HIGH PERFORMANCE POLYMERS

New nylon stories

RENYCLE®
nylon after nylon

RADICI GROUP

A real circular choice.

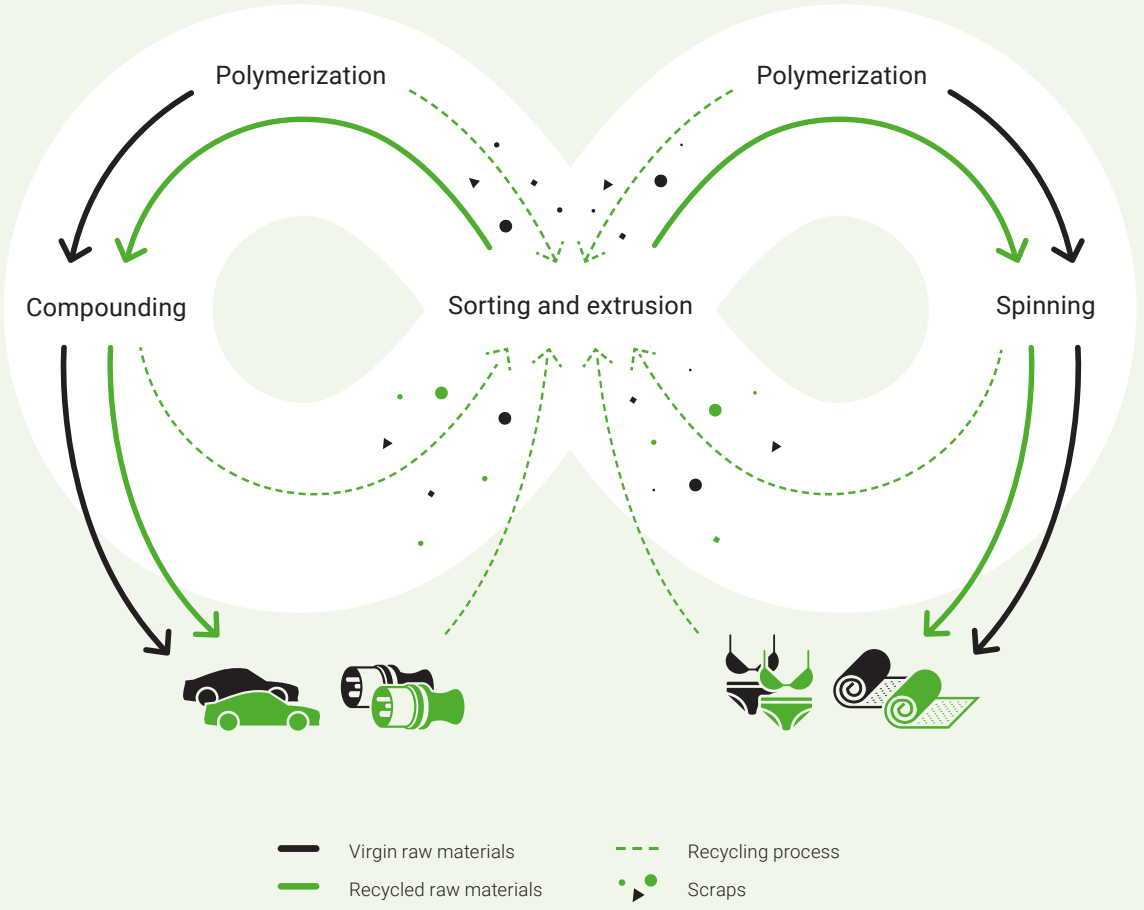
Renycle® is the RadiciGroup new sustainability-oriented engineering polymers range, from post-industrial and post-consumer sources, targeted at meeting the growing needs of the market that requires products with a low and measurable environmental impact without compromising on quality, reliability, traceability, safety.

This range has a lower environmental impact than prime grade material, based on LCA (Life Cycle Assessment) indicator data, currently available for each grade.
This new brand answers the growing demand for more sustainable products, guaranteeing high technical performances.

From scrap to new nylon

RadiciGroup, thanks to its long-standing know-how in material formulation and recycling, is able to convey scraps either in the same industry which originated them or in a different one. This depending on the specific characteristics of the materials and the performance expected from final applications, choosing the most sustainable solution.

This is true for post-industrial material, which is diverted from the waste stream during a manufacturing process, and for post-consumer material, which is generated by households or by commercial, industrial and institutional facilities as end-users of the product which can no longer be used for their intended purpose.



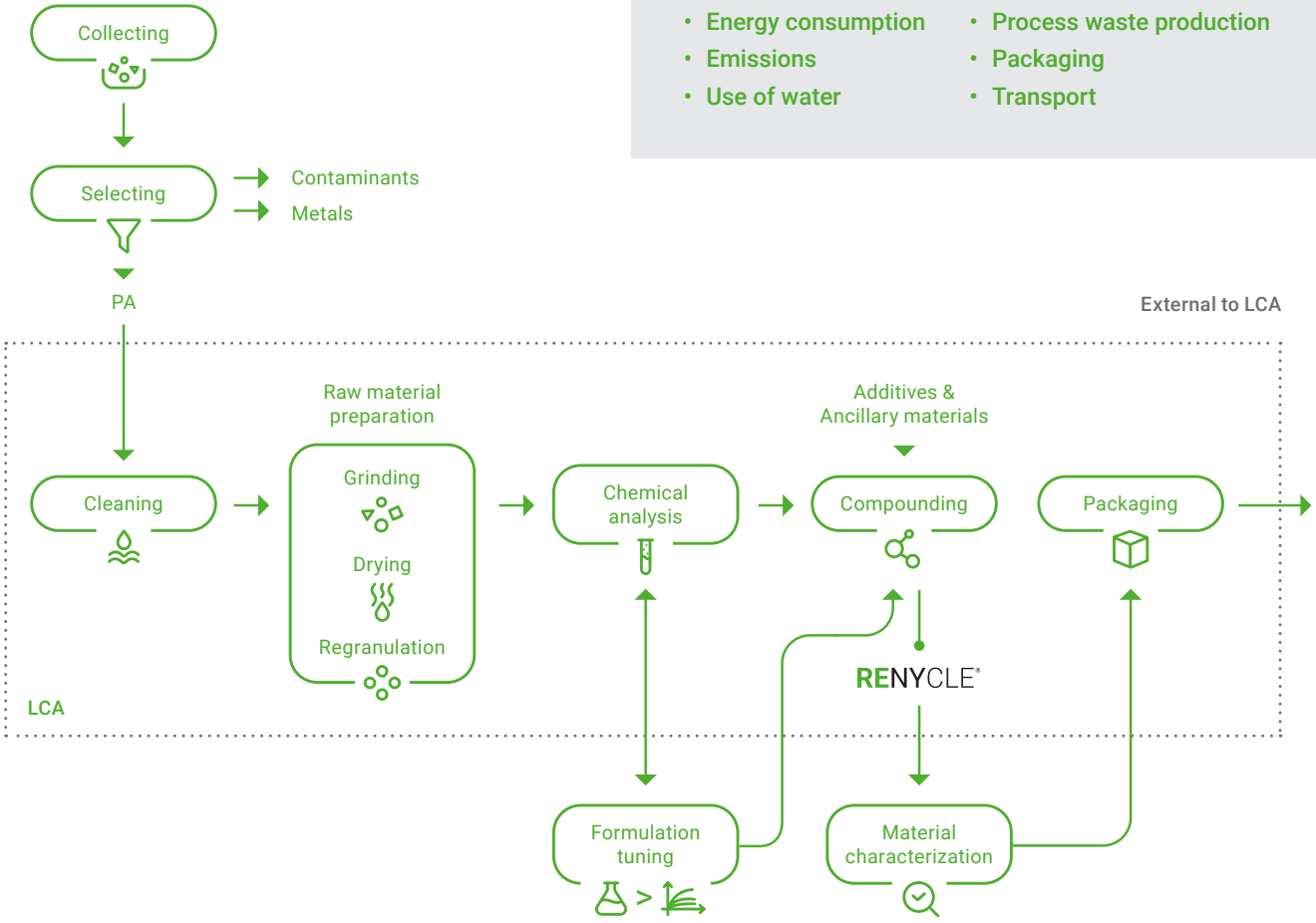
Our ecological footprint? Measured through the LCA study

The Life Cycle Assessment (LCA), regulated by ISO14040, is an integral part of the Renycle® offer. The LCA assessment focuses on determining the environmental impact resulting from the use and transformation of the resources into finished product.

This valuable contribution, developed for each Renycle® grade, is obtained following a worflow that uses, as input data, the process parameters measured directly on the RadiciGroup production plants. Periodically, surveys are carried out to determine impacts for each production step.

The calculation takes into account:

- **Raw materials**
- **Energy consumption**
- **Emissions**
- **Use of water**
- **Additives**
- **Process waste production**
- **Packaging**
- **Transport**



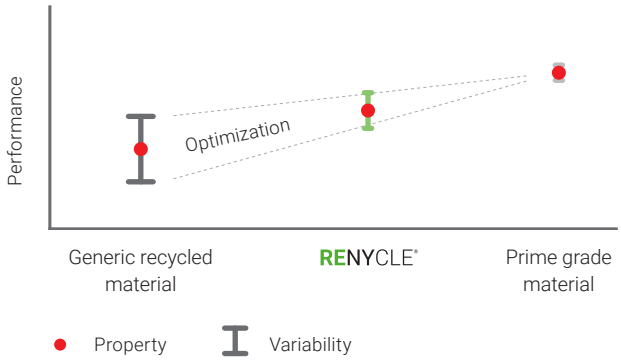
Product safety is essential

For this reason, the raw material used for the production of Renycle® is carefully selected and checked, in order to ensure its traceability and origin. Renycle® materials are subjected to strict controls to guarantee the absence of dangerous substances according to the GADSL (Global Automotive Declarable Substance List) and the reference regulations, including:

- **REACH (CE) n.1907/2006**
- **RoHS III (2011/65/CE)**

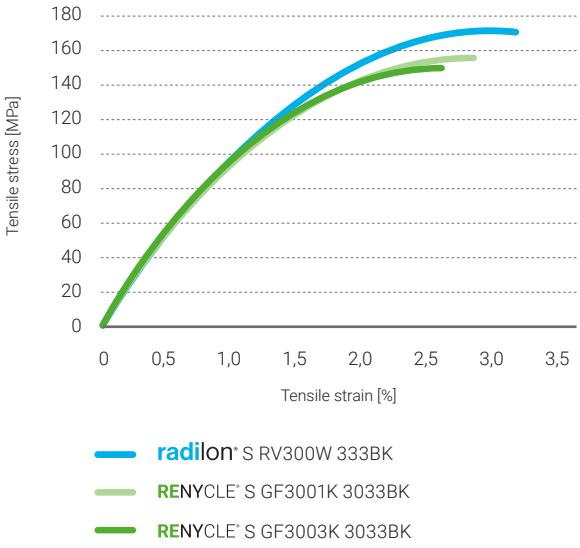
Let's talk about performance

Thanks to the optimization of the formulations, combined with the careful selection of high quality raw materials recovered from post-industrial and post-consumer sources, Renycle® represents the range of sustainable engineering polymers whose mechanical performances, and the related variability, are maintained over time.



Choose the Renycle grade suitable for your application

Particular attention should be paid to applications involving structural or safety components.
The graph, based on the table data, shows the tensile stress-strain curves obtained in compliance with the ISO527 standard, in DAM (Dry-As-Molded) conditions.
The materials in comparison are Radilon® S RV300W 333BK (PA6-GF30 of first choice and of fossil origin), Renycle® S GF3001K 3033BK (PA6-GF30 whose polymer base is partially recycled post-consumer) and Renycle® S GF3003K 3033BK (PA6-GF30 whose PA6 polymer is totally recycled).
What can be seen is that as the recycled content increases, although the design of the materials aims at maintaining the properties, there is a reduction in performance compared to the first choice which is not negligible. This aspect, of fundamental importance, must be taken into consideration in the component design phase when implementing the criteria for choosing the materials.



Property	radilon® S RV300W 333BK	RENYCLE® S GF3001K 3033BK	Δ vs prime [%]	RENYCLE® S GF3003K 3033BK	Δ vs prime [%]
Tensile modulus [MPa]	9,400	9,350	-0.5	9,500	1.1
Tensile stress at break [MPa]	165	150	-9.1	150	-9.1
Tensile strain at break [%]	3.2	3	-6.3	2,6	-18.8
Impact strength [kJ/m²]	85	70	-17.6	75	-11.8

Example: trade-off environmental vs mechanical performances

Finished Product	Global warming potential [$kgCO_2$ eq.]	Cumulative Energy Demand [MJ]	Stress at Break [MPa]	Strain at Break [%]	Impact Unnotched [kJ/m_2]
radilon® S RV300W 333BK	5.31	99.5	173	3.2	73
RENYCLE® S GF3004K 3033 BK	1.06	23	135	2.6	55
Δ [%]	-80%	-77%	-21%	-18%	-25%

Why choose Renycle®

RENYCLE®

Renycle® gives you the opportunity to be greener in several ways:

- **A global leader:** Renycle® is a product from RadiciGroup, one of the world's leading manufacturers of polyamides, synthetic fibres and engineering polymers.
- **Performance:** Renycle®'s technological value and performance are retained unchanged over time and there is no loss into the environment.
- **No waste:** conversion of scrap eliminates the need for new raw material.
- **Green energy:** the energy consumed in Renycle® polymer production is mainly green, as it comes from renewable sources.
- **Environmental conscious choice:** Renycle® promotes a culture of reuse and recycling, with materials that can still offer high technical performances.
- **Optimization:** Renycle® is targeted at meeting the right trade-off environmental vs mechanical performances.
- **CAE Service:** thanks to an advanced simulation software, RadiciGroup supports its customers to predict the behaviour of materials right from the very early stages of product development.
  The goal is to optimize design and also to take into account eco-design and environmental performance.

A number of possibilities with Renycle®

Renycle® is very versatile and can have different properties depending on the final application:

- **Flame retardant**
- **Laser markable**
- **Heat stabilized**
- **Halogen and red-phosphorus free**
- **Hydrolysis resistant**
- **Toughened**
- **Light and UV stabilized**
- **Electrically neutral**
- **High stiffness**

The Renycle® story does not end here. Its applications go on and on.

Renycle® is the ideal solution for all those sectors where creativity and high performance are required.
It has countless applications in:

Automotive

E-mobility

Electrical/ Electronic

Consumer goods

Furniture

Sports accessories

Examples of Renycle® applications
Automotive

1. Thermal management systems

Renycle® can be used in some typical components of the automotive “thermal management systems” segment. The proposal of low environmental impact formulations is intended as an alternative to first choice homologous products (fossil origin), subject to verification of the technical requirements of the final application. This allows to reduce the overall environmental impact even in consolidated applications.

Fan shroud

Made of fully recycled Renycle® A GF3004K 3033 BK (PA66-GF30).
This heat-stabilized material contains recompounded base polymer from high-quality post-industrial feedstock.
This assures a limited property drop compared to the primary grade, guaranteeing a low environmental impact.

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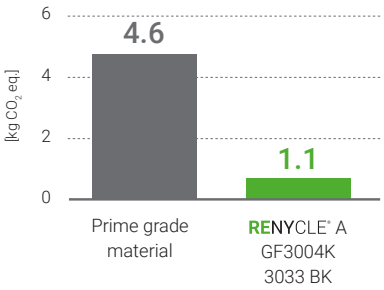
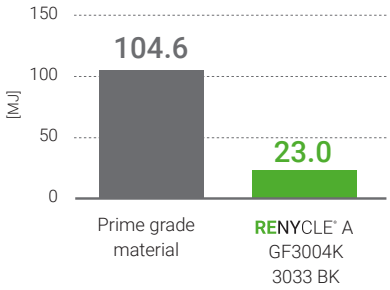
Global warming potential per kg [kg CO_2 eq.]

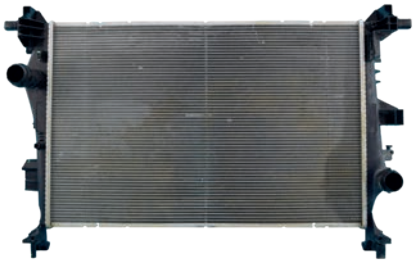


Cumulative Energy Demand per kg [MJ]



Radiator end tanks

Made of Renycle® A GF3002HR 3039BK, a product consisting of partially recycled content. The material has been specially formulated to ensure good resistance when directly exposed to engine cooling liquids.
It is a lower environmental impact alternative to glass fibre filled PA66s, which, since years, has been the material chosen for this application



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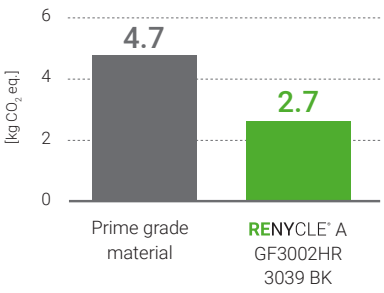
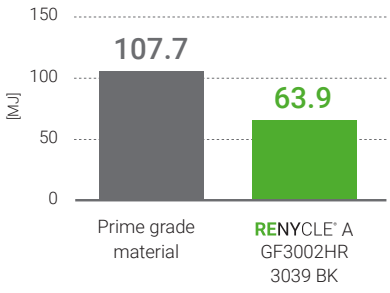
Global warming potential per kg [kg CO_2 eq.]



Cumulative Energy Demand per kg [MJ]



2. Power train and engine system

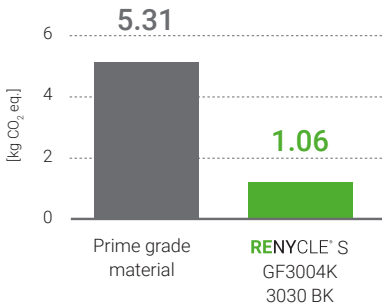
Also for this segment, where significant mechanical properties are required for the various components, such as resistance to exposure to high temperatures for a long time and to contact with chemicals, Renycle® products based on PA66 and PA6 are available.

Air intake manifold

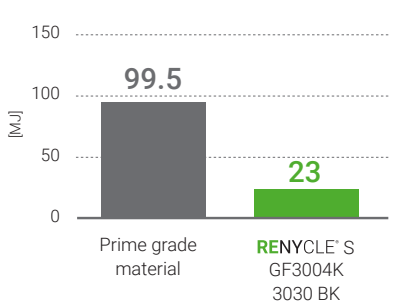
Used in both diesel and gasoline engines. In this case the optimal proposal falls on Renycle® S GF3004K 3033BK (PA6-GF30) and on Renycle® A GF3504K 3033BK (PA66-GF35) post-industrial fully recycled.
The correct selection of the source material guarantees an acceptable variability of the final properties and adequate mechanical strength to prevent breakage in situations of exposure to vibrations even at high operating temperatures and thermal shocks.

Copyright: A2MAC1

Global warming potential per kg [kg CO_2 eq.]



Cumulative Energy Demand per kg [MJ]



RENYCLE®S GF3004K 3033BK

Property	Dried-As-Molded	23°C - RH50
Tensile modulus [MPa]	9,300	5,400
Tensile stress at break [MPa]	135	85
Tensile strain at break [%]	2.6	3.6
Impact strength [kJ/m²]	55	70
Notched Impact Strength [kJ/m²]	8	12

Engine covers

Glass and glass/mineral filled Renycle® products are a valid alternative to primary materials. Typical materials for this application are Renycle® S GFK 3003K 3033BK (PA6 (GF+MD)30) or Renycle® S GF3001K 3030BK (PA6-GF30), providing good planarity and good surface appearance.

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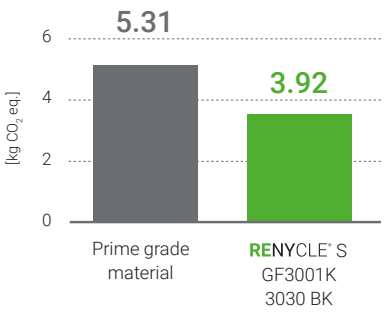
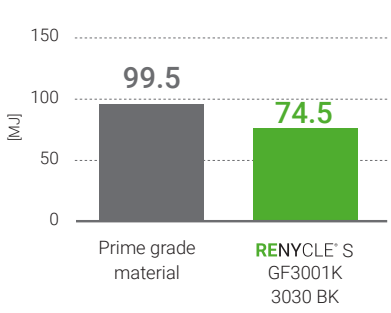
Global warming potential per kg [kg CO_2 eq.]



Cumulative Energy Demand per kg [MJ]



3. E/E Lighting systems

Formulations suitable for different components have been developed

Cable channels

For these applications it is possible to choose:

- Renycle® S GF1501K 3030BK (PA6-GF15): partially recycled material, formulated on a post-consumer basis, reinforced with 15% glass fiber, heat stabilized and black in colour.
- Renycle® S GF1501TK 3030BK (PA6-GF15): partially recycled post-consumer based compound, reinforced with 15% glass fiber, heat stabilized, toughened and black in colour.
- Renycle® S T203K 3030BK (PA6-I): fiber-free formulation, fully recycled post-consumer, heat stabilized, toughened and black.

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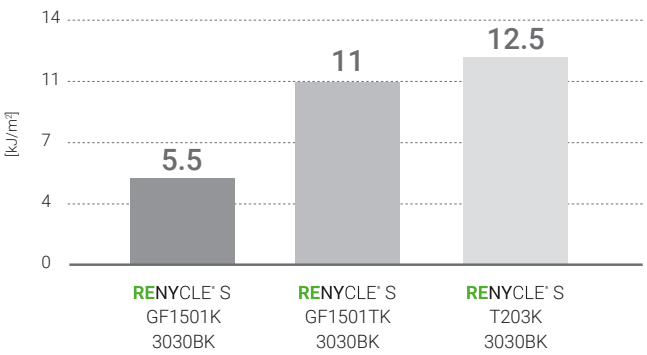
Charpy Notched Impact Strength (23°C DAM)



Examples of Renycle® applications
Flame retardant grade for E-mobility and electrical/electronic sector

E-mobility plug and socket components

Also in the E-mobility sector Renycle® S GF2501 HF0 3033BK is used in the production of the own components of the charging socket for electric vehicles. Among the peculiar characteristics of this partially recycled post-consumer engineering polymer, are the self-extinguishing properties, excellent stiffness and dimensional stability, good aesthetics and, finally, laser markability. Also this type of products can represent a valid alternative to first choice products of fossil origin with the advantage of having a reduced environmental impact.

	RENYCLE'S GF2501 HF0 3033BK
Property	**Dry-As-Molded**
Tensile modulus [MPa]	9,400
Tensile stress at break [MPa]	120
Tensile strain at break [%]	2.9
Impact strength [kJ/m^2]	50
Notched Impact Strength [kJ/m^2]	7
Flammability UL-94	V0 - 0.8 mm
Glow Wire Flammability Index (GWFI)	960°C - 1 mm
Glow Wire Ignition Temperature (GWIT)	750°C - 0.8 mm

Examples of Renycle® applications
Consumer goods

Garden tools

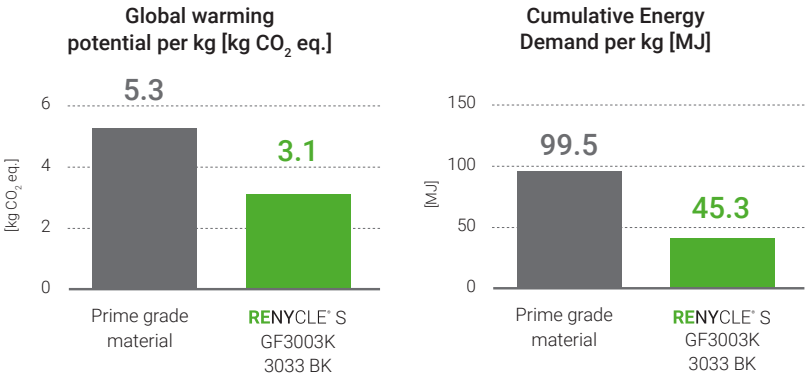
The Renycle® family is particularly suitable for garden tools as it allows the maximum reduction of the environmental impact without sacrificing the required mechanical and aesthetic performance.
An example of a technopolymer suitable for this kind of application is Renycle® S GF3003 3033BK (PA6-GF30), fully recycled, which has characteristics suitable for molding and overmoulding of handles, inserts and levers typical of gardening tools.

Furniture

Also in this case Renycle® S GF3003 3033BK turns out to be the winning choice that combines environmental and technical performance, without forgetting the aesthetic performance that is fundamental in the furniture sector.

Sports accessories

Even in the sports and leisure sector, sustainability raises the perceived value of applications made with low environmental impact materials.
In this case, the buckles and clips are made with the Renycle® S GF3003K 3033BK. The material is made of 100% post-consumer recycled polyamide 6, the reinforcement fiber is added in a percentage equal to 30% to give the right mechanical performance.



Material name (See legend)	Base Polymer	Recycled content range (on the base polymer)	Mechanical - Dry As Molded						Physical		
			Tensile Stress at Break	Tensile Strain at Break	Tensile Modulus	Flexural Modulus	Charpy Notched Impact Strength	Charpy Impact Strength	Heat Deflection Tempera-ture	Melting Tempera-ture	Density
ISO Standard			527	527	527	178	179/1eA	179/1eU	75/2Af	11357-1/-3	1183
Test Conditions			23°C	23°C	23°C	23°C	23°C	23°C	1.8MPa	DSC	23°C
Unit			MPa	%	MPa	MPa	kJ/m²	kJ/m²	°C	°C	kg/m³
RENYCLE® A GF1502K 3033BK	PA66-GF15	up to 50%	118	2.4	6,048	5,680	-	30	-	260	1,240
RENYCLE® A GF3002HR 3039BK	PA66-GF30	up to 50%	148	2.7	9,650	9,000	6	50	-	255	1,360
RENYCLE® A GF3502K 3033BK	PA66-GF35	up to 50%	168	2.3	10,800	10600	7	58	-	261	1,400
RENYCLE® A GF3504K 3033BK	PA66-GF35	up to 100%	160	2.2	11,500	10,300	7	55	230	260	1,400
RENYCLE® A GF5002K 3933BK	PA66-GF50	up to 50%	223	2.5	17,650	14,100	17	94	-	260	1,570
RENYCLE® A T204K 3030BK	PA66-I	up to 100%	65	28	2,500	2,410	12	-	66	260	1,110
RENYCLE® S GF1501K 3030BK	PA6-GF15	up to 50%	126	3	5,950	5,100	5.5	45	-	218	1,230
RENYCLE® S GF1501TK 3030BK	PA6-I-GF15	up to 50%	99	5	5,284	4,470	11	64	-	220	1,190
RENYCLE® S GF2501 HF0 3033BK	PA6-GF25 FR(40)	up to 50%	120	2.9	9,400	9,100	-	50	-	217	1,380
RENYCLE® S GF3001K 3033BK	PA6-GF30	up to 50%	150	3	9,350	7,950	8.5	70	-	217	1,350
RENYCLE® S GF3003 3033BK	PA6-GF30	up to 100%	150	3.4	9,500	7,700	10	75	-	219	1,360
RENYCLE® S GF3003TK 3033BK	PA6-I-GF30	up to 100%	120	3.5	8,300	7,400	15	75	-	220	1,370
RENYCLE® S GF3004K 3033BK	PA6-GF30	up to 100%	135	2.6	9,300	8,400	8	55	190	220	1,370
RENYCLE® S GF3501 3030BK	PA6-GF35	up to 50%	170	3.1	11,400	10,100	12	72	-	220	1,400
RENYCLE® S GF3501KN 3033BK	PA6-GF35	up to 50%	160	2.9	11,200	10,700	12	75	-	220	1,390
RENYCLE® S GF3503UK 3050BK	PA6-GF35	up to 100%	156	2.7	10,500	10,300	10	70	-	219	1,420
RENYCLE® S GF4001KN 3033BK	PA6-GF40	up to 50%	180	2.5	12,700	12,000	14	73	-	220	1,450
RENYCLE® S N101 3030BK	PA6	up to 50%	80	10	3,050	2,500	4.5	-	-	217	1,130
RENYCLE® S T203K 3030BK	PA6-I	up to 100%	65	>20	2,500	2,450	12.5	Not Br.	60	220	1,120
RENYCLE® S GFK3003K 3033BK	PA6-GF+MD30	up to 100%	100	3.8	6,100	5,500	-	42	-	219	1,360

T Impact modified
K Heat stabilized (copper-based)

KN Electrically neutral and heat stabilized
HR Hydrolysis resistance

UK Ultra-violet and light stabilized
HF0 flame retarded V0

RadiciGroup.
Inside your world.

RadiciGroup is one of the world's leading producers of a wide range of chemical intermediates, polyamide polymers, high performance engineering polymers and advanced textile solutions, including nylon yarn, polyester yarn, yarn made from recovered and bio-source materials, nonwovens and personal protective equipment for the industrial and healthcare fields. These products are the result of the Group's outstanding chemical expertise and vertically integrated polyamide production chain and have been developed for use in a variety of industrial sectors, such as: automotive, electrical and electronics, household appliances, consumer and industrial goods, apparel, furnishing, construction, sports. The basis of the Group's strategy is a strong focus on innovation, quality, customer satisfaction and social and environmental sustainability.

Sustainability

Every day at RadiciGroup we work to make circularity our business model. We optimize the use of materials while fine-tuning our processes, eliminating waste, promoting recyclability from the earliest product design phases. We are always looking for low-impact solutions in terms of natural resources and energy. We rely on certified management systems for Safety, Environment and Energy to keep our companies in line with the highest sustainability standards.

1st Sustainability Report in 2004

GRI, third-party certified **Sustainability Report** covering all RadiciGroup companies worldwide.

>70% Emission reduction

Since 2011, in RadiciGroup plants, up to present.

Up to 60 times Water re-used

Water re-used in RadiciGroup production plants.

Data Source: RadiciGroup Sustainability Reports

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