Tepex®

ALL AROUND *SUSTAINABLE*

Envalior
Imagine the Future

CONTENTS

Tepex® – All around sustainable

ABOUT BOND–LAMINATES

The thermoplastic fiber composite material Tepex® was developed in the 1990s and has since been produced by Bond–Laminates GmbH, based in Brilon in the Sauerland region of Germany. In 2023, Bond–Laminates became a wholly owned affiliate of Envalior, one of the world's leading suppliers of high–performance engineering materials.

As part of the Envalior Specialty Materials Group, to which Tepex® now belongs, we offer not only our Tepex® composite sheets and UDea® composite tapes, but also high–performance plastics such as Durethan®, Novamid®, Pocan®, Ecopaxx®, Fortii®, Stanyl®, Arnitel®, Arnite® A+T, and Xytron®. Our aim is to provide tailor–made material combinations for customer–specific requirements.

ENVALIOR'S SUSTAINABILITY GOALS

Climate protection and reducing greenhouse gas emissions play a crucial role in Envalior's comprehensive sustainability strategy. This is the only way to achieve the company's ambitious goals, above all the reduction of greenhouse gas emissions by 35% compared to 2024 and the switch to 100% green electricity by 2030.

As a participant in the United Nations Global Compact, the world's largest corporate sustainability initiative, Envalior is committed to offering a portfolio of bio–based and recycled alternatives by 2030, making it easier for customers to achieve their sustainability goals and drive positive change together.

LOW CARBON		SUSTAINABLE RESOURCES

YOUR APPLICATION
OUR TEPEX® SOLUTION

The path to a more sustainable future is based to a large extent on the conscious and economical use of resources and energy.

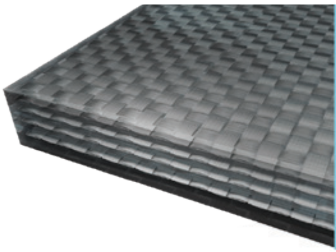
This applies not least to all areas of engineered mobility. Lightweight construction is a very effective method for saving raw materials and weight, reducing the energy required for movement or acceleration.

The weight reduction associated with the use of fiber-reinforced plastics can reduce greenhouse gas emissions, which is why the German federal government considers lightweight construction to be a key technology for reducing CO_2 emissions in the transport sector.

The German federal government is following the European Union's greenhouse gas reduction targets by setting a reduction target of 55% for greenhouse gas emissions by 2030 compared to 1990 levels. This target is to be achieved by, among other things, establishing a circular economy and promoting sustainable products.

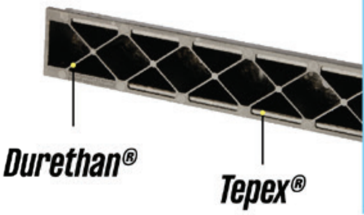
This makes lightweight construction and the use of fiber-reinforced thermoplastics attractive, especially in automotive and aircraft construction, as well as for boats or unmanned aerial vehicles such as drones, as this reduces greenhouse gas emissions during the usage phase.

Moving machine parts, such as those found in industrial robots, also open up interesting application potential for Tepex®. Other areas of application include sports and leisure articles, e.g., components for racing bikes, device housings for laptops or mobile phones.



Tepex®
Key properties

- Plastic composite panels with tailored property profile made of continuous fibers in thermoplastic polymer matrix.
- Reinforced with fully impregnated and consolidated fibers of different materials
- Can be combined with injection molding in plastic/plastic hybrid technology



Tepex®
Benefits

- Excellent mechanical properties
- Suitable for series production due to short cycle times
- Resource-saving due to fully automated, integrated processing procedures
- Thermoplastic-based, therefore easy to recycle
- Ideal lightweight material

TEPEX®
MANUFACTURING

As a thermoplastic fiber composite material, Tepex® is manufactured in a continuous process using thermal respectively mechanical methods without chemical reactions respectively direct emissions.

There is a wide range of options for processing the semi-finished products, depending on the type of fiber reinforcement (fabric, fleece, chopped fibers), the material thickness, fiber length, and the complexity or specific requirements of the component. Tailor-made processing methods offer maximum reliability, process and energy efficiency in each case.

The proportion of CO_2 emissions generated during the production phase is therefore less than 1 kg CO_2e/kg for Tepex®. A reduction in the production footprint will be achieved in the future through the expanded use of renewable energy sources.

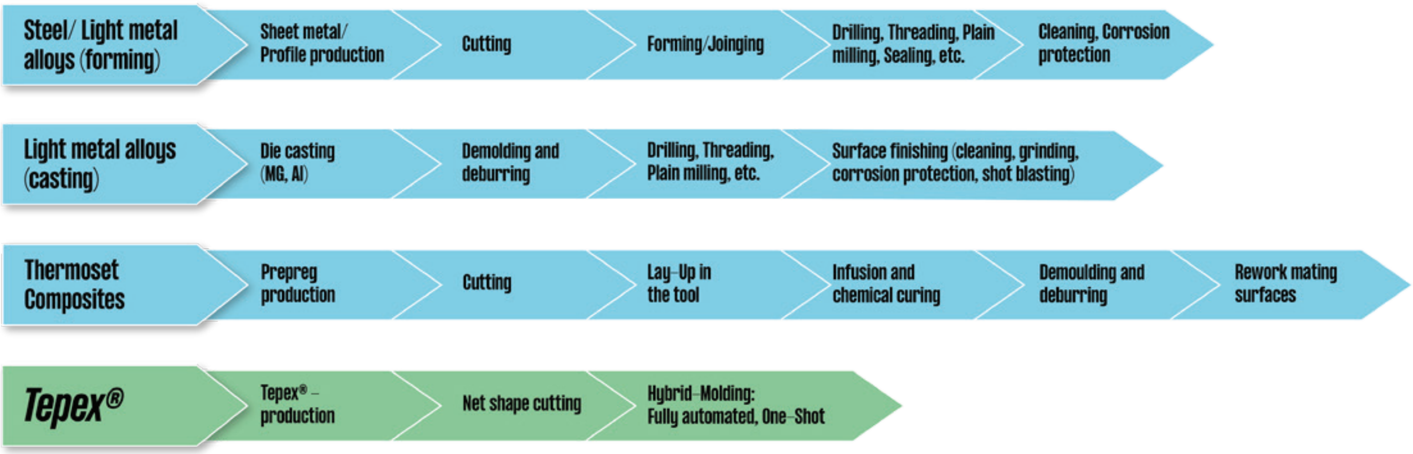
Tepex® is characterized by its thermoplastic matrix, which completely embeds and envelops the reinforcing fibers without significant voids, making the composite material ideal for lightweight construction—not least in terms of recycling and the circular economy.

INTEGRATION SAVES MATERIAL,
TIME AND ENERGY

A comparison of different processing methods for steel, light metal, thermoset composites, and Tepex® clearly shows that the increasing degree of integration enabled by Tepex® semi-finished products is associated with a significant simplification of the process. Fewer process steps mean lower manufacturing (and investment) costs for machines and equipment, as well as a better energy balance, because repeated cooling and heating are no longer necessary. Furthermore, less production waste can be expected between process steps. Hybrid molding in particular is a highly effective method of component manufacturing, as it combines the advantages of large-scale thermoplastic injection molding with the thermoforming of composite sheets: a heated and plasticized Tepex® blank is placed in a temperature-controlled mold, which is designed as a combined forming and injection mold. The forming process of the composite sheet takes place when the mold is closed. The injection molding cycle then starts, during which additional molten plastic is injected into the mold cavi–ties. Complex structures and functional elements can be realized by using insert molding and back molding. After the mold has been filled, the cooling process begins and the finished component can be removed.

Due to the "near net shape" manufacturing process, no further edge processing is usually necessary. Corrosion protec–tion and subsequent further post–processing and joining processes can also often be saved due to the deep integration possibilities and the nature of the material, resulting in extremely short process chains.

Even though the process steps vary in terms of time and energy intensity when compared, hybrid molding can be expec–ted to result in the lowest overall production waste, internal logistics, and other expenses.



1) Comparison of processes for processing different raw materials and semi–finished products

ADVANTAGES OF THERMOPLASTICS *VS. THERMOSETS*

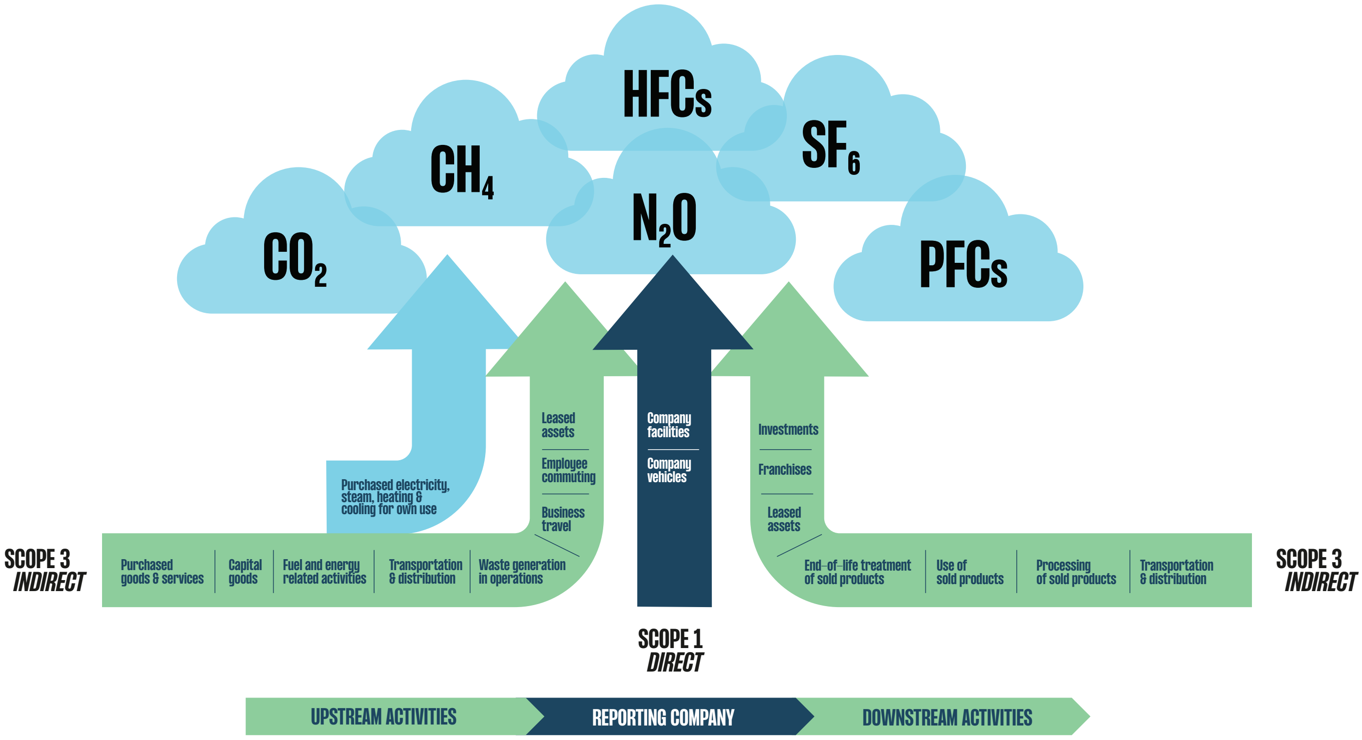
- No cooled logistics/storange of raw materials necessary
- Shorter cycle times
- No chemical processes > no emissions
- Occupational safety
- Recyclability

Occupational safety also plays a role that should not be underestimated: thermoplastic matrix materials offer many ad–vantages both during processing and during recycling at the end of their useful life.

In terms of occupational hygiene, a composite material with a thermoplastic matrix is also superior. Particularly acute health and environmental hazards, as well as hazards due to release, are particularly pronounced in the processing of thermosets (especially epoxy resins) – but are largely negligible in the processing of Tepex®.

CO_2 FOOTPRINT OF TEPEX® COMPOSITES

Life cycle assessments (LCA), also known as eco–balances, provide information about the potential environmental im–pact and energy balance of products throughout their entire life cycle. The definition of the boundaries of the analysis is crucial here. For example, a distinction is made between an analysis of the entire life cycle ("cradle to grave" or "cradle to cradle") and an analysis that only extends to the respective process boundaries ("cradle to gate" or "gate to gate"). In cont–rast to a complete life cycle analysis, in which a wide range of environmental impacts and effects on health and well–being are analyzed, the carbon footprint of a product focuses mainly on the CO_2 emissions generated during the period under consideration.

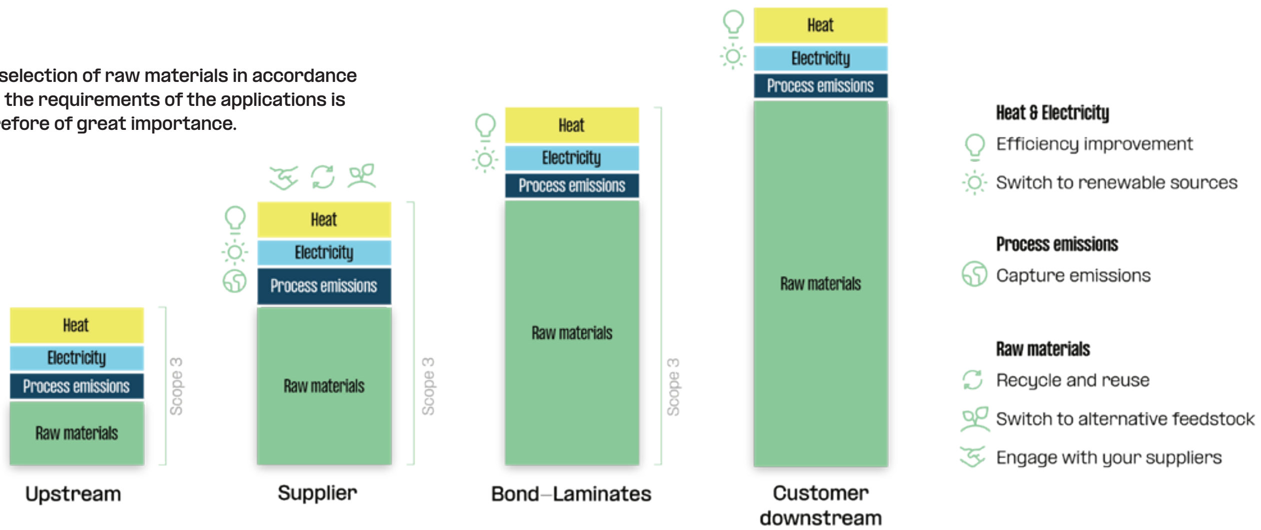


Carbon footprint information is available for all common Tepex® materials. The calculations were performed in ac–cordance to ISO 14040/44 standards for the cradle–to–gate assessment framework in the European sales region. Primary data from our production and supplier informa–tion are used for the calculations wherever possible. For data for which no supplier information is available, data from the EcoInvent database is used. The CO_2 footprint calculations for Tepex® materials are updated regularly.

The share of the Tepex® manufacturing process is low due to material–specific, optimized process control and the use of renewable energies, and is less than 1 kg CO_2/kg Tepex®. With an increasing share of renewable energy, the CO_2 footprint of Tepex® production can be further reduced in the future.

The raw materials used account for a significant propor–tion of the CO_2 footprint of Tepex®.

The selection of raw materials in accordance with the requirements of the applications is therefore of great importance.

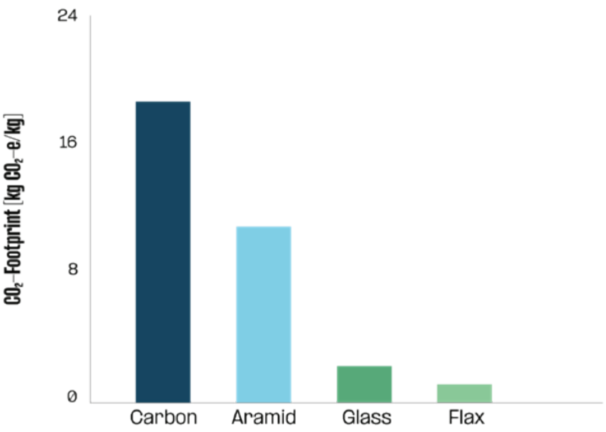


2) Proportion of the CO2 footprint attributable to the Tepex® manufacturing process

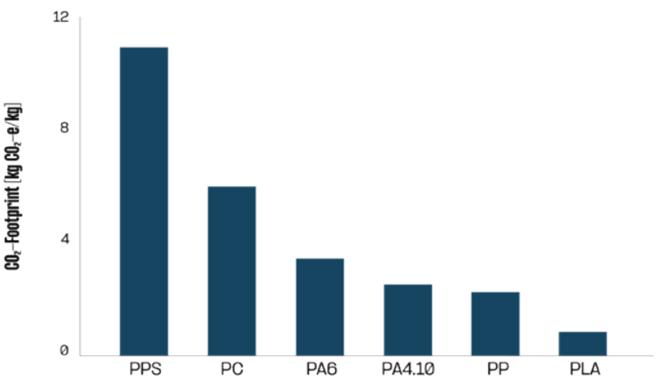
SUSTAINABLE RAW MATERIAL FOR TEPEX®

In addition to circular recycling processes and increased energy efficiency in the manufacturing process, recycled or bio–based raw materials offer attractive ways to reduce the carbon footprint of Tepex®. Tepex® is already available with many sustainable fiber and matrix alternatives, but we are continuously working to expand our sustainable product range. An overview of the sustainable fiber–matrix systems for Tepex® can be seen in figure 6.

A comparison of the carbon footprint reveals significant differences between the various fiber materials.

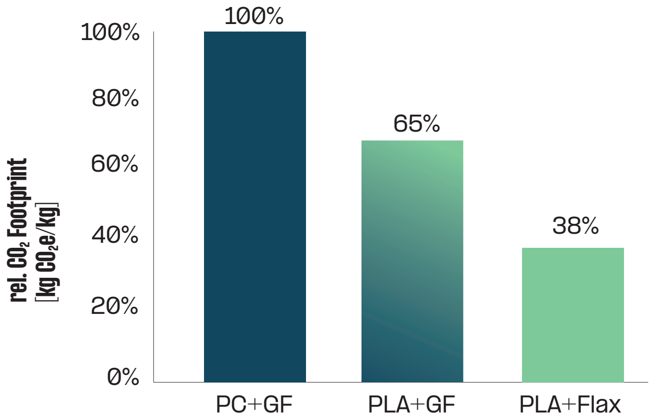


3) CO_2–footprint of different reinforcement fibers



4) CO_2–footprint of different matrix polymers

Wird eine erneuerbare Faser wie Flachs mit einem ebenfalls erneuerbaren Matrixmaterial wie Polymilchsäure (Polylactid, PLA) kombiniert, resultiert die größtmögliche Reduktion des CO_2–Fußabdrucks auf aktuell ca. ein Drittel im Vergleich zu einem konventionellen PC/GF–System.



5) Relative carbon footprint of different Tepex®–grades

Bond–Laminates now produces flax–based semi–finished products with different matrices in quantities and quality suitable for large–scale production. Due to the low specific weight of the fibers, the density of the composite material is also reduced by around a quarter compared to a PC/FG composite.

The following overview summarizes what Bond–Laminates has achieved so far in terms of sustainable products. Based on recycled and bio–based raw materials, new Tepex® grades have been developed and launched on the market, combining an attractive sustainability profile with remarkable material properties. Our goal is to develop a sustainable alternative for all established Tepex® grades that meets the requirements of the respective application.

	PLA*	PP	PA 10.10	PC	PA6	TPU	PA 4.10
Flax	Biobased / Biobased	Biobased / –	Biobased / Biobased				
Glass	– / Biobased		– / Biobased	– / Recycled	– / Biobased	– / Recycled	– / Biobased
Recyclate Non Woven	Recycled / Biobased	Recycled / –	Recycled / Biobased	Recycled / Recycled	Recycled / Biobased	Recycled / Recycled	Recycled / Biobased
Carbon	– / Biobased		– / Biobased	– / Recycled	– / Biobased	– / Recycled	– / Biobased
Aramid			– / Biobased	– / Recycled	– / Biobased		– / Biobased

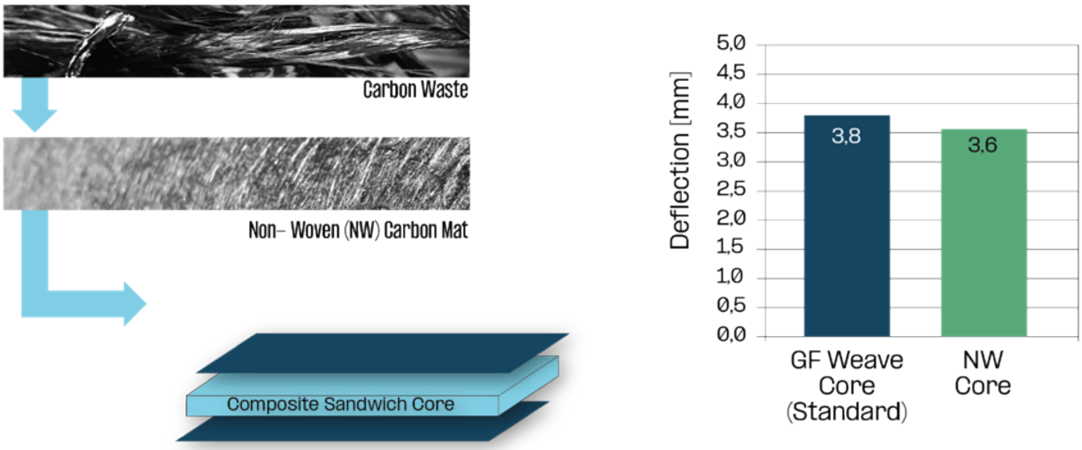
Biobased   Recycled

6) Overview of sustainable fiber matrix systems for Tepex®

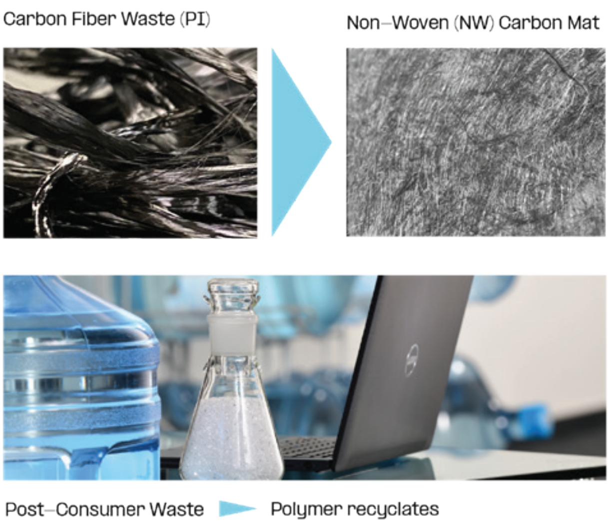
Our Tepex® materials are tailor–made to meet the needs of our customers. Accordingly, we are able to calculate the individual carbon footprint for each material.

USE OF RECYCLED RAW MATERIALS *FOR TEPEX®*

A concept for conserving resources is based on the recycling of fibers from old composites, production waste from fiber or industrial manufacturing, as well as thermoplastics from other sources. This has been implemented, for example, in the manufacture of laptop cases from a PC–CF composite. The polycarbonate comes from recycled water dispenser bottles, while the carbon fibers are obtained from various waste streams and then processed into fiber mats as the core of a sandwich structure. Many structural components of the laptop consist of around 30 percent PC–CF injection–molded recyclate, and the composite display cover even consists of half. The flexural strength of the recycled composite is almost equal to that of a composite system with a conventional core made of glass fiber fabric.



7) Highly flexible composite systems with mats made from recycled, isotropically distributed carbon fibers as a sandwich core



8) Use of CF waste and PC recyclate in laptop casings

CONCLUSION

The future belongs to circular and renewable raw materials. Research projects on the production of carbon fibers from lignin or atmospheric CO_2, which was previously bound by algae, offer interesting prospects.

Other matrix polymers with a high level of sustainability are also being tested or have already been added to the Tepex® portfolio. These include bio–based and circular polymers from Envalior, such as the recyclate–based polymers Durethan® Eco, Akulon® Repurposed, and Akulon® CRC–MB, as well as partially bio–based grades such as Ecopaxx® PA4.10, Durethan® Blue, and the sustainable grades of the Arnitel® and Stanyl® portfolios.

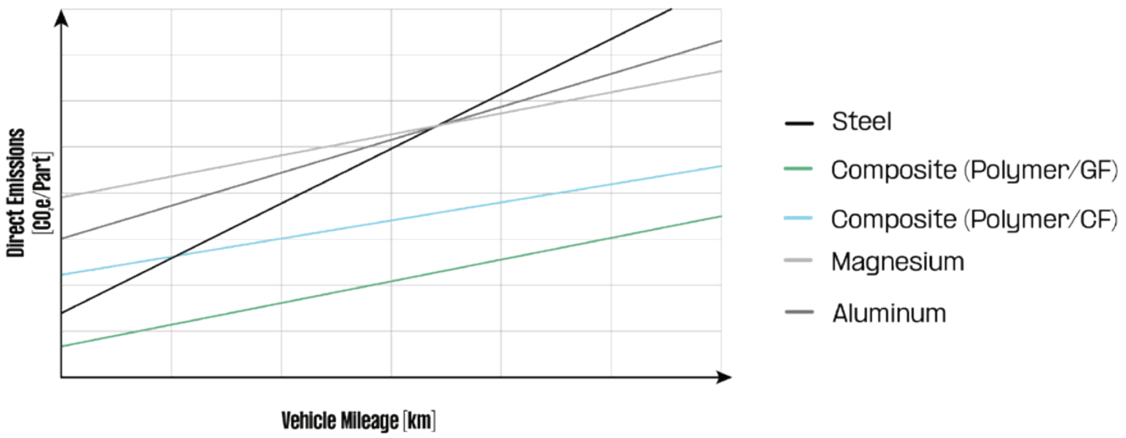
Polyethylene terephthalate (PET) from recycled beverage bottles as a cost–effective alternative to virgin PA or PC, and recycled thermoplastic polyurethanes (TPU) are also being investigated for their suitability.

CO_2 SAVING DURING *THE USAGE PHASE*

Lightweight materials are characterized by low weight combined with high mechanical resistance and load–bearing capacity. If the energy input for production is relatively low, then the material has a small overall CO_2 footprint. This means maximum climate protection due to minimal energy input and emissions during production and use.

A qualitative comparison of plastic composite materials with metallic materials makes this advantage clear: The ordinate intercept of the respective straight line corresponds to the CO_2 emissions during the production of an exemplarily selected component. These are usually higher for metallic materials than for glass fiber (GF) composite material, obtained from a melt. Composites reinforced with carbon fibers (CF) tend to perform worse because fiber production usually requires a lot of energy.

The slope of the straight line is a measure of the emissions during the vehicle's service life. It is proportional to the weight of the component and thus depends on the specific weight of the material and the design conditions resulting from the mechanical properties.



9) Dependence of direct emissions on the vehicle mileage for an exemplary automotive component made from different materials

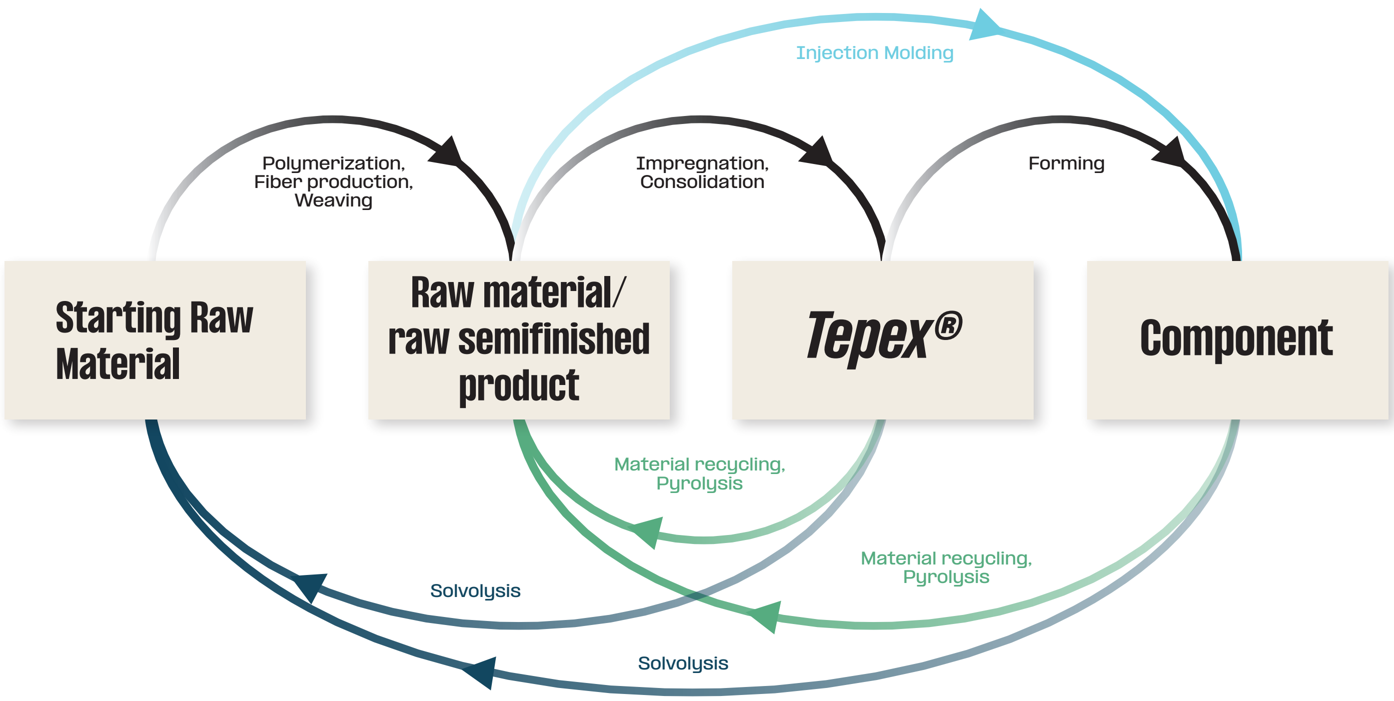
CLOSING LOOPS — *REDUCING EMISSIONS*

Tepex® as a semi–finished product is located in the middle of the value chain. This value chain begins with starting materi–als for fibers and polymers, moves to the actual raw materials (fibers or textiles and polymers) and the semi–finished

products (composite sheets) then finishes with components or complex products containing these semi–finished pro–ducts. Different processing techniques (black and blue arrows) are used along this path. The possibilities for recycling production

waste and trim remnants, as well as complete components at the end of their useful life, are correspondingly diverse. For example, raw materials such as fibers or mixtures of fibers and matrix can be recovered by mechanical means (green). Alternatively, composite materials can also be returned to their original raw materials by solvolysis (dark blue).

Together with partners from research and industry, Bond–Laminates has investigated such solvolysis processes for fiber–reinforced thermoplastics and developed them to pilot scale, for example as part of the EU–funded Multicycle pro–ject. In this way, both fibers and matrix material can be recovered and replace virgin material in the end products. The project has laid important foundations for the sustainable use of fossil–based materials in the circular economy.



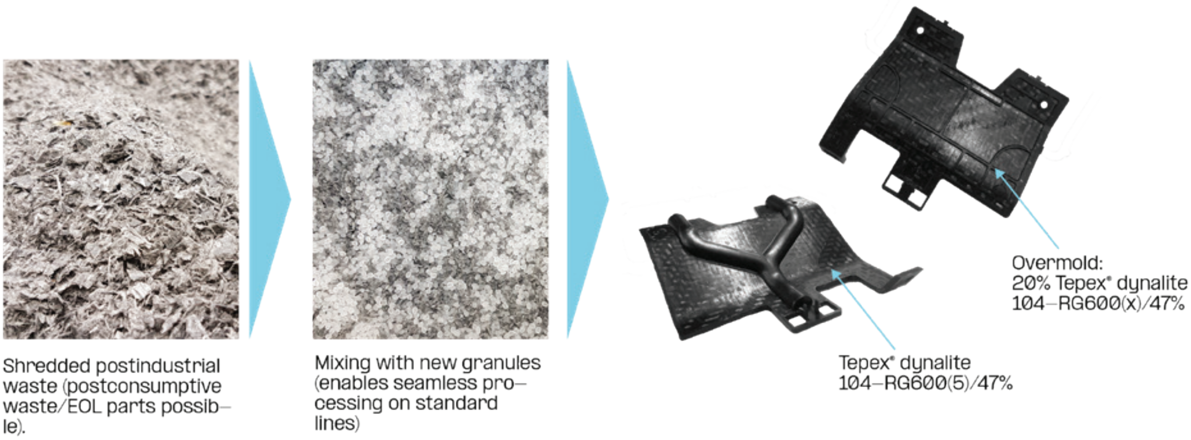
RECYCLABLE — MECHANICAL *AND MATERIAL*

A practical recycling concept already exists for industrial waste, primarily trim offcuts from Tepex® processing, in which the waste is ground up and then used for overmolding semi–finished sheets or could be used for conventional injection molding. Already today the process is used for the polypropylene (PP) and polyamide (PA) GF composites post–industrial waste. Fibers and matrix remain unseparated. The process was investigated and evaluated both economically and ecolo–gically for PP–GF composites as part of the ReproOrgano project.

Component manufacturers can also efficiently recycle their own production waste, and in some cases even end–of–life components, enabling a comprehensive material cycle to be realized.

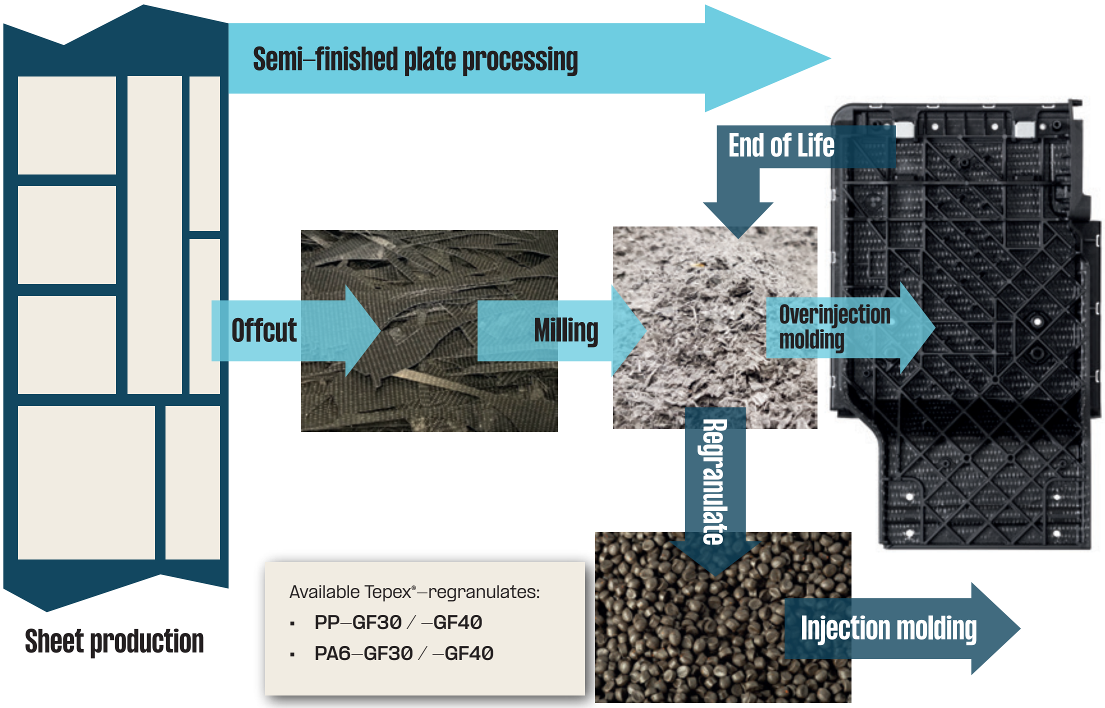
This has been shown by studies conducted by Bond–Laminates in cooperation with the Institute of Polymer Processing (KTP) at the University of Paderborn. Using a demonstrator – similar to a component from large–scale automotive pro–duction – it was proved that ground production waste is suitable for the injection molding of

functional elements. Market acceptance for such a process requires that processing can be carried out in existing ma–chines without significant adjustment of the operating mode. Trials prove that this is possible.



10) Ground material from production waste combined with new plastic granulate is suitable for injection molding.

Complex components can be manufactured in this way, such as the support for an automobile back seat bench, which at around 5 kg, would weigh only half as much as a comparable metal component. This avenue of thermoplastic recycling is advantageous over thermosets, because for thermoset composite systems, such as those produced with continuous fibers in a RTM (resin transfer molding) process, the most that could be considered is thermal recycling, e.g. in a cement kiln, but not mechanical recycling.



11) **Material recycling of ground trimmings from Tepex® processing in injection molding**

Essential prerequisites for economic recycling of "end–of–life" components are and remain:

– Organization and operation of a suitable return infrastructure

– Availability of components of the correct type after dismantling (if necessary, cleaning and removal of attachments or surface layers such as paint or foils)

– Continuous availability of material of consistent quality and quantity.

SUSTAINABILITY IN ACTION

The development of sustainable materials and resource–saving recycling models is an important part of Bond–Laminates' understanding of future requirements for lightweight materials. However, the processes used to manufacture Tepex® semi–finished products are just as important. That is why Bond–Laminates has certified itself in accordance with DIN EN ISO 140001 (environ–mental management) and 50001 (energy management). As a member of Operation Clean Sweep®, the company is also committed to preventing the loss of plastic granules, flakes, and powder and ensuring that these materials do not end up in the environment. The continuous improve–ment of internal processes to protect resources and our environment is a fundamental part of Bond–Laminates' self–image.

In addition to products and processes, people are an essential factor in any sustainability strategy – and this includes the employees of Bond–Laminates. It is not only important to take people with us on the journey to a sus–tainable future, but also to encourage personal initiative.

One example of how a company initiative has not only been accepted but also carried over into the private sphere is the offer of leased bicycles for employees, which is now used by around a third of all Bond–Laminates employees.

The bicycles can be purchased by employees at the end of the leasing period. This offer has also been taken up, so that even in the rather hilly Sauerland region, a process of rethinking sustainable mobility is undoubtedly underway. The leasing offer also includes e–bikes.

Another initiative was launched on the employees' own initiative: As part of a regional reforestation concept, a tree planting campaign was financed and carried out. With additional financial support from the company, employees helped plant around 1,500 young hornbeams and common oaks in the Brilon region in March 2022.

These should be less affected by heat and drought than the earlier tree population and thus safeguard the re–creational value and tourist appeal of the region in the long term. Due to prolonged drought, bark beetle infestation, and various storms, Brilon had previously lost around 40 percent of its forest area.

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