CLOSING THE GAPS TO INCREASED CIRCULARITY OF PLASTICS

Thor Kamfjord

Director Sustainable Development

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FULL SERVICE PORTFOLIO IN THE PLASTICS VALUE CHAIN

Norner Polymer Exploration Centre - from polymer to processing and end-use innovations

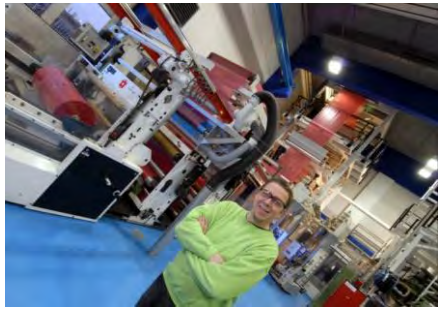
KEY COMPETENCIES USED IN >30 COUNTRIES ANNUALLY

Research | Development | Strategic Advisory | Laboratory Testing

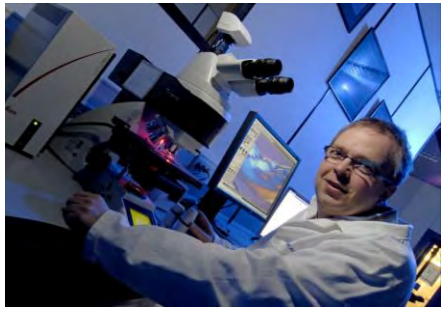
Catalysis & Polymerisation

Compounding Pilots/
Recycling Pilot Centre

Durability and Additives



Extrusion/
Moulding Pilots



Microscopy and
Failure analysis

Physical and
Mechanical

Chemical, Polymer
and Thermal

Food and
Pharma

Exposure testing
and HPHT

Coating testing/Anti corrosion

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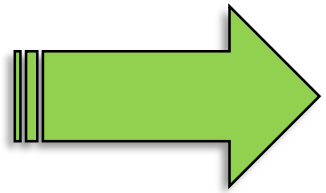
The Circular Economy – A path of Innovation!



Use resources in a smarter, more sustainable way by keeping them in use for as long as possible, extracting their maximum value and recovering and regenerating materials at the end of life

Boost global competitiveness, foster sustainable economic growth and generate new jobs

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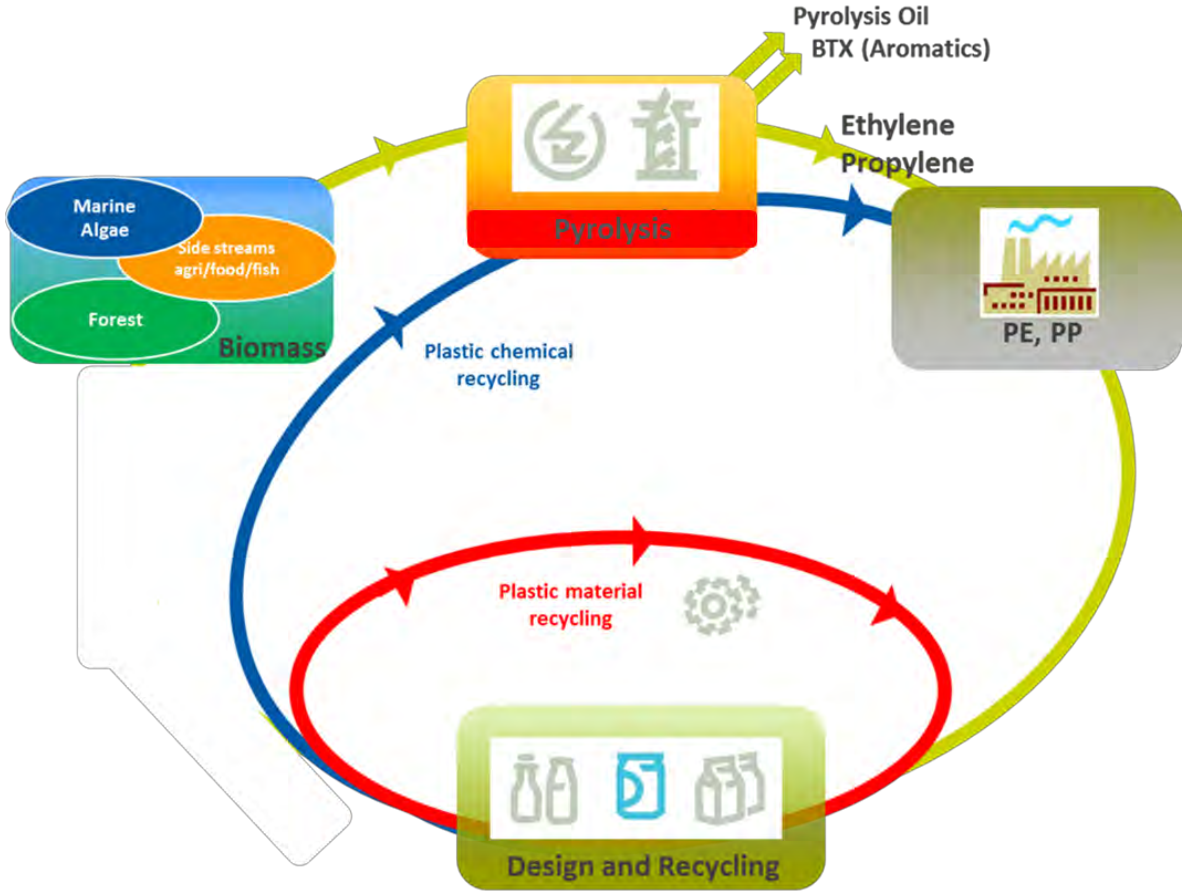
CLOSING THE LOOP - FUTURE PLASTICS PACKAGING

FuturePack

- Sustainable raw materials
- Building blocks for polymers from pyrolysis
- Polymer production (PE, PP)
- Recycled plastics in packaging
- Design for recycling
- Life Cycle Sustainability Assessment (LCSA)
- <u>Communication</u>



SOLVING THE MULTILAYER CHALLENGE!

MANDALA
Sustainable Multilayer Packaging

Bio-based Industries Consortium
BBI JU
Horizon2020 European Union Funding for Research & Innovation

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 N° 837715

Multi-material Packaging

Increasing packaging complexity to gain performance benefits

poorly sustainable

post-consumer scenario

2 pathways to solve this challenge

Mono-material solutions that deliver similar performance to multi-material counterparts

- Meat wrapping meat & ready-to-eat foods
- Blister packs for pharmaceuticals

Multi-material packaging or separation technologies that enable the separation of the different materials after use

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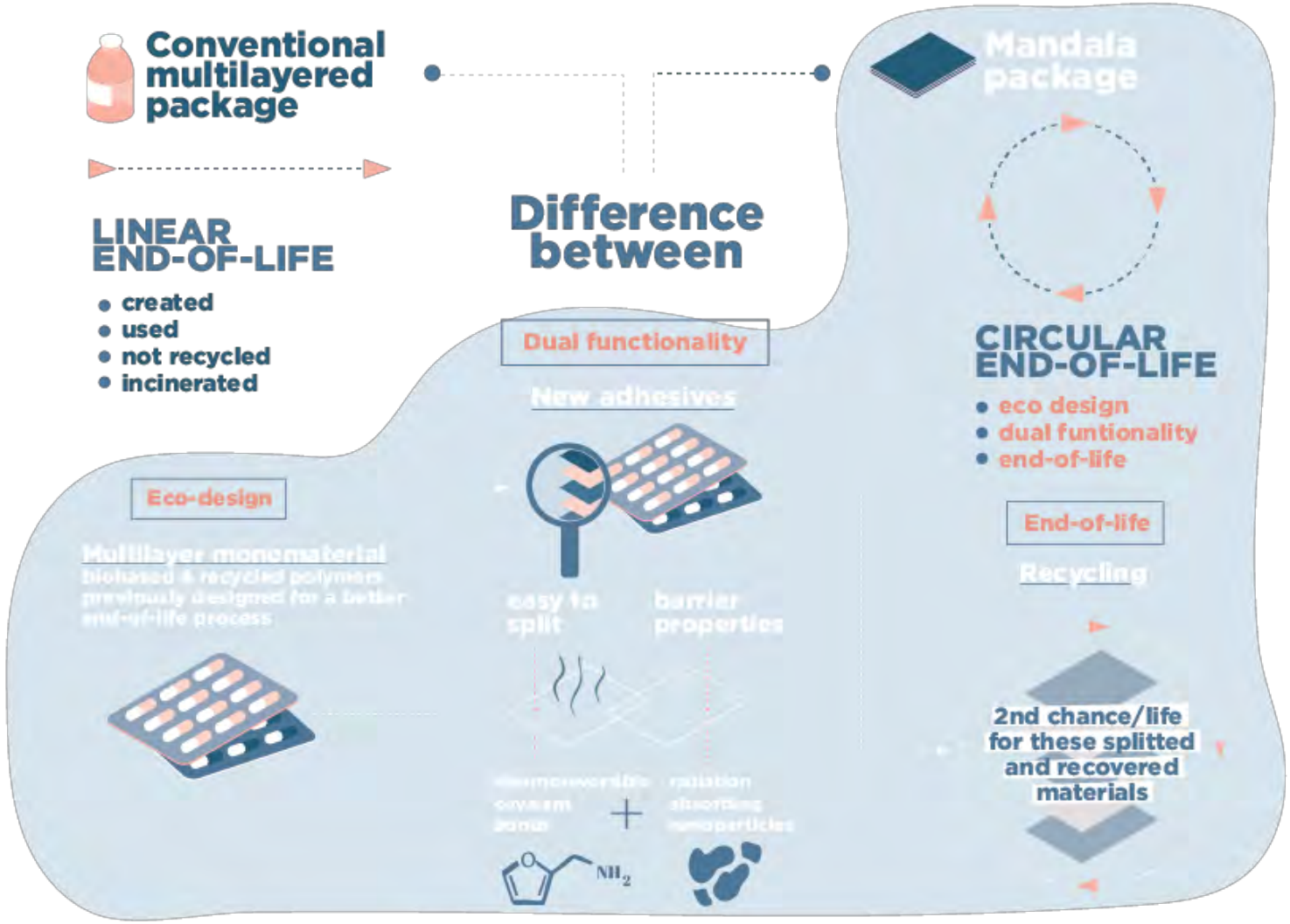
SOLVING THE MULTILAYER CHALLENGE!

MANDALA
Sustainable Multilayer Packaging



- Make the economics of recycling more attractive
- Decouple plastics from fossil feedstocks
- Develop laminated film being easy to separate and recycle
- Isolate biodegradable elements from recyclable
- Multi-layer packaging to be split into component parts without solvents

BOOSTING RECYCLABILITY BY REMOVING HAZARDOUS ADDITIVES

Project information

NONTOX

Grant agreement ID: 820895

Status
Ongoing project

Start date
1 June 2019

End date
31 May 2022

Funded under:
H2020-EU.3.5.4.
H2020-EU.3.5.3.2.

Overall budget:
€ 4 998 076,25

EU contribution
€ 4 998 076,25

Coordinated by:
Teknologian tutkimuskeskus VTT Oy
Finland

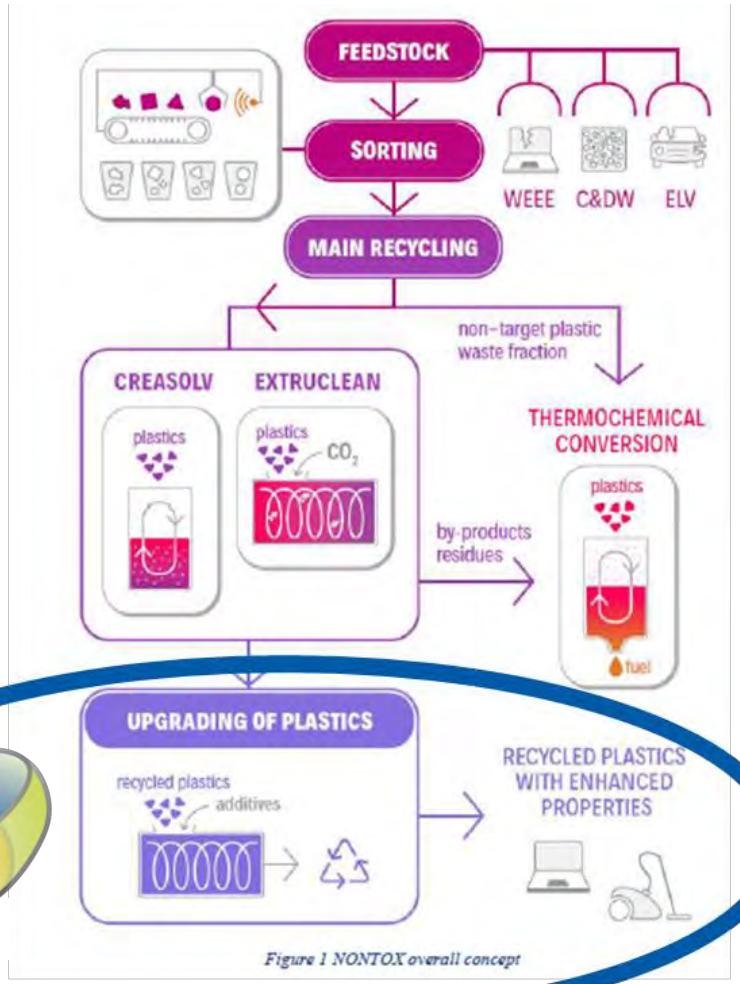


Figure 1 NONTOX overall concept

HORIZON 2020

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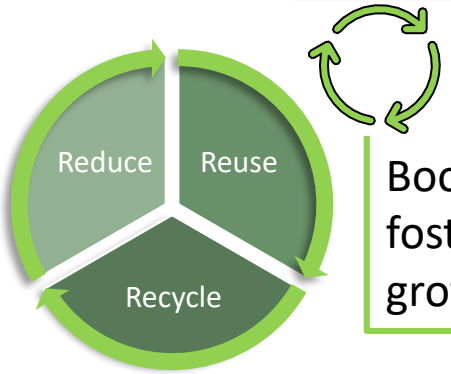
HOW CAN WE
RECYCLE MORE?

We have a major challenge ahead!

+ By 2025 ensure that ten million tonnes of recycled find their way into new products on the EU market



Boost global competitiveness, foster sustainable economic growth and generate new jobs

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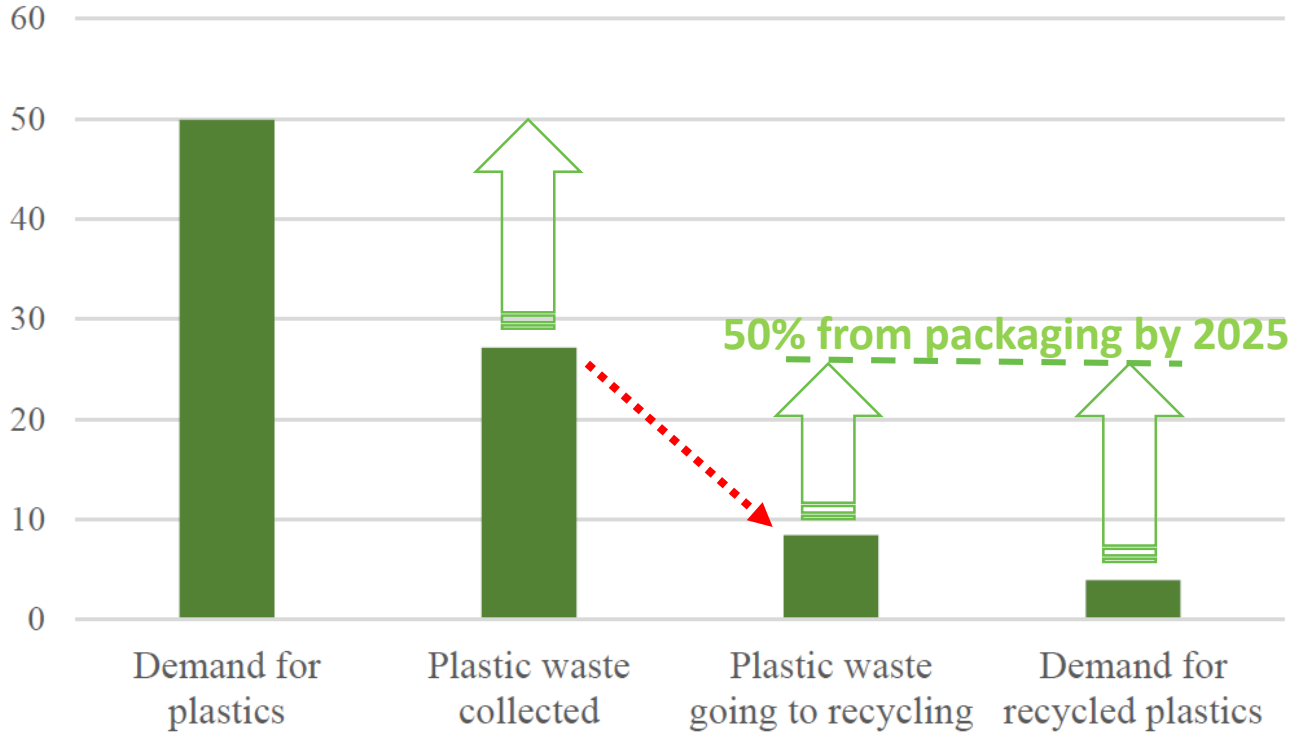
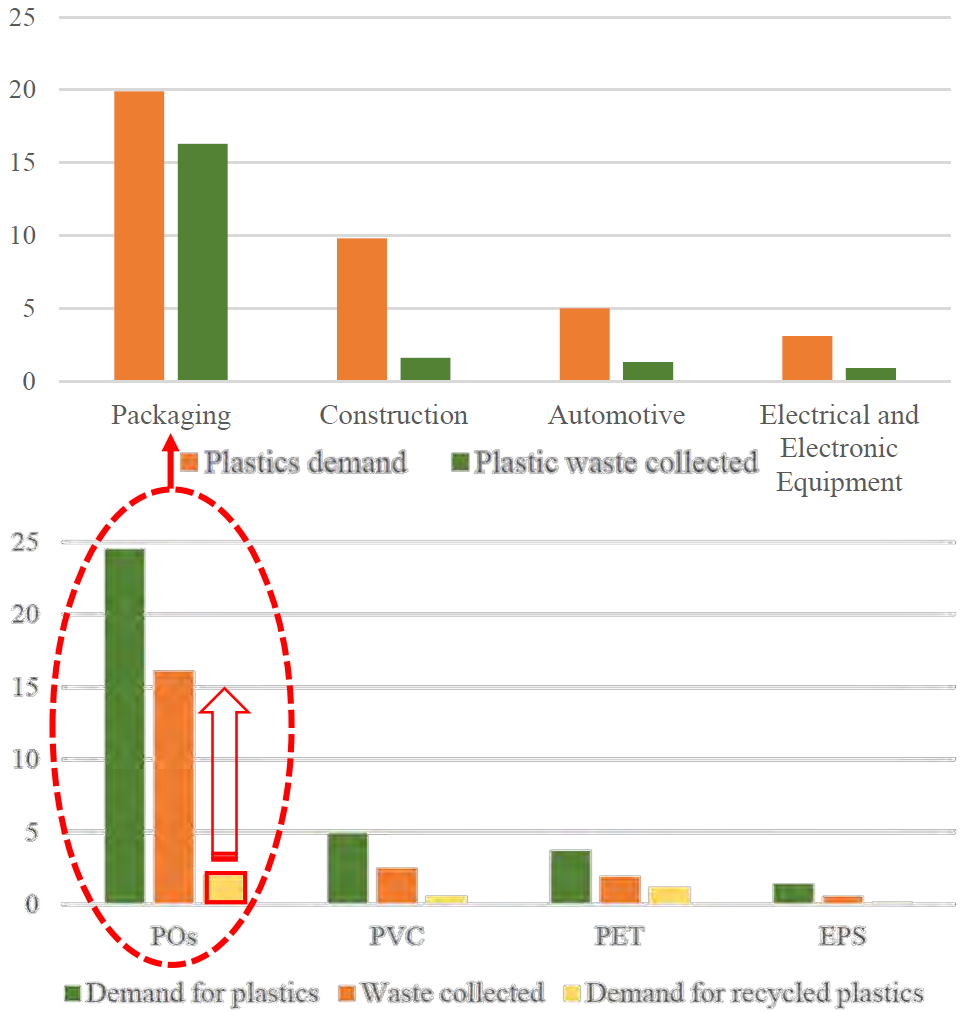
FROM VIRGIN PLASTICS DEMAND TO RECYCLED PLASTICS DEMAND





Source: Assessment report of the voluntary pledges under Annex III of the European Strategy for Plastics in a Circular Economy, European Commission, March 2019

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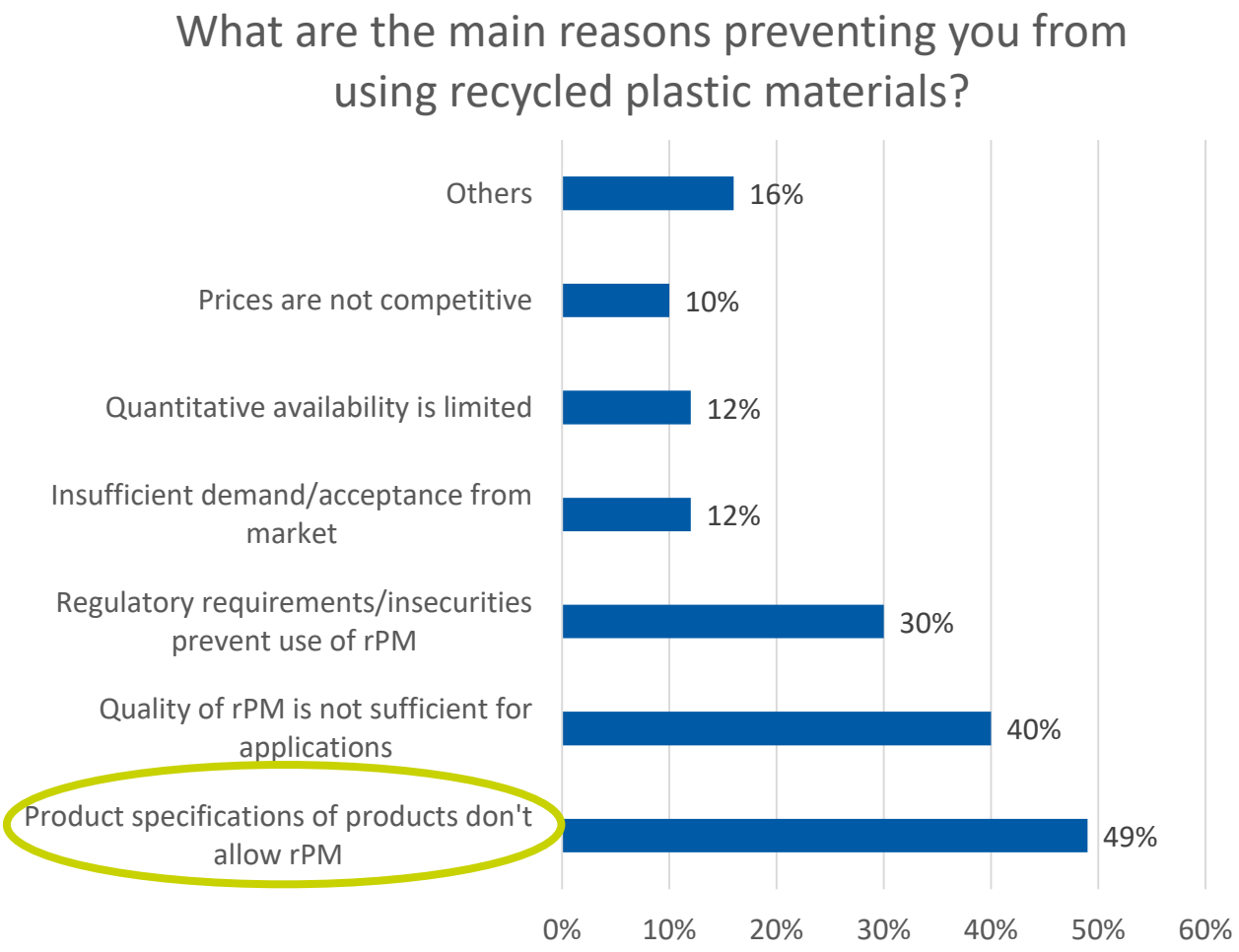
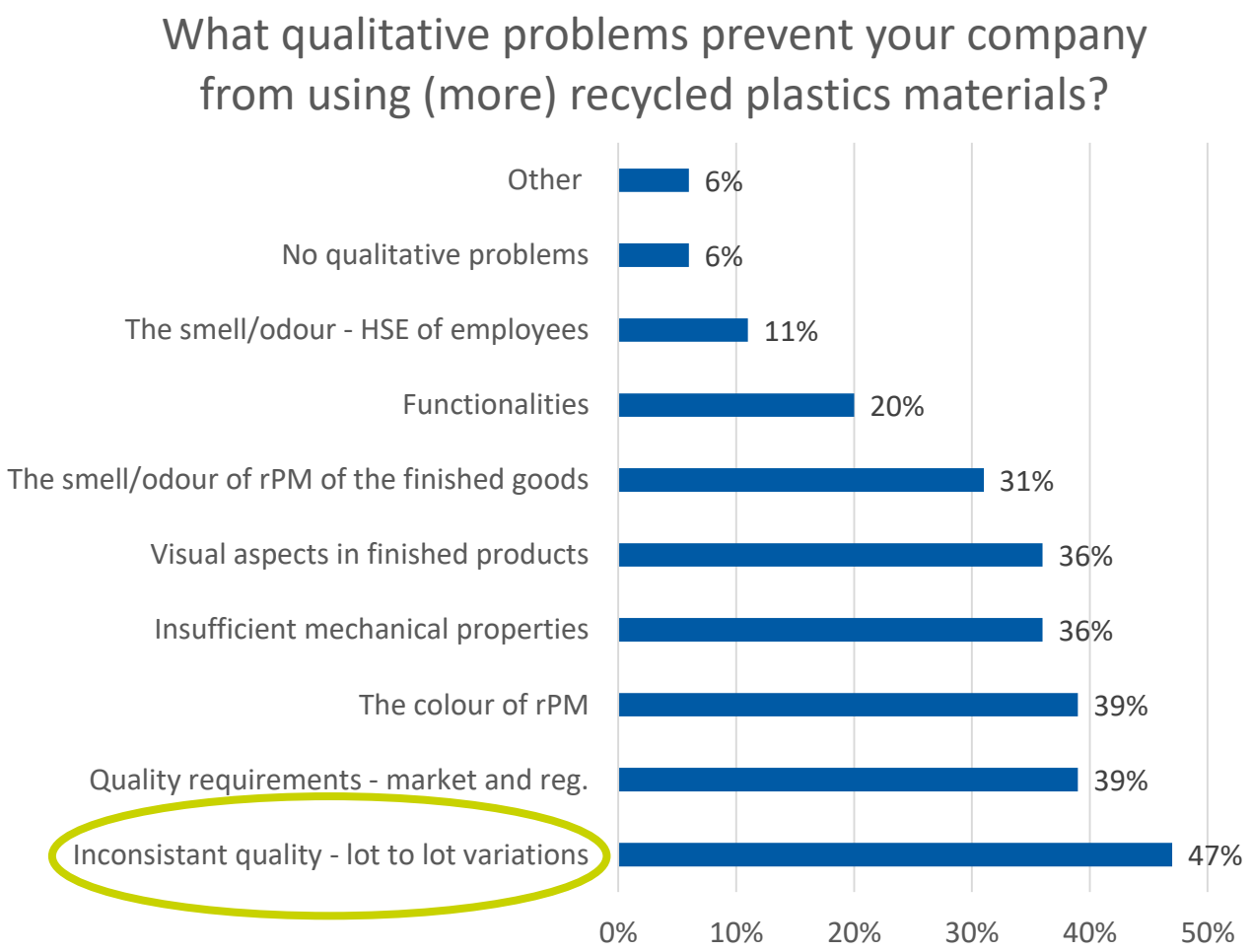
WHY NOT USE MORE RECYCLED PLASTICS? QUALITY!





Source: EuPC Recycled Plastic Materials Usage by Plastics Converters in Europe - 2019

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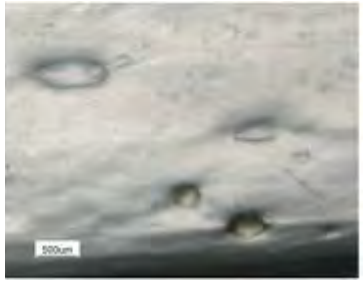
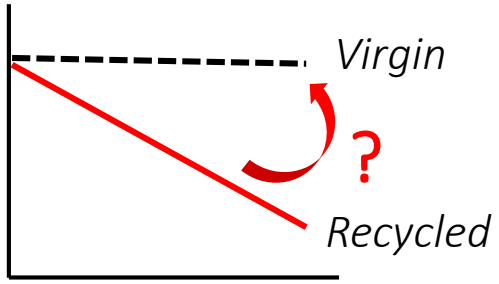
RECYCLED MATERIALS HAVE 5 KEY CHALLENGES

PROCESSING



GELS (INHOMOGENEITIES)



MECHANICAL PROPERTIES

ODOUR

COLOUR

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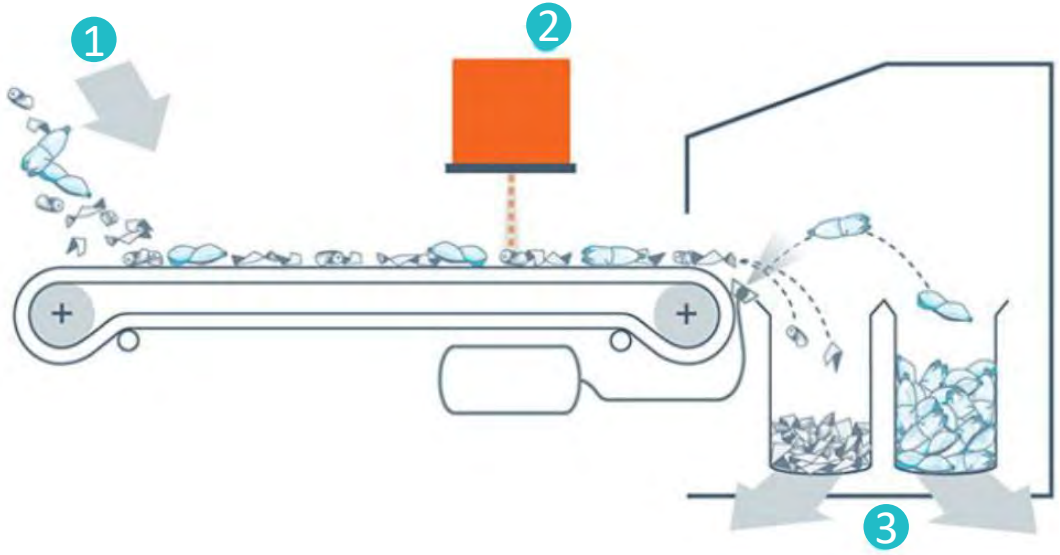
BASIC SORTING BY POLYMER TYPE IS NECESSARY - BUT NOT SUFFICIENT

+ PET
+ PE film

1. Feeding of unsorted material
2. Spectrometer scanner
3. Separation chamber



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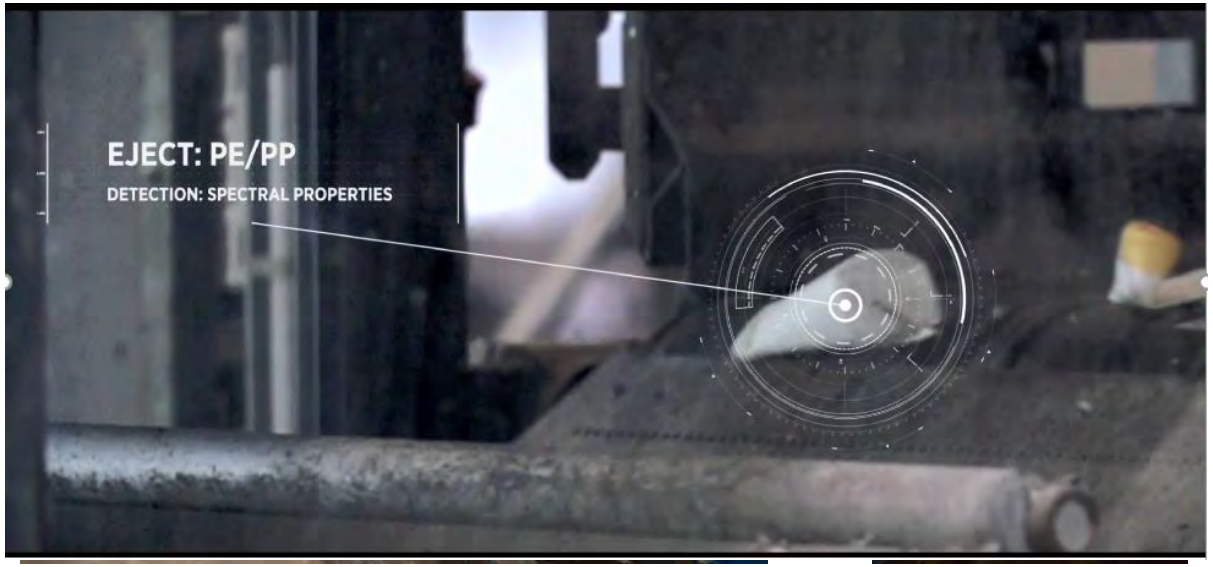
BASIC SORTING BY POLYMER TYPE IS NECESSARY - BUT NOT SUFFICIENT



+ PET
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1. Feeding of unsorted material
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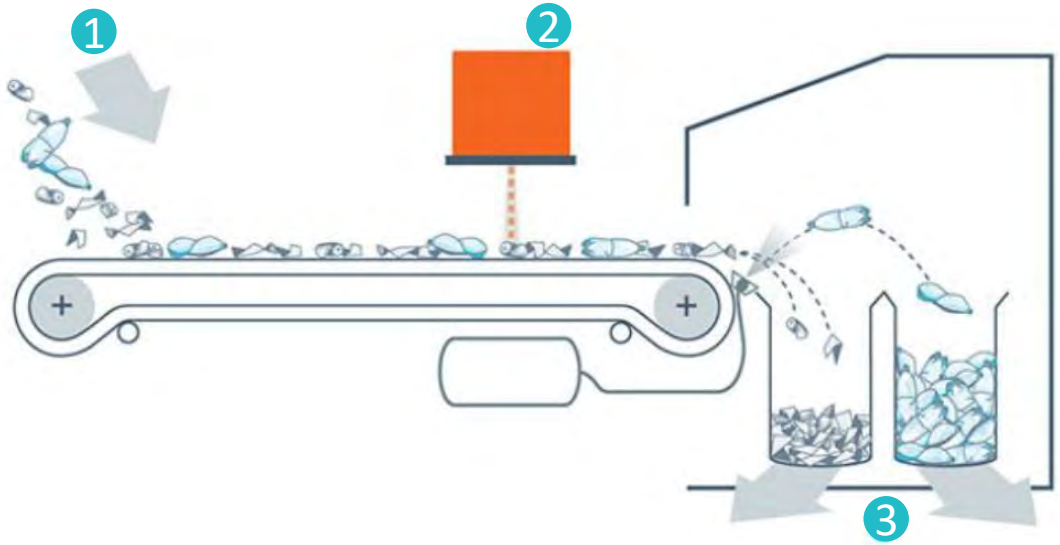

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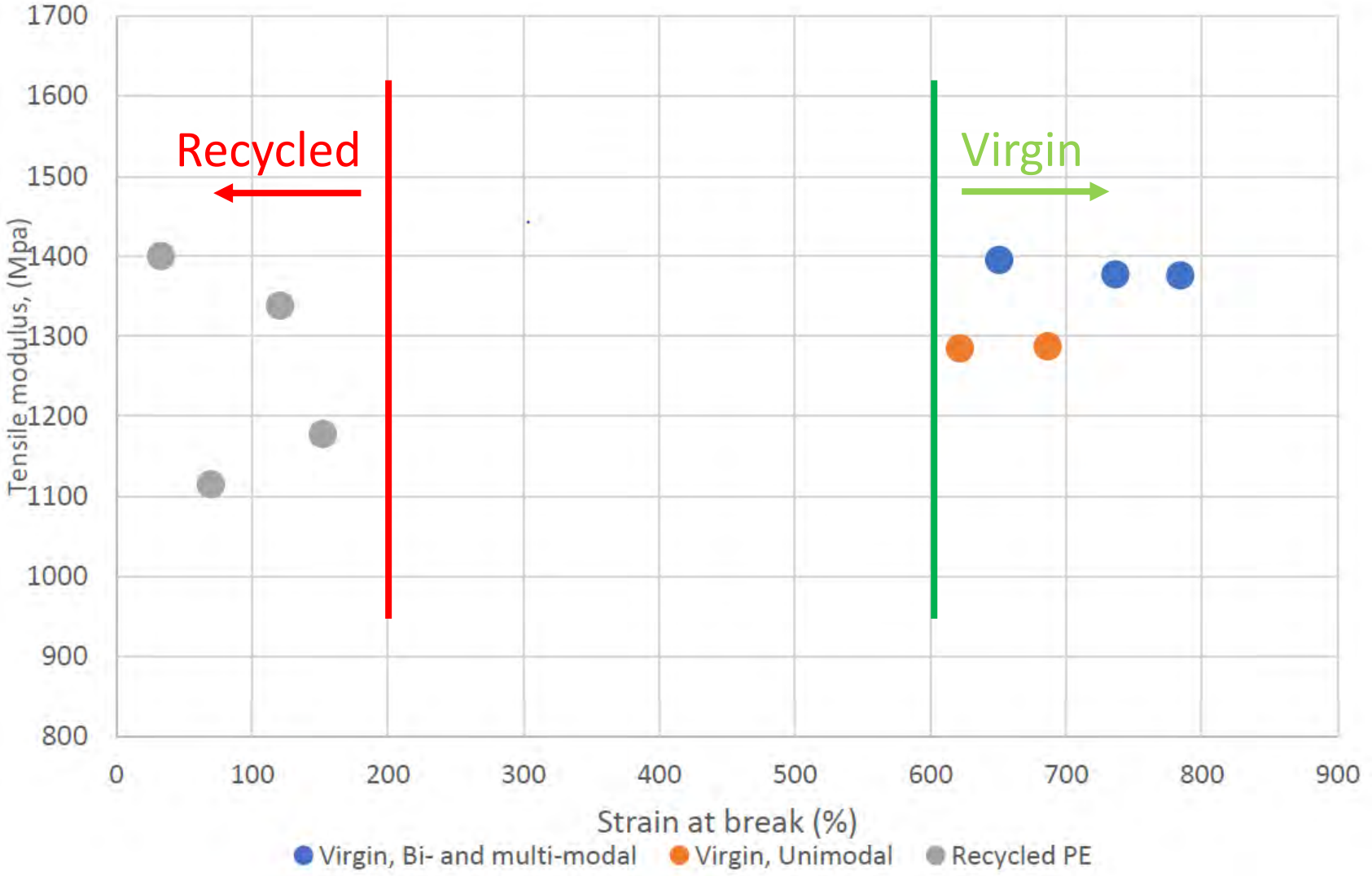
Household and Industrial Containers – Ideal for PCR?



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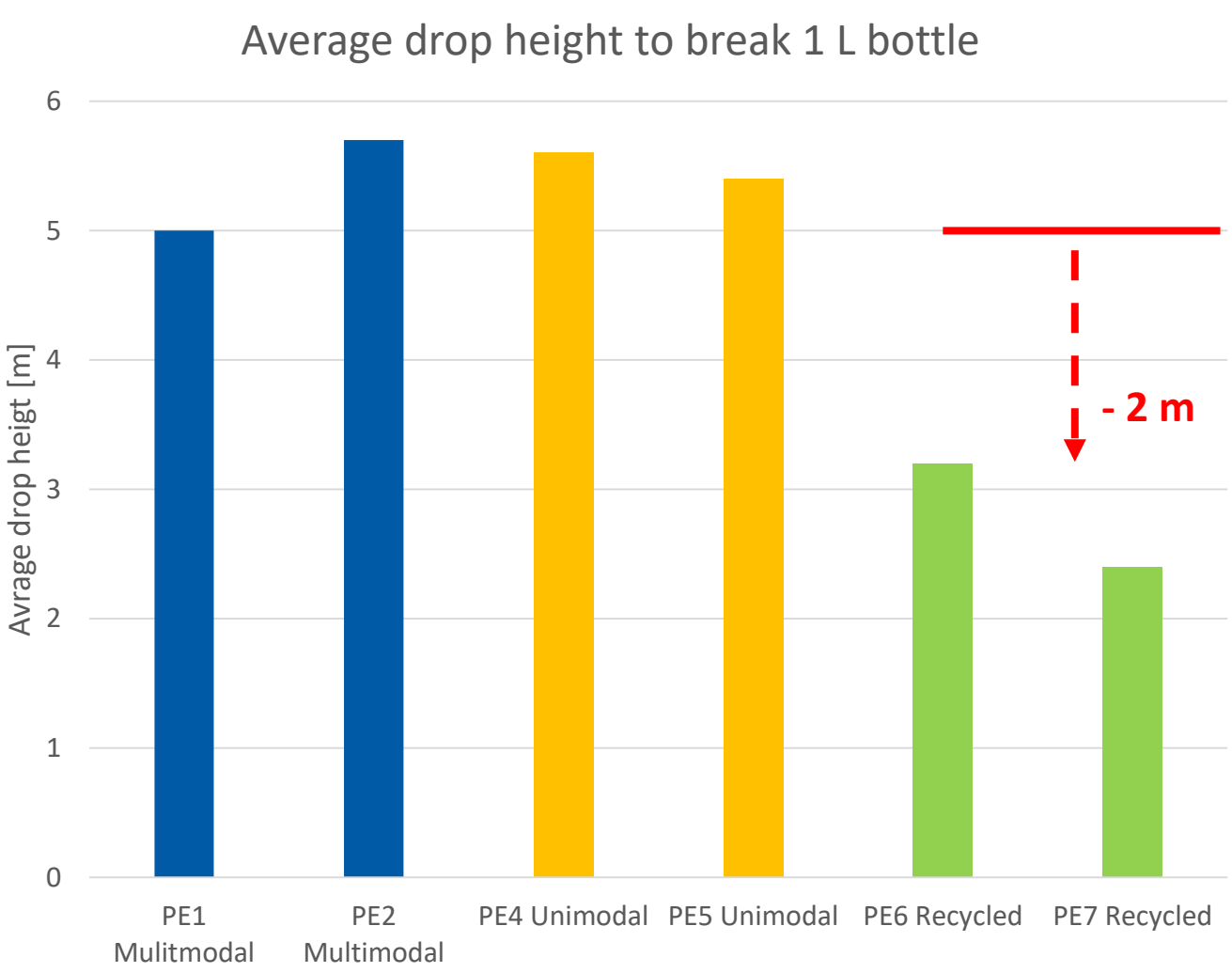
How does PCR affect application performance?



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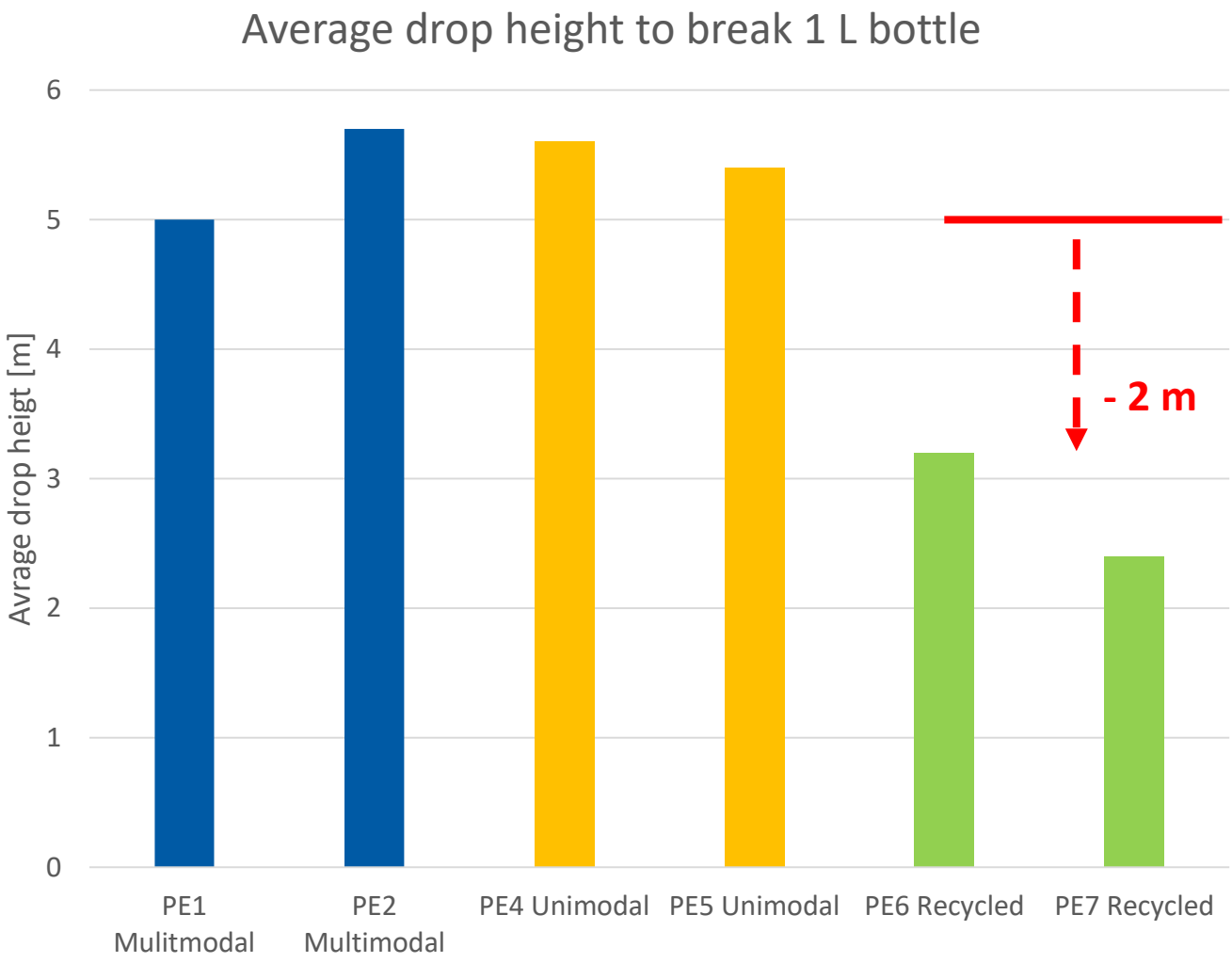
How does this translate in application performance?



PE6 Recycled:

- The transition did not go so smoothly as between the other grades
- Parison had much less melt strength - easily tears off the nozzle
- Some black particles and gels appeared in the bottles
- Odour/smell during processing
- Surface quality of the bottle, processing properties and parison stability became good after optimization

PE7 Recycled:

- Inconsistent quality of the bottles
- Lot of black particles and gels appeared in the bottles
- Odour/smell during processing

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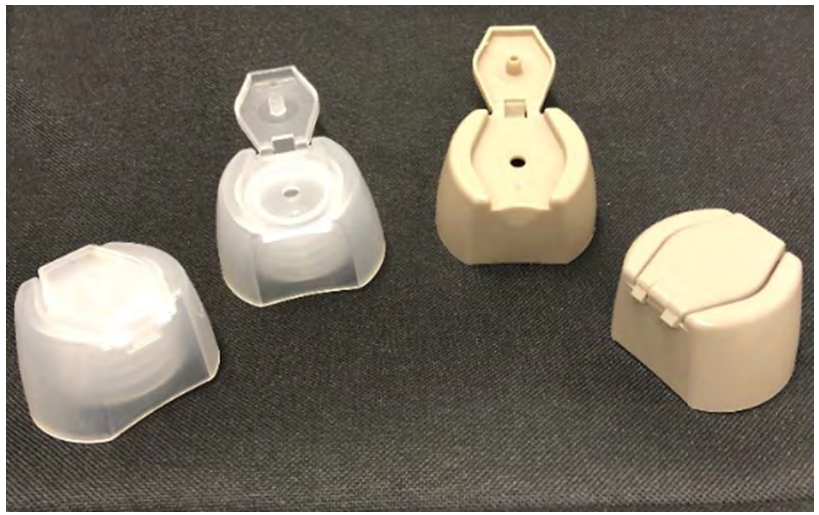
PCR MUST HAVE GOOD ENOUGH PROPERTIES TO AVOID "DOWNGRADING"



- Injection moulded hinge caps, mix of virgin PP + PCR-PP
- Mechanical properties are reduced
  - Tensile strength >25%reduction
  - Torque strength >25% reduction

- Poorly sorted plastics waste:
  - Downgrading
  - Use in less demanding applications like flower pots and park benches

PCR - Post Consumer Recycled

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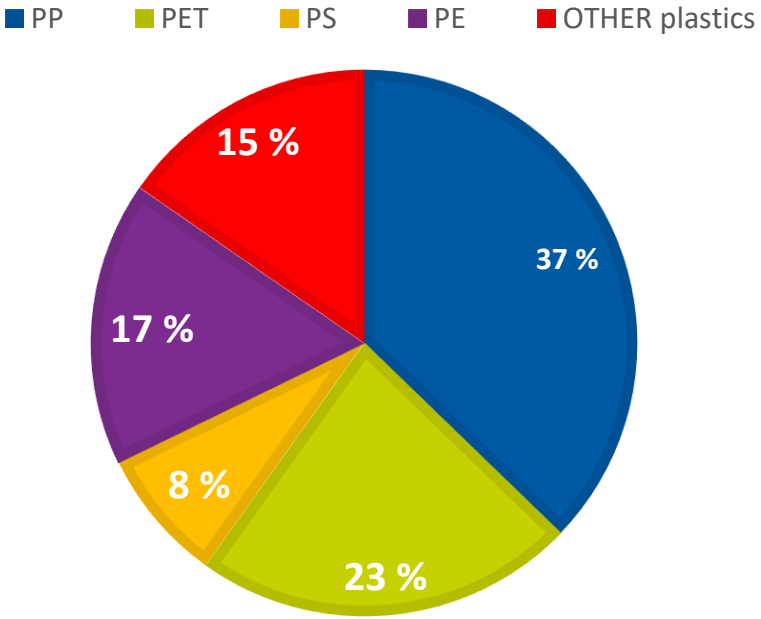
MORE DETAILED SORTING IS REQUIRED!

- Norner case study
- Collection of rigid plastic packaging waste from Norner employees
- Knowledge based sorting into four fractions (PP)



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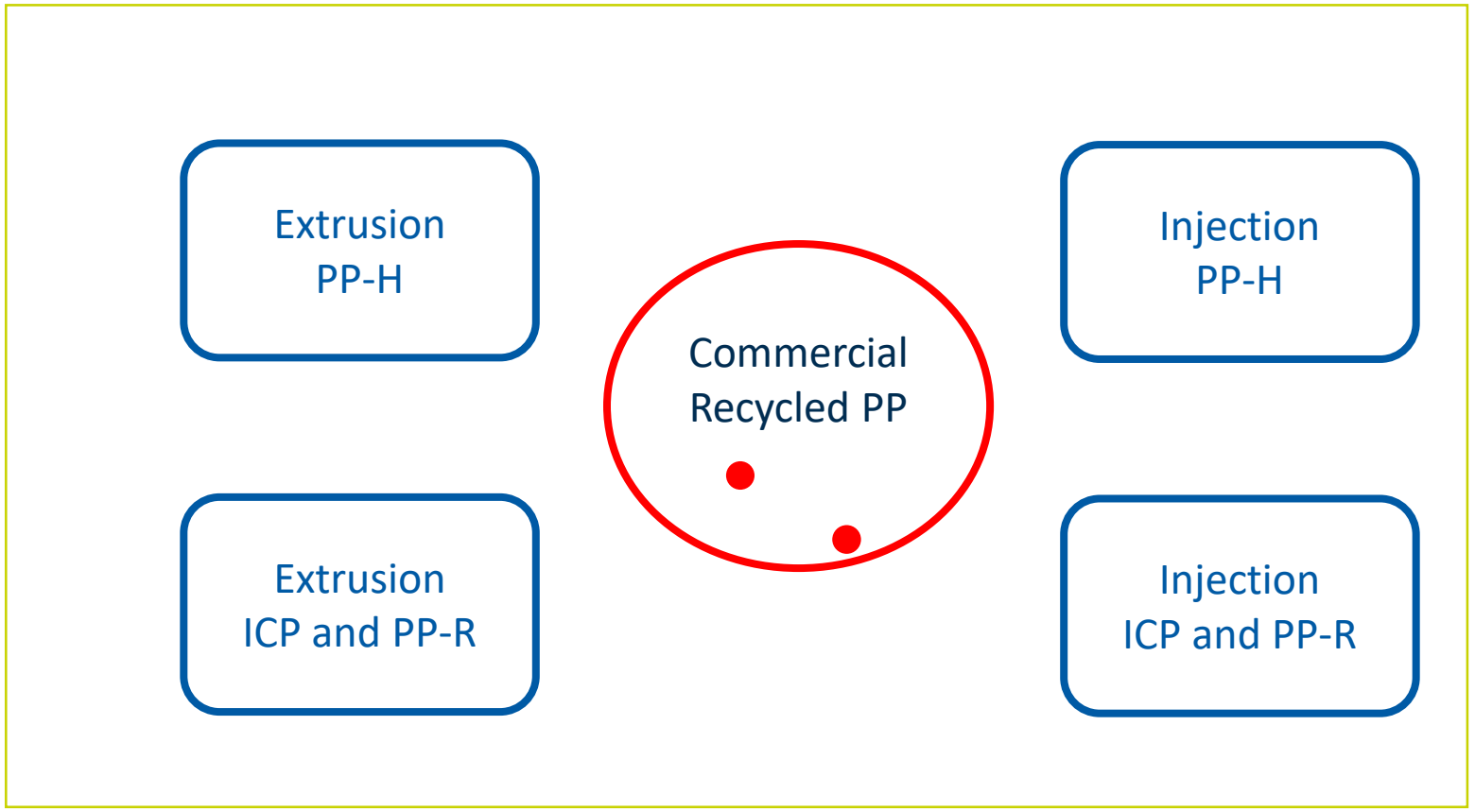
PP AND PP ARE DIFFERENT – AND SHALL NOT BE MIXED WHEN RECYCLING!

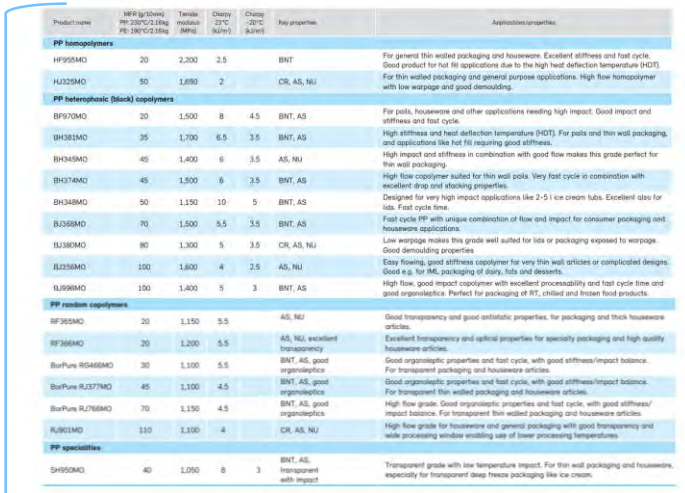


- PCW PP 1 – commercial grade
- PCW PP 2 – commercial grade

PP

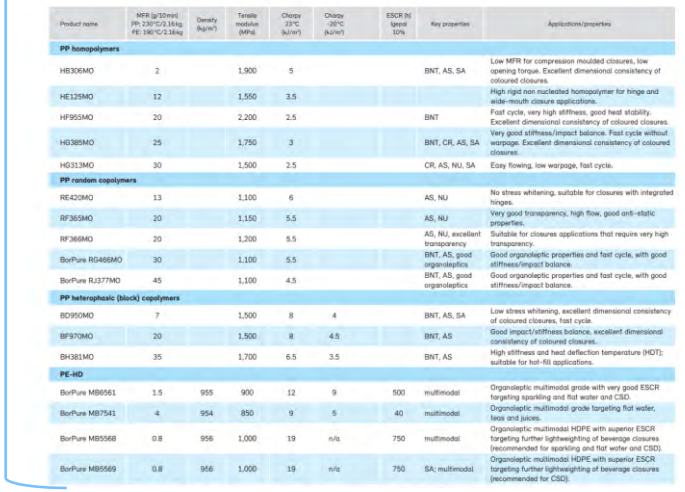
Thin wall packaging and houseware

Specific grades per application



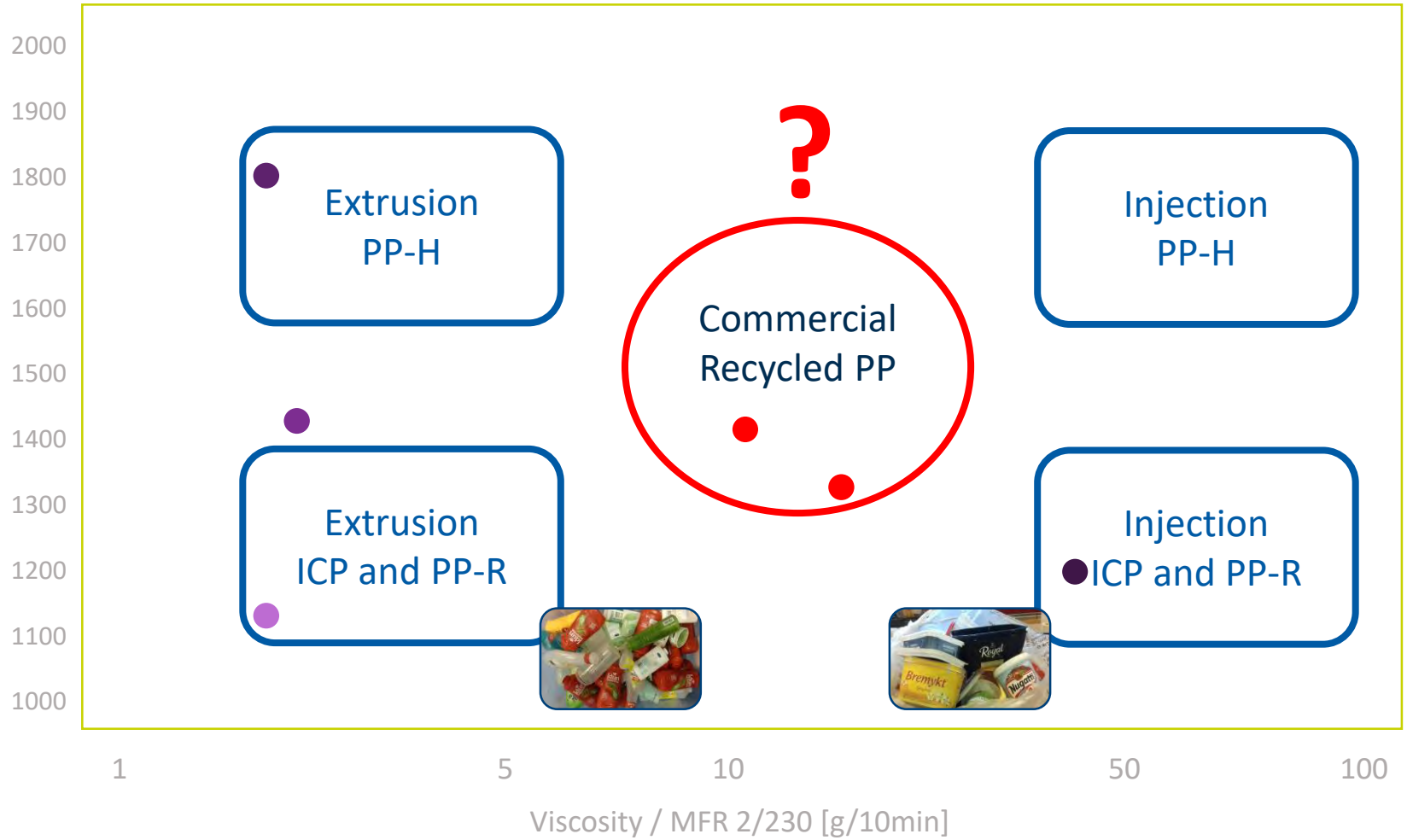
Product name	MFR (g/10min) PP: 230°C/2.16kg PE: 190°C/2.16kg	Tensile modulus (MPa)	Charpy 23°C (kJ/m²)	Charpy -20°C (kJ/m²)	Key properties	Applications/properties
PP homopolymers						
HF955MO	20	2,200	2.5		BNT	For general thin walled packaging and houseware. Excellent stiffness and fast cycle. Good product for hot fill applications due to the high heat deflection temperature (HDT).
HJ325MO	50	1,650	2		CR, AS, NU	For thin walled packaging and general purpose applications. High flow homopolymer with low warpage and good demoulding.
PP heterophasic (block) copolymers						
BF970MO	20	1,500	8	4.5	BNT, AS	For pails, houseware and other applications needing high impact. Good impact and stiffness and fast cycle.
BH381MO	35	1,700	6.5	3.5	BNT, AS	High stiffness and heat deflection temperature (HDT). For pails and thin wall packaging, and applications like hot fill requiring good stiffness.
BH345MO	45	1,400	6	3.5	AS, NU	High impact and stiffness in combination with good flow makes this grade perfect for thin wall packaging.
BH374MO	45	1,500	6	3.5	BNT, AS	High flow copolymer suited for thin wall pails. Very fast cycle in combination with excellent drop and stacking properties.
BH348MO	50	1,150	10	5	BNT, AS	Designed for very high impact applications like 2-5 l ice cream tubs. Excellent abs for lids. Fast cycle time.
BJ368MO	70	1,500	5.5	3.5	BNT, AS	Fast cycle PP with unique combination of flow and impact for consumer packaging and houseware applications.
BJ380MO	80	1,300	5	3.5	CR, AS, NU	Low warpage makes this grade well suited for lids or packaging exposed to warpage. Good demoulding properties
BJ356MO	100	1,600	4	2.5	AS, NU	Easy flowing, good stiffness copolymer for very thin wall articles or complicated designs. Good e.g. for IML packaging of dairy, tubs and desserts.
BJ998MO	100	1,400	5	3	BNT, AS	High flow, good impact copolymer with excellent processability and fast cycle time and good organoleptics. Perfect for packaging of RT, chilled and frozen food products.
PP random copolymers						
RF365MO	20	1,150	5.5		AS, NU	Good transparency and good antistatic properties, for packaging and thick houseware articles.
RF366MO	20	1,200	5.5		AS, NU, excellent transparency	Excellent transparency and optical properties for specialty packaging and high quality houseware articles.
BorPure RG468MO	30	1,100	5.5		BNT, AS, good organoleptics	Good organoleptic properties and fast cycle, with good stiffness/impact balance. For transparent packaging and houseware articles.
BorPure RJ377MO	45	1,100	4.5		BNT, AS, good organoleptics	Good organoleptic properties and fast cycle, with good stiffness/impact balance. For transparent thin walled packaging and houseware articles.
BorPure RJ766MO	70	1,150	4.5		BNT, AS, good organoleptics	High flow grade. Good organoleptic properties and fast cycle, with good stiffness/ impact balance. For transparent thin walled packaging and houseware articles.
RJ801MO	110	1,100	4		CR, AS, NU	High flow grade for housewares and general packaging with good transparency and wide processing window enabling use of lower processing temperatures.
PP specialities						
SH950MO	40	1,050	8	3	BNT, AS, transparent with impact	Transparent grade with low temperature impact. For thin wall packaging and housewares, especially for transparent deep freeze packaging like ice cream.

Caps and closures



Product name	MFR (g/10 min) PP: 230°C/2.16kg, PE: 190°C/2.16kg	Density (kg/m³)	Tensile modulus (MPa)	Charpy 23°C (kJ/m²)	Charpy -20°C (kJ/m²)	ESCR (h) Igepal 10%	Key properties	Applications/properties
PP homopolymers								
HB306MO	2		1,900	5			BNT, AS, SA	Low MFR for compression moulded closures, low opening torque. Excellent dimensional consistency of coloured closures.
HE125MO	12		1,550	3.5				High rigid non nucleated homopolymer for hinge and side-mouth closure applications.
HF955MO	20		2,200	2.5			BNT	Fast cycle, very high stiffness, good heat stability. Excellent dimensional consistency of coloured closures.
HG385MO	25		1,750	3			BNT, CR, AS, SA	Very good stiffness/impact balance. Fast cycle without warpage. Excellent dimensional consistency of coloured closures.
HG313MO	30		1,500	2.5			CR, AS, NU, SA	Easy flowing, low warpage, fast cycle.
PP random copolymers								
RE420MO	13		1,100	6			AS, NU	No stress whitening, suitable for closures with integrated hinges.
RF365MO	20		1,150	5.5			AS, NU	Very good transparency, high flow, good anti-static properties.
RF366MO	20		1,200	5.5			AS, NU, excellent transparency	Suitable for closures applications that require very high transparency.
BorPure RG466MO	30		1,100	5.5			BNT, AS, good organoleptics	Good organoleptic properties and fast cycle, with good stiffness/impact balance.
BorPure RJ377MO	45		1,100	4.5			BNT, AS, good organoleptics	Good organoleptic properties and fast cycle, with good stiffness/impact balance.
PP heterophasic (block) copolymers								
BD950MO	7		1,500	8	4		BNT, AS, SA	Low stress whitening, excellent dimensional consistency of coloured closures, fast cycle.
BF970MO	20		1,500	8	4.5		BNT, AS	Good impact/stiffness balance, excellent dimensional consistency of coloured closures.
BH381MO	35		1,700	6.5	3.5		BNT, AS	High stiffness and heat deflection temperature (HDT); suitable for hot-fill applications.
PE-HD								
BorPure MB6561	1.5	955	900	12	9	500	multimodal	Organoleptic multimodal grade with very good ESCR targeting sparkling and flat water and CSD.
BorPure MB7541	4	954	850	9	5	40	multimodal	Organoleptic multimodal grade targeting flat water, teas and juices.
BorPure MB5568	0.8	956	1,000	19	n/a	750	multimodal	Organoleptic multimodal HDPE with superior ESCR targeting further lightweighting of beverage closures (recommended for sparkling and flat water and CSD).
BorPure MB5569	0.8	956	1,000	19	n/a	750	SA; multimodal	Organoleptic multimodal HDPE with superior ESCR targeting further lightweighting of beverage closures (recommended for CSD).

SORTING NEEDS TO BE MATERIAL AND APPLICATION SPECIFIC!



Material specifications of recycled PP is “out of spec”

- Norner IM
- Norner Thermoformed 1
- Norner Thermoformed 2
- Norner Bottles
- PP recycled, commercial grade
- PP recycled, commercial grade

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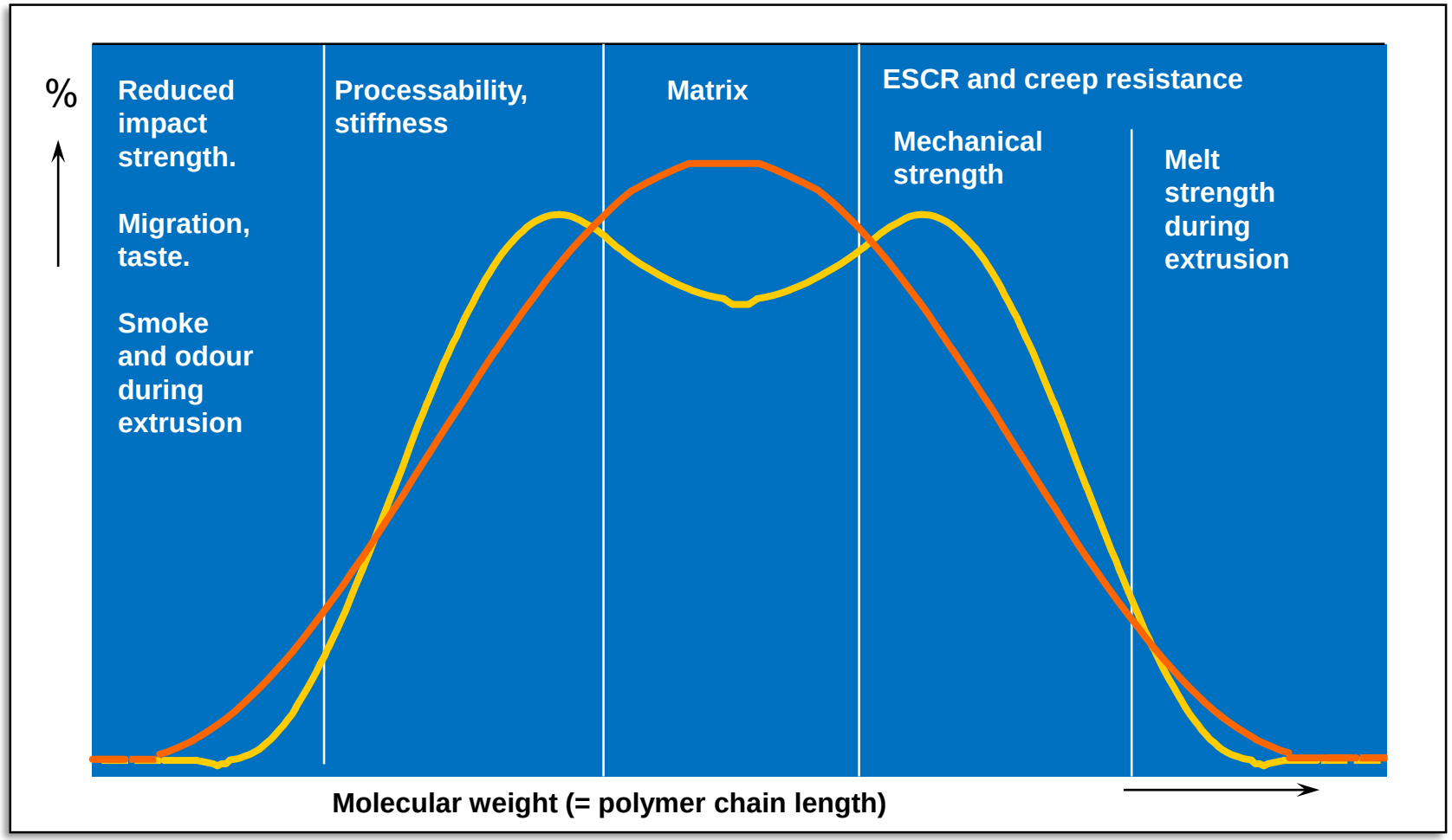
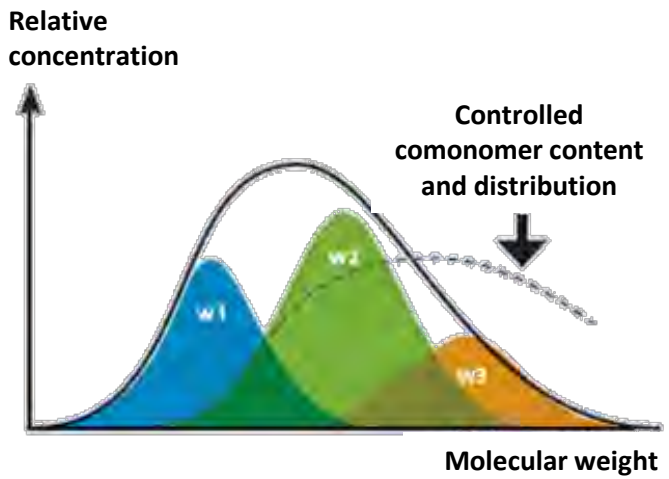
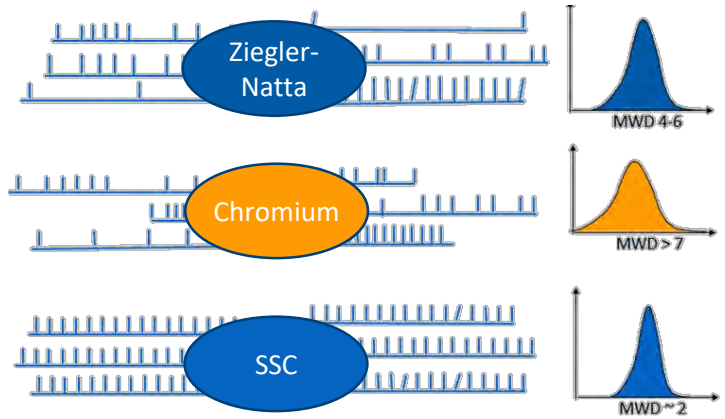
PCRs NEED TO BE DEVELOPED WITH SAME UNDERSTANDING AS VIRGIN





w1: Low molecular weight homopolymer
w2: High molecular weight copolymer
w3: Ultra high molecular weight copolymer



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CAN TECH. WITH 3D IDENTIFICATION AND NIR DO THE JOB?

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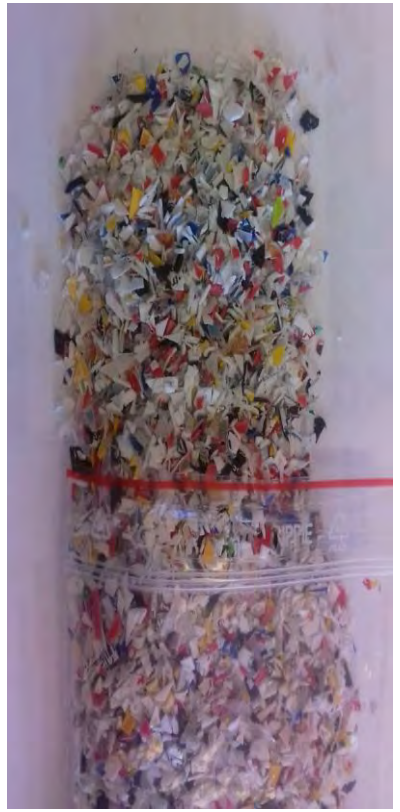
COLOUR IS STILL A CHALLENGE - EVEN WITH IMPROVED SORTING

SORTING

PREPARATION

WASHING
SHREDDING



FLAKES

REGRIND
(PELLETS)

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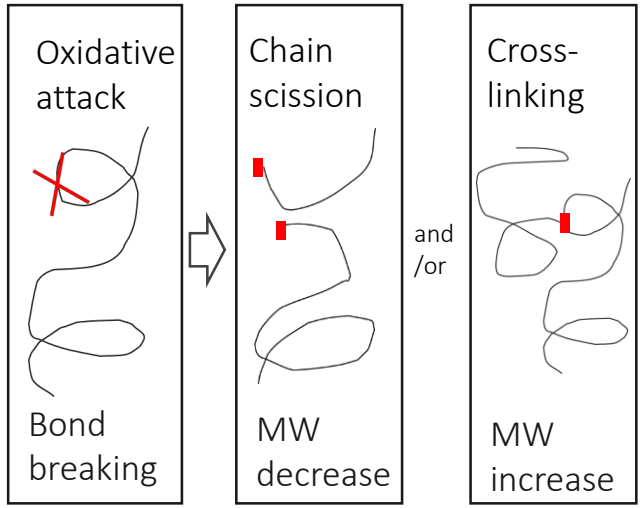
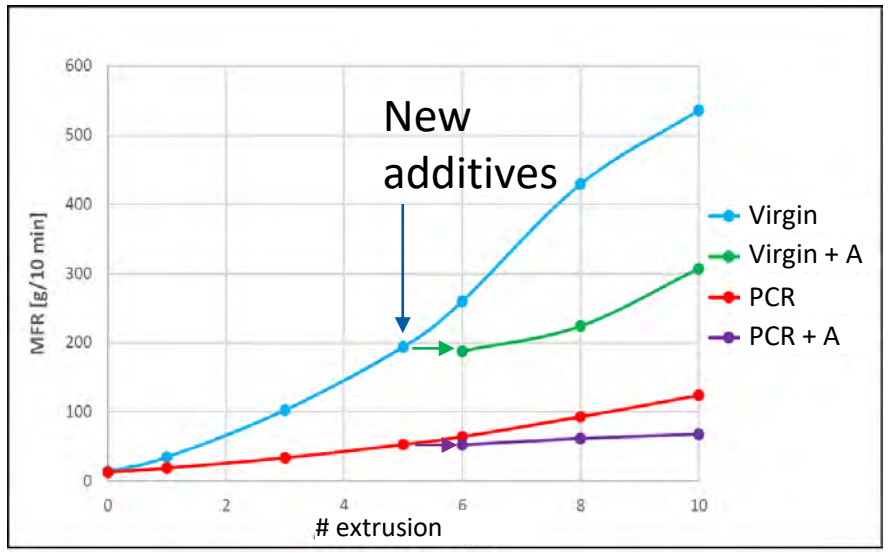
PCR (AND VIRGIN) TO BE FORMULATED FOR RECYCLABILITY!





- Study: Simulated recycling of PP-virgin and commercial PP-PCR by multiple extrusions
  - analysis of additive consumption (antioxidants, AO's)
  - analysis of MFR change
- Replenishing additives reduces degradation
- Degradation products from additives increase total migration (NIAS)
- Which stabilisers are the right ones for PCR? (work in progress…)

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NORNER MECHANICAL RECYCLING PILOT CENTRE

Modern pilot lines and test facilities

Recycling pilot centre
A sustainable service from Norner

Contribution:

- Tests and evaluation of waste streams
- Post Consumer Waste (PCW) to Post consumer recyclate (PCR) trials
- Processing trials including particle/gels removal (melt filtration)
- Odour and volatile reduction technology
- Application trials in state-of-the art pilots
- Article and material performance

Project cooperation and product support

QCP Plastics News Europe
March 20, 2018 06:00 AM
LyondellBasell and SUEZ establish plastics recycling JV

QUALITY CIRCULAR POLYMERS lyondellbasell SUEZ

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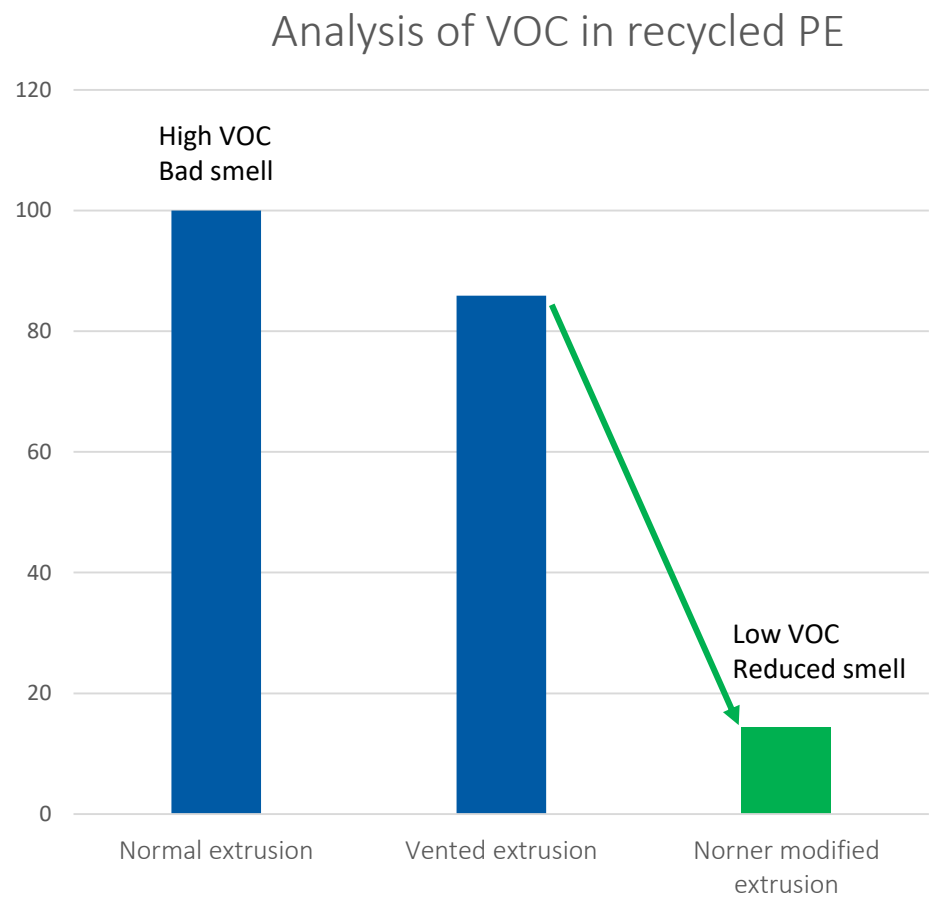
NORNER'S SOLVENT FLUSH TECHNOLOGY REDUCES ODOURS

- PCR has "bad smell"
- PCR smell depends very much on source of the plastic waste

Norner modified extrusion w/solvent flush

- Chemical analysis: > 80% reduction in VOC
- Odour panel: Significantly less smell



VOC= Volatile Organic Components

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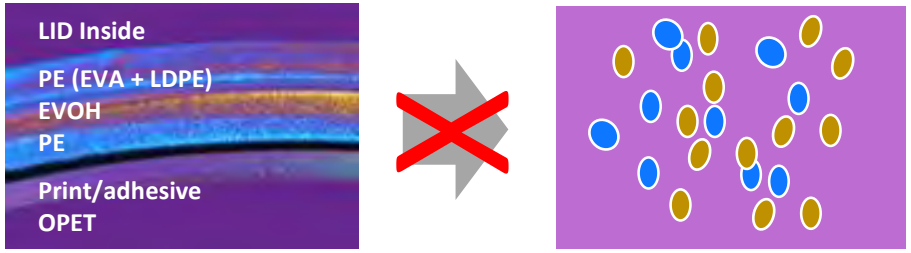
MULTILAYERED FILMS - GREAT FOR PACKAGING - A PAIN FOR RECYCLING



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CAN PA/PE LAMINATES BE REPLACED BY MONOMATERIAL?

- Can we get long shelf life with PE mono-material packaging – target 51 days? – **YES!**
  - HDPE – 41 days
  - PET – 51 days
- Will different packaging methods affect the shelf life of the product? – **YES!**
  - Modified atmosphere (MAP) – 45 days
- Will different active packaging concepts improve the shelf life of the product? – **YES!**
  - With CO_2 emitter: 51 days

MONOMATERIAL PACKAGING FOR HOT DOGS

DESIGN FOR RECYCLING!

Nilsen-Nygaard J. Sarfraz J, Radusin T, Pettersen MK, IAPRI 2019. *Replacing conventional laminate material (PA/PE) with recyclable mono-materials(PP, HDPE): A case study on hot dogs*

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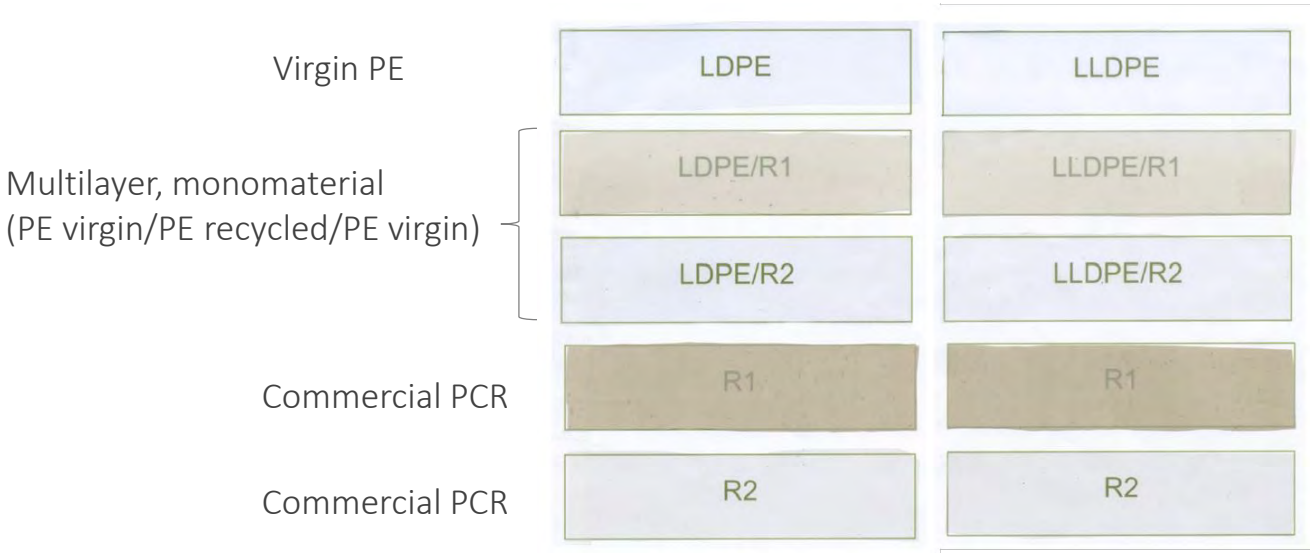
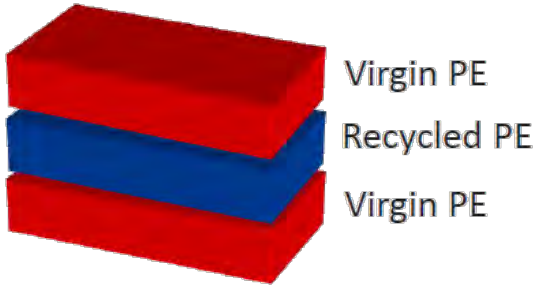
PCR CAN BE USED IN MULTILAYER, MONOMATERIAL FILMS



- Processability depends on PCR quality and amount of PCR
- PCR quality varies (homogeneity, colour, gels, odour)
- Blown films could be made for PCR in core layer in co-ex films



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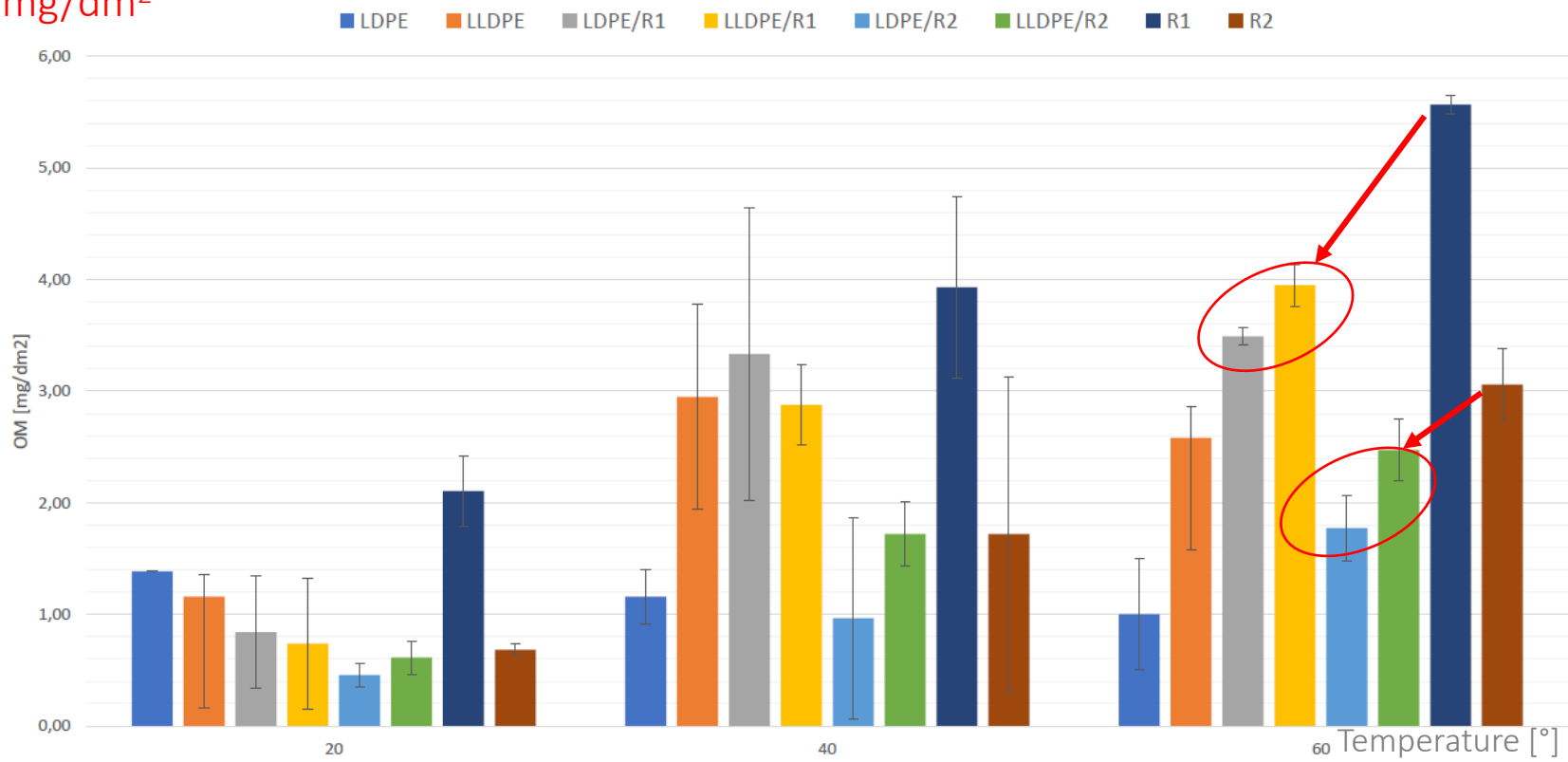
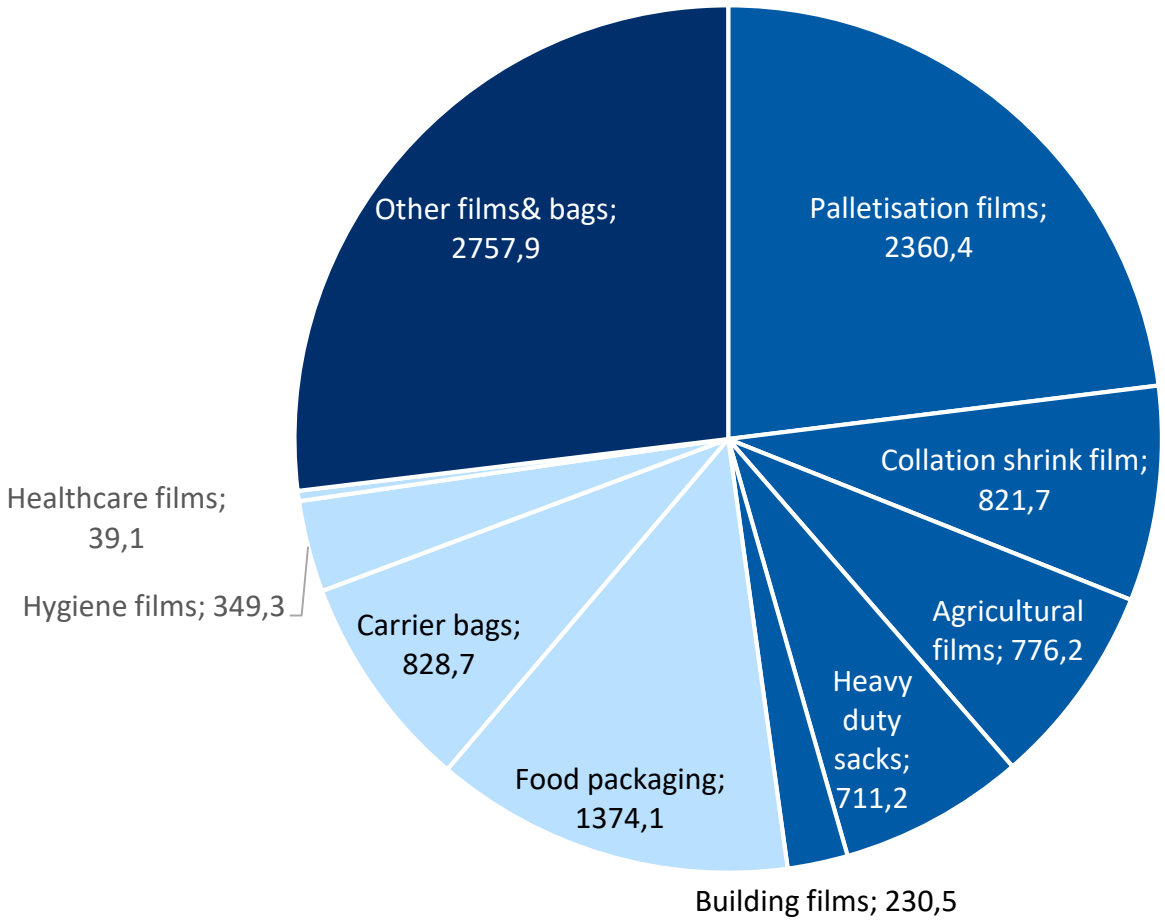
Multilayer PCR films have Overall Migration below treshold (OML)

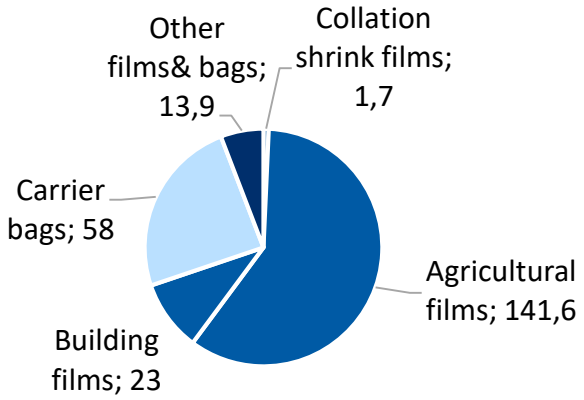
Overall migration limit OML = 10 mg/dm^2



- Screening conditions: 95% Ethanol/10 days/3 different temperatures

CAN WE FIND ANY LOW HANGING FRUITS TO INCREASE RECYCLING?





Total: 10.236 kT

Use of recycled PE: 238 kT

Source: AMI 2018

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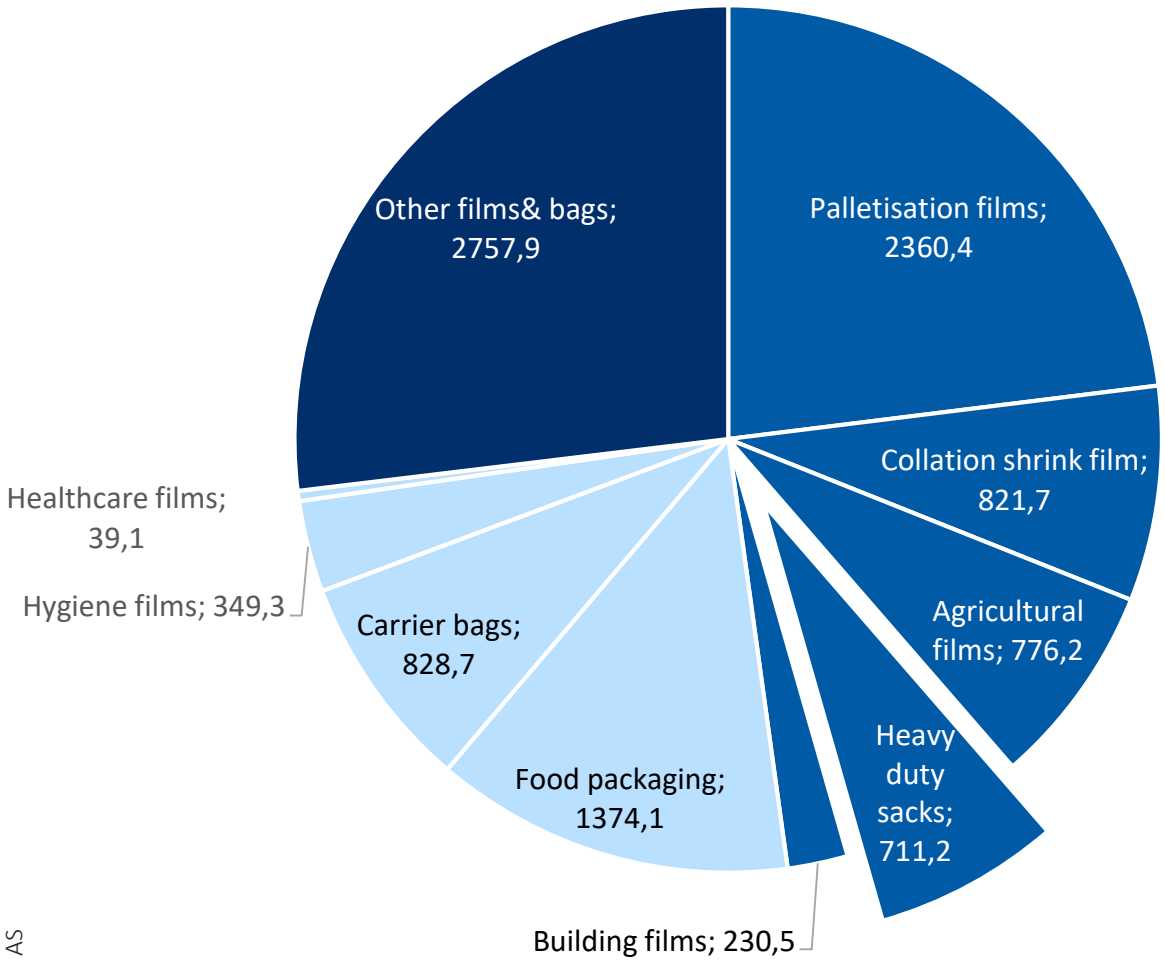
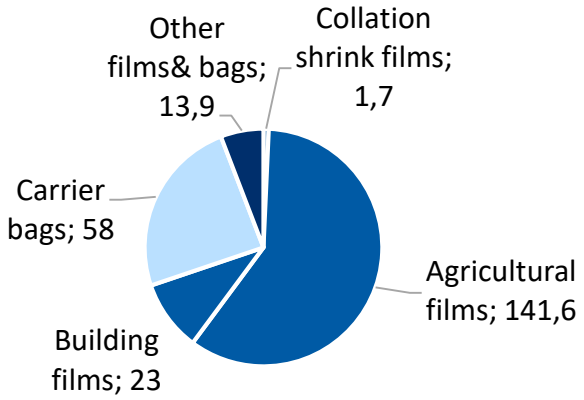
> 3% OF THE PE FILMS IN EUROPE USED RECYCLED IN 2017



Total: 10.236 kT



Use of recycled PE: 238 kT

Source: AMI 2018

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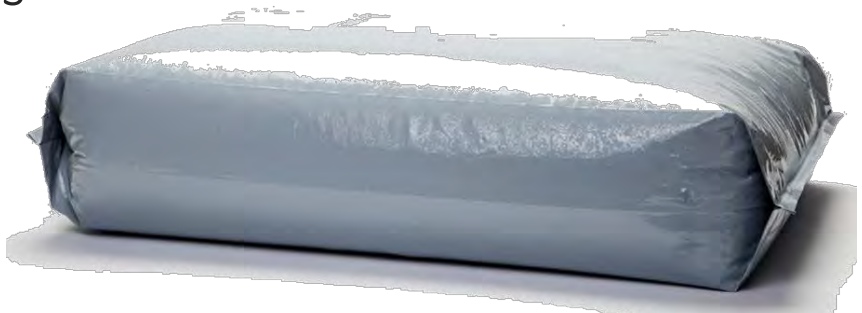
Closed Loop Systems enable consistent Quality

- Example: Sabic – 4 mill. plastic bags with 50% resirc.
  - Closed-loop collaboration between SABIC, Fardem Packaging and recycling company Morssinkhof Rymoplast
  - Recycling company collects the used plastic bags from a logistics service provider contracted by SABIC
  - Recycles them back into recycled plastic pellets
  - These bags are then used to package selected SABIC resins



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RETHINK! 50% RECYCLED CONTENT IS POSSIBLE

SONGWON PRODUCTS INDUSTRIES COMPANY INVESTORS MEDIA CONTACT

Media News SONGWON and RPC bpi nordfolien partner to produce sustainable packaging containing 50% recycled PE

SONGWON and RPC bpi nordfolien partner to produce sustainable packaging containing 50% recycled PE

SONGWON Industrial Co., Ltd. proudly announces that it has become one of the first chemical companies in the world to package its products in 20kg PE-bags made with 50% recycled PE.

sabic

50% RECYCLED CONTENT

- OVER 1 MILLION SABIC® POLYMERS PACKAGING BAGS MADE WITH 50% RECYCLED MATERIAL

STRONG MECHANICAL PERFORMANCE

- EXCELLENT MECHANICAL PROPERTIES ENGINEERED TO REDUCE DAMAGE DURING HANDLING, STORAGE AND TRANSPORTATION

COLLOBORATION WITH VALUE-CHAIN

- CLOSE CORPORATION WITH OERLEMANS PACKAGING, VALUE CHAIN PARTNERS MORSSINKHOF RYMOPLAST AND FARDEM PACKAGING
- PLASTIC WASTE IS DIRECTLY CONVERTED INTO HIGH-QUALITY PACKAGING AND THEREFORE IT'S GIVEN A SECOND LIFE IN THE SAME APPLICATION

2019 RETHINK AWARD

Rethink

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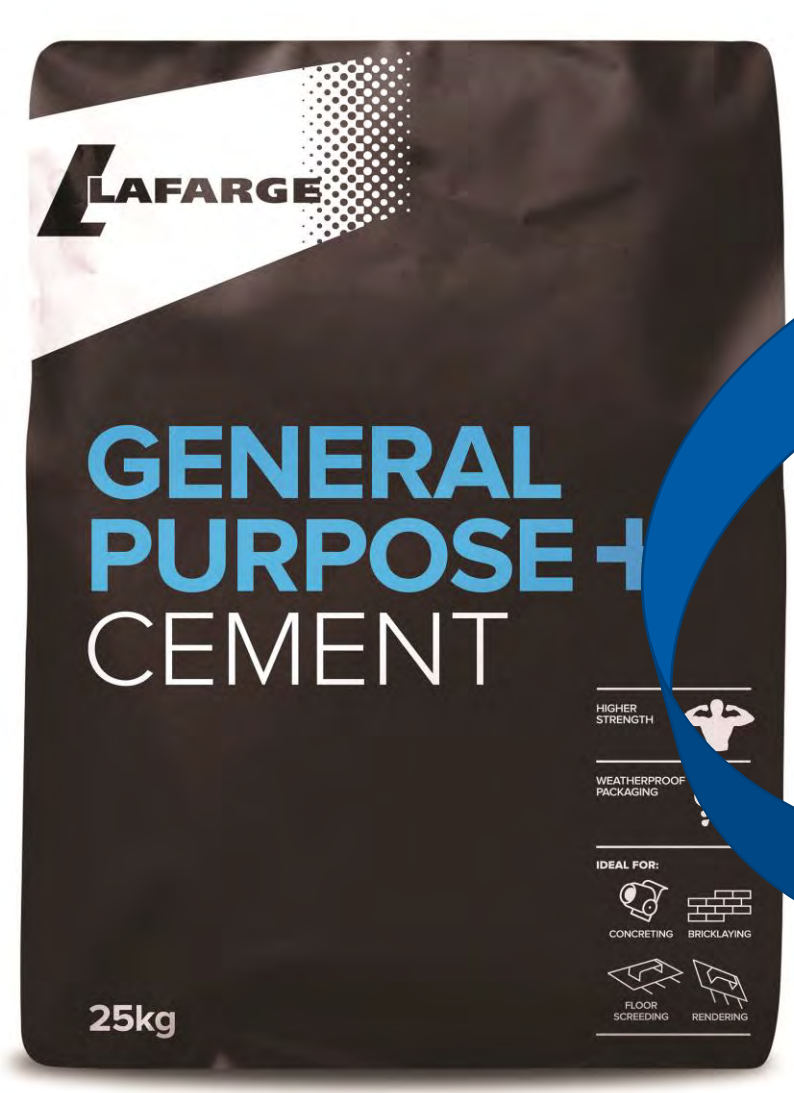
WHAT IF WE CLOSE THE LOOP ACROSS VALUE CHAINS?



+ Recycling Companies
+ Logistic Service providers
+ R&D
+ Converters

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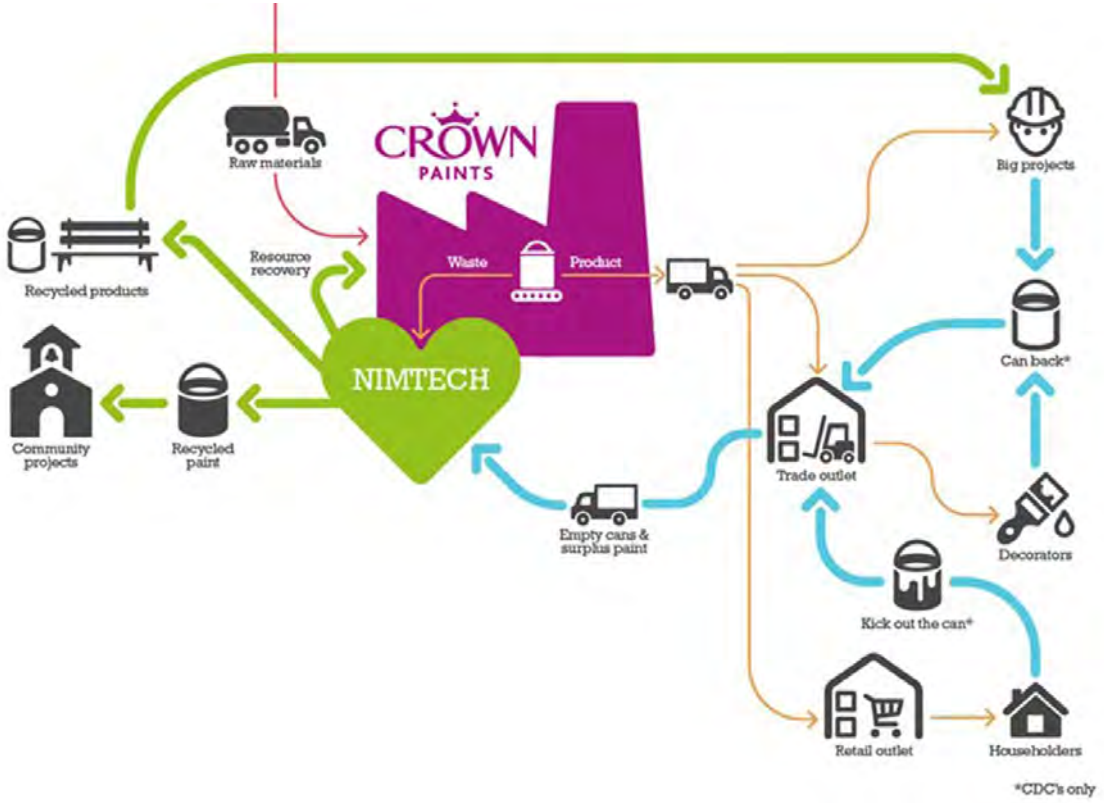
WHAT IF WE CLOSE MORE LOOPS?



emballator LAGAN PLAST

DE PAAUW RECYCLING

100%

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Still hard work to pick the low hanging fruits!

THE CHEMICAL RECYCLING OPPORTUNITY

CHEMICAL RECYCLING HAS THE POTENTIAL TO SOLVE KEY RECYCLING CHALLENGES

- COMPLEMENTARY TO MECHANICAL RECYCLING

Is Chemical Recycling the Solution?

- Waste sorting needs depending on technology
- Efficiency to desired product(s)
- Energy demand and LCA
- Feedstock composition: impurities and availability
- Economic feasibility
- Scale vs. fossil feedstock demand
- Cost

Chemical recycling:
Convert a polymeric material through cracking, gasification or depolymerization to its base monomers/starting substances

Chemolysis:	Depolymerization process mainly limited to PU or condensation polymers (PET/PA)
Pyrolysis:	Thermal cracking of waste plastic to liquid feedstock/fuel at low temperature (±400°C) in low oxygen environment
Gasification:	Thermal cracking of waste plastic or at elevated temperatures (±1200°C) to feedstock or chemicals via syngas

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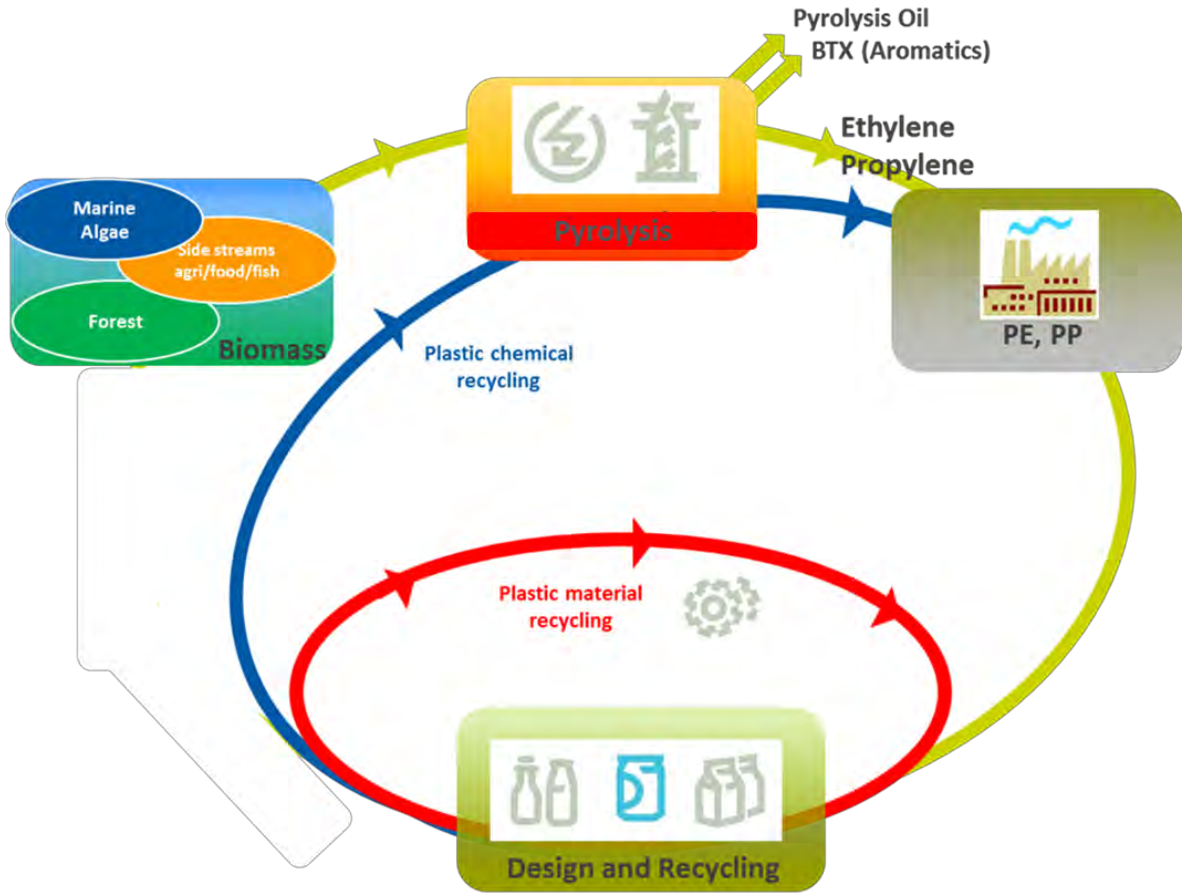
NORNER WILL ESTABLISH A SMALL SCALE PLASTIC WASTE PYROLYSIS PLANT

- Pyrolysis of plastic waste
  - breaks down the polymer chains
  - results in the building blocks, ethylene and propylene,
  - which are used to produce PE and PP in existing polyolefin plants
- Highly focused by polymer producers
- Virgin PE and PP are produced
- Any application, including food packaging



NORNER IS A TECHNOLOGY DEVELOPMENT PARTNER IN PLASTICS WASTE PYROLYSIS

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So, how to Increase the Circularity of Plastics?

- Design for recyclability
- Improve sorting to retain the value of already designed polymers
- Improve purification processes of mechanical recycling
- Develop the PCRs for applications with the same approach and quality control as for virgin materials
  - Polymer design
  - Additivation
- Upcycling with help of compatibilizers and “boosters”
- Close more loops for high quality and consistency of PCRs
- Integrate chemical recycling as part of the recycling tool-box
- Embrace value chain collaboration close the gaps to increased circularity of plastics

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Waste with a value is no longer waste

Snøhetta

From plastic aquaculture waste to furniture icons that last a lifetime

Thank you for the attention!

Thor.Kamfjord@norner.no

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