WORKSHOP

Residual Biomasses for Eco-compatible and Sustainable Food Packaging

BIOBASED AND SUSTAINABLE FOOD PACKAGING

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Outline

- Fossil plastics and biobased plastic materials for packaging
- Biobased materials
- Recycle, biodegradation and compostability
- Biobased materials market analysis
- Biobased compostable and biodegradable materials for food packaging
- Future perspectives

Biobased and natural polymers

Polymers partecipate to everyday life since prehistorical ages

- **As food**: polysaccharides, proteins
- **As clothes**: wool, cotton, silk,
- **As building materials**: wood, cellulose

Only recently (less than 200 years) the structure of polymers has been understood, and scientists are able to controll synthesis and therefore tailor the properties (thermal, mechanical etc.) of biobased polymeric materials

Plastic materials for packaging

A big plastics market segment is occupied by packaging:

- Rigid packaging (bottle, box, tray)
- Soft packaging (films, lids)

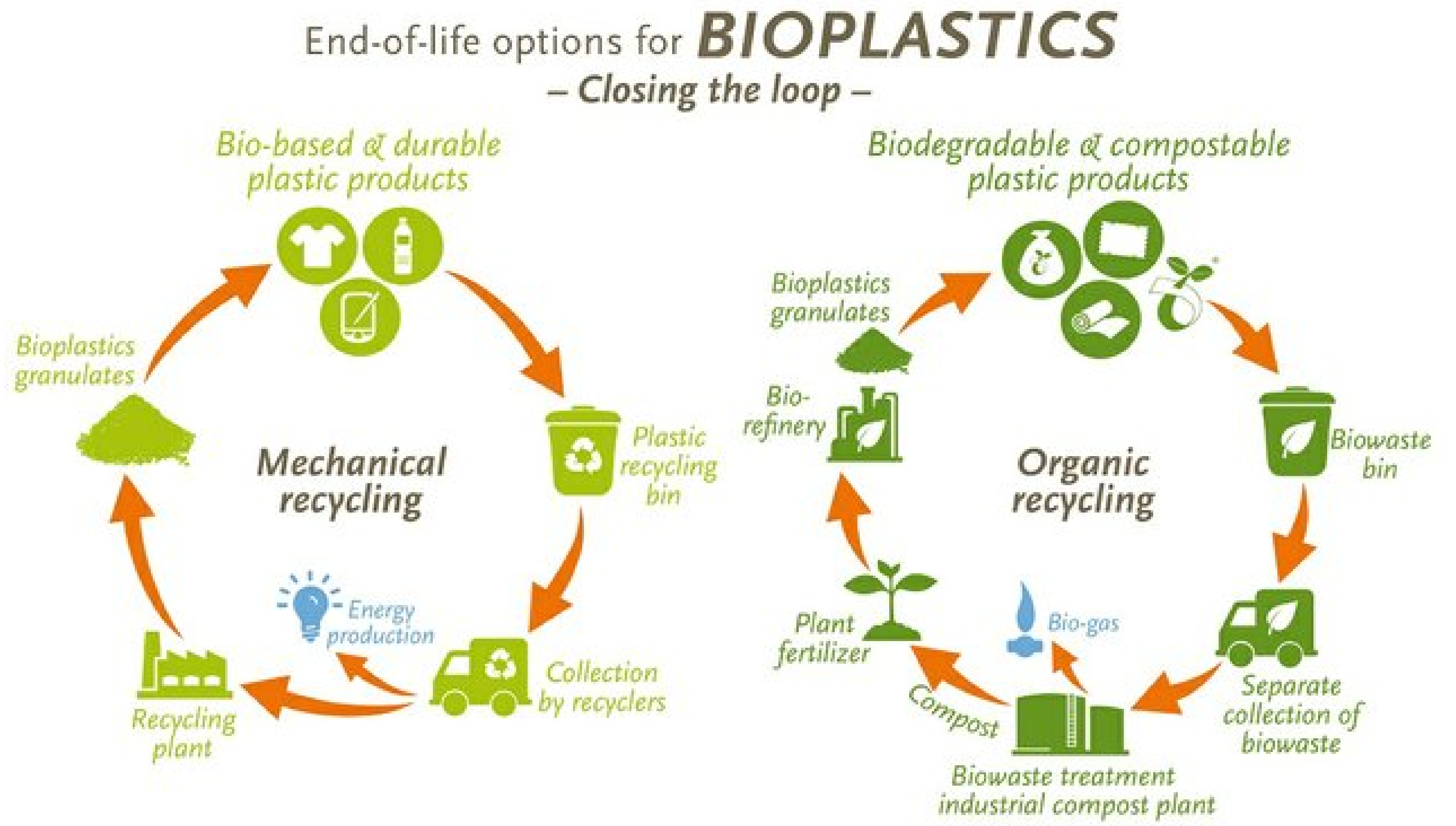
Plastic materials for packaging

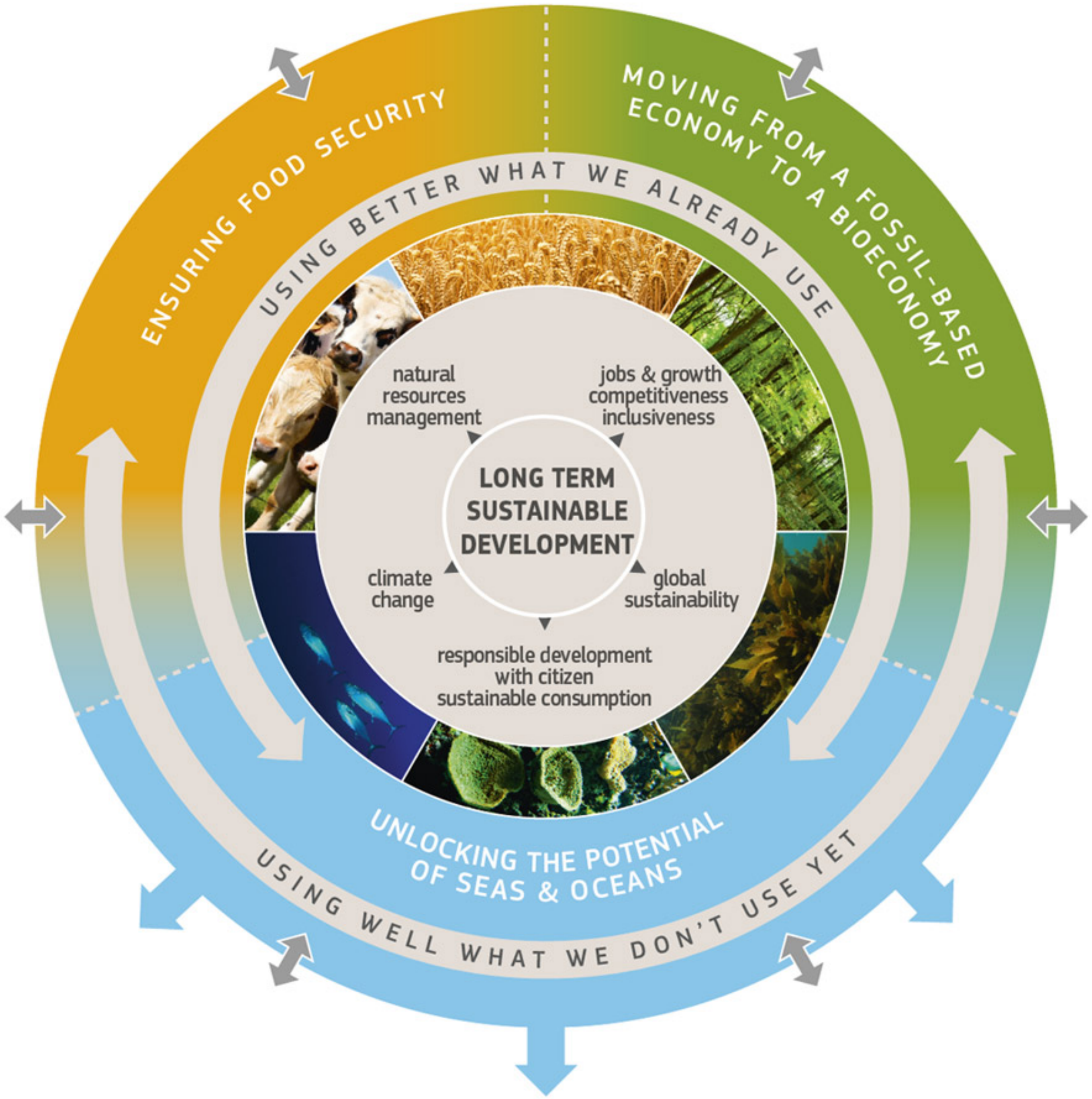
Packaging industry
produces large volumes
of plastic,
their improper disposal
is causing environmental
disasters

**An “environmentally friend” plastic (BIOPLASTIC)
is the winning alternative since,
being biodegradable and/or compostable, it is
characterized by a sustainable disposal.**

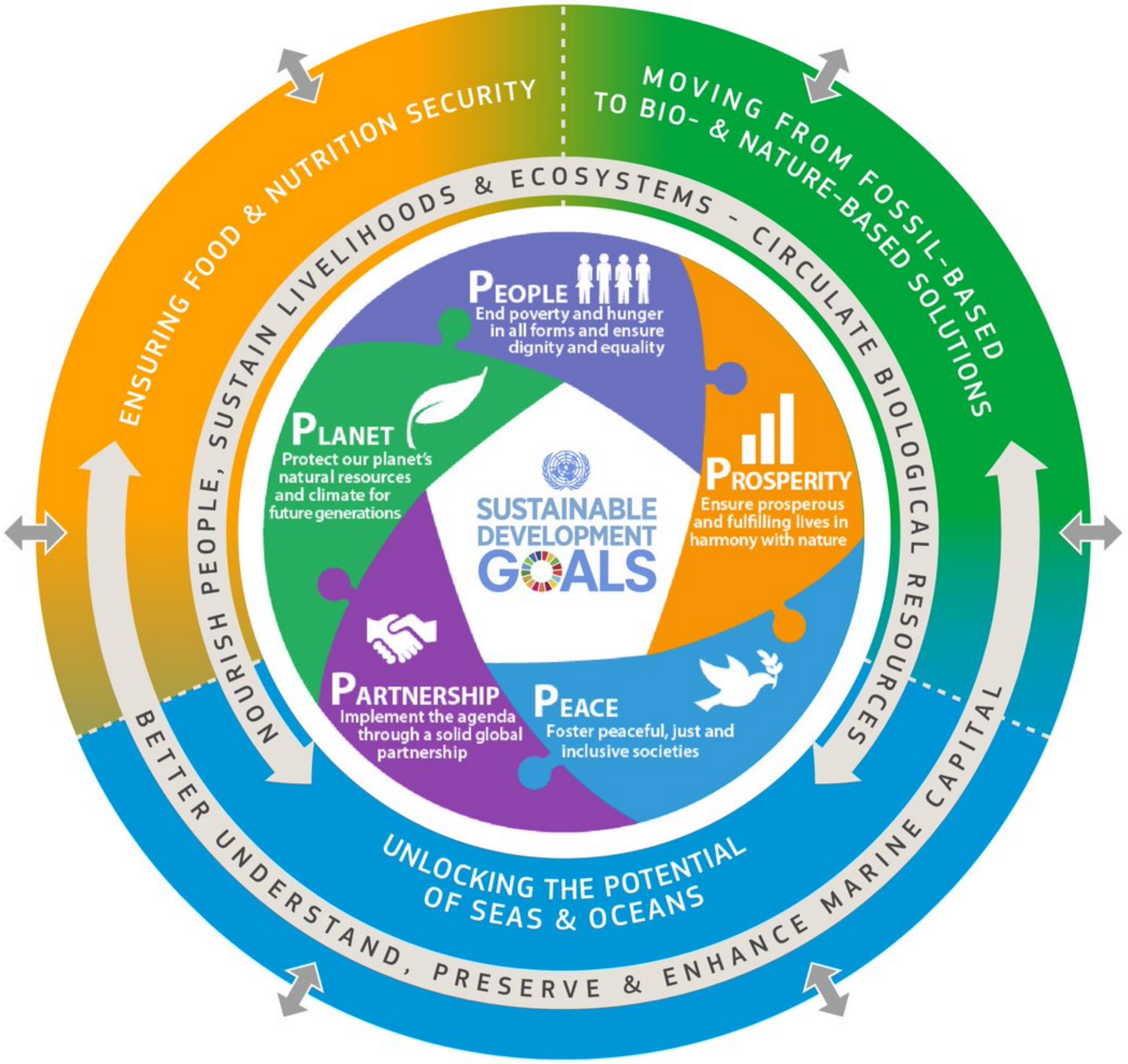
Plastic materials for packaging - Recyclable

- Less than 30% of plastic waste is collected for recycling
- **95% of the value of plastic packaging materials (70-105 billion €) is annually lost after a very short first use cycle**

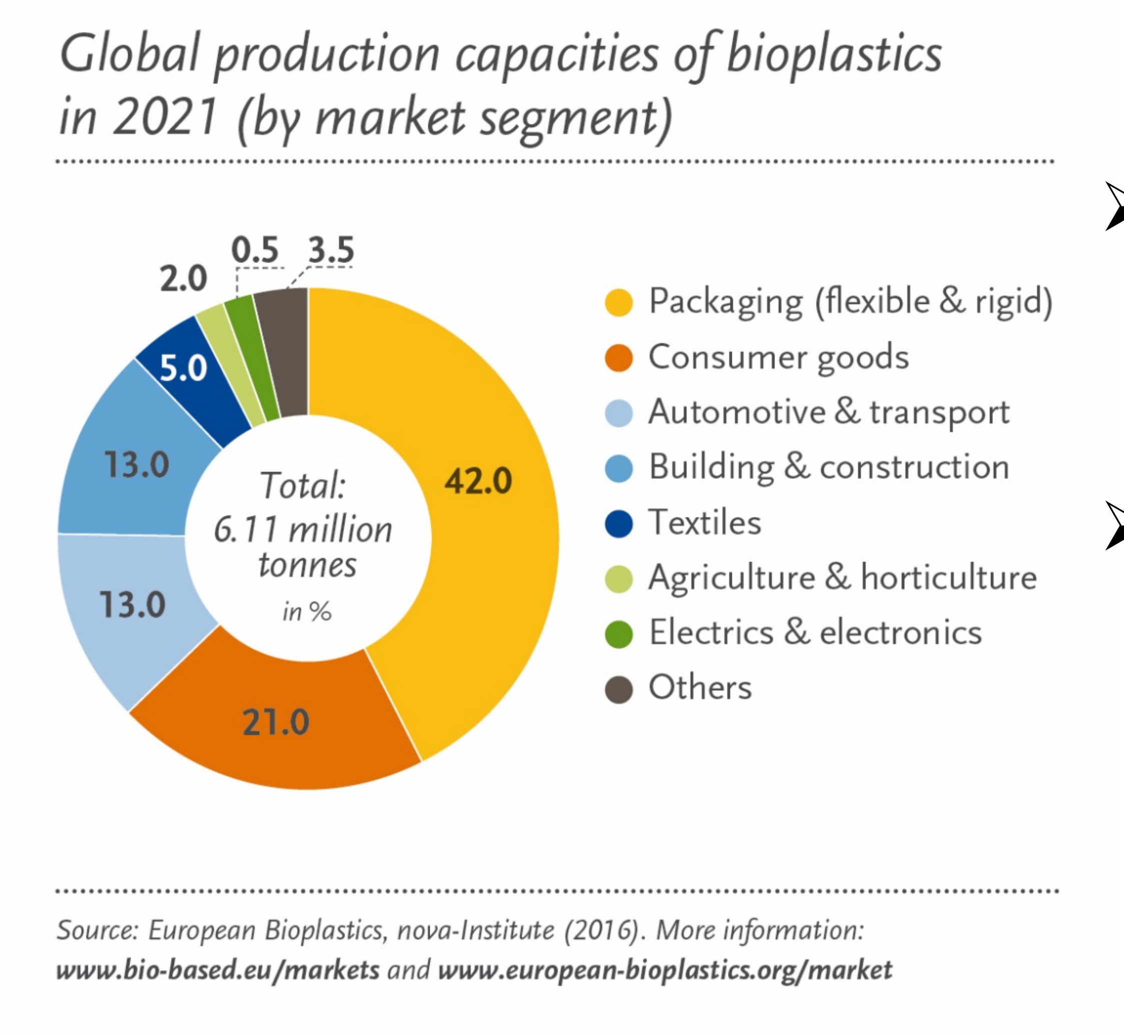

End-of-life options for BIOPLASTICS
– Closing the loop –
Bio-based & durable plastic products
Plastic recycling bin
Collection by recyclers
Energy production
Recycling plant
Bioplastics granulates
Mechanical recycling
Biodegradable & compostable plastic products
Biowaste bin
Separate collection of biowaste
Bio-gas
Biowaste treatment industrial compost plant
Compost
Plant fertilizer
Bio-refinery
Bioplastics granulates
Organic recycling



A SUSTAINABLE AND CIRCULAR BIOECONOMY FOR EUROPE



BIOPLASTICS APPLICATIONS

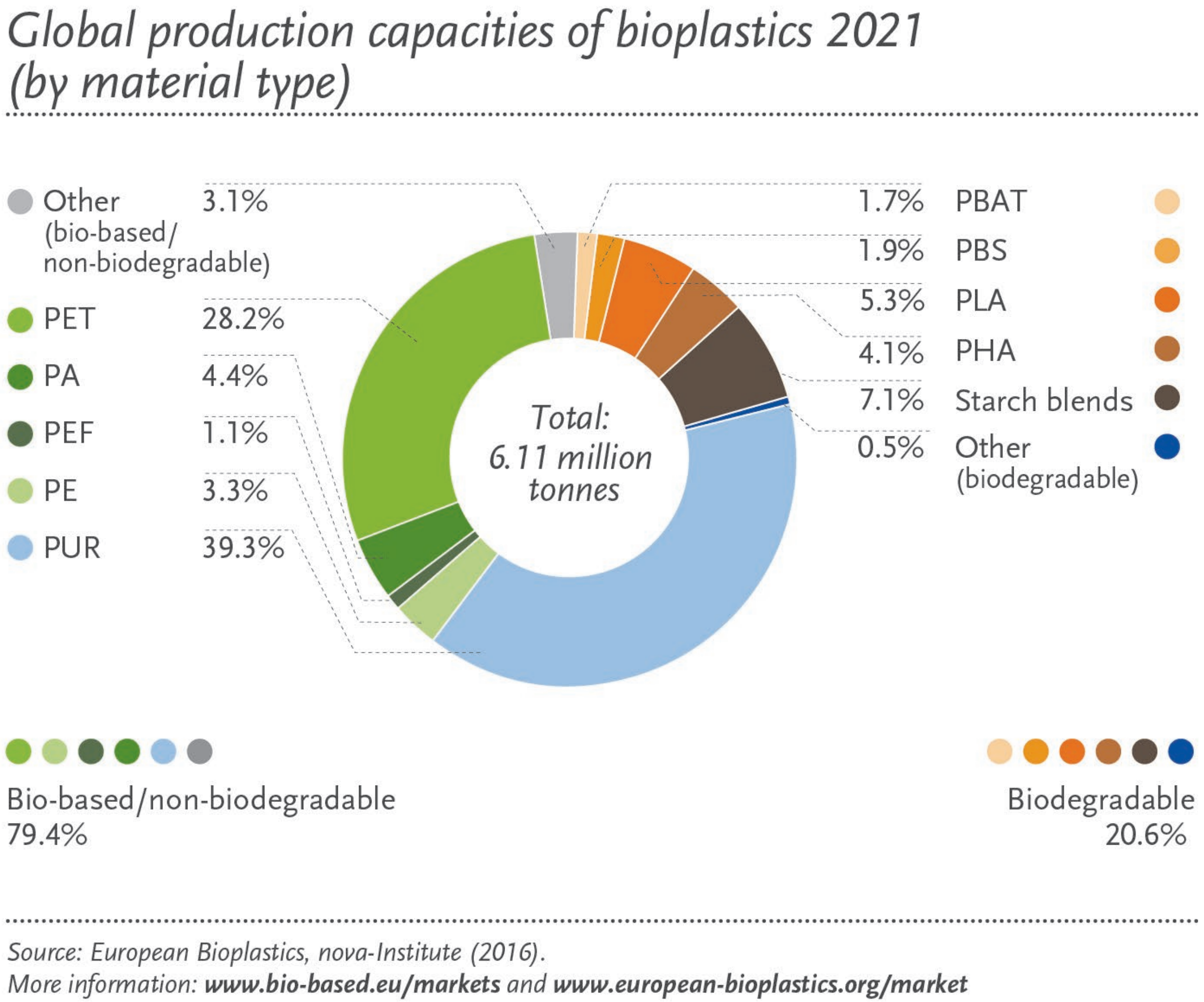


- A big bioplastics market segment will be occupied by Packaging.
- Packaging industry produces large volumes of plastic, an improper disposal causes environmental disasters.
- As a result, bioplastics in this field will be the winning alternative since, being biodegradable, they are characterized by a sustainable disposal.

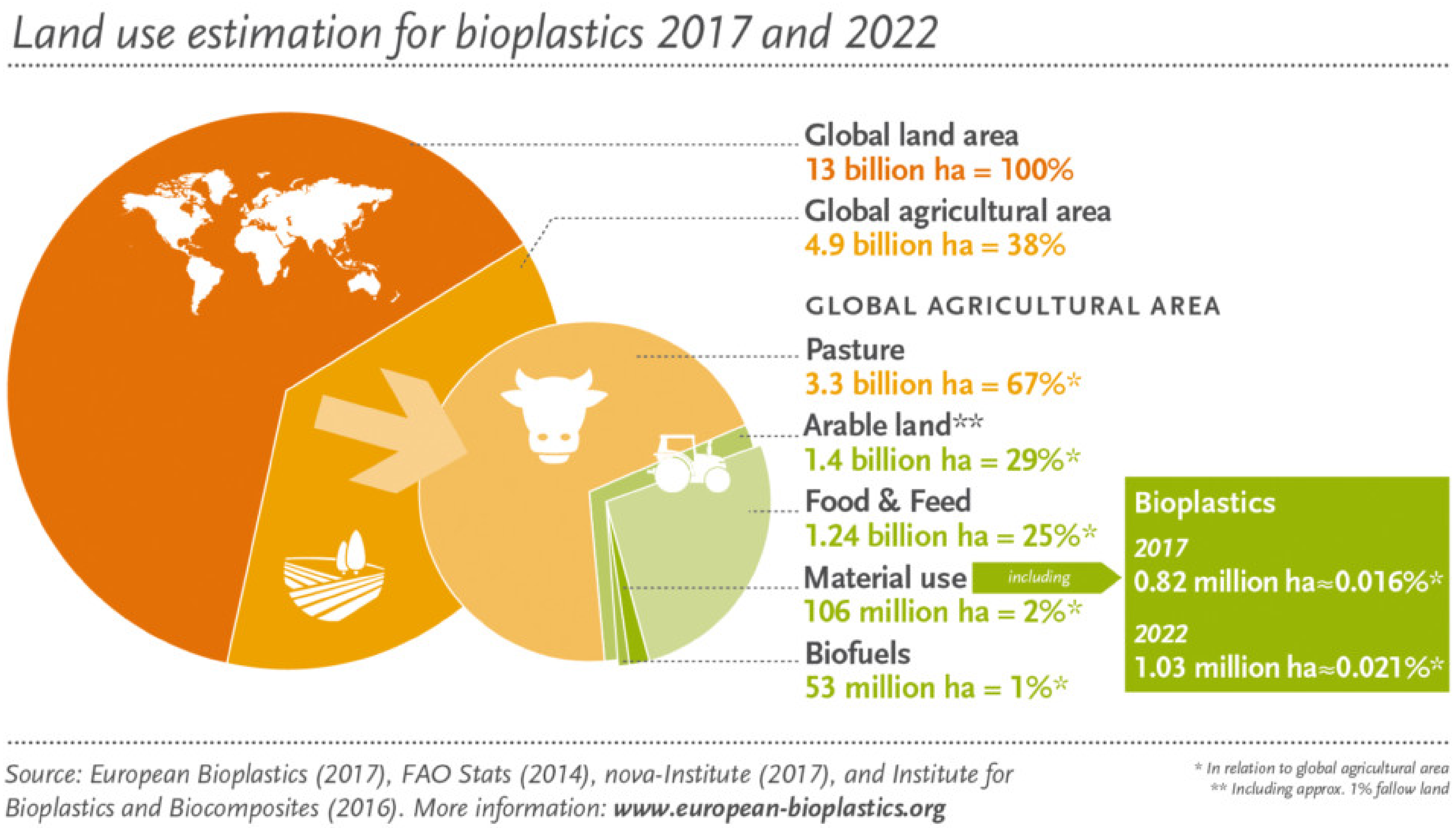
GLOBAL PRODUCTION OF BIOPLASTICS BY MATERIAL

- More than 75% of the bioplastics production capacity worldwide in 2016 was bio-based, durable plastics. This share will increase to almost 80 percent in 2021.

- Production capacities of biodegradable plastics, such as PLA, PHA, and starch blends, are also growing steadily from around 0.9 million tons in 2016 to almost 1.3 million tons in 2021.

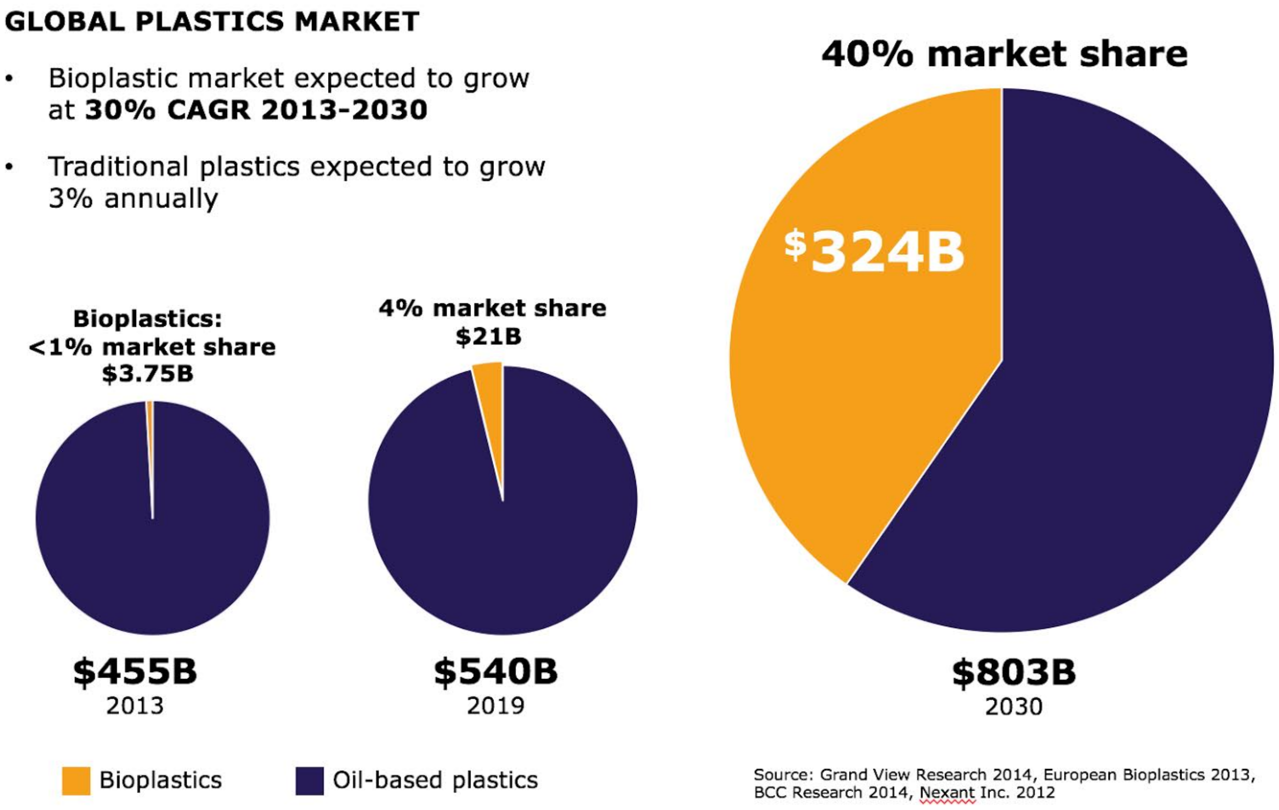


BIOplastic materials for packaging



Today, the European bio-economy sectors are worth €2 trillion in annual turnover and account for 22 million jobs in the EU, which is 9% of the EU's workforce.

Bioplastics have been designated a lead market by the European Commission. In line with the green movement analysts are expecting the bioplastic market to grow over 30% in 2030.



Source: European Bioplastics Association

Biobased plastic materials for packaging

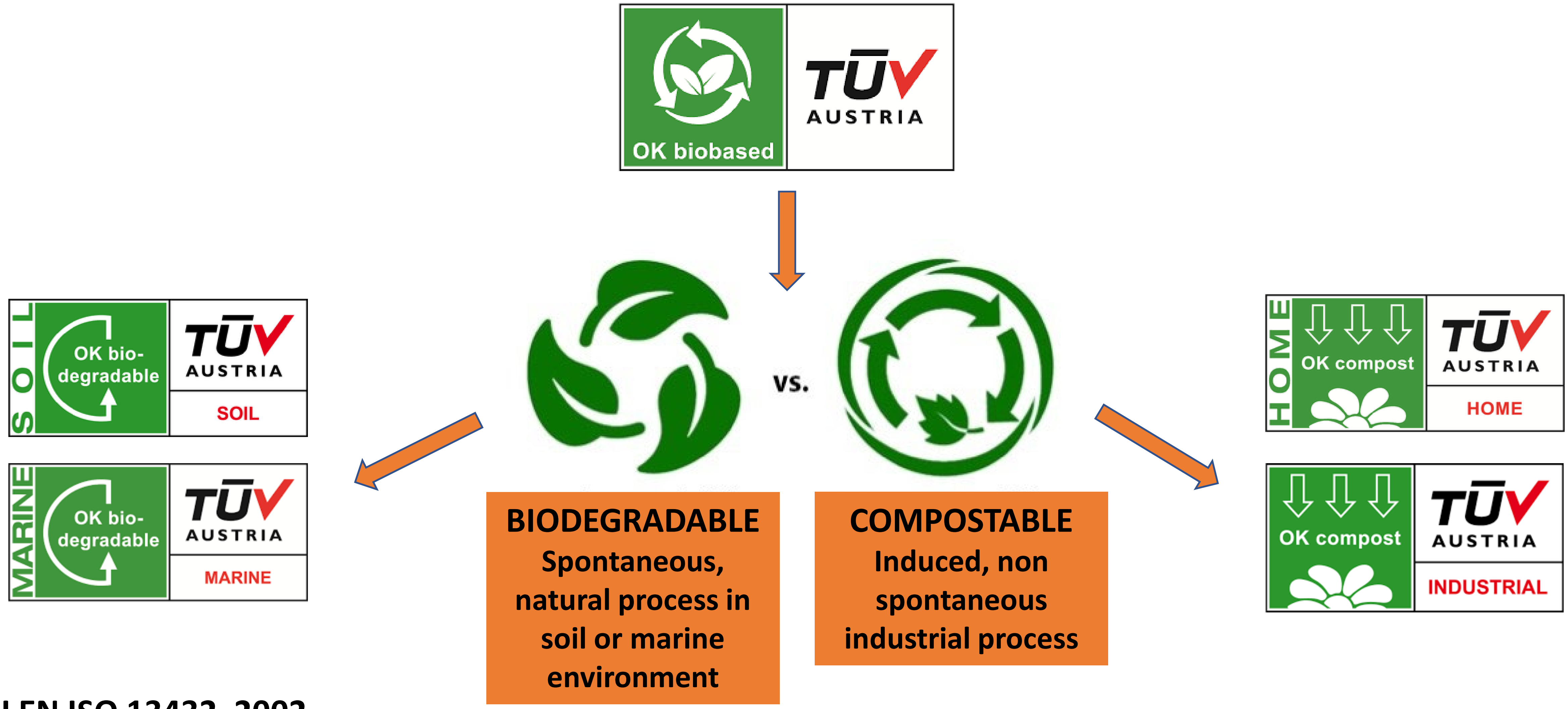
The ideal bioplastic is **BIOBASED** (made from renewable resources) and **BIODEGRADABLE and/or COMPOSTABLE**

vs.

BIODEGRADABLE	COMPOSTABLE
Spontaneous, natural process, soil or marine environment	**Induced, non spontaneous industrial process**

UNI EN ISO 13432, 2002

Bio based plastic materials for packaging



UNI EN ISO 13432, 2002

BIOPLASTICS AND BIOPOLYMERS… WHAT ARE THE DIFFERENCES?

- The main commercially available polymers derive from fossil fuels and they are difficult to recycle and / or reuse.

- The use of biodegradable and compostable materials from renewable sources is expected to contribute to sustainability and to reduce the environmental impact associated with the disposal of petroleum-based polymers.

- A bioplastic is a substance made from organic biomass sources.

- A polymeric substance to be termed “bioplastics”, according to the European Bioplastics Association[1], must possess at least one of the following characteristics:

  »Derived partly from renewable sources.
  »Being biodegradable.

1 http://www.european-bioplastics.org

European Bioplastics	**Biobased:** material or product (partly) derived from biomass (plants). Bioplastic: The term bio-plastics encompass a whole family of materials that are bio-based, biodegradable, or both.
SPI Plastic Industry Trade Association, Bioplastics Council	**Bioplastics:** plastic that is biodegradable, has bio-based content, or both. **Biodegradable Plastic:** a plastic that undergoes biodegradation (a process in which the degradation results from the action of naturally-occurring micro-organisms such as bacteria, fungi, and algae) as per accepted industry standards. As of 2008, accepted industry standard specifications are: ASTM D6400, ASTM D6868, ASTM D7081 or EN 13432 (see Table 1.4). **Biobased content:** Fraction of the carbon content that is new carbon content made up of biological materials or agricultural resources versus fossil carbon content. Biobased content is measured following the procedures set by ASTM D6866.

BIOBASED POLYMERS

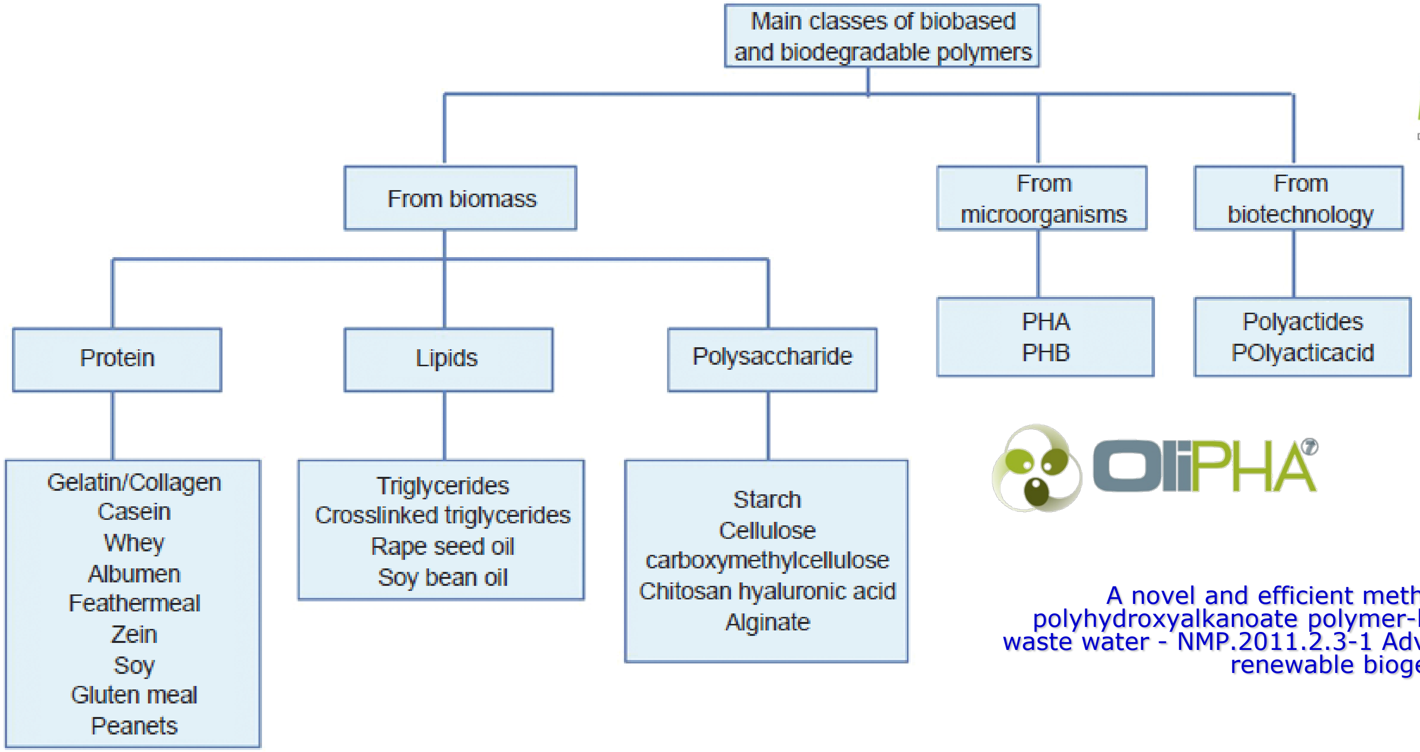


Figure 1. Different classes of polymers which are biobased and biodegradable (therefore not including biodegradable plastics from petrochemical resources and non biodegradable partly or fully biosourced plastics)

DEVELOPMENT OF INJECTION AND BLOW EXTRUSION MOLDED BIODEGRADABLE AND MULTIFUNCTIONAL PACKAGES BY NANOTECHNOLOGY: IMPROVEMENT OF STRUCTURAL AND BARRIER PROPERTIES, SMART FEATURES AND SUSTAINABILITY

A novel and efficient method for the production of polyhydroxyalkanoate polymer-based packaging from olive oil waste water - NMP.2011.2.3-1 Advanced packaging materials from renewable biogenic resources

FORBIOPLAST GA 212239, Star Project , KBBE-2007-3-1-04
Forest Resource Sustainability through Bio-Based-Composite Development

Express Polymer Letters, 2014, 8(11), 791-808, Polyhydroxyalkanoate (PHA): Review of synthesis, characteristics, processing and potential applications in packaging, E. Bugnicourt, P. Cinelli, A. Lazzeri, V. Alvarez

Understanding Biobased Carbon Content Measurement

•Biobased carbon testing is able to distinguish biobased from non-biobased products
•The terms biobased and non-biobased are applicable to carbon-containing products
•A product’s biobased carbon content is reported as a fraction of total organic carbon content (TOC) and not on its weight according to ASTM D6866
•A product’s biobased carbon content can be reported as a fraction of total carbon content (TC) according to other standardized methods such as ISO 16620-2 and CEN 16640.
Here are some definitions to clarify the concepts:

BIOBASED – Materials that are derived in whole or in part from biomass resources are biobased. Biomass resources are organic materials that are available on a renewable or recurring basis such as crop residues, wood residues, grasses, and aquatic plants. Corn ethanol is a well-known example of a biobased material derived from biomass resources.

BIOBASED PRODUCT – Any product that contains some amount of biobased material within it is technically a biobased product. The term is typically applied only to materials containing carbon.

NON-BIOBASED PRODUCT – Any product that does not contain any biobased materials in it is a non-biobased product, but the term is typically applied only to materials containing carbon. Products made entirely from petrochemical resources are referred to as non-biobased products. Glass, however, is not generally referred to as non-biobased material since it doesn’t contain any carbon.

BIOBASED LOGOS

Label	Biobased content range
One star	20% < Biobased < 40%
Two star	40% < Biobased < 60%
Three stars	60% < Biobased < 80%
Four stars	Biobased > 80%

between 20 and 40 % Biobased	between 40 and 60 % Biobased	between 60 and 80 % Biobased	more than 80 % Biobased

In the context of the "Lead Market Initiative for Europe" the European Commission created the Mandate M/429 addressed to the European Standardization bodies (CEN, CENELEC and ETSI) for the development of horizontal European standards for bio-based products. CEN initiated a new Technical Committee CEN/TC411 on "Bio-based products", which started working in the beginning of October 2011.

The main active institutes in this field are Vinçotte (Belgium) and Din Certco (Germany). They both have a ranking system based on the bio-based carbon content

http://www.dincertco.de.
http://www.okcompost.be

European Commission, "Mandate addressed to CEN, CENELEC and ETSI for the elaboration of a standardisation programme for bio-based products", M/429.

COMPOSTABLE LOGOS

BIOBASED 50 - 85 %
DIN
Geprüft
8C084/8C085

BIOBASED 20 - 50 %
DIN
Geprüft
8C083

BP®
バイオマスプラ
No.299/No.300

GreenPla
Biodegradable Plastics

HOME
OK compost
S534
VINÇOTTE

BPI ®

COMPOSTABLE
IN INDUSTRIAL FACILITIES
Check locally, as these do not exist in many communities. **Not suitable for backyard composting.** CERT # 10528580

recyclable
certified at WMU

OK compost
S534
VINÇOTTE

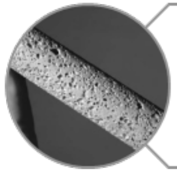
BIODEGRADABILITY FACTORS

Chemical Structure: A polymer with a more complex chemical structure (for example lignin has a lot of aromatics group and ramification point) biodegrades slowly.

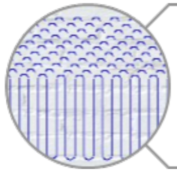
Functional Groups: Esters, amines and urethane bonds are more hydrophilic, hence more hydrolysable and more degradable.

Segmental Mobility: Polymers with high flexibility degree are easily degraded. Examples are PBA (polybutylenadipate) and PBS (polybutylensuccinate).

Molecular Weight: A high molecular weight is detrimental for the degradation.



Surface Features: If polymer surface is irregular and porous, the polymer is more susceptible to microbial attack and sensible to degradation.



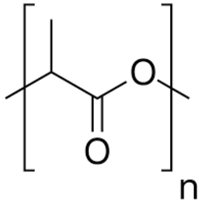
Crystallinity: If the polymeric chains are arranged in an orderly manner (more crystalline polymers) the degradation process is hindered.

Biobased plastic materials

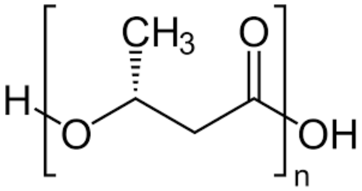
A BIOBASED plastic:

1) Does not come from fossil resources (petrol)

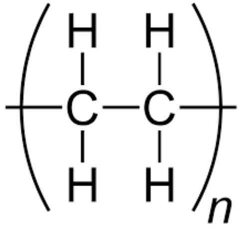
2) monomers derive from renewable resources (plants, bacteria)



PLA



PHA

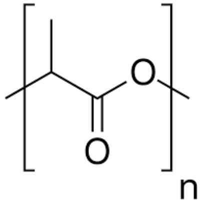


bioPE

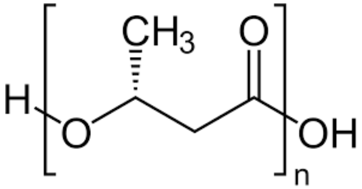
Biobased plastic materials

End of Life (EoL) of a biobased material

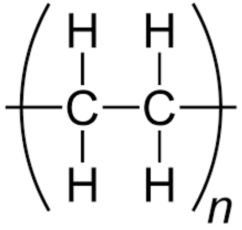
OK biobased TÜV AUSTRIA



PLA → Compostable



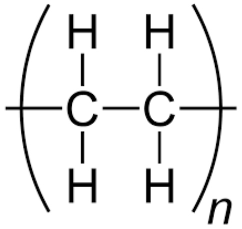
PHA → Biodegradable



bioPE → Recyclable

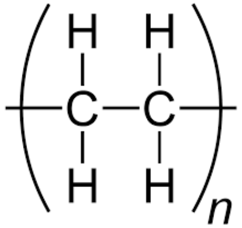
EoL of plastic materials

End of Life (EoL) of a biobased material:
depends on the **STRUCTURE** of the material, not on its **ORIGIN**



PE → Recyclable

Recycle of plastic materials



PE → Recyclable

The material:

1) maintaines the same structure and properties
2) can be recycled more than once

End of Life (EoL) of a biobased material:
depends on the **STRUCTURE** of the material, not on its **ORIGIN**

BIOplastic materials for packaging

Plastics for food and cosmetics packaging requirements:

- **Improved barrier properties** (isolating properties):
  - To oxygen
  - To aqueous vapour/water
  - To UV light
- **Improved inert behaviour** (low migration rate to and from the packaging):
  - Plasticizers
  - Nucleating agents
  - Processing aids

BIOplastic materials for packaging

Compostable/biodegradable plastics is ideal for food/cosmetics packaging

- Global cosmetic market is strongly growing (expected $675 billion in 2020, 6.7% annual growth)
- In the specific case of cosmetic packaging, re-use is rarely applied
- Recycle is difficoult due to the contamination by residues of greasy and creamy cosmetic residues, hard to be removed by washing

➡ **Compostable cosmetic packaging (bioplastics) would be very beneficial for the environment**

Rigid bioplastic
Food packaging

RECYCLE

Flexible bioplastic
cosmetic packaging

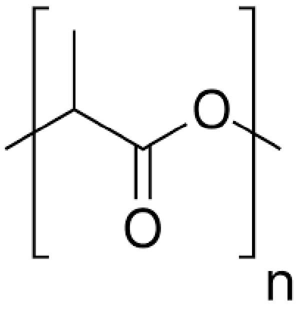
COMPOST

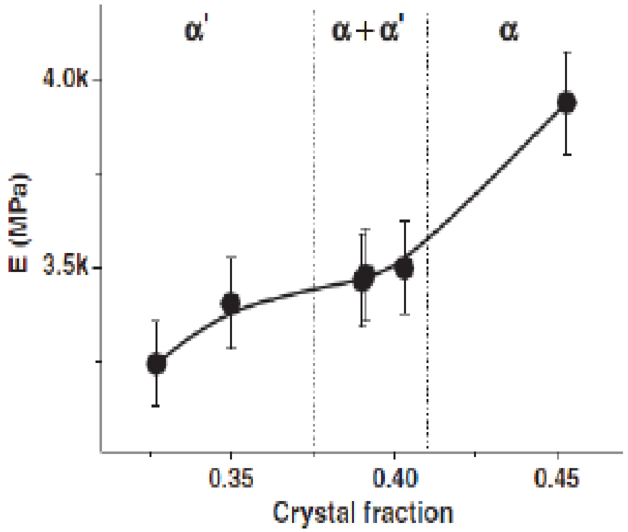
OK compost
TÜV AUSTRIA
INDUSTRIAL

compostable

Poly(lactic acid) , PLA

- Polar matrix, insoluble in water
- Semi-crystalline PLA shows Tg at 50-60 °C, crystallization temperature at 90-120 °C, melting temperature at 150-180 °C
- Mechanical properties shows high modulus (3 GPa) and short elongation at break (4%): RIGID MATERIAL
- Thermoplastic material processable by injection molding, blow mol extrusion
- Compostable





Cocca et al., Eur. Pol. Jour, 2011, 47, 1073-1080

BIOplastic materials for food/cosmetic packaging

Poly(lactic acid) , PLA

- RIGID PACKAGING
  - **Nucleating agents** to improve crystallinity and therefore thermal resistance
  - **Stereocomplexes** to improve thermal resistance and barrier properties
  - **Blends** with high Tg polymers (polycarbonate, cellulose acetate)
  - **Composites** with natural fibres to improve compostability
- SOFT PACKAGING
  - **Plasticizers**, to lower Tg for films and sheets

Biobased plastic materials for food packaging

Poly(lactic acid) , PLA

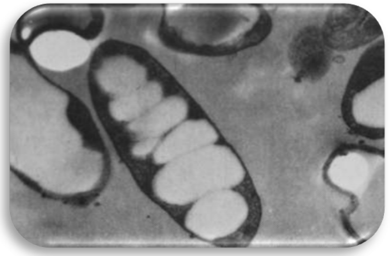
- BARRIER PROPERTIES
  - **Stereocomplexes** to improve thermal resistance and barrier properties
  - **Composites** with nanofillers (inorganic layred silicates)
- INERT BEHAVIOUR
  - Use of high molecular weight plasticizers/additives
- DEGRADABILITY
  - Addition of hydrophilic additives (nanocrystalline cellulose or PEG)

Poly(lactic acid) , PLA

Examples of rigid cosmetic packaging made of PLA (Ok compost)

POLYHYDROXYALKANOATES PHAs

Polyhydroxyalkanoate (PHA) is a family of biopolyester
Polyhydroxybutyrate (PHB) is the most common. It was discovered by Lemoigne at Pasteur Institute in 1925 as a constituent of *bacterium bacillus megaterium*
Since then more than 300 types of microorganisms have been identified to accumulate PHAs. Examples are *Alcaligenes latus* and *eutrophus* or *E.coli.*



- Good gas and moisture barrier
- Good thermo-mechanical properties
- Versatile convertibility
  - Injection moulding
  - Extrusion
  - Thermoforming
  - Film blowing and Blow moulding
  - Foaming
  - etc
- Biodegradable and compostable (according to ASTM and ISO standards), Degradable in soil and in marine water

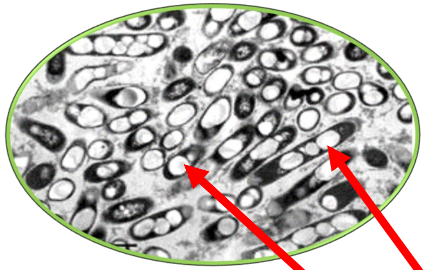
Suitable for food packaging

A number of bacteria are producers of PHA

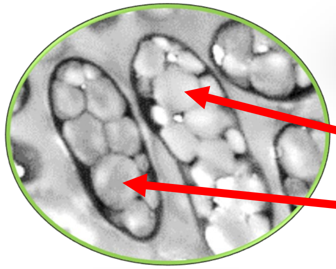
Two different processes are shown on this slide for PHA production

Fermentation

Carried out by heterotrophic bacteria



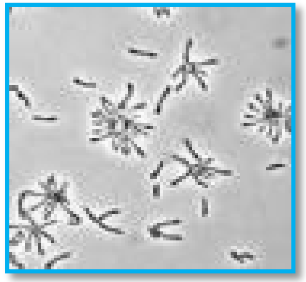
Pseudomonas sp.



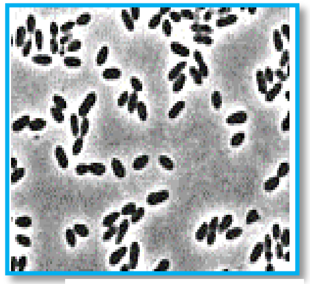
Ralstonia eutropha

Photofermentation

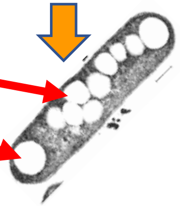
Carried out by purple bacteria



Rhodopseudomonas palustris



Rhodobacter sphaeroides



PHA Granules into bacterial cells

PHB AVERAGE PROPERTIES

PHA Average Properties

Properties (units)	Values
Tg (ºC)	2
Tm (ºC)	160-175
Xcr (%)	40-60
E (GPa)	1-2
σ (MPa)	15-40
ε (%)	1-15
WVTR (g.mm/m^2.day)	2.36
OTR (cc.mm/m^2.day)	55.12

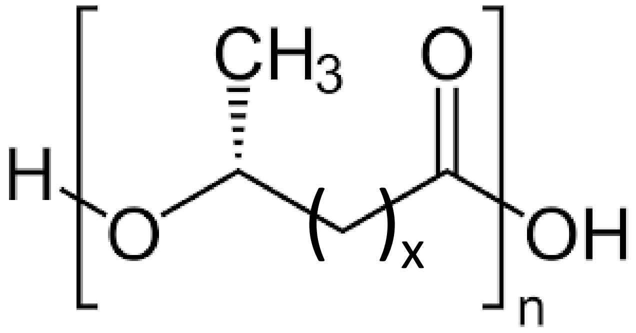
*Tg: glass transition temperature, Tm: melting temperature, Xcr: crystallinity degree, E: Young's modulus, ": tensile strength, ε elongation at break, WVTR: water vapour transmission rate; OTR: oxygen transmission rate.

Pacaking	Strength (MPa)	Modulus (MPa)	Elongation (%)	Oxygen barrier	Humidity barrier	Temperature resistance (°C)
Films	25-30	250-350	>100%	4900-7500 cm3 /m^2/day	15-25 g/m2 /day	-10 and 55
Pouches	25-30	250-350	>100%	4900-7500 cm3 /m^2/day	15-25 g/m2 /day	-10 and 55
Jars Standard Premium	20-30 MPa standard 50 MPa Premium	1000-2000 3000	200 2	Not required	High	-10 and 55

E. Bugnicourt, P. Cinelli, A. Lazzeri, V. Alvarez
Express Polymer Letters, 2014, 8(11), 791-808, Polyhydroxyalkanoate (PHA): Review of synthesis, characteristics, processing and potential applications in packaging,

Polyhydroxyalkanoates, PHAs

- Polar matrix, insoluble in water
- Modulable thermal and mechanical properties
- Thermoplastic material processable by injection molding, blow molding, thermoforming and extrusion
- More expensive than PLA (still accetable for high value applications)



Polyhydroxyalkanoates, PHAs

- Low vapor permeability (compared to HDPE)
- High biocompatibility
- Biodegradable in **soil** and **marine** environment

Strengths	Weaknesses
Technical	
• High modulus and strength • Processability using number of converting technologies • Good barrier properties	• PHB crystallinity and kinetic of crystallization • PHB brittleness • Molecular weight may vary depending on culture conditions • Difficulty to process films
Environmental	
• Biodegradable in the environment and marine water	• NA
Marketing	
• Suitability for a huge range of applications	• High cost

Bugnicourt E, Cinelli P, Lazzeri A, Alvarez V., The Main Characteristics, Properties, Improvements, and Market Data of Polyhydroxyalkanoates, Chapter 24th in Vijay Kumar Thakur and Manju Kumari Thaku, Eds, Handbook of Sustainable Polymers Processing and Applications. Pan Stanford 2015; pp.899-928. (Print ISBN: 978-981-4613-53-8; eBook ISBN: 978-981-4613-54-5; DOI: 10.1201/b19600-25)

P. Cinelli, M. Seggiani, N. Mallegni, V. Gigante, A. Lazzeri. International journal of molecular sciences 2019, "Processability and Degradability of PHA-Based Composites in Terrestrial Environments" DOI:10.3390/ijms20020284,

M.Seggiani,; P.Cinelli, E. Balestri; N. Mallegni, E. Stefanelli, Eleonora; A. Rossi, C. Lardicci, Claudio; A. Lazzeri, Materials, 11(5), 772 ,2018, "Novel sustainable composites based on poly(hydroxybutyrate-co-hydroxyvalerate) and sea grass beach-CAST fibres: performance and degradability in marine environments", doi: 10.3390/ma11050772.

PHA CRYSTALLINITY

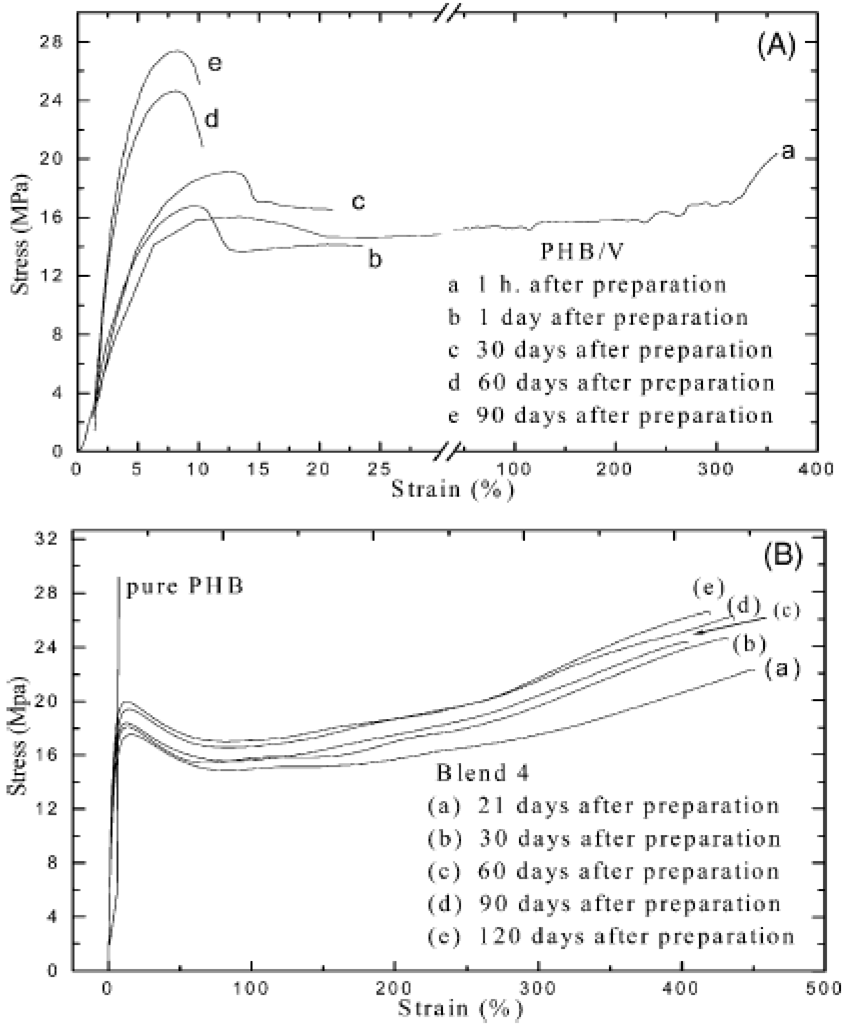


Fig. 2. Tensile stress–strain curves for the various samples with strain rate 50 mm/min for (A) PHB/V after storage at room temperature as indicated. (B) Blend 4 after storage at 20°C for times indicated.

PHAs secondary crystallization of the amorphous phase takes place during storage at room temperature .

de Koning G J M, Lemstra P J, Crystallization phenomena in bacterial poly[(r)-3-hydroxybutyrate]: 2. Embrittlement and rejuvenation. Polymer, (19), 4089-4094 (1993);
Di Lorenzo ML, Raimo M, Cascone E, Martuscelli E, Poly(3-hydroxybutyrate)-based copolymers and blends: Influence of a second component on crystallization and therman behaviour. Journal of Macromolecular Science, Part B, (5), 639-667 (2001).

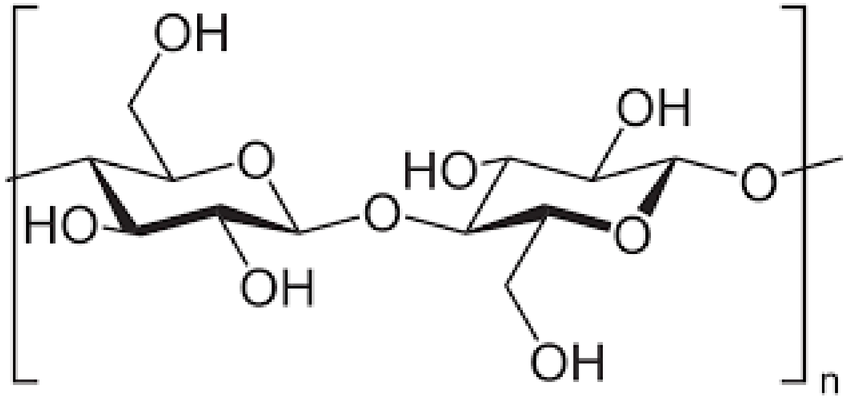
El-Hadi A, Schnabel R, Straube E, Muller G, Henning S,
Correlation between degree of crystallinity, morphology, glass temperature, mechanical properties and biodegradation of poly (3-hydroxyalkanoate) PHAs and their blends, Polymer Testing 21 (2002) 665–674.

BIOplastic materials for cosmetic packaging

Polyhydroxyalkanoates, PHAs

Polysaccharides, starch, cellulose

- Higly polar matrix, insoluble in water but very hydrophilic
- Poor barrier properties (for not hygroscopic, dry products)
- Brittle material
- Mainly used in multi layers materials or in composites materials



SOIL OK bio-degradable TÜV AUSTRIA SOIL

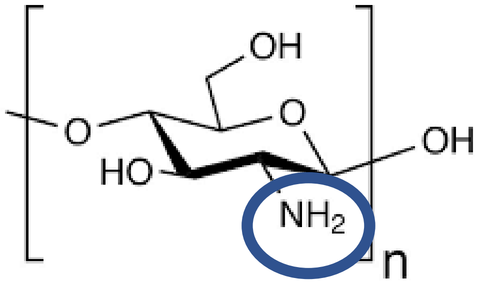
MARINE OK bio-degradable TÜV AUSTRIA MARINE

Future perspectives

A special polyaminosaccharide: CHITOSAN

- Higly polar matrix, insoluble in water but very hydrophilic
- Good barrier properties to oxygen
- Filmable
- Biodegradable
- Strong antibacterial and anti-fungal activity used in multi layers materials or in composites materials)

SOIL OK bio-degradable TÜV AUSTRIA SOIL



MARINE OK bio-degradable TÜV AUSTRIA MARINE

Future perspectives

Active packaging

Packaging plays an active role in protecting and preserving the product

- Antimicrobial activity
- Anti-fungal activity
- Antioxidant activity

    - Chitin/chitosan nanofibres
    - Naturally occurring antioxidant

Future perspectives

Active packaging

Packaging plays an active role in protecting and preserving the product

- Antimicrobial activity
- Anti-fungal activity
- Antioxidant activity

  - Chitin/chitosan nanofibres
  - Naturally occurring antioxidant → SAME ACTIVE MOLECULES IN AND AROUND THE PRODUCT

Previously funded projects

wheylayer

Legumal

BioBoard

OliPHA

dibbio pack

agrimax

PERFORMANCE

n-chitopack

H LM

FORBIOPLAST

AGROCYCLE for a circular economy

POLYBIOSKIN

ROBO-IMPLANT

Nano-Cathedral

erasmus+ bioplastictrain

PHA

EVOLUTION

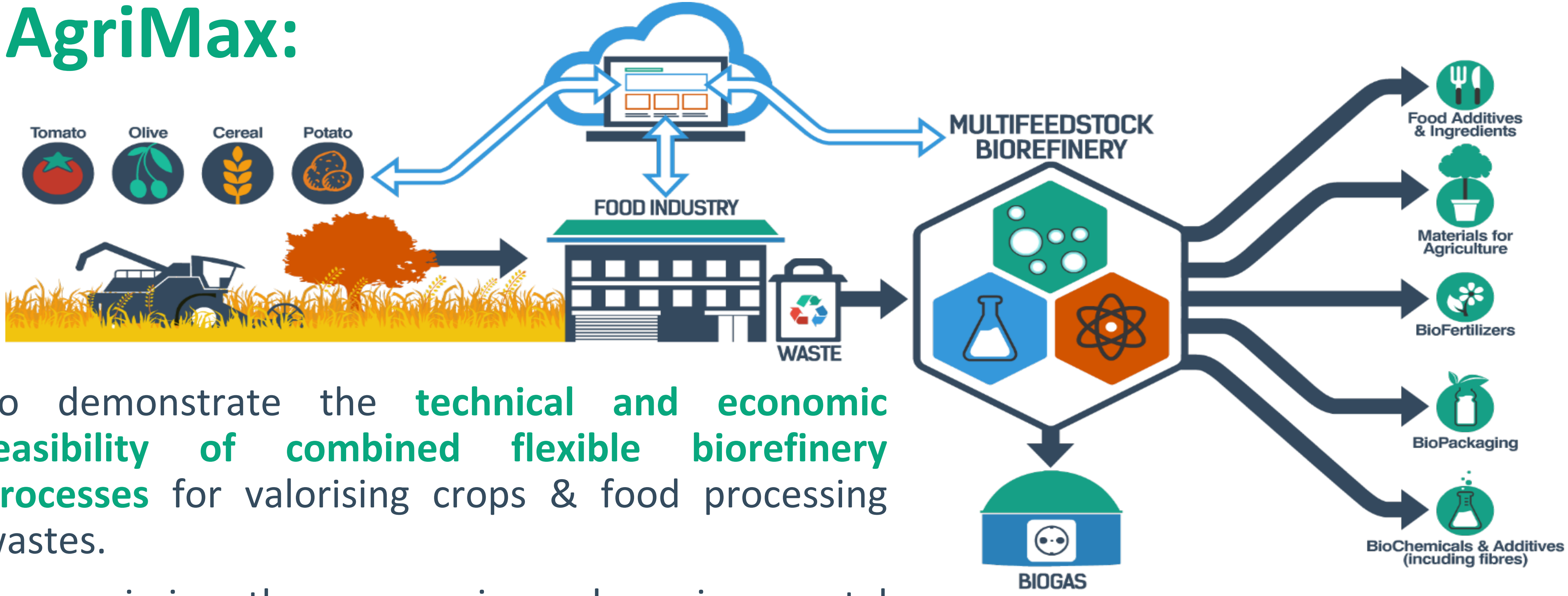
NANOMATUBAM

Agri & food waste valorisation co-ops based on flexible multi-feedstocks biorefinery processing technologies for new high added value applications

This project has received funding from the Bio Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 720719.
Cooridnated by IRIS http://www.iris-eng.com/

HORIZON 2020, running project .

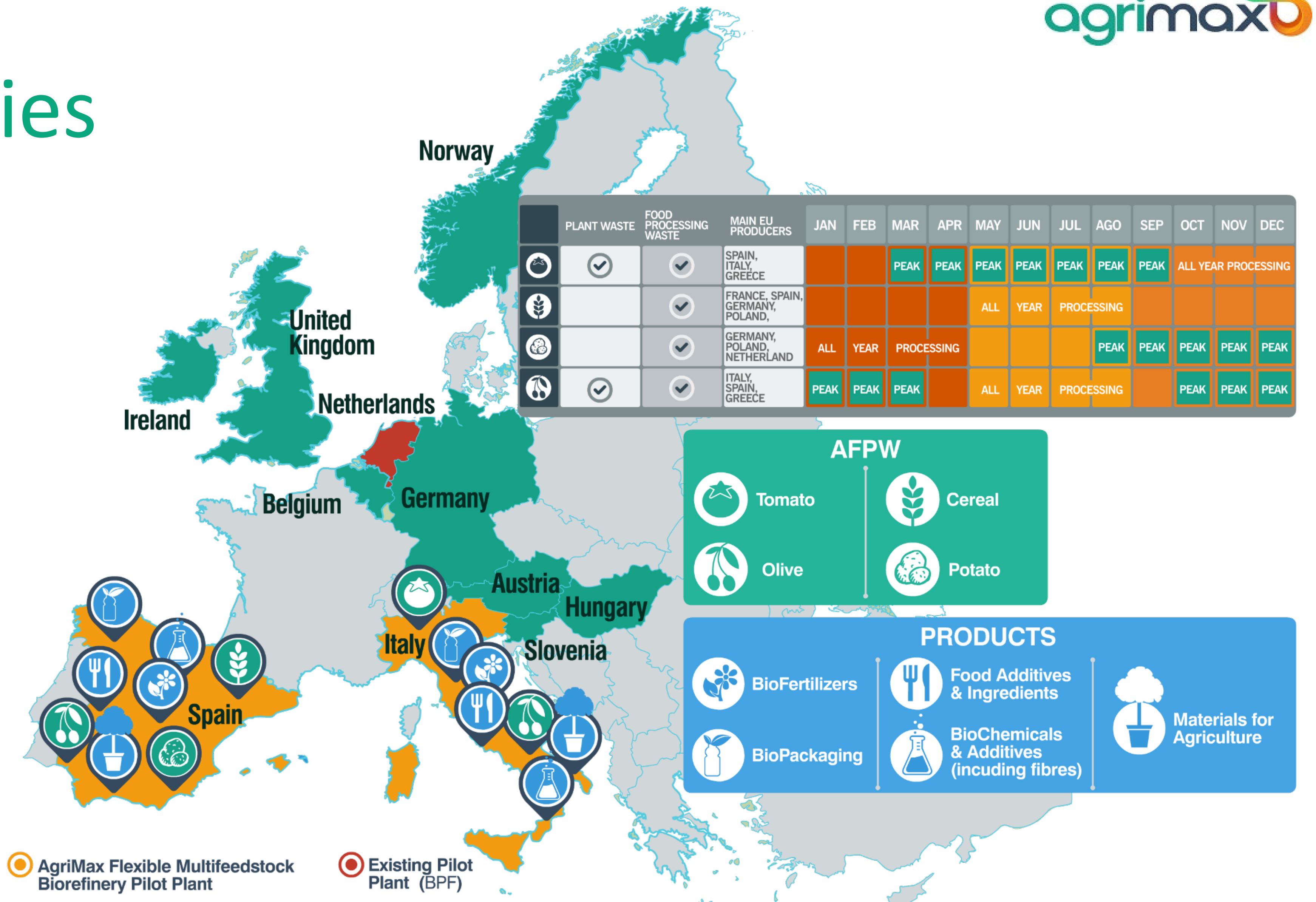
AgriMax:



- To demonstrate the **technical and economic feasibility of combined flexible biorefinery processes** for valorising crops & food processing wastes.
- To maximise the economic and environmental sustainability of the EU **agricultural and food sectors** while providing new **biocompounds to the chemical, food, packaging and agriculture sectors**

Two case studies

Two pilot plants are going to be designed and will run on a **cooperative base** to prove the viability of the proposed approach



	PLANT WASTE	FOOD PROCESSING WASTE	MAIN EU PRODUCERS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DEC
	✓	✓	SPAIN, ITALY, GREECE			PEAK	PEAK	PEAK	PEAK	PEAK	PEAK	PEAK	ALL YEAR PROCESSING		
		✓	FRANCE, SPAIN, GERMANY, POLAND,					ALL	YEAR	PROCESSING					
		✓	GERMANY, POLAND, NETHERLAND	ALL	YEAR	PROCESSING					PEAK	PEAK	PEAK	PEAK	PEAK
	✓	✓	ITALY, SPAIN, GREECE	PEAK	PEAK	PEAK		ALL	YEAR	PROCESSING			PEAK	PEAK	PEAK

Industrial scale processing

Processing with the Industrial COMAC co-rotating twin screw extruder EBC 25HT
Processing was performed at 8Kg/ hour, motor speed 2.70 rpm, processing temperature between 160-170 °C, screw speed 350 rpm.

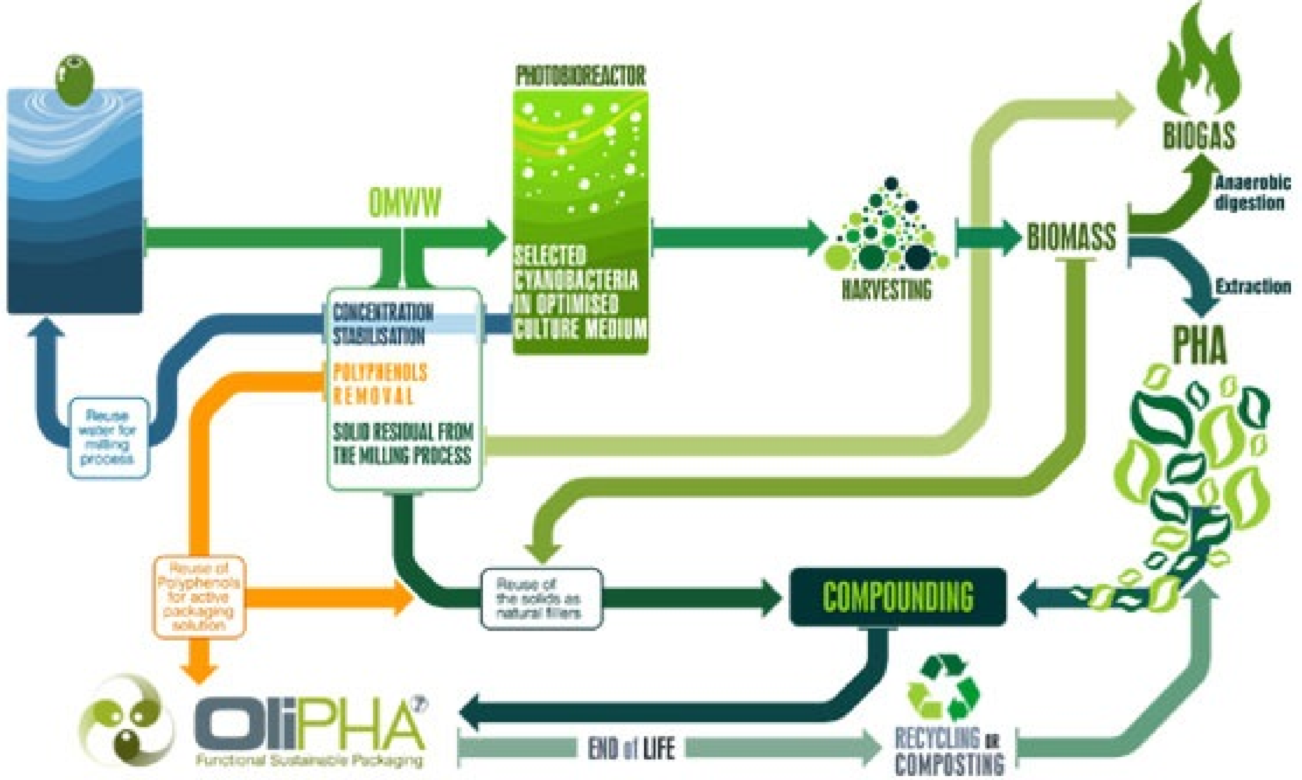
The final **Products**

Safe and environmentally friendly Bio-Packaging
(bioplastic flexible and rigid packaging, active and barrier packaging, biobased coatings for metal packaging, biocomposites, as well as secondary packaging).

Healthier and functional Food products
(additives, ingredients, coatings, microorganisms used in production, enhanced food products)

Bio-based Agriculture products
(bioplastics embedding fertilisers based solutions for **biodegradable** mulching films and pots as well as biofertilisers with biostimulant and biocontrol properties)

www.***olipha***.eu/



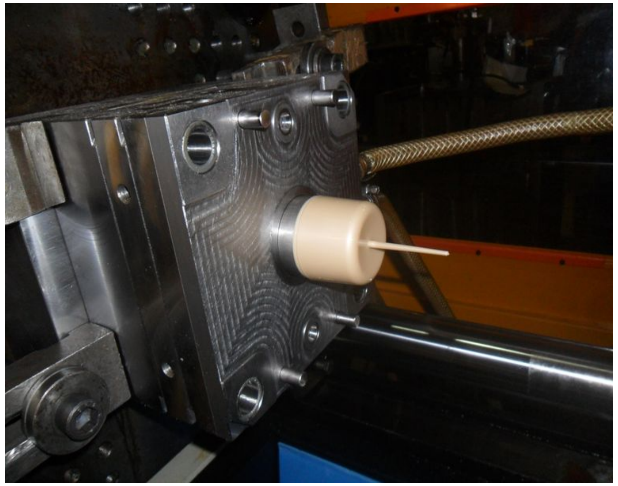
OLIPHA *"A novel and efficient method for the production of polyhydroxyalkanoatepolymer-based packaging from olive oil waste water"* ***NMP2011.Small*** *, 01.06.2012-31.05.2015*

Collaborative Project
Small or medium-scale focussed research projects - Specific International Cooperation Actions (SICA) to promote the participation of emerging economies and developing countries: Latin America.

Research Activity:

Characterization of the PHAs produced. Blends with PHAs and plasticizers, production of composites and nano composites.

Examples of materials produced by Injection molding: Cosmetic Jars.



Materials based on PHA, compostable,
soil and marine degradable !!!

Resources 2015, 4, 621-636, doi:10.3390/resources4030621 “An Innovative Device to Convert Olive Mill Wastewater into a Suitable Effluent for Feeding Purple Non-Sulfur Photosynthetic Bacteria” P. Carlozzi, G. Padovani, P. Cinelli, A. Lazzeri.

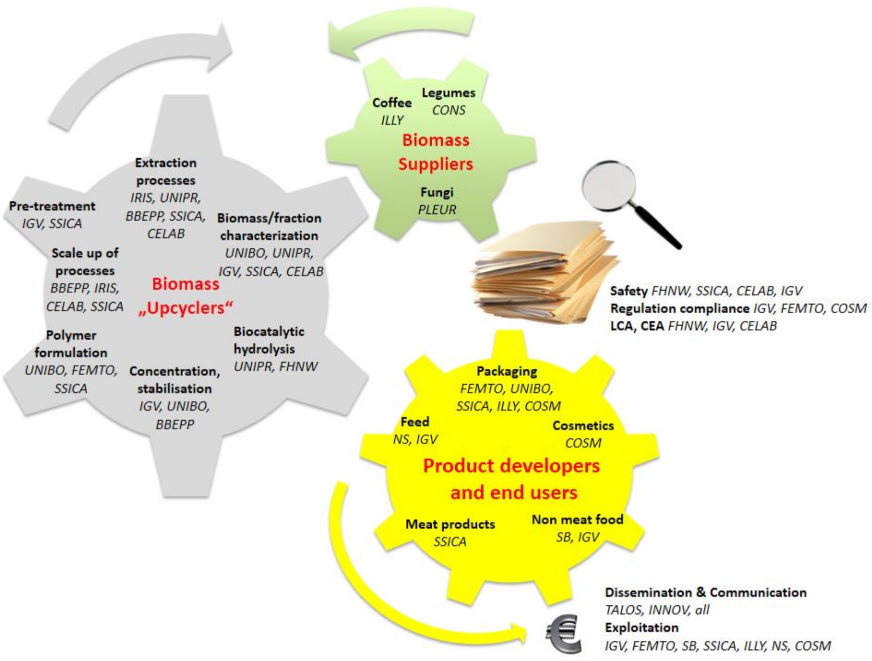
Future perspectives

SKIN SUMMER SCHOOL

PROLIFIC

Integrated cascades of PROcesses for the extraction and valorization of proteins and active molecules from Legumes, Fungii and Coffee agro-industrial side-streams

GA 790157 (2018-2021)



Accordingly to FAO roughly one third of the food produced in the world for human consumption every year – approximately 1.3 billion tonnes – gets lost or wasted globally” and
“Every year, consumers in rich countries waste almost as much food (222 million tonnes) as the entire net food production of sub-Saharan Africa (230 million tonnes).”

Food Packaging Coatings

Figure 1. Production volumes of each commodity group, per region (million tonnes)

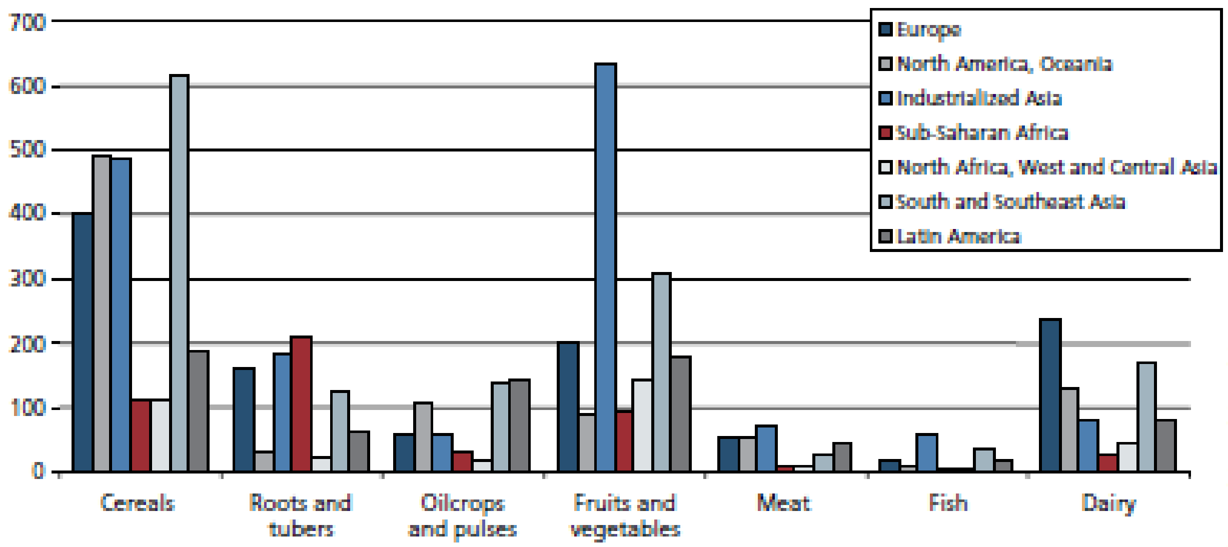
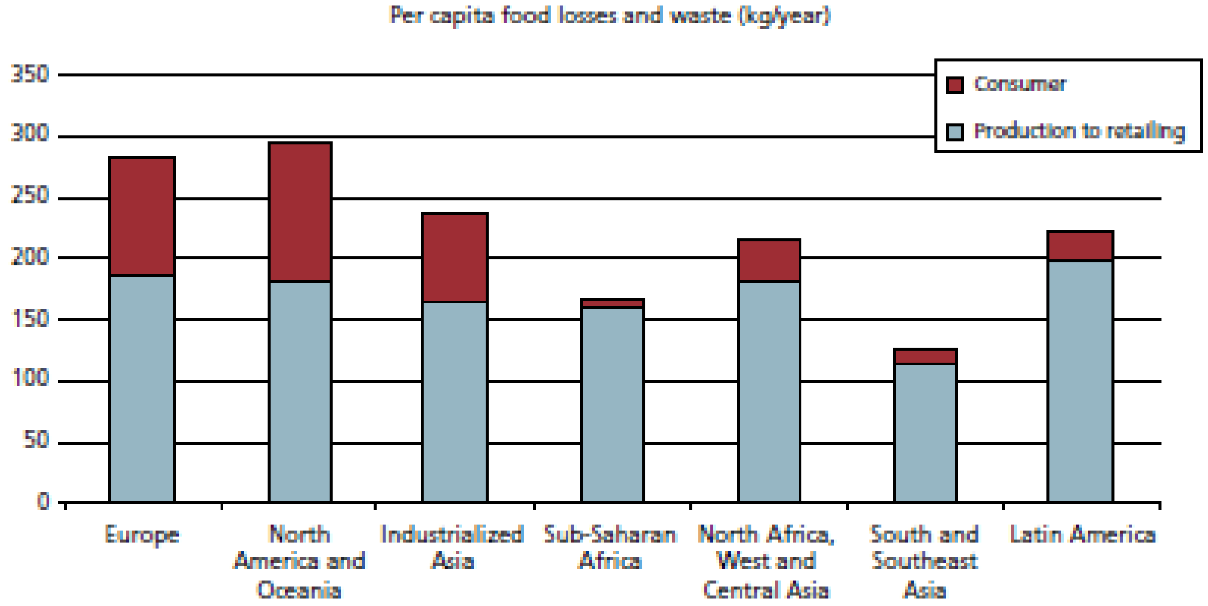


Figure 2. Per capita food losses and waste, at consumption and pre-consumptions stages, in different regions



Projects for development of sustainable packaging with Improved properties (barrier, anti microbial etc) in order to Reduce food spoilage ..

http://www.fao.org/docrep/014/mb060e/mb060e00.pdf Access 14 May 2018.

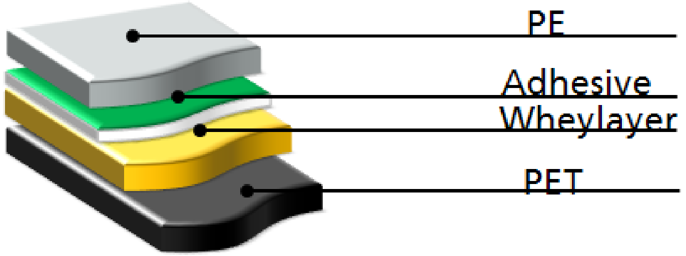
Partner of:

***WHEYLAYER** Whey protein-coated plastic films to replace expensive polymers and increase recyclability, **BSG Research for the benefit of specific groups,** 01.11.2008-31.10.2011*

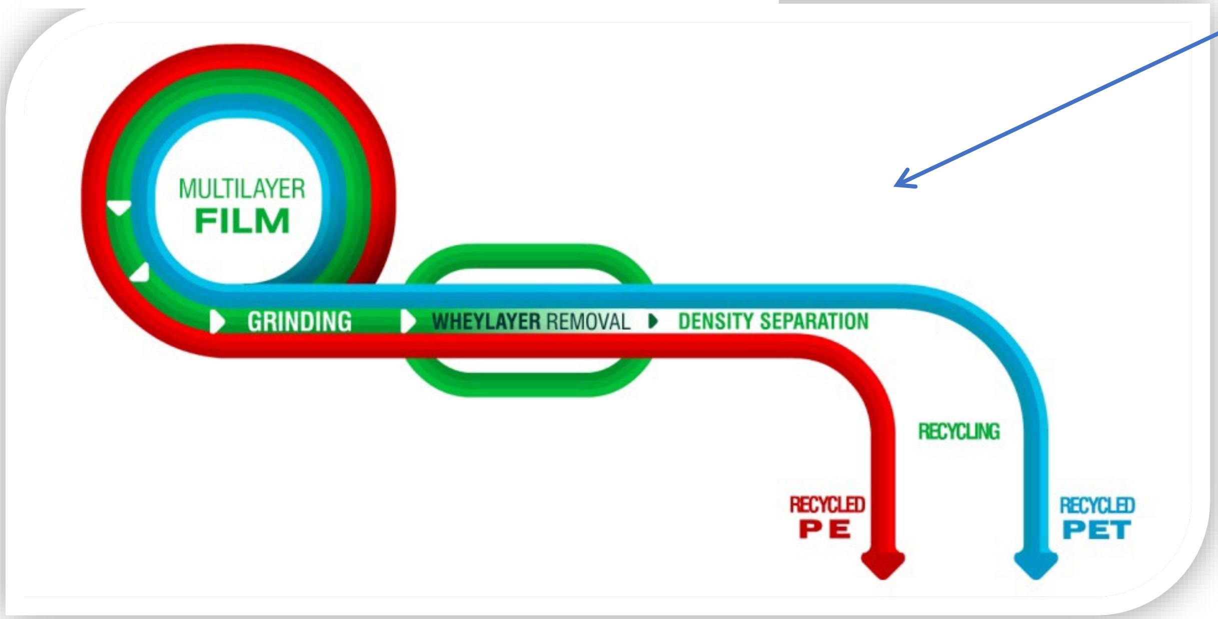
WHEYLAYER2 “Barrier biopolymers for sustainable packaging” **FP7-SME-2012 Activity 2.3: Demonstration Activity**: 01.08.2012-30.09.2014

www.**wheylayer**.eu/

Research activity in Wheylayer



Enzymatic Detergents



E. Bugnicourt, M. Schmid, O. Mc. Nerney, J. Wildner, L. Smykala, A. Lazzeri, and P. Cinelli «Processing and validation of whey protein coated films and laminates at semi-industrial scale as novel recyclable food packaging materials with excellent barrier properties", Advances in Materials Science and Engineering, Volume 2013, Article ID 496207.

P. Cinelli, M. Schmid, E. Bugnicourt, J. Wildner, A. Bazzichi, I.Anguillesi, A. Lazzeri "Whey protein layer applied on biodegradable packaging film to improve barrier properties while maintaining biodegradability", Polymer Degradation and Stability, 2014, 108, 151-157.

P. Cinelli, M. Schmid, El. Bugnicourt, M.B. Coltelli, A. Lazzeri, Materials, 2016, Vol. 9(6), 473; doi:10.3390/ma9060473 "Recyclability of PET/WPI/PE Multilayer Films by Removal of Whey Protein Isolate based Coatings with Enzymatic Detergents"

Partner of:

BioBoard

SEVENTH FRAMEWORK PROGRAMME

***BIOBOARD** Development of sustainable protein-based paper and paperboard coating systems to increase the recyclability of food and beverage packaging materials **Research for the benefit of SME AGs,** 01.11.2012-31.10.2015*

Research activity:

Production of sustainable plastic films containing protein derived by whey and potato by products.

Use of the film in multilayers on paper and paper boards, with barrier to gas and water vapour achieved by the presence of the protein based film.

Test of recyclability and sustainability.

M.B. Coltelli , F. Wild, E. Bugnicourt , P. Cinelli, M. Lindner, M. Schmid, V. Weckel, K. Müller, P. Rodriguez, A. Staebler, L. Rodríguez-Turienzo, A. Lazzeri "State of the Art in the Development and Properties of Protein-Based Films and Coatings and Their Applicability to Cellulose Based Products: An Extensive Review", Coatings 2016; 6(1): 1-59. doi:10.3390/coatings6010001

*www.**bioboard**.eu/*

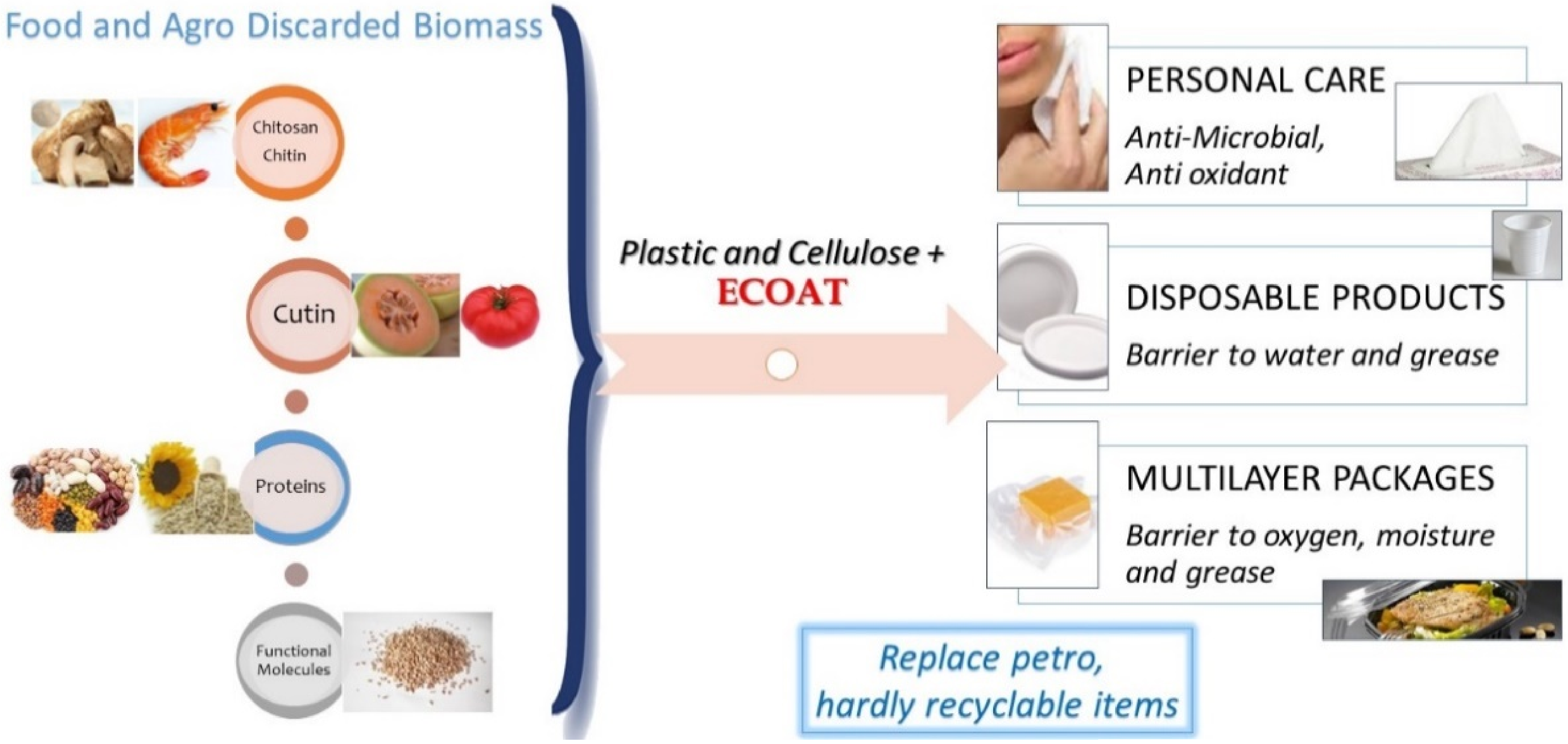
Partner of:

N-CHITOPACK *- Sustainable technologies for the production of biodegradable materials based on natural chitin-nanofibrils derived by waste of fish industry, to produce food grade packaging,* **Research for the benefit of SME**, 01.11.2012-31.10.2014

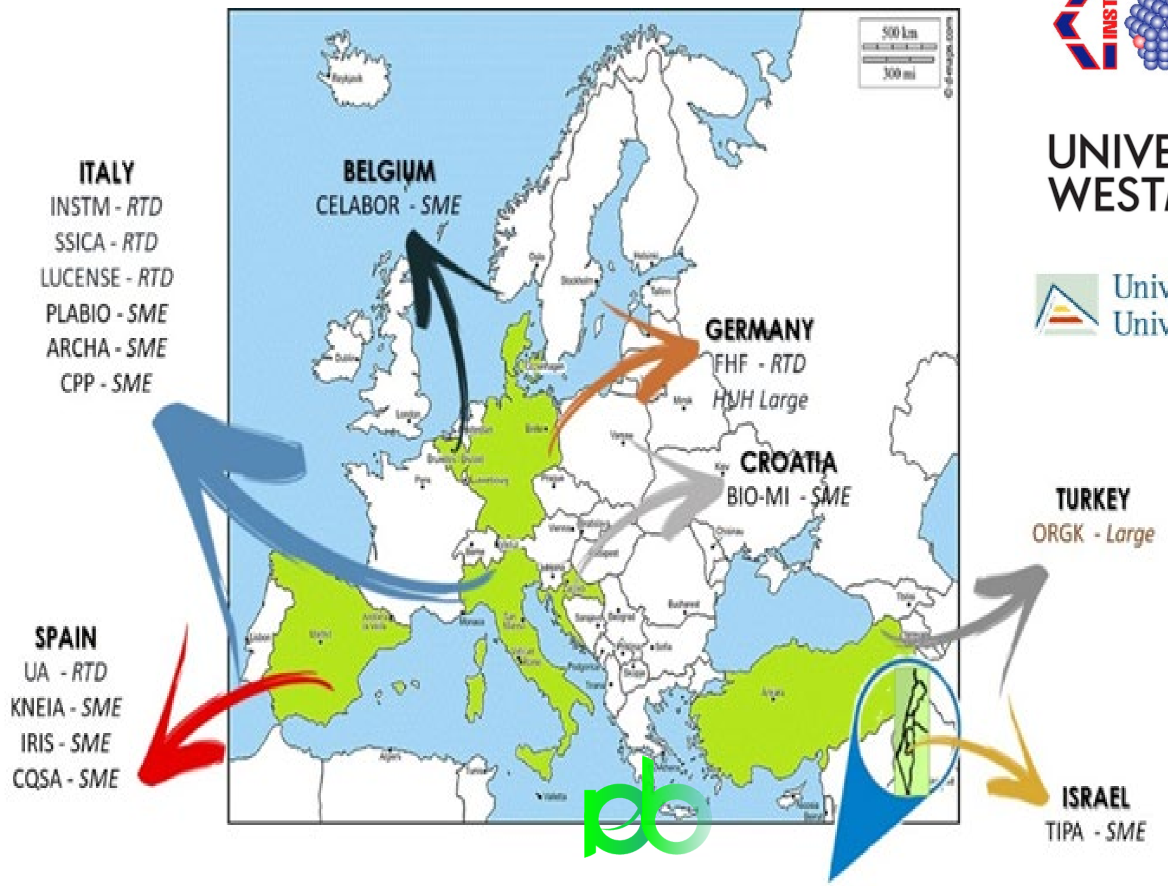
Research activity:
Development of nano composites based on biodegradable polymeric matrix and chitin nano fibrils. Characterization of thermal, mechanicla properties and morèhology. Biodegradation tests and evaluation of sustainability and Life Cycle Assessment.

http://www.n-chitopack.eu/

ECO sustainable multifunctional biobased COATings with enhanced performance and end of life options
GA 837863, BBI2018-RIA-A



Bio-based Industries Consortium
Horizon 2020
European Union Funding
for Research & Innovation



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RICERCA E SERVIZI PER L'INNOVAZIONE

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Laboratori ARCHA S.r.l. unipersonale

bio-mi
SUSTAINABLE SOLUTIONS

TIPA
Sustainable Packaging

PARMA

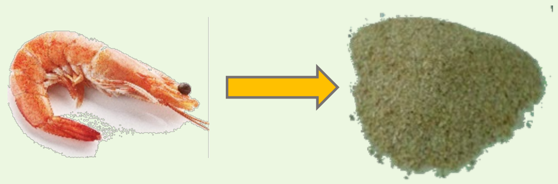
ORGANİK KİMYA
the chemistry between us

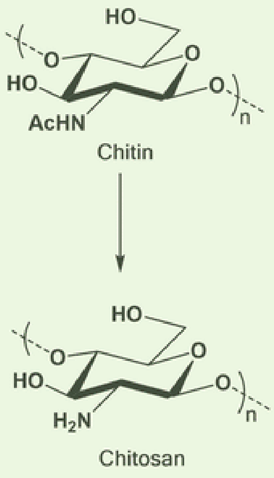
Huhtamaki

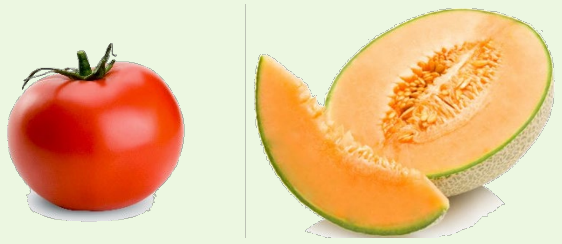
Kneia

Coordinatore INSTM-Università di Pisa
Prof. Patrizia Cinelli; Dipartimento di Ingegneria Civile ed Industriale

ECOAT STRATEGY







C_{16} Acids

$CH_3(CH_2)_{14}COOH$

$CH_2(CH_2)_{14}COOH$ (with OH on the first CH_2)

$CH_2(CH_2)_xCH(CH_2)_yCOOH$ (with OH on CH_2 and on CH)

y = 5, 6, 7, or 8, and x + y = 13

C_{18} Acids

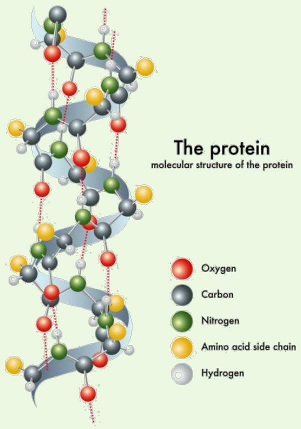
$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$

$CH_2(CH_2)_7CH{=}CH(CH_2)_7COOH$ (with OH on the first CH_2)

$CH_2(CH_2)_7CH{-}CH(CH_2)_7COOH$ (with OH on the first CH_2; O bridging CH–CH)

$CH_2(CH_2)_7CH{-}CH(CH_2)_7COOH$ (with OH on the first CH_2 and on each CH)

Cutin-forming acids



CONCLUSIONI E PROSPETTIVE

- Esistono materiali polimerici biodegradabili utilizzabili per la produzione di plastiche con proprietà compatibili per applicazioni monouso
- Fattori limitanti al loro utilizzo sono: costo relativamente elevato, rispetto a convenzionali plastiche non biodegradabili, lavorazione più sensibile, personale più qualificato
- Buona conoscenza delle proprietà chimico, fisiche, meccaniche dei polimeri costituenti le plastiche biodegradabili
- Necessità di una corretta informazione dei mezzi di informazione e dei consumatori su definizioni e prestazioni dei materiali
- Forte educazione al consumatore verso una corretta gestione del rifiuto
- Ricerca in corso con ottime prospettive verso la possibile sostituzione dei materiali in plastica non biodegradabili, difficilmente riciclabili con materiali da fonti rinnovabili e “bio-riciclabili”

Thanks for your kind attention!





patrizia.cinelli@unipi.it

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