FUTURE DEVELOPMENT AND MECHANICAL ENGINEERING OF POLYMERIC MATERIALS

How to combine sustainable developments with effective lightweight manufacturing

Dr. Katharina Haag | Fraunhofer IFAM

03.11.2020

BEVA & ALM Europe
Battery Electric Vehicle Architectures & Advanced Lightweight Materials 2020
Design & Mass Produce Affordable Battery Electric Vehicles

Strategies & Solutions For Design, Engineering, Material Selection & Manufacturing For Optimal Integration Of Battery & Systems Within The Car Body
2-3 November 2020 - Start TIme 0830 CET
LBCG

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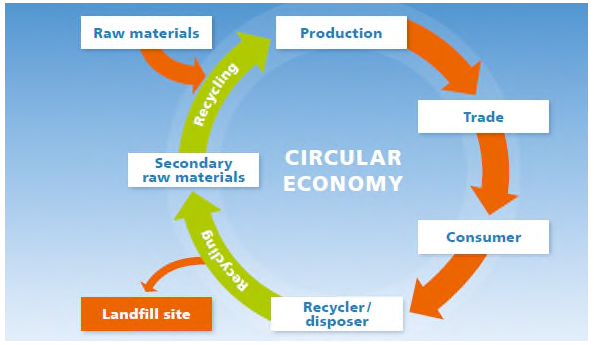
AGENDA



- Background of my research activities: Where do I come from?
- Circular Economy and Lightweight Design
- BestBioPLA – Biobased and Biodegradable Lightweight Materials for Automotive Interior
- Polymeric Solutions for Lightweight Materials with advanced Properties
- Outlook & Visions: Where do we go?

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Fraunhofer-Gesellschaft, the largest organization for applied research in Europe

- Applied research for the immediate benefit of private and public enterprises and as an asset to society as a whole
- 74 institutes and research units; 28.000 staff
- More than € 2.8 billion total annual research budget. Of this sum, around € 2.4 billion is generated by contract research
  - More than 70 % of this sum is generated through contract research on behalf of industry and publicly funded research projects
  - Roughly 30 % is contributed by the German federal and state governments as base funding

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The Fraunhofer-Gesellschaft

Fraunhofer-Gesellschaft

- Founded in 1949
- 74 institutes
- 28,000 employees
- R&D volume
  € 2.8 billion

Fraunhofer IFAM

- Founded in 1968, Fraunhofer institute since 1974
- **Bremen,**
  further locations in Dresden, Stade, Wolfsburg and Braunschweig, as well as a test center for maritime technologies on Helgoland
- About 700 employees
- Total budget in 2019
  € 56.6 million

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Fraunhofer IFAM – Locations

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BREMEN

Bremen Headquarters

DRESDEN Powder Metallurgy

Stade Automation and Production Technology

OLDENBURG Electrical Energy Storage

Wolfsburg Fraunhofer Project Center Wolfsburg
Lightweight Construction / Electromobility

Braunschweig Fraunhofer Project Center for Energy Storage and Systems ZESS

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Fraunhofer IFAM – Research, Development, Application

- Was founded in 1968 and has been a member of the Fraunhofer-Gesellschaft since 1974
- Is an internationally significant material science research institute in the fields of Adhesive Bonding Technology, Surfaces, Shaping, and Functional Materials
- Defines its central guidelines as:
  - Scientific excellence
  - A strong orientation towards applications with a measurable benefit for customers
  - Quality management
  - A high level of responsibility with respect to our employees and society

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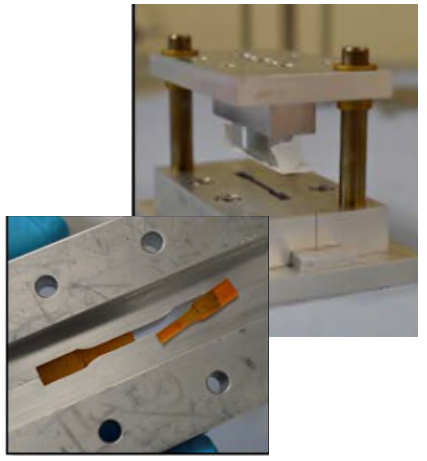
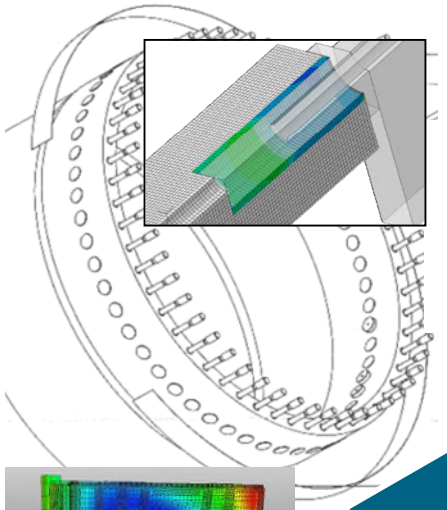
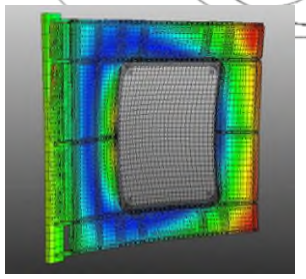
Department POLYMERIC MATERIALS & MECHANICAL ENGINEERING

Material development





Understanding the material-property-relationship for the description, focused development and application of polymeric materials



Engineering/ Structure – property relationship

Material-specific manufacturing concepts

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CIRCULAR ECONOMY AND LIGHTWEIGHT DESIGN: DEFINITIONS AND MOTIVATION

- **Lightweight Design**

  can be defined as “the science and the art of making things—parts, products, structures—as light as possible, within constraints”. (Tempelman 2014)

- **Circular Economy** and **EcoDesign**
  - Growing interest is observed in society, politics and industry

  “Ecodesign requires that the environmental impact of a product’s entire life cycle, including end-of-life, be considered at the design and product development stages.” (Mayer & Groß 2020)

→ Lightweight Design can make a major contribution to EcoDesign

In combination with new developments: also to a Circular Economy

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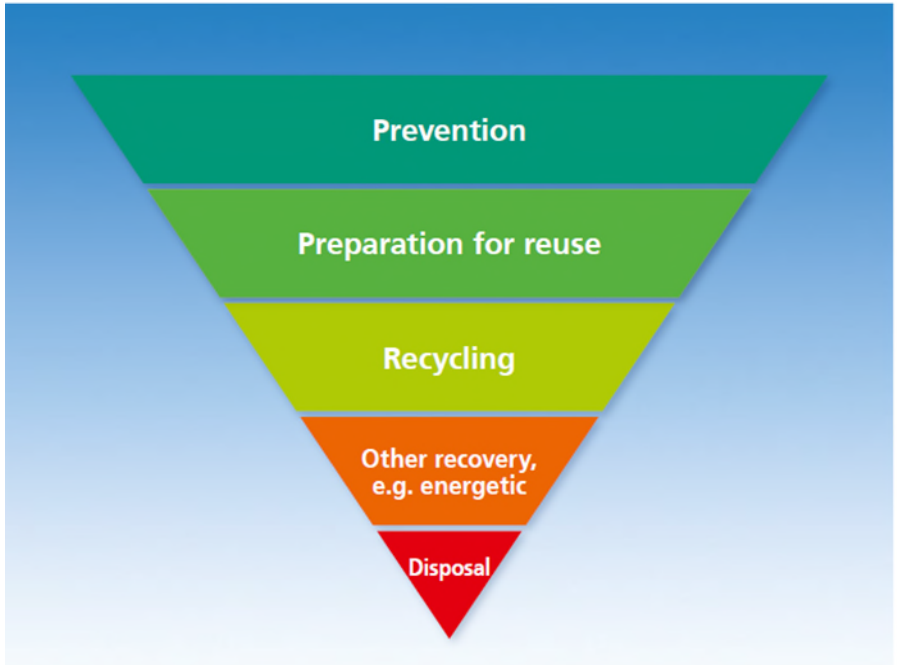
CIRCULAR ECONOMY AND LIGHTWEIGHT DESIGN: STARTING EARLY IN PRODUCT DEVELOPMENT

- European waste hierarchy as link between EcoDesign and Circular Economy
- Primary objective: Avoid waste
- **Waste prevention measures** with the aim to promote a product design that improves the product concerning
  - Resource-efficiency
  - Durability
  - Repairability
  - Reusability
  - Updatability
- Realisation:
  - As early in the design process as possible



EU waste hierarchy

(Mayer & Groß 2020)

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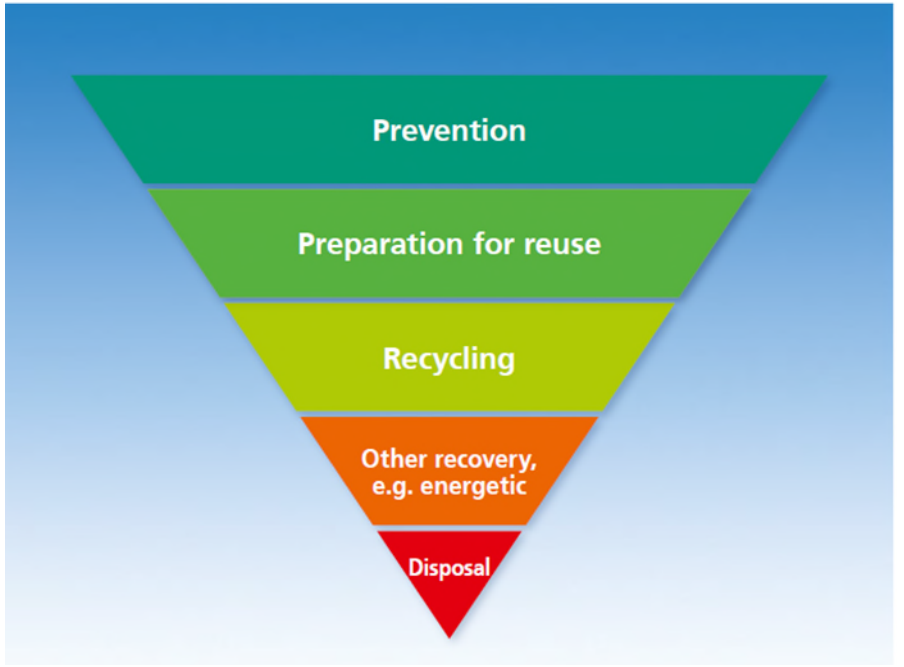
CIRCULAR ECONOMY AND LIGHTWEIGHT DESIGN: STARTING EARLY IN PRODUCT DEVELOPMENT

- First priority: **Prevention**
  - is achieved through measures to be taken before a substance, material or product has become waste
  - measures are intended to reduce the amount of waste
  - Examples: reuse of products or the extension of their service life
- Second stage: **Preparation for reuse**
  - describes ’any process whereby products or components other than waste are reused for the same purpose for which they were originally intended’
  - Recovery operations (testing, cleaning, repair of products or components) for reuse without further pre-treatment



EU waste hierarchy

(Mayer & Groß 2020)

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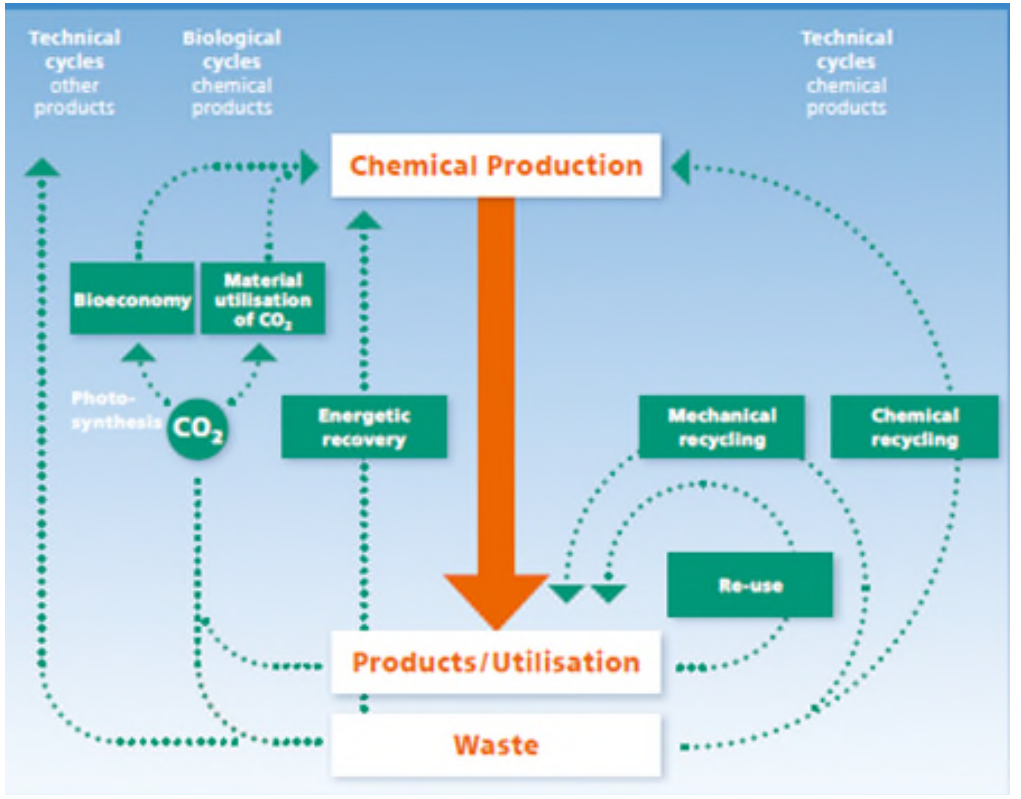
CIRCULAR ECONOMY AND LIGHTWEIGHT DESIGN: STARTING EARLY IN PRODUCT DEVELOPMENT

- Third priority: **Recycling**
  - Transformation of waste materials into products/ materials / substances either for the original purpose/ other pruposes.
  - Chemical or mechanical recycling
  - Energy recovery is excluded



(Mayer & Groß 2020)

Recycling of goods assigned only to Level 3 in waste hierarchy, but essential role for a Circular Economy

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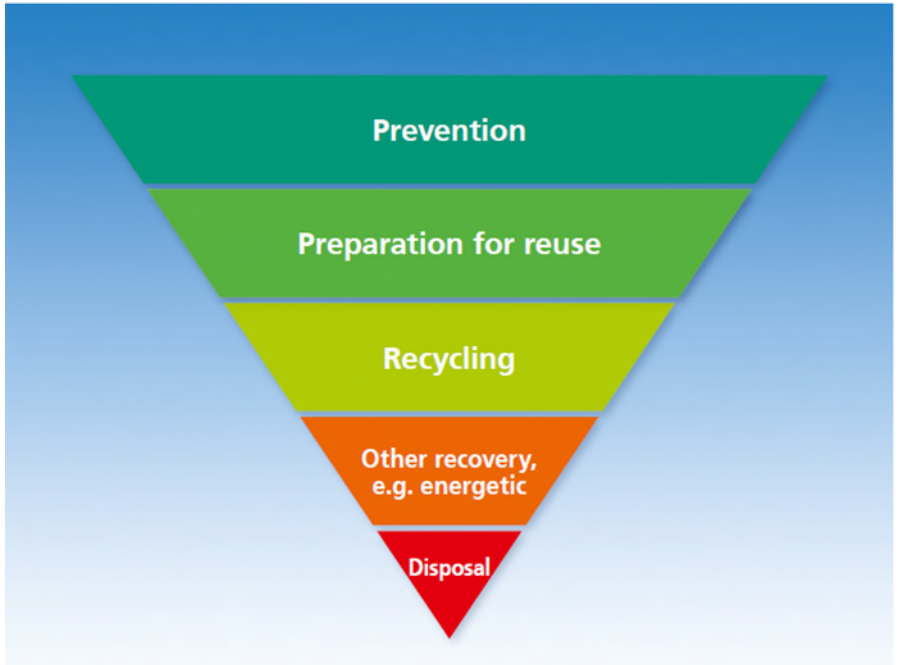
CIRCULAR ECONOMY AND LIGHTWEIGHT DESIGN: STARTING EARLY IN PRODUCT DEVELOPMENT

- Level 4: **Other recovery**
  - Waste is used for useful puproses
  - Replacing materials for a specific function
  - Includes: use as fuel, recovery of energy,…
- Last stage: **Waste disposal**
  - Includes all processes not leading to recovery (e.g.landfilling, treatment in the ground, disposal in sealed, incineration at land and sea, premanent storage)



EU waste hierarchy

According to the waste hierarchy: better start early in product development to realize priority measures

(Mayer & Groß 2020)

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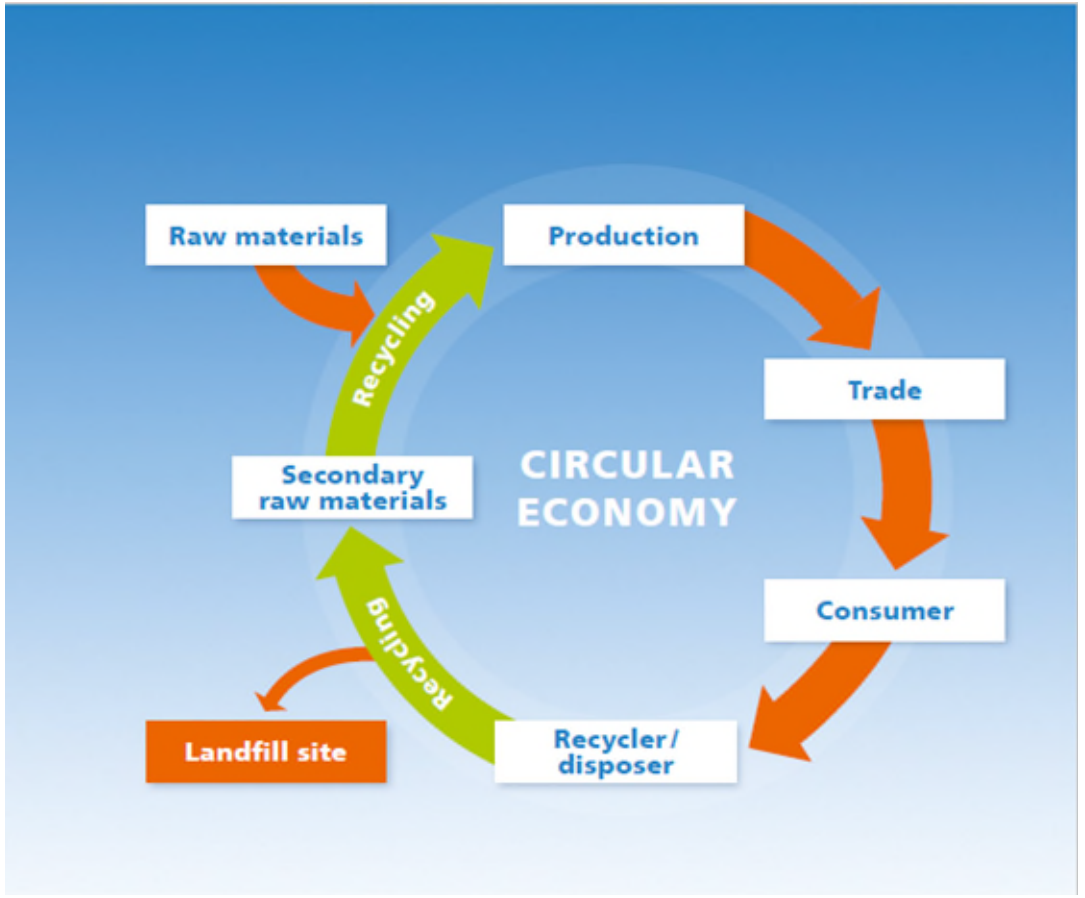
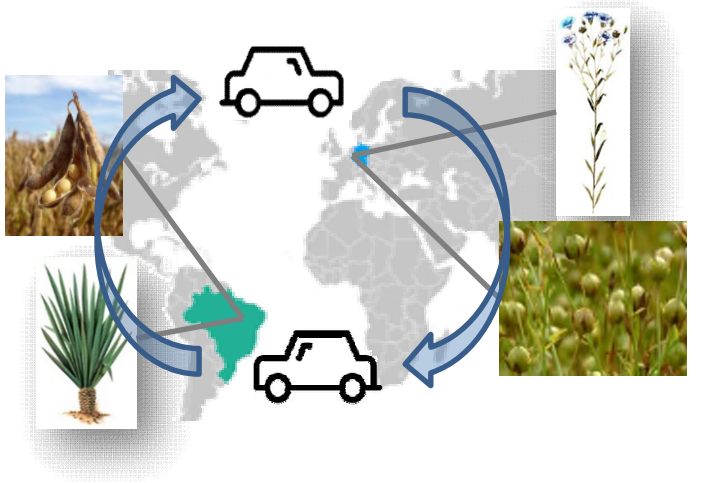
FUTURE DEVELOPMENTS TOWARDS A CIRCULAR ECONOMY



- Insights into Applied Research I:

BestBioPLA - Fully Bio-based PLA Composites Featuring Long Term Stability



Funding measure „CLIENT II – Internationale Partnerschaften für nachhaltige Innovationen“, FKZ 033R209A

GEFÖRDERT VOM Bundesministerium für Bildung und Forschung

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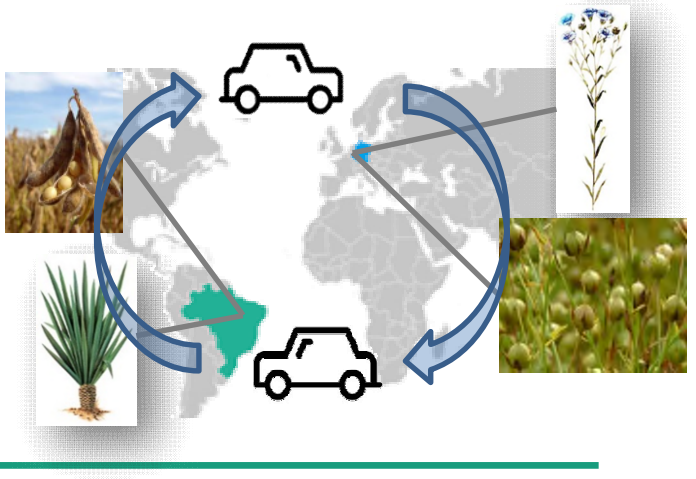
INSIGHTS INTO APPLIED RESEARCH I: BESTBIOPLA PROJECT IDEA

- Demand for alternative, sustainable materials with improved eco-efficiency in the automotive industry
- Fibre reinforced polymers (FRP) are already used in serial production (also with natural fibres)
- STATE OF THE ART
  Primarily based on fossil ressources and missing recycling concepts
- BESTBIOPLA APPROACH
  - Use of regional, renewable ressources + biodegradability
  - Closed cycle of materials with regional ressources
- CHALLENGES
  Properties + costs



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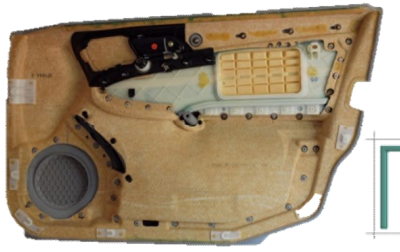
Bildquelle: Karus et al. (2005) Naturfaserverstärkte Kunststoffe – Pflanzen Rohstoffe Produkte. Fachagentur Nachwachsende Rohstoffe e.V. (FNR), Gülzow

INSIGHTS INTO APPLIED RESEARCH I: BESTBIOPLA REQUIREMENTS

- **Requirements in the automotive industry?**
  - In the beginning of the project: Requirement specifications for a bio-composite material in interior automotive applications
  - Supported by the industrial partners
- **Realisation part processing in an industrial environment?**
  - Upscaling of Polymersynthesis is necessary
  - Dimensoning and realisation of a demonstrator part in an industrial environment



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INSIGHTS INTO APPLIED RESEARCH I: BESTBIOPLA REQUIREMENTS – KEY POINTS FOR THE DEVELOPMENTS

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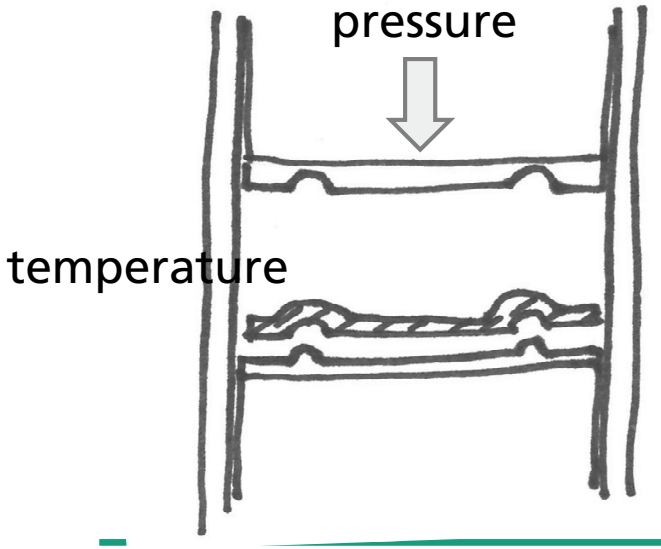
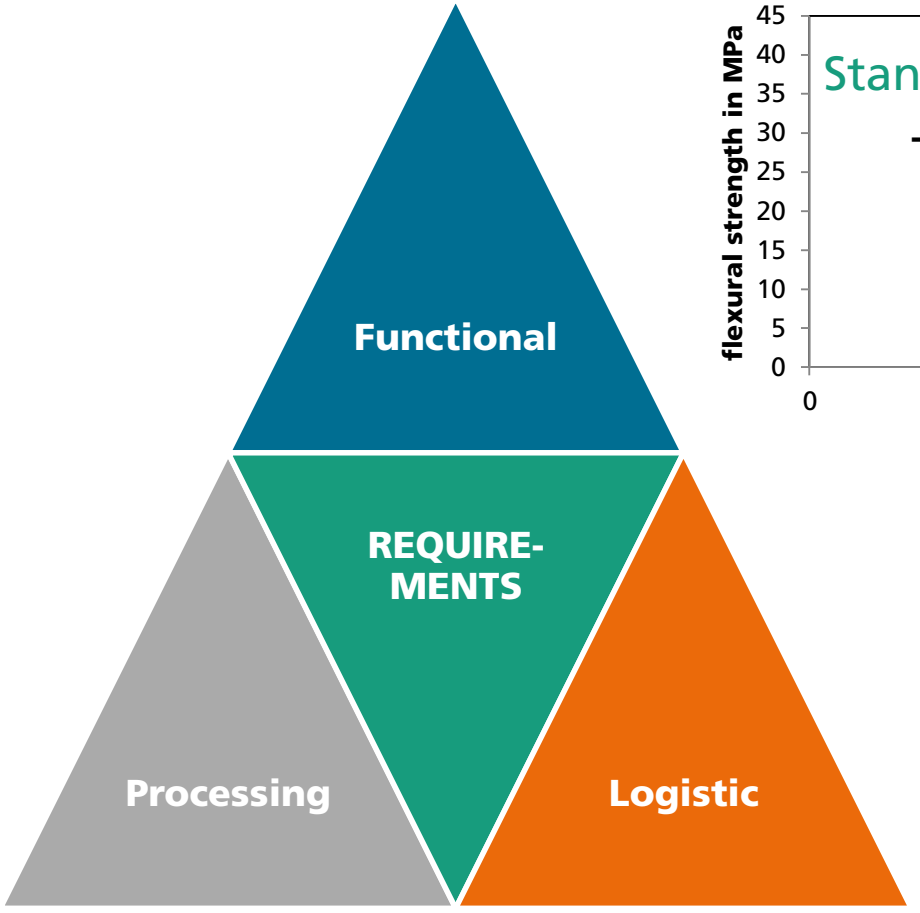
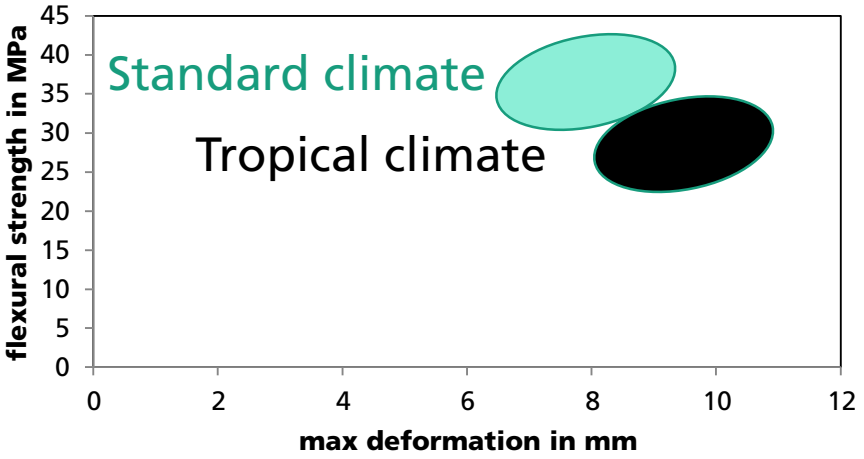
Entwicklung eines biobasierten Werkstoffes für den Einsatz im Fahrzeug-Innenraum

Anfragelastenheft für Entwicklungsleistungen

Projektbezeichnung	BestBioPLA – Spagat zwischen Beständigkeit und Biodegradierbarkeit - Vollständig bio-basierte PLA-Verbundwerkstoffe mit Langzeitbeständigkeit
Projektleiter	Katharina Haag (Fraunhofer IFAM)
Erstellt am	15.05.2019







General remark: Agreement with valid standards

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INSIGHTS INTO APPLIED RESEARCH I: BESTBIOPLA REQUIREMENTS – KEY POINTS FOR THE DEVELOPMENTS

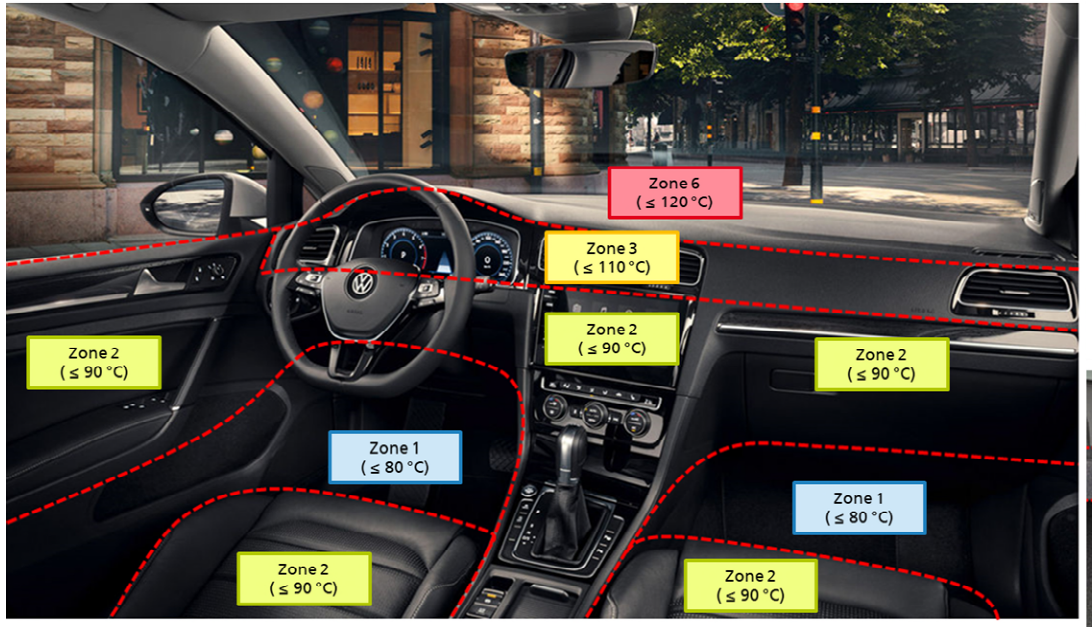
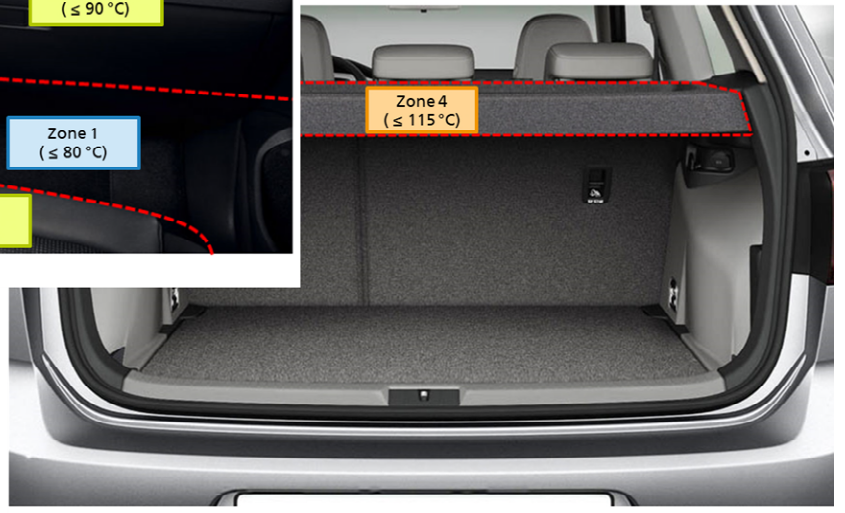


Bild Interieur Golf VII

Different requirements regarding thermal stability depending on the zone of application



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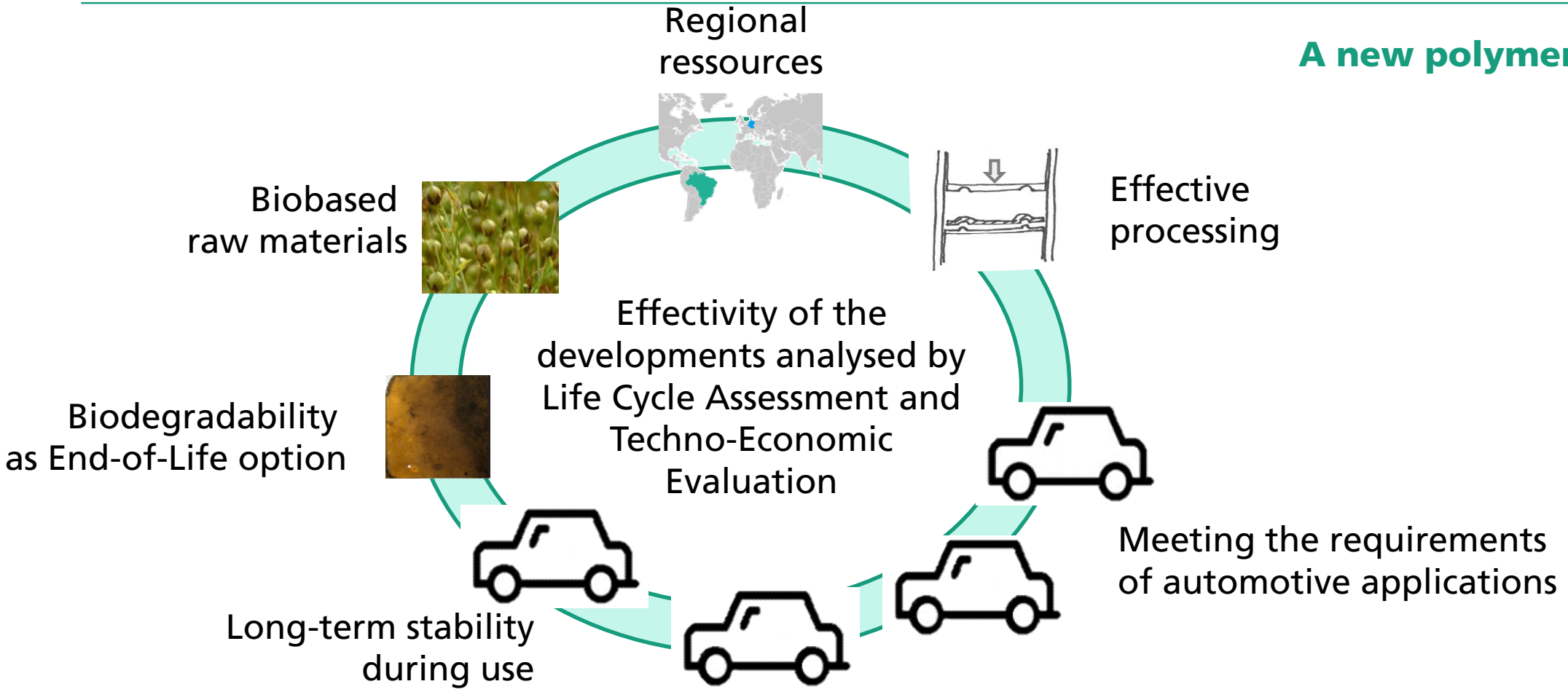
INSIGHTS INTO APPLIED RESEARCH I: BESTBIOPLA
OUR DEVELOPMENTS

A new polymeric material



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INSIGHTS INTO APPLIED RESEARCH I: BESTBIOPLA
OUR DEVELOPMENTS

A new polymeric material

- Regional natural Fibres: Flax and Sisal
- New cross-linked polymer based on a PLA-backbone, cross-linked as unsaturated polyester (thermosetting resin)
  - Thermal stability and mechanical properties can be adapted
- Effective composite processing in compression moulding
  - Attention: thermal stability of the natural fibres
- Standardized biodegradability tests of polymers and composites
- All developments are accompanied by Life Cycle Assessment and Techno-Economic Evaluation already at **early material development stage**

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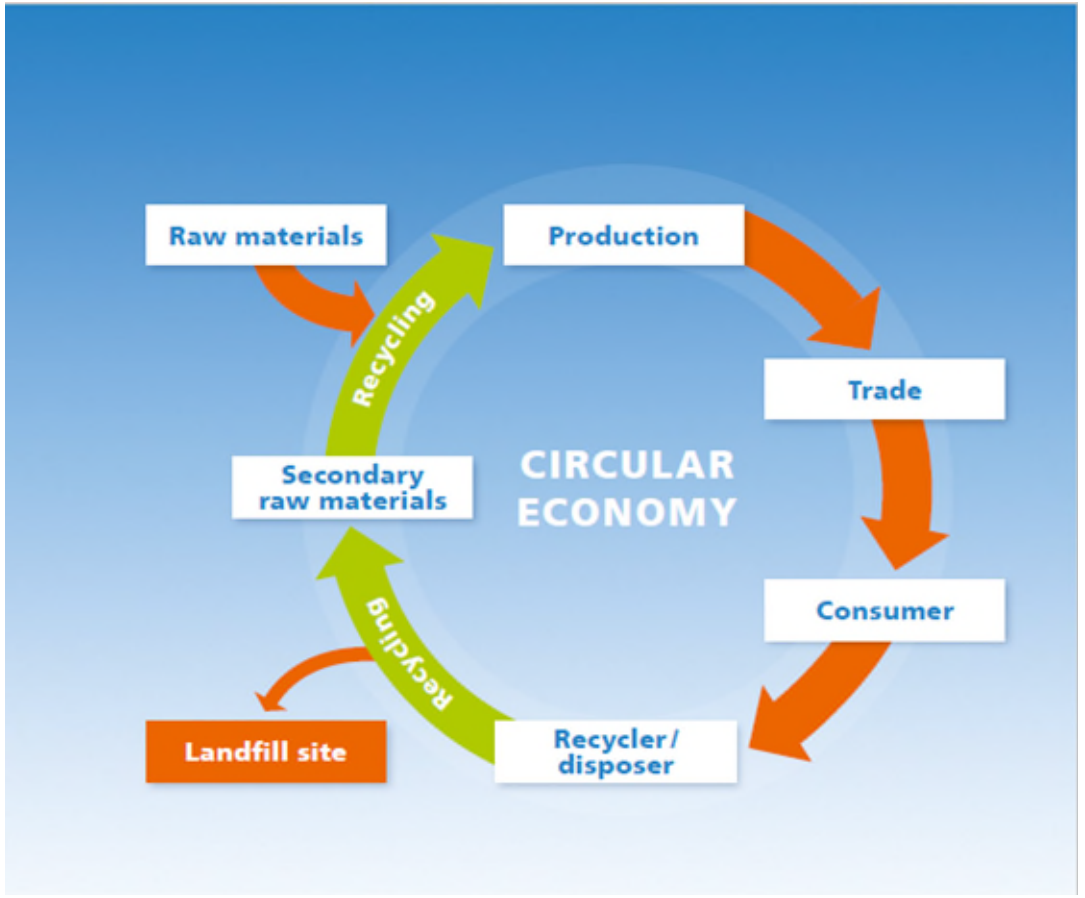
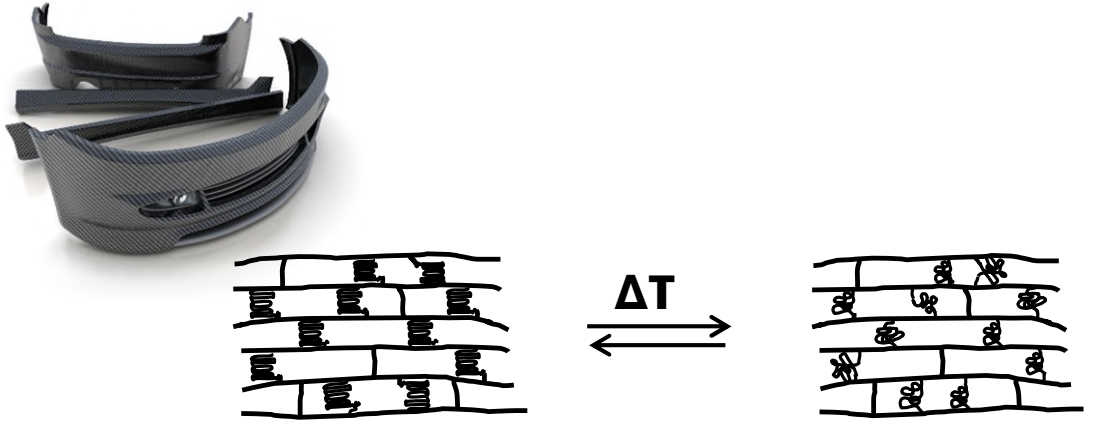
FUTURE DEVELOPMENTS TOWARDS A CIRCULAR ECONOMY



- Insights into Applied Research II:

DuroCycleFVK - Recyclable and formable duromers for the production of modulable fiber composites



NanoMatFutur award (DuroCycleFVK 03XP0001)

GEFÖRDERT VOM
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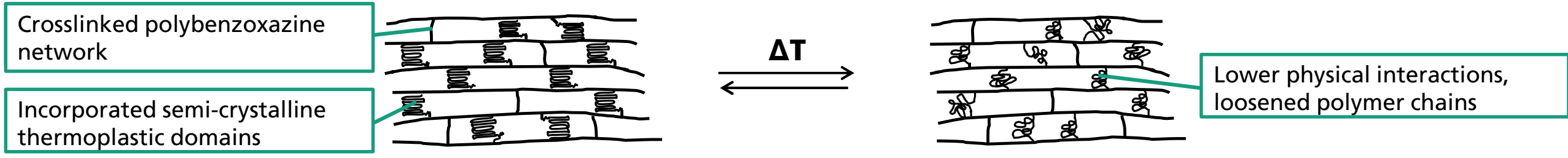
INSIGHTS INTO APPLIED RESEARCH II: DUROCYCLEFVK THERMORESPONSIVE FRP WITH SHAPE MEMORY

- Thermoresponsive properties + Shape Memory ability
  - Shapability
  - Adaptability: space-saving, self deployable structures, morphing,…
- Matrix system for lightweight FRP based on polybenzoxazine
- Thermoresponsive properties through incorporation of a semi-crystalline polyester into the thermoset network



At room temperature (RT):
- Solid and rigid network

At elevated temperatures:
- Mouldability due to loosened polymeric chains

(Schäfer et al. 2018)

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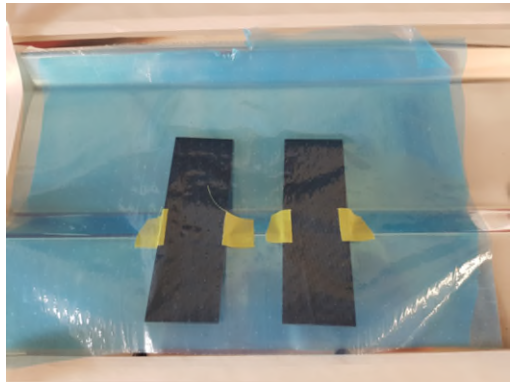
INSIGHTS INTO APPLIED RESEARCH II: DUROCYCLEFVK THERMORESPONSIVE FRP WITH SHAPE MEMORY

- Proof of Concept: thermoforming of thermoset FRP



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vacuum

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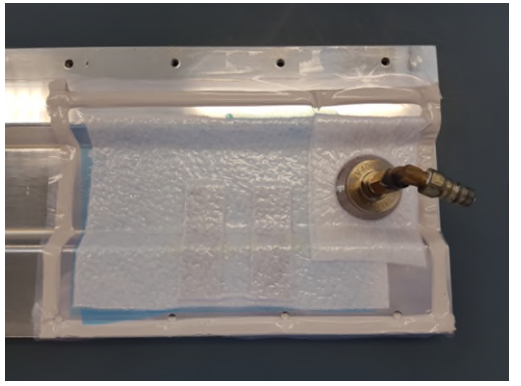
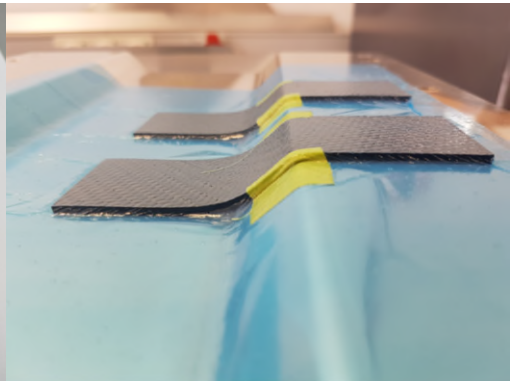
vacuum





Thermally deformed thermosetting FRP

(Schäfer et al. 2018)

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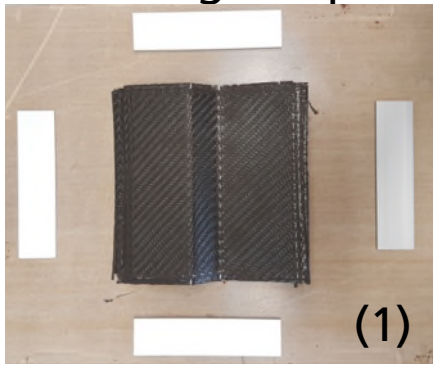
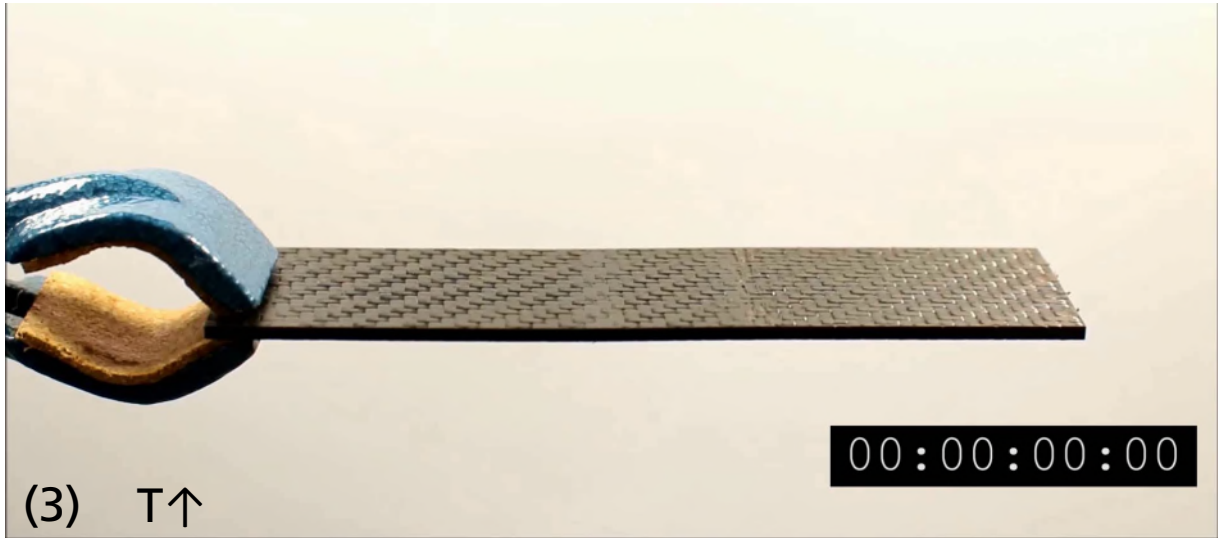
INSIGHTS INTO APPLIED RESEARCH II: DUROCYCLEFVK THERMORESPONSIVE FRP WITH SHAPE MEMORY

- Manufacturing the FRP in an appropriate shape (1) -> The sample was then flattened in a hot press (2). The flattened FRP is moving back to its previous and permanent shape when heated up over the softening temperature (3).



T↑ ↓ press



Due to shape memory abilities this FRP could be used for self-deploying and morphing lightweight strucutres

(Schäfer et al. 2018)

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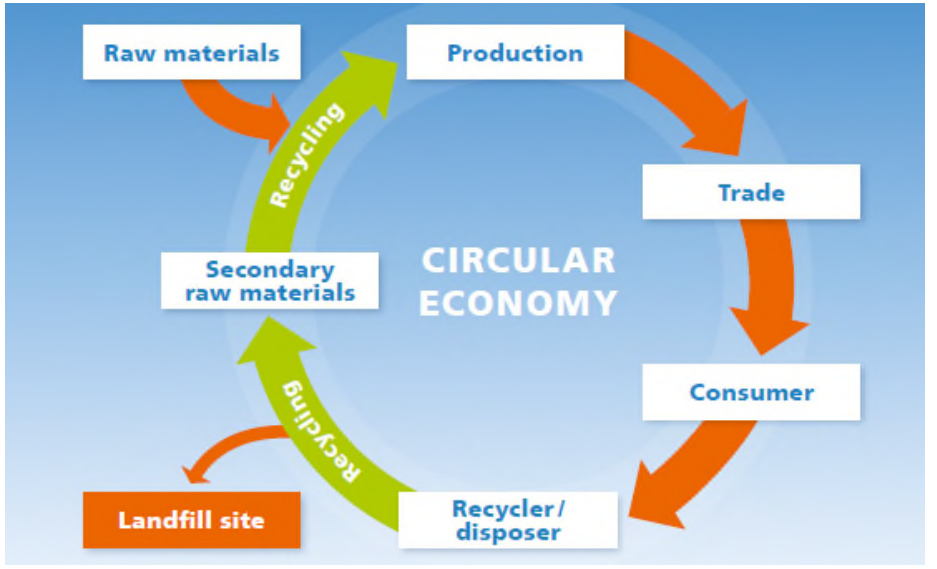
OUTLOOK AND VISIONS: WHERE DO WE GO

- Circular Economy as Key topic for future developments
- Lightweight Materials can have a major contribution

- **Further features:**
  - Alternative ressources / renewable carbon
  - Effective processing
  - Joining technologies as enabler for recycling
  - Smart materials / digitalisation
  - Repairability
  - End-of-Life Szenarios
  - …



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Further information on circular economy and adhesive bonding technology:
New study out now and available for free!

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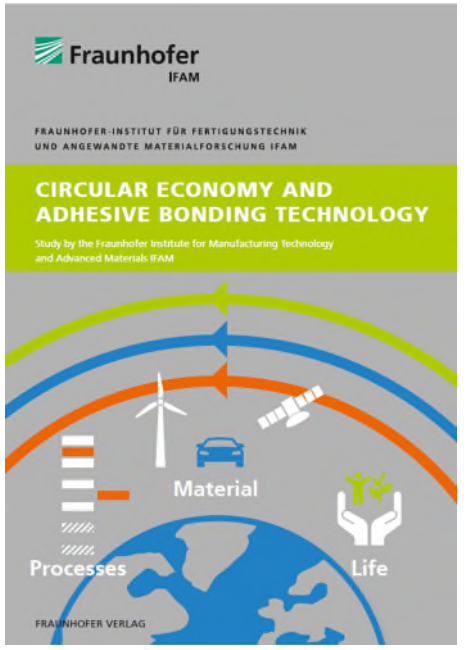

DOI: 10.24406/iml-n-603186

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