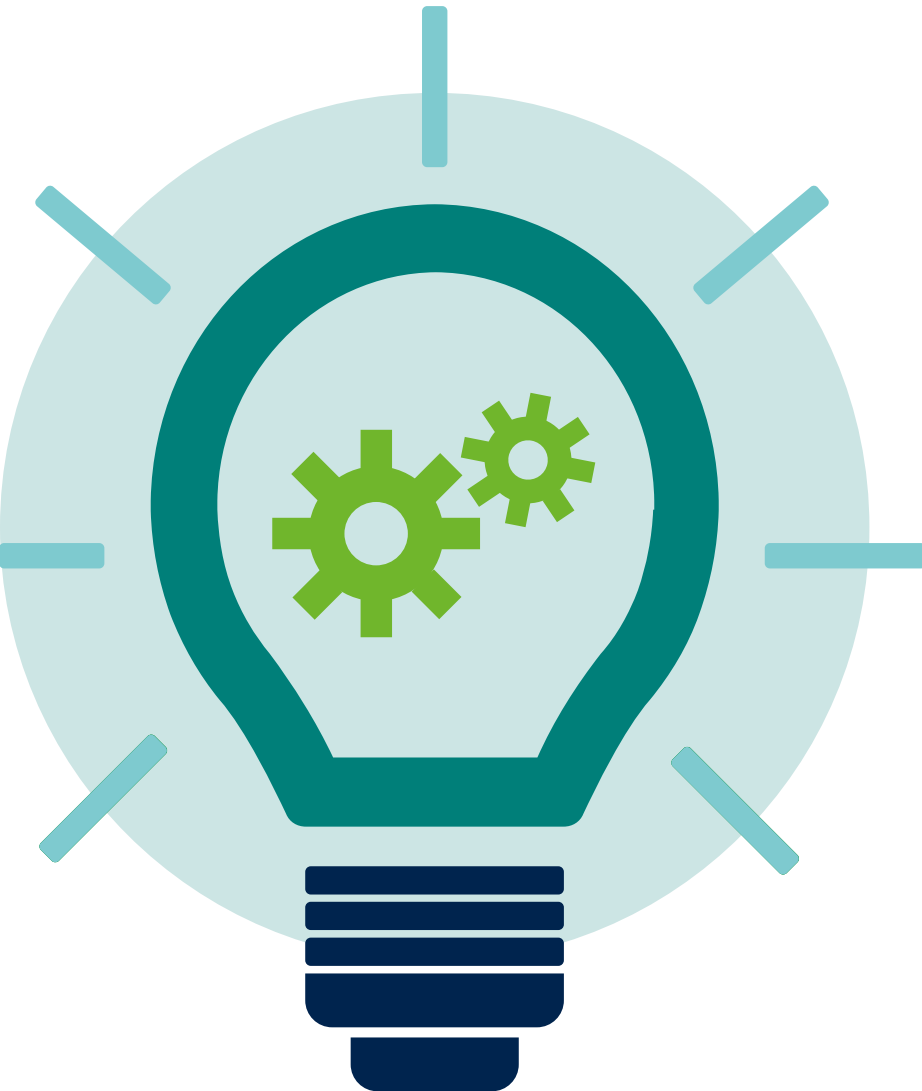


Bioeconomy in the automotive industry

Training on materials, technologies and demands



Discover – Develop – Connect

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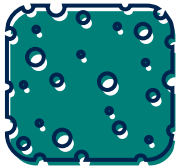


Content



Materials

- Status quo
- Important factors for sustainability



Foams

- Functions of foams
- Conventional foam materials
- Bio-based foams



Tires, rubber & lubricants

- Natural rubber from alternative sources
- Bio-based fillers
- Lubricants



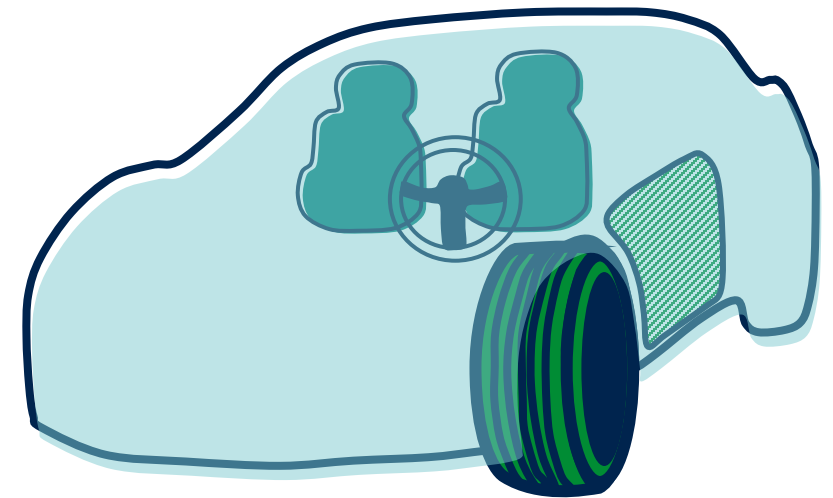
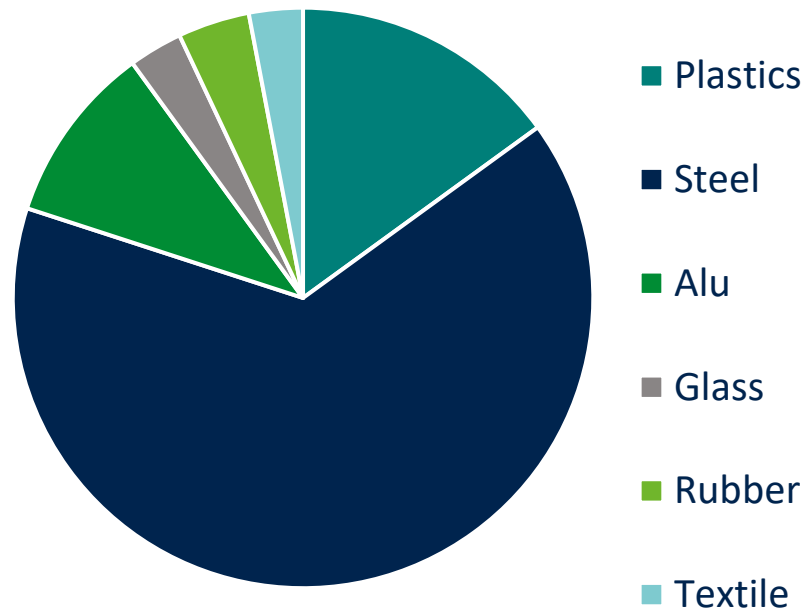
Interior materials

- Textiles
- Fiber-reinforced plastics



Status quo in the automotive industry

- The **automotive industry** uses a wide **variety of materials**, including **steel, plastics, aluminium, rubber, textiles and glass** (shown as a percentage by weight).
- Depending on their function and application, the materials must meet **high standards for mechanical, thermal and chemical resistance**.

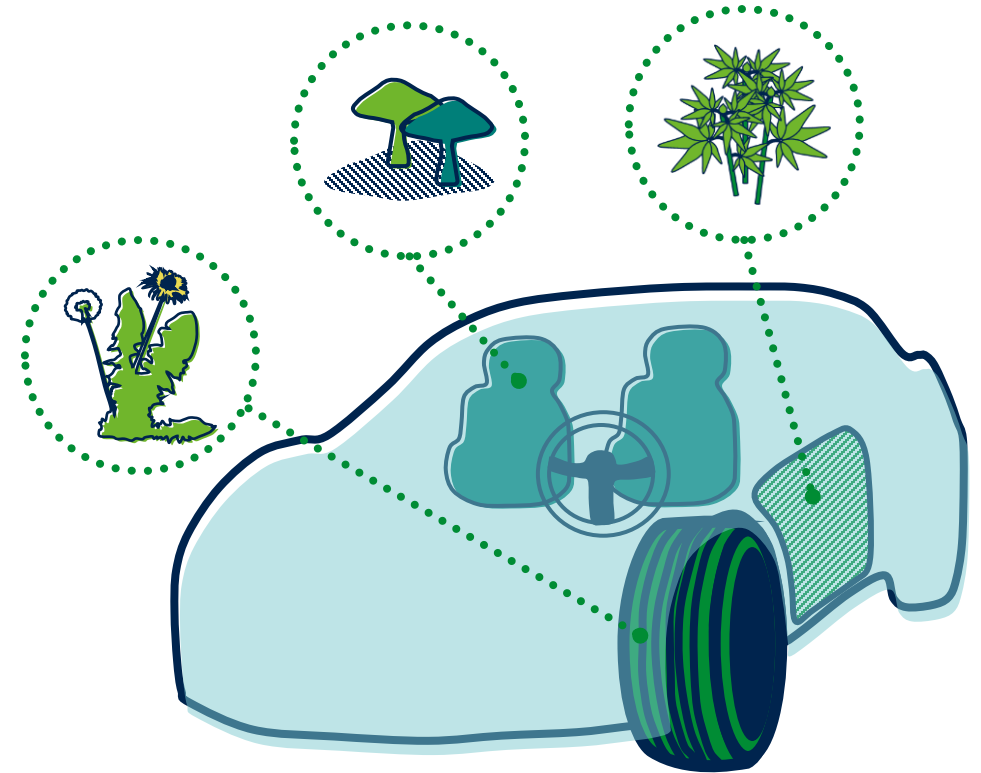




Typical materials in the automotive industry

- Despite the **strict requirements for physical, chemical and mechanical properties** in the automotive sector, there are numerous bioeconomic approaches aiming to reduce the use of fossil-based raw materials.
- **Plastics** constitute an important class of materials fulfilling diverse functions in the automotive sector.
- In line with the bioeconomy, they can be produced as **bio-based drop-in solutions, replaced by renewable alternatives or “programmed” for recycling.**

More information in the training on “Bioeconomy in the plastics industry”





Important factors for sustainability



Raw materials and energy requirements for production

- Excluding vehicle operation, CO₂ emissions in the automotive industry arise from the **selection of materials used**.
- **High energy consumption**, e.g., in the production of **steel and glass**, generates large amounts of CO₂ emissions.
- In addition, **long transportation distances** also have a negative impact on a material's carbon footprint.



Important factors for sustainability



Raw materials and energy requirements for production

- Excluding vehicle operation, CO₂ emissions in the automotive industry arise from the **selection of materials used**.
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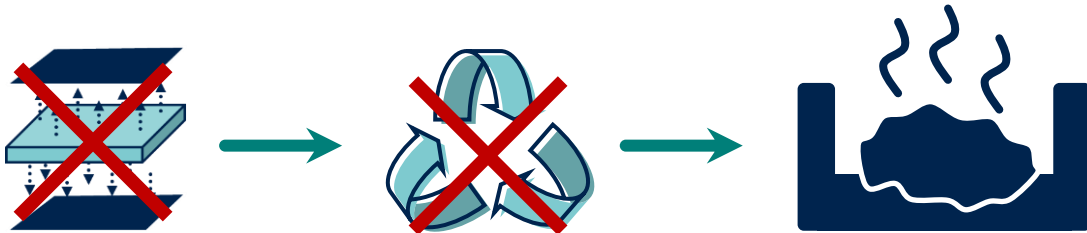


Dismantling, recyclability, and end-of-life

- Apart from consideration of the primary raw materials, the **recovery of raw materials** also plays an important role.
- Material recovery requires **low-energy, non-destructive methods for material separation and sorting**, as well as concepts for the modular dismantling of components.
- For closing material loops, concepts for the **collection and recycling of materials** are also important.



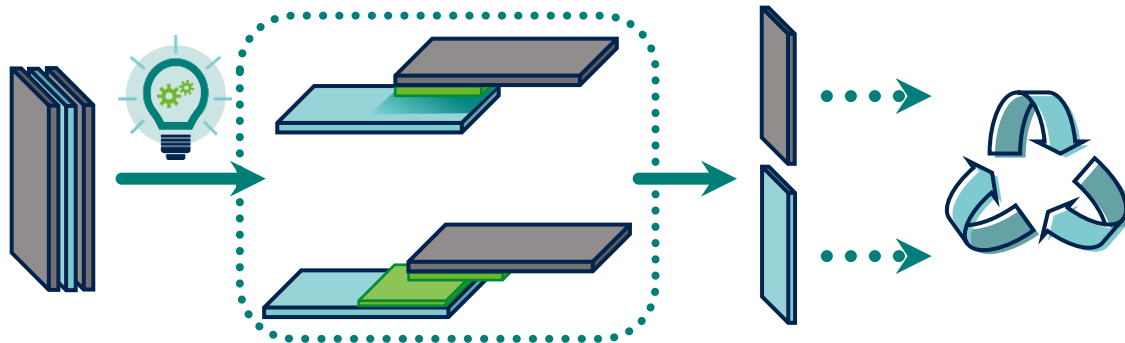
Programmed dismantling



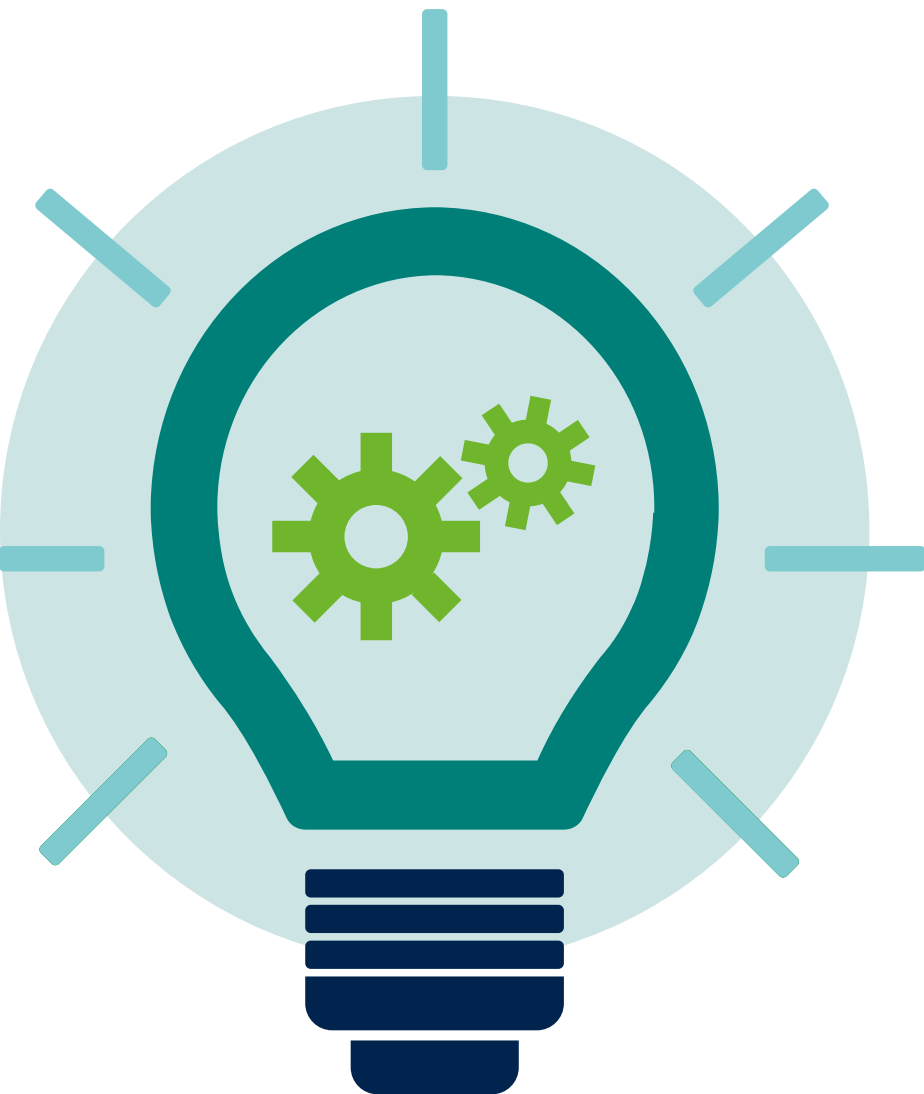
- Separating materials enables (single-type) reuse – heterogeneous **mixtures of materials are often sent to landfill.**
- **Composite materials and multi-component materials** are particularly challenging.
- Adhesive bonds are designed for **long lifespans** and are **not suitable for subsequent separation** of the materials.
- The separation of adhesive bonds usually results in residual **contamination and mechanical damage** to the material.



Programmed dismantling



- One approach to improving the **separation of composite materials** are **switchable adhesives**.
- This is based on **controlled adhesive failure**, which is triggered by activating a switch.
- A distinction is made between **adhesive failure** (between the adhesive layer and the material) and **cohesive failure** (within the adhesive layer).
- Controlled **“disassembly-on-demand”** can also be achieved using **bio-based adhesives** and **biological functional components**.



Foams

Functions & raw materials

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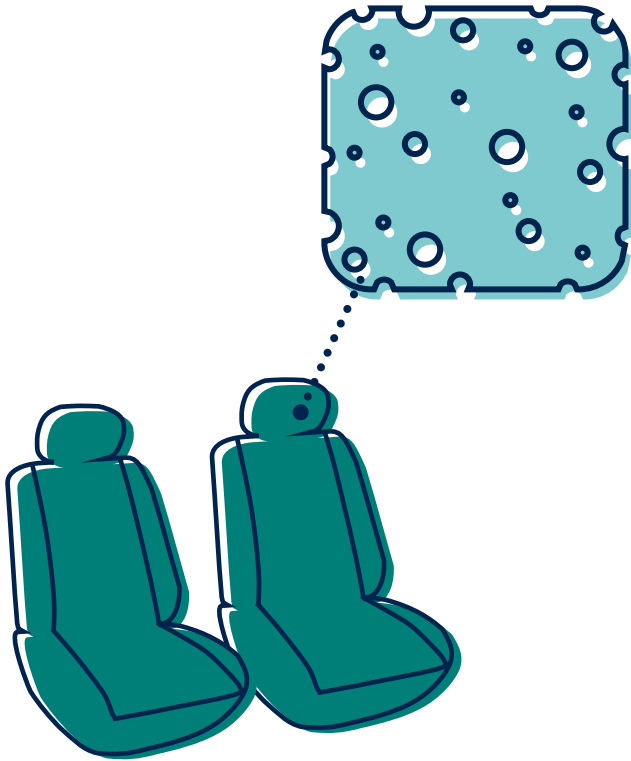
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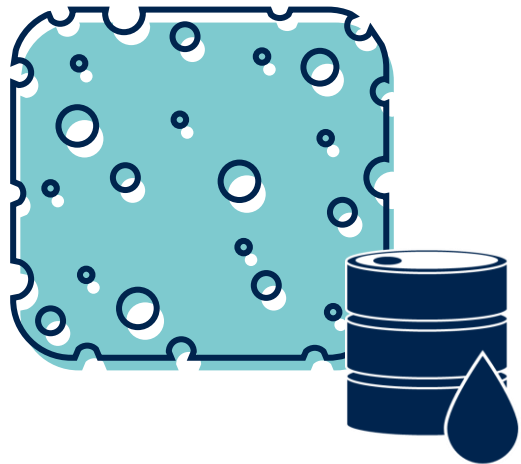
Functions of foams



- **Foams** are used in **various areas and applications** within the automotive sector.
- Particularly obvious is their use in **seating systems**: as **padding in seats, backrests and headrests** to provide comfort, structural support and stability.
- As **body protection**, they provide **rigidity and shock-absorbing crash performance** in body cavities.
- Their **acoustic insulation** properties make an important contribution to sound insulation (**external noise as well as structure-borne noise**) in the engine compartment, floor insulation layers, headliners and door frames.
- Depending on the required function, **different materials** are selected that meet the necessary requirements for **(compressive) strength, viscoelasticity, temperature resistance, thermal conductivity and sound absorption**.



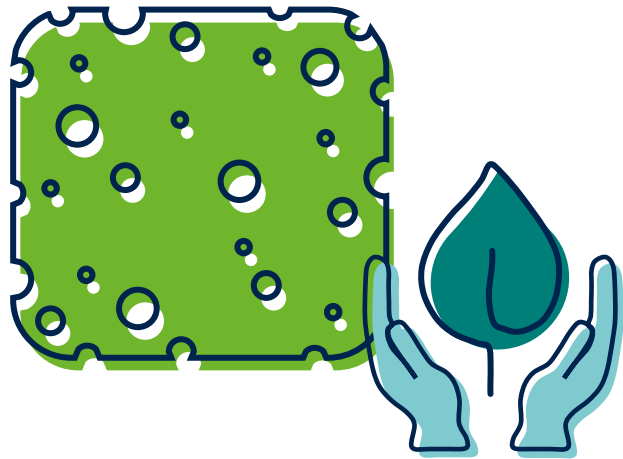
Conventional foam materials



- The foams commonly used in automotive manufacturing are based on **conventional petrochemical materials**.
- **Polyurethane (PU) foams** are the most common molecular type of foam. They are used both as **flexible foams in seats, armrests, headrests, door panels and the dashboard**, as well as in **rigid insulation for structural components**.
- **Polyethylene (PE) foams** have a closed-cell structure that provides high resistance toward water, chemicals and external influences. They are primarily used for **acoustic insulation and vibration control**.
- **Polypropylene (PP) foams** or expanded PP (EPP) are used in **structural components** such as bumpers, door and roof linings and cargo area reinforcement.



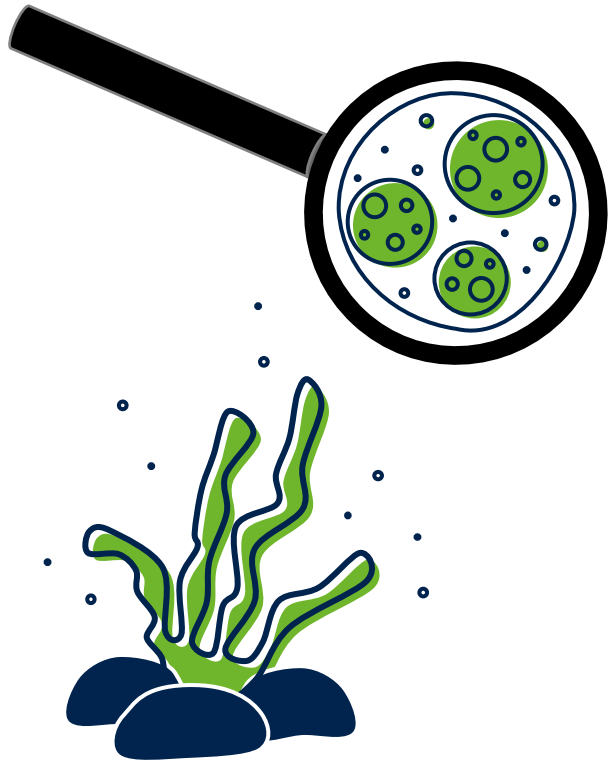
Bio-based foams



- **Bio-based foams** can serve as **drop-in solution**, meaning that chemically identical materials are produced from renewable raw materials and sources.
- Examples include **bio-PE made from ethylene** derived from **bio-ethanol** (produced by fermentation of plant-based sugars) and **PU based on bio-based polyols**.
- Current research is focused on **alternative bio-based foams** that can be used to replace fossil-based materials.
- **Examples of novel foams include lignin-based and wood foams** made from wood fibers, water and foaming agents.

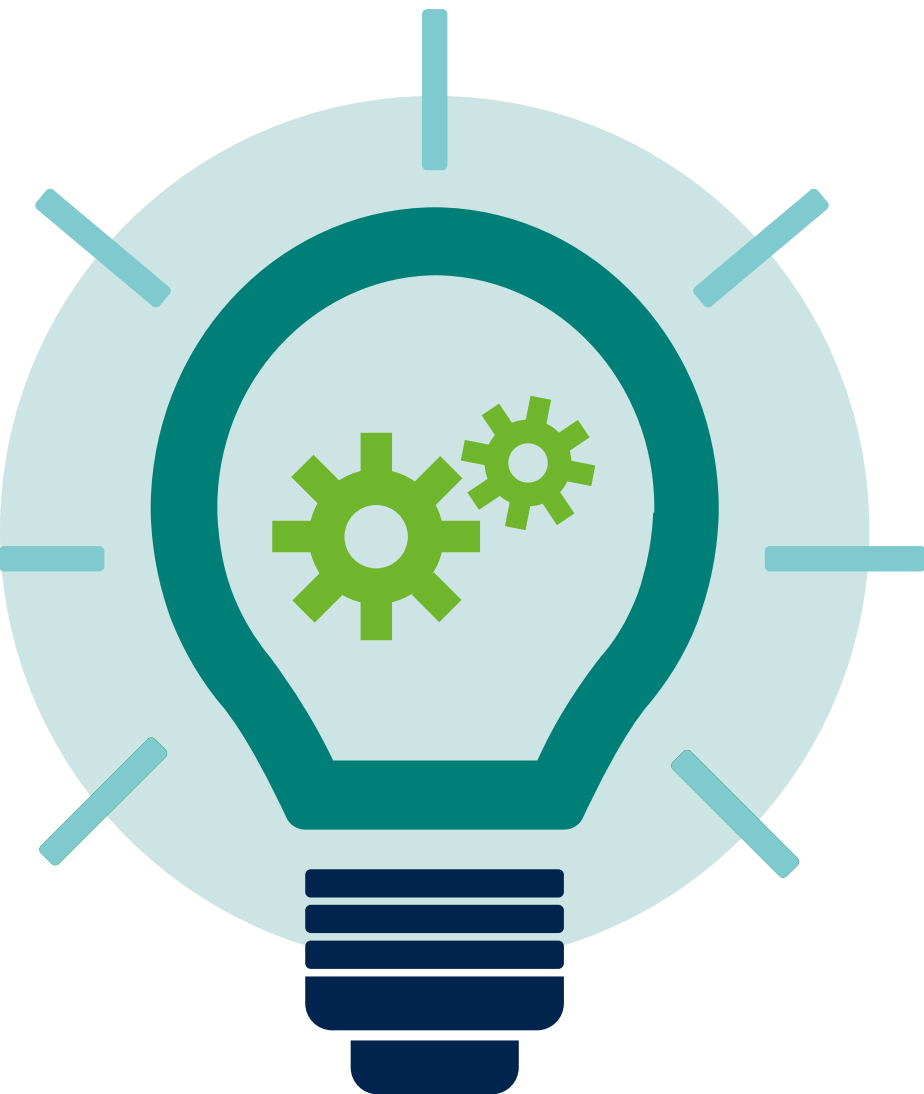


(Micro)Algae as raw material source



- Algae are emerging as an **interesting source of raw materials for the bioeconomy:**
- They grow rapidly, can be cultivated regardless of the season and **do not compete with land use and biomass production in the food industry.**
- During their growth, algae can **absorb and sequester significant amounts of CO₂.**
- Algae **contain or produce various classes of substances** that are suitable for the bio-based production of foams, among others:
 - **proteins** can be converted into functional **bio-based additives,**
 - **lipids/oils** can be turned into **polyols,** which are a **major component for PU foam synthesis,**
 - **carbohydrates** (mono-, di- and polysaccharides) are suited as raw materials for various **chemical building blocks** (functional molecules).

Tires, rubber & lubricants



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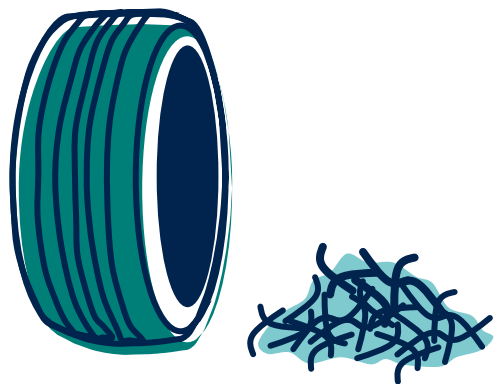
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Tires & rubber components



- Automotive components from rubber derive their performance-critical properties from the **blend of natural rubber with functional additives and fillers**.
- Many of these **powder- or fiber-based additives** are of fossil and petrochemical origin and therefore, require substitution with renewable materials.
- A successful example is the use of **microfibrillated cellulose** (derived from plant cellulose) as **reinforcing fibers in rubber membranes**, instead of conventional, fossil-based aramid fibers.
- **Peels and stones/seeds of various fruits** may also be suitable for use as **fillers, cross-linking agents, texturizing agents or reinforcing fibers**.
- A common **challenge is the difference in polarity** (hydrophilic/hydrophobic) of the matrix and additive materials, which can only be overcome through modification.



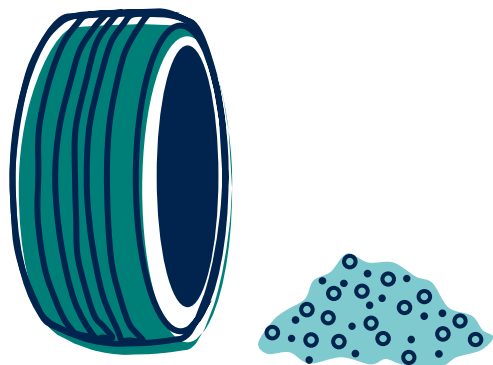
Natural rubber from alternative sources



- **Natural rubber** can be extracted from dandelions, particularly from the rubber-rich Russian dandelion (*Taraxacum kok-saghyz*).
- In a large-scale research project (Taraxagum), **Continental is participating as industrial partner**, to manufacture different types of tires from natural rubber extracted from dandelions.
- Unlike the rubber tree, which grows only in tropical climates, the dandelions are relatively **undemanding plants that can be cultivated in Europe or North America**. Thus, growth on fields near tire manufacturing plants with **short transportation distances** becomes conceivable.
- **Diversifying rubber sourcing** also helps to prevent further rainforest deforestation.
- Current research aims to increase the **proportion of rubber in the latex sap** of dandelion roots to further increase the yield per acre.



Bio-based fillers

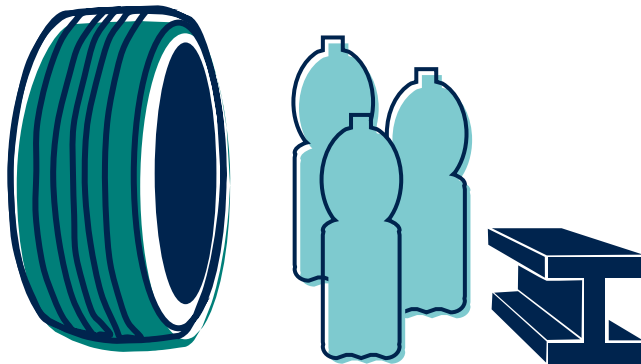


- **Silicates (silica)** are an **important component of car tires**, as they significantly **reduce rolling resistance**. This results in greater range and lower fuel consumption (combustion engine).
- Highly dispersed **silicon dioxide and silicic acid**, as used in tires, can also be obtained from **renewable sources** such as **rice husk ash (RHA)**.
- Rice husks are a biogenic **byproduct of the food industry** and consist of up to 20% silica. The extraction is **more energy-efficient and renewable** in comparison to extraction from quartz sand.
- **Biogenic silica** can also be obtained from the **skeletons of marine sponges and diatoms**.
- **Ground hemp shives** from industrial hemp are also suitable as **biogenic filler for rubber applications**. They can be used to replace carbon black or silica.



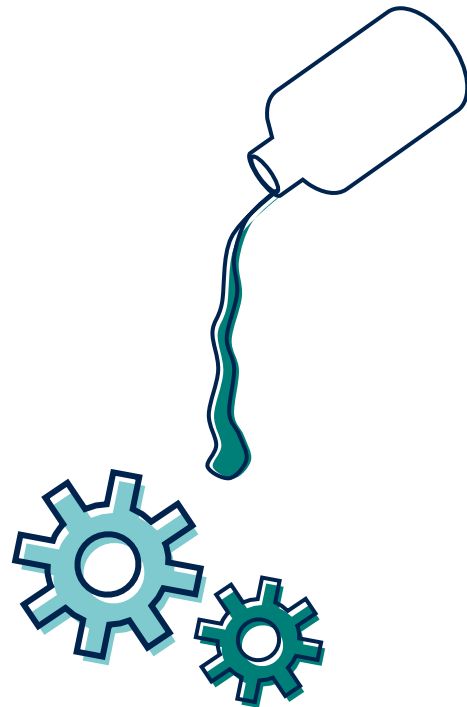
Approaches toward a circular economy

- **Textile fibers**, used as cord for reinforcement, are a key component of car tires. **Recycled PET bottles** are already being used to **produce technical PET fibers for tire manufacturing**.
- Finding a bio-based alternative to steel reinforcement in car tires is challenging due to the diverse and highly safety-critical properties that must be met. However, **steel is fundamentally suitable for recycling in closed-loop systems**.
- **Recycled rubber** is used in **relatively small proportions** in tire manufacturing, primarily because it is **not chemically identical to virgin rubber** prior to vulcanization.
- **Current research** is focused on largely **reversing the vulcanization process (the formation of a three-dimensional network)** in order to increase the potential proportion of recycled rubber and provide an **alternative to thermal recycling**.





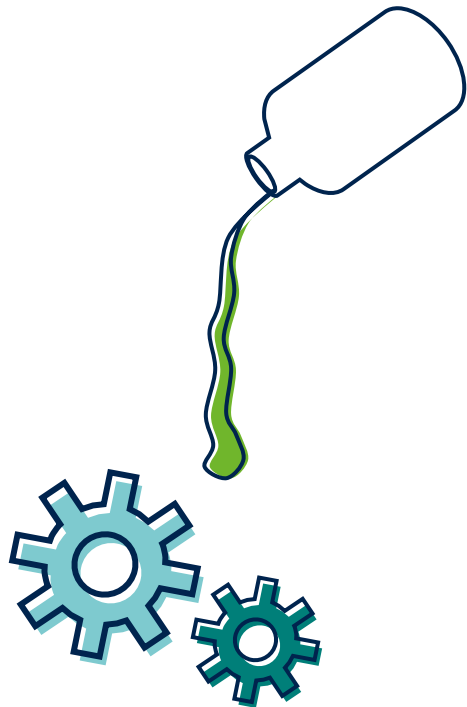
Lubricants



- **Lubricants fulfill various functions:**
 - reducing friction and damping vibrations,
 - sealing
 - and corrosion protection.
- They must be designed to withstand a wide range of stresses:
 - **mechanical** stress,
 - **chemical** influences from surrounding substances,
 - and **thermal** stress caused by heat transfer.
- The composition typically consists of a **base fluid and additives** for targeted, **application-specific functionalization.**
- Key physical properties of lubricants include their **viscosity** (and resulting rheological properties) and **density** as well as **flash, fire or ignition point.**



Bio-based lubricants



- For **bio-based lubricants**, both the **base fluid** and the **functional additives** can be addressed.
- **Plant oils, as a renewable raw material**, are suitable as a base fluid. Modifications to adjust specific physical properties can be carried out, e.g., enzymatically.
- Depending on the application, **aqueous systems** can also be used, whose **physical and thermal properties are modified by biopolymers**.
- High-performance **additives** account for **up to 15%** of a lubricant: known molecular structural motifs (e.g., functional groups) can also be found in **bio-based raw materials** or generated through **modification**.
- For example, **micro algae** can provide access to classes of substances (polysaccharides, proteins, fatty acids) that are of interest for **use as lubricant additives**: key parameters include the algal strain and cultivation conditions.



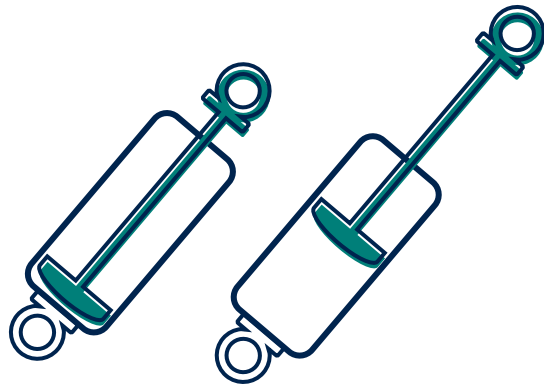
Grease



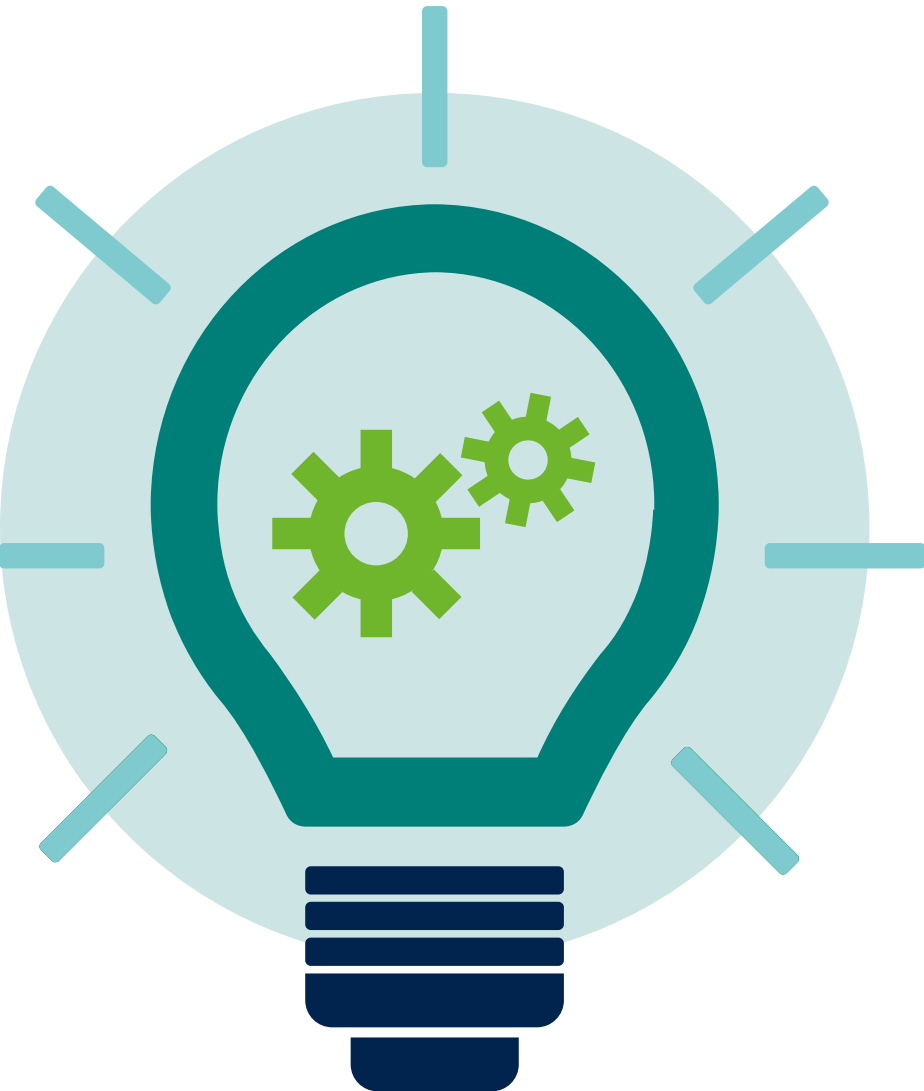
- **Greases** are used primarily for lubricating bearings and consist, in their basic composition, of a base oil mixed with a thickener and functional additives.
- **Conventionally, mineral** (e.g., paraffin oil) or **petrochemically produced** synthetic oils are used.
- **Vegetable/plant oils** such as rapeseed, sunflower, castor, olive, or soybean oil are being investigated as renewable, biological alternatives.
- Suitable **bio-based thickeners** include, for example, various bio-based polyesters, polyurea, or polyamides.
- In addition to the focus **on renewable resources, environmental compatibility** and, where applicable, **biodegradability** are also **important aspects for the sustainability** of lubricants.
- Apart from the individual components, it is important to investigate possible **interactions between the lubricant's components** (e.g., during aging).



Hydraulic fluids



- For **bio-based hydraulic fluids**, water may be used as the base fluid and combined with **functional components (additives) derived from renewable raw materials**.
- The use of **glycerin** (e.g., as a byproduct of biodiesel production from **vegetable oils**) and **chitosan** (derived from chitin, which is produced in particular in the fishing and insect farming industries) is promising, as these lead to high initial performance of the resulting fluid.
- **Targeted optimization of the necessary application properties** (e.g., shear stability, foaming behavior, wear protection) can be achieved, e.g., through **controlled reduction of the biopolymer chain lengths** (in this case, chitosan).
- Depending on the application, lubricants are **highly functional mixtures of various additives**, which is why the use of renewable raw materials requires individual blending and testing: **Biopolymers** are a promising **basis for the development of bio-based lubricants**.



Interior materials

Textiles & fiber-reinforced plastics

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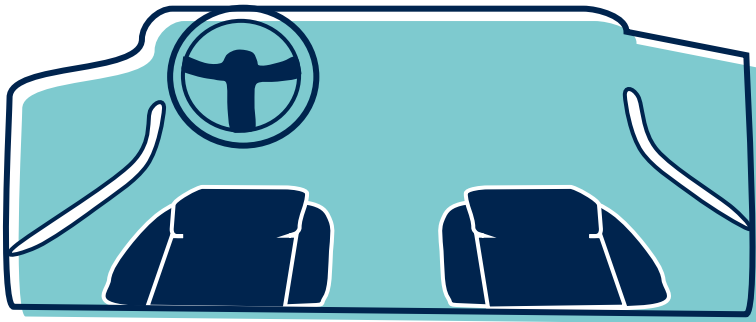


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Textiles in automotive

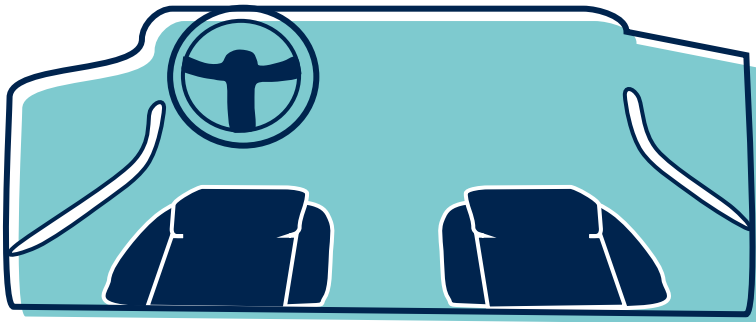
- **Technical textiles** perform a wide range of important functions in vehicles. A passenger car contains approximately **30–35 kg of textile material**.
- Some **textiles fulfill obvious functions**, such as in seats, floor mats, the headliner, and seat belts.
- Other functional textiles perform **“invisible” roles**, such as **filter and nonwoven materials** that ensure clean air inside the car, or the nylon bag in the airbag.
- **Typical requirements for the material include:**
 - high **strength** with low weight per unit area
 - abrasion resistance and **durability** under continuous use
 - processing via standard methods.
- In addition, **flame-retardant properties** or low flammability are often required.





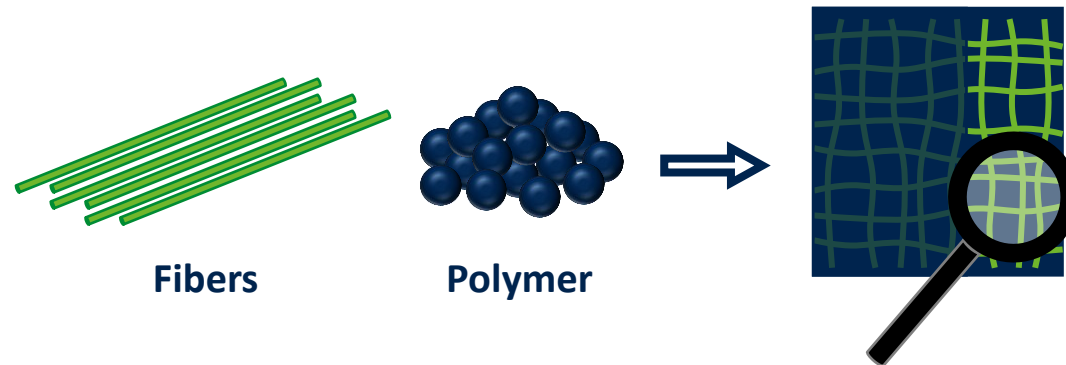
Textiles from renewable resources

- The increased **focus on mono-materials** serves as a supporting factor for **material recycling and the recovery** of raw materials.
- There is a growth in manufacturing of **polyester textiles** (e.g., seat covers, headliners) from **recycled PET** (e.g., from beverage bottles).
- **Natural fibers** (e.g., hemp, flax, or kenaf) have seen **little use in visible textiles** within the vehicle interior to date.
- The challenges here are the **high requirements for abrasion resistance and durability**, which lead to the use of synthetic polymer fabrics.
- **Leather** as an upholstery material is found exclusively in luxury interiors and is viewed controversially due to its animal origin.
- **Plant-based synthetic leather alternatives** (e.g., hemp or algae) are currently in product development as a robust, renewable, and aesthetic material for vehicle interiors (as seen at: revoltech GmbH)



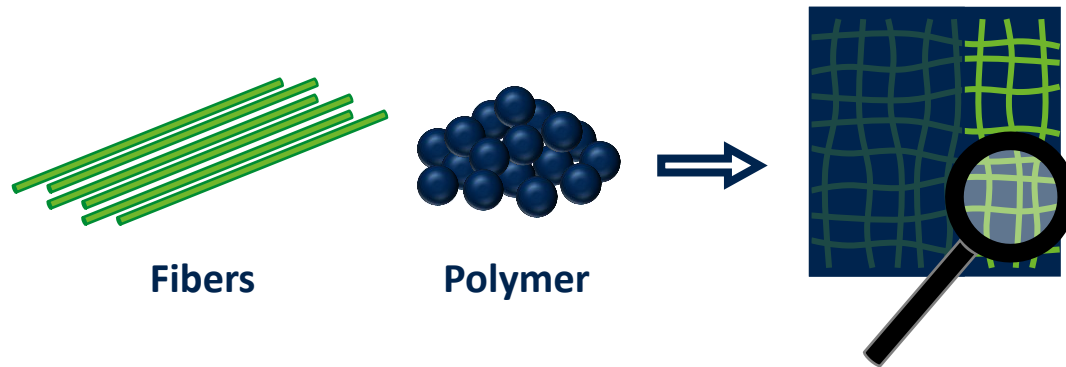


Fiber-reinforced plastics



- Plastics and polymers in general can be reinforced in terms of their **mechanical strength and stiffness**.
- Reinforcement is achieved by **embedding fibers in the polymer matrix** to create a composite material (FRC = *fiber-reinforced composite*).
- Typical fibers used in industrial applications are **carbon or glass fibers and polymer fibers** (e.g., aramid).

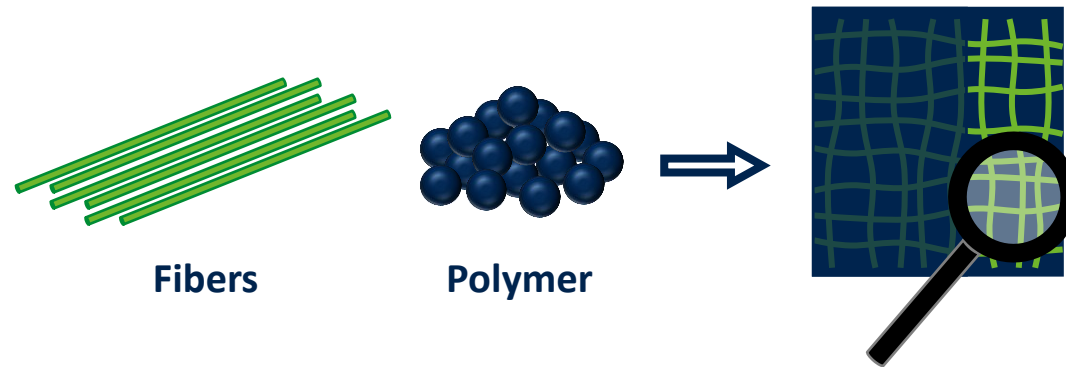
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- The fibers reinforce the material, while the polymer matrix holds them together, protects and **distributes mechanical stress**.
- Fiber-reinforced polymer composites are characterized by **high load-bearing capacity and mechanical strength** at low weight (good strength-to-weight ratio) and good durability.

Fiber-reinforced plastics



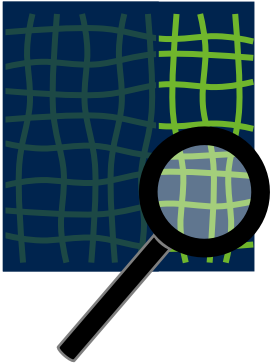
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- Fiber-reinforced polymer composites are characterized by **high load-bearing capacity and mechanical strength** at low weight (good strength-to-weight ratio) and good durability.
- **Natural fibers** are also suitable for use as reinforcements and fillers.
- **Typical applications** in the automotive industry include interior trim, such as door panels.

More information in our training on “fiber-reinforced plastics”



Sustainability of fiber-reinforced plastics



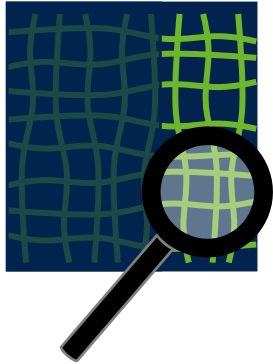
Critical aspects:

- The production of glass and carbon fibers requires **large amounts of energy** (generating **large amounts of CO₂**).
- The fibers and technical polymers are usually produced from **fossil raw materials**.
- The combination of fibers and polymer matrix (GFC, CFC) **cannot be recycled** and therefore ends up as growing amounts of **waste in landfills**.

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Sustainability of fiber-reinforced plastics



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Solutions & demands:

- **Alternative fibers** (e.g., renewable fibers = *NawaRo*) can partially replace GF and CF. Their **growth stores CO₂**, instead of releasing it.
- **Bioplastics** from **renewable resources** can be used in the polymer matrix as **substitution or drop-in solution**.
- New **recycling technologies** must enable **efficient separation of polymers and fibers** or be taken into account in the **design of materials**.



“The automotive industry embodies Germany's innovative spirit, prosperity, and industrial strength more than almost any other sector of the economy.”

Katherina Reiche,
Federal Minister of Economics



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Your contact and partner regarding
Bioeconomy in the automotive industry

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Institute of Biotechnology,
RWTH Aachen University

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Self-check

True or false? Evaluate the following statements based on the content from the recent chapter (solutions are presented on the following slide).

- (1) Adhesive bonds are particularly well-suited for recycling and the recovery of single-material streams.**
- (2) Lignin is a promising biopolymer that is suitable, e.g., for use as filler.
- (3) Natural fibers are widely established as a textile material for vehicle interiors.
- (4) Tires and rubber-based materials offer various opportunities for bio-based, bioeconomic solutions.





Self-check

True or false? Evaluate the following statements based on the content from the recent chapter (solutions are presented on the following slide).

(1) Adhesive bonds are particularly well-suited for recycling and the recovery of single-material streams.

False! Conventional material bonding makes it difficult to recycle materials by type and can often only be separated by damaging or contaminating the materials or by using a significant amount of energy. Current research is focused on reversible adhesive failure, which enables the controlled separation of materials and thus their return to material cycles.





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(2) **Lignin is a promising biopolymer that is suitable, e.g., for use as filler.**

True! In addition to its high availability, it possesses inherent chemical and physical properties that make it suitable for use as, e.g., a reinforcing agent or binder. A challenge is the heterogeneity of lignin, which requires purification processes of varying complexity depending on the application.





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False! Although there is a wide variety of plant-based fiber materials with different properties, they have so far been used primarily as reinforcements in plastic composites, such as in door panels. Due to the high requirements for abrasion and wear resistance, synthetic polymer fibers are predominantly used for textile coverings.





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- (4) Tires and rubber-based materials offer various opportunities for bio-based, bioeconomic solutions.**

True! Tires are made of a complex blend of different materials, with bioeconomic and innovative approaches focusing in particular on the origin of the rubber and functional additives used.





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