UPMBIOCHEMICALS | UPM

TOWARDS NET ZERO

with UPM BioMotion™
Renewable Functional Fillers

View of the Leuna biorefinery site, May 2024

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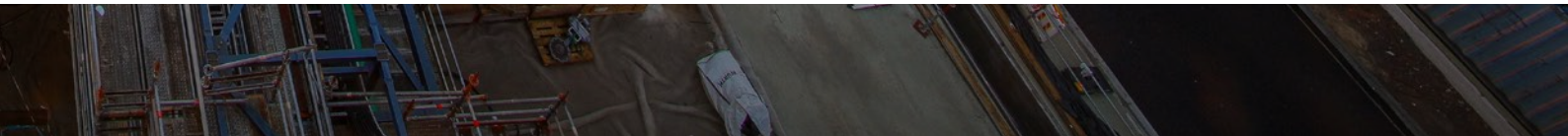


Made in Germany

Pioneering Sustainable Chemistry, Transforming Industries

We take the production of wood-based renewable chemicals from idea to industrial scale.

About UPM Biochemicals

UPM is leading the way and investing in the biochemicals industry of tomorrow. Bioeconomy inspires us, and we want to create a future beyond fossils.

We are building the world's first-of-its-kind biorefinery in Leuna, Germany. Our biochemicals are made from responsibly sourced hardwood and have significantly improved carbon footprints compared to fossil-based alternatives. Our UPM BioPura™ renewable monoethylene glycol (BioMEG) will serve as a base material for various industrial products and consumer goods, such as PET bottles, packaging materials, polyester textiles and engine & battery coolants.

Our renewable monopropylene glycol (BioMPG) will be ready to be converted into cleaning agents, de-icing fluids, fragrances, and cosmetics. As they can be fully integrated into existing production and recycling processes, they enable the transformation of the entire chemicals value chain towards renewable circularity.

The biorefinery will produce Renewable Functional Fillers (RFF) which will be commercially available under the trade name UPM BioMotion™. RFF are a sustainable alternative to highly CO_2 intensive traditional fillers like carbon black and silica in a variety of rubber and plastics applications.

UPM BioMotion™ **Renewable Functional Fillers (RFF)**

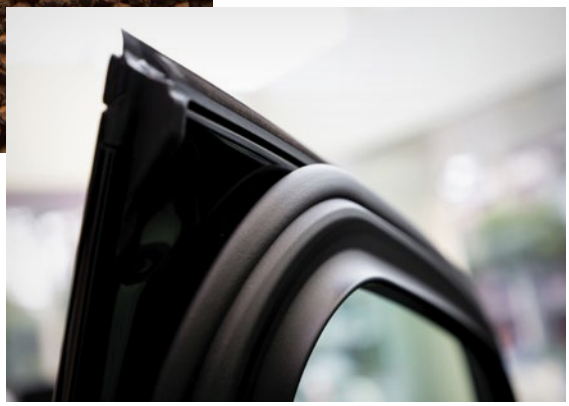
Moving to a sustainable future

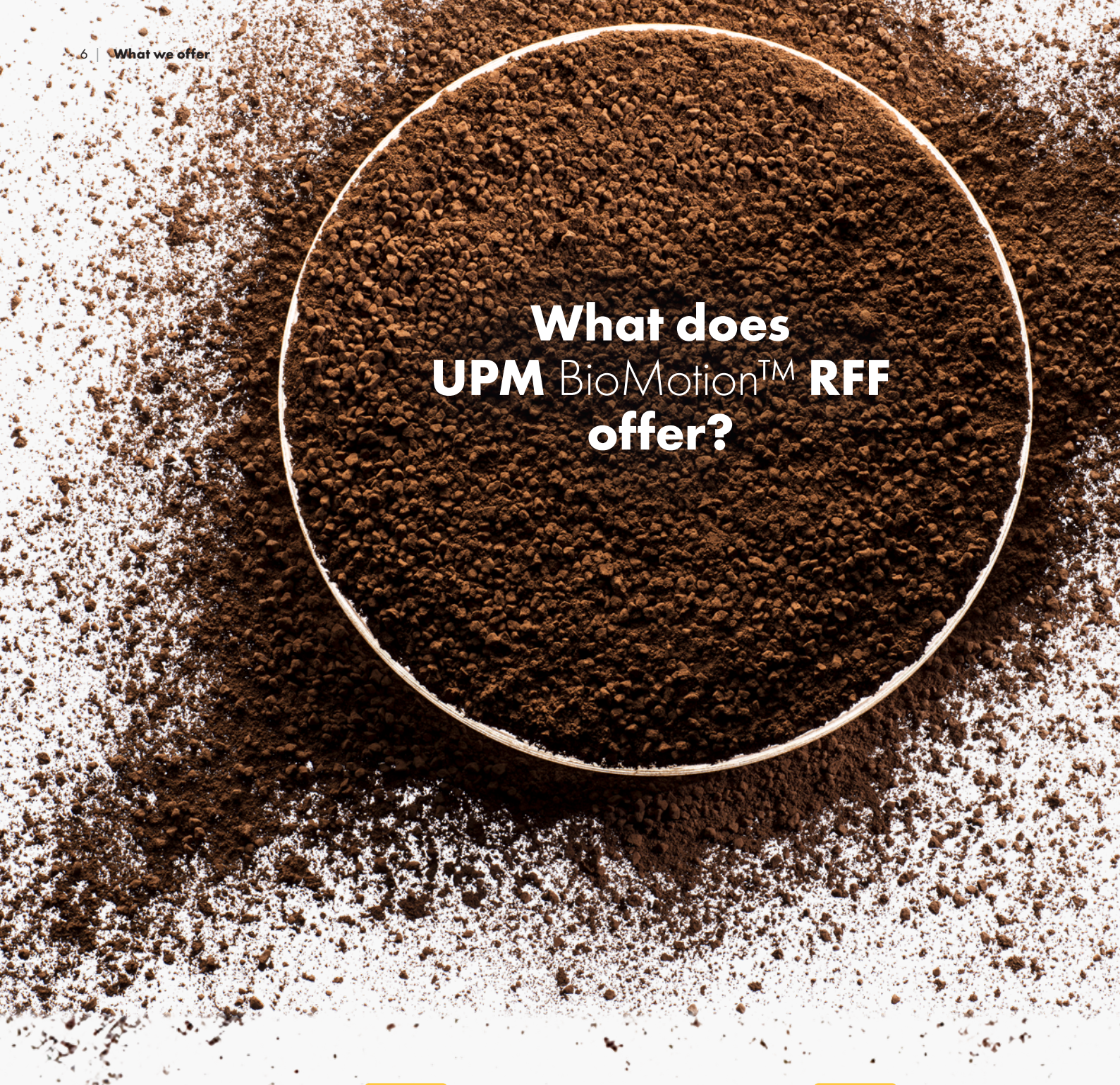
Why UPM BioMotion™ RFF?

Climate change, raw material scarcity, regulatory pressure, and consumer preferences for sustainable products, are key drivers for replacing fossil-based materials with innovative, renewable, and sustainable solutions. Especially rubber and plastics materials used by key industry sectors, e.g., automotive, building and construction, consumer electronics, and packaging are often in contradiction to a circular economy approach, because the vast majority is not biobased, highly CO_2-intensive, hard to recycle, or not biodegradable.

What is UPM BioMotion™ RFF?

To address these needs, UPM has developed a completely new material class of renewable functional fillers, which enables a switch from fossil raw materials to a sustainable alternative: UPM BioMotion™ RFF. It combines a unique set of properties for rubber and plastic applications enabling the next step towards a more sustainable future. It is made from responsibly sourced hardwood from regional, sustainably managed forests and will be produced at UPM's award-winning, first-of-its-kind biorefinery in Leuna, Germany, for which start of production is planned by end of 2024.





What does UPM BioMotion™ RFF offer?

Renewable raw materials

Renewable raw materials accumulate carbon during plant growth, by sequestration of carbon dioxide from air. The amount of biobased carbon in a product can be measured and certified. UPM BioMotion™ RFF has been awarded the highest quality level "DIN-Geprüft biobased" certification mark. Its biobased carbon content has been confirmed 100% according to ASTM D6866 test method. The impact of the biogenic carbon amount of UPM BioMotion™ RFF is directly measurable in the final rubber and plastic articles, especially at higher filler loadings.

Negative carbon footprint

High biogenic carbon contents enable materials with low climate impact. UPM BioMotion™ RFF features a negative carbon footprint from cradle to gate considering biogenic carbon from our feedstock and purchasing green electricity.

Light-weight

Light-weight materials are an important element, especially in the automotive industry for better fuel economy. Thanks to its low material density of only 1.3 g/cm³, UPM BioMotion™ RFF is regarded truly light-weight. Compared to traditional functional fillers, the density is more than 25% lower. This unique feature allows to reduce the compound density of the final products.

High purity

UPM BioMotion™ RFF is characterized by high purity. It does not contain polycyclic aromatic hydrocarbons (PAHs) above the thresholds of Commission Regulation (EU) No. 1272/2013 and possesses only a very low sulfur content of smaller than 0.2%.

Biodegradable

Independently of the filler loading, UPM BioMotion™ RFF has proven to be the perfect additive for industrial, home, soil, and marine biodegradability. UPM BioMotion™ RFF has been awarded the certification mark "DIN-Geprüft Additive EN 13432" with unlimited use quantity in the final product. DIN CERTCO confirmed UPM BioMotion™ RFF as being biodegradable in industrial, home, and soil environments. In addition, UPM BioMotion™ RFF has demonstrated conformity according to DIN EN ISO 22403 for biodegradability in the marine environment.

100% electrically insulating

Like white, inorganic fillers, and unlike industrial carbon blacks, UPM BioMotion™ RFF is 100% electrically insulating. This natural feature effectively prevents electrochemical corrosion of metal and electrochemical degradation of rubber parts.

Characteristic black coloring

UPM BioMotion™ RFF has also proven of high potential as additive for thermoplastic materials. When applied as pigment it yields a characteristic black coloring with a slightly reddish and yellowish tone. In contrast to articles colored with carbon blacks, near infrared (NIR) detection of the base polymer is still possible allowing for sorting and thus recycling of the plastic materials. Thus, UPM BioMotion™ RFF supports a better circular economy resulting in less resource consumption and lower carbon footprints.

UPM BioMotion™ RFF will be available in different packaging units: bulk, in big bags and in smaller quantities from 5 to 20 kg.

UPM BioMotion™ **RFF Product Portfolio**

Our UPM BioMotion™ RFF product portfolio for rubber applications currently covers three different grades with specific surface areas in the range from 10–40 m^2/g. In addition, we offer a special grade tailor-made for optimized dispersion in thermoplastics, UPM BioMotion™ XP.

Packaging, Handling and Storage

UPM BioMotion™ RFF will be available in bulk deliveries, big bags, and low melting EVA bags ranging from 5 kg to 20 kg. UPM BioMotion™ RFF will be available as granulate. Pellets are much easier to handle due to significantly better flow and conveying properties.

UPM BioMotion™ RFF should be stored in closed packaging in a dry, cool, and well-ventilated area protected from sunlight, exposure to higher temperatures and away from highly flammable materials. The material should not be stored and handled near sources of ignition, and it should be protected from electrostatic discharge. The packaging should be closed when not in use.

Overview of current UPM BioMotion™ RFF product portfolio for rubber applications.

UPM BioMotion™	**X10**	**X20**	**X40**
STSA surface area	11 m^2/g	23 m^2/g	40 m^2/g
pH	6 – 10	6 – 10	6 – 10
Sulphur content	< 0.2%	< 0.2%	< 0.2%
Benzo[a]pyrene	< 0.1 ppm	< 0.1 ppm	< 0.1 ppm
each of 22 FDA PAHs	< 1 ppm	< 1 ppm	< 1 ppm
Loss on drying	< 3%	< 3%	< 3%
Bulk Density	> 250 kg/m^3	> 250 kg/m^3	> 250 kg/m^3

Produced from responsibly sourced beech wood

What makes wood a sustainable feedstock?

As trees grow they absorb carbon dioxide from the air. Hence forests are a giant natural carbon storage and often also a significant carbon sink. The high carbon content makes wood a true alternative to fossil feedstocks for producing performance chemicals like UPM BioMotion™ RFF. Wood is a renewable raw material – when sustainability managed, the forest stock continues growing, even though part of the wood is removed. In addition, it is ensured that forest is continually renewed.

The growing demand for renewable, sustainable materials creates a powerful incentive for forest owners and companies to ensure the continuous growth of forests through sustainable forestry practices. Nearly one-third of the total area of Germany is forest land, and over the last four decades, the forest area has increased.

How is responsibility ensured in wood sourcing?

UPM's Central European Wood Sourcing ensures that all wood used in the biorefinery is responsibly sourced with a fully transparent supply chain avoiding any deforestration. The wood used to produce UPM BioMotion™ RFF comes exclusively from sustainability managed forest and it is either FSC™ or PEFC certified*. It is fully traceable, controlled, and covered by a verified third-party chain of custody. Regional sourcing of wood will enable local value creation and ensure compliance with high social and environmental standards.

We will utilize industrial beechwood, and sawmill side streams. Using these wood streams increases circularity and assures that nothing that can be used goes to waste.

Why beech wood?

UPM's biochemical refinery feedstock in Leuna, Germany, is currently beech wood. Beech trees are native to Germany, and their share in German forests is increasing. Broadleaves trees such as beech improve forest growth and yield and increase the diversity of forests. This provides a stable source of wood raw material to fulfil the demand of the biochemical refinery in the long term.

Due to limited end-use options minority of all harvested industrial beechwood is used in any material applications. Typically it is used for thermal energy generation. Thus, developing new industrial applications based on beech wood supports climate-adaptive forest management goals.

*FSC-C158663, PEFC/04-31-3324

Sustainable at the source

Sustainably managed forests provide a renewable feedstock.

Wood is a renewable material outside the food value chain

All the wood we will use is FSC™ or PEFC certified

We know the origin of wood, and our supply chain is 100% certified

Our wood sourcing is reginal, it causes zero deforestation, and forest renewal is always ensured

Biodiversity and the function of forests as carbon storages are preserved

Turning wood into green chemicals in Leuna

At the Leuna Biorefinery, wood is processed into sustainable biochemicals. Utilising every part of the biomass, this cutting-edge technology supports the environmentally friendly production of fuels, polymers and materials.

Wood consists of three primary organic polymers: cellulose, lignin, and hemicellulose. Cellulose represents approximately 50% of the wood's dry weight. It is the primary strengthening material in wood and provides structural support. Lignin represents approximately 25% of the wood's dry weight. It gives trees their rigidity, acting as a natural adhesive but also makes them water and degradation resistant. Hemicellulose represents up to 25% of the wood's dry weight and has two unique roles. First, it helps bind cellulose and lignin together. Second, it contains numerous moisture sorption sites, so it helps to store more water in the cell walls.

Leuna biorefinery combines wood processing with innovative chemistry

The novelty of the Leuna biorefinery processes is to extract these building blocks and refine them into high-value base and performance chemicals, combining the best of wood processing technology with innovative chemistry, using almost everything of the woody biomass in our final products and side streams.

We use thinning and industrial hardwood from responsibly and sustainably managed regional forests which is debarked and chipped after arrival in our biorefinery in Leuna. In the next step, the hemicellulose is separated and

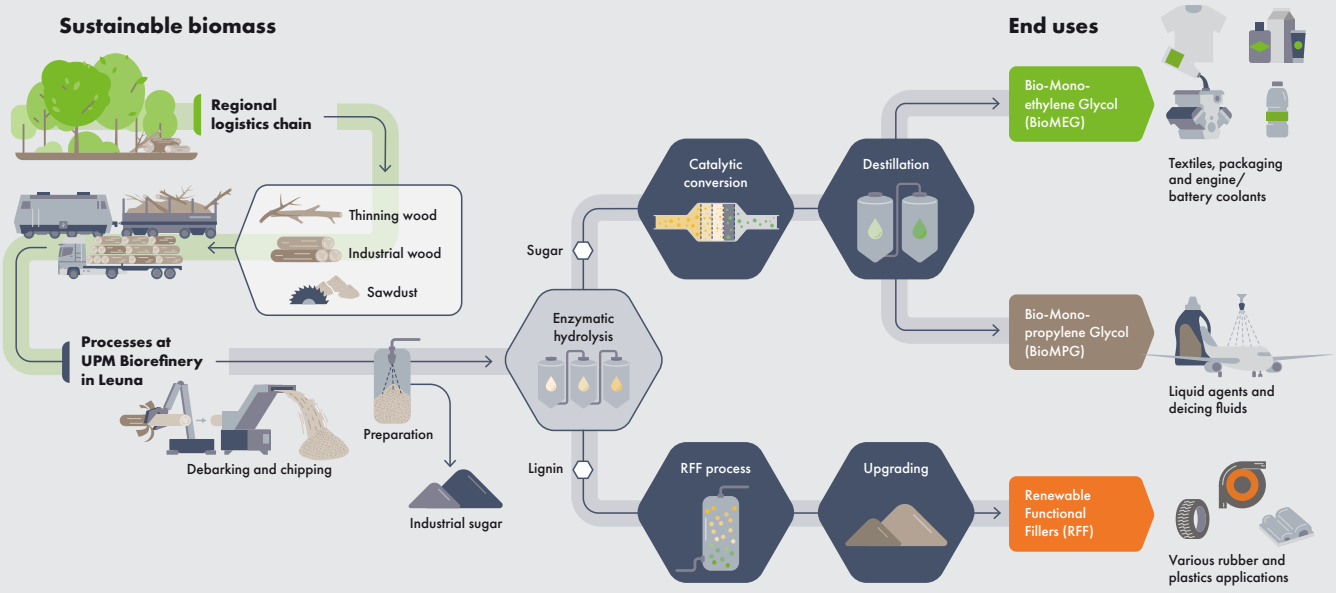
converted into industrial sugars by a pre-treatment process. Hemicellulose-based industrial sugars can be processed further into a large variety of products including fuel, food, and polymers for diverse applications.

After removal of the hemicellulose, the cellulose is separated from the lignin by an enzymatic process yielding sugars which are converted into renewable glycols: bio-monoethylene glycol (BioMEG) and bio-monopropylene glycol (BioMPG). These renewable biochemicals can improve the sustainability performance of various end use applications, such as textiles, coolants, or packaging. As a 1:1 drop-in replacement, the biochemicals derived from cellulose can be seamlessly integrated into existing recycling cycles, compensating the losses in the recycling loop with renewable materials.

To date, lignin is not widely used in industrial applications. We are determined to change this. The successful utilization of lignin can broaden the spectrum of renewable resources in producing chemicals, fuels, and materials. After removal of the cellulose in form of sugars the lignin is converted into an entirely new category of biochemicals produced from lignin. Our UPM BioMotion™ RFF offers a sustainable alternative to carbon black and precipitated silica in a broad range of rubber and plastic applications.

Our renewable glycols, BioMEG and BioMPG, can improve sustainability performance in various end-use applications. UPM BioMotion™ RFF is a sustainable alternative to carbon black and precipitated silica in a variety of rubber and plastic applications.

The UPM biorefinery in Leuna combines wood processing with innovative chemistry



Third-party tested and certified: 100% biobased carbon content

UPM BioMotion™ RFF has been certified with the internationally recognised „DIN-Geprüft biobased" label at the highest quality level.

Renewable raw materials accumulate carbon during plant growth, by sequestration of CO_2 from air. The amount of biomass-based carbon can be verified by measuring the proportion of ^{14}C isotopes, which is different in fossil-based products in comparison to biomass-based products. The American committee developed the ASTM D6866 Standard Test Method for Determining the Biobased (Carbon) Content of Solid, Liquid and Gaseous Samples using Radiocarbon Analysis. It is often used to estimate the age of archaeological discoveries because of the fixed percentage of ^{14}C in living organisms. Once an organism, whether plant, animal, or human dies, the concentration of the unstable radioactive ^{14}C isotope starts to decrease over time. Radiocarbon dating is applied to determine the concentration of biobased carbon in %. Carbon derived from renewable resources (i. e., plants) show a ^{14}C activity of about 100% while carbon derived from fossils (i. e., crude oil) is inactive (0%). A value in between represents a mixture. For example, a product with a ^{14}C activity of 80 %, consists of 80% renewable and 20% fossil carbon.

The certification of biobased carbon content according to the American standard ASTM D6866 quantifies the ratio of non-fossil organic carbon to total organic carbon in a product. This demonstrates the use of renewable raw materials and the proportion of biobased carbon in the product. ASTM D6866 verifies that the carbon in these products originates not from petroleum, but biomass instead.

Manufacturers of biobased products can have their products certified in accordance with ASTM D6866 by DIN CERTCO. The certification mark "DIN-Geprüft" confirms that an independent, neutral and competent body has carefully examined and assessed the products. The certification distinguishes different quality levels based on the biobased carbon proportion of total carbon: 20%–50%, 50–85% and >85%.

UPM BioMotion™ RFF has been awarded the internationally recognized "DIN-Geprüft biobased" certification mark with the highest quality level "biobased >85%". The biobased carbon content of UPM BioMotion™ RFF according to ASTM D6866 method is 100%. Information about the certificate can be viewed in the certificate database of DIN CERTCO www.dincertco.tuv.com.

UPMBIOCHEMICALS | UPM

TOWARDS NET ZERO

with **UPM** BioMotion™ Renewable Functional Fillers

#noexcuses

CO_2-negative
from cradle to gate considering biogenic carbon
from our feedstock and purchasing green electricity

Bio-based
100% renewable carbon,
certified by DIN CERTCO

Light-weight
Material density of
only 1.3 g/cm³

Made in Germany

IT'S TIME TO ACT NOW!

Contact us at
rff@upm.com

UPM Biochemicals GmbH
Am Haupttor, Bau 4614
06237 Leuna, Germany

Cradle-to-gate life cycle assessment

UPM's Life Cycle Assessment (LCA) of BioMotion™ RFF, conducted according to ISO standards, provides insights from raw material extraction to manufacturing, helping to improve sustainability and reduce carbon footprints.

Life cycle assessment (LCA) is a scientific method for analysing the environmental impacts of products. The LCA study of UPM BioMotion™ RFF was carried out in accordance with ISO standard 14040 and 14044 based on cradle-to-gate system boundary excluding potential environmental impacts after final packaging. It enables UPM to provide environmental impact information to its customers and downstream users. The data will also be used to further develop products and processes in future.

What is Life Cycle Assessment?

LCA is defined as the systematic analysis of the potential environmental impacts of products or services during their entire life cycle. A complete life cycle includes raw material extraction, processing, transportation, packaging, storage, use and waste management, and is called a cradle-to-grave. If the life cycle study includes all the life cycle phases up to manufacturing (but not the use phase and waste management), it is called a cradle-to-gate analysis.

Life cycle impact assessment (LCIA) covers all relevant inputs from the environment (e.g., ores and crude oil, water, land use) as well as emissions into air, water, and soil (e.g., carbon dioxide and nitrogen oxides). The International Organization for Standardization provides guidelines and requirements for conducting a LCA according to ISO 14040 and 14044.

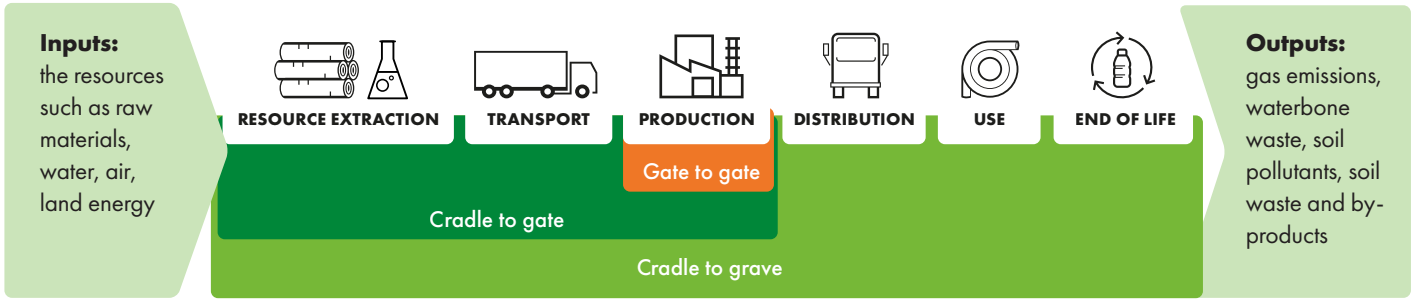
Methodology

The LCA model was created using the GaBi 10 software. The GaBi 2024.1 LCI database provides life cycle inventory data for the raw materials and process chemicals. The study was made following the principles of ISO14040 standard and the latest CML impact assessment methods were applied. The data collection is based on supplier design, process simulation and pre-commercial trial data and represent current best knowledge of the biorefinery process. A critical third-party review has been conducted by DEKRA Assurance Services GmbH according to ISO 14044.

System boundaries and functional units

The LCA study of UPM BioMotion™ RFF covers the life cycle stages "cradle to gate" including the production of raw materials, fuels and energy, manufacturing, treatment of wastes and by-products, packaging, and transportations in the value chain from the beginning to the warehouse. Transportation to customers, its use, and the end of life are excluded because it is an intermediate product used by customers to produce different products in different industry sectors. UPM BioMotion™ RFF can be used for example as a raw material in rubber and plastics, which again have different applications ranging from hoses to casings used in automotive or electronics industry. The end-of-life is strongly depended on the product stage therefore no reliable scenario can be determined.

Overview of particular life cycle phases of a product and which are in scope of what type of analysis.



The LCA study of UPM BioMotion™ RFF was carried out in accordance with ISO standard 14040 and 14044 based on cradle-to-gate system boundary excluding potential environmental impacts after final packaging.

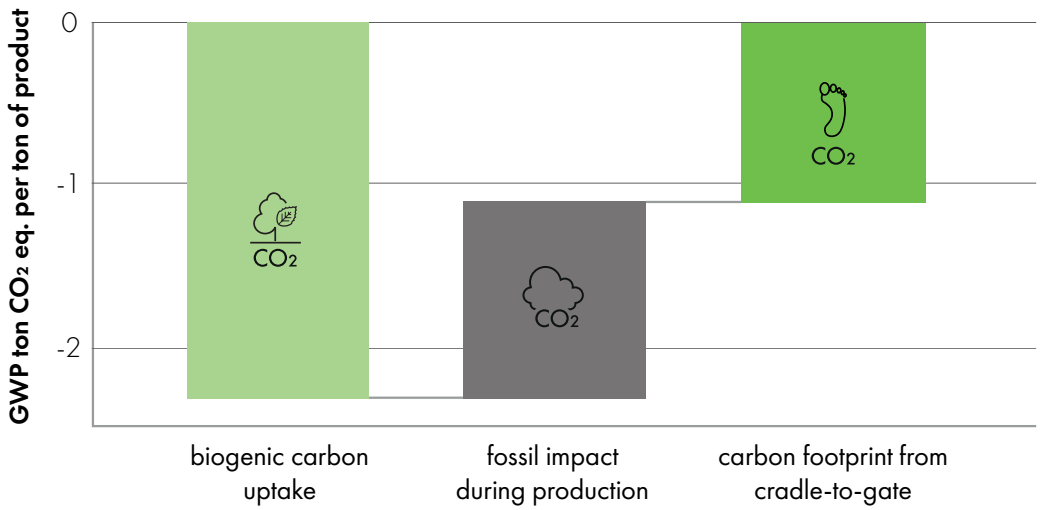
The environmental impacts associated with capital goods are also not considered in the study. All material inputs and energy carriers used are considered. Direct emissions to air are considered, but as they are based on digital process simulation, adjustments might be needed once the plant starts operating. The results are displayed per one ton of UPM BioMotion™ RFF.

Allocation and cut-off criteria

The production process of main products is bound to the chemical and physical composition of the feedstock. The main components of wood (cellulose, hemicellulose, and lignin) are utilized to produce BioMEG, BioMPG, UPM BioMotion™ RFF, and industrial sugars. In general, an allocation rule based on dry matter content has been applied. For raw materials and output flows containing biogenic carbon, the allocation is based on biogenic carbon content. No cut-off criteria are defined for this study. For the processes within the system boundary, all available energy and material flow data have been included in the model. In cases where no matching life cycle inventories are available to represent a flow, proxy data have been applied based on conservative assumptions regarding environmental impacts.

Results

UPM BioMotion™ RFF have a negative carbon footprint considering biogenic carbon from our feedstock and buying 100% green electricity via GOs for the production process. Replacing fossil-based materials with UPM BioMotion™ RFF can help effectively reduce carbon footprint of rubber and plastics products. As the biorefinery is currently in the process of being built, the LCA results will enable UPM to understand where potential environmental hotspots and improvement potential lie. Our LCA will be gradually updated with primary data, from manufacturing and supplier specific data for purchased raw materials as soon as they become available.



Global warming potential (GWP) contributions of UPM BioMotion™ RFF from cradle to gate according to ISO 14040 and ISO 14044.

Clean and safe use due to the absence of banned carcinogenic substances

UPM BioMotion™ RFF contains exceptionally low levels of PAHs, making it safe for use in consumer goods. It complies with EU regulations, ensuring protection from carcinogenic substances.

No PAHs above the thresholds of Commission Regulation (EU) No. 1272/2013

Polycyclic aromatic hydrocarbons (PAHs) represent a group of chemicals composed of multiple aromatic rings which are formed, among others, during the combustion of fossil fuels or other organic matter. Several hundreds of PAHs exists. They belong to an alarming group of substances for humans end environmental organisms. Many PAHs are carcinogenic, mutagenic and/or toxic for reproduction. Some PAHs are at the same time persistent, bio accumulative, and toxic for humans and other organisms. PAHs can enter the environment and reach consumer in manifold ways. To protect the health of consumers from the risk arising from exposure to PAHs, the European Commission has limited their concentration in plastic or rubber parts that come into direct and prolonged contact with human skin or the oral cavity under normal or reasonably foreseeable conditions of use in the Commission Regulation (EU) No. 1272/2013. This includes all kind of consumer goods like for example sporting equipment, household items, tools, clothing, footwear, and accessories, as well as toys and childcare items. The Commission Regulation (EU) No. 1272/2013 sets limits for in total eight different PAHs that are classified as carcinogens of category 1B: Benzo[a]pyrene, Benzo[e]pyrene, Benzo[a]anthracene, Chrysene, Benzo[b]fluoranthene, Benzo[j]

Maximum Content of EU and AfPS GS PAHs in UPM BioMotion™ RFF.

PAH	Content [mg/kg]	CAS Registry Number	according to	
Benzo[a]pyrene	< 0.1	50-32-8	(EU) No. 1272/2013	AfPS GS 2019:01 PAK of April 10, 2020
Benzo[3]pyrene	< 0.1	192-97-2		
Benzo[a]anthracene	< 0.1	56-55-3		
Benzo[b]fluoranthene	< 0.1	205-99-2		
Benzo[j]fluoranthene	< 0.1	205-82-3		
Benzo[k]fluoranthene	< 0.1	207-08-9		
Chrysene	< 0.1	218-01-9		
Dibenzo[a,h]anthracene	< 0.1	53-70-3		
Benzo[g,h,i]perylene	< 0.1	191-24-2		
Indeno[1,2,3-cd]pyrene	< 0.1	193-39-5		
Anthracene	Sum < 1	120-12-7		
Fluoranthene		206-44-0		
Phenanthrene		85-01-8		
Pyrene		129-00-0		
Naphthalene	< 0.1	91-20-3		
Total 15 PAHs	Sum < 1			

In contrast to many fossil-based materials, UPM BioMotion™ RFF contains exceptionally low levels of PAHs.

fluoranthene, Benzo[k]fluoranthene, and Dibenzo[a,h] anthracene. The content of each of the eight PAHs in accessible plastic or rubber parts of consumer articles may not exceed 1 mg/kg. For toys and childcare articles, the limit may not exceed 0.5 mg/kg each.

In contrast to many fossil-based materials, UPM BioMotion™ RFF contains exceptionally low levels of PAHs. The corresponding content for each of the eight different PAHs determined by GC/MS analysis is well below 0.1 mg/kg after Soxhlet extraction with toluene for 48h. In compliance with Commission Regulation (EU) No. 1272/2013, UPM BioMotion™ RFF are perfectly suited to be used even at very high concentrations in plastic or rubber parts of consumer goods as no PAHs are added by their introduction. The absence of hazardous PAHs is further proven by the fact that UPM BioMotion™ RFF can be even applied for category 1 materials of the voluntary "Tested Safety" Mark (Geprüfte Sicherheit, GS-Mark) of German Product Safety Committee (Ausschuss für Produktsicherheit, AfPS) without concentration limits.

Meet highest purity requirements

UPM BioMotion™ RFF is characterized by high cleanliness: zero grit in form of coke and refractory materials, sulfur levels of less than 0.2 wt%, traces of heavy metals like Cr, Cu, Ni, Pb, Zn well below 10 ppm, and a low residual ash content.

The perfect additives for industrial, home, soil, and marine biodegradability

UPM BioMotion™ RFF meets strict EU standards for biodegradability and compostability, ensuring safe use in different environments. Certified by DIN CERTCO, it promotes a circular economy.

Additives used in the manufacture of polymeric products made of biodegradable materials greater than 1 wt% need to comply with the European Norm DIN EN 13432. According to the norm a material is defined to be biodegradable, if it is naturally capable being degraded in new biomass, mineral salts, water, and carbon dioxide in the environment. Most chemically unmodified organic materials and constituents of natural origin, such us starch, cellulose or lignocellulose are biodegradable in nature. Therefore, the materials are accepted as being biodegradable in the different environments (i.e., home compost, industrial compost, and soil) according to DIN EN 13432. However, they must be chemically characterized and meet the criteria for disintegration and compost quality. Under these conditions, UPM BioMotion™ RFF has passed the required tests and have been awarded the certification mark "DIN-Geprüft Additive EN 13432" in conjunction with the registration number 8Z0085 by DIN CERTCO with unlimited use quantity, a maximum concentration of 100 wt%, in the final product. In addition, DIN CERTCO confirmed UPM BioMotion™ RFF as being biodegradable in industrial, home, and soil environments.

In connection with the different composting environments, UPM BioMotion™ RFF demonstrates conformity according to DIN EN ISO 22403 for the assessment of biodegradability in the marine environment. On this basis, UPM BioMotion™ RFF has passed the required tests and have been awarded the certification mark "DIN-Geprüft Biodegradable in Marine Environment" in conjunction with the registration number 11Z0001 by DIN CERTCO with unlimited use quantity, a maximum concentration of 100 wt%, in the final product.

In line with DIN CERTCO's certification work, UPM BioMotion™ RFF has been awarded the compostable 'Seedling' mark in conjunction with the registration number 7Z0047. The Seedling logo is a registered

trademark owned by European Bioplastics. It proved that UPM BioMotion™ RFF is certified industrially compostable according to EN 13432 as well as the additional requirements in EN 14995, ISO 18606, ISO 17088, and/or ASTM D6400. In turn, the 'Seedling' offers a basis for transparency including all parties within the supply chain to produce biodegradable polymeric products made of biodegradable raw materials and additives.

However, the final product can only be certified as compostable, if all its components with concentrations greater than 1 wt% meet the same high standards of compostability under the frame of DIN EN 13432. By using raw materials like UPM BioMotion™ RFF or semi-finished products that have already been certified by DIN CERTCO, manufacturers can make sure to receive the certification under the frame of DIN EN 13432 for their products. At the end a truly circular economic operation is possible by using renewable raw materials to build up biodegradable polymers and return them after use via composting as new biomass to nature. Information about the certificates can be viewed in the publicly accessible database of DIN CERTCO www.dincertco.tuv.com.

Biodegradability and certifications

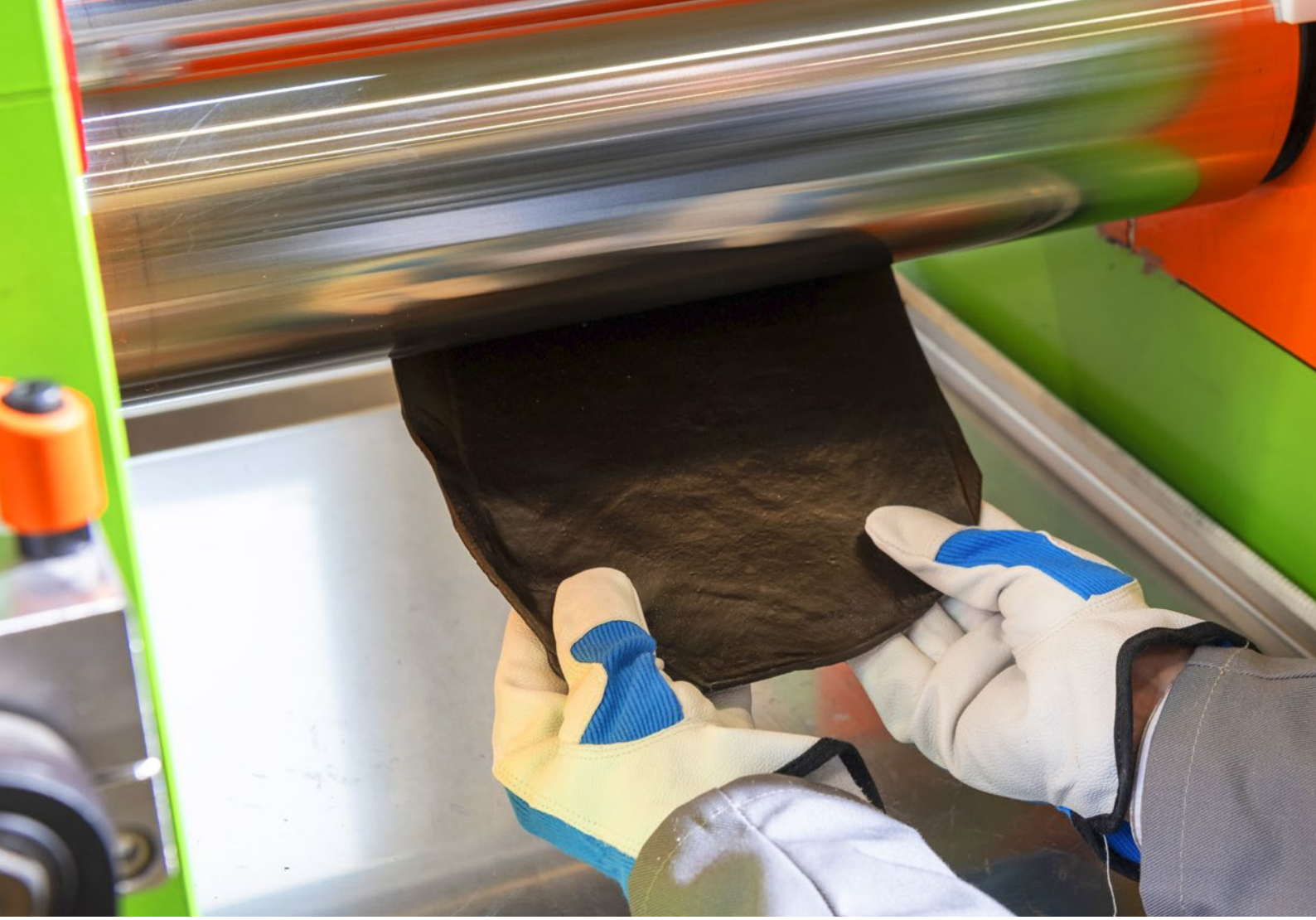
Enviroment	Temperature condition	**UPM** BioMotion™ **RFF certifcation marks** [a,b]	**UPM** BioMotion™ **RFF Seedling certifcation** [c]	**Final polymeric product** [d]
Industrial composting		Registration Number: 8Z0085	Registration Number: 7Z0047	✓
Home composting				
Soil				
Marine		Registration Number: 11Z0001		

a UPM BioMotion™ RFF applied with an unlimited use quantity in the final product is certified by DIN CERTCO with test mark "Additive according to DIN EN 13432" and is safe in the industrial, home and soil composting process.

b UPM BioMotion™ RFF applied with an unlimited use quantity in the final product ist certified by DIN CERTCO based on DIN EN ISO 22403 with test mark "Biodegradable in the Marine Environment" and is safe in the marine waterenvironment.

c Seedling – Industrial compostable with unlimited use quantity in the final product.

d Manufacturers of final polymeric products can dispense with possible further test procedures and successfully prove the safety of their products for the different composting environments.



Transforming rubber and plastics from within

UPM BioMotion™ RFF can be used to increase the proportion of renewable materials in rubber and plastic compounds, and thus reduce their carbon footprint.

Benefits

UPM BioMotion™ RFF offer a perfect solution to significantly increase the renewable material content of rubber and plastic compounds, while concurrently reducing the global warming potential. By exchanging fossil-based and CO_2-intensive materials like carbon black, precipitated silica and other traditional filler systems, the environmental impact of final articles can be easily improved by 50% and more. In combination with other renewable raw materials, such as bio-based polymers and process oils, even CO_2-negative rubber and plastic compounds are already possible today.

In contrast to other traditional functional fillers, UPM BioMotion™ RFF features a much lower material density of only 1.3 g/cm^3, which, compared to carbon black and precipitated silica, is more than 25% and 35% lower, respectively. Inactive, inorganic white fillers like kaolin, talcum, or siliceous earth are even twice as heavy. This unique natural feature of UPM BioMotion™ RFF allows for significantly reducing the overall compound or final article weight. Depending on the compound design (i.e., polymer type, filler to be replaced, and actual filler loading), final weight savings of 20% and higher can be achieved. Lower compound densities directly result in less consumption of CO_2-intensive raw materials, further improving the compound carbon footprint.

Rubber Applications & Processing

UPM BioMotion™ RFF are characterized by high specific resistivity of greater than $1*10^{10}$ Ωm in a dry state. The corresponding electrical conductivity in an aqueous solution has been determined to be less than 1500 µS/cm

An innovative raw material for sustainable rubber and plastic products

according to ISO 787. In contrast to carbon black and like precipitated silica or other inorganic white fillers, rubber compounds applying UPM BioMotion™ RFF maintain their electrical insulating performance at any filler concentration. This feature effectively prevents electrochemical corrosion and thus improves lifetimes of metal parts in direct contact to the rubber. Similarly, electrochemical degradation of rubber parts in direct contact with water and other cooling liquids are effectively avoided.

In contrast to many fossil-based materials, UPM BioMotion™ RFF is characterized by high purity. The related content for each of the eight different EU PAHs is well below 0.1 mg/kg. In compliance with Commission Regulation (EU) No. 1272/2013, UPM BioMotion™ RFF are ideally suited to be used even at very high concentrations in plastic or rubber parts of consumer goods as no PAHs are added by their introduction. Due to the absence of hazardous PAHs, UPM BioMotion™ RFF can be even applied for Category 1 materials of the voluntary "Tested Safety" mark (Geprüfte Sicherheit, GS-Mark) of the German Product Safety Committee (Ausschuss für Produktsicherheit, AfPS) without concentration limits.

UPM BioMotion™ RFF offer high cleanliness: zero grit in the form of coke and refractory materials, sulphur levels of less than 0.2 wt%, traces of heavy metals like Cr, Cu, Ni, Pb, Zn well below 10 ppm, and a residual ash content of less than or equal to 1 wt%.

Driven by a total oxygen content of greater than 25 wt%, UPM BioMotion™ RFF are polar and thus perfectly suited to improve the swelling resistance of rubbers against non-polar media. Surface OH-groups in phenolic and aliphatic functionalities are available for chemical modification and reaction, further expanding the range of possible applications.

UPM BioMotion™ RFF facilitate the creation of high-performance rubber compounds by state-of-the art industrial mixing, extrusion, and molding processes. Low to medium-specific surface areas combined with tailor-made pellet properties in terms of hardness and fines content enable the highest compound qualities at low mixing costs (e.g., time, energy consumption, number of stages). Colloidal properties and pellet characteristics are designed for the highest level of filler dispersibility which in combination with zero coke or refractory grit enable high extrusion speeds and maximum strainer sieve lifetimes. UPM BioMotion™ RFF are perfectly suited for top-in-class extrusion performance. In addition, their tailor-made colloidal properties and surface functionalities enable compounders to design rubber compounds that are perfectly suited for all kinds of molding applications.

Plastic Applications & Processing

UPM BioMotion™ RFF are a versatile product, built to increase the sustainability performance of various end-use applications made from thermoplastics. On the one hand, they can be used as additives, mainly for coloring of compounds, but also compounds with a high UPM BioMotion™ RFF content are of interest, representing a completely new class of materials. Independent of the loading, UPM BioMotion™ RFF can be used in products for industrial, home, soil, and marine composting. The areas of application for UPM BioMotion™ RFF in thermoplastics are diverse, from packaging and consumer electronics to automotive, transportation and household items.

In terms of sustainability and resource conservation, it is desirable to recycle thermoplastics, such as packaging materials, in a closed loop. However, if carbon black is used as a pigment in black-colored plastics, these materials cannot be sorted in recycling plants and therefore cannot be recycled. Due to the strong absorption of carbon black, the polymer of which the article is made cannot be detected with a near-infrared (NIR) detection system.

UPM BioMotion™ RFF offer manufacturers of plastic articles and components the perfect alternative solution to help their customers achieve their sustainability goals. Unlike compounds colored with carbon black, UPM BioMotion™ RFF allow NIR detection of the base polymer and thus enables sorting and recycling of black-colored

plastic products. The use of UPM BioMotion™ RFF as black pigment allows a characteristic black coloring of thermoplastic materials, with a slightly reddish and yellowish tone. Most efficient are loadings up to 3–5 wt%.

If a thermoplastic material is fed into the recycling cycle, it is important that the thermal and oxidative stress of further processing does not damage the polymer too much so that the recycled material can also be used in high quality applications. Thermoplastic materials colored with UPM BioMotion™ RFF show excellent thermal stability in terms of melt flow index (MFI) and oxidation induction time (OIT) during recycling. The MFI remains constant over a series of up to ten recycling cycles while the OIT even increases. No color changes of the thermoplastic materials are observed. Thus, additives used for thermal stabilization, especially of polyolefins during processing, might be even partially replaced by UPM BioMotion™ RFF.

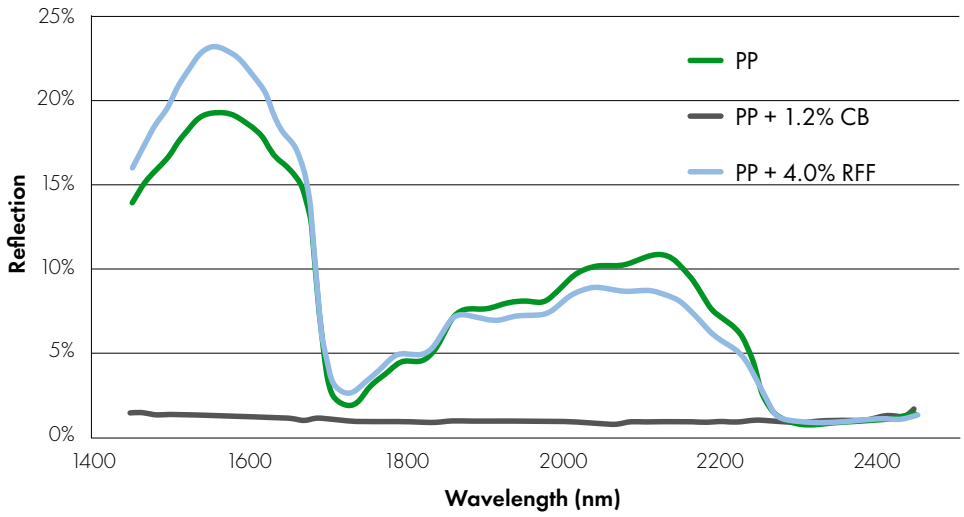
UPM BioMotion™ RFF can be added directly during extrusion or as a masterbatch in extrusion or further processing of the thermoplastic materials. A UPM BioMotion™ RFF masterbatch has a significantly higher renewable material content and a significantly improved carbon footprint than masterbatches using fossil additives and pigments.

UPM BioMotion™ RFF can also be used in higher loadings as functional filler in thermoplastic compounds. Its unique combination of properties makes it advantageous over other filler materials. In addition to reduced carbon footprints and lightweight, UPM BioMotion™ RFF provides renewable material content which can be directly measured in form of biobased carbon in the final article with standardized methods. Further, it increases the stiffness of polymer compounds, while a characteristic black color is achieved. Even at high filler loadings easy processing in extrusion, injection molding and other conversion methods is given up to temperatures of 260°C without the characteristic strong odor which is known from Kraft lignin. Furthermore, UPM BioMotion™ RFF can be used in unlimited amounts as an additive for industrial, home, soil, and marine biodegradable products (according to DIN EN 13432 and DIN EN ISO 22403). This opens possibilities for various compostable applications with increased renewable material content.

Color measurements show that UPM BioMotion™ RFF is providing similar black coloring effects like carbon black at slightly higher pigment loadings.

	L*- value	a*- value	b*- value
1.2 wt% CB in PP	8.6	0.3	0.3
4.0 wt% RFF in PP	8.3	2.3	1.7

Near infrared (NIR) reflection spectra of black plastics



Supporting Customers from Innovation to Market Approval

UPM's team of experts provides personalised support from selection to after-sales, ensuring optimal performance and processing.

UPM BioMotion™ RFF is a new to the world generation of functional fillers that need a deeper technical understanding in compound design, material processing and final article testing. Our technical experts are here to shape your ideas and requirements to facilitate a ready-to-use solution. A team of well-qualified and experienced people in the field of rubber and plastics technology are available to render services to customers. We provide guidance for the selection of appropriate UPM BioMotion™ RFF grades, performance optimization, and best-suited processing parameters for various applications. Our aim is to provide the highest level of services to customers from UPM BioMotion™ RFF implementation to after-sales support. Our Application Development Centre in Leuna is equipped with state-of-the-art compound processing and testing capabilities.

Overview of current rubber compound processing and testing capabilities at UPM Biochemicals' Application Development Centre in Leuna.

Testing Device	Compound Property
Mooney Viscometer	Viscosity Pre-Vulcanization Characteristics Stress Relaxation
Rubber Process Analyzer (RPA)	Vulcanization Characteristics Viscoelastic Properties before, during and after Cure
Temperature Scanning Stress Relaxation (TSSR) Meter	Crosslink density
Compression Set	Retaining of Elastic Properties after prolonged Action of Compressive Stresses
Durometer	Hardness
Tensile Tester	Stress-Strain Properties
Densimeter	Specific Gravity
Resistivity Meter	DC Resistance or Conductance
Rotary Drum Abrasion Tester	Resistance against Frictional Loss
Rebound Tester	Damping Energy
Dynamic Mechanical Analyzer (DMA)	Viscoelastic Properties from -125°C to +250°C
DisperTester	Filler Dispersion in the Size Range from 1-250 µm

FAQ about UPM BioMotion™ **Renewable Functional Fillers**

In which countries/regions will UPM BioMotion™ RFF be offered?
UPM BioMotion™ RFF will be available globally in all regions, either directly from a local UPM-affiliate or through one of our distribution partners.

UPM BioMotion™ RFF is based on biomass, i.e., wood. Does this mean that the product quality is fluctuating more than for traditional functional fillers?
No! UPM uses exclusively hardwood, which means that the composition of the feedstock for UPM BioMotion™ RFF production is very constant. In addition, very tight process controls and stringent quality control schemes ensure highest product consistency.

Does UPM BioMotion™ RFF fall under the new European Regulation on Deforestration Free Products (EUDR)?
UPM is aware of the obligations set in the EUDR and takes all necessary measures to be compliant with the regulation. We are actively engaging with our suppliers, customers, and competent authorities to share information on EUDR, and to ensure the timely adaptation to the regulation.

All UPM Biochemicals wood comes from sustainably managed forestry with FSC™ / PEFC certified chain of custody. Furthermore, UPM BioMotion™ RFF is classified according to customs tariff number position 3913 which does not belong to any of the product categories defined in ANNEX I of the regulation. Consequently, UPM BioMotion™ RFF does not fall under the EUDR.

How does UPM BioMotion™ RFF differ from lignin?
Lignin can come from many different processes with different qualities, while UPM BioMotion™ RFF will be produced using a dedicated process leading to a constant quality. As UPM BioMotion™ RFF production is using lignin as feedstock some chemical structures known from lignin can be found as well. In contrast to lignin, UPM BioMotion™ RFF has a defined specific surface area, the particles are not softening with increasing temperature, and it is nearly insoluble. In addition, smell and VOCs of UPM BioMotion™ RFF are significantly lower than of standard market lignin. When using UPM BioMotion™ RFF in rubber compounds this leads to improved mechanical properties.

How does UPM BioMotion™ RFF differ from traditional functional fillers like carbon black and precipitated silica?
UPM BioMotion™ RFF is CO_2-negative from cradle to gate considering biogenic carbon from our feedstock and purchasing green electricity, bio-based with 100% renewable carbon, and light-weight in comparison to other fillers. It contains mainly carbon (> 60%) like carbon black, but also a significant amount of oxygen (> 25%). Thus, UPM BioMotion™ RFF is like precipitated silica polar by chemical nature containing functional OH-groups. Today's specific surface areas are in the low to medium range matching the most common soft carbon blacks while the filler morphology is closer to precipitated silicas. UPM BioMotion™ RFF represents a new generation of functional fillers for rubber and plastics with a unique property and performance profile.

Is UPM BioMotion™ RFF FSC™ or PEFC-certified?
We have already started to prepare the FSC™ and PEFC certification for our operations and products in Leuna. FSC™ or PEFC-certified UPM BioMotion™ RFF will be available when we start production and commercial sales from our biorefinery.

Is UPM BioMotion™ RFF ISCC+ certified?
We have already started to prepare the ISCC+ certification for our operations and products in Leuna. ISCC+ certified UPM BioMotion™ RFF will be available when we start production and commercial sales from our biorefinery.

What is the moisture uptake of UPM BioMotion™ RFF over time?
UPM BioMotion™ RFF is polar by chemical nature and tends to absorb water if stored openly, especially at high humidity. The packaging materials have been chosen for maximum protection against moisture uptake. If stored properly under closed and controlled dry conditions, no significant moisture uptake will occur over time.

What is the shelf-life of UPM BioMotion™ RFF?
Final shelf life is not yet defined as we are still producing at pilot and not at industrial scale including final packaging in small EVA or big bags. For now, we advise a shelf-life of two years when stored at ambient temperatures in closed containers and away from sunlight and other sources of UV light. Depending on the actual storage conditions, retesting of moisture level should be considered every 6-12 months.

Does UPM BioMotion™ RFF contain VOCs and what about its odor?
Volatile Organic Compounds (VOCs) are organic chemical compounds which can quickly evaporate to air due to their high vapor pressure and low boiling point. Common VOCs include ethanol, formaldehyde, benzene, toluene, and xylene. VOCs are of concern to both indoor and outdoor quality. Many countries have implemented regulations to limit the use of VOCs in products. UPM BioMotion™ RFF production takes measures for minimum odor and low amount of VOCs. The performance is regularly monitored by external testing according to VDA270 and VDA278, respectively.

UPM BioMotion™ RFF appear to have a brown color. Does this mean that my compounds will be brown instead of black?
No, both rubber and thermoplastic compounds with UPM BioMotion™ RFF have a very dark color, which is similar to carbon black based compounds.

Do I need to adjust my rubber or thermoplastic mixing process when exchanging traditional functional fillers like carbon black, precipitated silica, or other inorganic materials by UPM BioMotion™ RFF?
No, UPM BioMotion™ RFF pellet properties are optimized for fast and efficient filler incorporation and dispersion in rubber and thermoplastics.

Which UPM BioMotion™ RFF loading should be used for coloring application in thermoplastics?
In general, a loading of 3–5 wt% gives the best color properties. At all UPM BioMotion™ RFF loadings NIR detection of the matrix polymer is possible, allowing sorting and recycling of the material.

What are the benefits of high UPM BioMotion™ RFF loading in thermoplastic composites?
At higher loadings UPM BioMotion™ RFF will lead to stiffer materials, with increased renewable material content and reduced carbon footprint. This will come along with a lower compound density, as the density of UPM BioMotion™ RFF is significantly lower than the density of other functional filler materials.

Can UPM BioMotion™ RFF be applied for high temperature rubber and/or plastics applications?
Yes, UPM BioMotion™ RFF features an extremely high temperature stability for a bio-based material and can withstand peak temperatures of up to 260°C for a short time.

Our biochemicals are made from responsibly sourced hardwood and have significantly improved carbon footprints compared to fossil-based alternatives.

#noexcuses

LEARN MORE ABOUT US

Get in touch now to learn more about our business, the Leuna biorefinery and its products, which will enhance the sustainability transformation in various industries.

RFF@upm.com

UPM Biochemicals GmbH
Am Haupttor, Bau 4614
06237 Leuna, Germany

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