Session: Products
Presentation by: Lawrence Theunissen, *Reverdia*

Title: **New products with biobased PBS**

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Curriculum:
Since 2011 Lawrence works for Reverdia as Director Marketing and Application Development. As part of the Commercial Team, Lawrence works along the value chain to assess and demonstrate technical feasibility, and develop value propositions addressing the trends and needs of multiple industry segments.
Lawrence Theunissen joined DSM in 2002 and since then managed application development activities for various business units in research and innovation environments. He received a bachelor's degree in Mechanical Engineering, with focus on plastics technology, from University of Applied Sciences, Heerlen, the Netherlands. This study has been complemented with various courses in polymer chemistry and polymerisation. After graduating he worked in the field of product design and application engineering.

Abstract:
This presentation will highlight the APPS project, which aims at developing biobased PBS-compounds for durable, injection moulding applications. The APPS-project is executed by 4 companies, which together represent the complete value chain. Within the project, the novel biobased PBS-compounds have been validated in multiple challenging applications, including bottle caps including a film hinge, a horticultural transport crate and an automotive panel with a large number of complex-to-mould features. The most important results of the project will be highlighted, as well as some view on how the outcome of the project can serve as basis for further developments.

APPS project - PBS for Injection Molded Applications

June 14, 2018
Lawrence Theunissen
Reverdia

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sustainable solutions
powered by DSM + Roquette

World-leader in biobased succinic acid

- Produce & Sell Biosuccinium®
- 10kt plant, producing since 2012

HQ in The Netherlands

Production in Italy

Reliable partner

- 50/50 JV of DSM & Roquette
- Market & Application Development
- Global supply

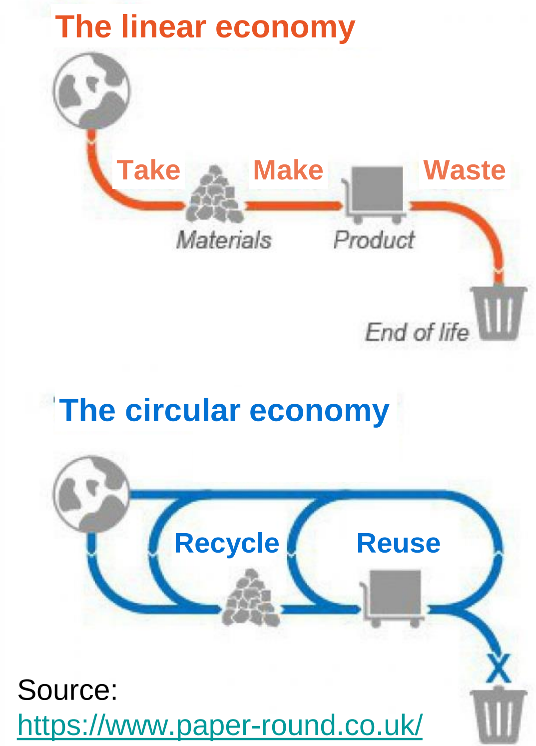
Main markets

- Bio-based materials
- Bio-based chemicals
- Compostable plastics
- Cosmetics

Bio-based Materials in The Circular Economy

Renewable materials and recycling/reuse of materials are complementary

- The Circular Economy will increasingly replace the linear economy !
- The Circular Economy will still have “system losses” so there is a need for sustainable waste disposal options
- Bio-based materials are the sustainable way to compensate for such system losses



Source:
https://www.paper-round.co.uk/
Towards-the-circular-economy

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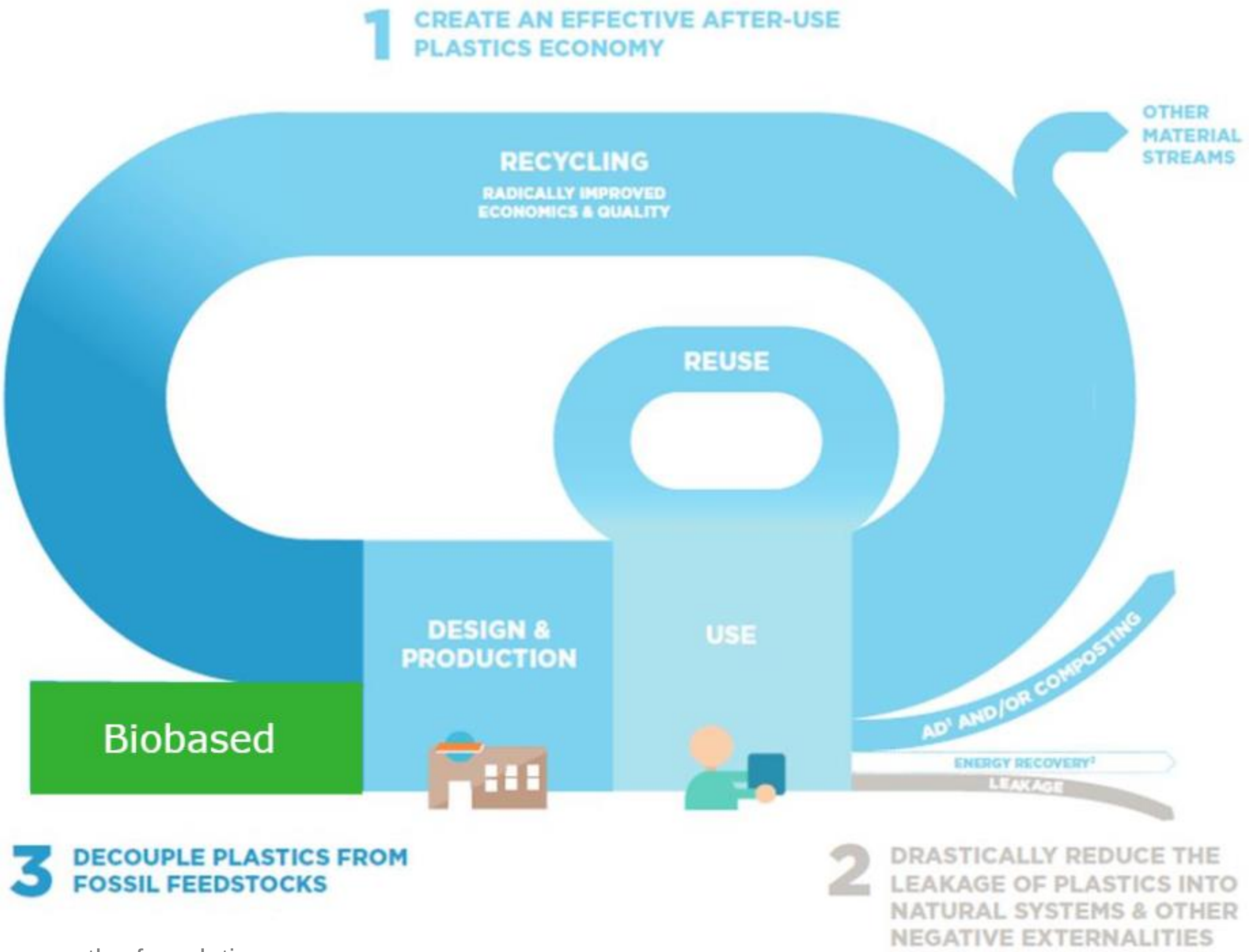
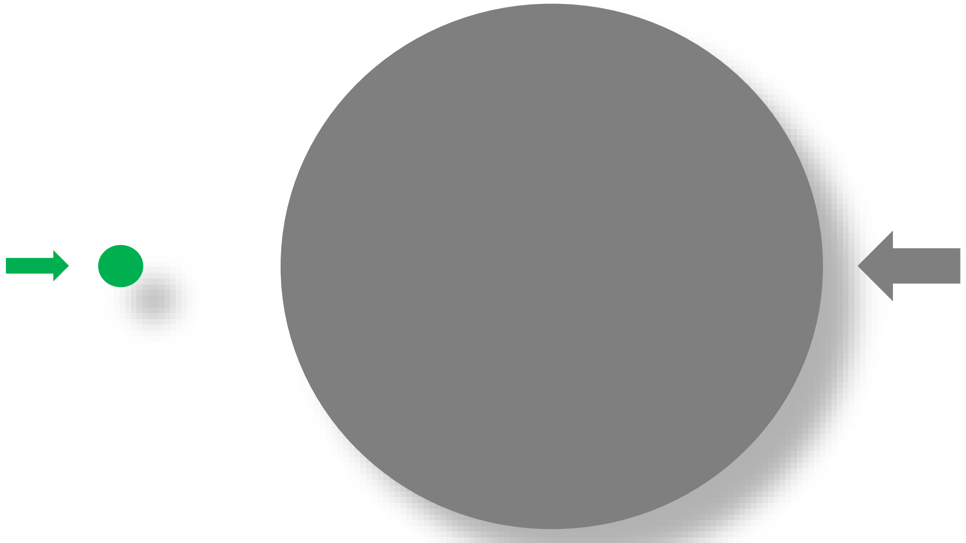


Source: www.ellenmacarthurfoundation.org

Bioplastics production capacity

Bioplastics



Oil-based plastics

- **2.2 million tons in 2020**
- **CAGR of 3.5% (2017 – 2022)***

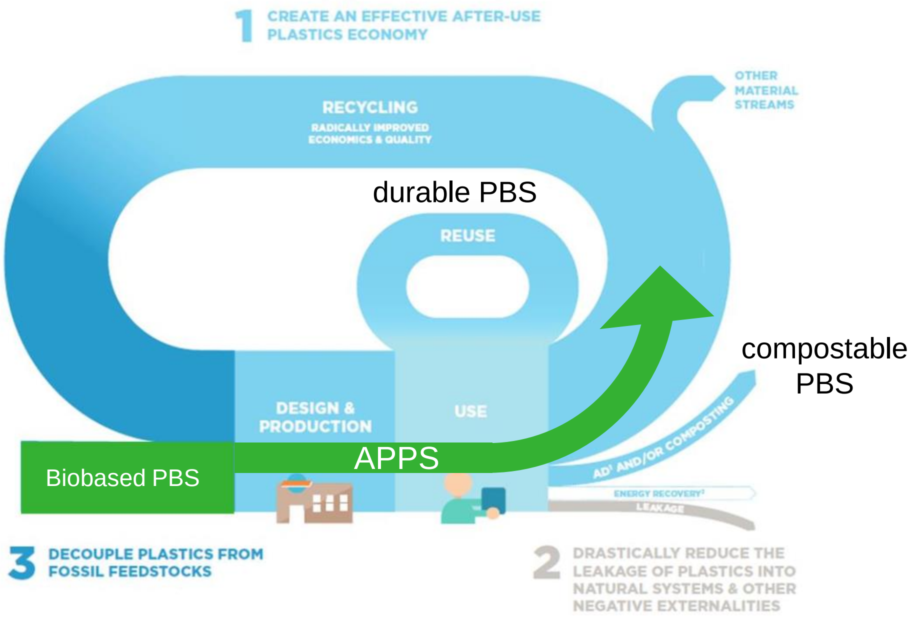
- **335 million tons in 2020**
- **CAGR of 5.3% (2014 – 2020)****

**   European Bioplastics, Nova Institute, 2017*
*** Grand View Research, 2015*

Drivers and Objective of the APPS project

- Project drivers
  - increase the use of Bio-based Materials
  - develop new market segments in order to get to economies of scale
  - find differentiated performance to accelerate market acceptance

- Project objective
  - Develop bio-PBS based compounds suitable for application in durable, injection moulded applications



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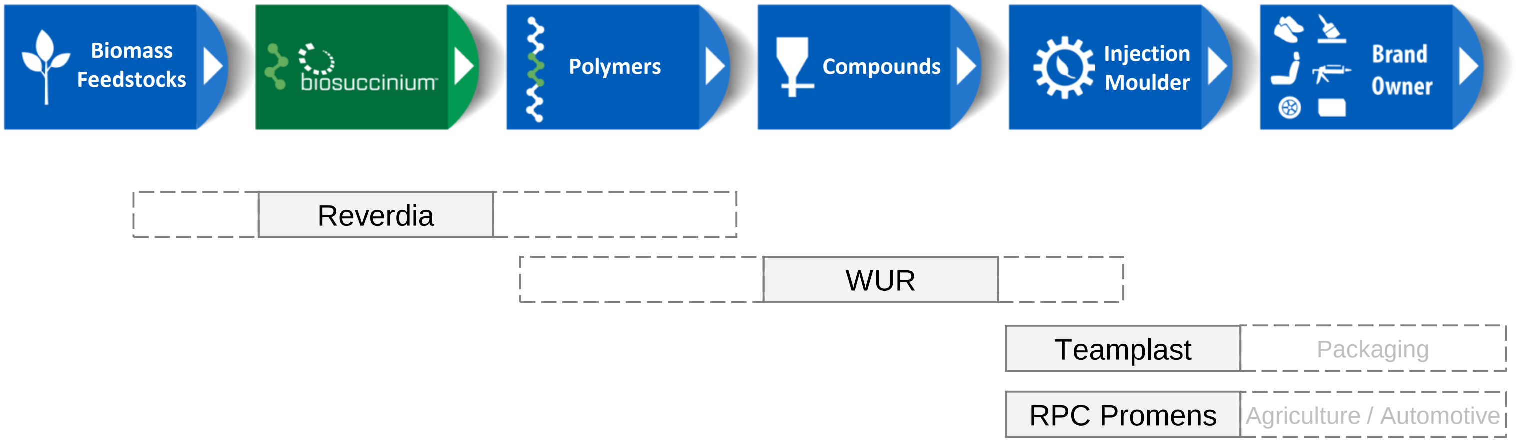
APPS project members

- 4 project partners, representing the whole value chain



What is PBS ?

- PBS is a relatively new polymer
- Well balanced properties
- Easy to process

- Produced from 2 raw materials
  - Succinic acid **biobased (Reverdia)**
    oil-based also available
  - Butanediol **fossil-based**
    biobased not available (yet)

Properties	Unit	BioPBS™	
		FZ91 (PM/PB)	FZ71 (PM/PB)
Melt Flow Rate (190°C/2.16kgf)	g/10min	**5**	**22**
Density	g/cm^3	**1.26**	**1.26**
Melting Point	°C	**115 (239°F)**	**115 (239°F)**
Tensile Stress at break	MPa	**30**	**36**
Tensile Strain at break	%	**210**	**170**
Flexural Modulus	MPa	**650**	**630**
Izod Impact	kJ/m^2	**10**	**7**
Heat Deflection Temp. (0.45MPa)	°C	**95 (203°F)**	**95 (203°F)**
Recommendation		**Thermoform Foam Flexible packaging Film**	**Paper coating Injection Extrusion**

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Target applications and their key properties

Some overlap in application requirements

	Teamplast		RPC Promens	
	Spice box	Hinged caps	Horticulture crate	Automotive panels
Mechanical properties	X	X	X	X
Optical properties	X			X
Food safety	X	X		
Durability			X	X
Thermomechanical stability			X	X
Injection molding behavior	X	X	X	X

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Mechanical properties

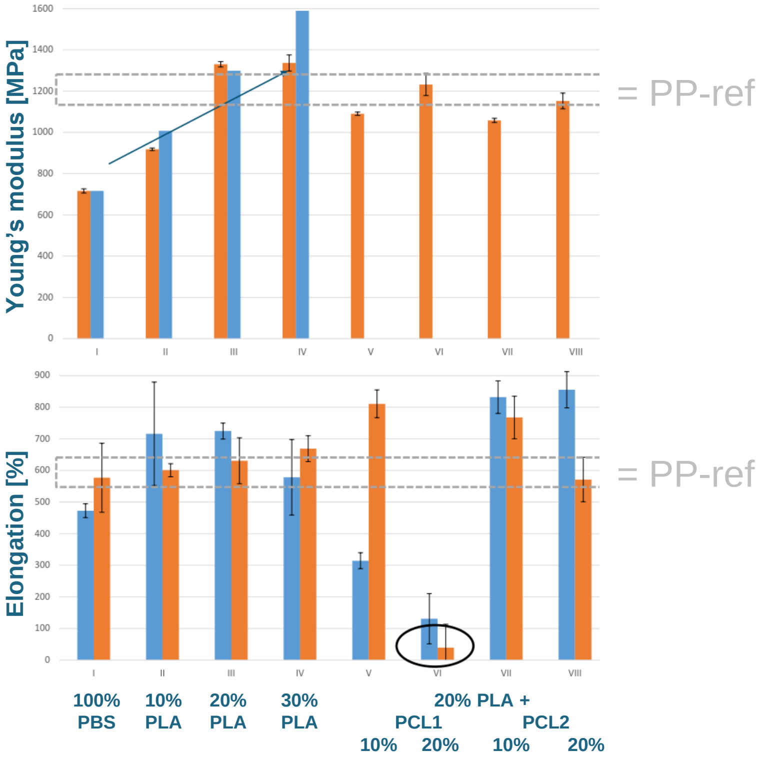
Stiffness, strength, elongation and impact resistance

Approach

1. PBS blended with PLA
2. PBS/PLA blends modified with various additives (polycaprolactone and others)

Result

- As expected, stiffness, strength, elongation and impact resistance can be well controlled to match the incumbent material (polypropylene)



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Low temperature impact resistance

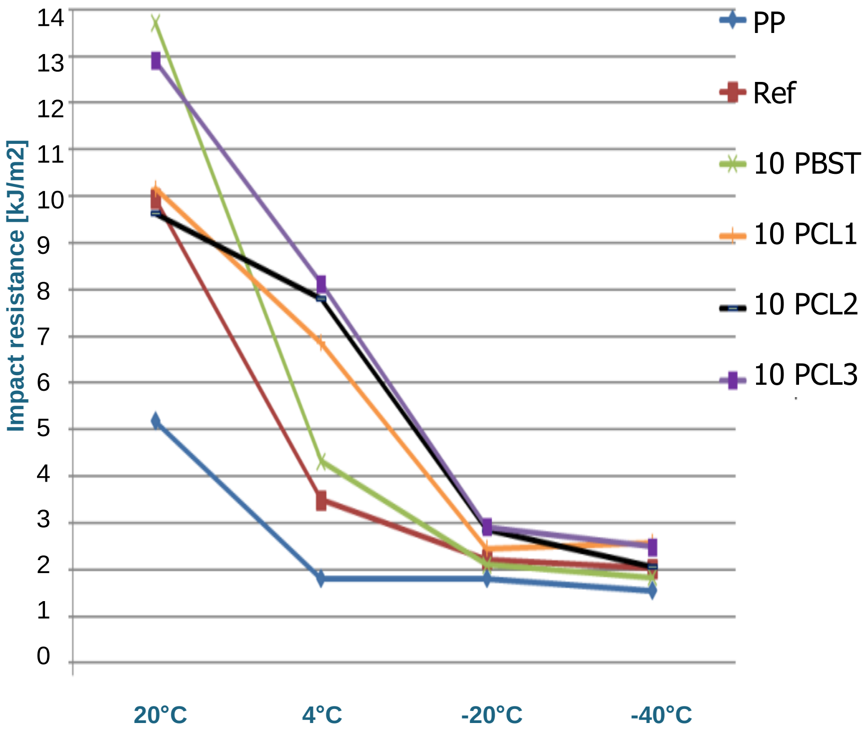
Notched impact resistance at low temperatures

Approach

- PBS modified with rubbery materials such as PBST, PBSA, PCL, a-PHA, etc
- Ductile/brittle transition determined by Charpy notched impact resistance

Result

- Low temperature impact resistance strongly improved.
- Biggest improvements with PCL types



Transparency / coloration

Approach transparency

- PBS modified with
  - Clarifiers described in literature (amides)
  - Commercially available clarifier for PP

Result

- No observed difference in optical transparency
- No significant difference in crystallisation kinetics

Approach coloration

- PBS modified with
  - Color masterbatch

Result

- Red: initially to light. Good colour match to PP after 1 modification
- Black: not opaque enough. May be due to type of carrier (non-miscible)

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Hydrolysis resistance

Expected life-time under hot/humid conditions

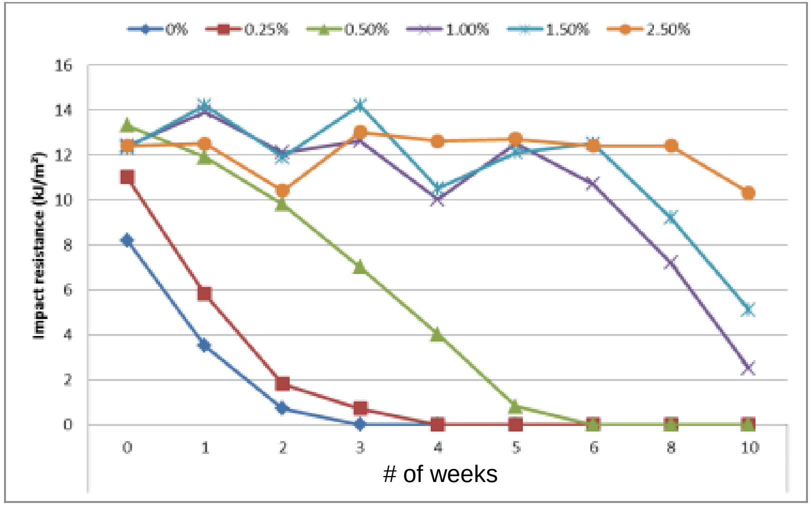
Approach

- PBS modified with hydrolytic stabilizers
- Hydrolytic stability assessed by
  - retention of molecular weight (screening)
  - impact resistance

Result (at 1.5-2.5% addition rate)

- Large differences in effectiveness
- Best results
  - 50°C/50% RH: > 184 days
  - **70°C/80% RH: > 56 days**
  - Extrapolation at 25°C > 25 years

70°C/80RV



Injection molding trials

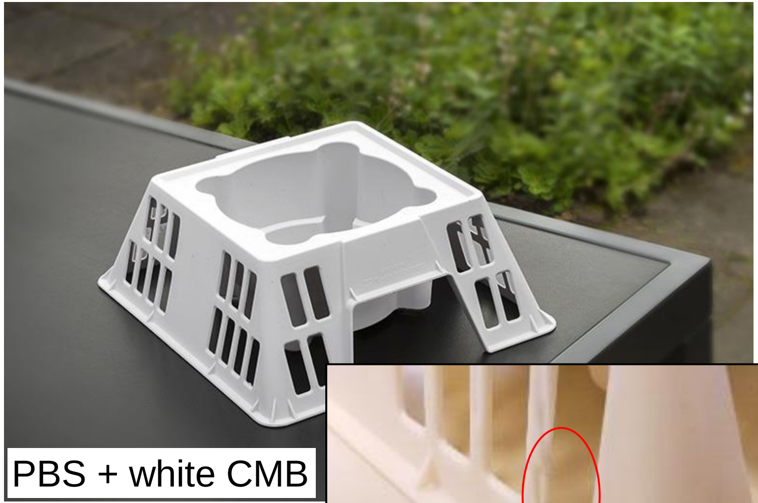
RPC Promens - Horticultural crate

Product:

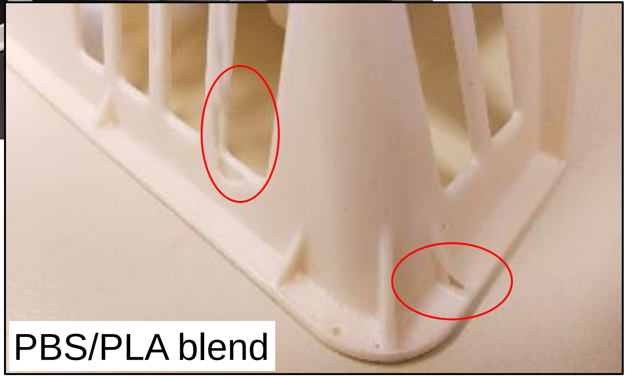
- Plant tray (HDPE), 276 grams

Observations:

- PBS
  - good parts can be produced without problems, using “standard” process
- PBS/PLA (50/50)
  - significant issues with sink marks (picture)
- PLA :
  - Not possible to mould products (shrinkage)



PBS + white CMB



PBS/PLA blend

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Injection molding trials

Teamplast - Bottle caps

Product:

- Bottle cap, PP-r, 4-cavity mold

Observations

- PBS
  - good parts but to flexible ; issues with automatic closing
- PBS/PLA (80/20) + additives
  - fully automatic molding process, no issues
  - fully automatic, in-mould closing of the lid

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Application testing

Teamplast - Bottle caps

Product:

- Bottle cap, PP-r, 4-cavity mold
- Parts clamped, and film hinge loaded under tension and torsion

Observations (properties)

- PBS parts are more flexible than PP-reference. Film hinge performs well.
- PBS/PLA (80/20) shows good strength, but (torsional) flexibility decreases

Injection molding trials

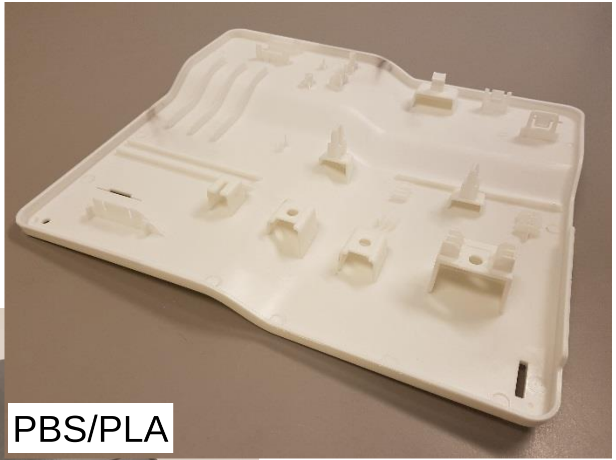
RPC Promens – automotive panel

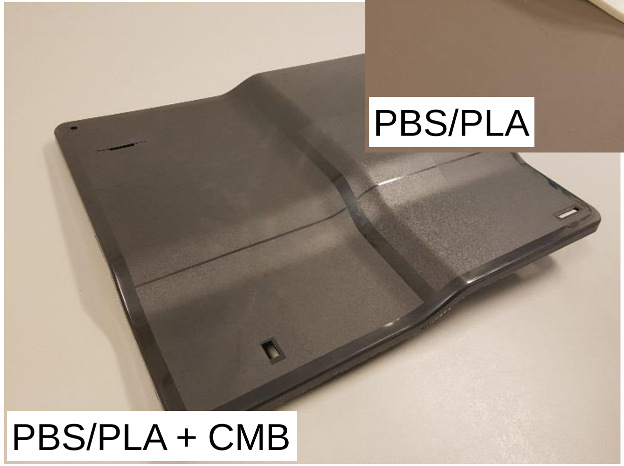
Product:

- Demo panel (PP-C), 40*60cm, >1000 gr
- Many ribs, undercuts, textures, etc

Observations:

- PBS
  - Good parts but to flexible
- PBS/PLA (80/20) + various additives
  - No problems with moulding





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Summary and Conclusions

- Application of BioPBS in complex, injection moulded products is possible
- Application of BioPBS in durable products is possible

- Today, PBS production capacity is very limited ; cost of BioPBS limits broad market acceptance
  - Growing economies of scale by pilot-applications will improve cost position
  - Market growth in the compostable segment will support this

- Market introduction is most likely with innovative, sustainability-minded customers

Thank you !

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