Biobased plastics for packaging

Christiaan Bolck (christiaan.bolck@wur.nl)

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FOOD & BIOBASED RESEARCH
WAGENINGEN UR

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- Introduction FBR-Biobased Products
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  - Biobased vs Biodegradable
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Wageningen UR (University & Research centre)

- Three pillars:
  - Wageningen University
  - Van Hall Larenstein Univ. of Appl. Sci
  - DLO - Applied Research Institutes
- Annual budget about 650 m euros
- About 6500 employees
- 9000 BSc/MSc; 1200 PhD (>100 countr.)
- Extensive international network
- Active partner in Food Valley

…to explore the potential of nature to improve the quality of life…

FOOD & BIOBASED RESEARCH
WAGENINGEN UR

Wageningen University & Research Centre

- University: academic research
- Research Centres: contract R&D

- > 6000 employees
- Five Sciences Groups

Supervisory Board

Executive Board

Life long learning
IAC, PHLO, WMS

Statutory tasks units
Rikilt, CIDC

Board of Directors

Plant Sciences

Board of Directors

Animal Sciences

Board of Directors

Agrotechnology & Food Sciences

Board of Directors

Environmental Sciences

Board of Directors

Social Sciences

Agrotechnology & Food Sciences Group

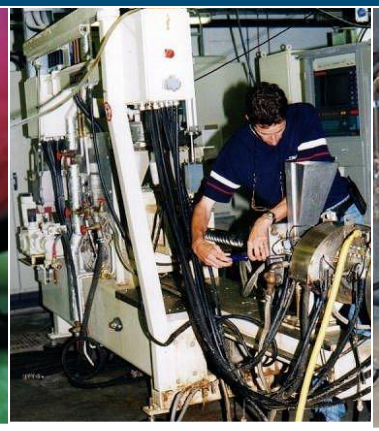
- AFSG: ~ 1000 employees
  - University: ~ 700
  - Research Centre Food and Biobased Research: ~ 300
- Food and Biobased Research (formally ATO) : two business units
  - Fresh, Food & Chains
  - Biobased Products
- BU Biobased Products
  - Biomass conversion technologies
  - Renewable chemicals and materials development

Biobased Products

- Development of novel technologies, materials and products (mainly) based on renewable raw materials
- Focus on Materials, Chemicals and Biofuels following a biorefinery approach
- Cooperation with industry to find innovative, sustainable solutions (towards a biobased economy)

FBR-Biobased Products

- Technologies
  - Biotechnology (enzyme catalysis, fermentation, etc)
  - (Bio)polymer processing (extrusion, injection moulding, ...)
  - Organic chemistry and catalysis on carbohydrates and fatty acids
- Markets
  - Plastics and additives
  - Coatings, inks and adhesives
  - Bio fuels
  - Chemicals
  - Paper


Bioplastics research at FBR-BBP

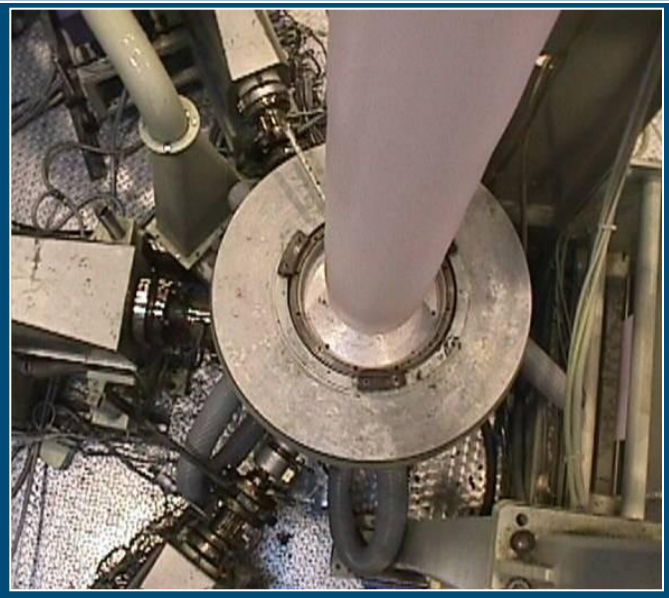
- Since 1990 important research topic at FBR-BBP
- Various multi-partner EU-projects
- Many bilateral contracts
  - With raw material producers
  - With plastic converters
  - With additive manufacturers

Paragon Products B.V.

Rodenburg Biopolymers B.V.

BIOP Biopolymer Technologies AG

Research facilities at FBR-BBP



- Processing
  - Extrusion (single/double screw)
  - Co-extrusion; 1-5 layers sheet/blown film
  - Injection moulding
  - Compression moulding
  - Thermo forming
- Analysis
  - Thermal (DSC, TGA, HDT)
  - Mechanical (tension, bending, compression, DMTA, impact, falling dart)
  - Rheological (capillary, dynamic)
  - Structural (SAXS, FTIR, SEM)
  - Chemical (ss-NMR, HPSEC-MALLS, GPC tri-sec, GC-MS)
  - Biodegradation (controlled composting, pilot-scale composting, aquatic tests)

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Sustainability

What is going on?

Duurzaam

natuurlijk

Afbreekbaar

CO2 neutraal

Hernieuwbaar

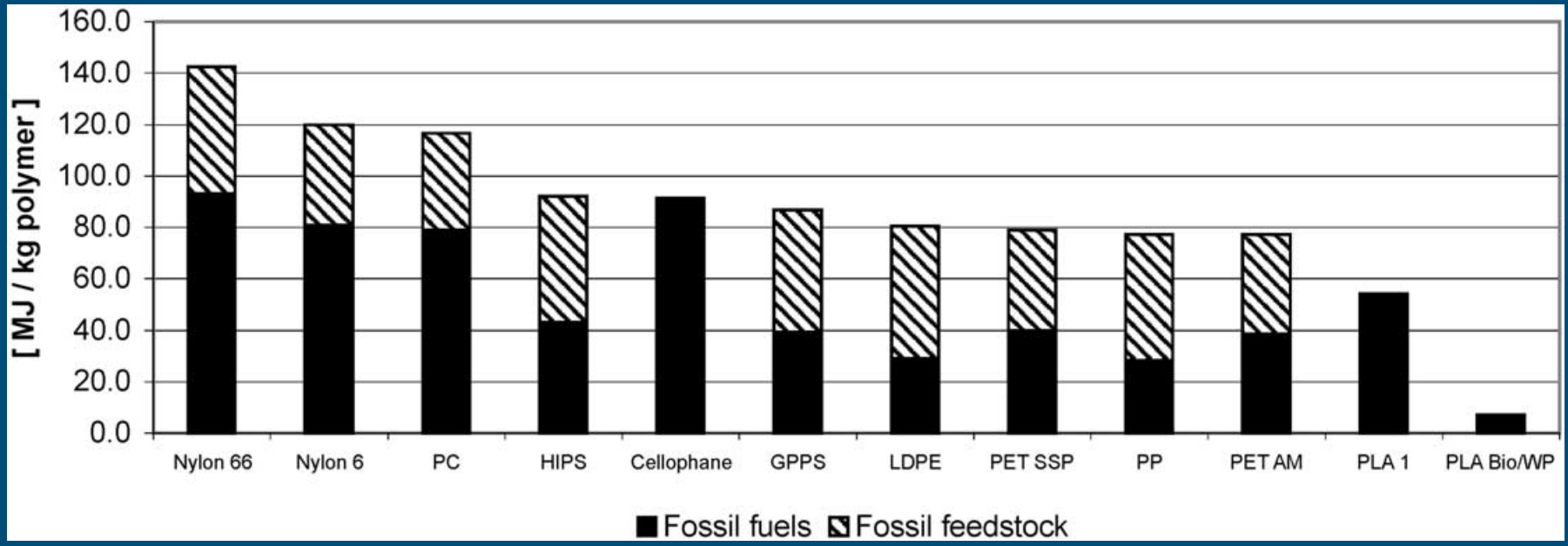
Composteerbaar

Gerecycleerd

Biobased

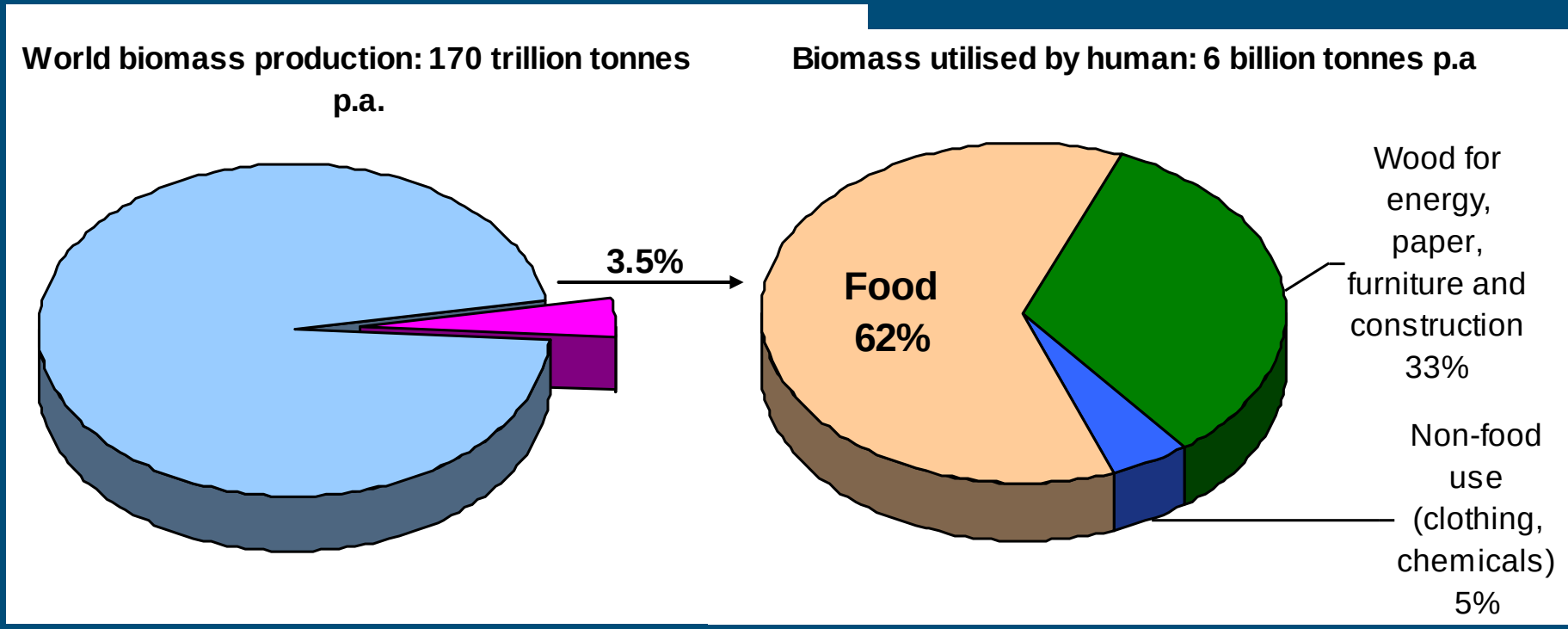
Greenhouse effect

- Energy in product
- Energy for production



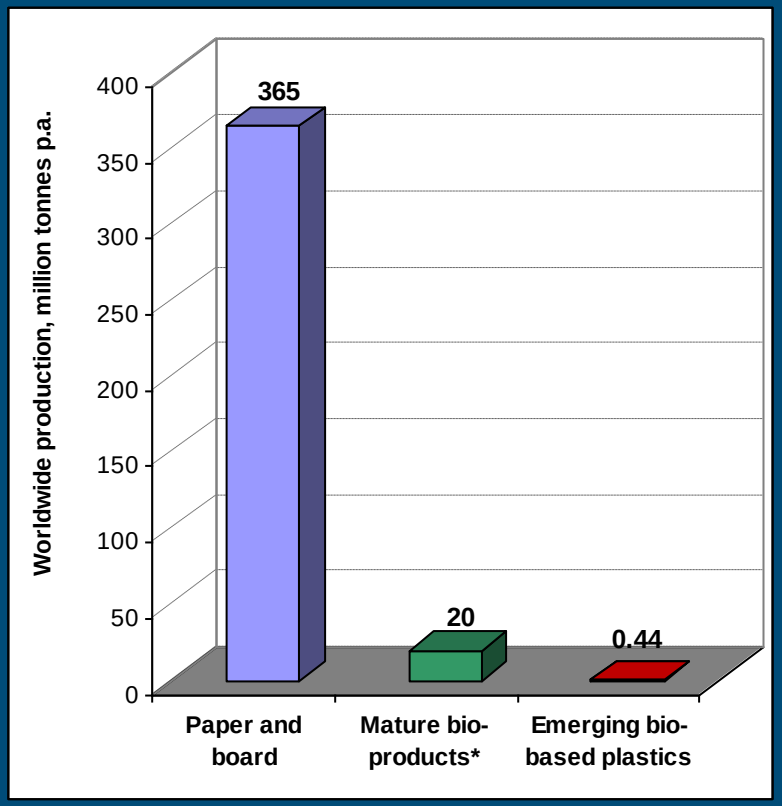
PLA & Energy

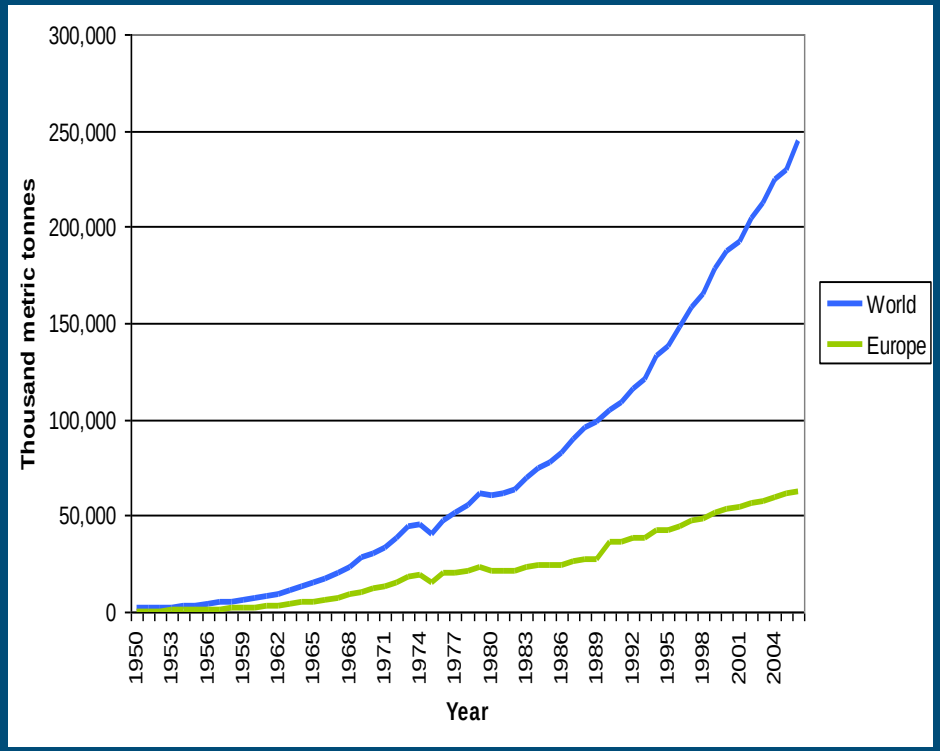
Food vs Fuel



World biomass production (left) and biomass utilised by human (right)

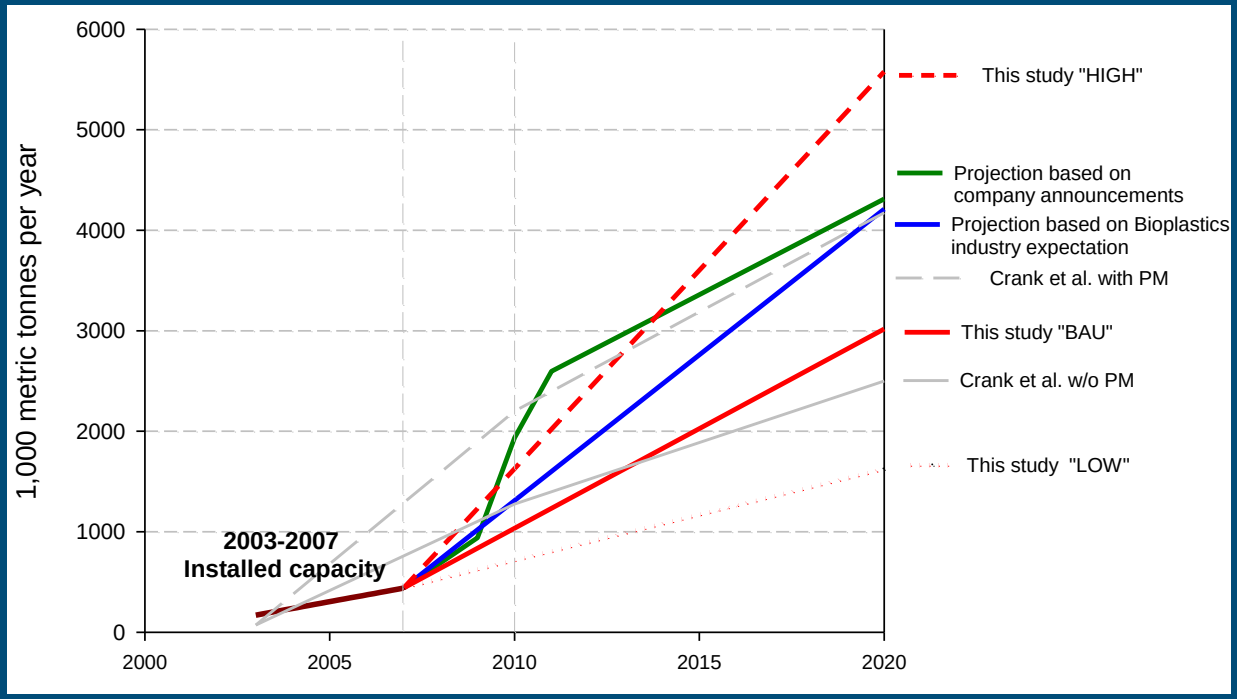
Food vs Fuel





Production of plastics

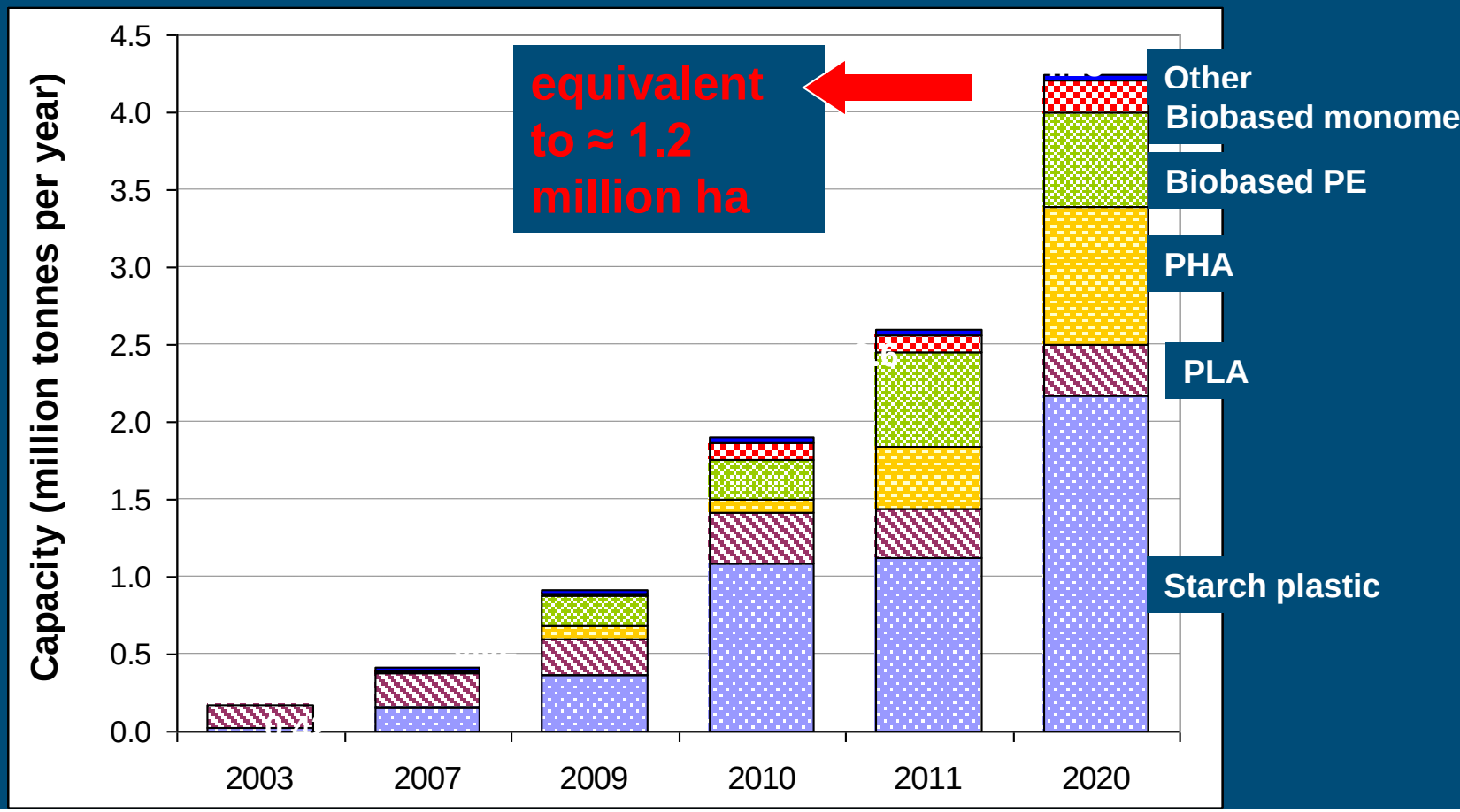
Market



Projection of the worldwide production capacity of bio-based plastics until 2020 (Probip 2009)

Production capacity (in kt)

(historie 2003-2007; aankondigingen voor >2007)

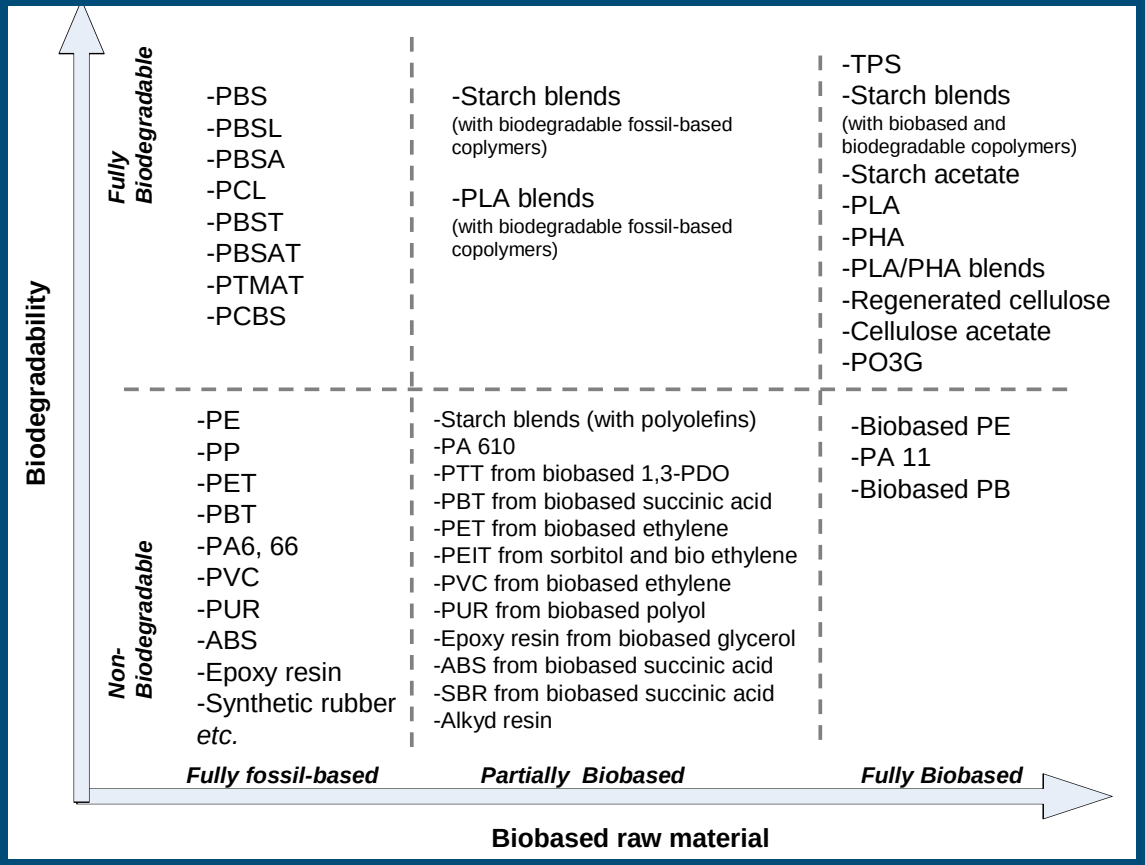


Production capacity

(2007)

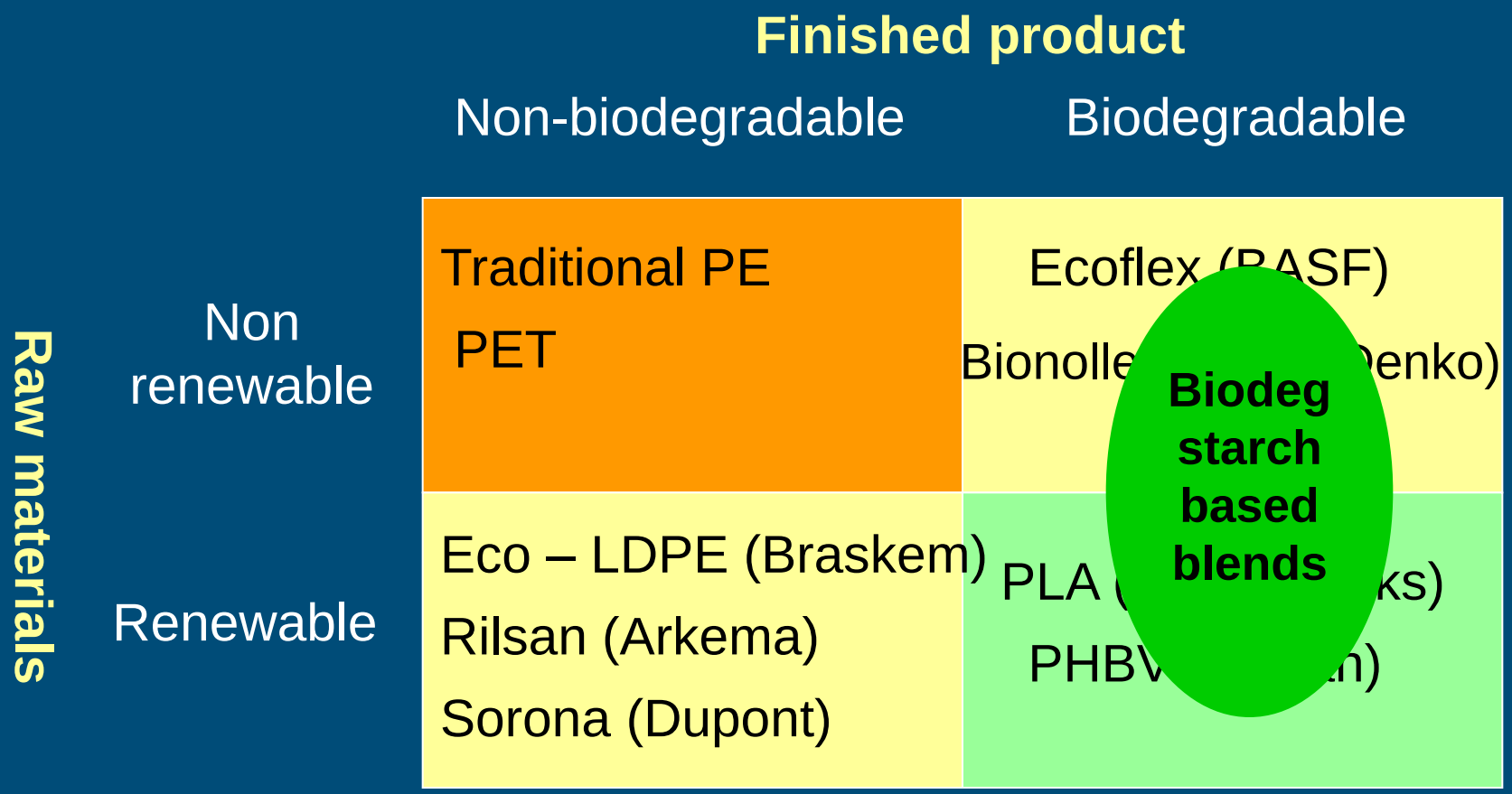
			ton/year	
PLA materials				
Natureworks LLC	Natureworks polymer	USA	70.000	(140.000 in 2009)
Hisun Corp.	Hisun	China	4.000	(expanding)
Purac Lactide customers		Europe/Asia	…….	(starting up)
Starch based materials				
Novamont SpA	Mater-bi	Italy	60.000	
Rodenburg	Solanyl	The Netherlands	40.000	
Biotec GmbH	Bioplast	Germany	10.000	
Biop	Biopar	Germany	4.000	
Plantic	Plantic	Australia	…..	
Biograde	Biograde	Australia	…..	
Cereplast Corp.		USA	>>	
Cellulose based materials				
Innovia films	Natureflex	England	10.000	
Celanese	Clarifoil	England	…..	
FKUR	Biograde	Germany	4.000	
PHB				
Tianan	Enmat	China	4.000	
Biomer	Biomer	Germany	1.000	
PHB Industrial SA	Biocycle	Brazil	….	(starting up)
Telles	Mirel	USA	….	(starting up)
Biodegradable polyesters				
BASF	Ecoflex	Germany	8.000	(expanding in 2010)
Showa Denko	Bionolle	Japan	3.000	
Solvay/Perstorp	CAPA	England	……	
Mitsibishi Chemical	GS Pla	Japan	3.000	
Others				
Limagrain Cereales	Biolice	France	….	
(Idroplast	Hydrolene (PVA)	Italy	….	)

Types



Current and emerging (partially) bio-based plastics and their biodegradability

Biodegradable vs. biobased materials



Biobased plastics

- Renewable or biobased polymers are polymers from which the raw materials originate directly or indirectly from nature

- Classification of biobased polymers:
  - (Modified) natural polymers
  - Directly from micro-organisms or gene-modified crops
  - From biobased feed stock (eg via fermentation)

- Biobased plastics ≠ biodegradable plastics

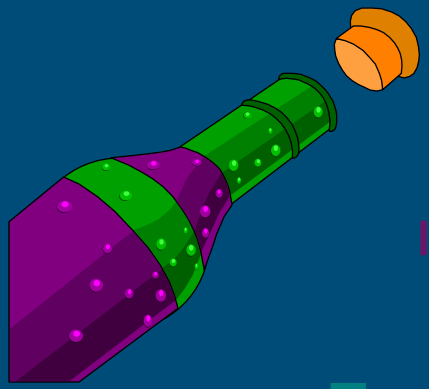
Biodegradable plastics

- Biodegradation: degradation catalyzed by biological activity leading to mineralization and/or biomass
- Biodegradability: degree to which biodegradation leads to mineralization and/or biomass
- Mineralization: the conversion of (organic) constituents in naturally occurring gasses, water and inorganic constituents

- Standardisation and certification is very important!
- Demands for biodegradable products

  are described in EN13432

EN 13432: Test scheme for compostable products



Characterisation of materials and individual components

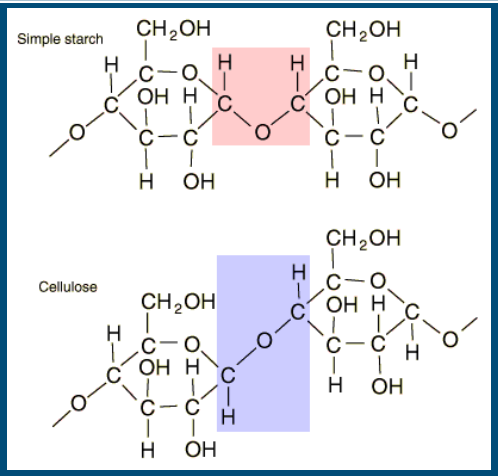
Assessment of **biodegradability** of materials or components in laboratory tests

Evaluation of results

Assessment of **disintegration** of product (components) in pilot-scale plants

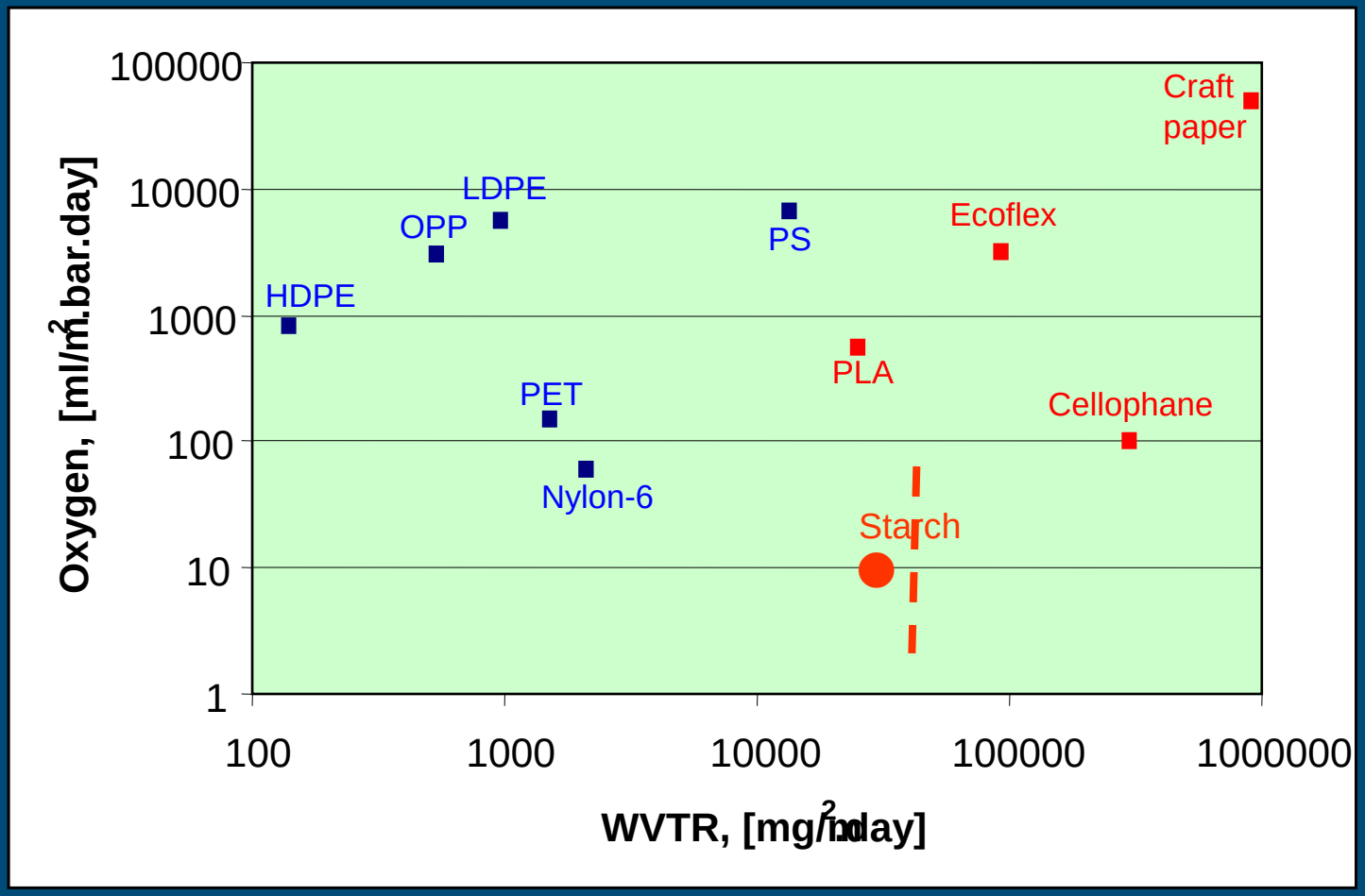
Assessment of **effect on composting process** in pilot-scale plants

Assessment of **effect on compost quality** in pilot-scale plants



Technical

Permeability of plastics



Available biodegradable plastics

Most important groups of biodegradable plastics

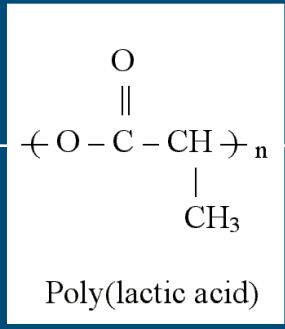
- Cellulose and cellulose derivatives
- Starch based plastics (thermoplastic starch)
- Polyesters
  - Poly lactic acid (PLA)
  - Poly caprolactone (PCL)
  - Polyhydroxy alkanoates (PHA, PHBV)
  - Several (co-)polyesters
- Materials based on industrial proteins
- Blends of various bioplastics (eg thermoplastic starch & polyesters)

Cellulose derivatives (cellulose diacetate)

- Advantages
  - Good mechanical properties (like PS)
  - Good thermal resistance
  - Glossy transparent appearance
  - Renewable

- Disadvantages
  - Price (>4€/kg)
  - Use plasticiser
- Processing
  - It is advised to dry the material
  - Suitable for:
    - Injection moulding
    - Sheet extrusion (thermo forming
    - Fibre extrusion
  - Processing temperature 190-240°C
  - Thermal degradation possible

Polylactic acid (PLA)



- Advantages
  - Good mechanical properties (like PET)
  - Transparent
  - Price (1.8-2.0 €/kg)
  - Renewable
- Disadvantages
  - Only compostable in industrial composting facilities
  - Water sensitivity during processing
- Processing
  - Material needs to be dried
  - Suitable for:
    - Film extrusion (and thermo forming)
    - Blow molding
    - Injection moulding
    - Fibre extrusion
  - Processing temperature 170-210°C

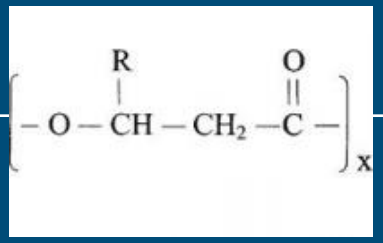
Starch based plastics

- Advantages
  - Good mechanical properties (LDPE to PS)
  - Excellent gas barrier properties
  - Anti-static
  - Fast biodegradable

- Disadvantages
  - Humidity dependent
  - Not completely transparent

- Processing
  - Processed as delivered (no drying)
  - Suitable for:
    - Film blowing (incl multilayer)
    - Injection moulding
    - Sheet extrusion (and thermo forming)
    - Foam extrusion
  - Processing temperature 120-180°C

Poly hydroxy alkanoates (PHA's)



- Advantages
  - Mechanical properties can be varied
  - Hydrophobic (low water vapour permeability)
  - Rather high HDT (>100°C)
  - Renewable

- Disadvantages
  - Expensive (for now > 4€/kg)
  - Harvested from micro organisms
  - Low melt strength

- Processing
  - Suitable for:
    - Injection moulding
    - Sheet extrusion (and thermo forming)
    - Film blowing, Film casting

Synthetic (co)polyesters and polyester amides

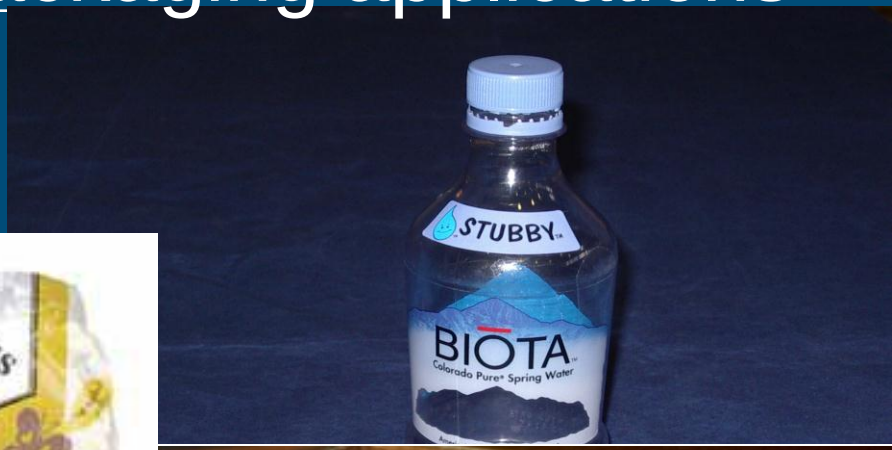
- Not renewable (not yet)
- Mechanical properties possible from PE to PP
- Compostable
- Suitable for films and extrusion (in most cases not for injection moulding)

Biodegradable (packaging) products

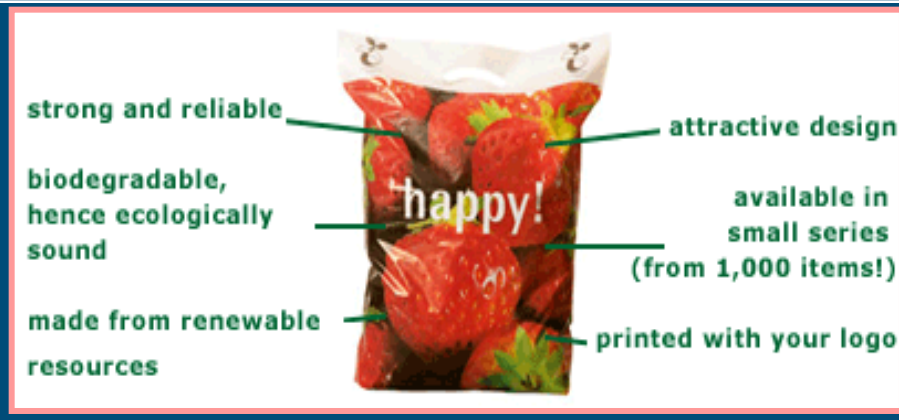
Towards biodegradable products

- Biodegradable products are preferably applied:
  - Where biodegradation is a functional advantage or a requirement: green waste bag
  - Where biodegradability is imposed by law
  - When recycling is impossible or too costly or impractical (various agricultural applications)
  - In case of better price-performance (PLA fibres for clothes)

Examples of (existing) packaging applications



Examples of (existing) agricultural applications

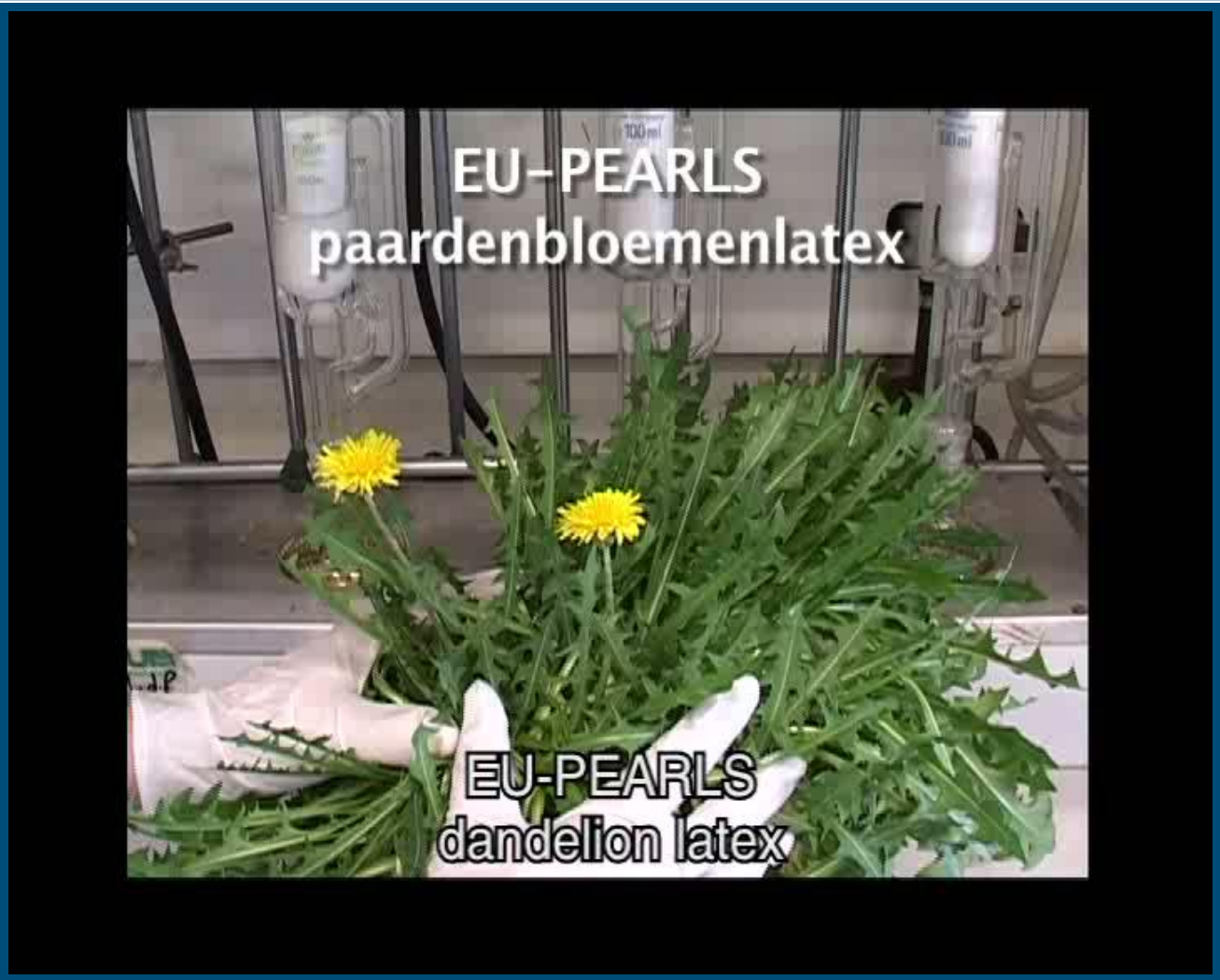


New developments:

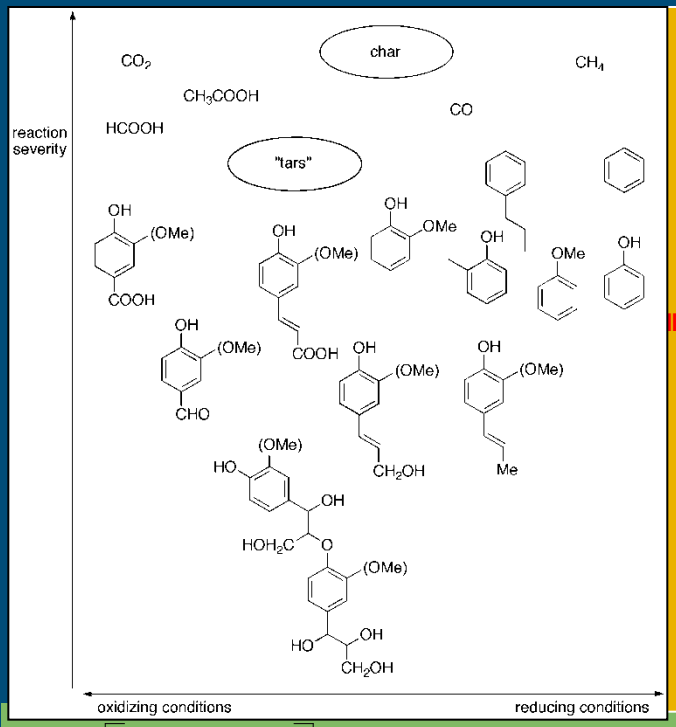
- Recourses
- Polymers from nature
- Biobased building blocs
- Application of available polymers

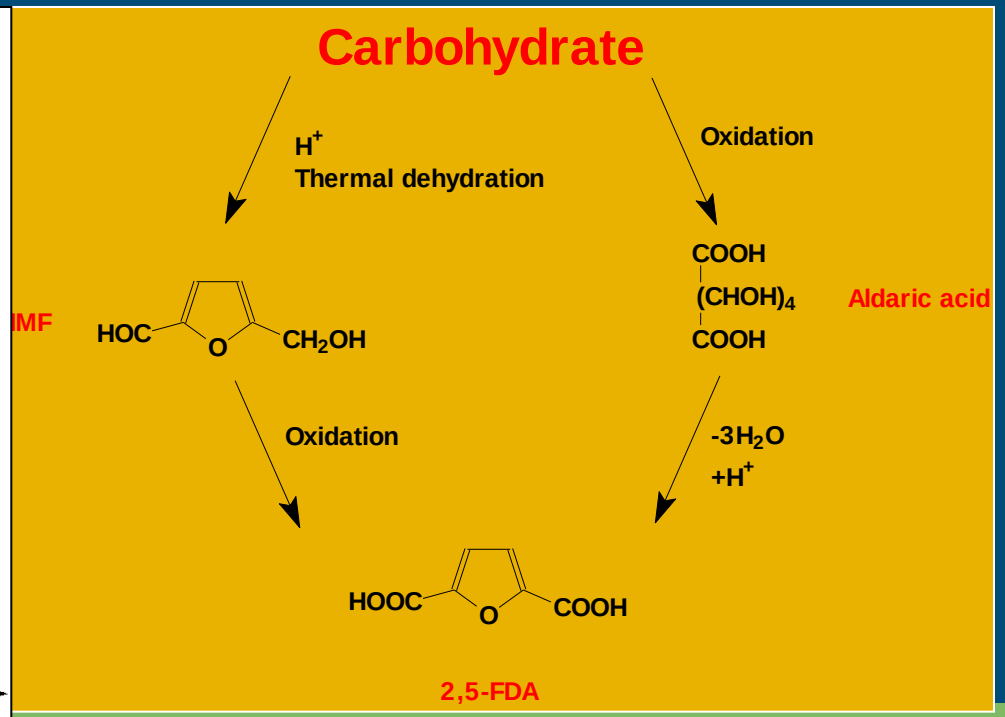
Resources

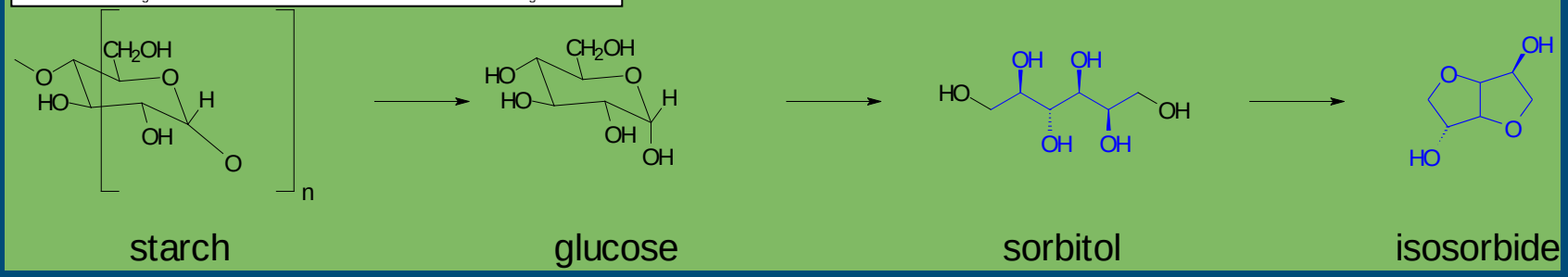
Polymeren from nature

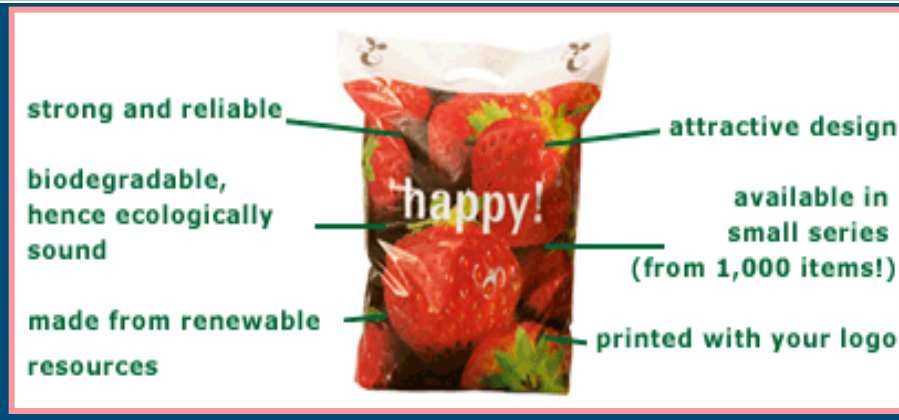


Biobased building blocs









Application of available polymers

- 5 examples

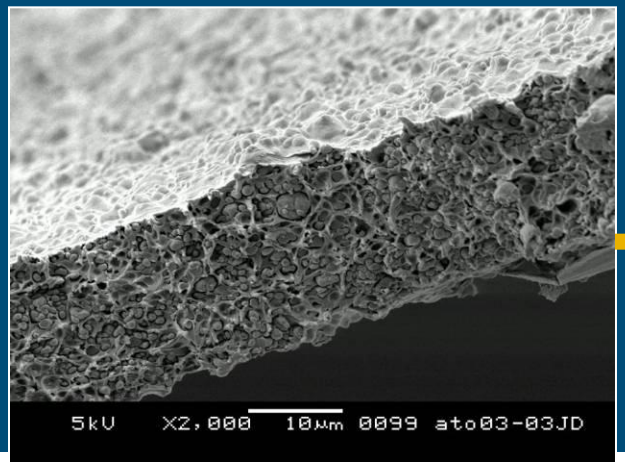
Example 1: processing aspects PLA

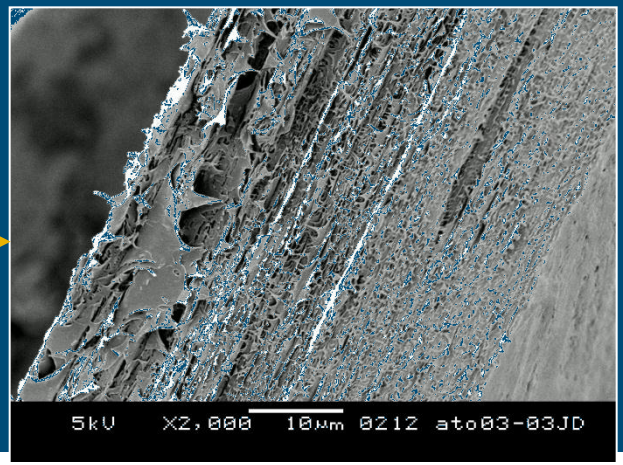
Without reology modifier

With reology modifier

Example 2: Compatibilisers in blends

- Example of a compatibilised starch/polyester blend with improved properties
  - Cost reduction: increase starch content
  - Improved properties: co-continuous system
    - Toughness
    - Barrier properties
    - Clarity





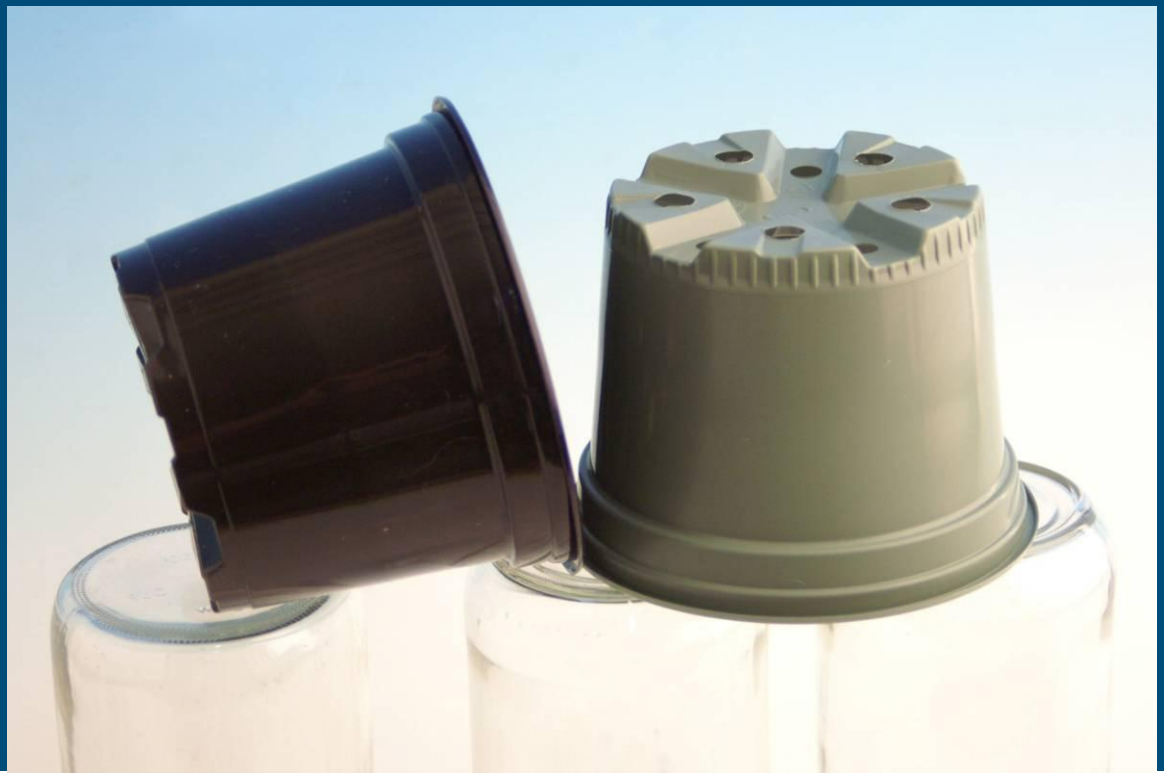
Example 3: Improving heat stability

Material	HDT-B value (°C)
Biograde 300A (cellulose derivative)	> 100
Enmat 1000 (PHBV)	> 100
Natureworks 4042D (PLA)	50-60
Starch based materials	< 80

Hot coffee in PLA cup for cold drinks

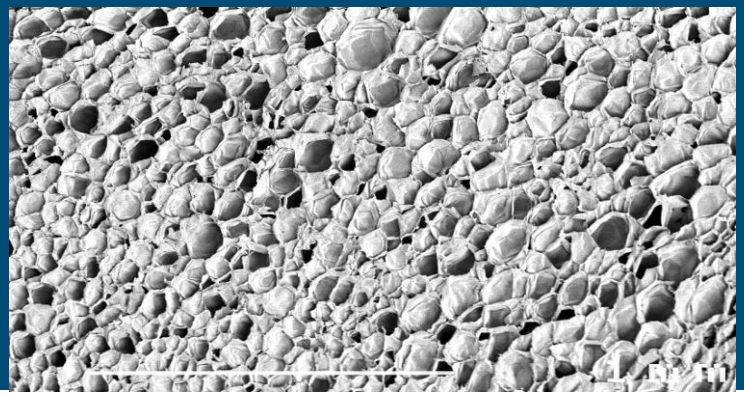
Example 4 : Thermoformed products

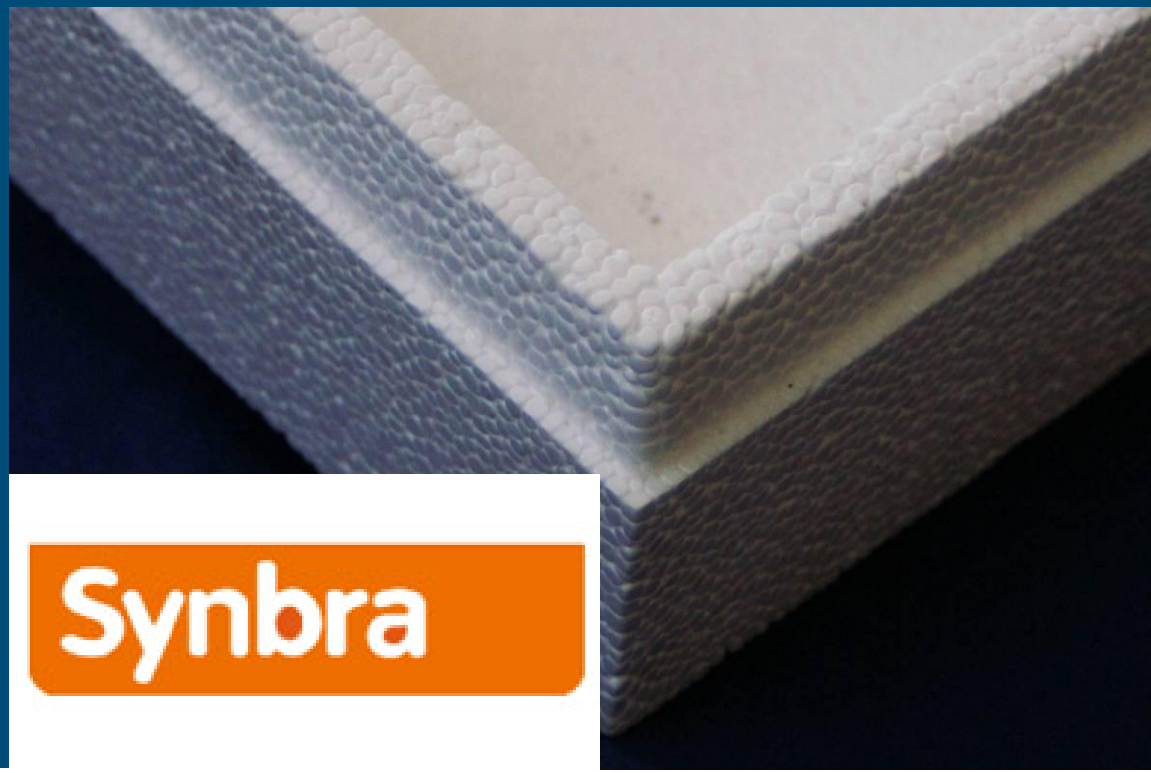
- High HDT
  - PLA type
  - Nucleation
  - Processing



Example 5 : 3D-foamed structures

- Expandable bead technique
  - Good cell structure
  - Density <30 g/l





Synbra

Thank you for your attention

christiaan.bolck@wur.nl

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