MobilityScience™

DRIVING THE FUTURE OF SUSTAINABLE MOBILITY:

TPO circularity

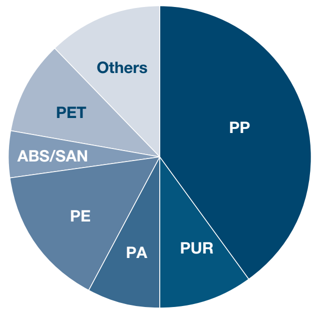
The need

To address today's climate and plastic waste crises, we need to make the plastics used in vehicles more sustainable.

This drive for circular, low-carbon automotive plastics is reinforced by ambitious targets set by OEMs, including the amount of recycled content that cars must contain.

This need is especially relevant for **polypropylene (PP)**. Used in a wide range of parts – from bumpers, frames and fenders to skins, trims and door and instrument panels – PP is the plastic that contributes most to the weight of every type of vehicle (see chart[1] on the right).

The automotive industry therefore needs to produce PP compounds which are recycled and recyclable, but which – crucially – are also lightweight, meeting the same automotive standards, in terms of safety, performance and aesthetics.



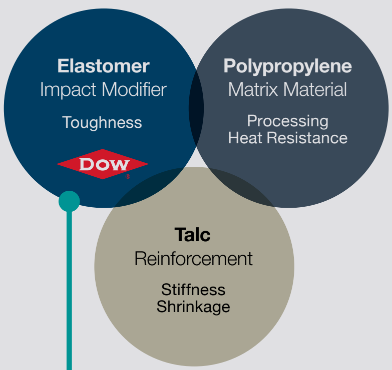
Thermoplastic olefinic elastomer (TPO)

TPO is a blend of a polyolefin, like **polypropylene** (PP), and a conventional rubber– for example, a **polyolefin elastomer** (POE)[2]. TPO is also known as "PP-EPDM", since the rubber component was historically a type of rubber called EPDM (ethylene propylene terpolymer). Today, rigid or hard automotive TPO is typically a blend of mainly **PP, POE and talc.**

Each component plays a part in the final TPO, with PP – as the matrix material – supplying the processing properties and heat resistance. Elastomer, the impact modifier, gives toughness, while talc, the key reinforcement material, brings stiffness and shrinkage properties.

TPO formulation is therefore the science of choosing the proportion and types of all three components to achieve the desired melt flow, flexural modulus, toughness and thermal expansion characteristics.

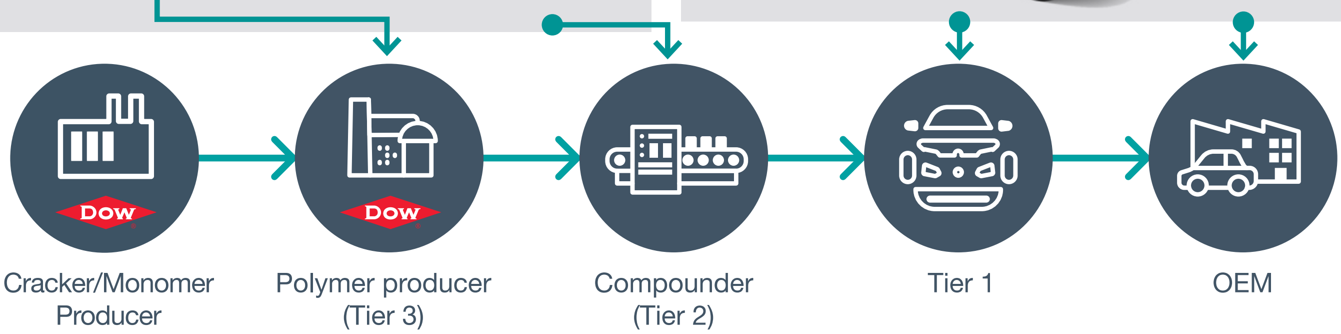
Formulation adjusted to produce a TPO with the required mix of characteristics: lightness, toughness, moldability etc.



- Lightweighting
- Vehicle safety
- Aesthetics
- Faster production

Exterior: Bumpers, frames, fenders

Interior: Door panels, instrument panels, skins, trims

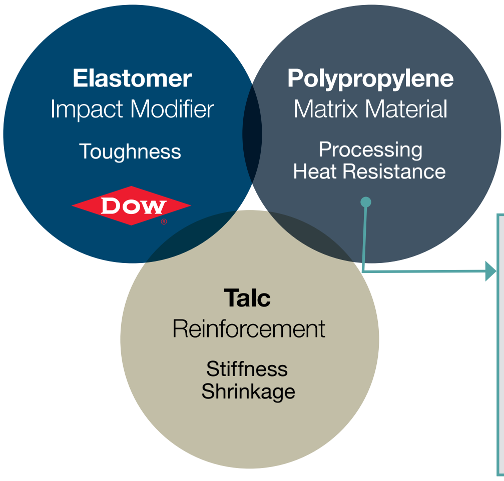


The production of TPO involves players across the automotive plastics value chain – from POE producers like Dow, to the compounders who produce TPO, and Tier 1 suppliers and OEMs who use it to produce vehicle parts.

[1]Garcia-Gutierrez, P., Amadei, A. M., Klenert, D., Nessi, S., Tonini, D., Tosches, D., Ardente, F., & Saveyn, H. (2023, February 17). Environmental and economic assessment of plastic waste recycling. JRC Publications Repository. https://publications.jrc.ec.europa.eu/repository/handle/JRC132067 [2]McKeen, L. W. (2023). Effect of temperature and other factors on plastics and elastomers (4th ed.) - 8. The effects of temperature, humidity, and other factors on the properties of thermoplastic elastomers (p. 559). Elsevier.

Producing TPO using recycled PP: the challenges

To make TPO more circular, we can replace the virgin PP component of its 3-part formula with recycled PP (PCR PP). However, this presents two key challenges:



1

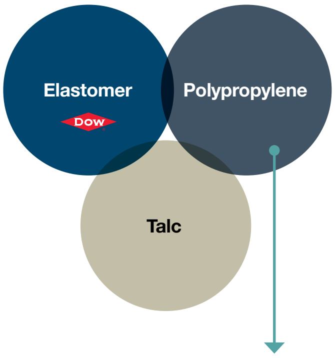
Loss of properties

PCR PP alters the properties of the TPO and makes it much harder to achieve the right balance of characteristics.

2

Cross-polymer contamination

Commercially available PCR PP may contain a mix of different polymers. This impurity makes it much harder to produce TPO with the required properties.



Challenges of recycling polymers into new vehicles:

1

Loss of properties

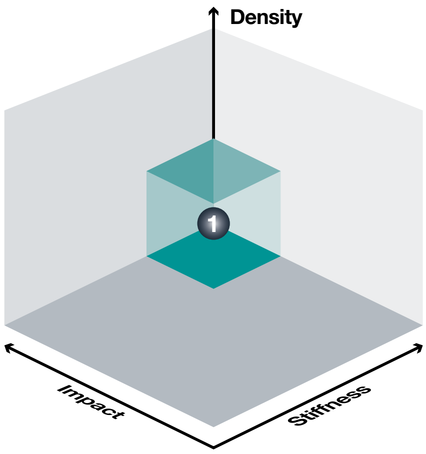
2

Cross-polymer contamination

For TPO to meet the lightweighting and safety performance needs for automotive applications, it needs to have **high impact strength, high stiffness, and low density.**

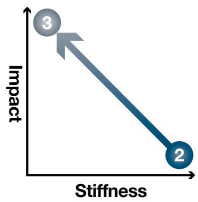
Producing TPO with this combination of properties requires careful formulation, since each of its ingredients (PP, elastomer and talc) offers both benefits and trade-offs.

Replacing virgin PP with recycled PP (PCR PP) upsets this delicate balance, making it difficult to produce TPO with the necessary mix of characteristics:

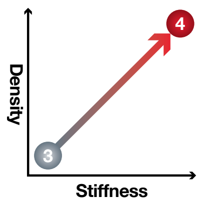


1 Replacing virgin PP with PCR PP reduces impact strength and stiffness.

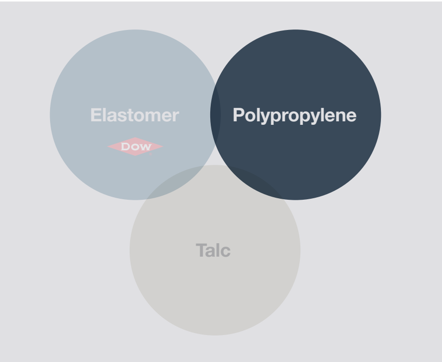
2 Adding elastomer increases impact strength, but reduces stiffness.



3 Adding talc increases stiffness, but reduces the impact strength, and significantly increases density.

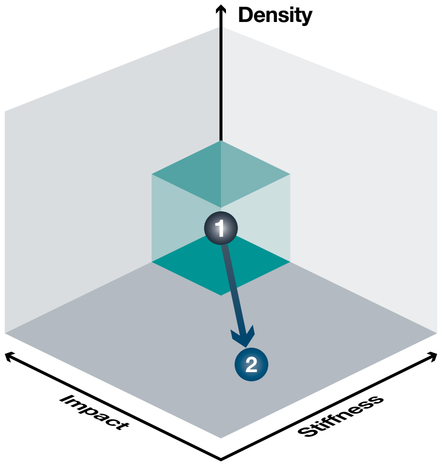


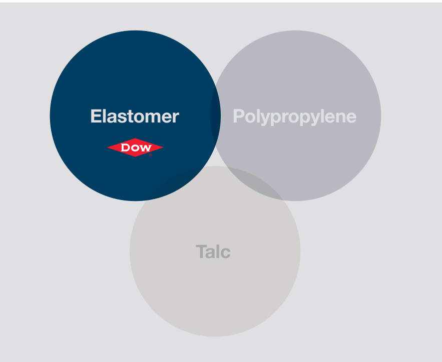
What this challenge looks like in practice



1

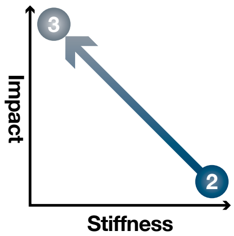
Replacing virgin PP with PCR PP has a negative impact on the TPO's impact resistance and stiffness.

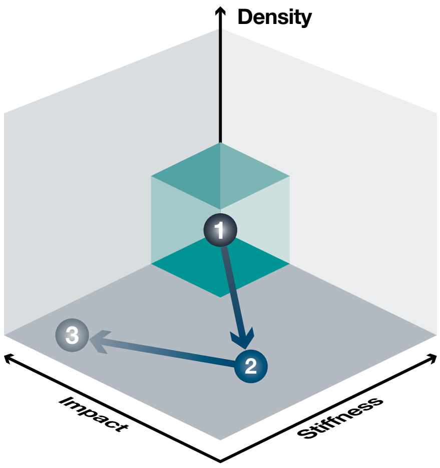


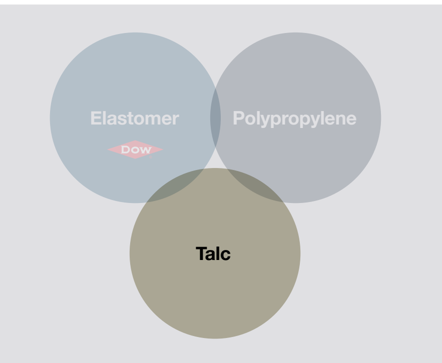


2

The compounder compensates for the loss of impact resistance by adding more elastomer. However, this makes the material less stiff.

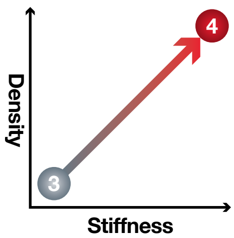


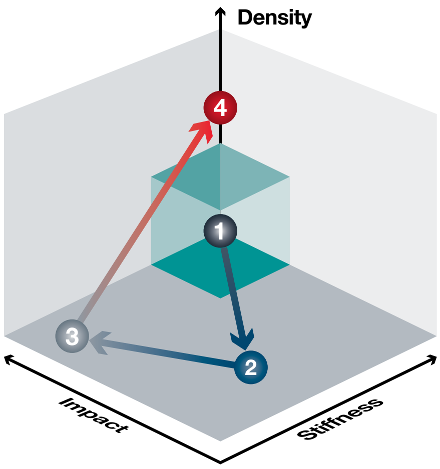




3

Talc is added to restore stiffness. However, as well as reducing the impact resistance, this increases density – making the resulting TPO compound heavier.

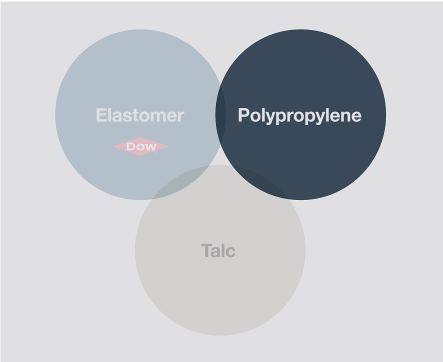




Our solution: ENGAGE™ 11000 Polyolefin Elastomers

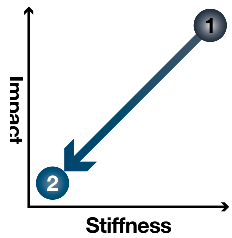
Upgrading to **Dow's ENGAGE™ 11000 Polyolefin Elastomers** means that less elastomer needs to be added to the TPO formulation. This in turn means that less talc (which increases density) is needed to bring back stiffness.

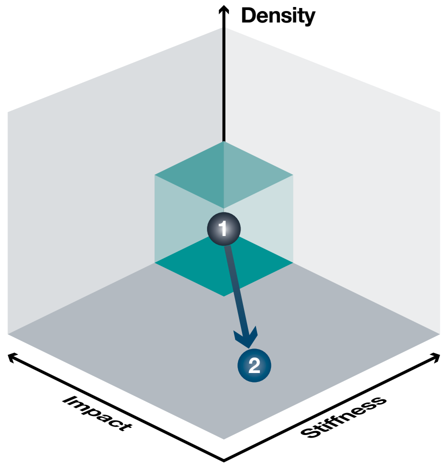
The result is a lightweight TPO that incorporates PCR PP, but which also offers the necessary balance of toughness and stiffness.

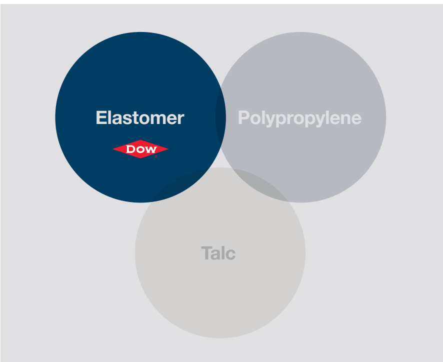


How it works

1 Adding recycled polypropylene reduces both impact resistance and stiffness.

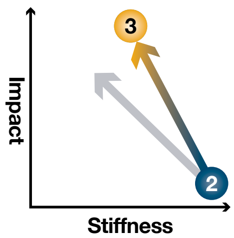


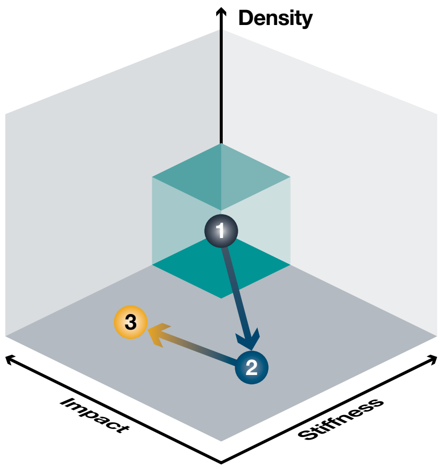


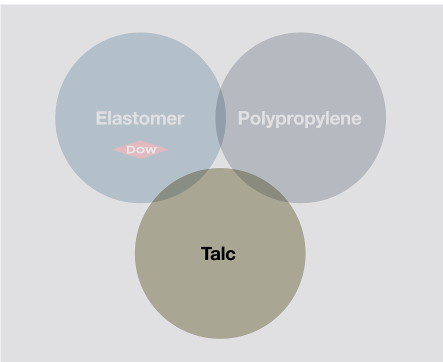


2 Adding ENGAGE™ 11000 Polyolefin Elastomers boosts impact resistance more efficiently than standard elastomers: a smaller amount is needed to achieve the same level of impact resistance.

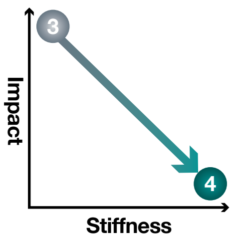
Engage 11000 series polyolefin elastomers

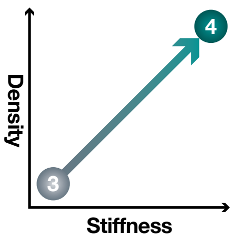


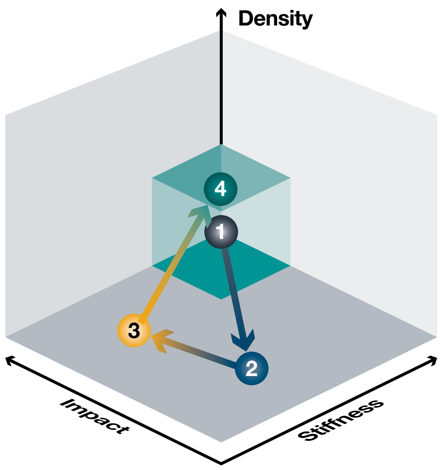




3 Less talc needs to be added to achieve the right stiffness, so the resulting TPO is lightweight, while incorporating PCR and achieving the impact resistance needed.





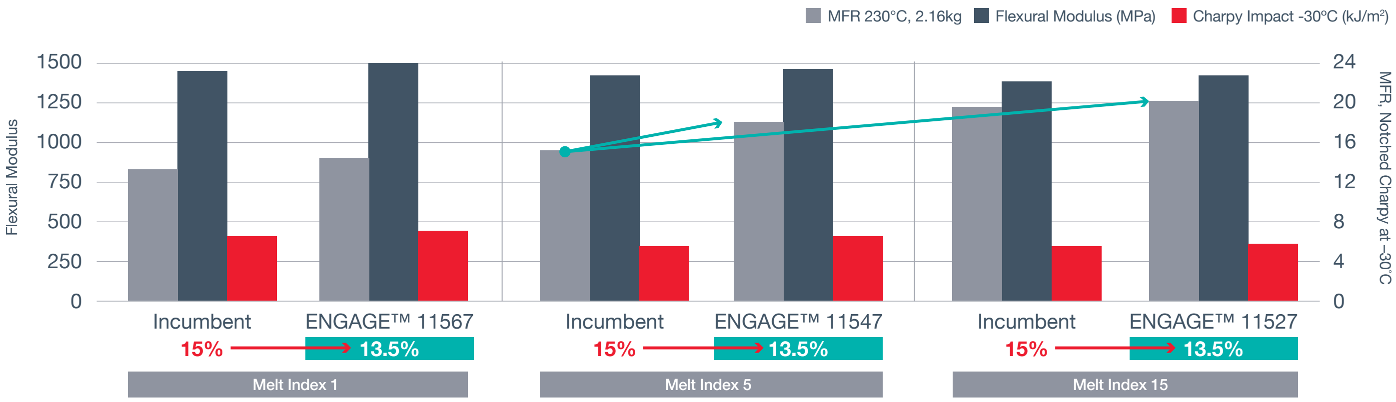


How ENGAGE™ 11000 POEs' impact performance compares versus incumbent POEs

By offering higher impact resistance, ENGAGE™ 11000 Polyolefin Elastomers can be used at 10% lower amounts than incumbent elastomers. This means compounders need less filler to compensate for the decrease in rigidity caused by adding recycled PP.

Reducing the rubber quantity while keeping the impact performance constant

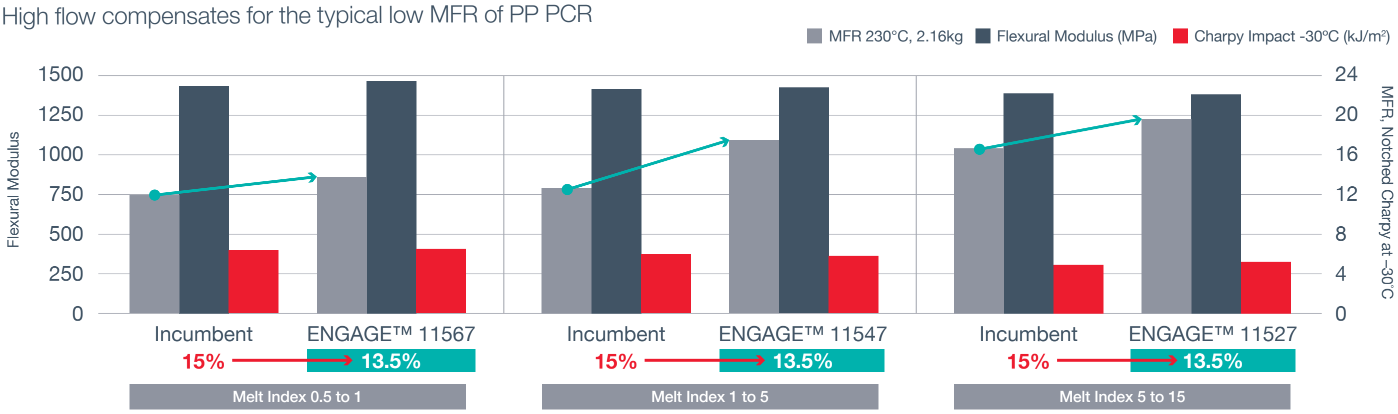
Low glass transition temperature ➔ High rubber efficiency



Recycled PP typically has a low Melt Flow Rate (MFR), which makes compounding and thermoforming TPO more challenging. ENGAGE™ 11000 Polyolefin Elastomers have a **high flow** that helps address this, while also bringing the **high impact resistance** needed for TPO.

Combining high flow with high impact resistance

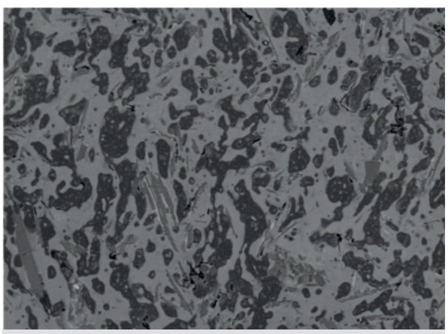
High flow compensates for the typical low MFR of PP PCR



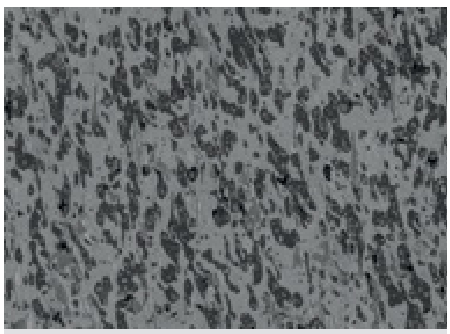
Improved compatibility

ENGAGE™ 11000 Polyolefin Elastomers' high molecular weight at low crystallinity means they have better dispersion than standard elastomers.

A finer morphology with improved rubber dispersion and smaller domain size can be achieved when using a product from the ENGAGE™ 11000 series.

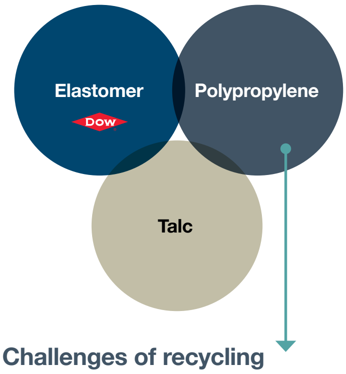


TPO with 15% Incumbent POE



TPO with 13.5% ENGAGE™ 11567

*Typical values, not to be construed as specifications. Users should confirm results by their own tests.



Challenges of recycling polymers into new vehicles:

1

Loss of properties

2

Cross-polymer contamination

Recycled polypropylene (PCR PP) comes from a range of sources – e.g. from household plastic waste like shampoo bottles to recycled automotive parts.

PCR PP can therefore contain a range of different plastics, like polyamide (PA), polyester (PET), ethyl vinyl alcohol (EVOH) from the production of packaging materials, and even recycled glass fiber – all of which contaminate the TPO production process and worsen the mechanical properties of the TPO.

*Typical values, not to be construed as specifications. Users should confirm results by their own tests.

Our solution:

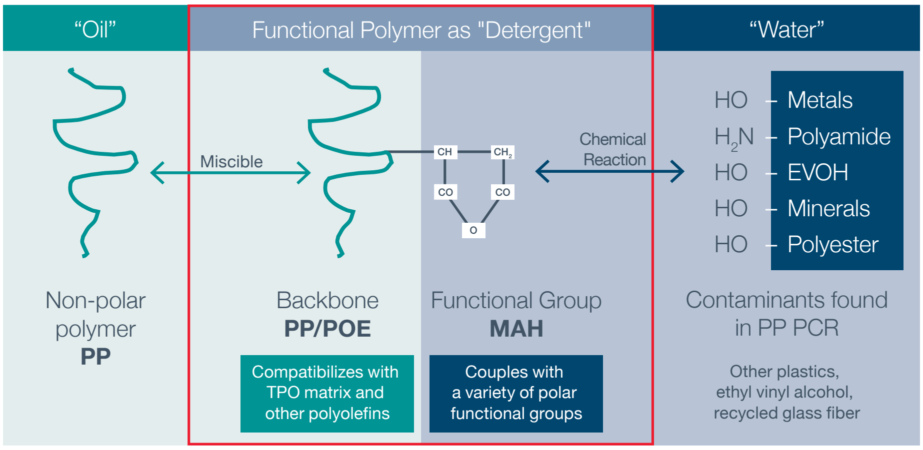
FUSABOND™ Functional Polymers help compounders to produce TPO using recycled PP streams that contain a wide range of contaminants, from other plastics to metal and minerals.

How it works

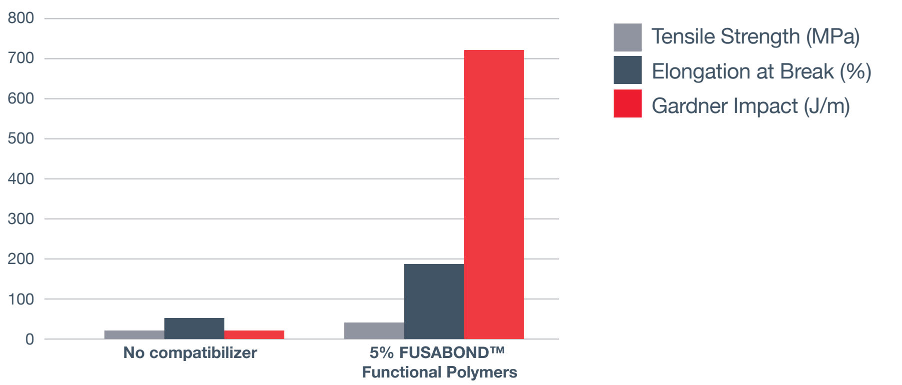
As well as being miscible with PP polymers, FUSABOND™ Functional Polymers also bond with PP PCR contaminants – much in the same way that soap enables oil and water to mix.

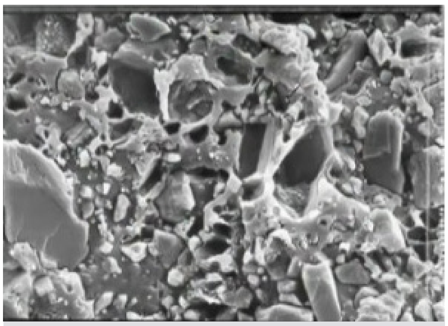
The difference

FUSABOND™ Functional Polymers make it possible to bond PP with diverse contaminants found in the recycled waste streams.

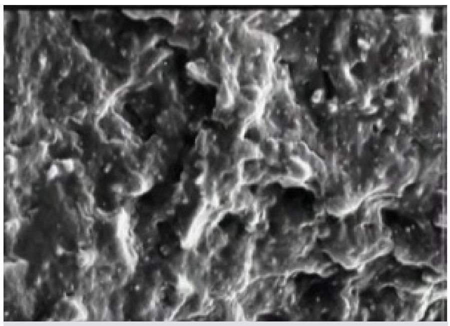


Compatibilizing PP with PA contaminants makes the resulting TPO much tougher





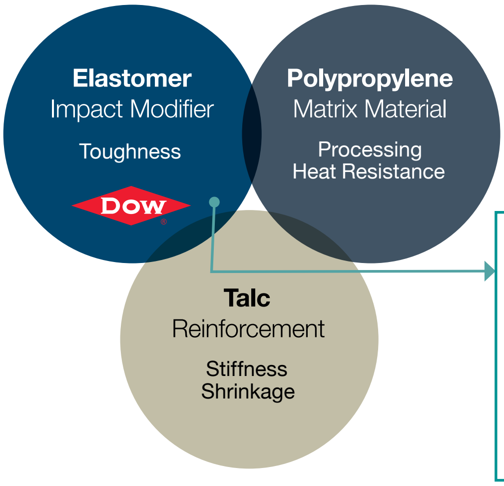
PP + 65 wt% $CaCO_3$
No compatibilizer



PP + 65 wt% $CaCO_3$
4% FUSABOND™ Functional Polymers

Using circular elastomers to increase TPO circularity

To produce TPO with as high a proportion of recycled content as possible, we not only enable our customers to incorporate circular PP, but give them the option of using a recycled or bio-circular elastomer.



ENGAGE™ CIR
A circular elastomer produced using recycled materials – reducing the use of virgin fossil-based resources. This production process is ISCC+ certified on a mass balance basis.

ENGAGE™ REN
A bio-circular elastomer made using other industries' plant residues as raw materials – which significantly reduces its carbon footprint.

Recycled Polymers / Circular Feedstocks

Engage CIR polyolefin elastomers

Circular option

Bio Feedstocks

Engage REN polyolefin elastomers

Bio option

Polyolefin elastomers (POE) made with bio-circular feedstocks produced from residues of other industries, reducing the use of virgin fossil resources

- No food/feed competition
- Certified sustainable forestry/farming
- Plant-based POE resins are ISCC+ certified
- Identical performance to virgin material: **No requalification needed**
- Supporting CO_2 reduction versus fossil fuel-based equivalent

New Vehicles

POE Impact Modifiers for Polypropylene (TPO/PP-EPDM)

Bumpers, frames, fenders, door panels, instrument panels, skins, trims

Image Source: A2MAC1

How mass balance accelerates circularity

ENGAGE™ REN and ENGAGE™ CIR Polyolefin Elastomers are produced using a mass balance model, where different types of material (e.g. circular or fossil-based) use the same infrastructure. A standard in the renewable energy industry, the mass balance approach helps accelerate the switch to sustainable materials.

No need for requalification

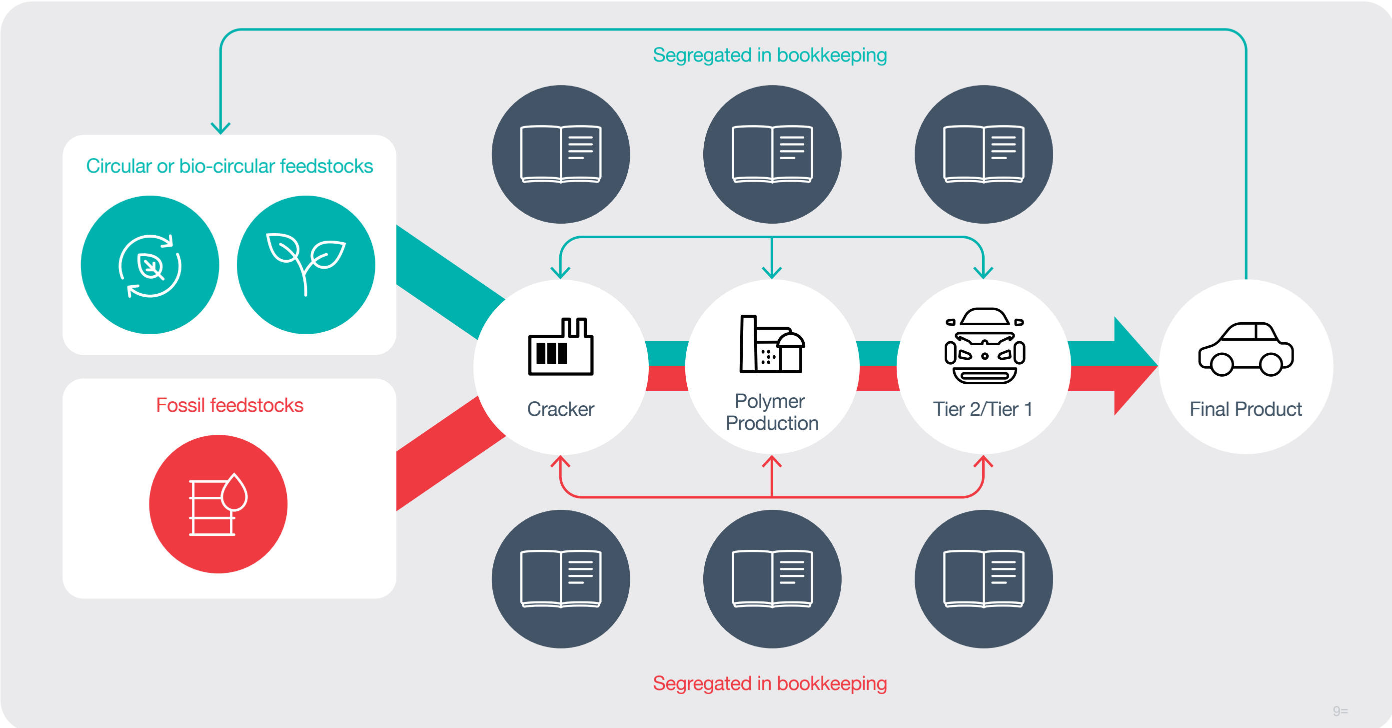
Mass balance helps to enable manufacturers to produce plastics that are more sustainable while offering the same performance as those produced using 100% virgin, fossil-based materials. This means there's no need to requalify these new products.

No need for new infrastructure

Manufacturers can instantly shift to sustainable materials using their existing infrastructure, just as we can switch to renewable energy at home, without building a new grid or energy storage facilities. This saves time, costs, and the need for additional carbon emissions from the construction and maintenance of a parallel production stream.

Traceable recycled content

Every input and output is carefully controlled, monitored, and independently verified at every stage of the supply chain and production process via ISCC+ certification. This supports enabling manufacturers and customers alike to know the amount of recycled content in their products in a credible and transparent way.



Our wider MobilityScience™ sustainability strategy

Innovating for TPO circularity is just one of the ways that we're helping to build a sustainable future that supports resilient, low-carbon mobility.

Innovating across the full spectrum of automotive plastics, and the full range of mobility challenges, we're committed to driving sustainability in three key areas: **climate protection, safer materials,** and **circular economy.**

Dow's circular technologies

Zooming in on circularity from our three sustainability goals, we are investing in innovations and collaborations across the value chain, to help build a circular ecosystem for all types of automotive plastic.

1 Design

We help design for longer life and end-of-life by bringing in-depth experience and innovative materials that make vehicle parts easier to recover, reuse and recycle, while offering properties needed both for production and for performance during the vehicle's life.

Circulibrium

2 Mechanical Recycling

Coupled with our experience in automotive requirements for safety and aesthetics, our technologies support mechanical recycling into new vehicles not just with our PCR offering, but also a wide range of boosters and binders for diverse recyclates.

3 Waste to Intermediates Recycling

We give a second life to hard-to-recycle materials like thermosets, by converting them back into monomers, significantly reducing overall product carbon footprint and our reliance on fossil feedstocks.

4 Waste to Feedstock Recycling

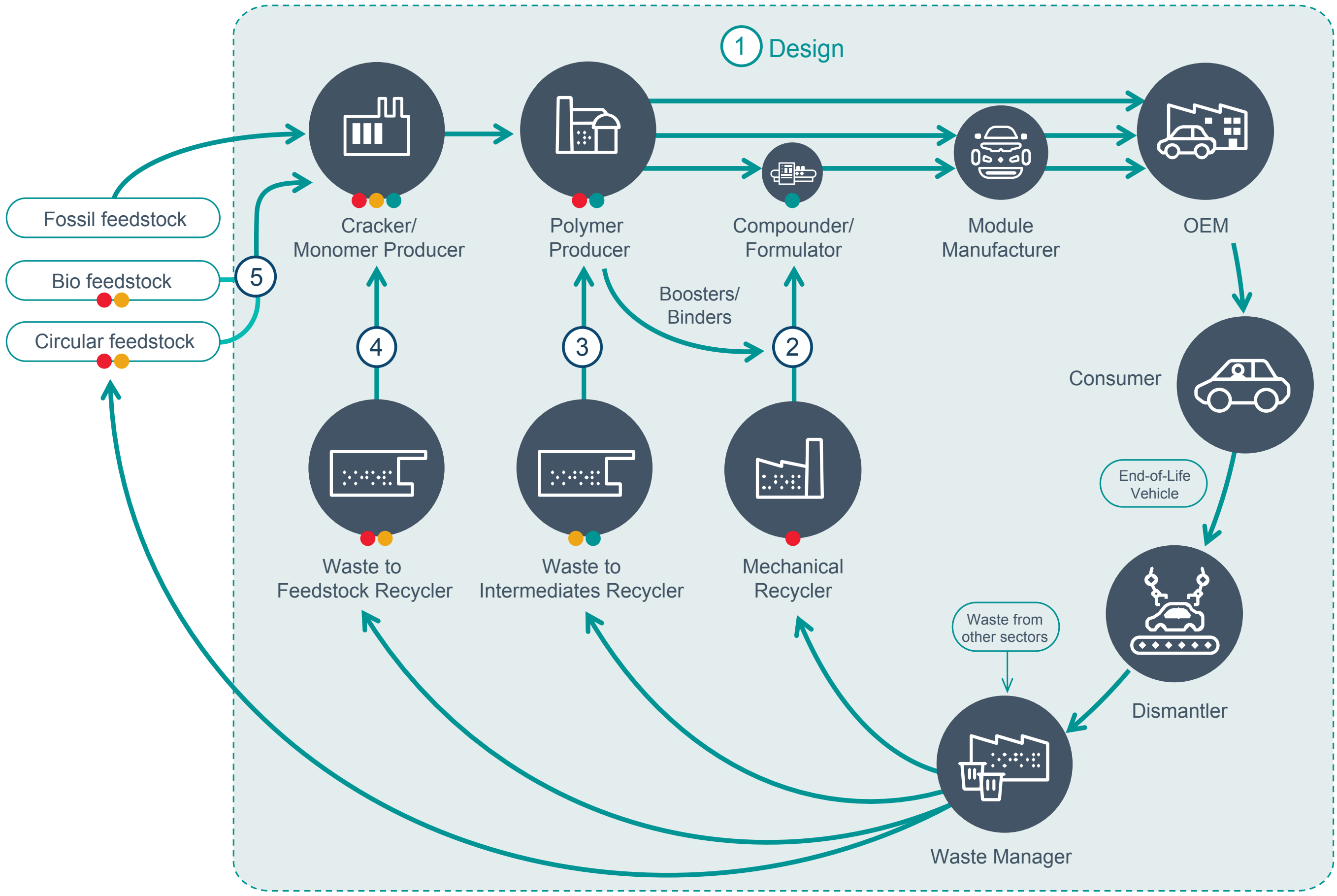
We contribute to the circularity of even harder to recycle streams by converting plastics back into feedstock, producing new materials with identical performance and reducing the plastic waste going into landfilling or incineration.

Renuva

5 Bio or Circular Feedstocks

We help the industry realize further decarbonization and circularity with our products made from bio-circular and circular feedstocks. These come from non-food/feed-compete sources and have virgin-identical properties.

Renuva Ecolibrium



Technologies for Automotive Circularity from Dow & Dow Partners		
Polyolefins	Boosters for PP (TPO), PA, PET, PBT, ABS, PC & PC Blends	Exterior (bumpers, etc.), Interior (panels, skins, airbag covers, etc.), Under-the-Hood
	EPDM	Weatherseal, Under-the-Hood, Tires
	PE	Under-the-Hood (air ducts, windshield water tanks)
Polyurethanes	PU (PUR)	Interior (seats, skins, etc.), Acoustics, Battery Systems, Tires
Silicones	Silicone Composites, VMQ	Battery Systems, Interior (skins, airbags), Power Electronics/ADAS, Under-the-Hood, Cables & Connectors, Lighting Systems, Tires

2 Mechanical Recycling

Dow's innovations in TPO circularity is part of a wider portfolio of technologies supporting the incorporation of PCR into the diverse plastics within a vehicle.

Recycled Polymers | **Mechanical Recycling** | **New Vehicles**

Polypropylene (TPO/PP-EPDM)

Bumpers, frames, fenders, door panels, instrument panels, skins, trims

Polyamide (PA) / Nylon

Charge air coolers, engine covers, style covers, electrical connectors, oil pans, hubcaps, opening control supports, cooling fans, etc.

Polyester (PET, PBT)

Carpet, fabric, insulation, electrical connectors, fastener covers, etc.

Acrylonitrile Butadiene Styrene (ABS)

Grille, consoles, panels and trims, housing and supports, etc.

Polycarbonate & Polycarbonate Blends (PC, PC-ABS, PC-PBT)

Instrument panel parts and interior trims

Challenges of recycling polymers into new vehicles

1

Loss of properties

Mechanical recycling alters the properties of the plastic, thus creating the need for **impact/ rheology modification.**

2

Cross-polymer contamination

Commercially available PCR may contain a mix of different polymers. This impurity would require **compatibilization** to produce new plastic compounds.

Engage™ 11000 series polyolefin elastomers

Fusabond™ functional polymers

Surlyn™ ionomers

Elvaloy™ copolymers for alloys

Elvaloy™ AC acrylate copolymers

	Impact Modifier	Compati-bilizer	Coupling Agent
Polypropylene (TPO/ PP-EPDM)	ENGAGE™	FUSABOND™	FUSABOND™
Polyamide (PA) / Nylon	FUSABOND™ SURLYN™	FUSABOND™ RETAIN™	FUSABOND™
Polyester (PET, PBT)	ELVALOY™ ELVALOY™ AC SURLYN™	ELVALOY™ ELVALOY™ AC	ELVALOY™ ELVALOY™ AC
Acrylonitrile Butadiene Styrene (ABS)	ELVALOY™ AC	ELVALOY™ AC	
Polycarbonate (PC) & PC Blends (PC-ABS, PC-PBT)	ELVALOY™ ELVALOY™ AC	ELVALOY™ ELVALOY™ AC	FUSABOND™

Binder	
Polyurethane (PU)	VORAMER™

Images: dow_57804181767, dow_68946109356, dow_75633951220

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