Re-inventing polyolefins together

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BOREALIS

Borealis at a glance

Worldwide

Head Office in **Vienna**, Austria.
Operating on **five continents**
in **120 countries**

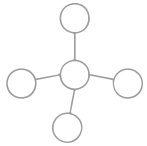
Market Position

#2 among polyolefin
producers in **Europe**
#8 worldwide

Employees

About
6,900 employees

Line of Business



Production and distribution of
polyolefins, **base chemicals**
and **fertilizers**

Ownership Structure

75% OMV, Austria /
25% Mubadala, United Arab
Emirates

Financial figures

Net profit 2021 – **1,396** MEUR
Total sales 2021 – **12,342** MEUR

Joint Venture

Borouge – one of the world's
largest integrated polyolefin
complexes (Ruwais, UAE)

Joint Venture

Bayport Polymers – brings
Borstar® technology to American
polyethylene markets

Circularity

Two **polyolefin recycling**
operations in Europe

Patents

133 priority patents
filed in 2021,
#1 in Austria

Re-inventing polyolefins together

Network efforts involving academia and industry

1. **The history: Achievements in DPI projects**
   - Systematic catalyst development
   - High performance copolymers
   - Understanding polymer crystallization

2. **The present: Moving towards sustainability and circularity**
   - Planetary limits in perspective
   - Multiple paths to circularity
   - The science of upcycling

3. **The future: Addressing challenges from society and environment**
   - Nutrition, energy and health for a growing population
   - Zero waste strategies including polymers

Systematic catalyst development

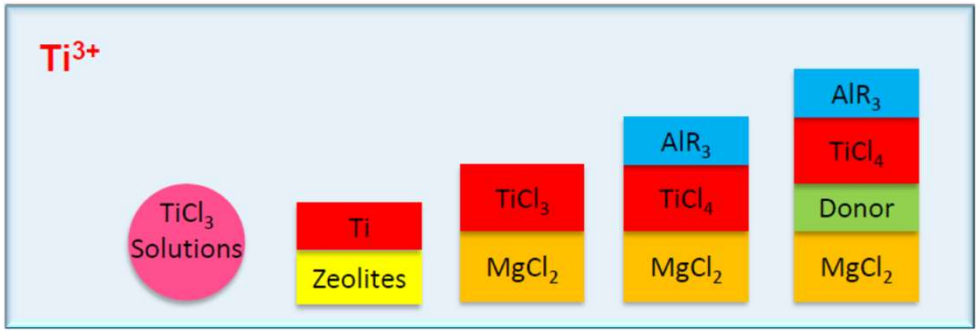
„Conventional“ heterogeneous systems

- Many DPI projects have been dedicated to understanding formation and function of Ziegler-Natta catalysts (ZNC, for example Zn-Ti and DisMgCl2), always combining different characterization techniques and advanced modelling
- Multiple groups, with a focus on Italy and Japan, have been working on these – finding that, after more than 50 years of successful application, there‘s still a lot to learn
- The work continues – like in the ZN/TCLB project

„Advanced“ single-site catalysts

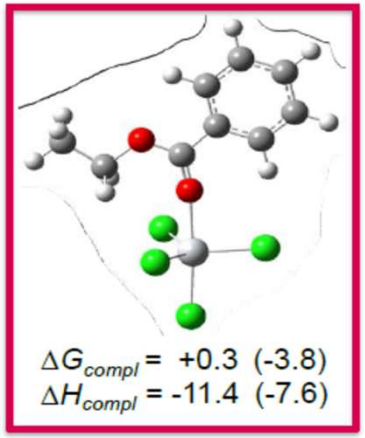
- The complexity of single-site catalyst (SSC) complex structures has been sucessfully explained by applying quantitative structure–activity relationship (QSAR) models, again combining experiment and modelling
- One working group in Russia (Uborsky / Voskoboynikov) was elementary for the progress made due to their unique synthetic expertise
- More work on activation and industrial application will be necessary

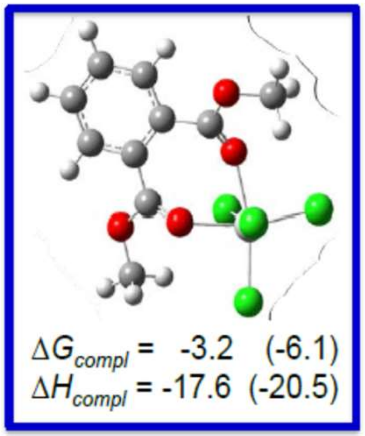
Understanding ZNC systems



- ZNC-systems continue to dominate industrial production
- Replacement of phthalates as dominant internal donors for ZNC is required from customer & environmental perspective (phthalates acting as endocrinic disruptors)
- Next to productivity and isotacticity, internal donors co-define comonomer incorporation, molecular weight control and product range

Step-wise ZN iPP catalyst construction and $TiCl_4$ binding energies for mono- and bidentate internal donors from the ZN-Ti project

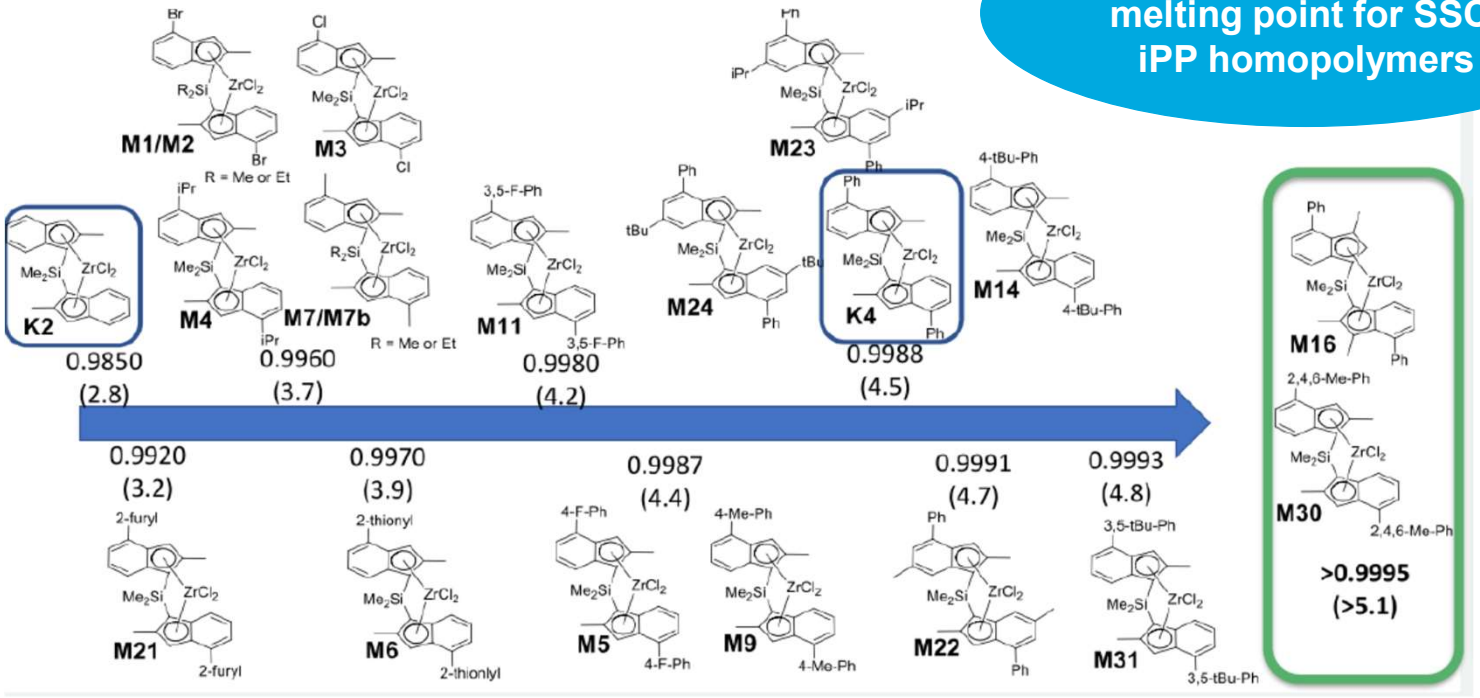




The history: Achievements in DPI projects

Optimizing SSC systems

Maximising stiffness & melting point for SSC-iPP homopolymers



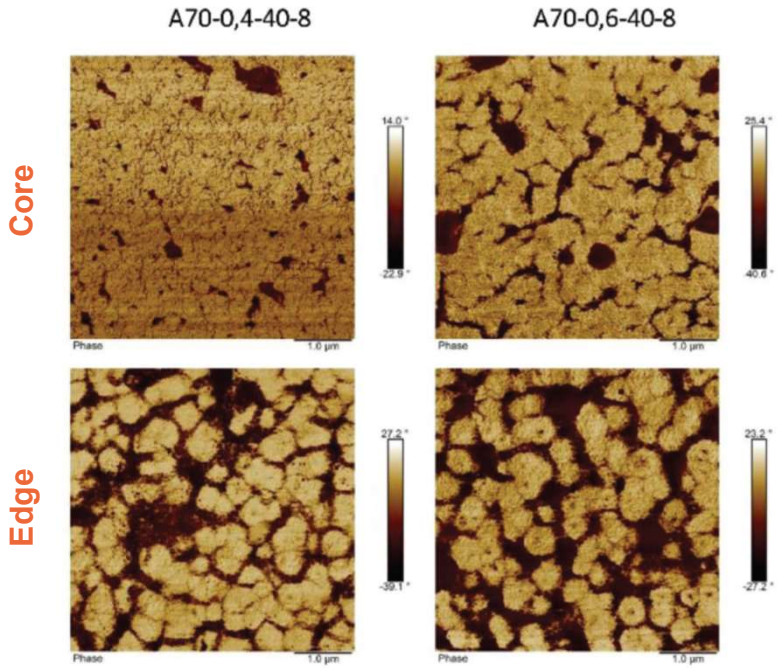
Stereoselectivity trend for SSC-iPP complexes from the MET-QSAR project

The history: Achievements in DPI projects

High performance copolymers

- Within just two projects, HETCOPRO & HIPSTER, massive progress was made in understanding the polymerization process for high-impact polypropylene copolymers
- These materials are at the top of reactor-based performance materials and essentially enable many applications, but are also very important in mechanical recycling
- Interaction between catalyst and process for allowing a certain performance is more complex here than for other polymers
- Specific learnings regarding pre-polymerization and AFM analysis of copolymer powders were especially valuable

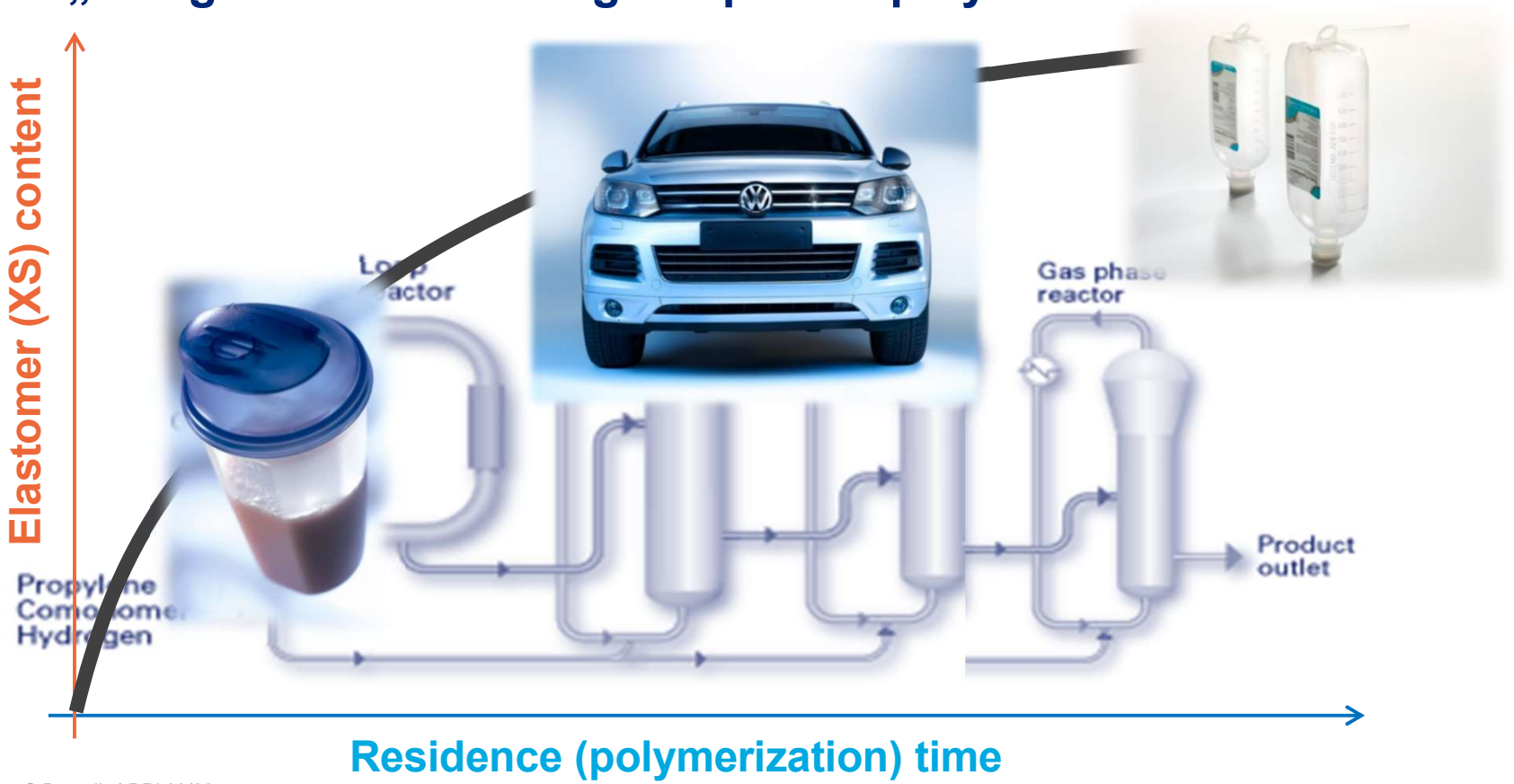
Intra-particle heterogeneity by AFM
Project HIPSTER



C2(XS) by NMR: 38 mol-% 52 mol-%

The history: Achievements in DPI projects

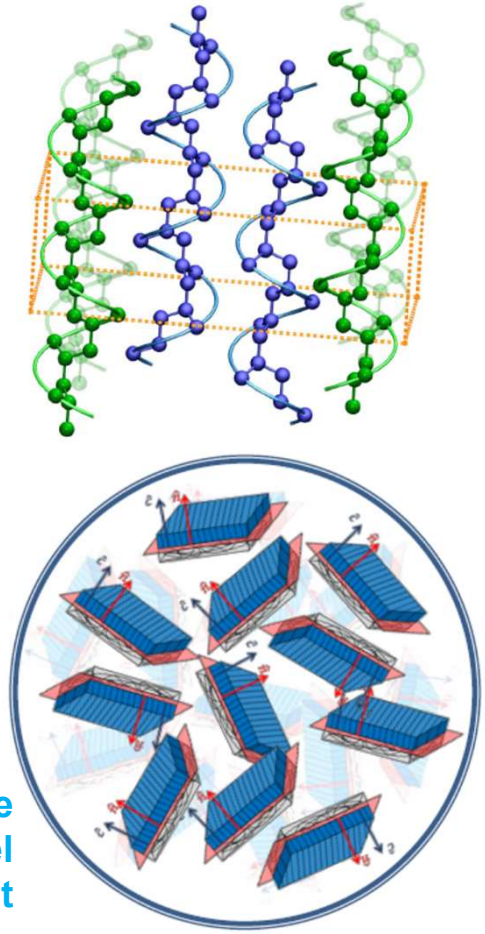
The „design window“ for high-impact copolymers



The history: Achievements in DPI projects

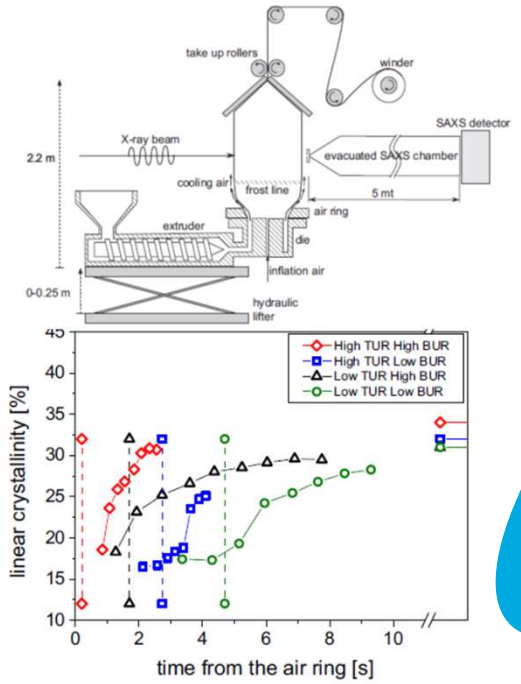
Processing-induced structure formation

- Projects like ISX, orientXpress and OpCaFE have changed our view on processing-related structure formation for polypropylene and polyethylene
- Characterization and modelling work at TU Eindhoven, but also the unique possibilities of the European Synchrotron Radiation Facility (ESRF) in Grenoble, have been elementary for that progress
- Industrial input came via polymer design aspects (chain structure & nucleation) and processing targets
- The work continues with multiple partners, for example in the PERMANENT project on biaxially oriented PE



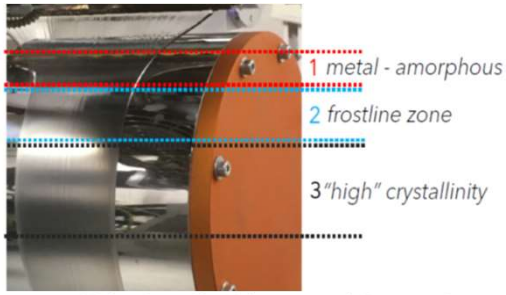
iPP α-crystal lattice and aggregate inclusion model from the orientXpress project

Understanding polymer crystallization and its consequences

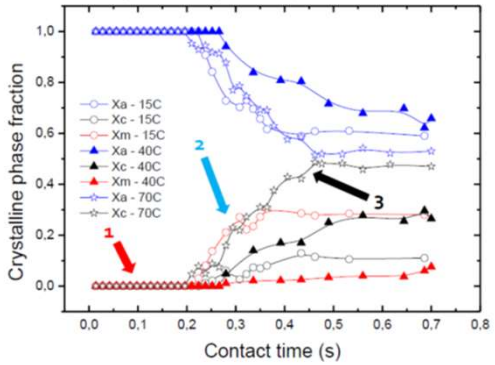


LLDPE blown film – Project ISX
Time to frost line at different take-up- and blow-up-ratios (TUR / BUR)

Online WAXS/SAXS analysis for processes << 1 second



iPP-high-iso [high line speed 5mt/min]



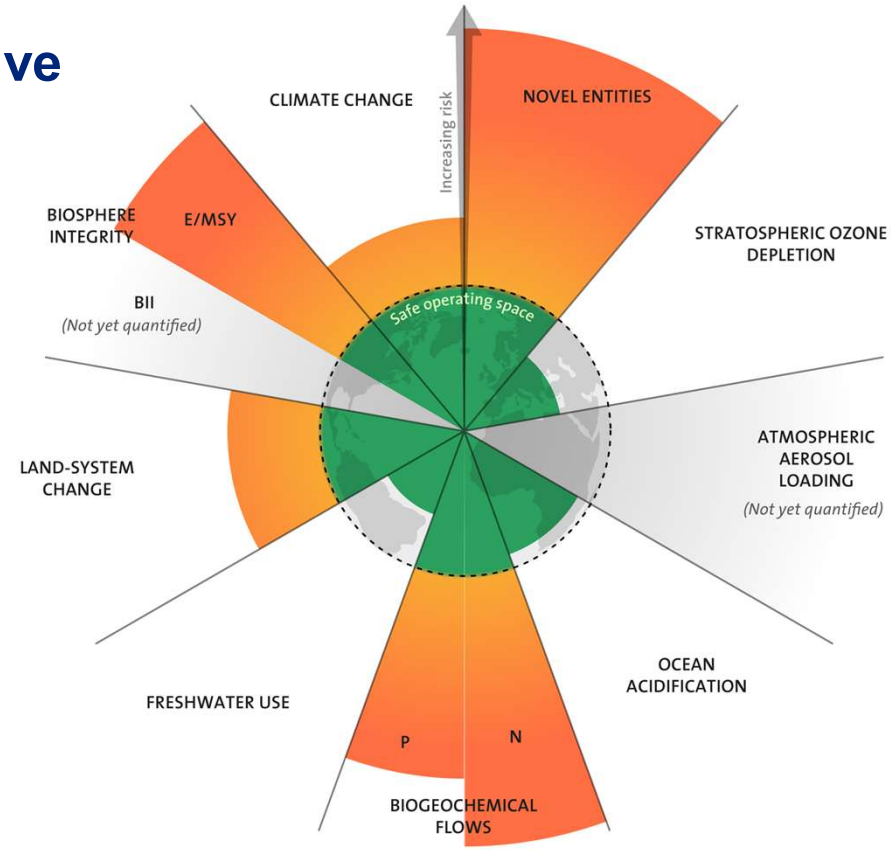
PP cast film – Project OpCaFE
Time to final crystallinity for α- and mesomorphic crystal phase

The present: Moving towards sustainability and circularity

Planetary boundaries in perspective

- The presently dominant linearity of economical and industrial processes is exceeding the planetary boundaries in multiple ways
- While polymers have a lower carbon footprint than other materials, they are largely based on non-renewable ressources
- Even in the EU only ~ 30% of plastics are recycled, still ~ 25% landfilled*
- A system change including design, production and end-of-life strategies is required (not just for packaging)
- Carbon-neutral production cannot rely on bio-based renewables**

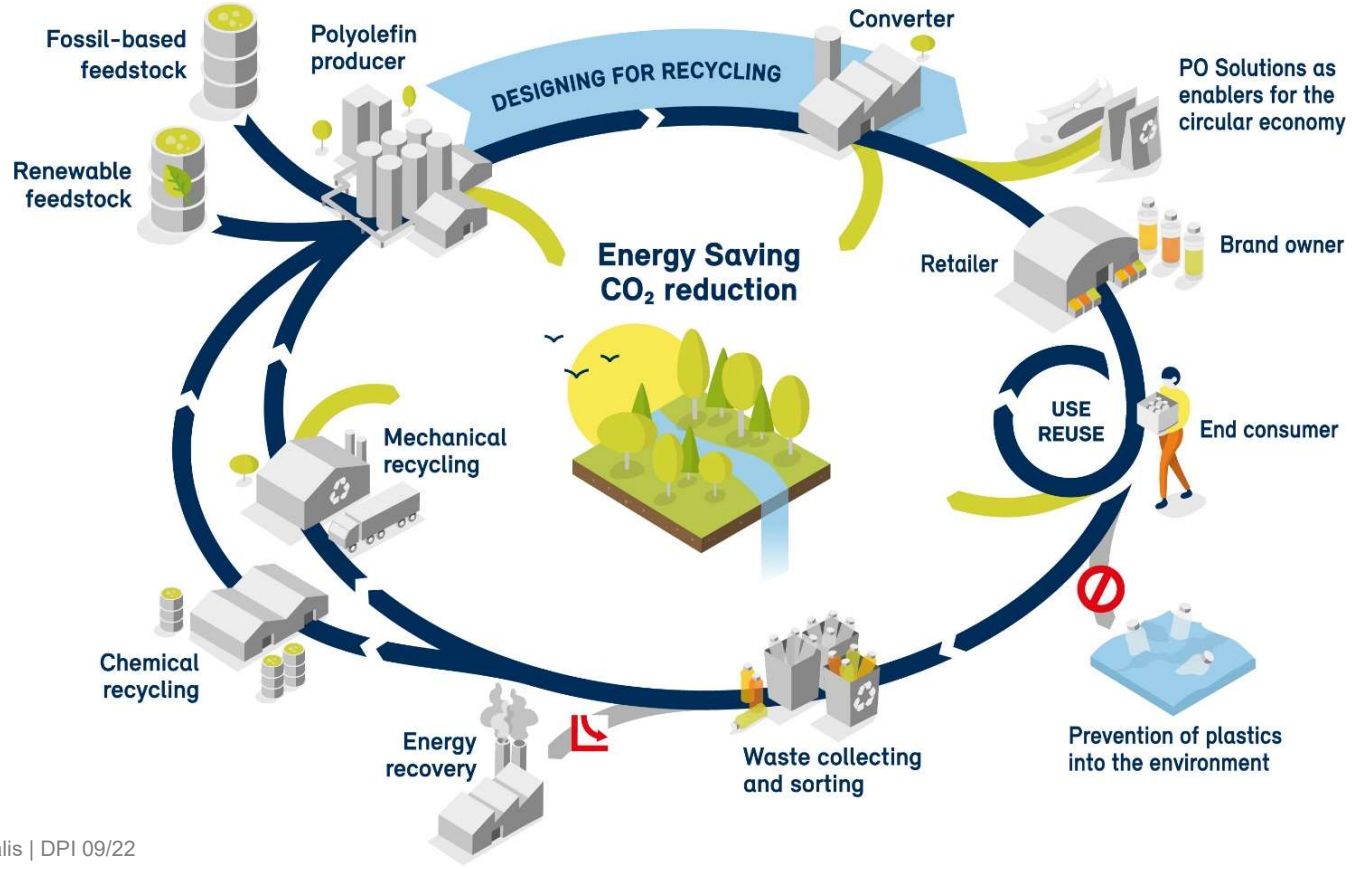
** Figures from 2018 (Conversio)*
*** 100% wood-based energy production would deplete Europe's forests in 10 years*



Azote for Stockholm Resilience Centre, based on analysis in Wang-Erlandsson et al 2022

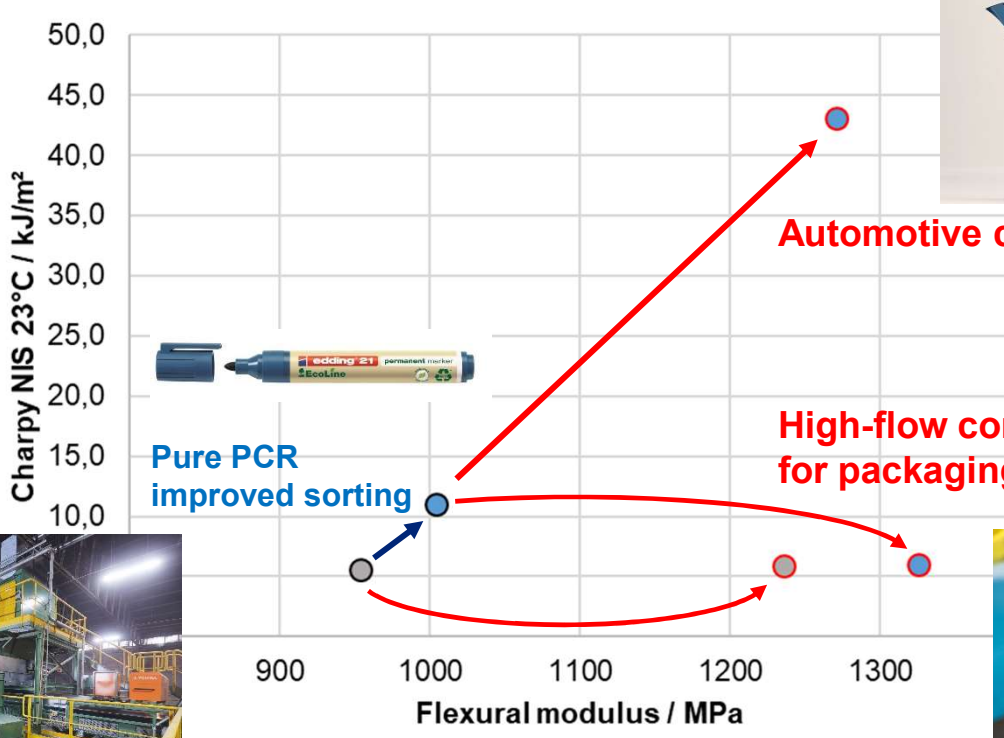
The present: Moving towards sustainability and circularity

Multiple paths to circularity – The Borcycle™ portfolio



The present: Moving towards sustainability and circularity

The science of upcycling



The future: Addressing challenges from society and environment

Nutrition, energy and health for a growing population

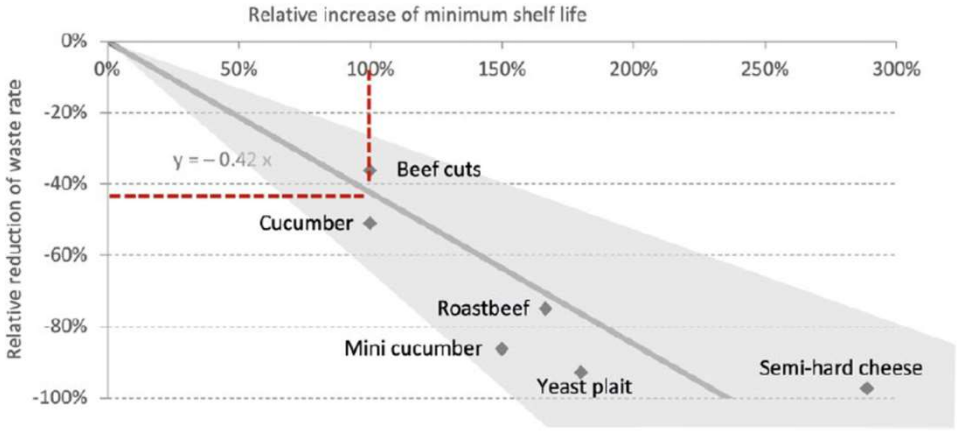
Polyolefins can contribute positively in all of these areas:

- **Nutrition**: Combatting food waste with better packaging, Sustainable irrigation ad growth assistance systems, Using food waste as 2nd generation raw material for monomer production, …
- **Energy**: Essential elements for solar and wind power electricity generation, Advanced thermal insulation systems, Low-loss electricity transport insulation (HV-DC), E-mobility components, …
- **Health:** Plasticiser-free pouch and tube systems, Sterile diagnosis systems, Recyclable packaging concepts, Antiviral face masks, …

The future: Addressing challenges from society and environment

Combatting food waste with better packaging

- 1.3 billion tons of edible food are wasted, accounting for 8-10 % of GHG emissions worldwide
- Limited storability is one of the major reasons for waste (but also for food-related diseases)
- Polymer-based packaging is indispensable in many cases



Shelf lifetime increase and waste reduction potential of adapted modified atmosphere packaging (MAP) for different foodstuff

Austrian Research Promotion Agency (FFG, 2020) – Food Packaging Sustainability, based on the project "STOP waste – SAVE food“

The future: Addressing challenges from society and environment

Zero waste strategies including polymers

- Waste is just badly placed resources (not recycled properly)
- Polymers are not alone in waste generation, but plastic waste is receiving more attention
- The „Microplastics“ issue may appear inflated, but it‘s there to stay
- Like phthalates, waste handling and the dispersion of primary and secondary microplastics requires our attention
- Industry must act – but academia should support by suggesting action

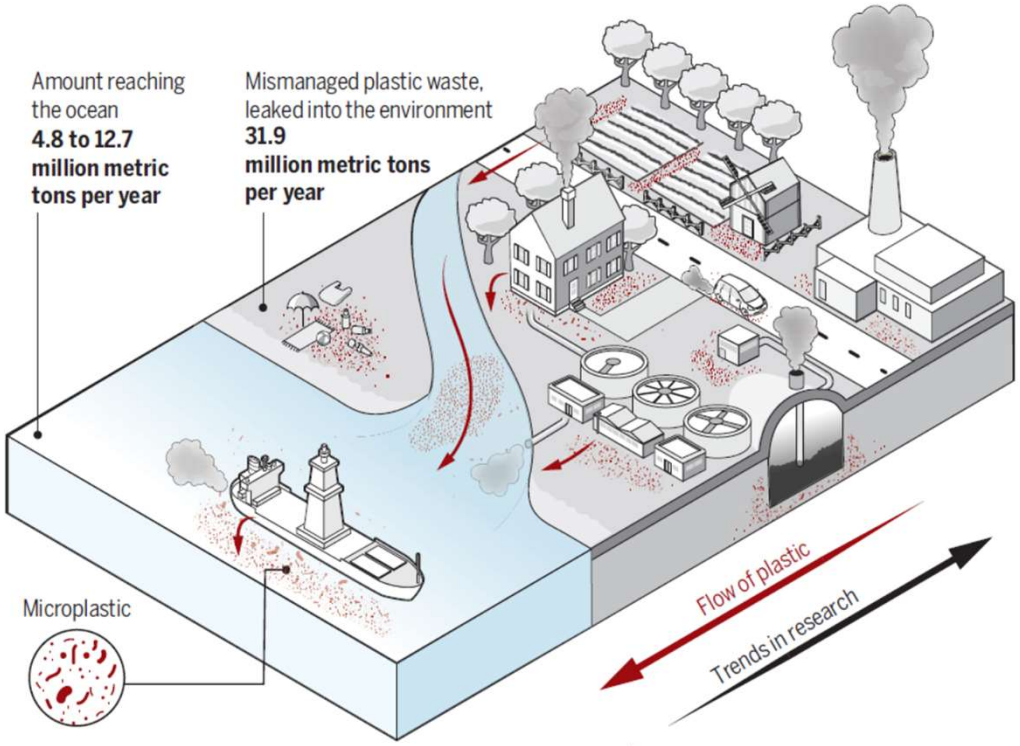


Image source: Rochman et al, Science 2018

Circular Economy
no waste

STOP
WWW.STOPOCEANPLASTICS.COM
AN INITIATIVE CO-FOUNDED BY BOREALIS AND SYSTEMIQ

We aim to provide **450,000** Indonesians living in the cities of Muncar, Pasuruan and Jembrana, with collection and sustainable waste treatment for over **80,000 tons of ocean bound waste** (~10% plastics) by 2025

Strategic partners

BOREALIS Keep Discovering · SYSTEMIQ · Norwegian Embassy · NOVA Chemicals · Nestlé · ALLIANCE TO END PLASTIC WASTE · Borouge · SIEGWERK

Supporting and technical partners

SCHWARZ · SW · VEOLIA · hp

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… and many more!

Thank you!

Let’s re-invent!

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