Celanese

Santoprene® TPV

The sustainable elastomeric material solution

Contact Oliver Kloth (oliver.kloth@celanese.com)

December 2022

Sustainable engineered materials solutions

Celanese

✓ Available with Santoprene® TPV ECO-R

Available with POM, PBT, TPC and potential TPV fit

Under evaluation for POM

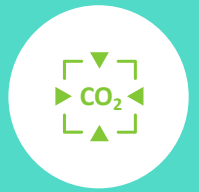
Available with Clarifoil® Cellulosic Film

Recycled content ECO-R

Products that contain post-industrial or post-consumer recycled materials while still maintaining consistency and quality

Bio-mass balance ECO-B

Products derived from biological feedstock like forestry and agricultural waste materials or renewable domestic waste using a mass balance approach



Carbon capture ECO-CC

Products based on CO_2 emissions converted into methanol as building block for downstream products

End-of-life

Products that are biodegradable and compatible with waste streams that go into composting

Santoprene® thermoplastic vulcanizate (TPV)

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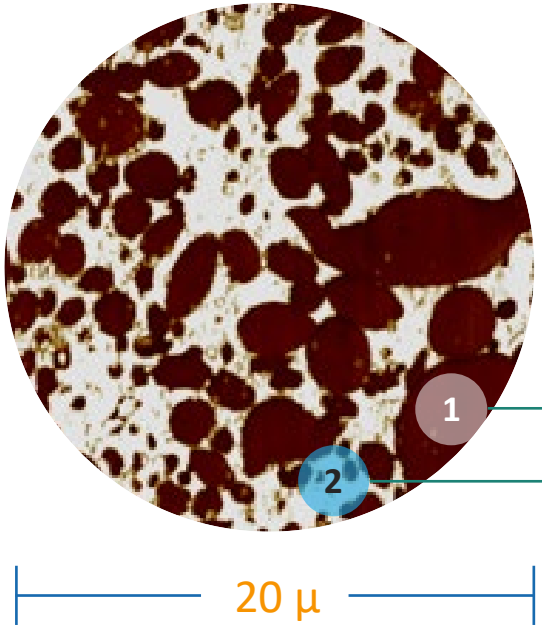
AFM micrograph



Rubber (cross-linked EPDM)

Thermoplastic (polypropylene)

Performs like rubber, processes and recycles easily like plastic

- **Broad range of Shore hardness 35A to 50D**
- **Temperature resistance -60°C to 135°C**

Sustainability attributes Santoprene® TPV

Santoprene® TPV

- Helps achieve **circular economy**
- Enables industry to **lower CO_2 emissions**

Post-consumer recycle (PCR)

- Santoprene® TPV ECO-R that incorporates **post-consumer recycle**
- **Maintaining quality** and lot-to-lot consistency

Easy to recycle

- Santoprene® TPV parts are easier to recycle than thermoset rubber
- High level of regrind addition possible with **very strong property retention**
- In-house recycling (regrind) with **~30% less scrap** vs EPDM

Lower CO_2 emissions

- Estimated **59% lower carbon footprint** vs EPDM in extruded seals
- Rubber-like performance with **up to 30% less material density**
- Weight reduction potential to **reduce fuel consumption** or increase EV range
- CO_2 footprint calculation values available on request

"Calculated carbon footprint results are based predominately on industry average carbon footprint values and may not contain Celanese primary data" and "Values provided herein are general estimates based on approximate reference values for specific materials and processes. Values are intended for use as part of high-level screening only and should not be construed as exact measurements of CO_2 or other values for specific products. The contents of this document may be updated or modified by Celanese at any time".

New Santoprene® TPV ECO-R platform

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Contains a minimum of 15% and 25% post-consumer recycle (PCR) content*

Santoprene® TPV quality consistency

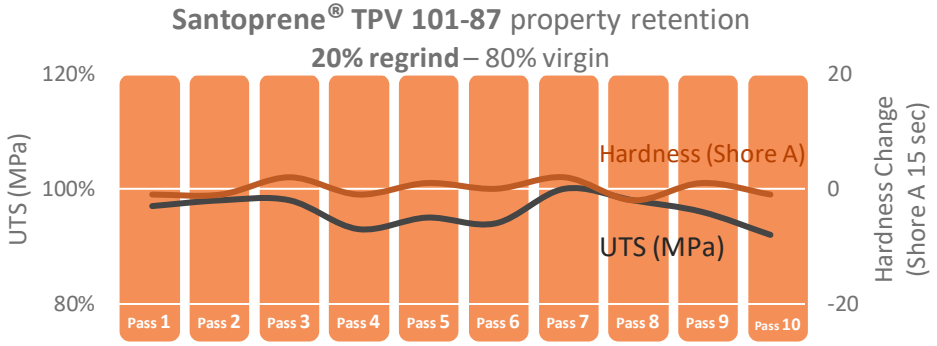
Global availability

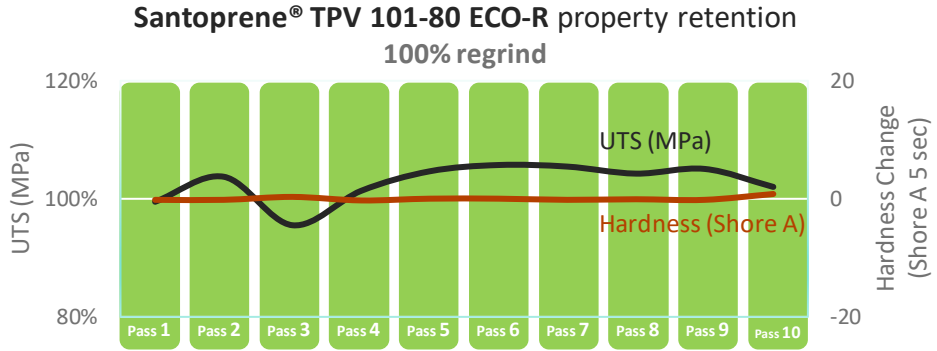
Suitable for injection molding and extrusion

Physical property	Test method* based on	Units	Santoprene® TPV 101-80 ECO-R	Santoprene® TPV 101-87 ECO-R
PCR content	-	%	Minimum 15%	Minimum 25%
Color			black	black
Specific Gravity	ASTM D792	g/cm³	0.98	0.96
Hardness (15s)	ISO 868	Shore A	80	92
LCR App Viscosity 204 °C	TPE-0200	Pa.s @ 200s^{-1}	331	317
	TPE-0200	Pa.s @ 1200s^{-1}	89	90
Tensile stress at 100% elongation	ASTM D412	MPa	3.7	6.7
Tensile strength at break	ASTM D412	MPa	7.6	8.6
Elongation at break	ASTM D412	%	495	520
Compression set, RT 22h, 25% strain	ASTM D395B	%	30	38
Compression set, 125°C 70h, 25% strain	ASTM D395B	%	56	56

* Certification available for Santoprene® TPV 101-80 ECO-R with minimum 15% PCR content

Santoprene® TPV: Easier to recycle than thermoset rubber





- Easy recycling as with other thermoplastics
- Strong property retention after several rounds of molding & regrinding
- Enables waste reduction via in-house recycling
- Drying of regrind is recommended

Santoprene® TPV 101-87: Lot# PDA3019 test conducted with 20% regrind material, 80% virgin; blow molded and regrinded, properties measured on injection molded plaque

Santoprene® TPV 101-80 ECO-R: Lot# PXG5958 test conducted with 100% regrind material; properties measured on injection molded plaque

Santoprene® TPV vs EPDM part production – CO_2 footprint

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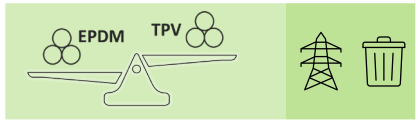
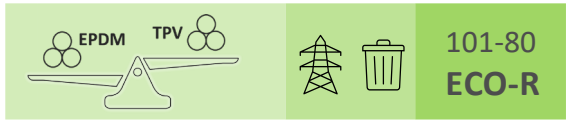
Calculated CO_2 footprint reduction - Santoprene® TPV vs EPDM

Santoprene® TPV vs EPDM
density adjusted
incl. curing energy & scrap



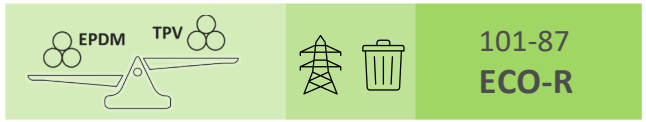
Up to **38%**

Santoprene® TPV
101-80 ECO-R vs EPDM
density adjusted
incl. curing energy & scrap



Up to **52%**

Santoprene® TPV
101-87 ECO-R vs EPDM
density adjusted
incl. curing energy & scrap



Up to **59%**

- Up to 38% CO_2 footprint reduction potential vs avg EPDM profile due to
  - Lower density (kg CO_2 eq/liter)
  - Lower processing energy (no curing needed)
  - Lower scrap rate due to regrind option
- Up to 52% CO_2 footprint reduction potential with Santoprene® TPV 101-80 ECO-R (15% PCR)
- Up to 59% CO_2 footprint reduction potential with Santoprene® TPV 101-87 ECO-R (25% PCR)

Additional in-use phase potential for downstream footprint benefits via vehicle light-weighting

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ECO-Design with Santoprene® TPV

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- ECO-Design considers environmental aspects of the entire product development process
- Create products with lowest possible environmental impact

- **Reduce:** raw materials, weight, production steps, parts, waste, energy

From: Multiple parts and assembly

To: One part (no assembly)

ECO-Design with Santoprene® TPV

Celanese

- ECO-Design considers environmental aspects of the entire product development process
- Create products with lowest possible environmental impact

- **Reduce:** raw materials, weight, production steps, parts, waste, energy
- **Reuse:** raw materials & waste, energy
- **Repair:** options to disassemble, tutorials and spare parts
- **Recover:** devices, parts, upgradability
- **Dispose:** parts, waste

Santoprene® TPV ECO-R platform

Design freedom with thermoplastic processing

property retention

Proven long-term performance

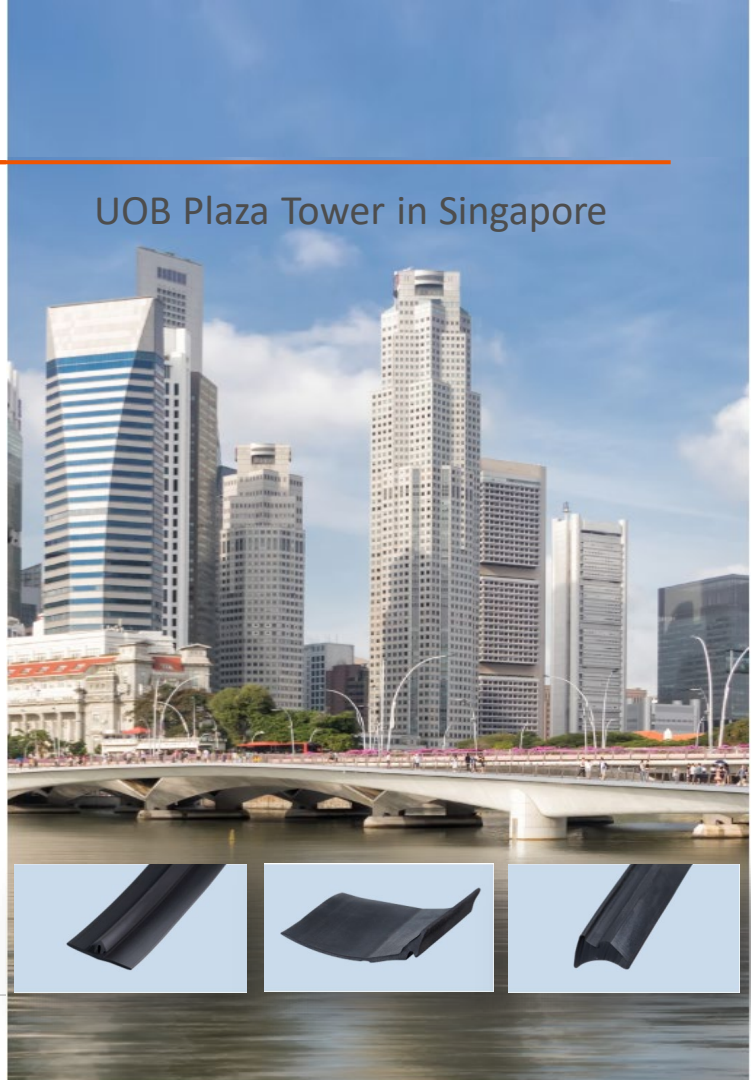
- After 22 service years in facade sealing, Santoprene® TPV profiles were tested vs new profiles for retrofit

Physical property	Test method* based on	Units	Old profile	New 121-67W175
Shore A Hardness	ExxonMobil method	Shore A	57	56
Tensile at 100% elongation	ISO 37, Type 1	MPa	3.0	2.5
Tensile strength at break	ISO 37, Type 1	MPa	7.4	6.8
Elongation at break	ISO 37, Type 1	%	406	504
Compression set 125°C 70h, 25% strain	ExxonMobil method	%	28	** 27

- Strong property retention for reduced maintenance and less replacements
- Option to use Santoprene® TPV ECO-R (PCR)

*, **: More information in backup slide

UOB Plaza Tower in Singapore

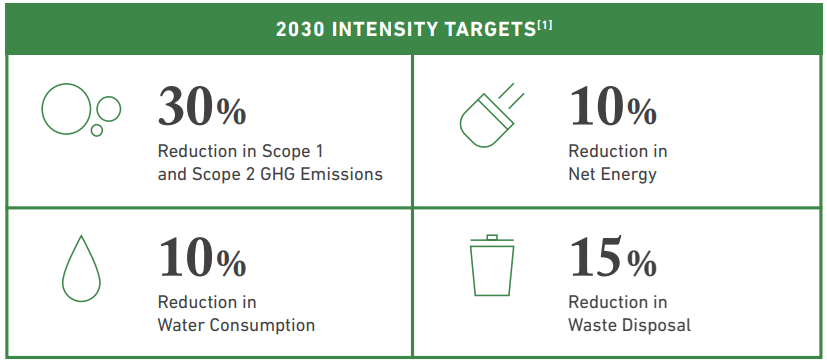


Preserving the environment

Refining our Targets to reduce our impact

Environmental initiatives play a key role in building solutions to support customers' sustainability objectives and improving the sustainability of our existing products:

- We have set 2030 goals to reduce water, waste, energy, and GHG intensity
- Goals are based on the 2021 environmental metrics we are sharing in the Celanese sustainability report, and have taken the added step to have ERM CVS, provide limited assurance of these baseline numbers
- Our intensity-based environmental targets are founded on production for Celanese owned and operated assets to provide increased transparency around the impact of future organic and inorganic growth opportunities through mergers and acquisitions

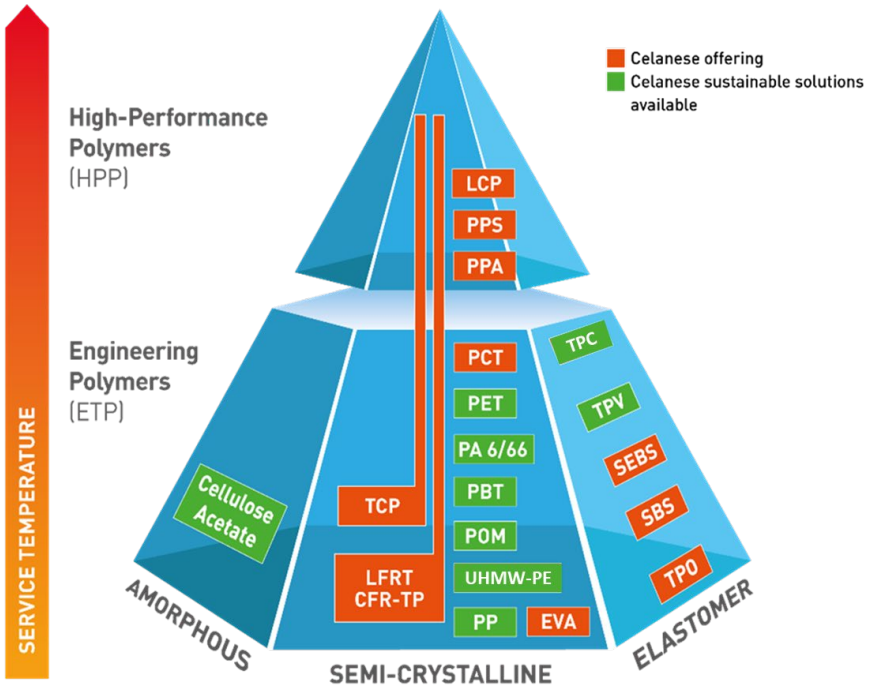


[1] 2021 Baseline

Santoprene® TPV: the sustainable solution for soft materials

- ✓ Santoprene® TPV ECO-R with PCR content
- ✓ Easier to recycle than thermoset rubber
- ✓ Up to 59 % CO_2 footprint reduction potential vs EPDM
- ✓ Supports ECO-design principles
- ✓ Part of broad Celanese material portfolio
- ✓ Collaborating for expanding ECO offering

To learn more, view our sustainability website:
www.celanese.com/corporate-sustainability-strategy



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Santoprene® TPV ECO-R Grades

The sustainable elastomeric material solution

New Santoprene® TPV ECO-R platform

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Santoprene® TPV quality consistency

Global availability

Suitable for injection molding and extrusion

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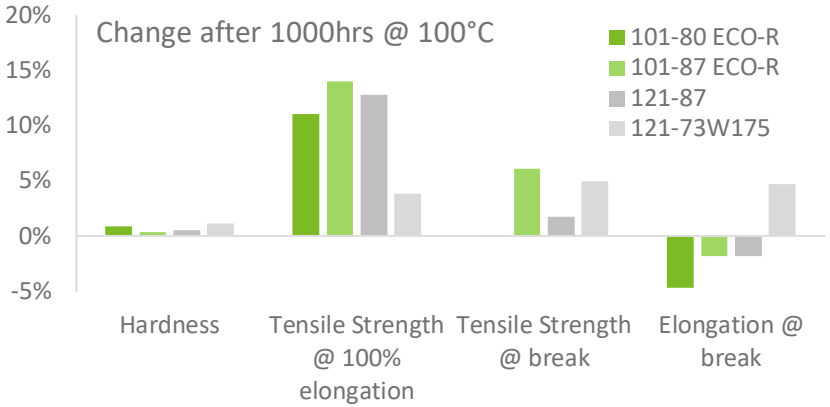
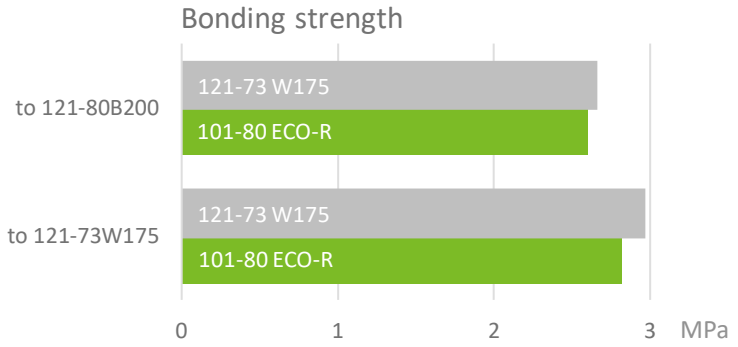
* Certification available for Santoprene® TPV 101-80 ECO-R with minimum 15% PCR content

Similar performance to other Santoprene® TPV grades





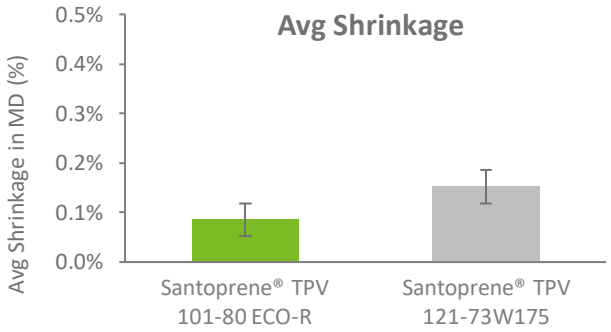
Aging performance

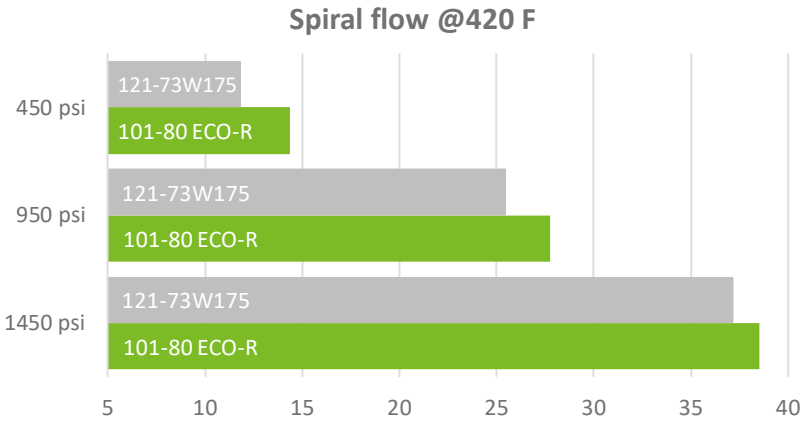
- Santoprene® TPV features good aging performance
- Santoprene® TPV ECO-R aging performance in line with comparable Santoprene® TPV grades

Bonding strength

- Bonding strength is important for co-extrusion, 2k molding or corner moldings in glass run channels
- Santoprene® TPV ECO-R bonding to standard grades and B200 series is in line with comparable Santoprene® TPV grades

Santoprene ® TPV ECO-R demonstrates good processability





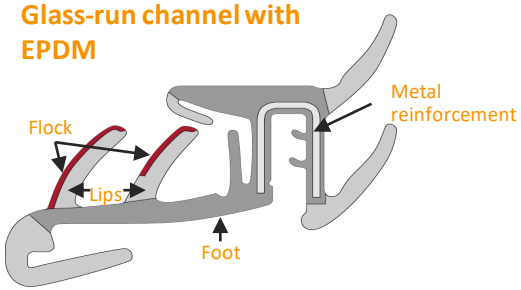
Shrinkage

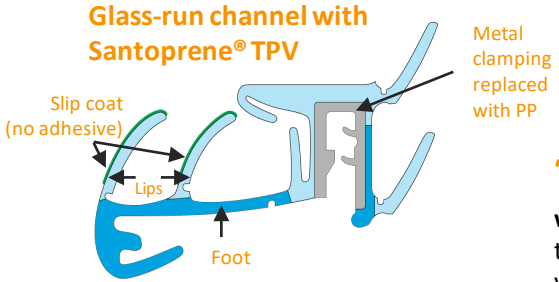
- Shrinkage is important for extrusion processes and mold design for injection molding
- Low shrinkage (<0.5%) meets requirements for glass run channel extrusion
- ECO-R shrinkage in line with comparable Santoprene® TPV grades

Spiral flow

- Important for injection molding and extrusion
- Comparable behavior to standard Santoprene® TPV grades

Potential application: weather seal glass-run channel (GRC)





~50%*

weight reduction
through design optimization
vs. original EPDM design

Application description

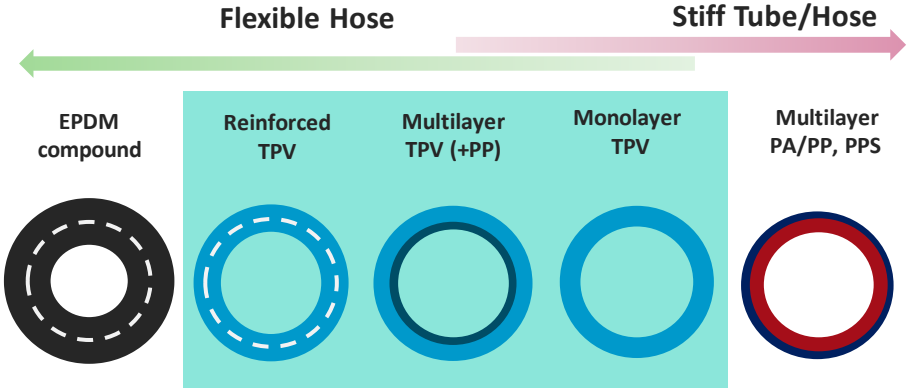
- Extruded profiles in which car windows slide up and down
- High-performance part that seals against weather, dust and noise

Benefits of Santoprene® TPV ECO-R

- Weight savings vs EPDM
- Incorporate post-consumer-recycle (PCR) and reduce carbon footprint
- Less energy consumed in part production vs EPDM
- Easier to recycle than EPDM

Source: Santoprene assessment.
*Indicative directions

Potential application: cooling hose for electric vehicles



Application description

- Cooling hose in electric vehicles
- Transports cooling liquid to battery and other heat emitting parts
- Depending on pressure, re-enforcement with braiding needed

Benefits of Santoprene® TPV ECO-R

- Incorporate post-consumer-recycle (PCR) and reduce carbon footprint
- Enables mono-material or fully polyolefinic solution that is easier to recycle than EPDM
- Weight savings vs EPDM

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The products mentioned herein are not intended for use in medical or dental implants.

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SCS recycled content certified

SCS Global Services does hereby certify that an independent assessment has been conducted on behalf of:

Celanese International Corporation

Pensacola Specialty Elastomers Plant, Cantonment, FL, United States

For the following product(s):

Rubber and Elastomers:
Santoprene™ 9101-80E100 TPV

The product(s) meet(s) all of the necessary qualifications to be certified for the following claim(s):

SCS RECYCLED CONTENT CERTIFIED
Conforms to SCS Recycled Content Standard V7-0 for a **Minimum 15% Post-Consumer Recycled Material Content.** The material quantification and mass-balance calculations are completed on a dry-weight basis.

MINIMUM 15% RECYCLED CONTENT POST-CONSUMER

Registration # SCS-RC-07407
Valid from: November 16, 2021 to February 15, 2023

SCSglobal SERVICES

Stanley Mathuram, PE, Executive Vice President
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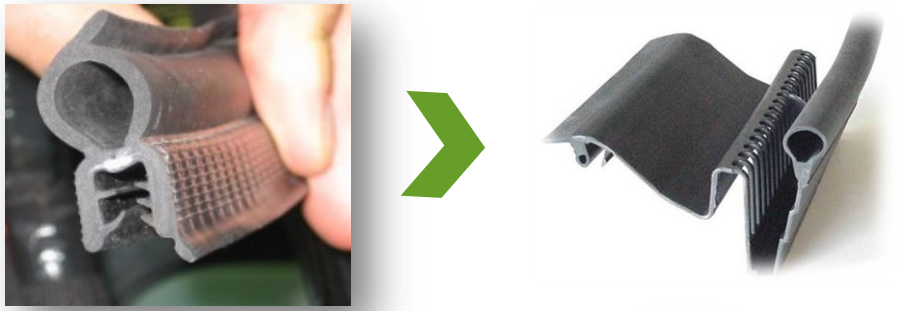
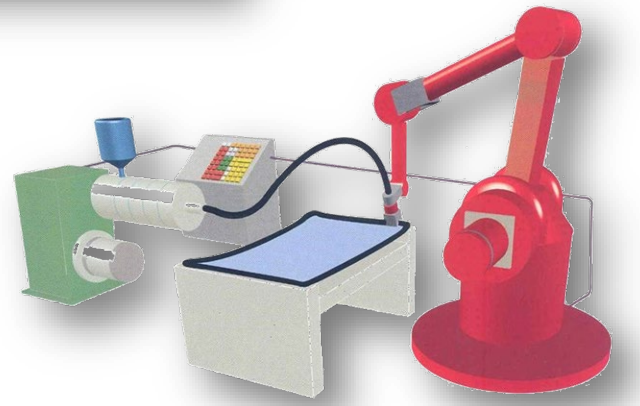
Santoprene® TPV in robotic extrusion cowl vent panel seals





Application and process description

- Sealing of cowl vent panel (PP) to windscreen
- EPDM seal produced via rubber extrusion and metal reinforcement
- Manually mounted onto cowl vent panel

ECO-Design with Santoprene® TPV

- Robotic extrusion process automatically applies seal to cowl vent panel
- No clamping mechanism needed due to chemical bonding to PP panel
- Weight savings with thinner design and lower density vs EPDM
- Easy to recycle polyolefinic solution

Santoprene® TPV in renewable energy applications

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Commercial application examples

- Photovoltaic (PV) connectors
- Strain relief for auxiliary PV equipment
- PV sealing caps
- PV cushion pad for frame clamp system

Reasons for success

- Great sealing performance
- Excellent weather resistance, outstanding electrical properties and flame retardancy
- UL listing
- Easy processing via injection molding and extrusion

Santoprene® TPV in electric vehicle charging infrastructure

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Commercial application examples

- Charging plug grip
- Strain relief and caps
- Auxiliary equipment

Reasons for success

- Easier to recycle
- Soft-touch and aesthetics
- Excellent weather resistance, outstanding electrical properties and flame retardancy
- UL listing

Product CO_2 footprint calculator

- An Excel tool to calculate "estimated" CO_2 emissions ($kgCO_2eq/kg$ product) based on Cradle-to-Gate approach
- Global industry average CO_2 footprint for each raw material used in manufacturing (or its close proxy*) is pre-populated using LCA database, regional association studies, and literature
  - No Scope 1 (direct GHG emissions) are considered due to minimum impact from compounding step
  - Scope 2 (indirect GHG emissions – from purchased electricity) and Scope 3 (upstream GHG emissions – from raw materials) are considered
- Accounts for at least 95% of the formulation
- Calculations include high level estimates of energy needed for compounding, material packaging and transport
- Each report is specific to a grade

*when data is unavailable

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Celanese Carbon Footprint Estimate

Product Carbon Footprint Estimate

Prepared by	Prashant Bhadane
Prepared by Title	Product Specialist
Date	3/17/2022
Customer Prepared for	OEM

Overall Results

Product Name	Santoprene® 101-80
Product Carbon Footprint	2 kgCO2eq/kg product
	1.92 kgCO2eq/L product

Calculated carbon footprint results are based predominately on industry average carbon footprint values and may not contain Celanese primary data

Product CO_2 footprint and life-cycle analysis are different

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Product CO_2 footprint (PCF)	Life-cycle analysis (LCA)
Provides high-level estimate of Global Warming Potential (GWP) of the product	Provides specific, more real-life impact on environment including GWP
Not specific to Celanese products	Specific to Celanese product, process, sites
Uses database and literature value	Uses Celanese primary data
Only total CO_2 value for the product	Specific data of each aspect contribution, able to understand main drivers and how to improve
Difficult to assess alternative options	Understand technology and regional impact

Since compounding operations are comparatively straightforward, PCF value provides a quick insight into GWP of the product. LCA, on the other hand, is a more useful tool for a base polymer resin producer.

Case example: UOB Plaza (technical data)

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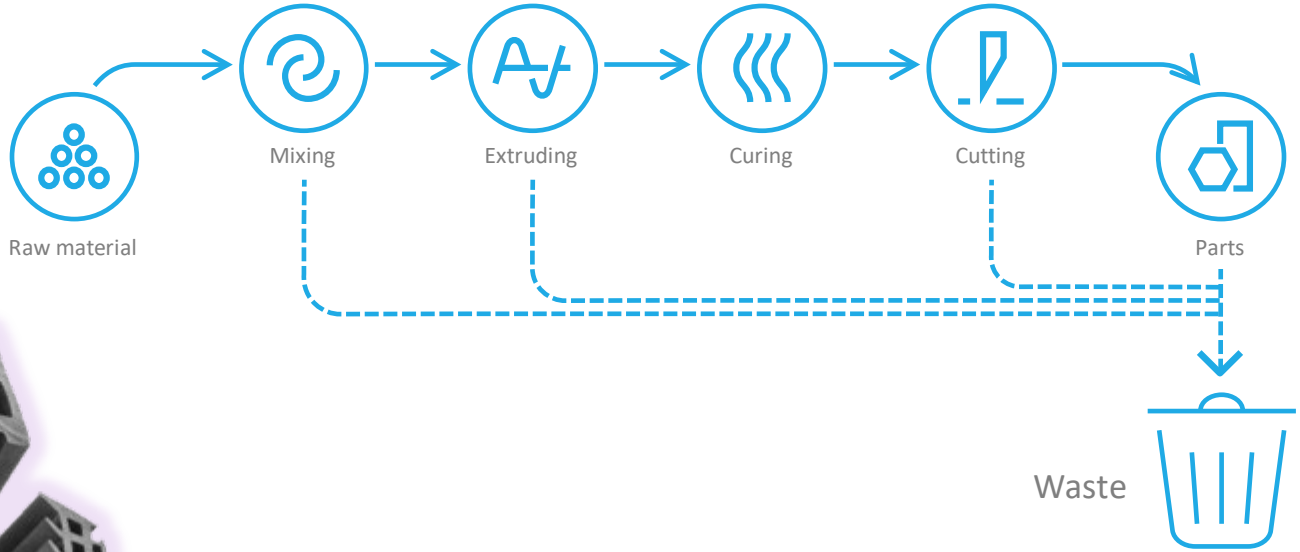
Test Items	Test Method	Unit	Old UOB profile	New 121-67W175 profile
Hardness	*ExxonMobil method (extruded sheet)	Shore A	57	56
Tensile @25% elongation	*ExxonMobil method based on ISO 37,Type 1	MPa	1.72	1.35
Tensile @100% elongation	*ExxonMobil method based on ISO 37,Type 1	MPa	2.96	2.47
Tensile @break	*ExxonMobil method based on ISO 37,Type 1	MPa	7.42	6.8
Elongation @break	*ExxonMobil method based on ISO 37,Type 1	%	406	504
Compression set 70℃, 22 hours, 25%	*ExxonMobil method	%	28	** 27

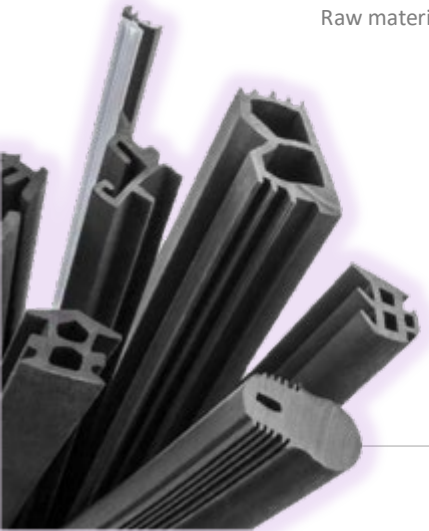
Note:

- Hardness: test samples were cut from both UOB profiles, 6 slices were piled up to > 6 mm thick. Five data were measured with each slice one data. The more layers, the larger difference of final average hardness. Other requirements are based on ISO 868.
- Tensile / Elongation: test samples were cut from both UOB profiles, ~1 mm thick.
- ** Compression set: cut both old UOB profile and STC injection molded new 121-67W175 plaques into small pieces, then hot pressed into ~2 mm thick sheet. Test samples were made from the hot-press sheet by piling 6 discs up to ~ 12 mm thick. Three samples were tested and the results show above are average data.
- As all above tests were conducted with non-standard specimens, the results can only be reference.

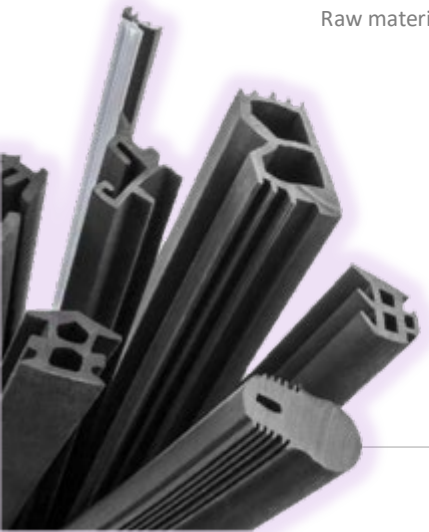
Recyclability performance | Thermoset rubber production

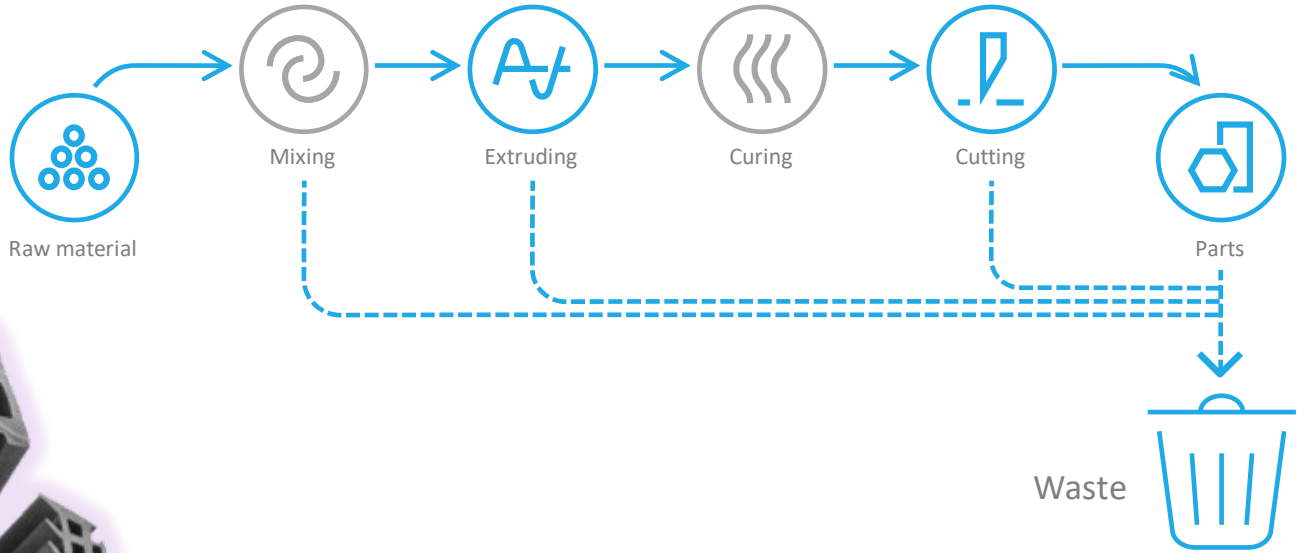
Celanese





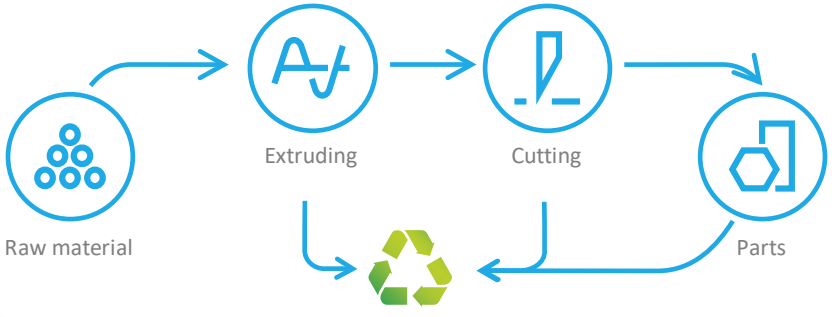
Recyclability performance | Thermoset rubber production



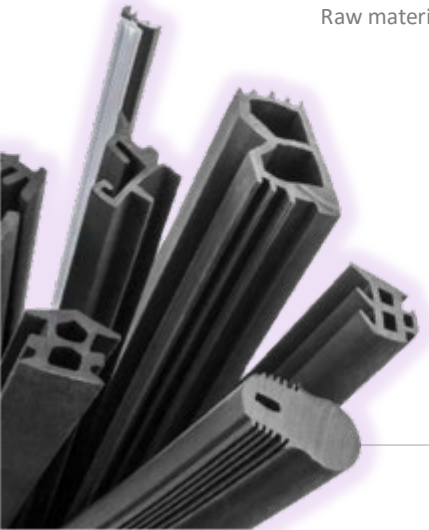


Recyclability performance | Santoprene® TPV vs. EPDM

Celanese



up to 30%
less waste*



*During consumer conversion phase