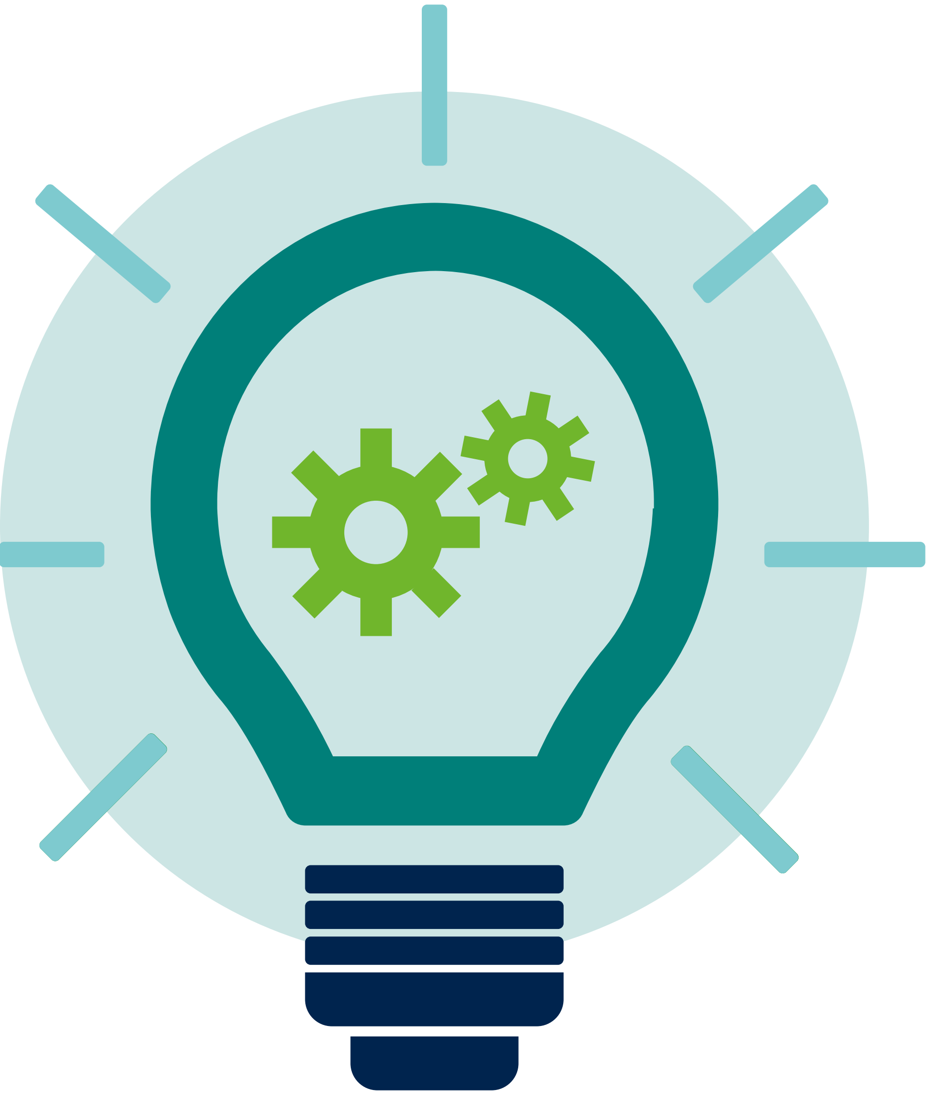
TransBiB
Boost. Industrial. Bioeconomy.



Bioeconomy in the construction industry

Training on materials, technologies and demands

Discover – Develop – Connect

Gefördert durch:

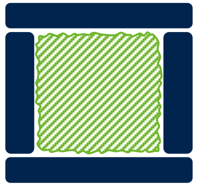
Bundesministerium für Wirtschaft und Energie

aufgrund eines Beschlusses des Deutschen Bundestages

Content

Construction industry

- Status quo
- Important factors for sustainability
- Strategies for sustainability



Insulation materials

- Renewable insulation materials
- Fire behavior and flame retardants
- Installation and ecology

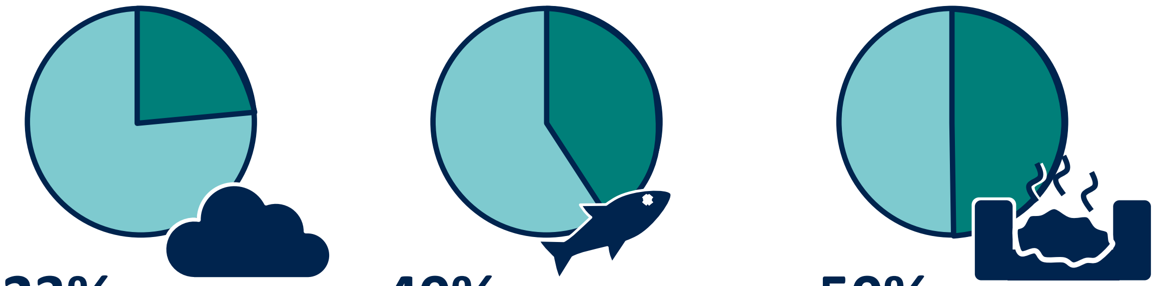
Finishes and coatings

- Switchable adhesives for improved recyclability
- Biobased functional coatings
- Material preservation and health

Outlook

Status quo in the construction industry

Globally, the construction industry is responsible for:



23%
Air pollution

40%
Water pollution

50%
Landfill waste

- **Cement production** consumes **fossil raw materials and large amounts of energy.**
- **Large quantities of CO_2** are released.
- **National Circular Economy Strategy (NKWS):** Per capita consumption of primary raw materials is to be reduced by **50% until 2045** (from 16 t to 6 – 8 t).

Typical building materials

- **Mineral raw materials** play a central role and account for the **largest share of primary raw material consumption** in Germany (e.g., sand, gravel, gypsum). Their consumption must be reduced and their recyclability increased.
- The production of different building materials varies significantly in terms of the **amount of energy required** and the resulting **CO_2 emissions.**
- **Natural building materials** are used in various forms (e.g., floor coverings, insulation materials, wallpaper, wall coverings, fiber plasters).
- Building with natural materials is **not a revolution, but often a renaissance** – materials such as wood, straw, and clay plaster have a long history of use.

Important factors for sustainability

Raw materials and energy requirements for production

Promotion of energy saving

Durability/lifespan of the building material

Dismantling, recyclability, and end-of-life

Important factors for sustainability

Raw materials and energy requirements for production

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Durability/lifespan of the building material

Dismantling, recyclability, and end-of-life

- The construction industry in particular uses many materials whose production requires **large amounts of energy.**
- As long as the source of **energy is not completely renewable,** the production of energy-intensive materials represents a significant contribution to the environmental impact of the construction industry.

Important factors for sustainability

Raw materials and energy requirements for production

Promotion of energy saving

Durability/lifespan of the building material

Dismantling, recyclability, and end-of-life

- Materials that ensure the **most efficient use or saving of energy** have a positive effect on CO_2 reduction.
- Materials that provide **good insulation against heat loss** while preventing buildings from overheating in summer are particularly important in this regard.

Important factors for sustainability

Raw materials and energy requirements for production

Promotion of energy saving

Durability/lifespan of the building material

Dismantling, recyclability, and end-of-life

- Long durability to conserve resources and **save energy and CO_2** is an important aspect of sustainability.
- Materials that were once considered "eternally durable" often are not, such as asbestos, while historic buildings made of materials we have little confidence in today still remain standing.
- At the **end of its life cycle,** durability is often synonymous with a **disposal problem.**

Important factors for sustainability

Raw materials and energy requirements for production

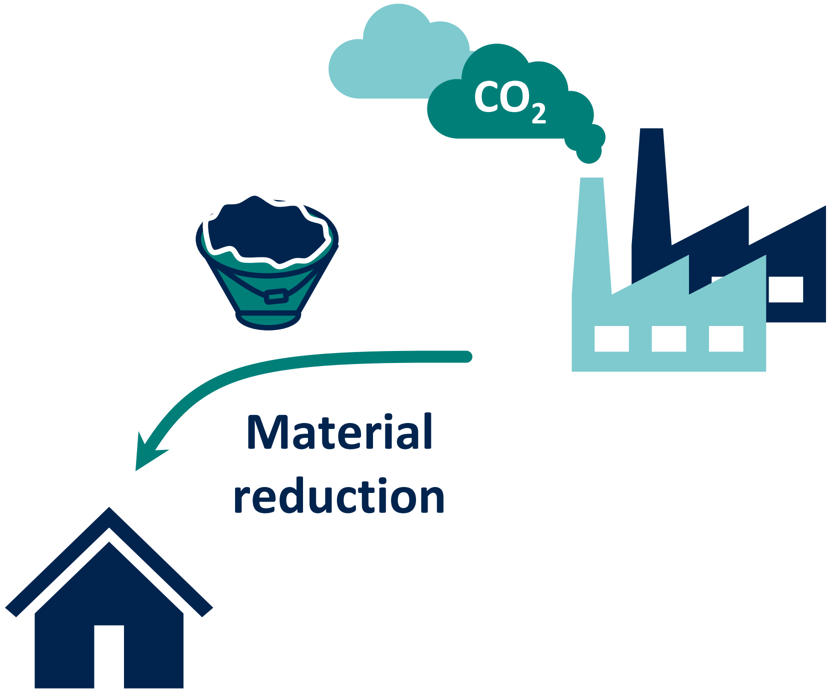
Promotion of energy saving

Durability/lifespan of the building material

Dismantling, recyclability, and end-of-life

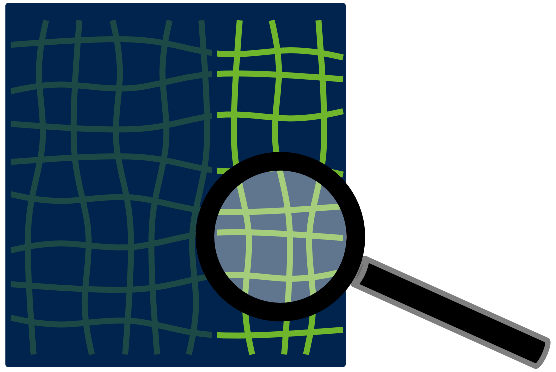
- Not all components can be easily **dismantled or separated into (unmixed) building materials** at the end of a building's life.
- Dismantling and separation are not only significant cost factors, but also usually determine the general fate of a building material: **composting, recycling, thermal utilization, landfill, or hazardous waste.**

Strategies for sustainability



- **Saving materials** can already lead to significantly improved sustainability in the construction sector.
- This is based on both the **principles of lightweight construction,** in which structures are designed to bear the highest possible load with low dead weight, and **material-optimized construction.**
- Monitoring the **structural health** of buildings, mechanisms for **self-healing materials,** and precise **analysis of actual loads** prevent excessive use of materials for safety reasons.

Lightweight construction

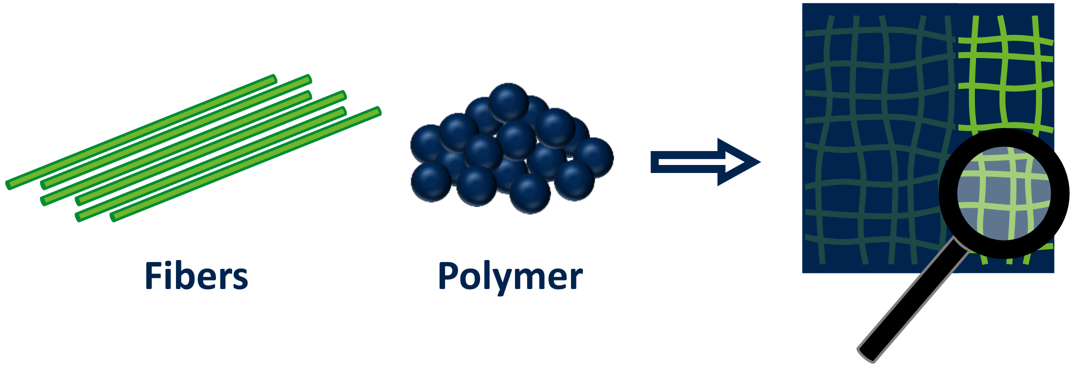


- **Lightweight construction** is associated with major industries:
  - **Automotive**
  - **Aerospace/aviationLuft- und Raumfahrt**
- **BUT** the construction industry already uses typical lightweight materials and structures.

Strategies:

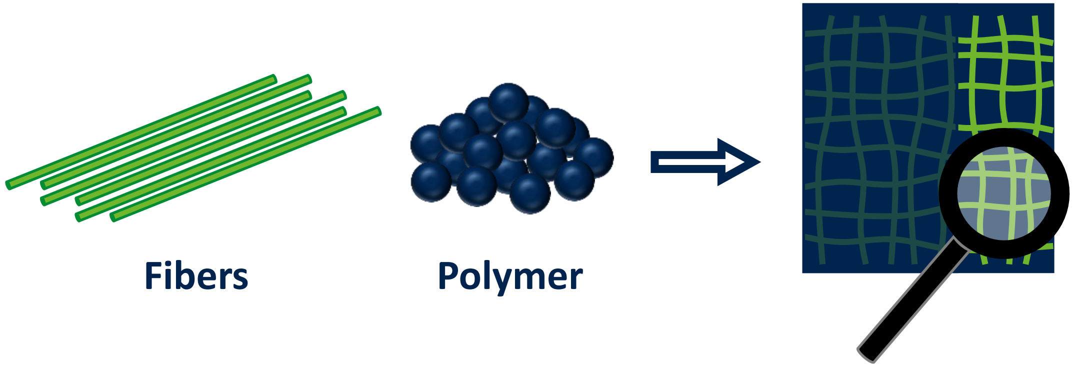
- **Material-optimized construction**
- **Savings in material per component**
- **Use of renewable raw materials**
- **Concepts for dismantling/recycling**

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 = *fibre-reinforced composite*).
- Typical fibers used in industrial applications are **carbon or glass fibers and polymer fibers** (e.g., aramid).

Fiber-reinforced plastics



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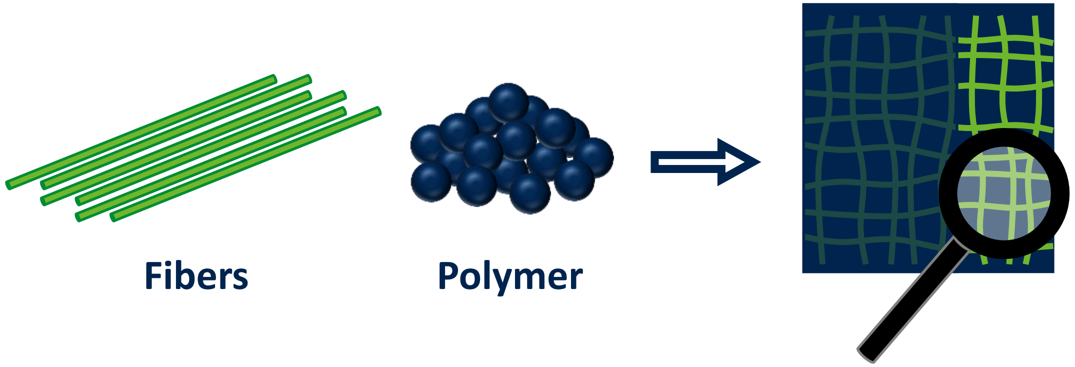
- The fibers reinforce the material, while the polymer matrix holds them together, protects and **distributes mechanical stress.**
- Fiber-reinforced polymer composites are characterized by **high load-baring capacity and mechanical strength** at low weight (good strength-to-weight ratio) and good durability.
- **Typical applications** are in automotive, aerospace, construction, and the sports industry, where **high material strength and low weight** are required simultaneously.

Fiber-reinforced plastics



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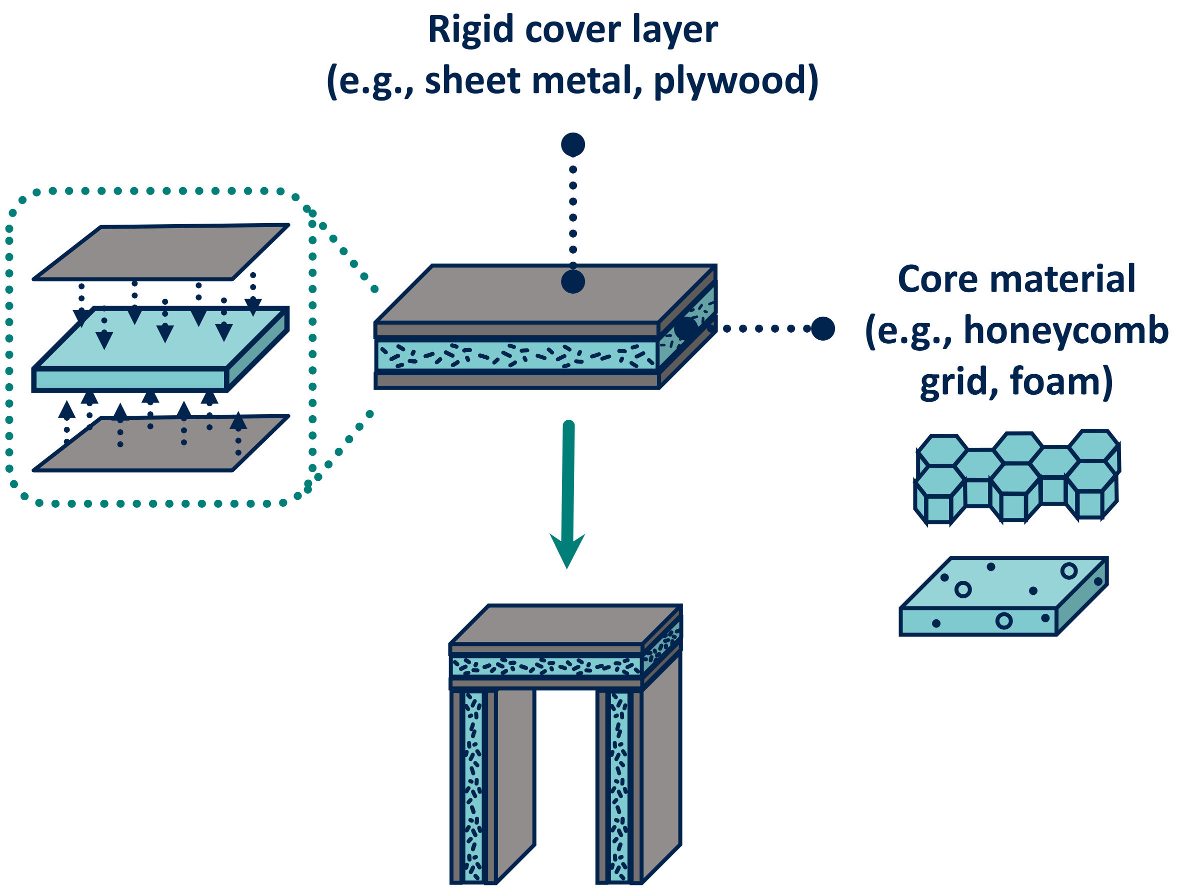
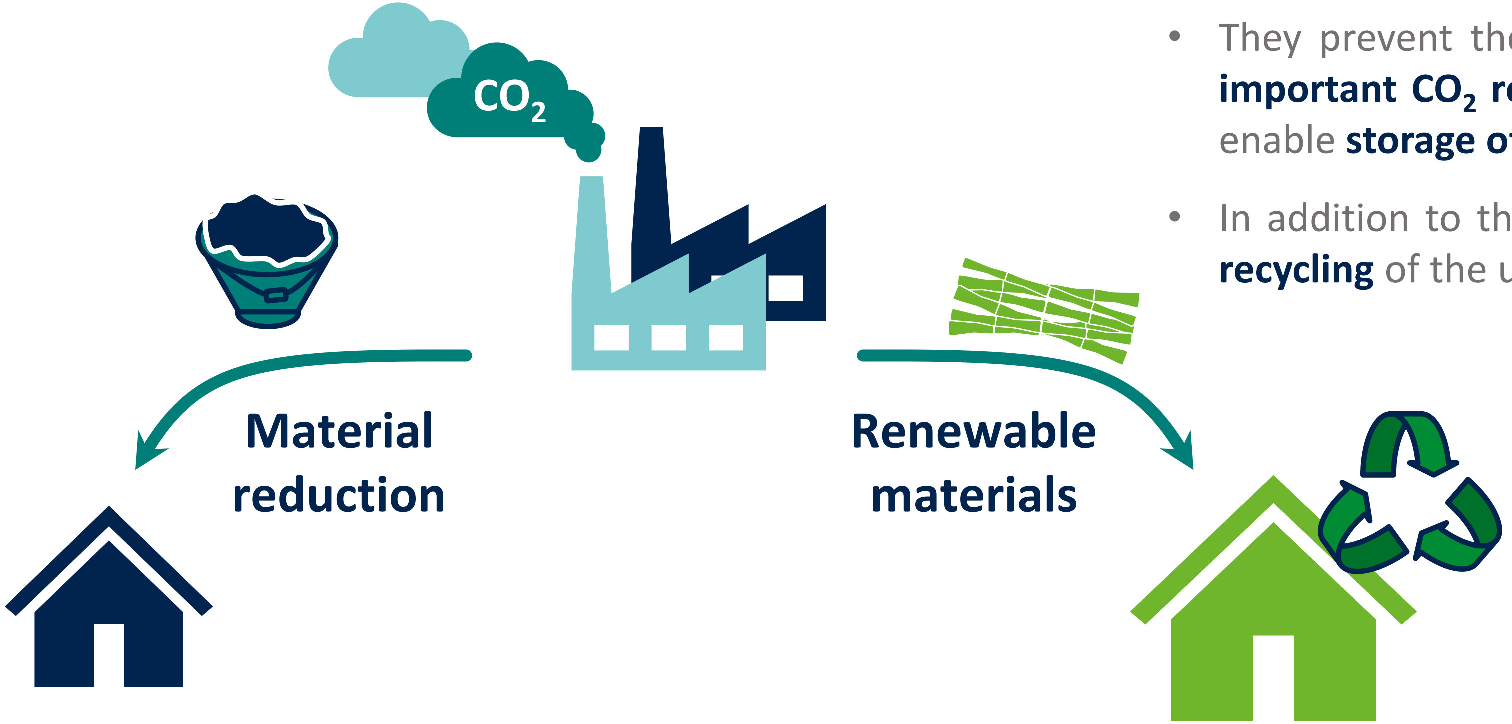
More information in the training on „fiber-reinforced plastics"

Sandwich construction



- **Sandwich elements** as semi-finished products or components consist of several layers: typically, the sequence is **cover layer – core – cover layer.**
- They have **high rigidity and strength** while being lightweight (**lightweight construction**).
- The **cover layers** are usually made of rigid materials and provide strength (e.g., sheet metal, fiber composites, or plywood).
- The core material provides **stability and load transfer** and can consist of a **honeycomb grid** (e.g., made of paper/cardboard, metal, plastic), foam (e.g., polyurethane, metal foam), or solid material (e.g., polyethylene, wood).

Strategies for sustainability



- The use of building materials based on **renewable resources,** such as "regrowing" raw materials (NawaRo), is an important **contribution to sustainability.**
- They prevent the consumption of finite resources and represent **important CO_2 reservoirs.** As building materials in particular, they enable **storage of CO_2 in long term.**
- In addition to the raw materials, concepts for the **dismantling or recycling** of the used materials are also important.

Sustainability of fiber-reinforced plastics

Critical aspects:

- The production of glass and carbon fibers requires **large amounts of energy** (generating **large amounts of CO_2**).
- 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.**

More information in the training on „fiber-reinforced plastics"

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Solutions & demands:

- **Alternative fibers** (e.g,. renewable fibers = *NawaRo*) can partially replace GF and CF. Theis **growth stores CO_2**, 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.**

Sustainability of sandwich construction

Critical aspects:

- Polymer foams (polyurethanes) are generally produced from fossil raw materials.
- The adhesive bonding of the different materials is usually **not recyclable.** Sandwich elements and composite materials are therefore sent to **landfill** or only used in **thermal recycling.**
- Contamination due to the separation of cover layers and cores that are **not sorted by type prevents the recycling of valuable raw materials** such as steel.

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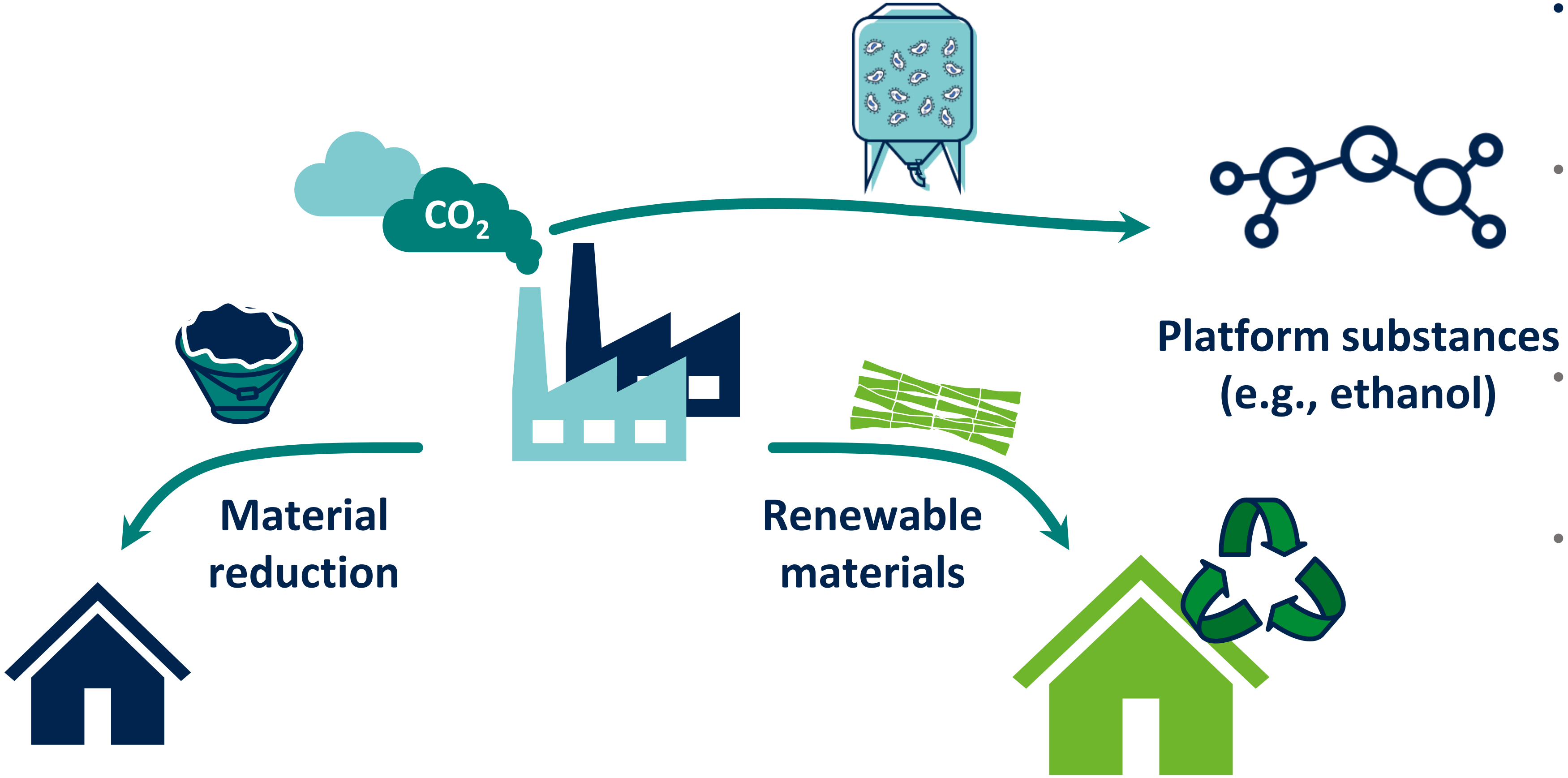
Solutions & demands:

- **Alternative core materials** can be used in sandwich panels – **renewable materials or side streams** from paper production and agriculture are suitable.
- **Recyclable materials for the cover layers** reduce the consumption of primary raw materials.
- Technologies for the **programmed separation of different materials** enable more efficient recycling (example: switchable adhesives).

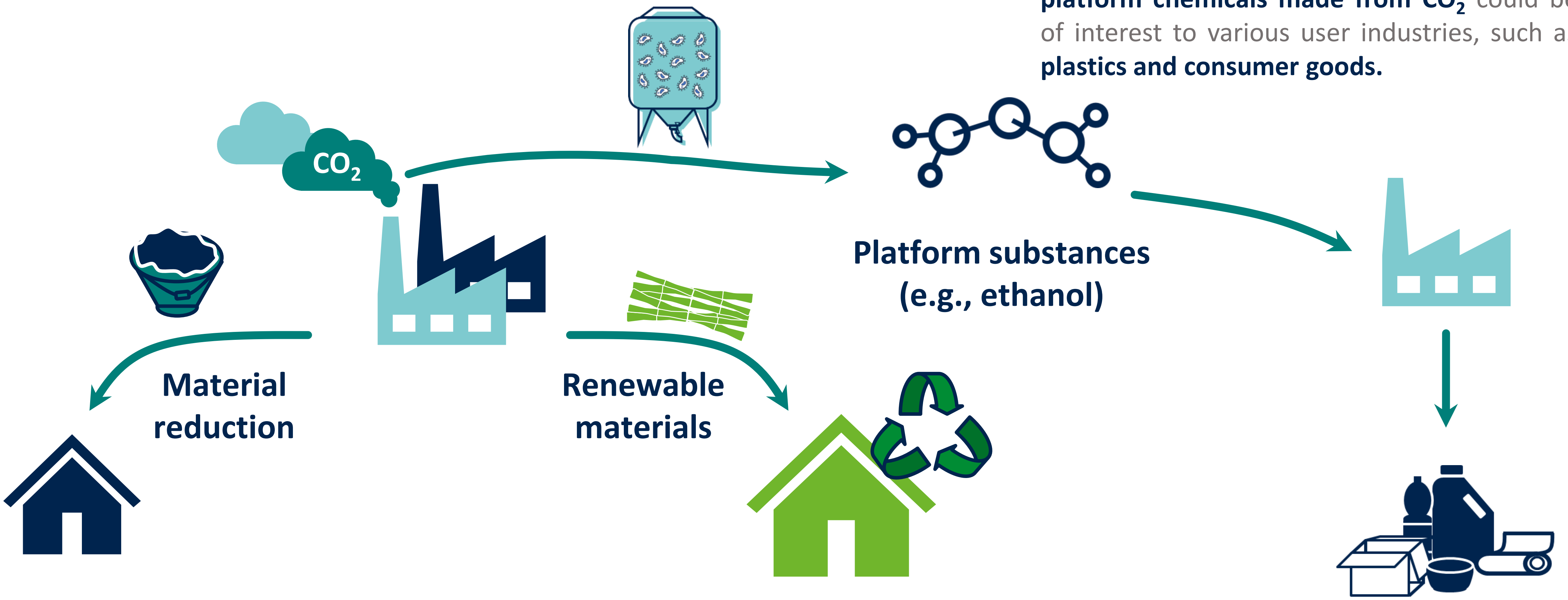
Strategies for sustainability



- **CO_2** can be understood **not only as a harmful greenhouse gas**, but also as a **raw material.**
- Biotechnological and chemical-catalytic research is focusing on the **conversion of CO_2 into useful platform substances.**
- Short-chain **hydrocarbons such as methanol and ethanol** are accessible.
- The main limiting factor is the **high energy requirement;** hydrogen must be generated to produce hydrocarbons.

Strategies for sustainability

- Once the problems of affordable and green energy and hydrogen have been solved, **platform chemicals made from CO_2** could be of interest to various user industries, such as **plastics and consumer goods.**



Insulation materials

Properties, materials and assessment

Discover – Develop – Connect

Gefördert durch:

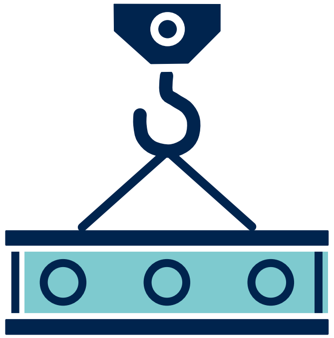
Bundesministerium
für Wirtschaft
und Energie

aufgrund eines Beschlusses
des Deutschen Bundestages

Good reasons to start bioeconomy with insulation materials

Low structural strength requirements

- Insulation materials are **not load-bearing** materials or structures in construction.
- The required **properties are easier to fulfill** than for load-bearing structures.



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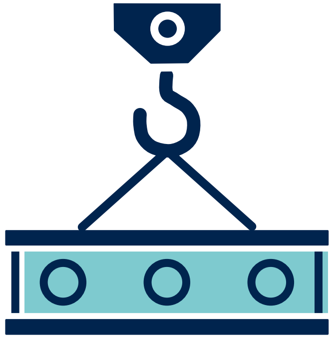

Variety of possible materials

- Unlike other building materials, there are many **different renewable and bio-based substitute materials available** for insulation, which means they are readily available.
- Usually, complete **information on their performance characteristics** is already available, for example with regard to their thermal and acoustic insulation properties.

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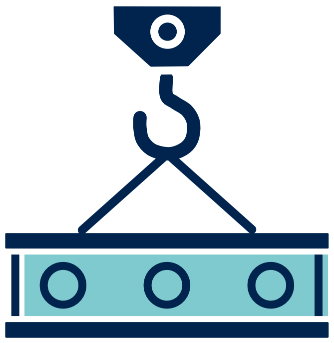

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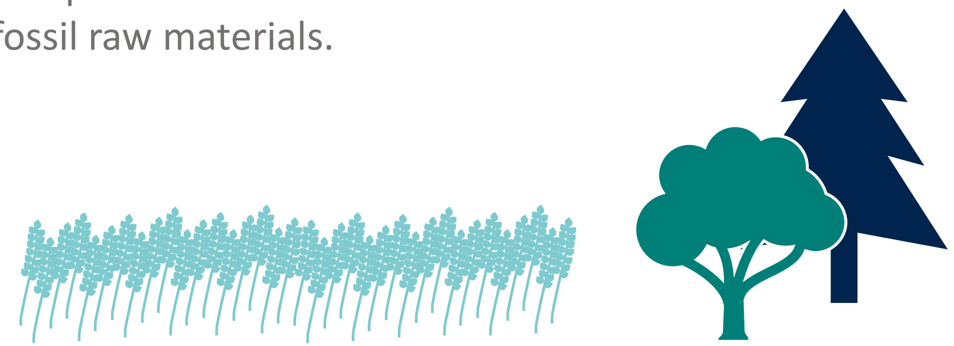
Steadily increasing market acceptance and customer demand

- Sustainability awareness has grown steadily in recent years, thus, builders actively **seek for alternative materials.**
- Bio-based materials are associated with a **positive impact on indoor climate and health.**
- **Public funding** has not only driven research and development in this area, but also rewards the use of these materials.

Renewable insulation materials

- Renewable raw materials (German: *NawaRo*) refer to **agricultural or forestry products** that are available again and again after they have been used.
- These insulation materials are therefore **renewable products** of plant or animal origin.
- A distinction is made between **annual** raw materials, e.g., hemp or straw, and **perennial** raw materials such as wood.
- Their share (sales volume) in 2019 was still only 9%, compared to 43% for mineral raw materials and 48% for fossil raw materials.



[1] FNR Pressemitteilung.

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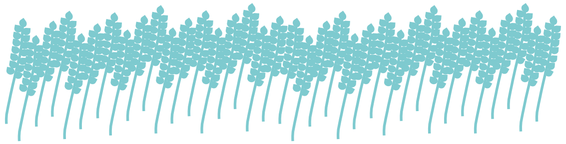

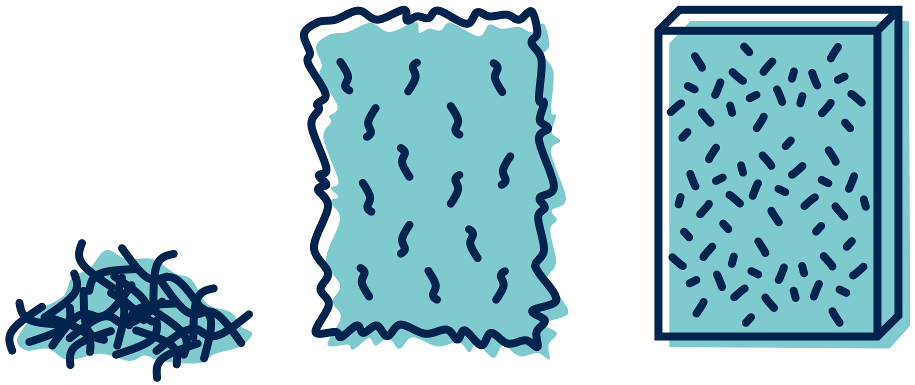

- Since some products contain additives to protect them against moisture, pests or fire, they are only referred to as **“natural” insulation materials** if the **proportion of synthetic additives does not exceed 25%.**
- Renewable insulation is suitable for both **new buildings** and **renovations of existing buildings** (old buildings).
- It can be used in **different types of insulation:** mats/boards, blow-in and loose-fill insulation, composite thermal insulation systems.

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Fire behavior

Classification	Description
A1*	Non-flammable
A2*	Non-flammable
B1	Hardly flammable
B2	Normally flammable
B3**	Highly flammable

***A1:** Building materials that do not contain any combustible components (e.g., concrete)
A2: Building materials that are not combustible themselves but contain combustible components
**Insulation materials of this classification must not be used

A classification of A2, B1 is desirable for building materials based on renewable raw materials.

- Insulation materials are tested and classified according to **DIN 4102 or DIN EN 13501** (European level).
- It is important to distinguish between the fire behavior of an untreated, **pure insulation material** and that of a **treated insulation material** (e.g., through coating, flame retardants, charring, adhesives).
- In the case of composite materials, the **entire composite must be tested.**

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Categorization can be challenging when it comes to **renewable raw materials** and the use of biogenic materials – here, the **properties are often more divers** than with synthetic materials.

Fire behavior of different insulation materials

	Insulation material	Thickness [mm]	Classification
Mineral	Foam glass (sheets)	180	A1
	Glass wool (rolls)	160	A1
	Rock wool (rolls)	180	A1, A2
Plastic-based	Polyurethane (PUR) (sheets)	140	B1, B2
	Polystyrene (EPS/XPS) (sheets)	160	B1, B2
Renewable raw material	Wood fibers (sheets)	180	B2
	Cork (sheets)	180	B1, B2
	Cellulose (sheets)	180	B2
	Flax (mats)	180	B2
	Hemp (mats)	80	B2
	Sheep wool (mats)	200	B2

- Insulation materials based on **renewable raw materials** only meet the **lowest approved building material class:**
- The use of **flame retardants** or technological solutions to **improve fire protection** is therefore necessary.
- Common additives are **natural salts** such as soda or boron salt.

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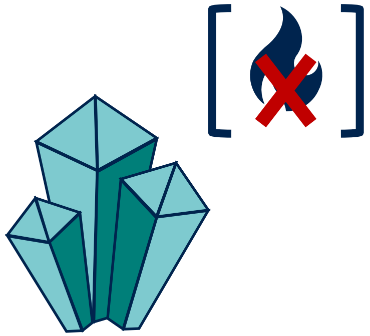
BUT:

- The best building material class is achieved **exclusively by mineral insulation materials.**
- Renewable, “natural” insulation materials often have **more predictable fire behavior.**
- They produce **less toxic smoke gases** in the event of a fire.

Bio-based flame retardant

- **Halogenated flame retardants** (brominated or chlorinated compounds), which stop the chain reaction of combustion, are already **partially banned or restricted** in their use due to their **toxicity** to humans and the environment and their **long-term/bioaccumulation.**
- **Halogen-free flame retardants** often use the mechanism of fire inhibition by forming a **layer of ash.**
- **Inorganic salts and minerals** can release water or promote the formation of ash. They have **low environmental persistence and toxicity.**



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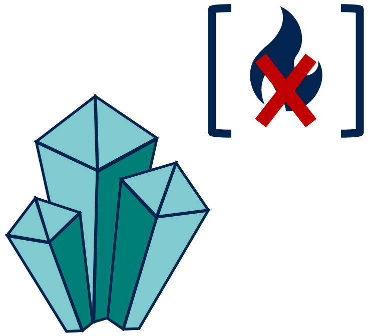
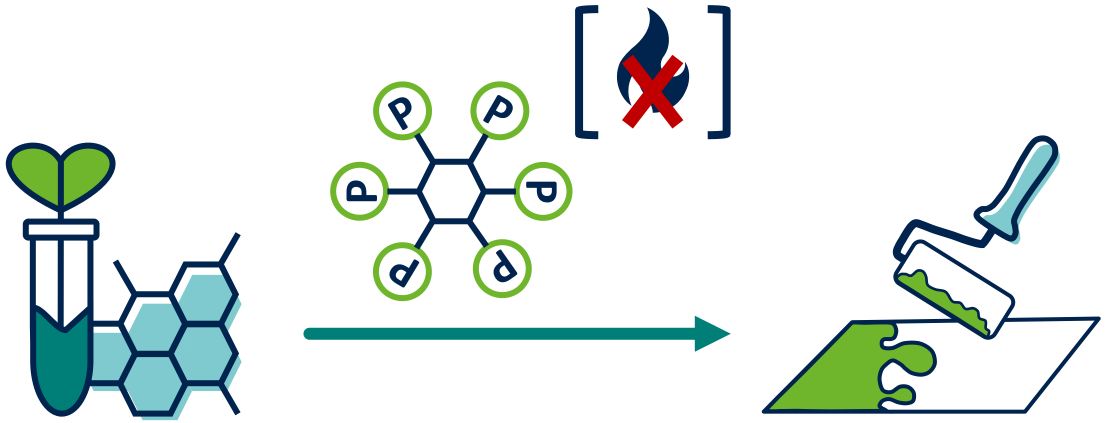
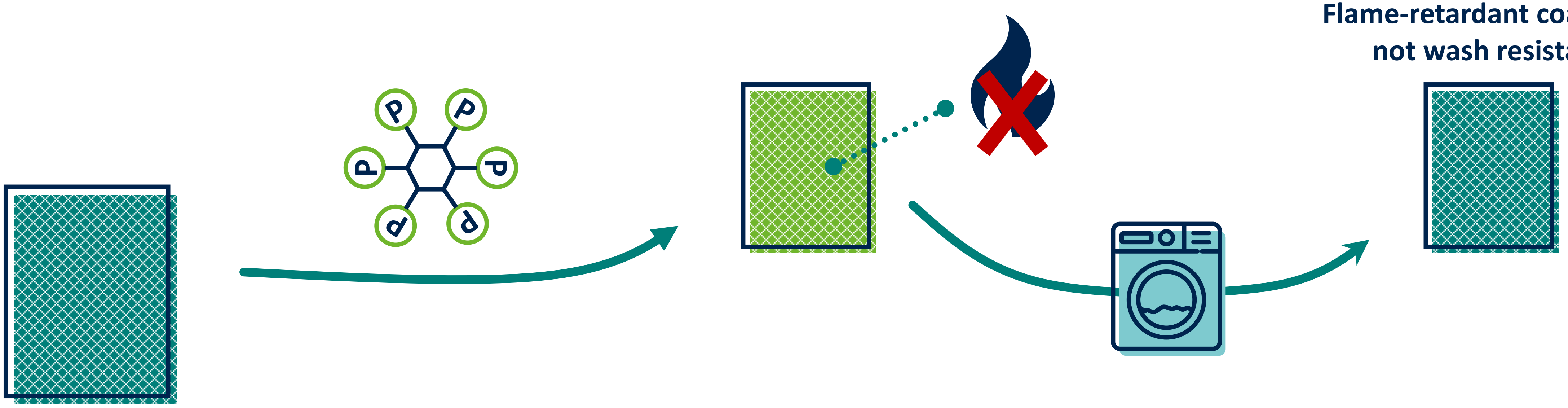




- A **high proportion of phosphorus atoms** is typical of the molecular structure of other halogen-free alternatives.
- Suitable **phosphorus-containing compounds** can be found **in nature,** e.g., **phytic acid,** which can be extracted from legumes and grains (e.g., rice husks).
- **Tannic acid** (polyphenol) can also be used as a **biological flame retardant** and is found in various plants.

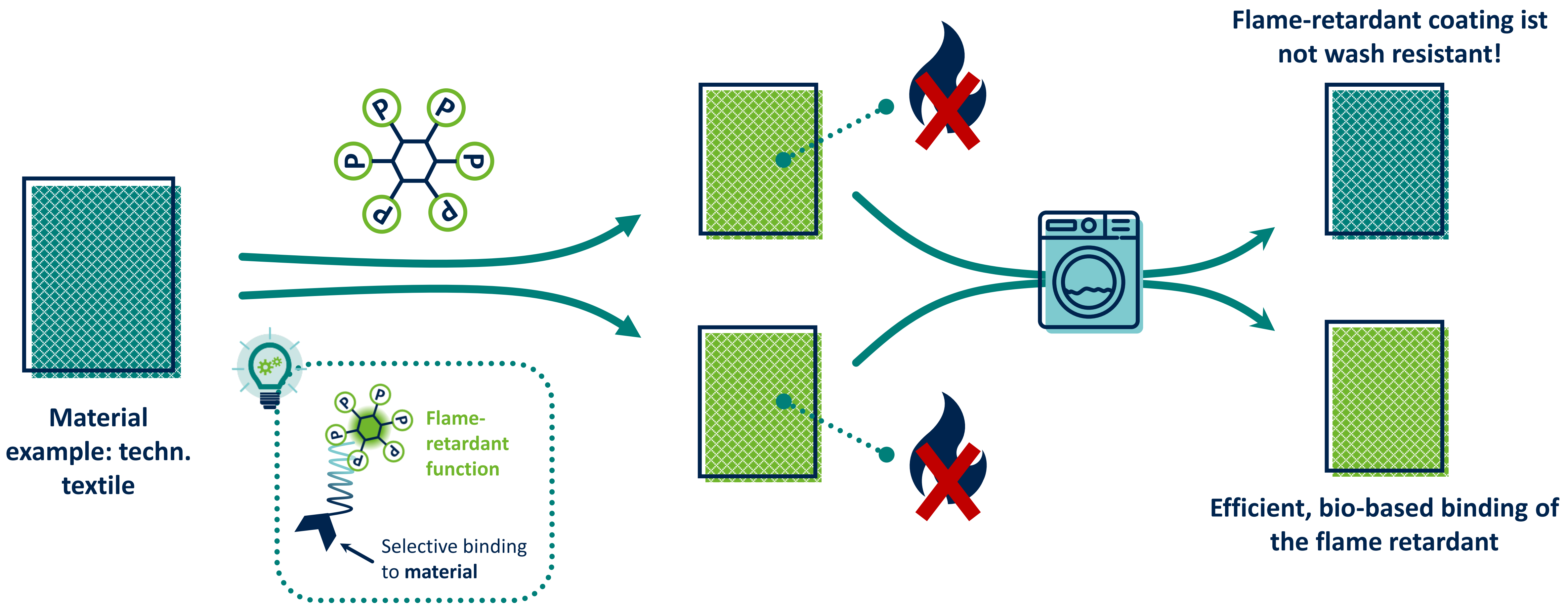
Use Case: Binding of flame retardants

Flame-retardant coating ist not wash resistant!



Material example: techn. textile

Use Case: Binding of flame retardants



Installation of renewable insulation materials

- **Renewable insulation materials** are more **skin-friendly** to work with than conventional insulation materials such as glass wool.
- Processing and installation can be carried out using **standard tools,** meaning that **no new machines** need to be purchased.
- As with conventional insulation materials, **blow-in insulation** can cause dust to form.
- Blown-in insulation must *always* be installed by trained and certified specialists.*

*According to general building approval by the German Institute for Building Technology (independent of material)

Ecology of renewable insulation materials

- There is **no generally applicable test mark** for insulation materials to classify them as "ecological."
- The following labels exemplarily indicate products that are **environmentally friendly and harmless to health, as well as their origin and suitability for recycling:**

natureplus: Products consist of at least 85% renewable or mineral raw materials. They have been tested for their **environmental and health relevance** throughout their **entire life cycle.**

FSC „Forest Stewardship Council": Products originate from **forestry that adheres to ecological and social principles.** It is the most comprehensive label available for (sustainable) forestry.

Blauer Engel: Products are manufactured to be **low in pollutants** and harmless to health in the living environment, exceeding legal requirements. Thermal insulation, sound insulation, and limiting emissions from products are taken into account.

Cradle to Cradle: Products are evaluated and classified in terms of material health, material reutilization, use of renewable energy, clean air and climate protection, stewardship of soil and water, and social fairness.

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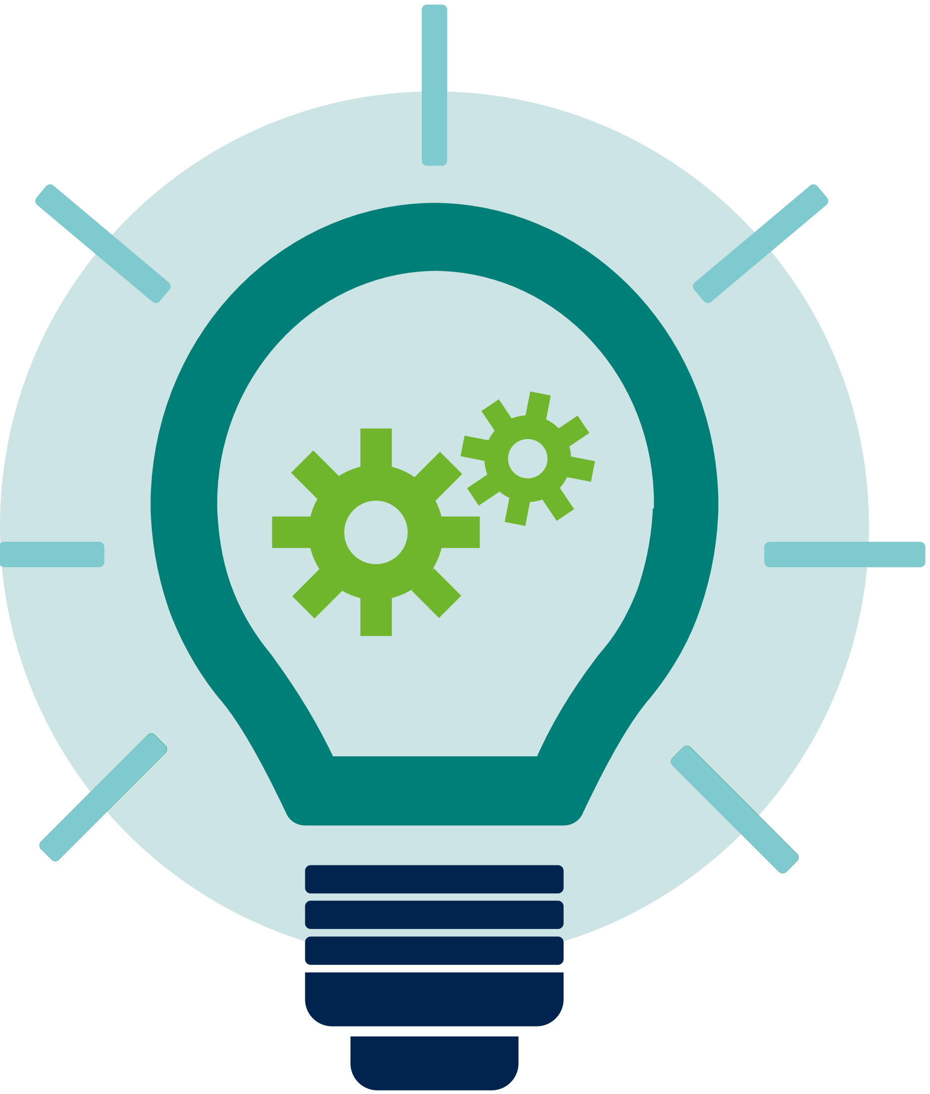

Finishes and coatings

Bonding as a joining technique, biofunctional components, and technologies for material health

Discover – Develop – Connect

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Bundesministerium für Wirtschaft und Energie

aufgrund eines Beschlusses des Deutschen Bundestages

Adhesive basics

- Adhesive **bonding distributes the force** exerted on the component to a larger area.
- Adhesive formulations are available for **bonding of very different materials.**
- Adhesives allow **variable assembly/joining** of components.
- Bonding as a joining technique is **cost-effective** and can be **automated.**

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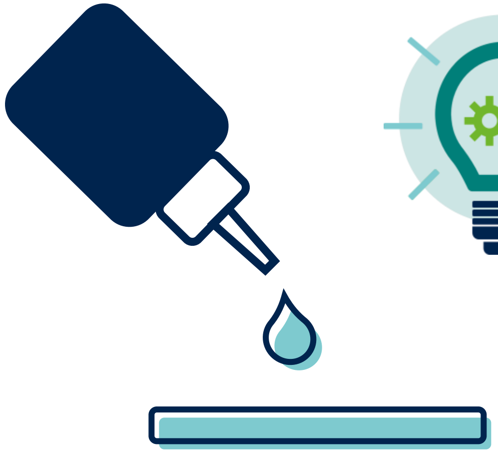
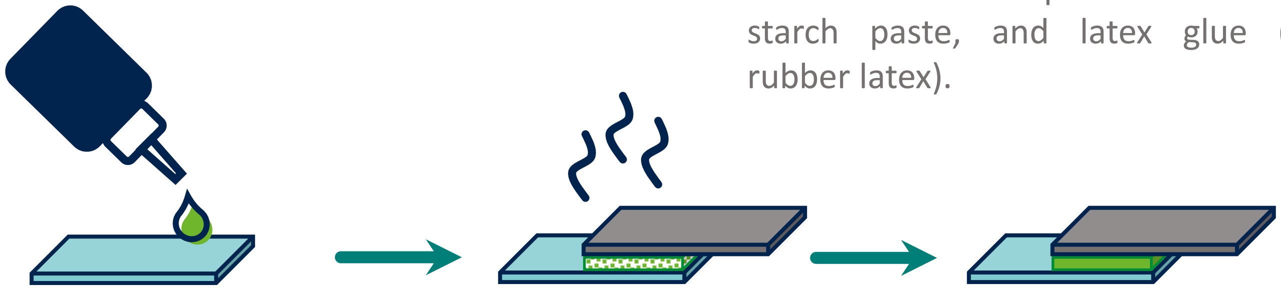


- Traditional construction adhesives are made from **petrochemical raw materials.**
- They often contain **chemical functional components** that can lead to the **release of harmful substances** in the short or long term.
- Bonded connections between materials **limit the recyclability** of products: the materials can only be separated by **damaging, contaminating, or using technical means.**

Adhesive basis

Solvent-based adhesives

- Contain polymers **dissolved in organic solvents.**
- After application, the **organic solvent evaporates,** causing the adhesive bond to cure.



Water-based (dispersion) adhesives

- Do not contain any organic solvents, but use **water as a solvent.**
- The **polymers are usually not dissolved (dispersed)** and bond when the **water evaporates** or is absorbed by the material surface.
- Well-known examples are craft glue, starch paste, and latex glue (natural rubber latex).

Adhesive basis

Caution!
The term “***polymer***” can refer to both synthetic polymers (plastics) as well as natural polymers (e.g., starch)!

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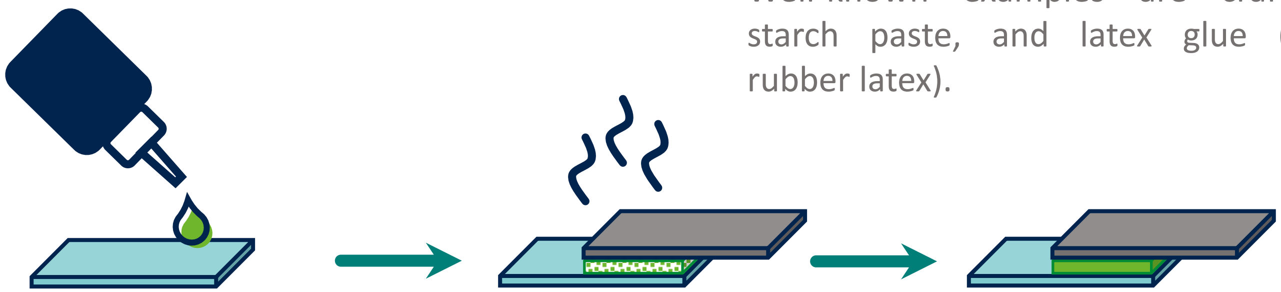

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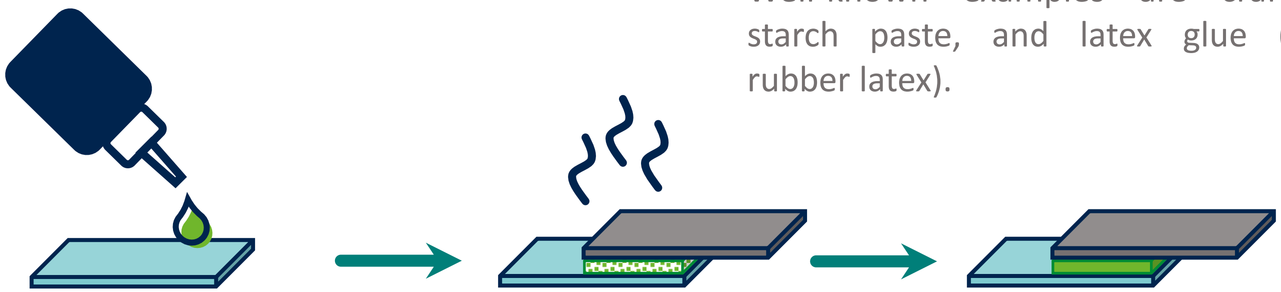

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Hot melt adhesives

- Consist of base polymers and resins or waxes in a solid state.
- The melt is applied, which creates a bond immediately after application and cooling.
- **Disadvantages** include low elasticity and embrittlement over time.
- In addition to classic fossil-based polymers, some of which can also be produced from bio-based sources, the use of bio-based PLA as a hot melt adhesive for the packaging sector is currently being tested.[1]

[1] FNR Projekt PLA-PackGlue.

Bio-based adhesives & binders

- Approaches to improving the **sustainability of adhesives** focus primarily on the use of **water as a solvent, natural polymers** (such as sugar), and the **elimination of petrochemical additives** that could cause the release of harmful substances.
- Within the **natural biopolymers,** there are some with long and short (e.g., lignin, peptides) chain structures.
- Depending on their composition, bio-based adhesives can release **less harmful smoke gases** in the event of a fire.
- The **properties of the materials** to be bonded (e.g., roughness, porosity, surface energy), the required **product lifespan,** and possible **weather influences** (e.g., moisture, UV radiation) are decisive factors in choosing the appropriate adhesive system.

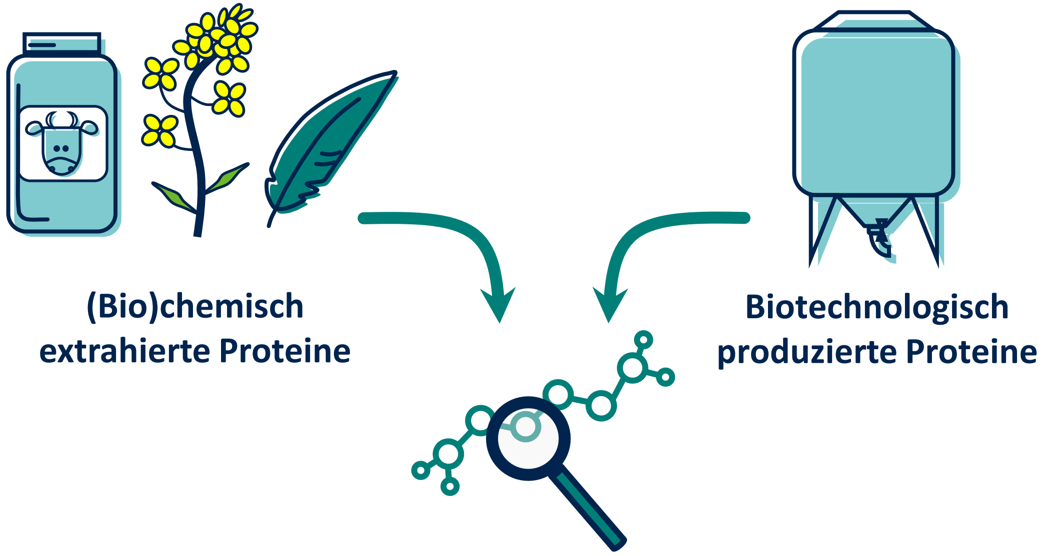
Bio-based adhesives & binders | Lignin

- **Lignin** is a **natural polymer** found in the cell walls of plants, which causes these parts of the plant to become woody.
- It is often produced as a **by-product** (e.g. in paper manufacturing) and is one of the most common organic substances on earth. This makes it an **interesting renewable carbon resource.**
- Challenges for its use include the naturally occurring **mixture of different lignins,** which require purification depending on the application, and further functionalization for additional chemical, physical, or biological functions.
- Research is being conducted on the use of **lignin-based binders** for the **production of plywood/chipboard.** In addition, hydroxymethylfurfural produced from sugar is used as a biological substitute for formaldehyde, which is harmful to health.

Bio-based adhesives & binders | Mycelium

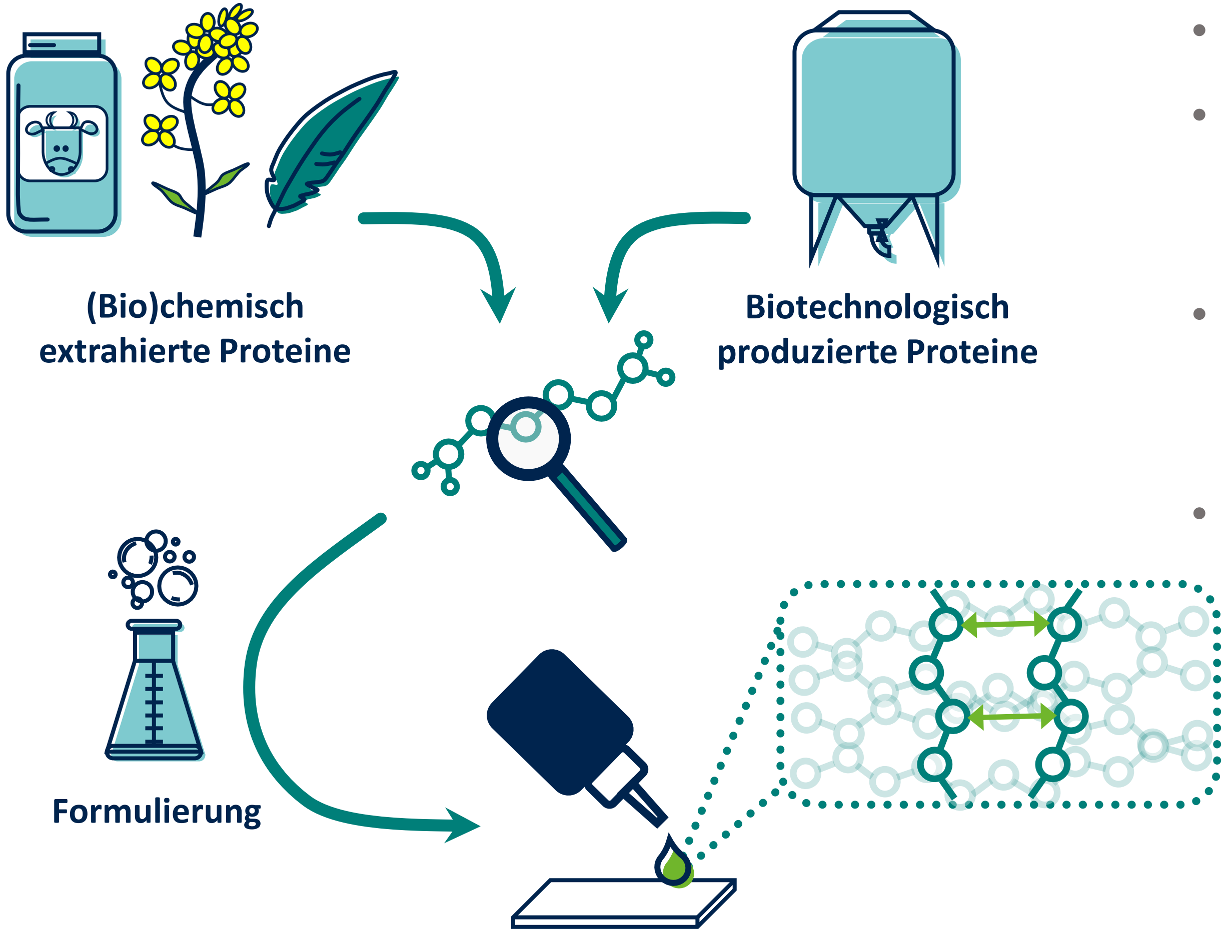
- **Mycelium is the network-like root system of fungi**, which is usually found underground.
- It not only penetrates soil, but can also **permeate organic residues** such as wood chips, straw, hemp shives or other **plant materials.**
- Its stable network, which grows through the materials, acts as a **natural binding agent** and strengthens the organic material.
- It is **biodegradable** and requires less energy to produce than conventional binding agents and is **free of chemicals.**
- While the production of mycelium-based insulation materials has already been researched, its **use as an alternative to adhesives** is the subject of current research.

Protein-based adhesives



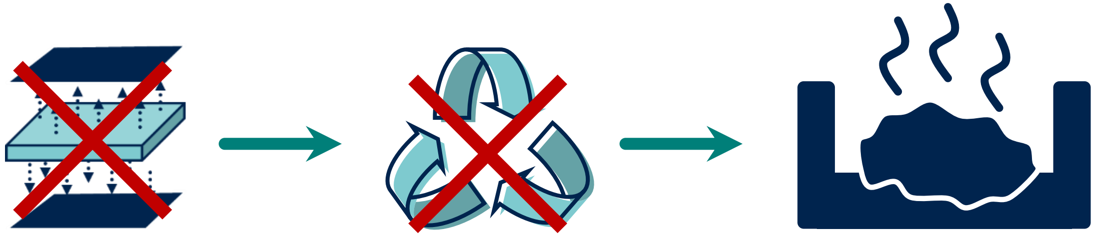
- Proteins are versatile biopolymers representing nature's polyamides (cf. nylon).
- They occur **naturally** and can be **extracted** from raw materials (e.g., casein from milk) or **produced biotechnologically** (fermentation).
- Their properties can be **chemically modified or biotechnologically tailored** (*Protein Engineering*).
- Proteins are generally **dispersible in aqueous solutions,** making them suitable for the production of **dispersion adhesives.**
- Bonding with **protein-based adhesives is NOT limited to natural materials** (such as wood)!

Protein-based adhesives



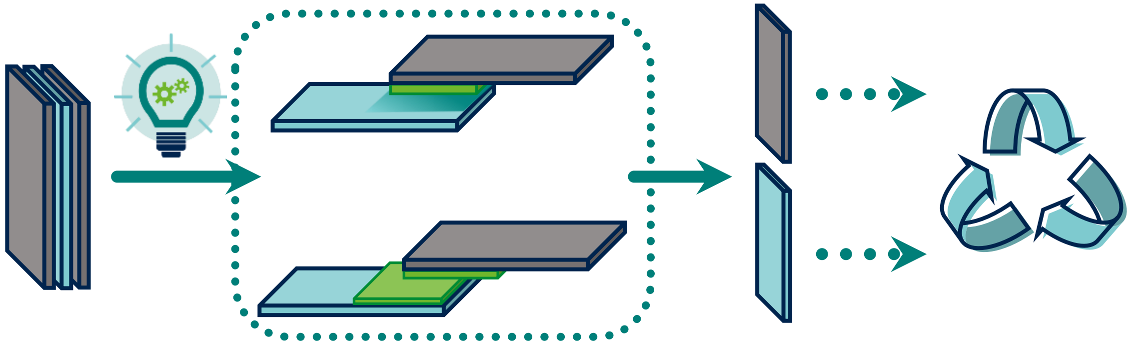
- Non-functionalized proteins form films during drying.
- The **chemical structure of proteins** can be further modified by **targeted or randomized functionalization** or copolymerization.
- Similar to the **formulation** of classic petrochemical adhesives, **additives, plasticizers, and flow or thickening agents** can be added.
- As in the case of synthetic polymers, **proteins form a network:**
  - **Physically** (e.g., chain entanglement, hydrophobic interactions)
  - **Chemically** (e.g., reactions of functional groups)
  - **Enzymatically** (cross-linking of amino acids)

Programmed dismanteling



- Separating materials enables (single-type) reuse – heterogeneous **mixtures of materials are often sent to landfill.**
- **Composite materials and multi-component materials,** such as those used in sandwich structures, are particularly challenging.
- Adhesive bonds, especially in construction, 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 dismanteling



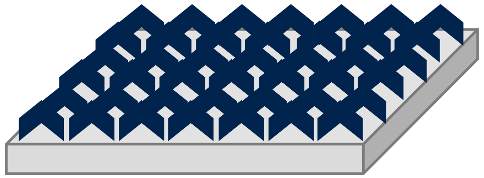
- One approach to improving the **separation of composite materials** are **switchable adhesives.**
- This is based on **controlled adhesive failure,** which is triggered by activating a switch.
- A distinction is made between **adhesive failure** (between the adhesive layer and the material) and **cohesive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

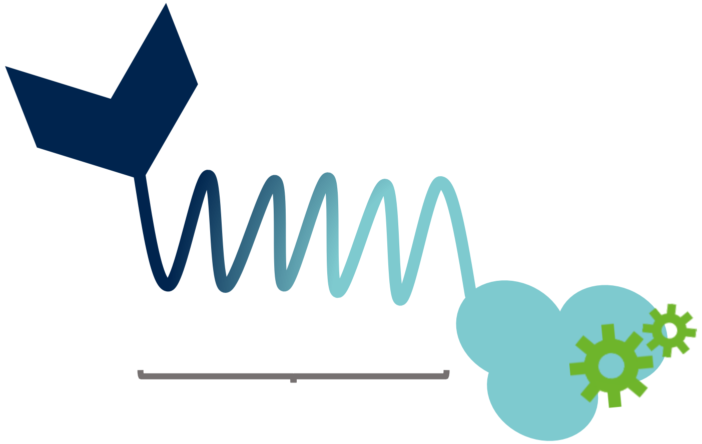
Bifunctional peptides

Tailored biological adhesion promoters[1]

Peptide A | ADHESION

- Small domain (ca. 10-50 amino acids)
- Tailor-made for **strong, specific binding** to **Material 1**





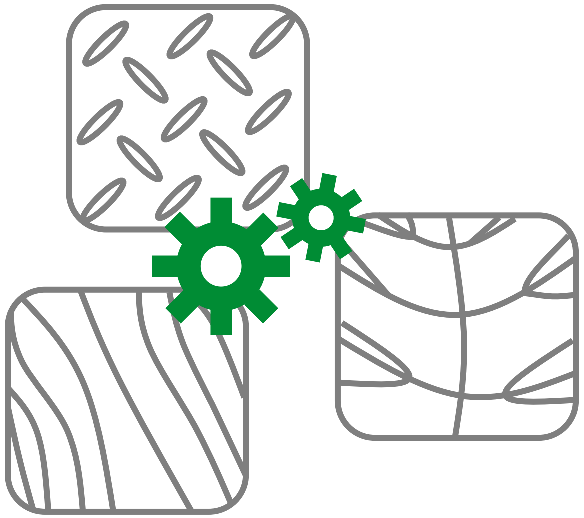
Spacer

- small helix
- separates peptide A and peptide B to prevent undesired interactions

Peptide B | FUNCTION

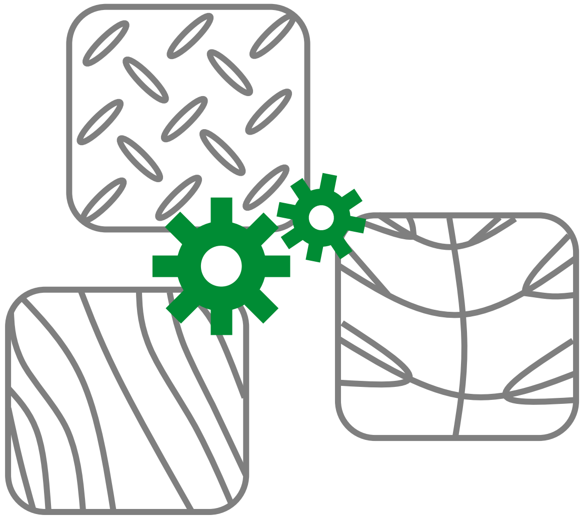
- Small domain (ca. 10-50 amino acids)
- Tailor-made for:
  Binding of molecules (e.g. flame retardant)
  Function: biological (e.g. anti-microbial), chemical (e.g. anti-corrosive), physical (e.g. hydrophobic, hydrophilic)
  strong, specific binding to **Material 2**

Functionalization ON material



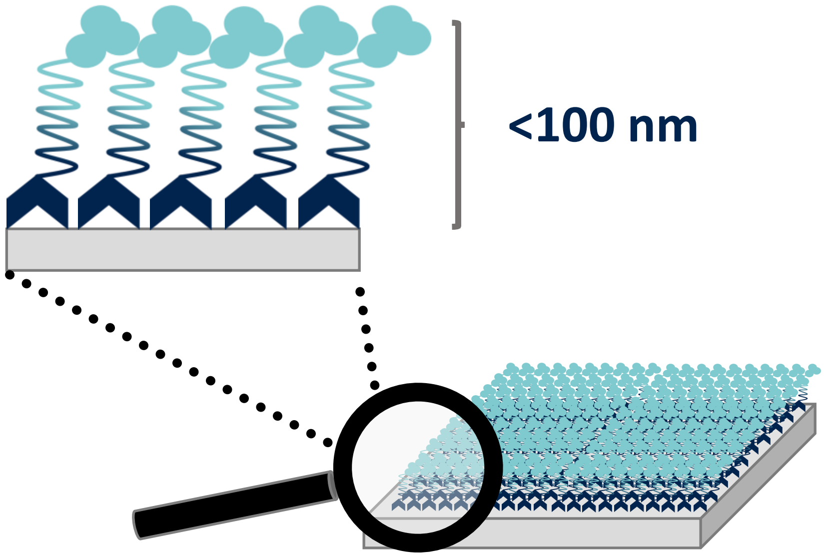
- **Functional coatings** (e.g., hydrophobic, hydrophilic, flame-retardancy or other functions)
- **Switchable adhesives** (e.g., for selective disassembly of multi-component material)

Functionalization ON material



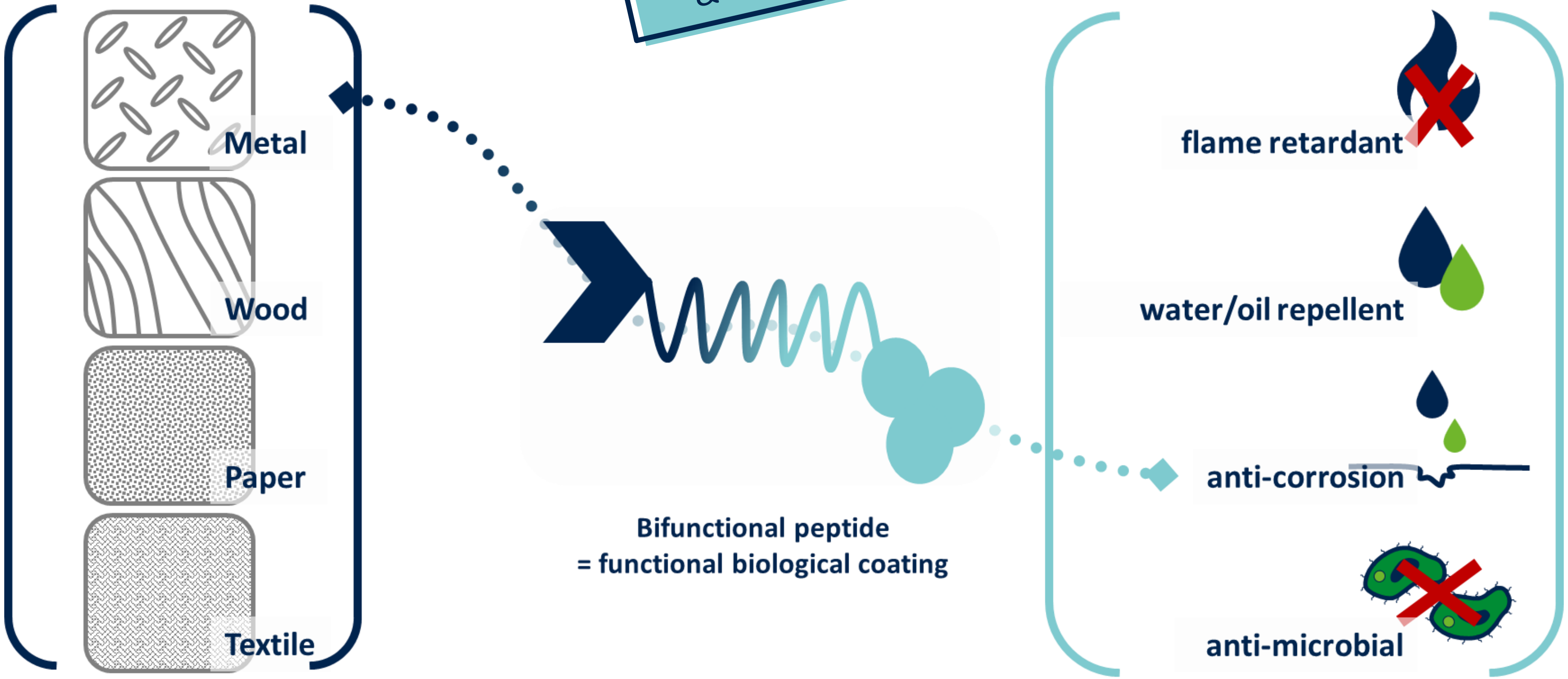
- **Functional coatings** (e.g., hydrophobic, hydrophilic, flame-retardancy or other functions)
- **Switchable adhesives** (e.g., for selective disassembly of multi-component material)

- ✓ material-specific binding (e.g., to PLA, PE, PA)
- ✓ high **mass/area efficiency** (1 g peptide for ca. 250 m^2)
- ✓ high **coating density**
- ✓ **scaleable** & cost efficient production
- ✓ compatible with **standard coating methods** (e.g. dip-coating, spray coating)



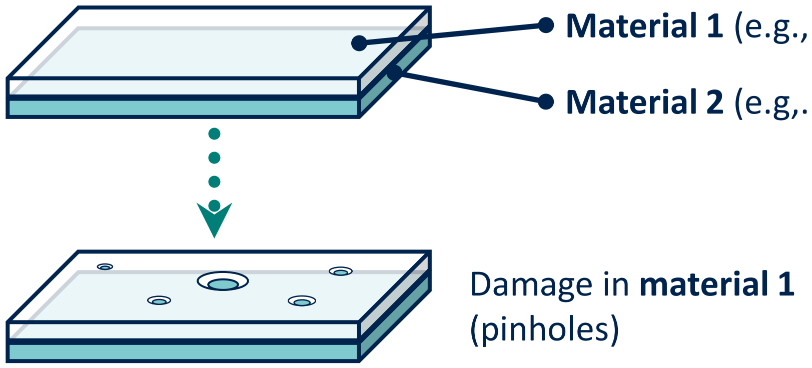
Bio-based coatings

More information in the training on "Biotechnology & Biomanufacturing"



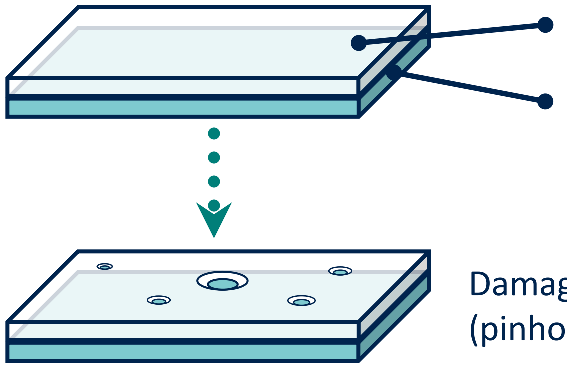
Bifunctional peptide
= functional biological coating

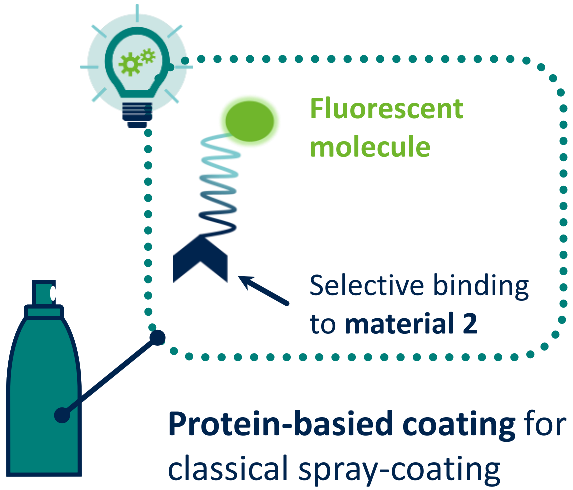
Material health



- **Damage** such as scratches or pinholes can lead to accelerated material fatigue or aging (e.g., rust), especially in **protective coatings.**
- **Microscopic damage and (semi-)transparent materials,** where the damage is not visible to the naked eye, are particularly challenging.

Material health





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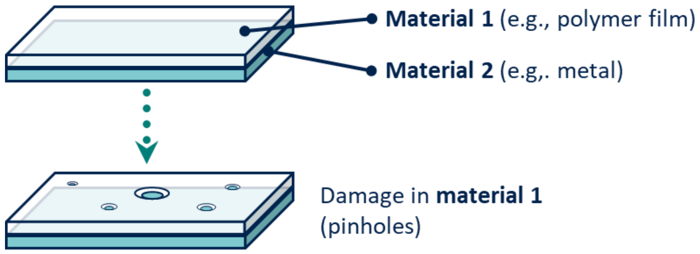
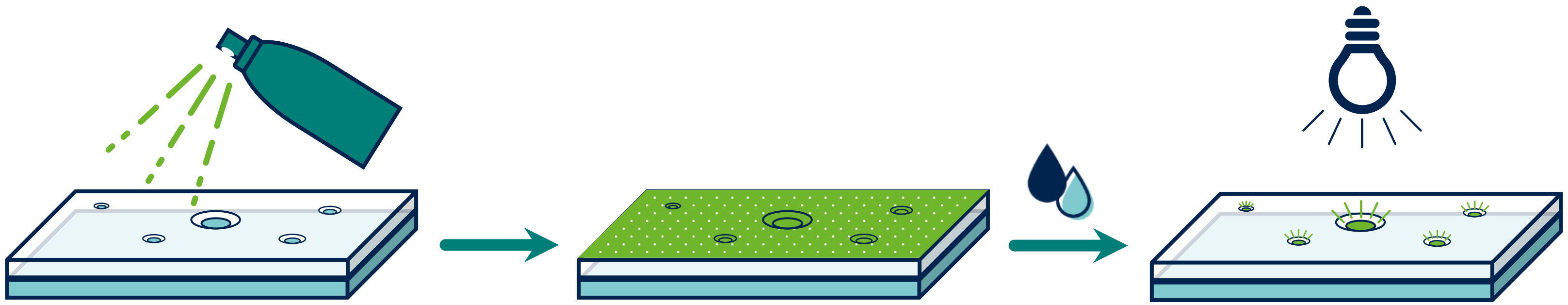
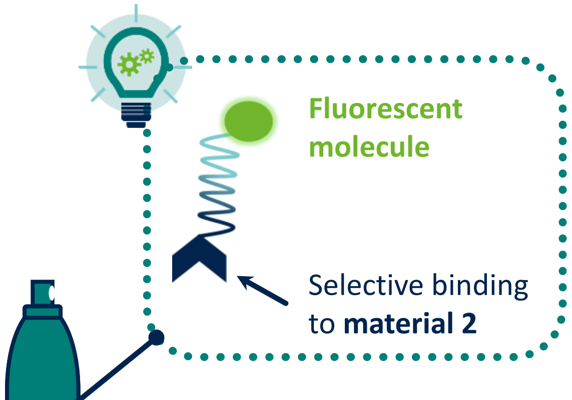


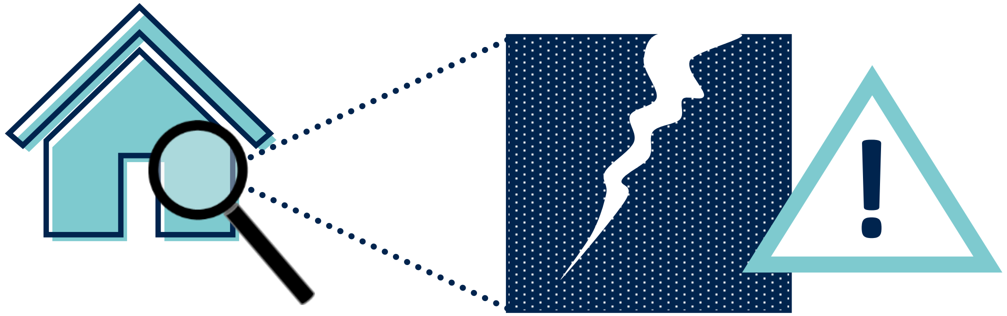




Protein-basied coating for classical spray-coating

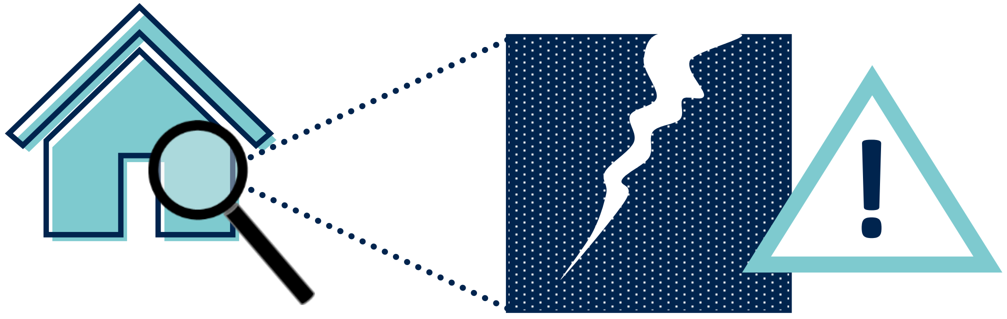
- The **functional coating** is sprayed onto the **surface** (material 1).
- **Non-adherent residues** are rinsed off with water.
- What remains is a clearly visible **fluorescence at the defect sites** where the protein-based coating has **selectively bound to material 2.**

Material preservation



- Structure-relevant building materials such as concrete are particularly important when assessing the **structural integrity** of buildings.
- Concrete production consumes large amounts of material and energy resources, making **material conservation essential for improved sustainability.**
- Fast, non-invasive **(non-destructive) detection of material damage** and integrated **self-healing mechanisms** are important.

Material preservation



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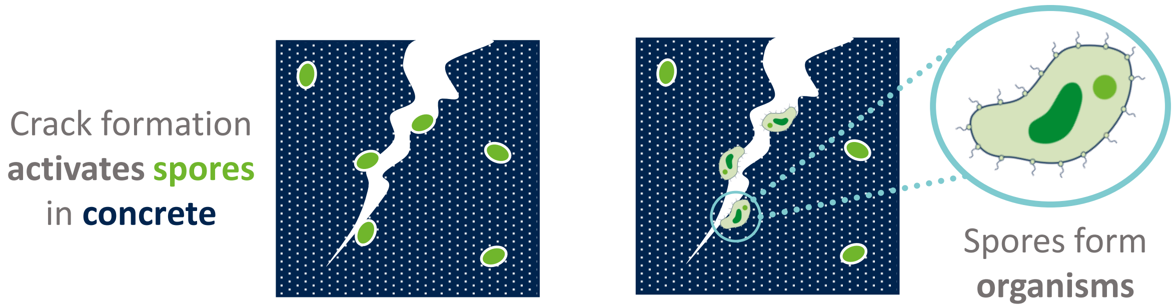
- Some **microorganisms** are capable of producing mineral, inorganic compounds such as calcium carbonate (known as **biomineralization**).
- This function is interesting for the integration of **self-healing or self-sealing properties** in materials such as concrete or cement.



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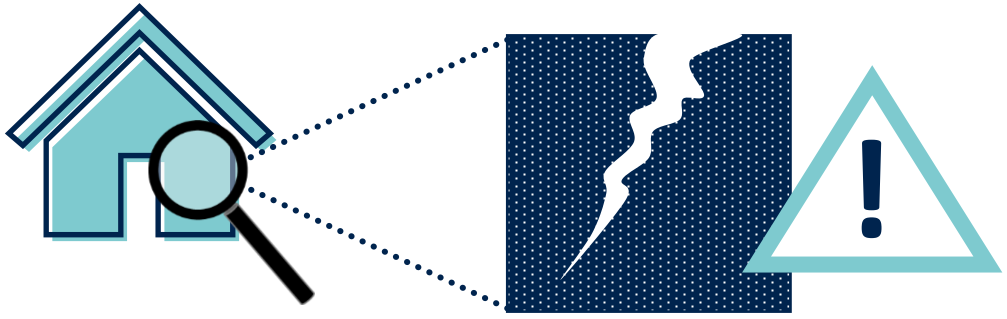

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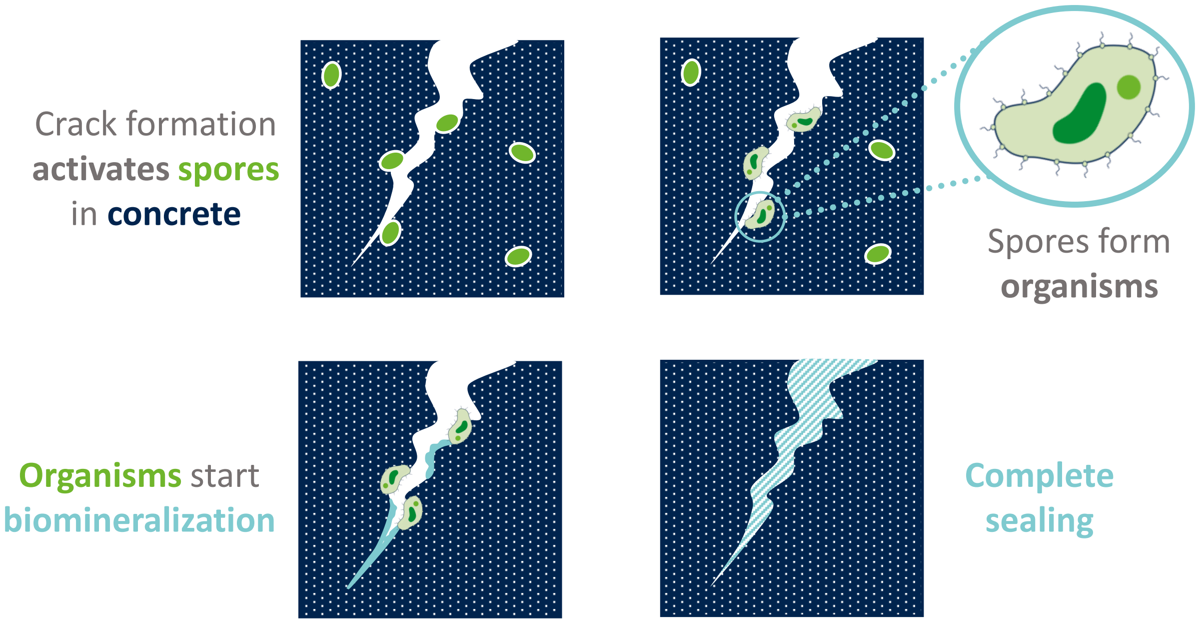

Outlook: construction industry and climate change

- **More extreme climatic conditions are relevant for the planning of new buildings and the renovation of existing buildings.**
- Larger temperature ranges, sudden **temperature changes,** and hazards caused by **extreme weather conditions** (storms, floods) pose **challenges for materials and construction methods.**

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- **Nature-based solutions** can create synergy between the environment (protection) and man-made structures.
- The objectives can include, for example, **improving air quality, preventing heat islands, protecting against heavy precipitation,** treating water, and preserving **biodiversity.**
- **Additive manufacturing** of components, **3D scans, and simulations** can contribute to the **efficient planning and design** of new and existing buildings.

"To overcome the challenges in the construction industry, neither conventional concrete construction, timber construction, masonry construction, steel construction, nor conventional construction with carbon or clay will be the solution on their own."

René Hagemann,
German Construction Industry Association

Discover – Develop – Connect

Your contact and partner regarding Bioeconomy in construction

Dr. Thomke Bergs
Institute of Biotechnology,
RWTH Aachen University

transbib@rwth-aachen.de

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-type materials.

(2) Lightweight and sandwich construction methods can contribute to sustainability in the construction industry.

(3) The selection of bio-based and biogenic insulation materials with technical relevance is very limited.

(4) Current technologies focus on early detection of material damage or self-healing functions.

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-type materials.

False! Conventional material bonding makes it difficult to recycle materials by type and often requires damaging and contaminating the materials or consuming a lot of energy to separate them. Current research is focusing on switchable adhesive failure, which enables controlled separation of materials and thus their return to material cycles.

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True! Saving on materials by using lightweight structures that can bear heavy loads and adapting the materials used to the actual load-bearing requirements can lead to significant savings in energy and resources.

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False! There is a variety of suitable fiber materials such as straw, hemp, wood wool, cellulose, and various grasses that are suitable as insulation materials. They have good technical properties such as thermal and acoustic insulation and moisture regulation.

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True! Early detection of damage or mechanisms for material self-healing can limit its spread and thus ensure that the structure is preserved. It is important that the testing method is non-invasive, i.e., does not require disassembly.

Note

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