SYNVINA
functional. sustainable. bioplastics.



Developing sustainable plastic products with PEF

International Symposium on Bioplastics, Biocomposites and Biorefining – July 25th 2018

Jesper van Berkel | Technical Application Manager

Synvina company profile

Joint Venture between Avantium and BASF

- Established September 23rd 2016

~ 70 Employees

Global Company with Locations in:

- HQ and R&D: Amsterdam, Netherlands
- Pilot plant: Geleen, Netherlands
- Commercial Plant Site: Antwerp, Belgium
- Satellites: Canada, Japan, USA




HQ in Amsterdam, NL

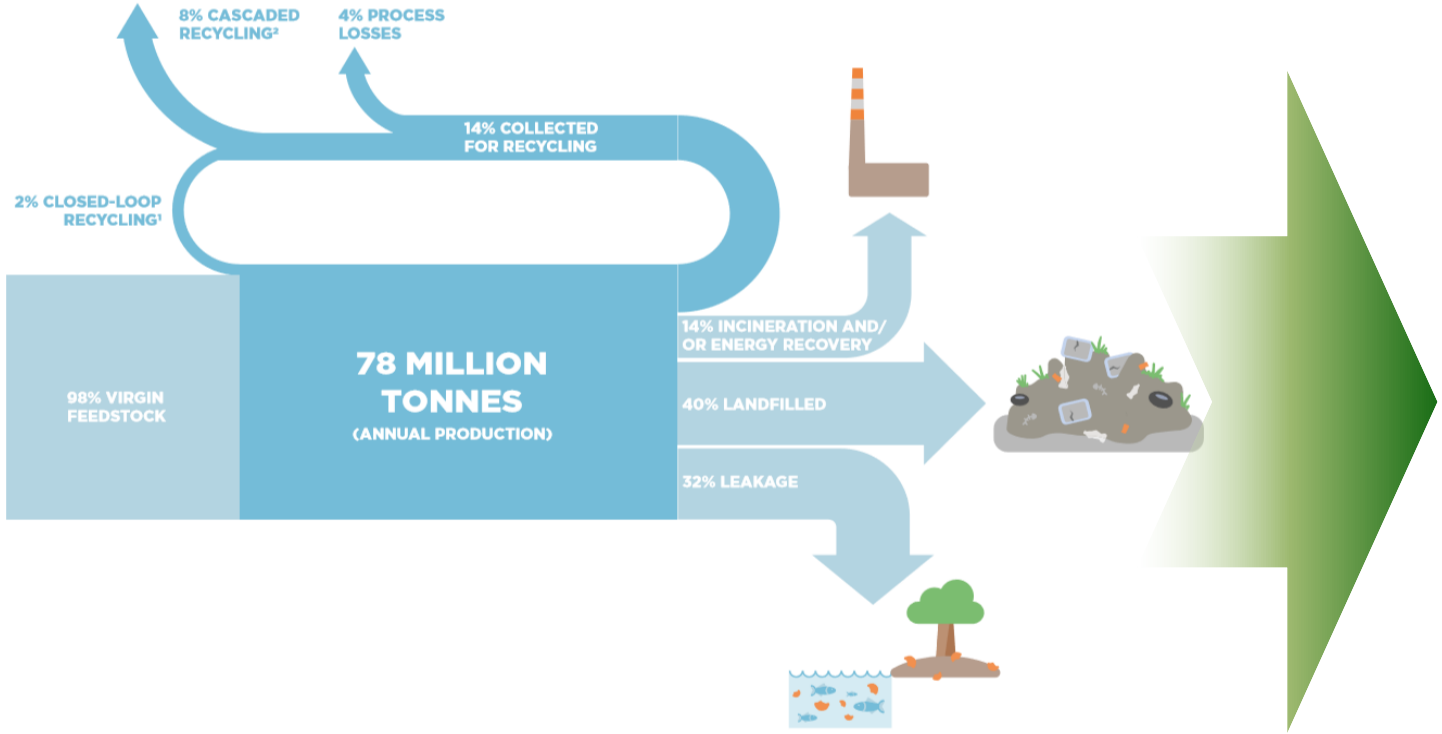

R&D in Amsterdam, NL


Pilot Plant in Geleen, NL


BASF Verbund site in Antwerp, BE

What's on the mind of the (packaging) industry?

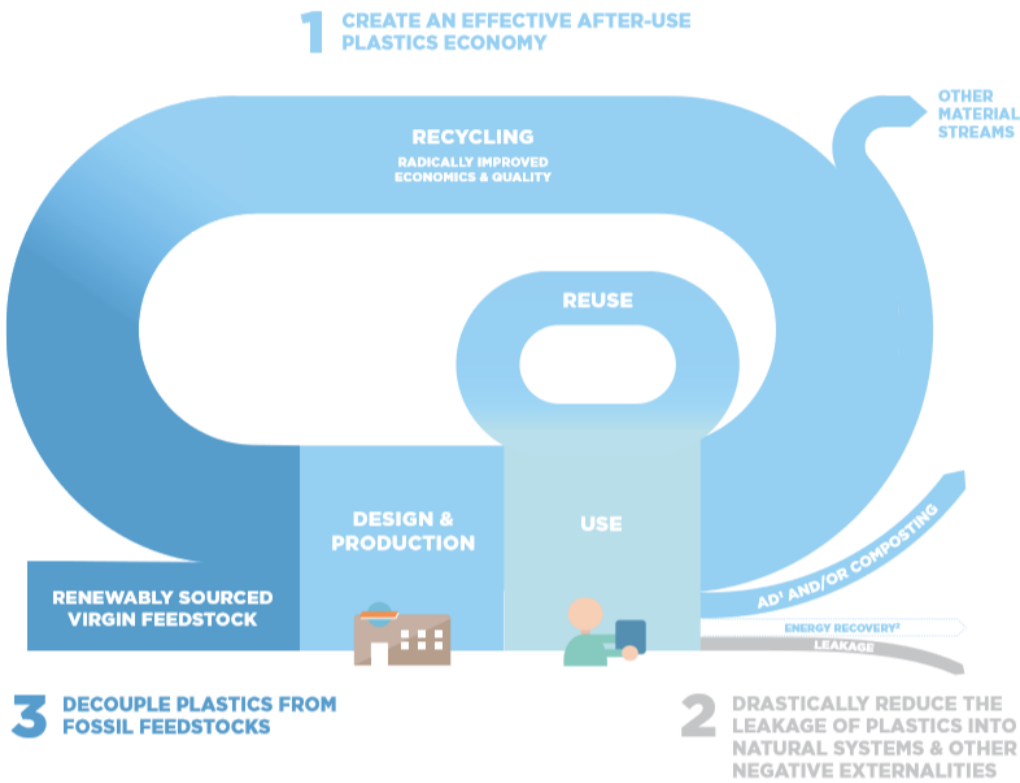
CURRENT (2013) SITUATION



When do bio-plastics come in?

AMBITIONS OF THE NEW PLASTICS ECONOMY

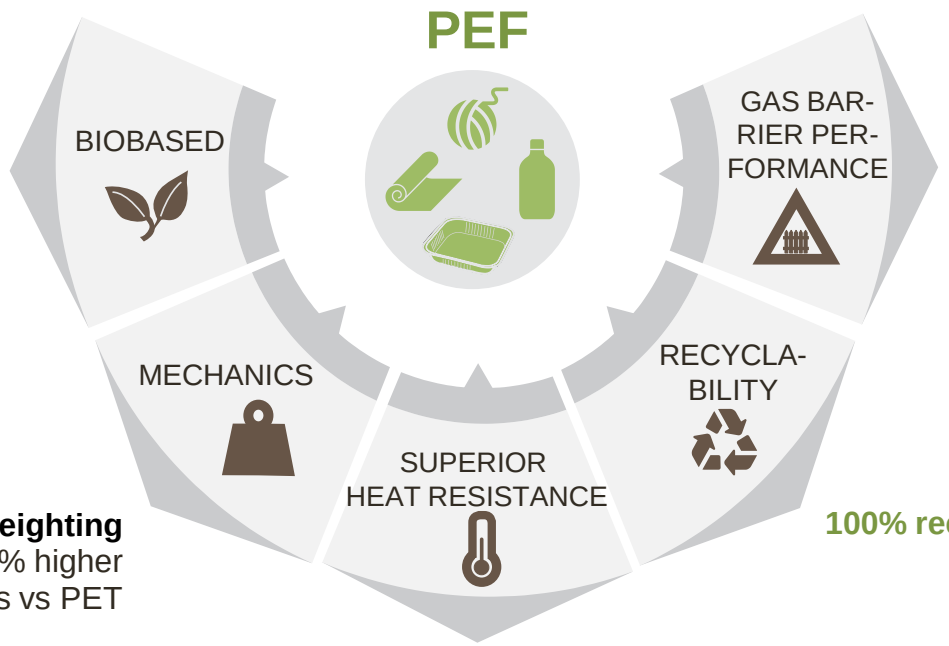
?



Bio-based

Biodegradable

PEF: adding functionality to end-products



Sustainability
100% biobased polymer

Shelf Life
improved transfer rates vs PET:
- O_2 10x
- CO_2 6-10x
- H_2O 3x

Lightweighting
60% higher modulus vs PET

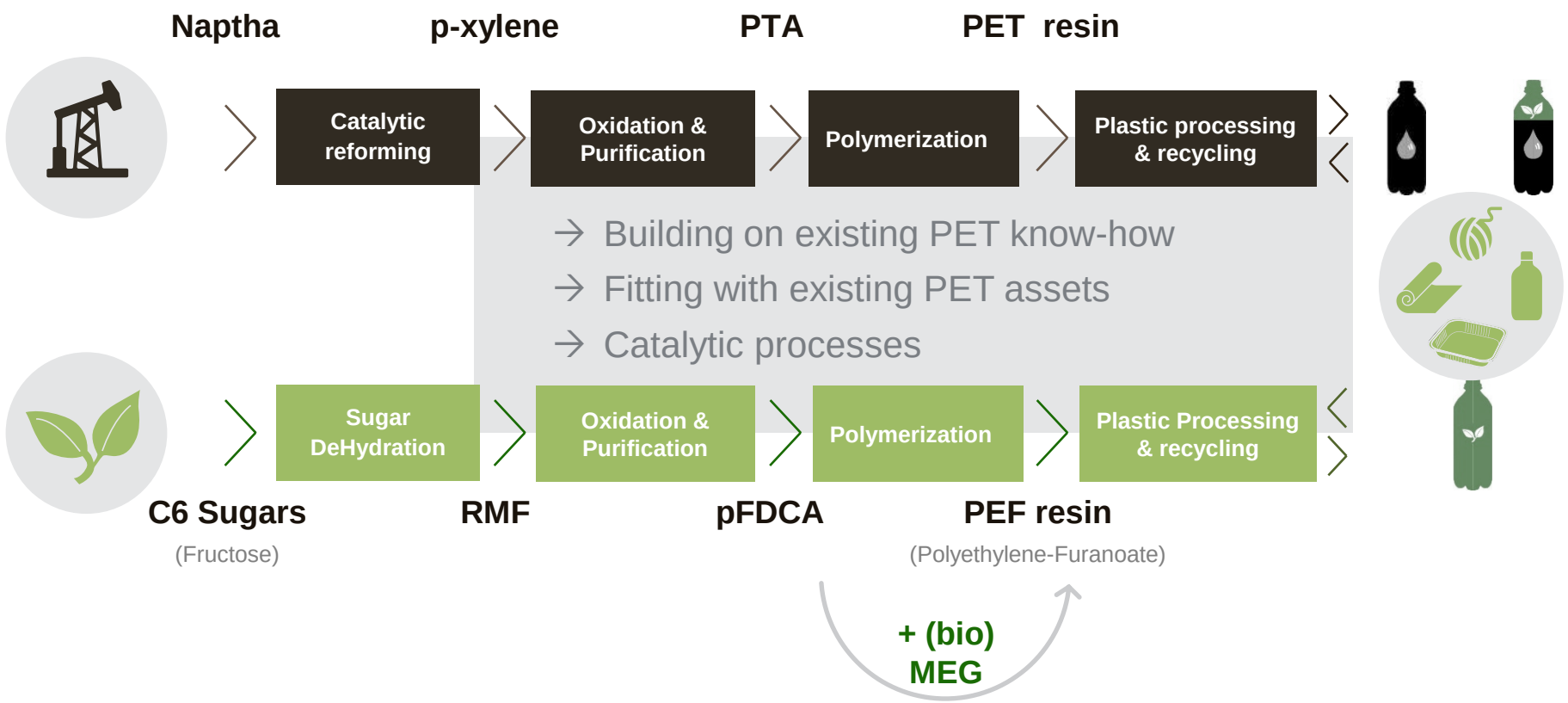
Hot Filling
12°C higher glass transition vs PET

100% recyclable

Superior mechanical and barrier **properties**

Potential to **reduce** (multiple) **material needs** to meet product functionality

PEF: renewable sourcing for an existing value chain

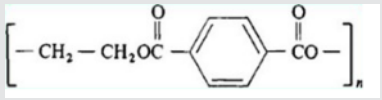
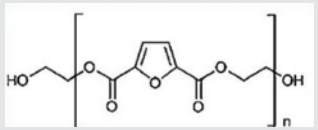


Conventional chemistry

Up to **100% Renewable** sourcing through **existing** polyester **infrastructure**

Design and processing with PEF

A closer look to PET and PEF properties

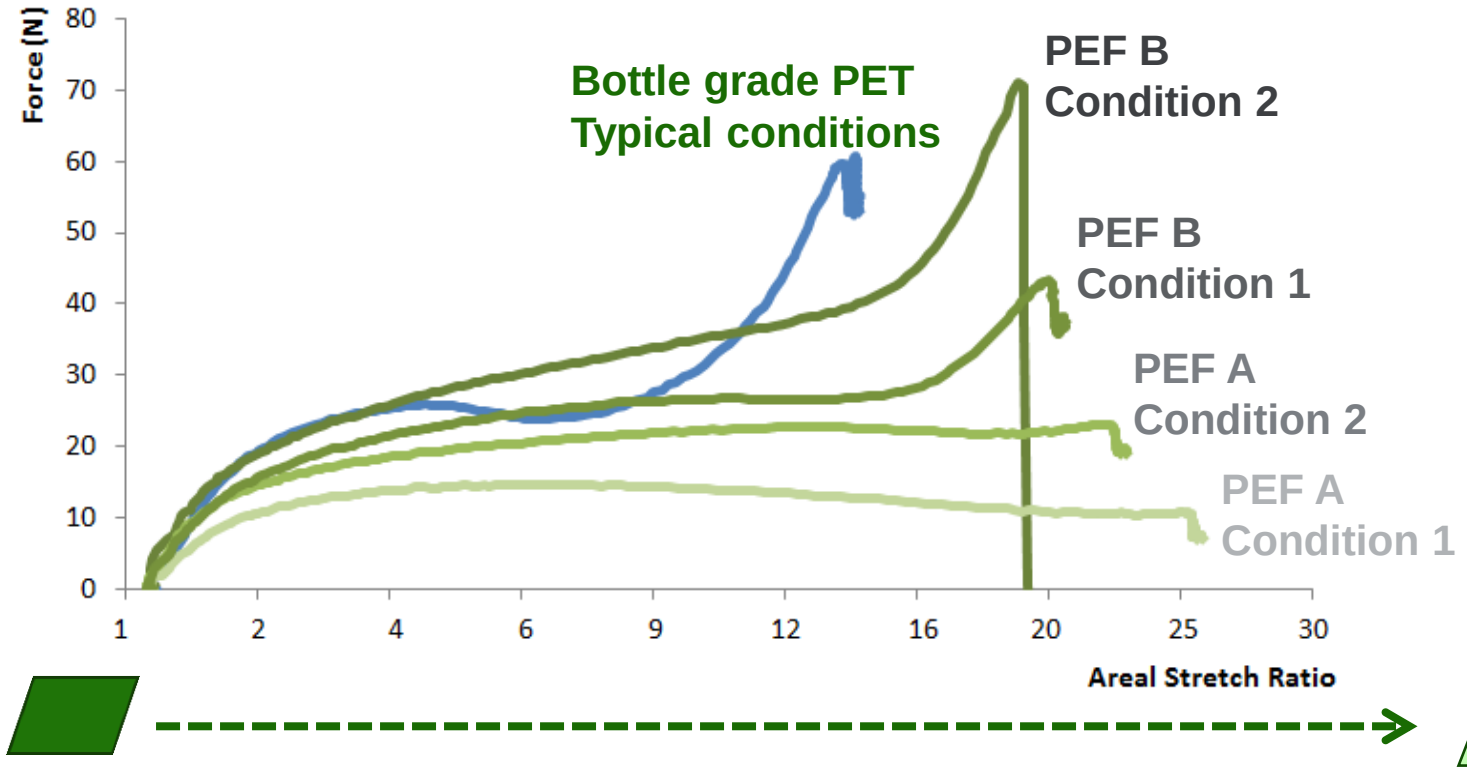
Property	PET (Amorphous)	PEF (Amorphous)
Molecule		
Density	1.36 g/cm^3	1.43 g/cm^3
T_m	250-270°C	210-230°C
T_g	~76°C**	~88°C**
Crystallization time	2-3 min**	20-30 min**
E-modulus	2.1-2.2 GPa	3.1-3.3 GPa
Yield strength	50-60 MPa	90-100 MPa
O_2 permeability	0.114 Barrer*	0.0107 Barrer*
CO_2 permeability	0.460 Barrer*	0.0260 Barrer*

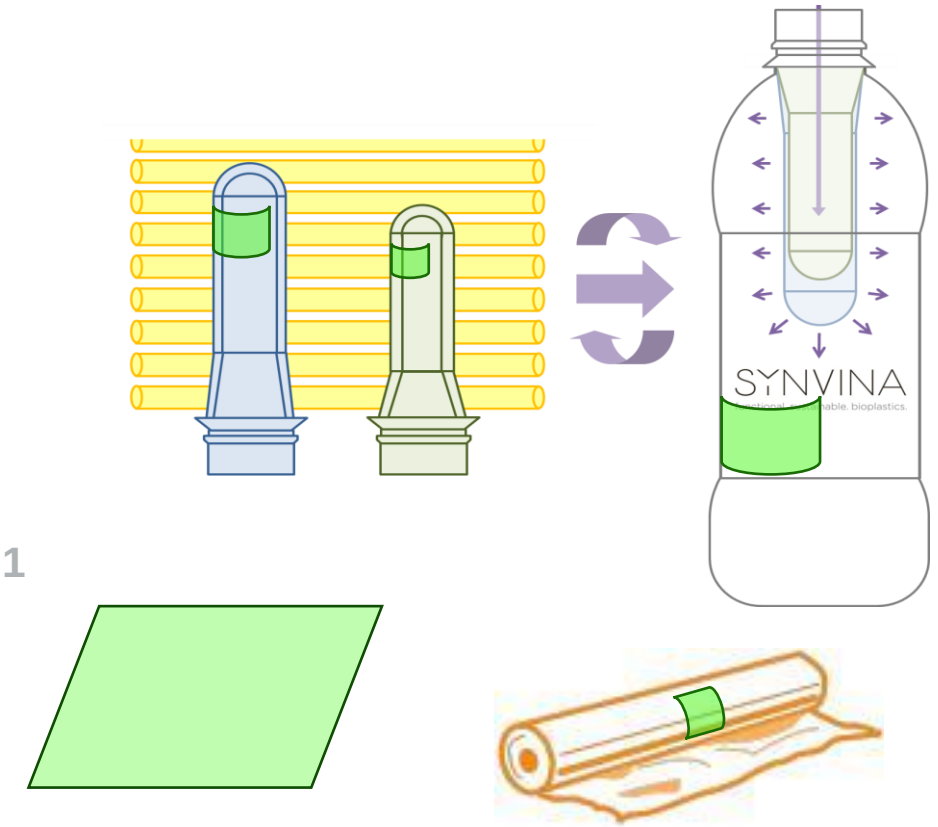
S. Burgess et. al. (PhD project Georgia Tech, funded by The Coca-Cola Company), a.o. Marcomol. 2014, Polymer 2014, J. Polym. Sci. 2014

**A. Codou, L. Martino, N. Guigo et al., (Part of EU Project BIOFUR between Avantium and Nice University) a.o. Macromol. Chem. Phys. 2014, Phys.Chem.Chem.Phys. 2016*

Design and processing with PEF

Biaxial orientation behavior





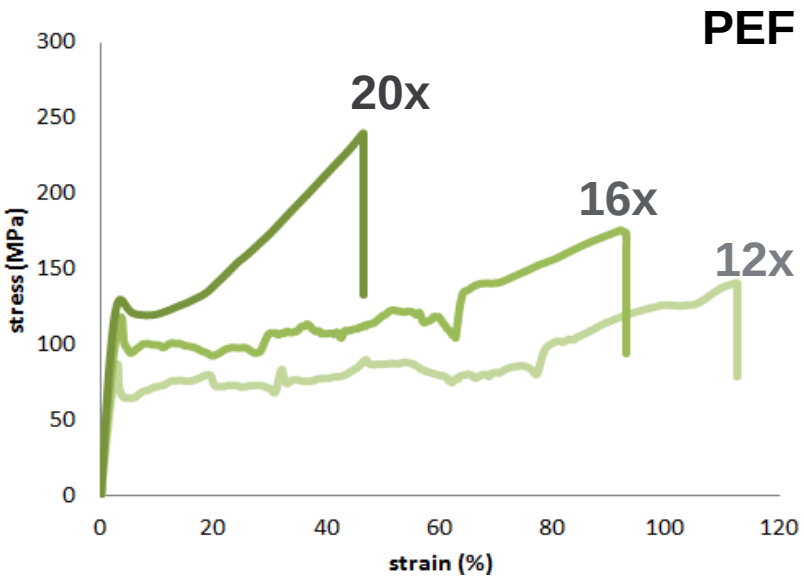
- PEF shows strain hardening at higher stretch ratios than PET
- The right PEF grade and conditions are needed to obtain desired behavior (Synvina proprietary know-how)

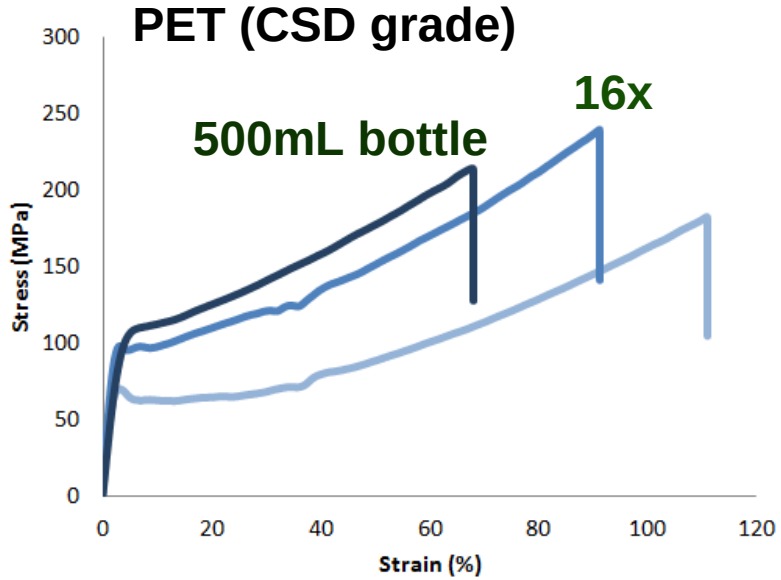
*J.G. Van Berkel, N. Guigo et. al, Macromol. Mat. Eng. 2018 (Part of EU Project BIOFUR between Avantium and Nice University)

Design and processing with PEF

Maximizing oriented properties

- Oriented Mechanical properties





Material	BOPEF[1]	BOPET[1]	BOPET[2]	BOPP[2]	BOPLA[3]
Tensile modulus, GPa	4.5-8.0	3.9-5.3	3.3-3.5	2.4	3.6
Max tensile Strength, MPa	120-300	170-250	140-180	184	123
Elongation at break, %	40-80	60-120	90-110	80	130

1 Data obtained using instron 5565 tensile tester at Avantium, 50%/min extension rate
2 Plastic Films: Technology and Packaging Applications", K. R. Osborn and W. A. Jenkins, CRC Press, 1992.,
3 Natureworks Technical data sheet 4043D

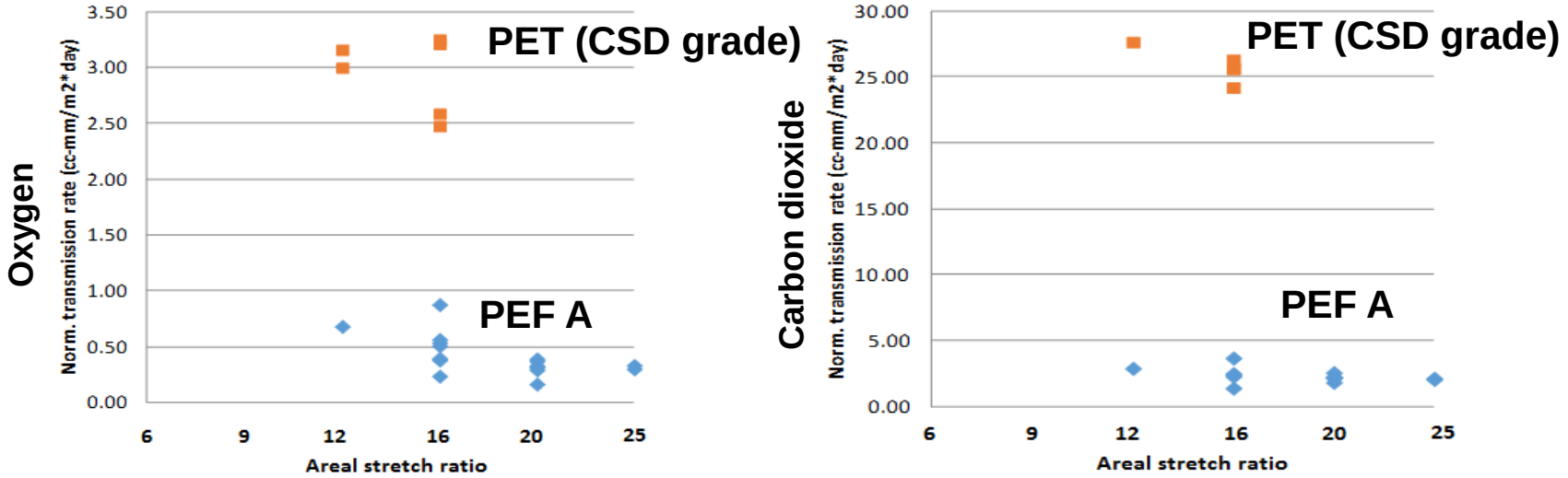
[*]J.G. Van Berkel, N. Guigo et. al, Macromol. Mat. Eng. 2018 (Part of EU Project BIOFUR between Avantium and Nice University)

- Mechanical properties of PET at 16x in our experiment similar to bottle side-wall (lower stretch ratio but higher stretch rate)
- Mechanical properties of PEF show variation at similar stretch ratios to PET; no self-flattening
- At 20x, higher stretch ratio than PET, PEF oriented properties start to exceed those of PET

Design and processing with PEF

Maximizing oriented properties

- Oriented Barrier properties



Material	BOPEF[1]	BOPET[1]	BOPET[2]	BOPP[2]	BOPLA[3]
OTR, cc-mm/m^2-day-atm	0.13-0.61	2.4-3.3	1.4-6.0	42	17
CO_2 TR, cc-mm/m^2-day-atm	1.4-2.6	24-28	21-22	100	70
WVTR, g-mil/100in^2-day	0.6	1.3	1.0-2.0	0.25-0.4	24

1 Data obtained using Mocon OXTRAN & Mocon PERMATRAN at CWRU, 77˚ F 0% RH for O2 & CO2, 100˚ F, 90%RH for Water
2 Plastic Films: Technology and Packaging Applications", K. R. Osborn and W. A. Jenkins, CRC Press, 1992.,
3 Natureworks Technical data sheet 4043D

[*]J.G. Van Berkel, N. Guigo et. al, Macromol. Mat. Eng. 2018 (Part of EU Project BIOFUR between Avantium and Nice University)

- Barrier improvement of PEF maintains in the oriented state
- Optimal barrier properties found at higher stretch ratios
- Variation in OTR for PEF due to variations of crystallinity at various orientation conditions
- Fully annealed BOPEF yields the lowest OTR values and 11x improvement over BOPET (table only)

Application Example
100% Bio- based Bottle

1 - Shelf Life extension & Material reduction
- 6x higher CO_2 Barrier for Carbonated Beverages &
  10x higher O_2 Barrier for Juices, Nectars, Soft-Drinks, Teas

→ **Avoids need for barrier technologies or 'heavyweighting'**

2 – Use in bottles & containers
- Equal pressure & break resistance, transparency & shape freedom
- No additional equipment; standard investments in new molds

3 - Circular Economy
- 100% bio-based
- Easy to separate by NIR sorting
- Fully recyclable in similar steps to PET





	PET		PEF	
Bottle volume	237 mL		237 mL	
Preform / bottle weight	9 g	13 g	10 g	14 g
4.2 Vol. CO_2 Shelf life to -17.5%	4 wks	**6 wks**	12 wks	**20 wks**
Oxygen ingress - time to 5 ppm	3 wks (est.)		26 wks (est.)	

* based on 100 % yield assumption

Application Example

Flexible Packaging with BOPEF film

1 - Shelf Life extension & Material reduction

- 11x higher O_2 barrier than BOPET with same humidity resistance & 3x higher moisture barrier than BOPET

→ **Avoids need for barrier layers such as PVDC and EVOH**

→ **Potential for ultra high-barrier vapor coated films**

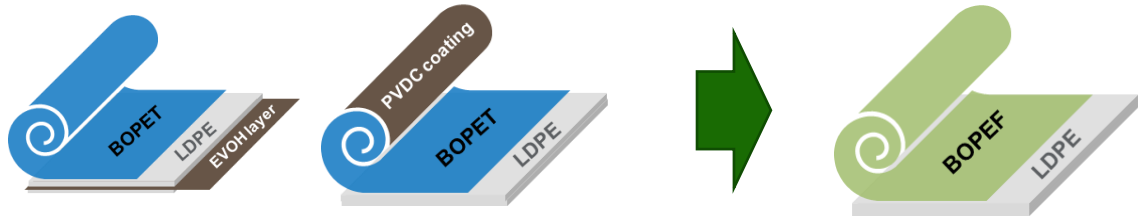
2 - Use in flexible packaging

- Equal thermo-mechanical & surface properties to BOPET
- No new equipment required; typical printing & lamination

3 - Circular economy

- 100% Bio-based layer
- Reduce structure complexity
- Reduced GHG emissions upon incineration
- PEF is recyclable





Biaxially Oriented film	BOPET		BOPEF	
Gauge (µm)	12	16	12	16
Strength (MPa)	230		260	
Break elongation (%)	100		47	
Oxygen transmission (cc/m^2.day.atm)	120	90	11	9
Moisture transmission (g/m^2.day)	50	38	15	11

Creating an effective after-use economy

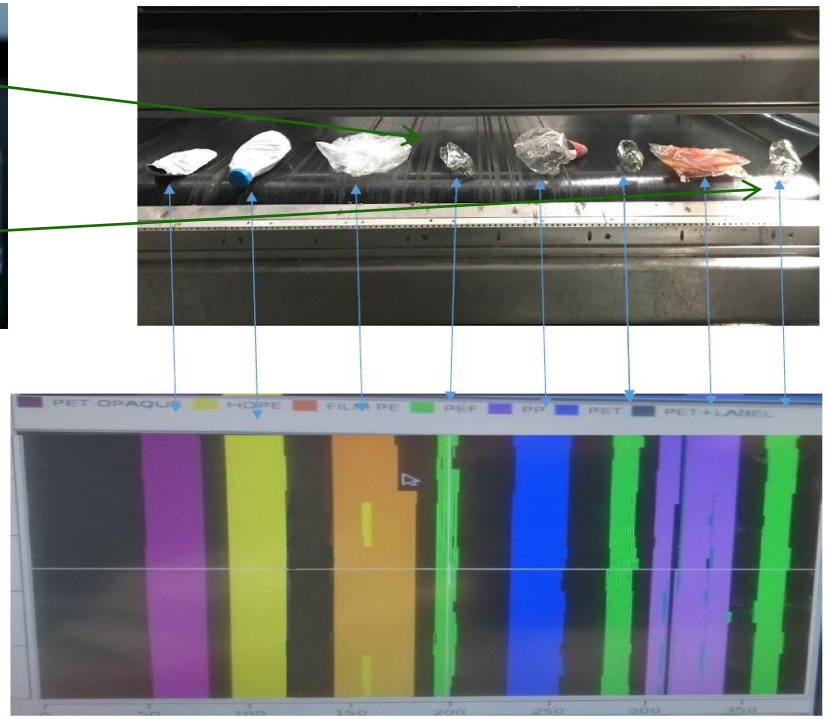
PEF sorting & recycling options

PEF can be sorted from any other plastic

Easier sorting than packaging containing multiple known materials



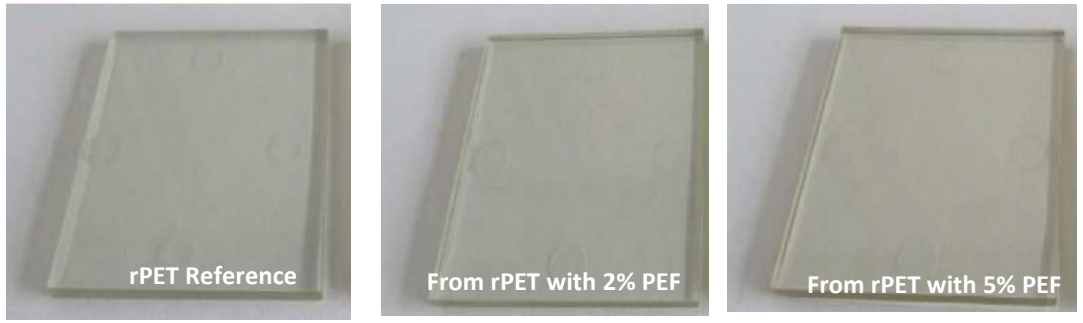
237mL, 13.7g



NIR detection by TOMRA and Pellenc (shown) equipment

PEF shows compatibility with RPET

No issues by incidental contamination, PEF/PET hybrid packaging options



PEF in RPET plaques following EPBP route 1 with 50% vPET

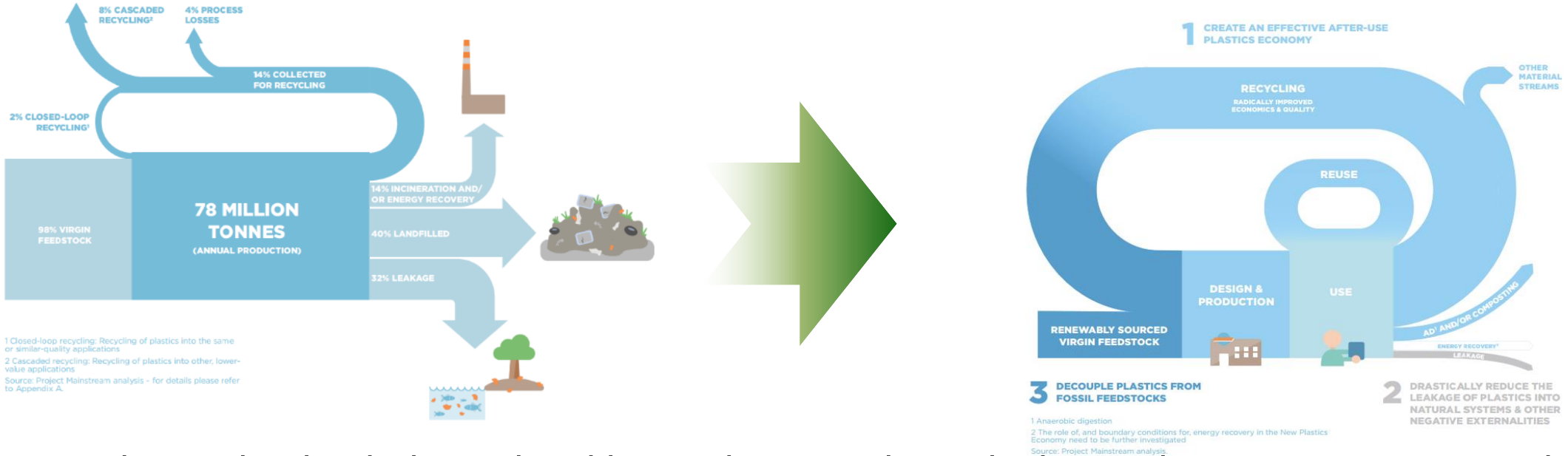
PEF can be recycled to RPEF

Reprocessing steps are similar to PET; potential to use existing assets



T-shirt from recycled PEF bottles

Circular economy



- The packaging industry is taking major steps in re-design and waste management, but the need for **multi-material functionality** remains a key challenge
- Through existing polyester infrastructure, PEF can offer a **renewable** and **recyclable** solution with **reduced** material requirements for the same food protection

PEF is a next step towards a more sustainable economy

Source: Ellen McArthur Foundation - The New Plastics Economy (2016)



SYNVINA

functional. sustainable. bioplastics.

Thank you for your attention!

Gerald Michael
Global Business Manager
Gerald.Michael@Synvina.com

Takeshi Irie
Sr. Business Manager Japan
Takeshi.Irie@synvina.com

Jesper van Berkel
Technical Application Manager
Jesper.vanberkel@synvina.com