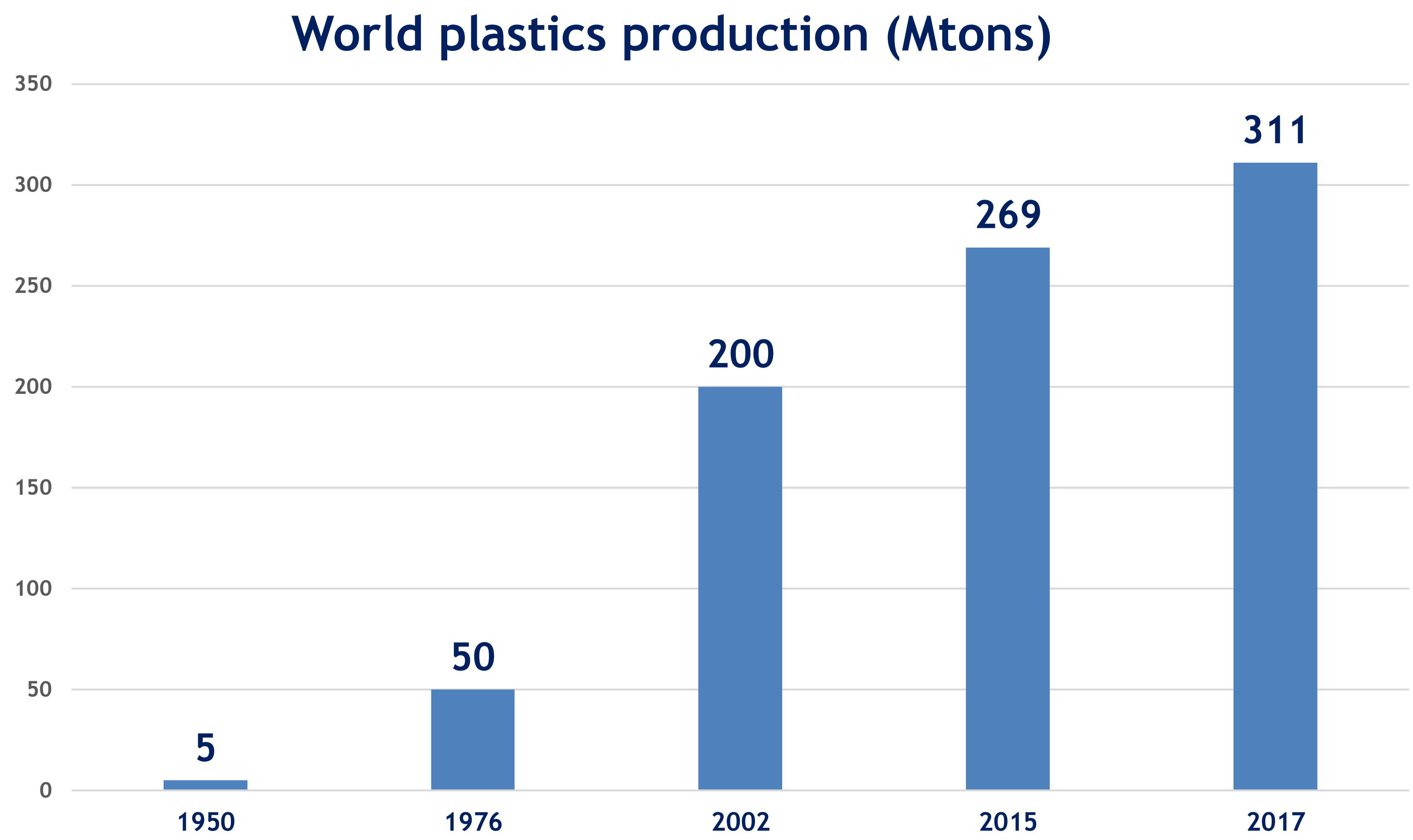
A Platform for Action World Environment Day is the UN's most important day for encouraging worldwide awareness and action for the protection of our environment. Since it began in 1974, it has grown to become a global platform for public outreach that is widely celebrated in over 100 countries.

The People's Day Above all, World Environment Day is the "people's day" for doing something to take care of the Earth. That "something" can be focused locally, nationally or globally; it can be a solo action or involve a crowd. Everyone is free to choose.

The Theme Each World Environment Day is organized around a theme that focuses attention on a particularly pressing environmental concern. The theme for 2018 is beating plastic pollution.

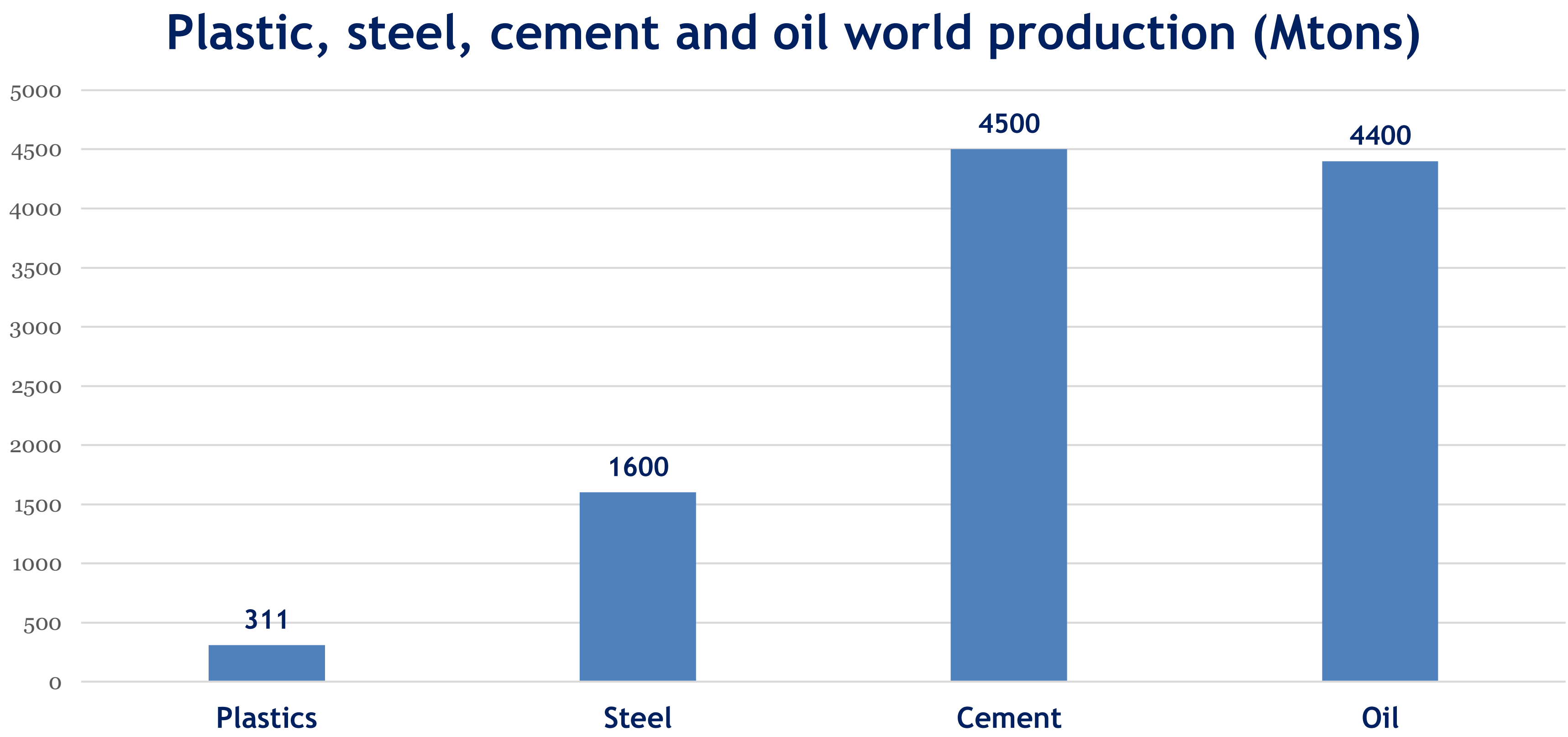
The Host Every World Environment Day has a different global host country, where the official celebrations take place. The focus on the host country helps highlight the environmental challenges it faces, and supports the effort to address them. This year's host is India.

World Plastics Production



Source: Statista, PlasticsEurope
[https://www.theguardian.com/environment/2017/jun/28/a-million-a-minute-worlds-plastic-bottle-binge-as-dangerous-as-climate-change]

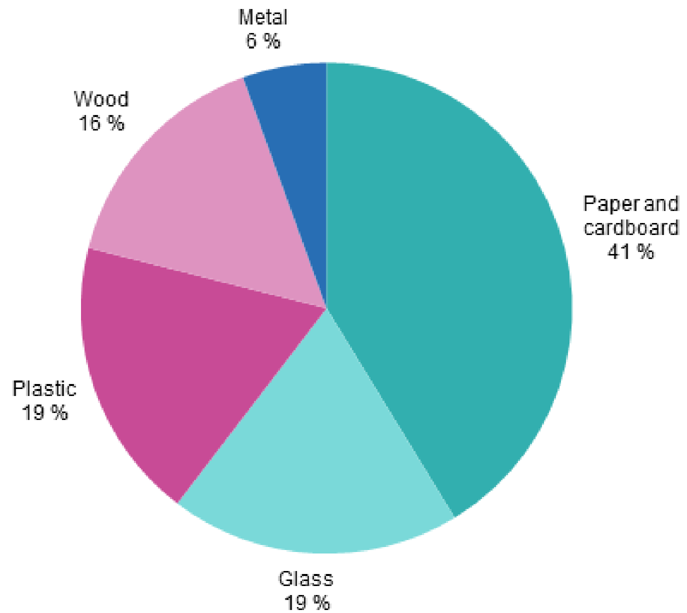
World Plastics Production



https://yearbook.enerdata.net/crude-oil/world-production-statitistics.html
https://www.cemnet.com/Publications/Item/176633/Global-cement-report-12.html

Facts and Figures

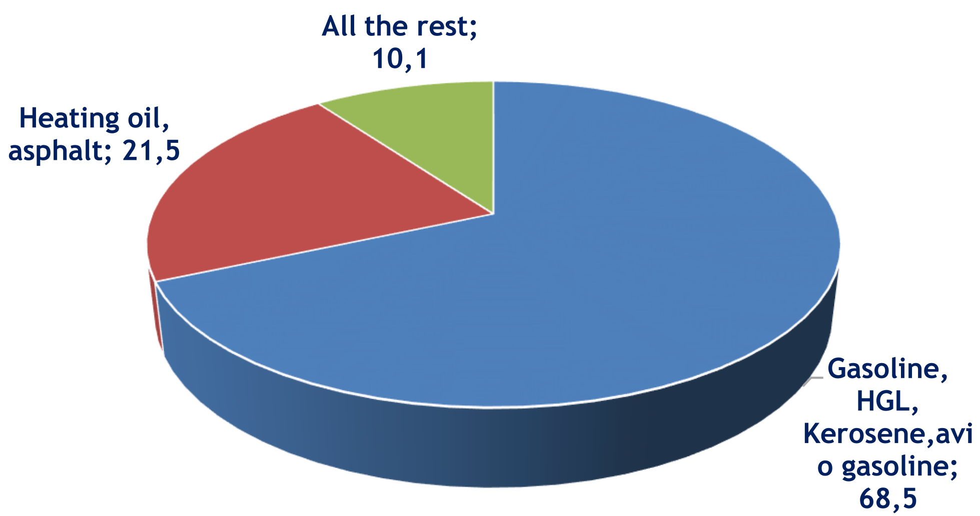
The packaging materials in Europe



Note: estimates for Romania (2012 data); and Ireland, Greece and Cyprus (2013 data)

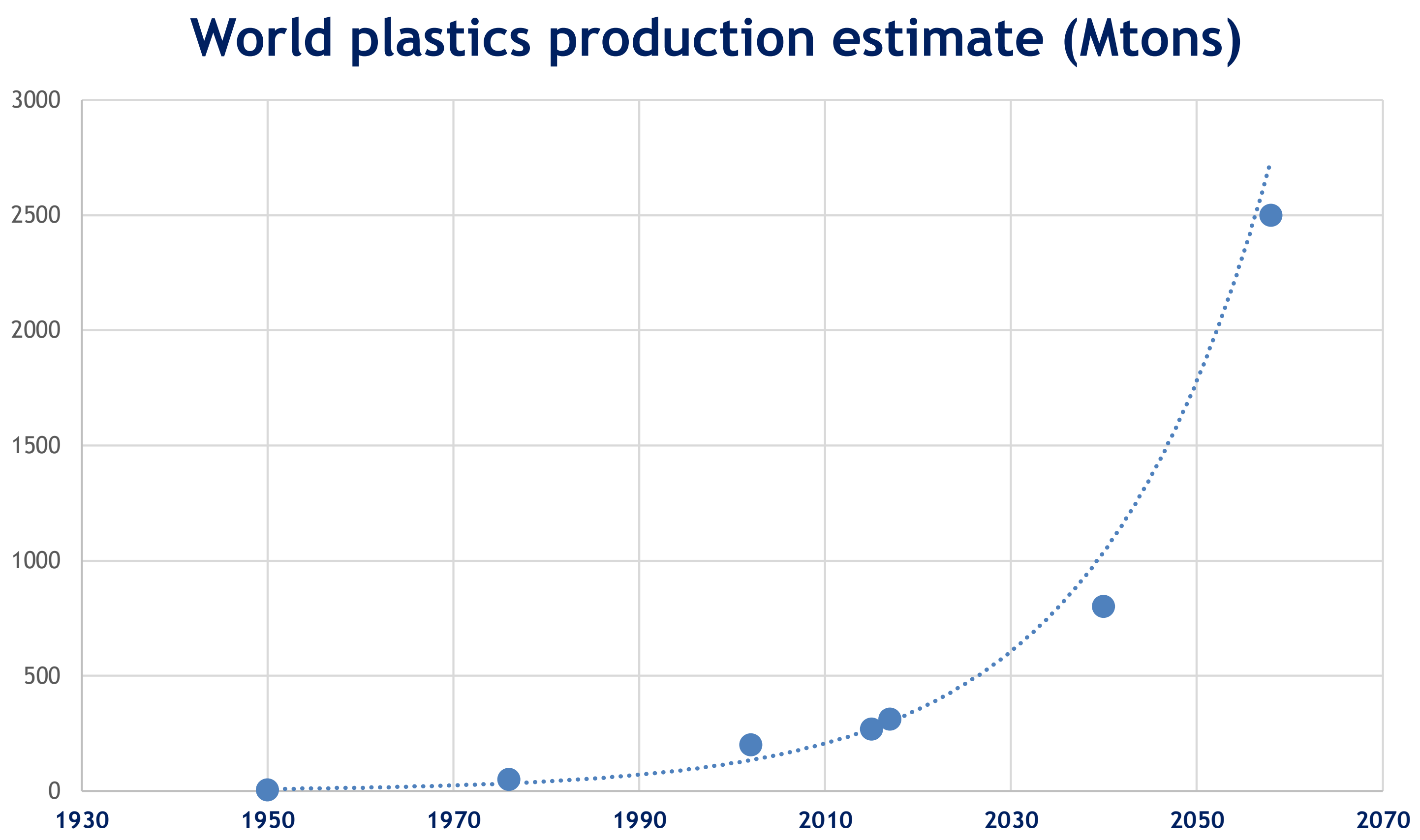
Source: CONAI
http://www.conai.org/en/

What are the petroleum products people consume most?



https://www.eia.gov/energyexplained/index.php?page=oil_use

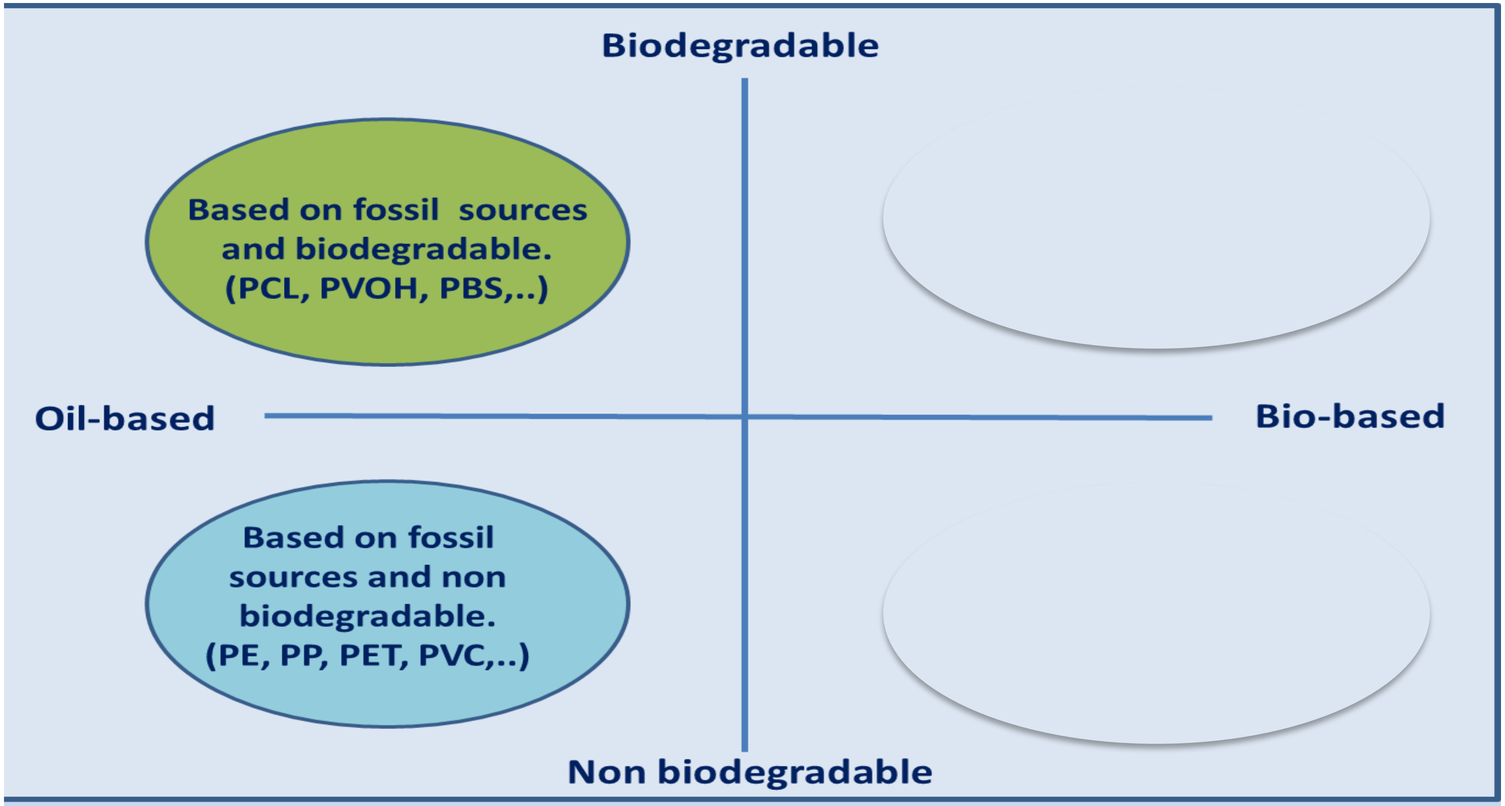
World Plastics Production



BIO vs non-BIO

It seems reasonable to think that problems posed by materials that originate from fossil resources and are obtained through chemical processes can be solved through a ***reversal of the conventional paradigm, a change in the model of reference*** Therefore looking for "BIO" solutions.

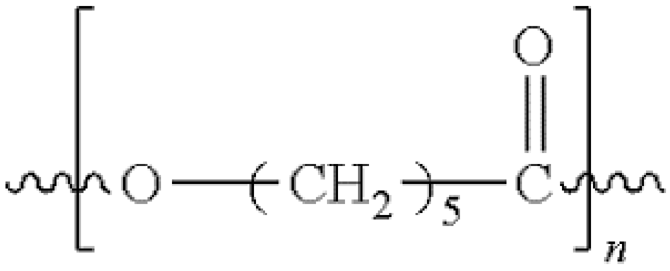
BIOPLASTICS



Bio-plastics are not a single kind of polymer but rather a family of materials that can vary considerably from one another. The term bio-plastics refers to materials which are **bio-based, biodegradable, or both**.

BIOPLASTICS

PCL: Polycaprolactone is a biodegradable polyester with a low melting point of around 60 ° C.
The most common use of PCL is in the manufacture of special polyurethanes, even adhesives.
It is oil-based but completely bio-degradable.



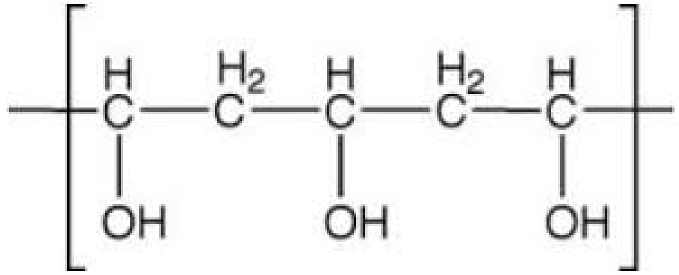
Biodegradability vs Compostability

Biodegradation is the process in which materials are metabolised to CO2, water, and biomass with the help of microorganisms, enzymes, living organisms. The process depends on the conditions (e.g. location, temperature, humidity, presence of microorganisms, etc.) of the specific environment (industrial composting plant, garden compost, soil, water, etc.) and on the material or application itself.
Biodegradability is a feature of the material and the process of biodegradation can vary considerably, according to the media.

Compostability is a characteristic of a product that ***allows it to biodegrade under specific conditions*** (e.g. a certain temperature, timeframe, etc). These specific conditions are described in standards, such as the European standard on industrial composting EN 13432 (for packaging) or EN 14995 (for plastic materials in general).

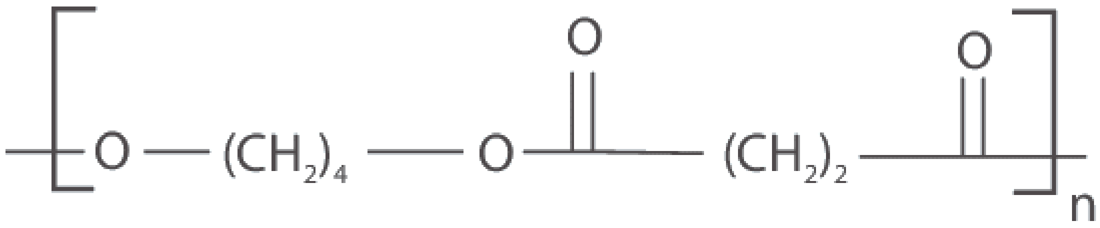
BIOPLASTICS

PVOH: Poly(vinyl alcohol) (PVOH, PVA, or PVAl) is a water-soluble synthetic polymer. It is used in papermaking, textiles, and a variety of coatings.
It offers a very high oxygen barrier if maintained dry.
It is oil-based but completely bio-degradable.

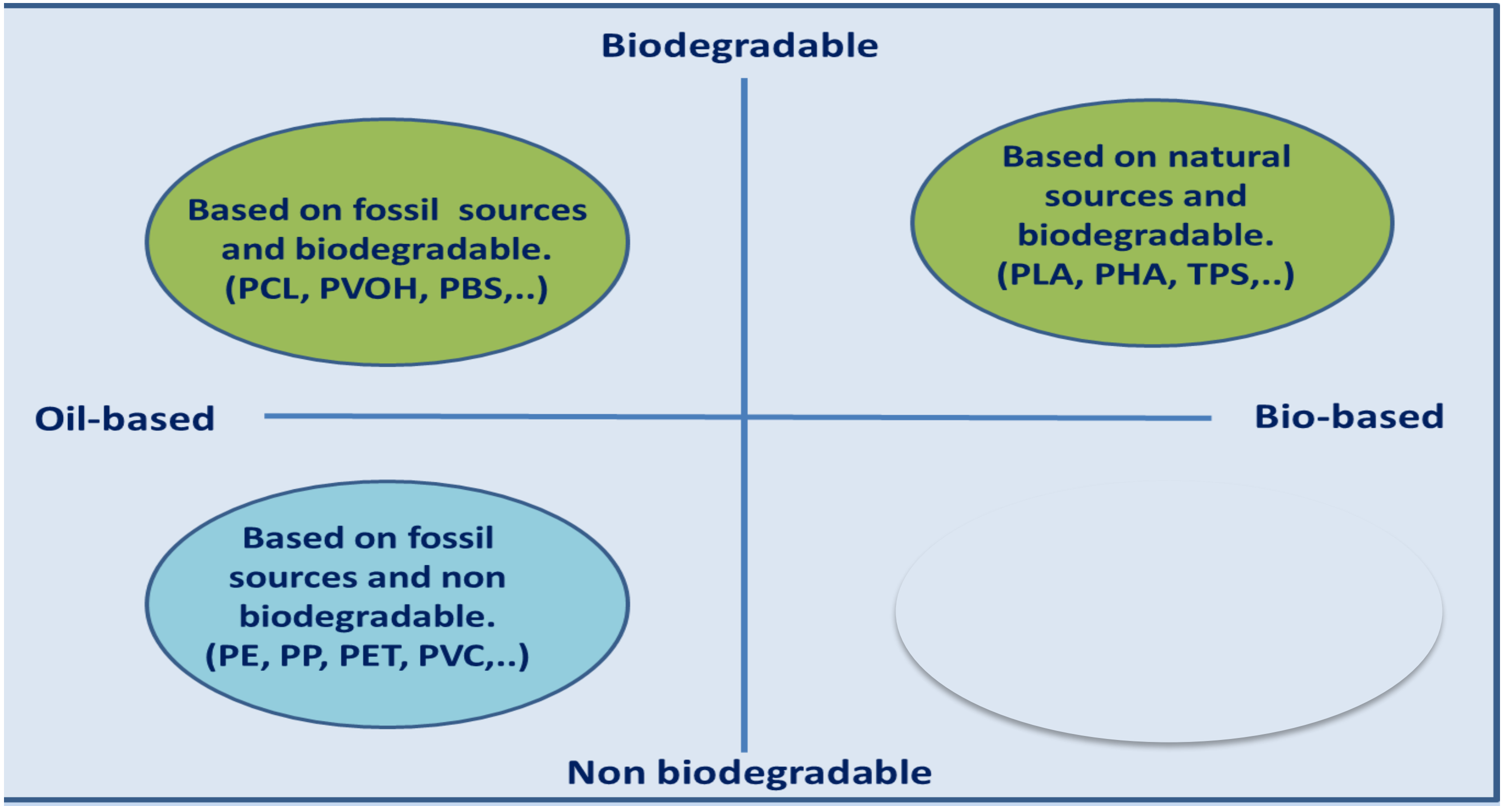


BIOPLASTICS

PBS: Polybutylene succinate is a thermoplastic polymer with properties that are comparable to polypropylene.
It is oil-based but completely bio-degradable.
Nowadays, new technologies are available to obtain PBS from biomasses.



BIOPLASTICS



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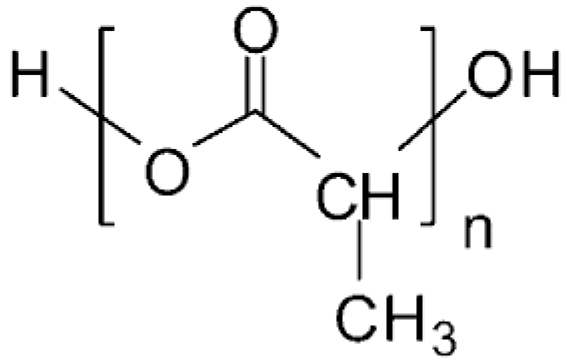
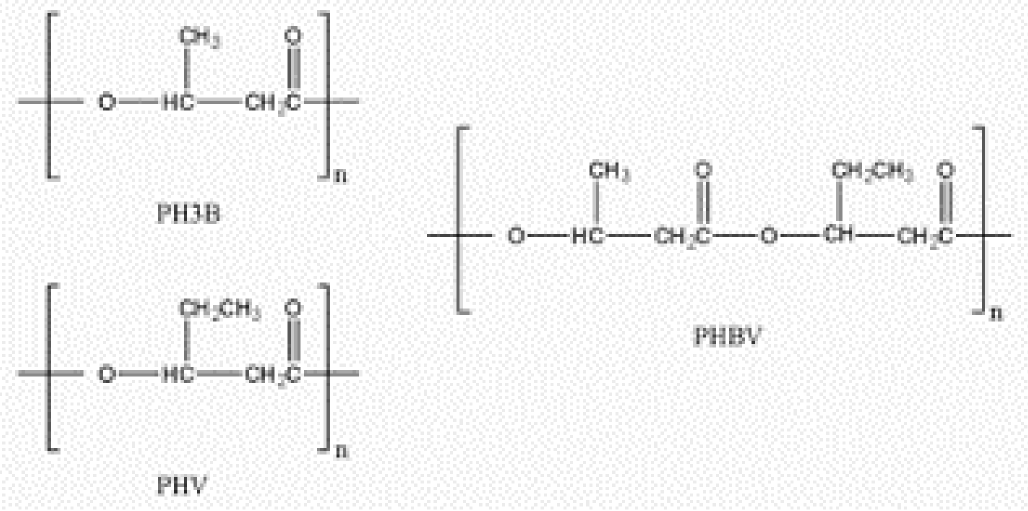
BIOPLASTICS

PLA: polylactic acid or polylactide is a biodegradable thermoplastic polyester derived from corn starch, cassava roots, or sugarcane. The most common route to PLA is the ring-opening polymerization of **lactide** with various metal catalysts in solution, in the melt, or as a suspension.



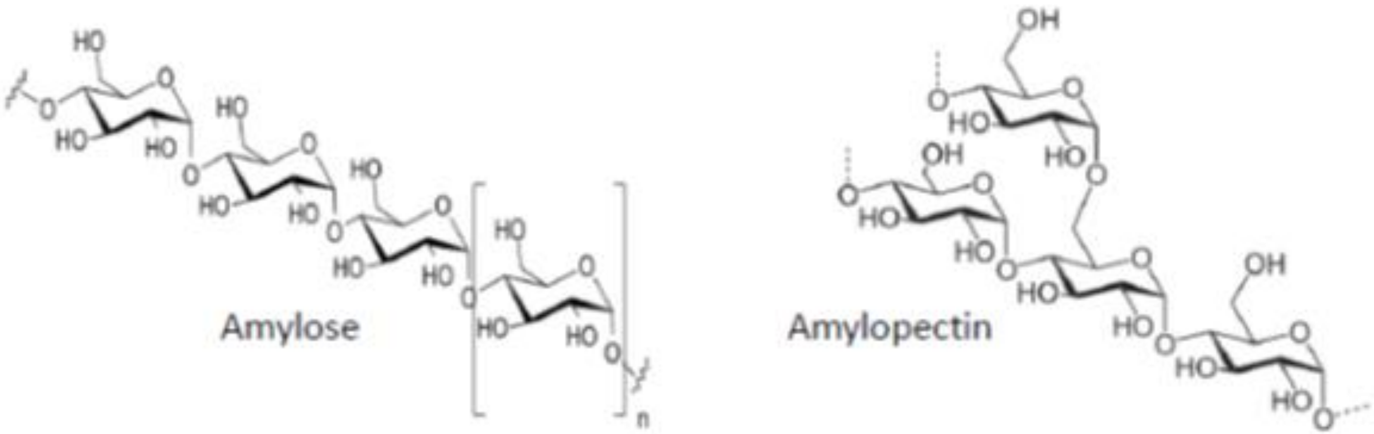
BIOPLASTICS

PHA: Polyhydroxyalkanoates are polyesters produced through bacterial fermentation of sugar or lipids. More than 150 different monomers are known with extremely different properties, but always biodegradable.

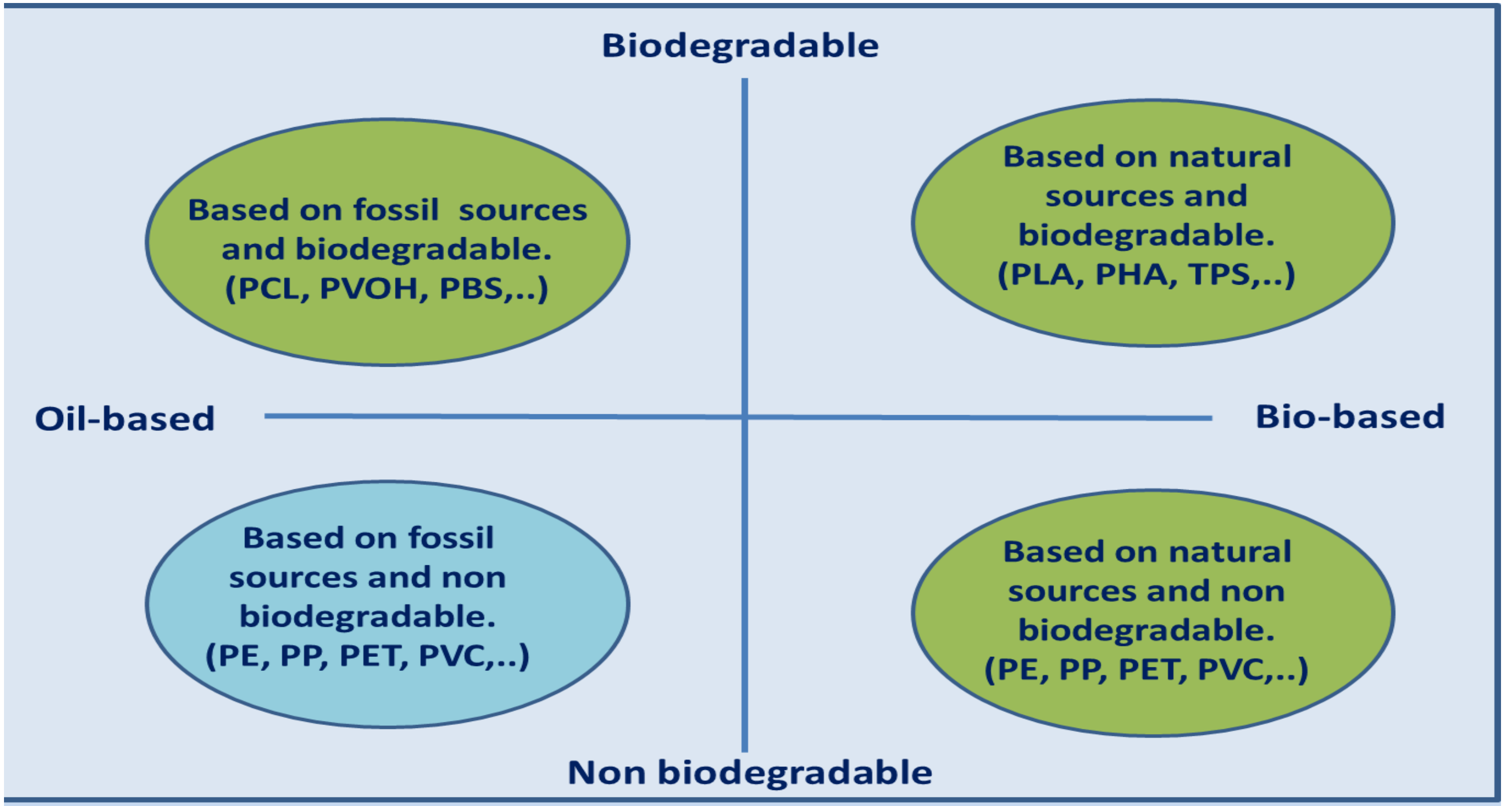


BIOPLASTICS

TPS: Thermo-plastic starch. The characteristics of TPS bio-plastics can be tailored to specific needs by adjusting the amounts of plasticiser such as sorbitol and glycerine. Starch-based bioplastics are often blended with PLA or PHA.



BIOPLASTICS



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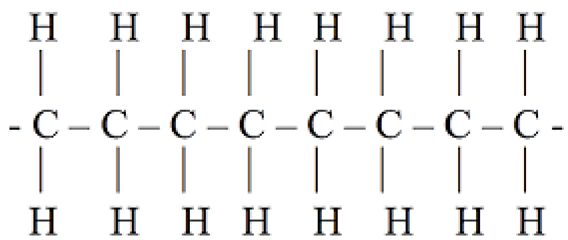
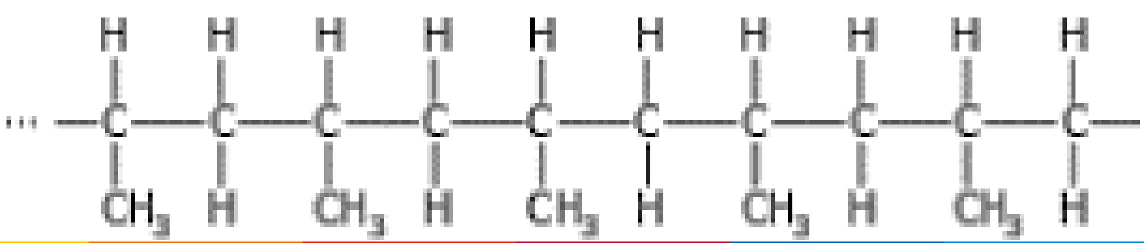
BIOPLASTICS

Bio-PE: Ethylene is obtained by the catalytic dehydratation of bio-ethanol, followed by normal polymerizations.

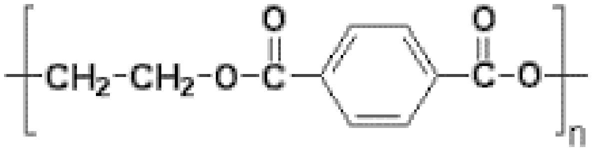


Bio-PP: the ethylene obtained from bio-ethanol is dimerized to produce n-butene. The n-butene is then reacted with the ethylene to produce bio-PP. A similar production route is possible using butanol from sugar fermentation.

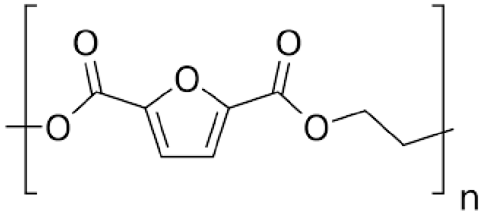


BIOPLASTICS

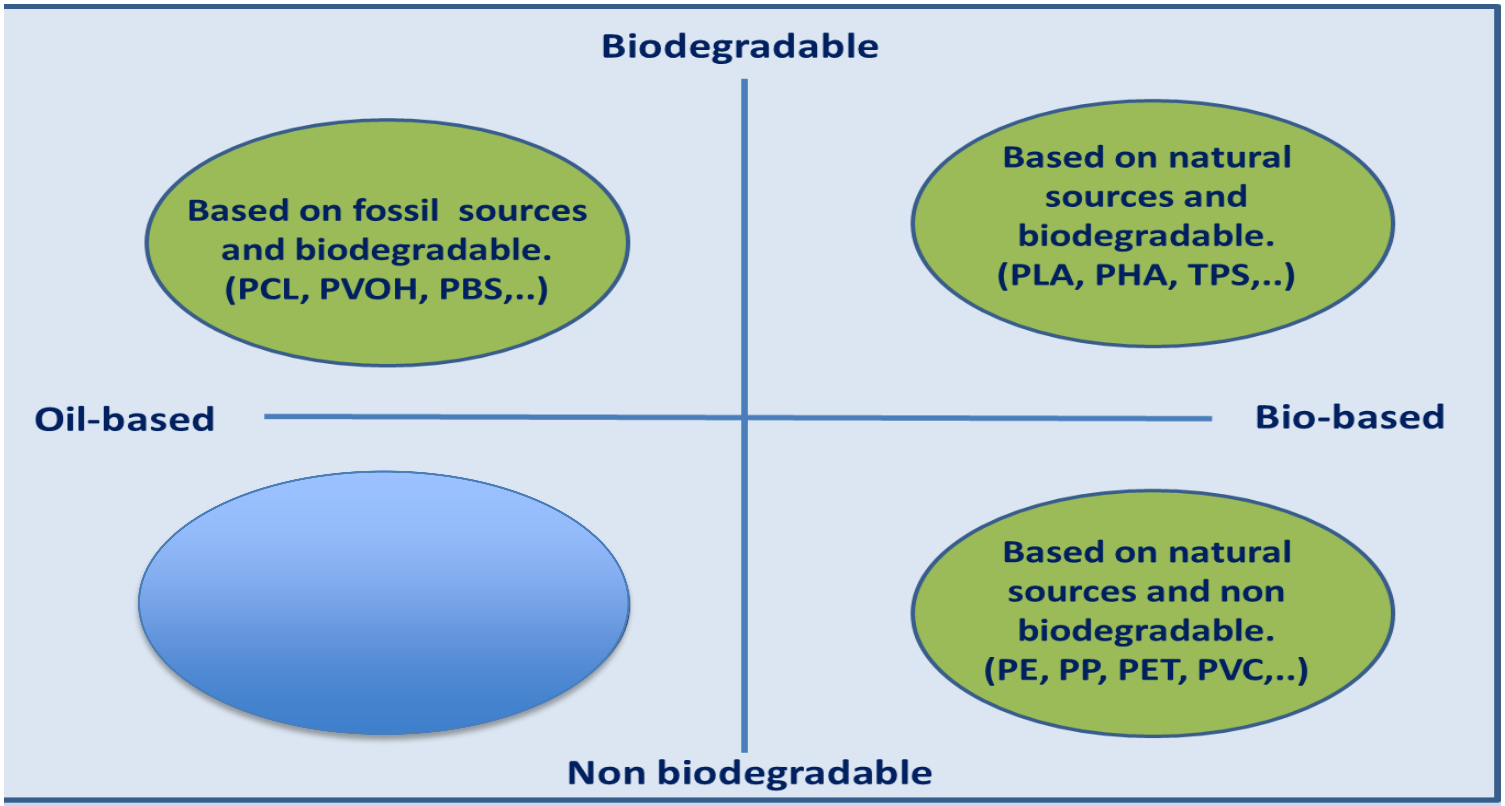
Bio-PET: Bio-ethylene glycol is already produced from bio-ethanol; Bio-para xylene (precursor of therephtalic acid) might be produced, by **pre-commercial technologies**, converting biomasses into para xylene or muconic acids to obtain bio-therephtalic acid



Bio-PEF: a new bio-based not biodegradable polyester (polyethylene furanoate) can be obtained converting fructose into 2,5-furan dicarboxylic acid that can be polymerized to PEF, by reaction with bio ethylene glycol



BIOPLASTICS



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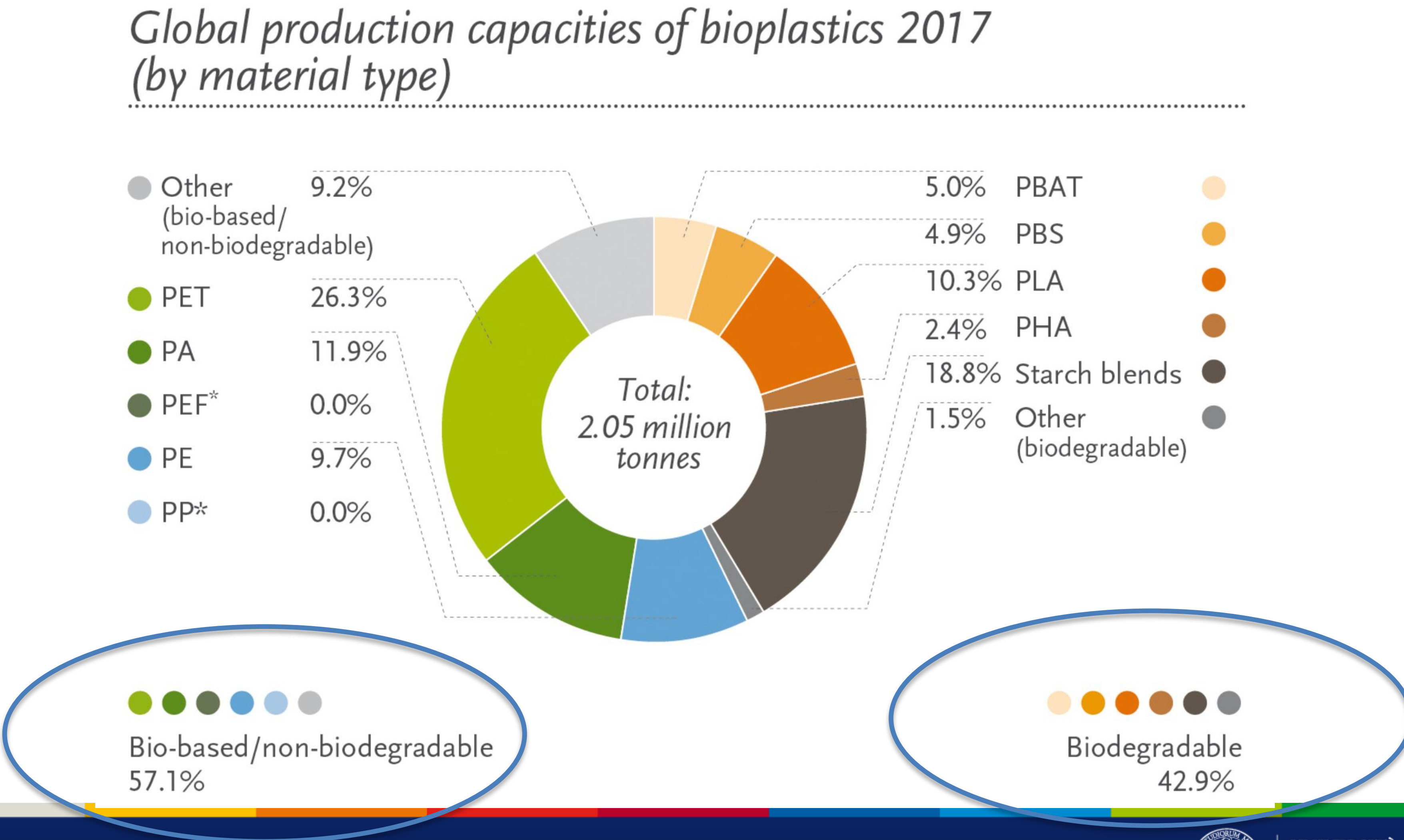
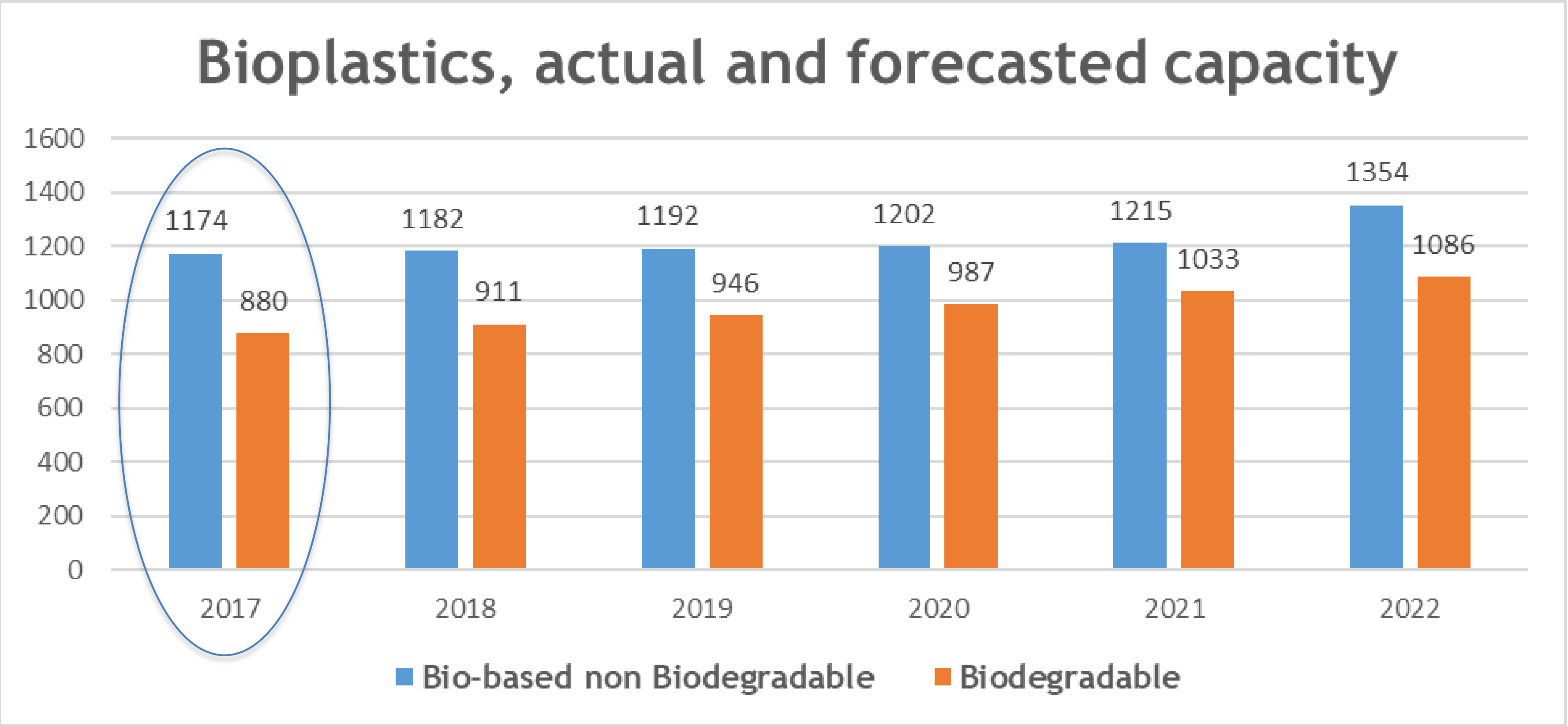
Biodegradable vs Bio-based



Source: European Bioplastics – nova institute
http://www.european-bioplastics.org/market/

Biodegradable vs Bio-based



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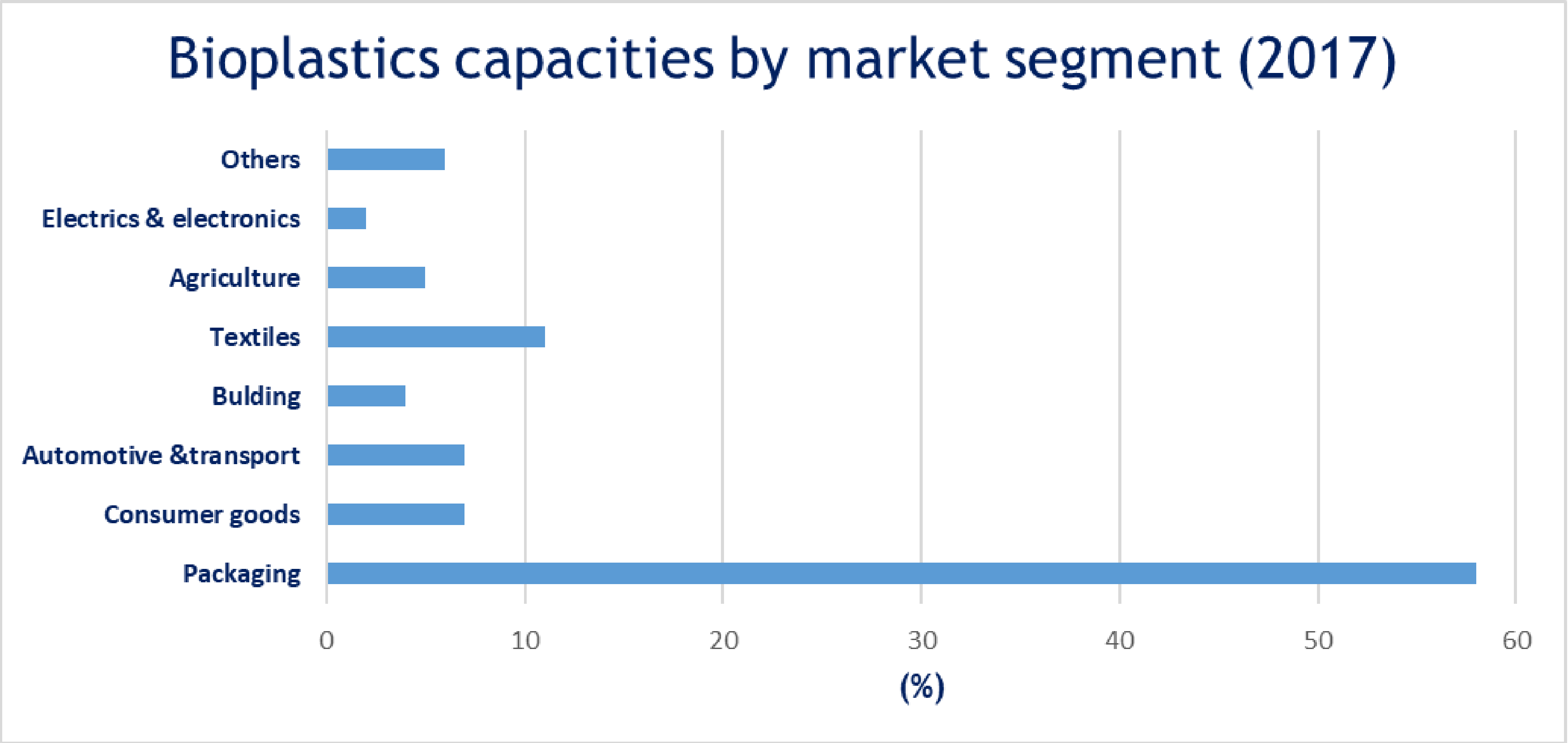
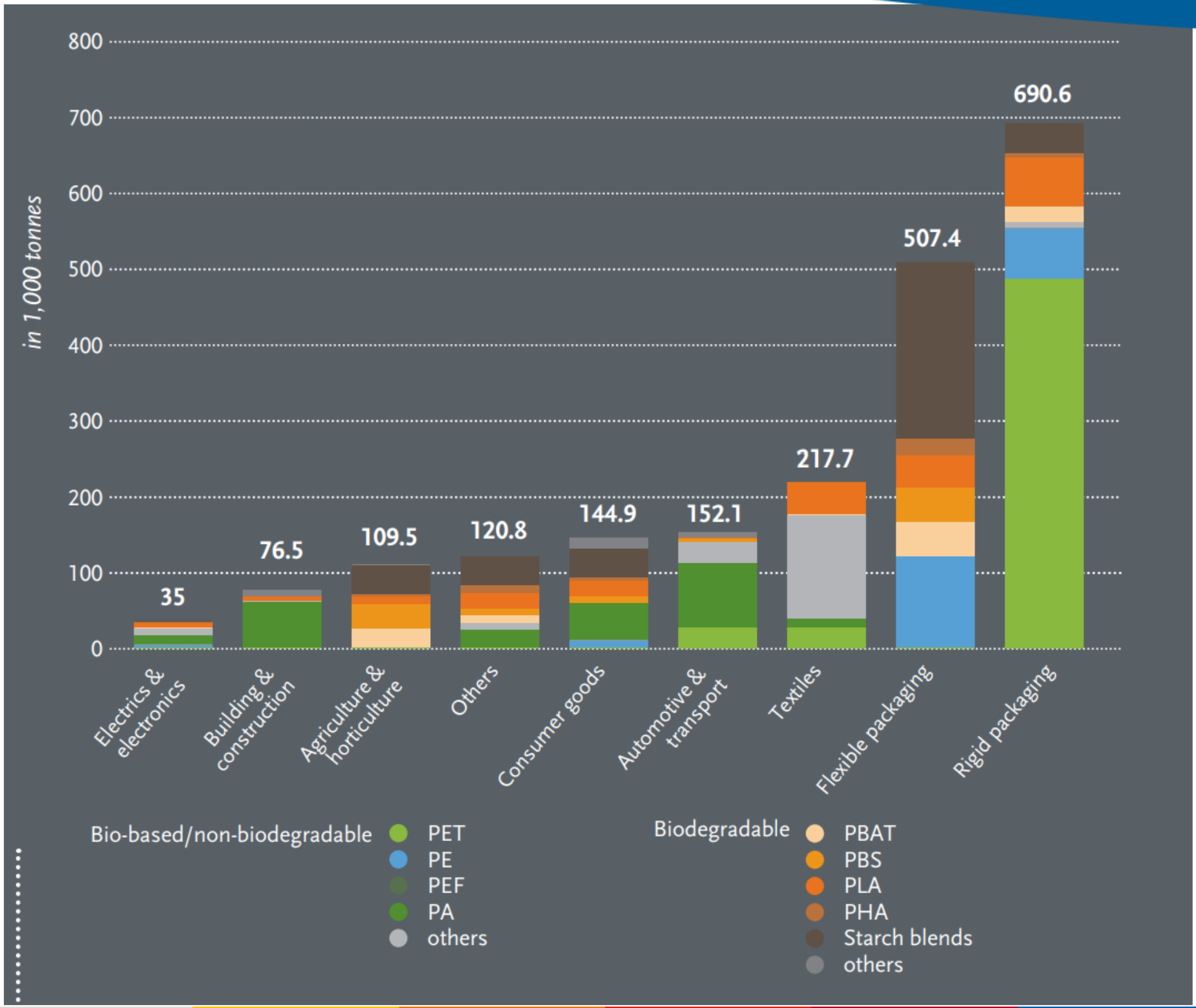
Biodegradable vs Bio-based



Biodegradable vs Bio-based



About 690 tons (mainly of Bio-PE and Bio-PET) over 1200 tons of Bioplastics for flexible and rigid packaging. Around 58%

Source: European Bioplastics – nova institute
http://www.european-bioplastics.org/market/

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Biodegradable vs Bio-based

It seems that the Packaging sector is already addressed toward Bio-based non biodegradable bioplastics, instead of biodegradable materials.

Why ?

- **Biodegradable bioplastics are more expensive and less performing.**

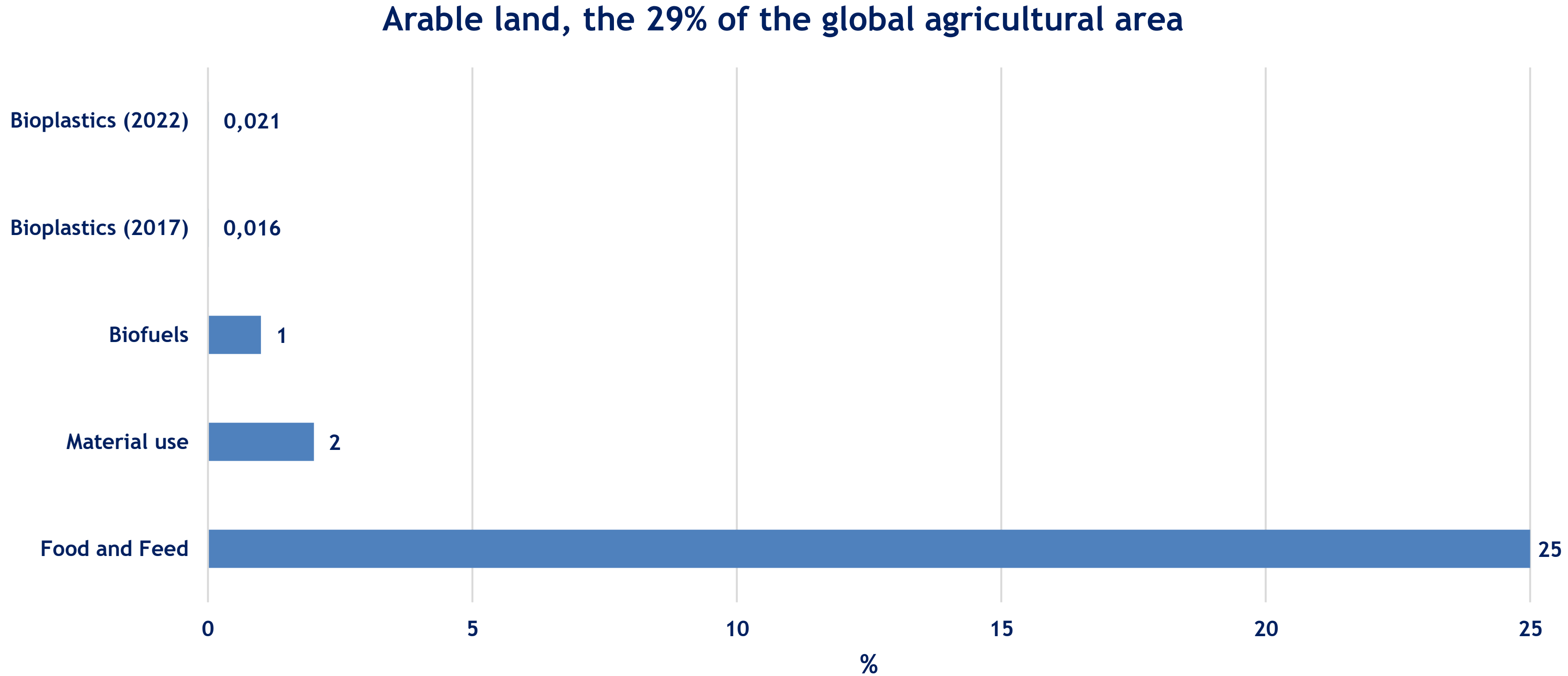
Biodegradable vs Bio-based

Why ?

- Biodegradability is not always the best choice for food products….
- Disposable problems, doubts about the landfill capacity…
- Converting a solid material to a gas via composting is considered not really sustainable, being much better to recycle or recover the feedstock energy…
- Bio-based non biodegradable bioplastics can make energy recovery more attractive because of their almost complete carbon neutrality; *a zero carbon footprint, refers to achieving net zero carbon emissions by balancing amount of carbon released with an equivalent amount sequestered or offset*.

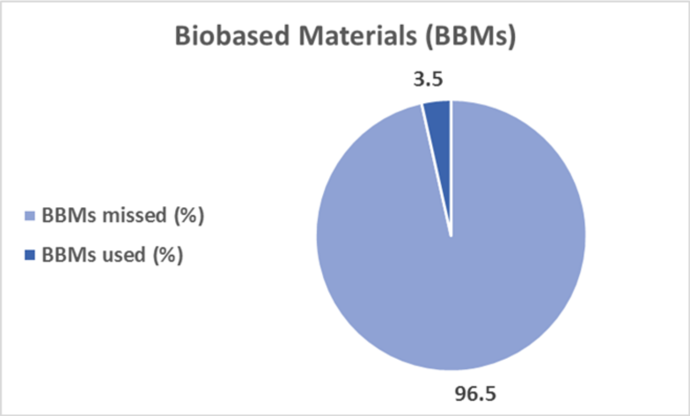
Bio-based instead of food?

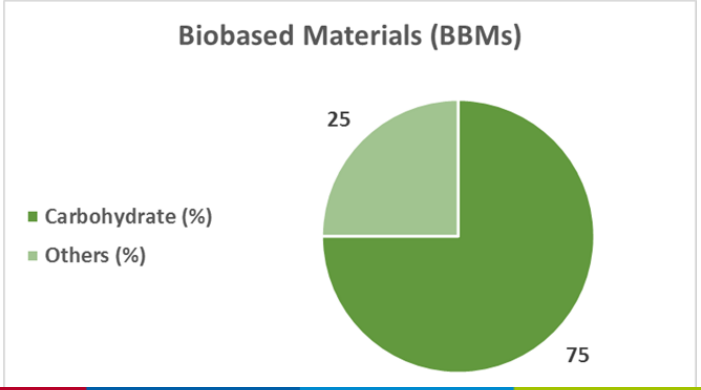
One more controversial topic, in fact, deals with the use of land to produce bioplastics (and bio-fuels) instead of foods



Bio-based instead of food?

According to UNEP's findings, 5 billion tons of waste agricultural biomass is generated every year.
Cellulose amount in the agricultural biomass waste ranges from 32% to about 43%:
ALMOST 2 BILLION TONS OF CELLULOSE ARE AVAILABLE EVERY YEAR FROM AGRICULTURAL WASTE ONLY





Bio-based products

Bio-based products have been properly defined by various Institutions. According to the **European Committee for Standardizations (CEN) they are:**

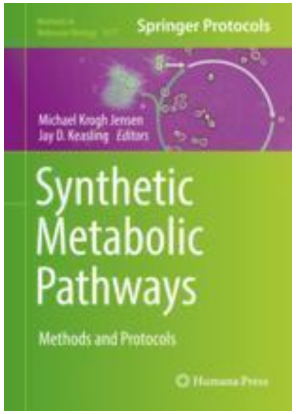
"Products that are wholly or partly derived from ***biomass****: material of biological origin, such as from trees, plants or animals.*

The biomass may have undergone some kind of physical, chemical or biological treatment before being turned into a product.

Bio-based products can be either material, intermediate, semi-finished or final products"

Bio-based products for innovative and sustainable food packaging

May 2018

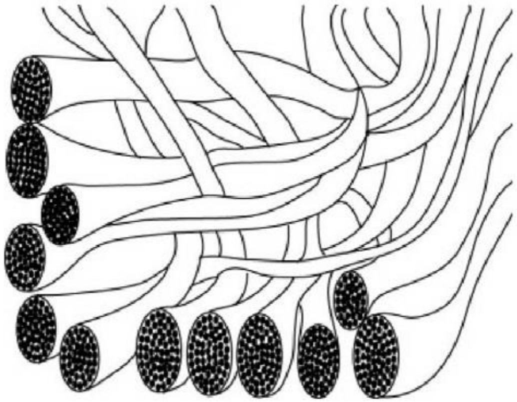


Computational Methods to Assess the Production Potential of Bio-Based Chemicals

ABSTRACT: Elevated costs and long implementation times of bio-based processes for producing chemicals represent a bottleneck for moving to a bio-based economy. A prospective analysis able to elucidate economically and technically feasible product targets at early research phases is mandatory. **Computational tools can be implemented to explore the biological and technical spectrum of feasibility**, while constraining the operational space for desired chemicals. In this chapter, **two different computational tools for assessing potential for bio-based production of chemicals from different perspectives** are described in detail.

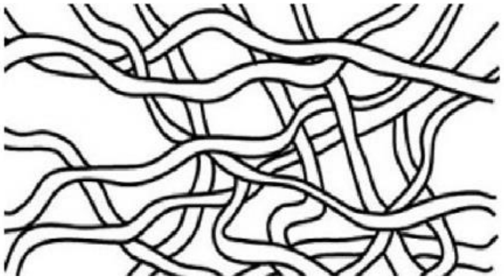
From Cellulose to nano-cellulose

Adequate fragmentation of native fibers and fibrils of cellulose leads to cellulose nanoparticles (CNs) whose properties may be really interesting for packaging applications; their use as possible mechanical reinforcement and for a gas barrier enhancement has been largely investigated

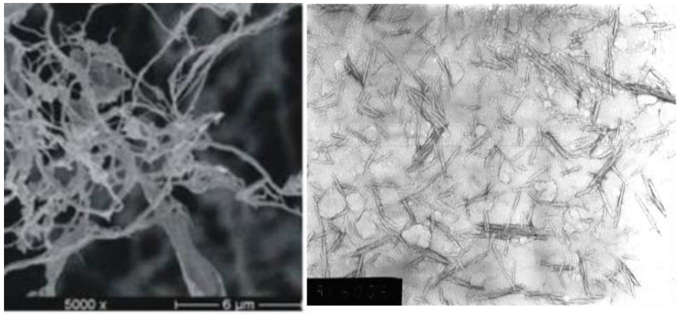


Single fiber network

Cell. Nanocrystals (CNC)

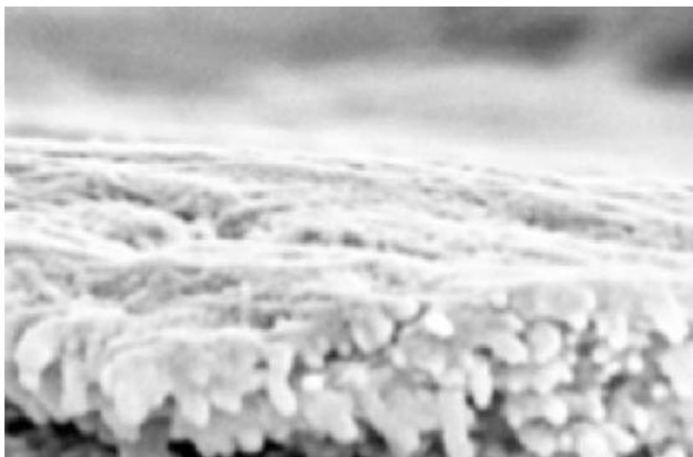


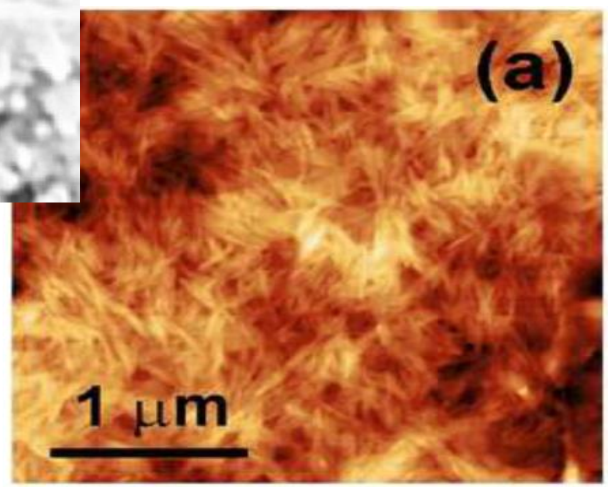
Nanofibrillated Cell. (CNF)



Bio-based products for innovative and sustainable food packaging

- ◊ poly(ethylene terephthalate) PET, 12 ± 0.5 μm
- ◊ oriented polypropylene OPP, 20 ± 0.5 μm
- ◊ oriented polyamide OPA, 12 ± 0.5 μm
- ◊ cellophane 12 ± 0.5 μm





Bio-based products for innovative and sustainable food packaging

Packaging Technology and Science
An International Journal
PACKAGING TECHNOLOGY AND SCIENCE
Packag. Technol. Sci. (2015)
Published online in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/pts.2121

The Potential of NanoCellulose in the Packaging Field: A Review

By Fei Li, Erika Mascheroni and Luciano Piergiovanni*

Packaging Technology and Science
An International Journal
PACKAGING TECHNOLOGY AND SCIENCE
Packag. Technol. Sci. 2017;
Published online in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/pts.2308

Cellulose Nanocrystals from Lignocellulosic Raw Materials, for Oxygen Barrier Coatings on Food Packaging Films

By Riccardo Rampazzo,[1,3†] Derya Alkan,[1†] Stefano Gazzotti,[2,3] Marco A. Ortenzi,[2,3] Giulio Piva[4] and Luciano Piergiovanni[1,3]*

Cellulose (2013) 20:2491–2504
DOI 10.1007/s10570-013-0015-3
ORIGINAL PAPER

Multi-functional coating of cellulose nanocrystals for flexible packaging applications

Fei Li · Paolo Biagioni · Monica Bollani · Andrea Maccagnan · Luciano Piergiovanni

Contents lists available at ScienceDirect
European Polymer Journal
journal homepage: www.elsevier.com/locate/europolj
ELSEVIER
Macromolecular Nanotechnology

Polylactide/cellulose nanocrystals: The *in situ* polymerization approach to improved nanocomposites

Stefano Gazzotti[a,b], Hermes Farina[a,b], Giordano Lesma[a,b], Riccardo Rampazzo[a], Luciano Piergiovanni[b,c], Marco Aldo Ortenzi[a,b,*], Alessandra Silvani[a,b]

polymers
MDPI
Article

The Effect of Moisture on Cellulose Nanocrystals Intended as a High Gas Barrier Coating on Flexible Packaging Materials

Ghislain Fotie [1], Riccardo Rampazzo [2,3], Marco Aldo Ortenzi [2,3], Stefano Checchia [2,3,4], Dimitrios Fessas [1,3] and Luciano Piergiovanni [1,3,*]

Cellulose (2016) 23:779–793
DOI 10.1007/s10570-015-0853-2
ORIGINAL PAPER

Comparison of cellulose nanocrystals obtained by sulfuric acid hydrolysis and ammonium persulfate, to be used as coating on flexible food-packaging materials

Erika Mascheroni · Riccardo Rampazzo · Marco Aldo Ortenzi · Giulio Piva · Simone Bonetti · Luciano Piergiovanni

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Thanks for your attention !

Mon, June 11, 2018 9:00 AM CEST

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