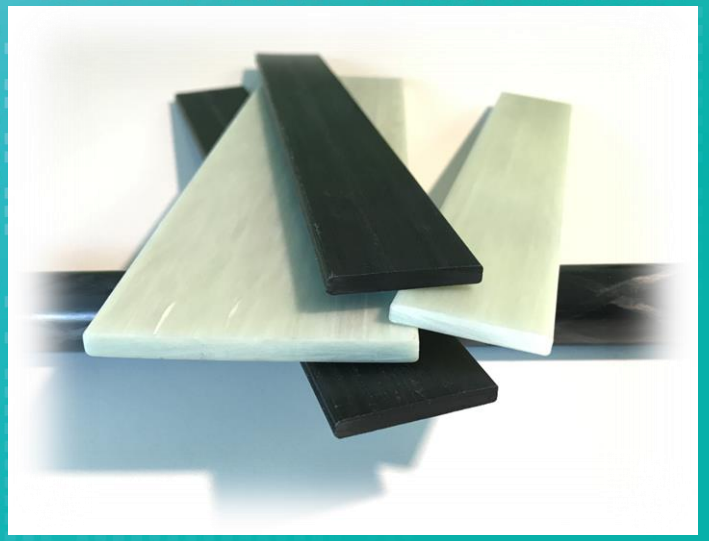
SPE AUTOMOTIVE COMPOSITES CONFERENCE & EXPO (ACCE) 2022

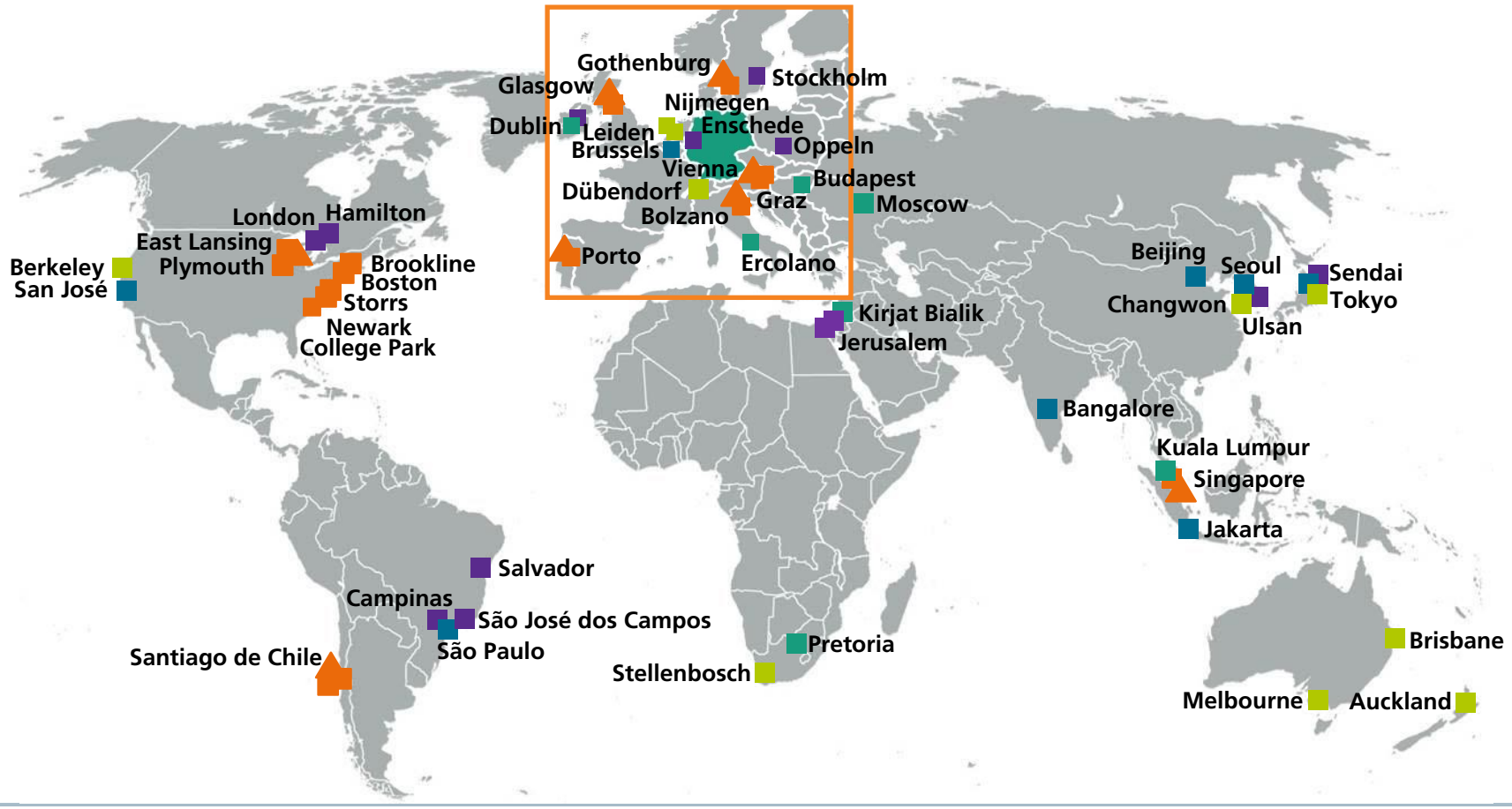
M.Sc. Michael Wilhelm

Doing it more sustainable - In-situ pultrusion of profiles based on PA6



Fraunhofer-Gesellschaft

Worldwide



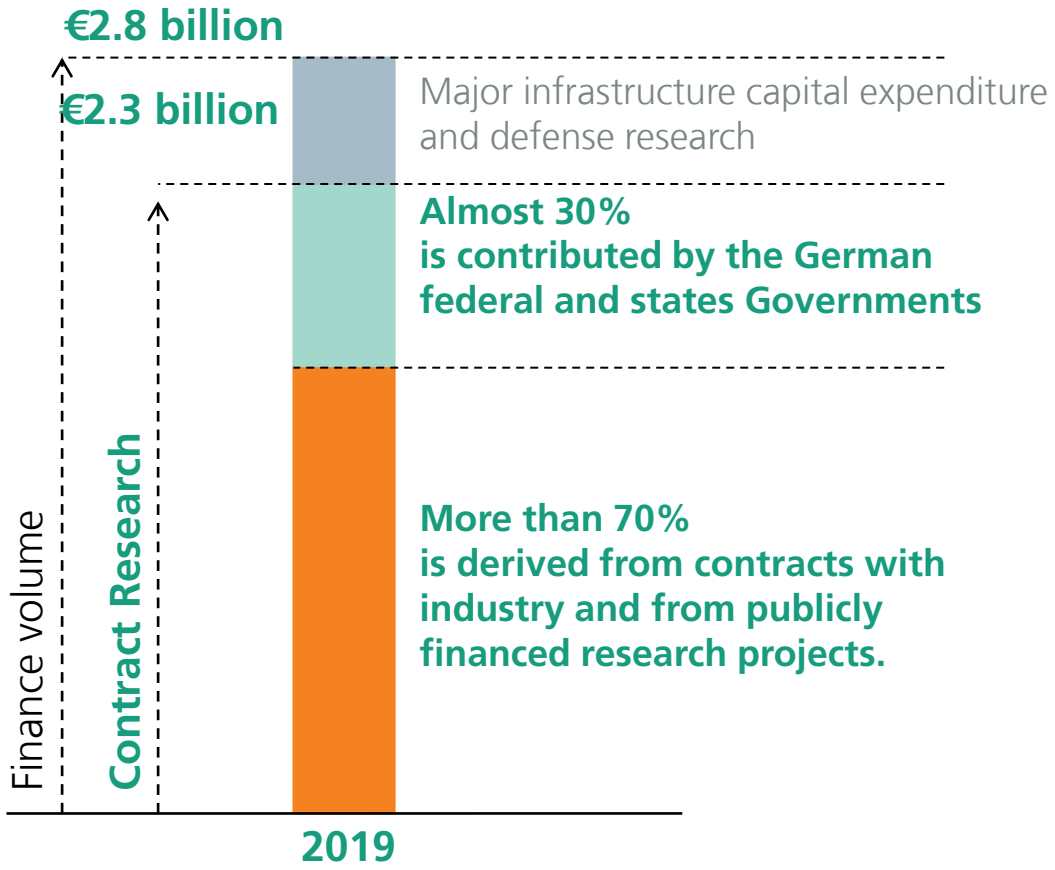
- 8 Affiliates
- 16 Center
- 12 Project Center
- 10 ICON
- 6 Representative Offices + BRU
- 7 Senior Advisor

The Fraunhofer-Gesellschaft at a Glance

The Fraunhofer-Gesellschaft undertakes applied research of direct utility to private and public enterprise and of wide benefit to society.

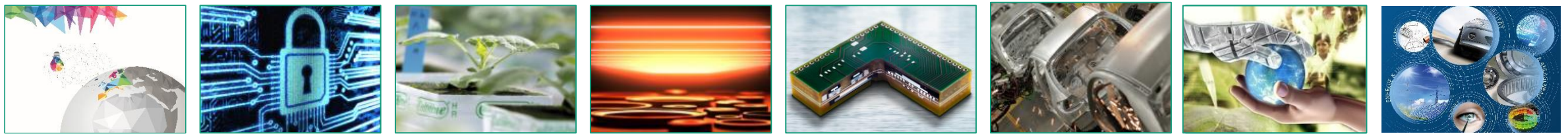
28,000 staff

74 institutes and research units



Fraunhofer Groups

Pooling expertise



Institutes working in related subject areas cooperate in Fraunhofer Groups and foster a joint presence on the R&D market. They help to define the Fraunhofer-Gesellschaft's business policy and act to implement the organizational and funding principles of the Fraunhofer model.

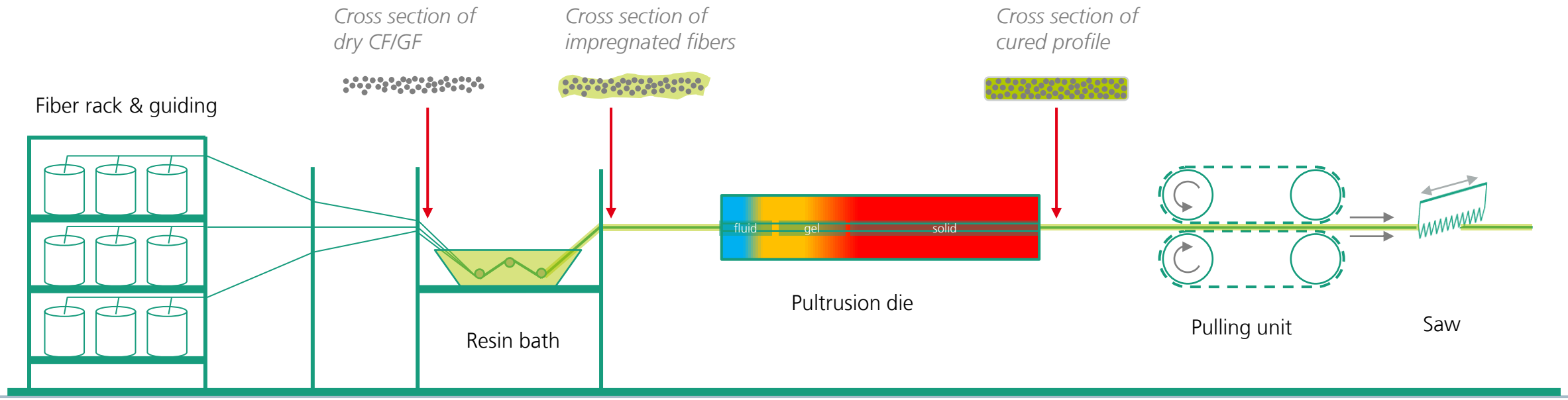
- Innovation Research
- Information and Communication Technology
- Life Sciences
- Light & Surfaces
- Microelectronics
- Production
- Defense and Security
- Materials and Components – MATERIALS


Fraunhofer
ICT
Photo: Peter Eich, Karlsruhe

Pultrusion
Process

- **State of the art Pultrusion with resin bath**
  - Wetting of fibers usually in an open impregnation bath with thermoset matrix
  - Almost all pultrusion profiles are based on thermoset matrices up to now

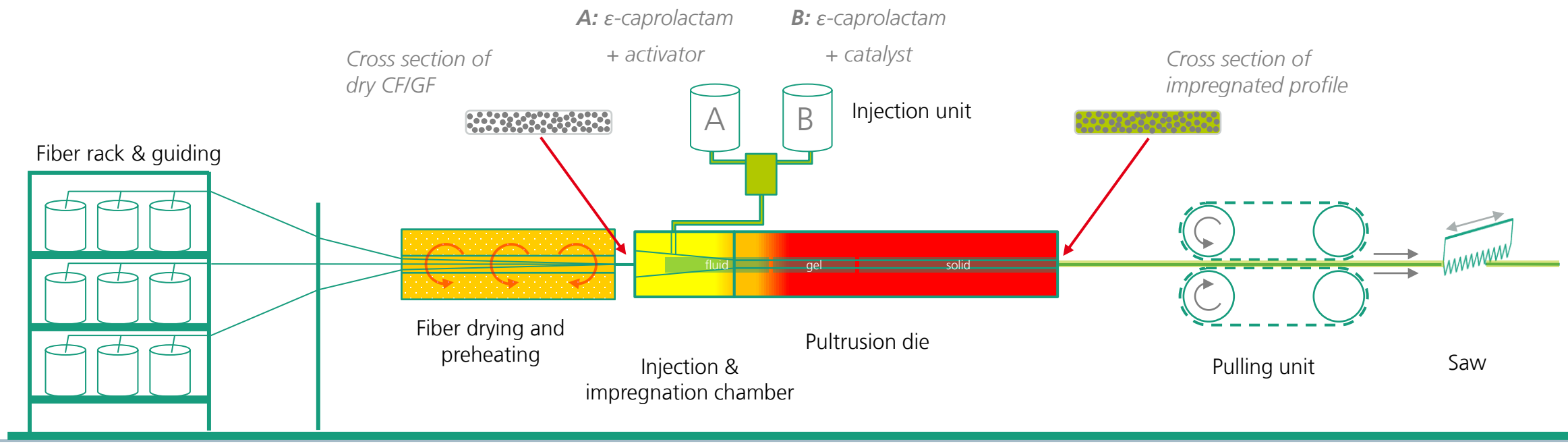
    → **Functionalization and recyclability is limited**



In-situ-Pultrusion

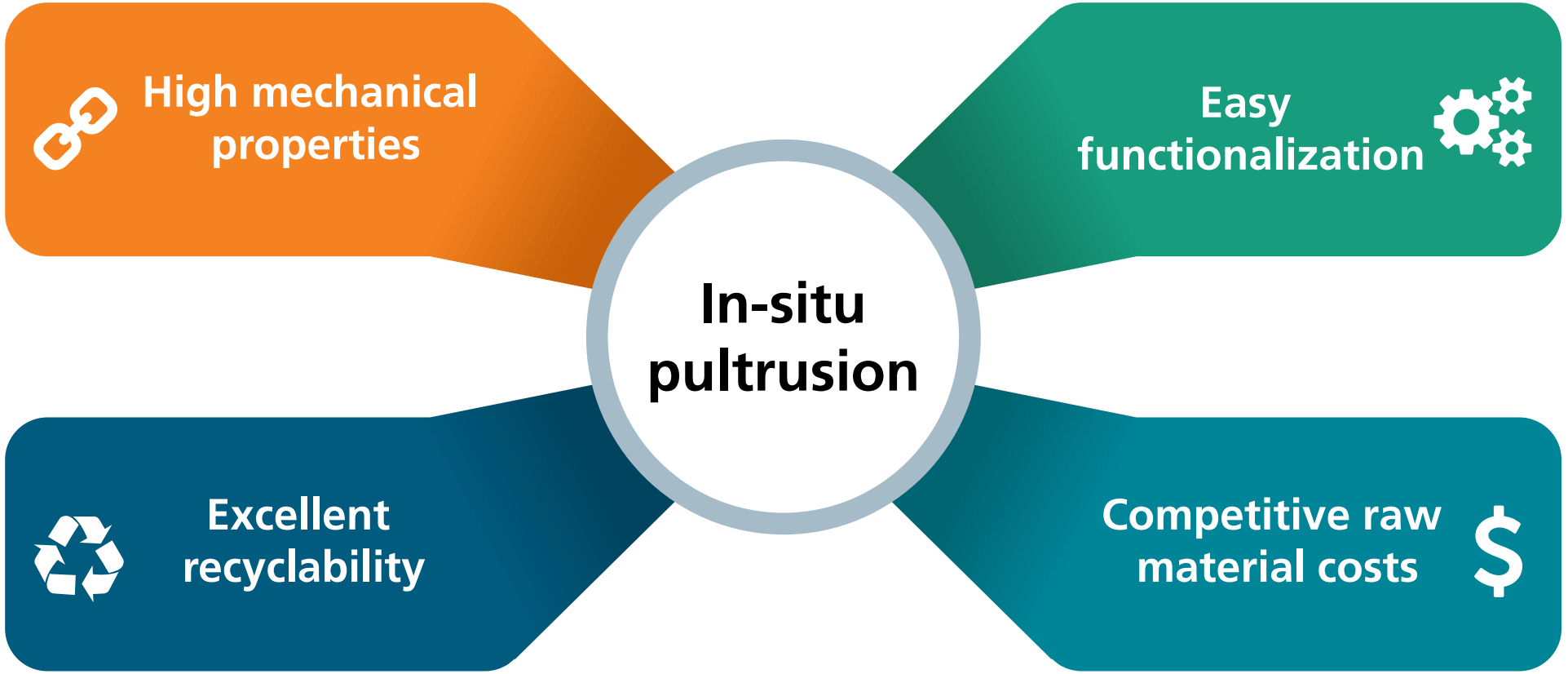
Process

- **In-situ-Pultrusion for the production of high-performance, thermoplastic FRP profiles**



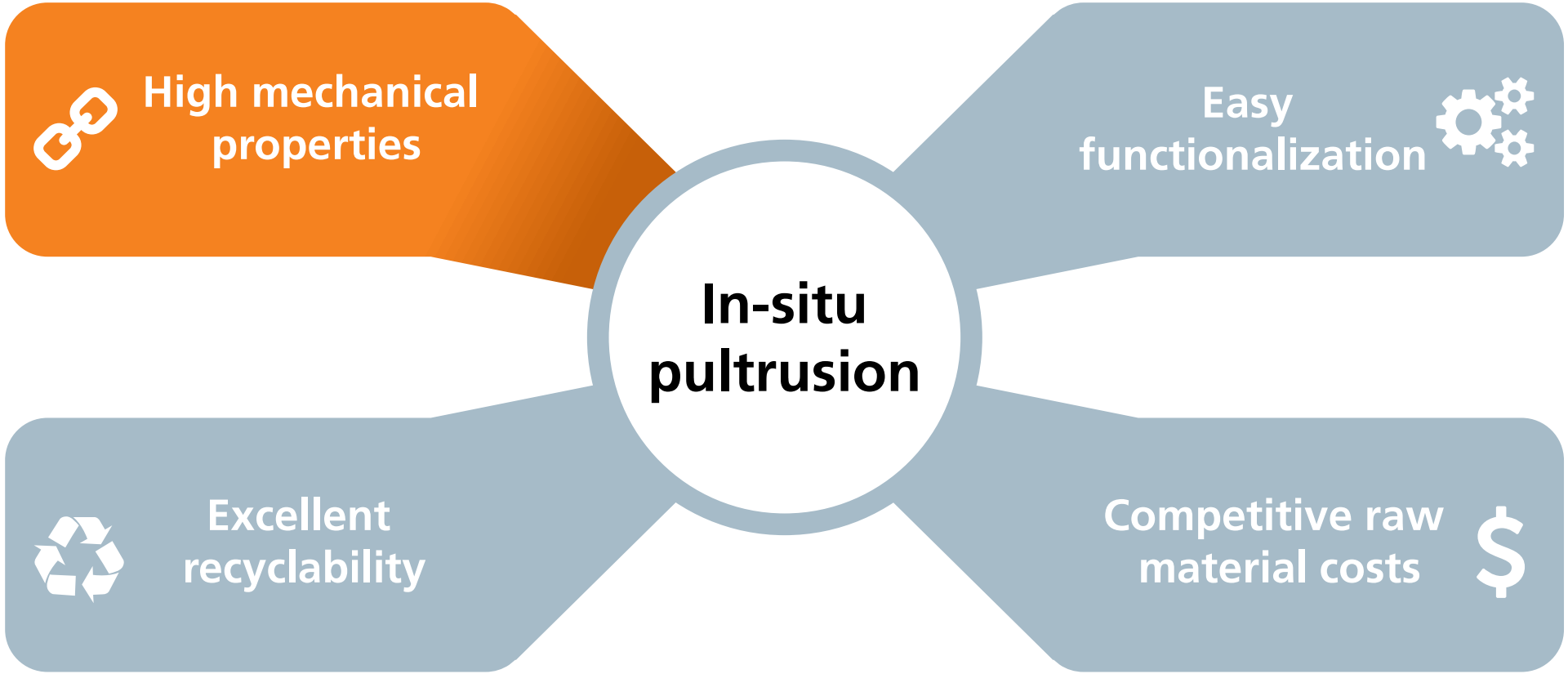
In-situ-Pultrusion

Key benefits



In-situ-Pultrusion

Key benefits

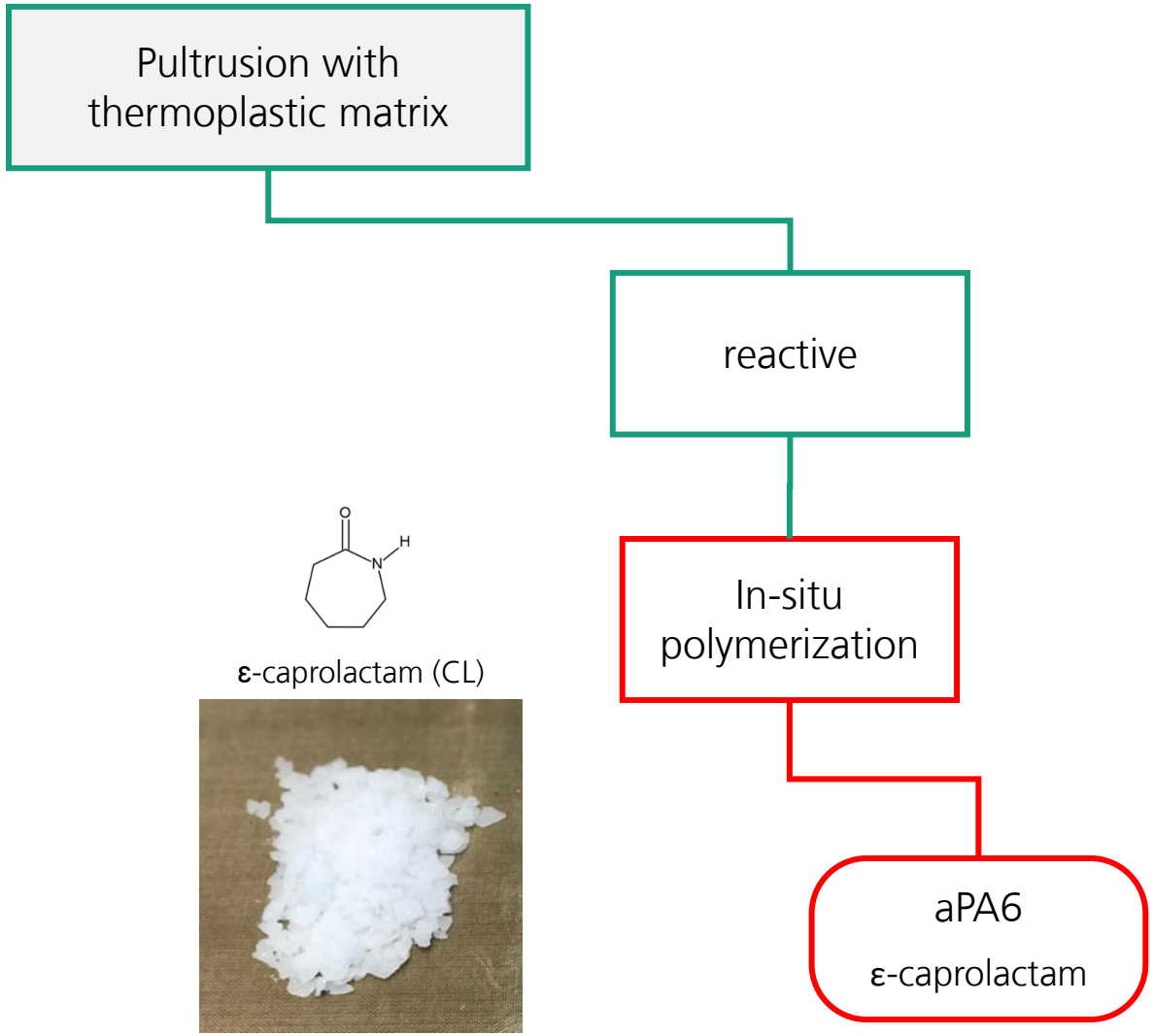


Thermoplastic Pultrusion

Matrix

- **Properties of the aPA6 matrix**
  - Extremely low viscosity: 5-10 mPa*s @ > 70°C
  - Adjustable reactivity via activator and catalyst

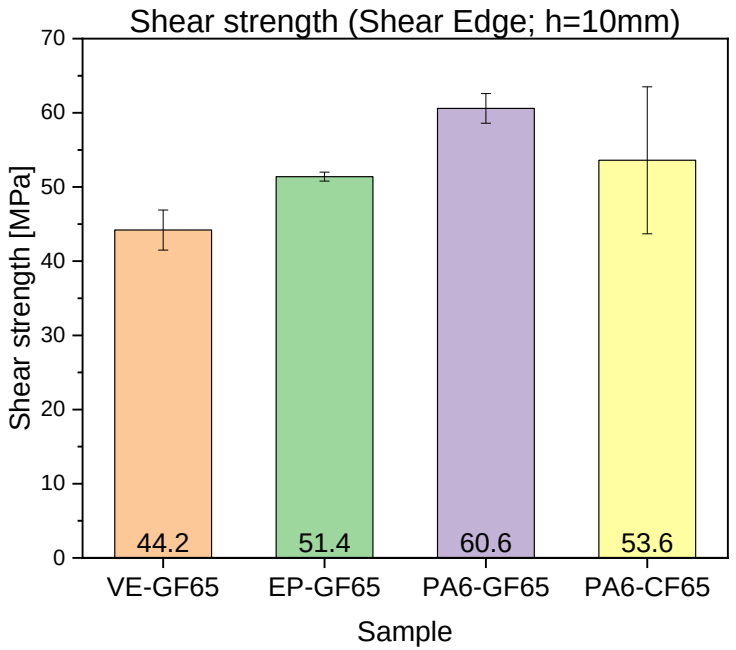
    → Short curing time and high haul off speeds
  - Good polymer properties
    - Extremely high molar mass (10^5 – 10^6 g/mol)
    - High degree of crystallinity
  - Modification with additives (Impact, UV, color, flame retardants, chemical stabilizers, …)
- **Challenges**
  - Sensitive to environmental influences (e.g. H_2O)
  - Suitable sizings for FRP required

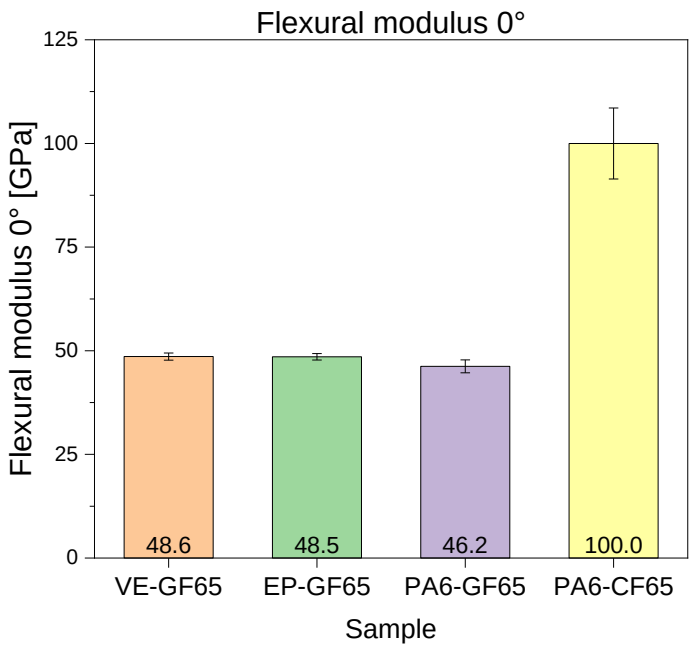


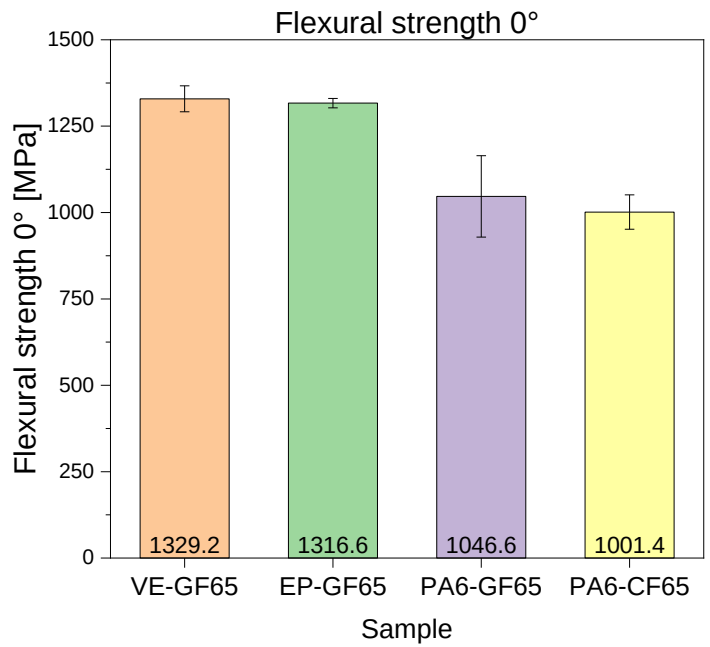
Benchmark of mechanical properties

VE / EP / PA

- Competitive mechanical performance of thermoplastic and thermoset profiles
- Shear strength of >60 MPa for PA6-GF65



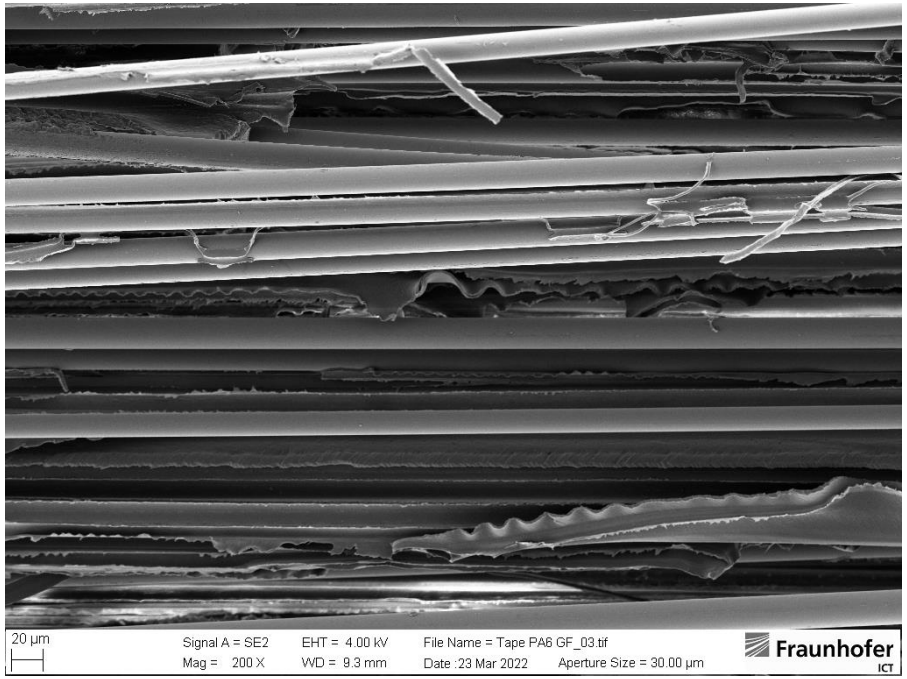




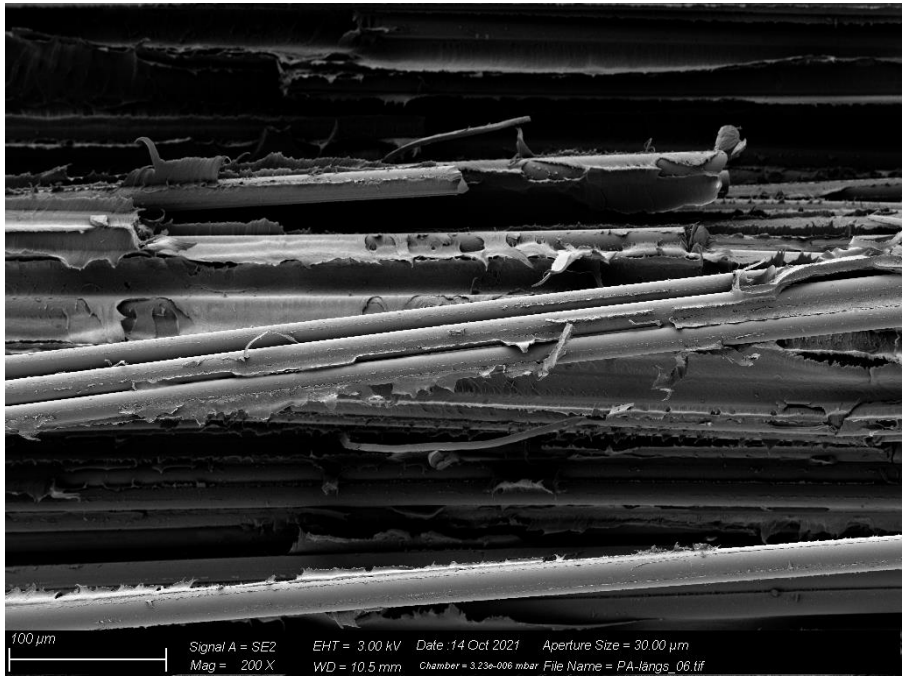
Benchmark of mechanical properties

PA6 non-reactive vs. reactive

- **Reactive processing with suitable sizing increases fiber-matrix bond significantly**



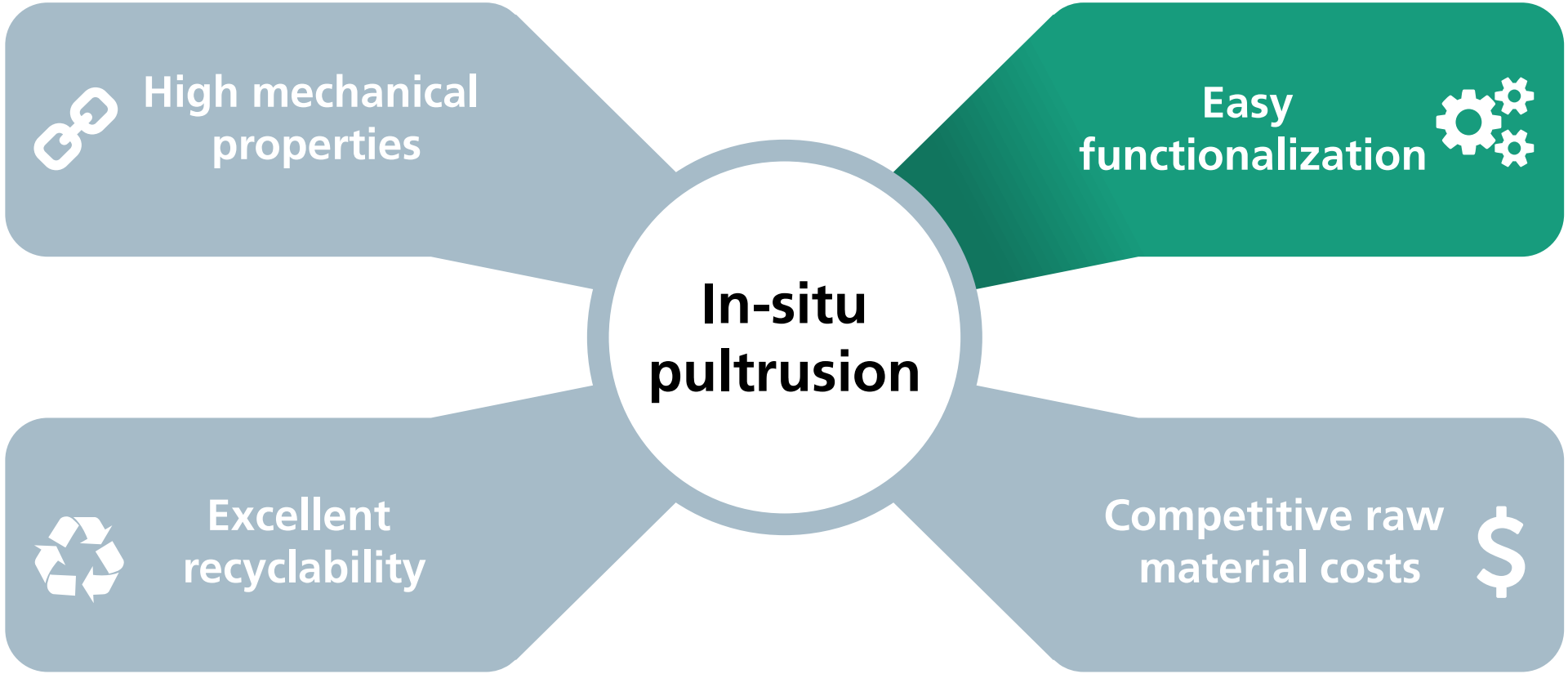
Non reactively processed PA6GF tape



In-situ-pultrusion profile aPA6GF

In-situ-Pultrusion

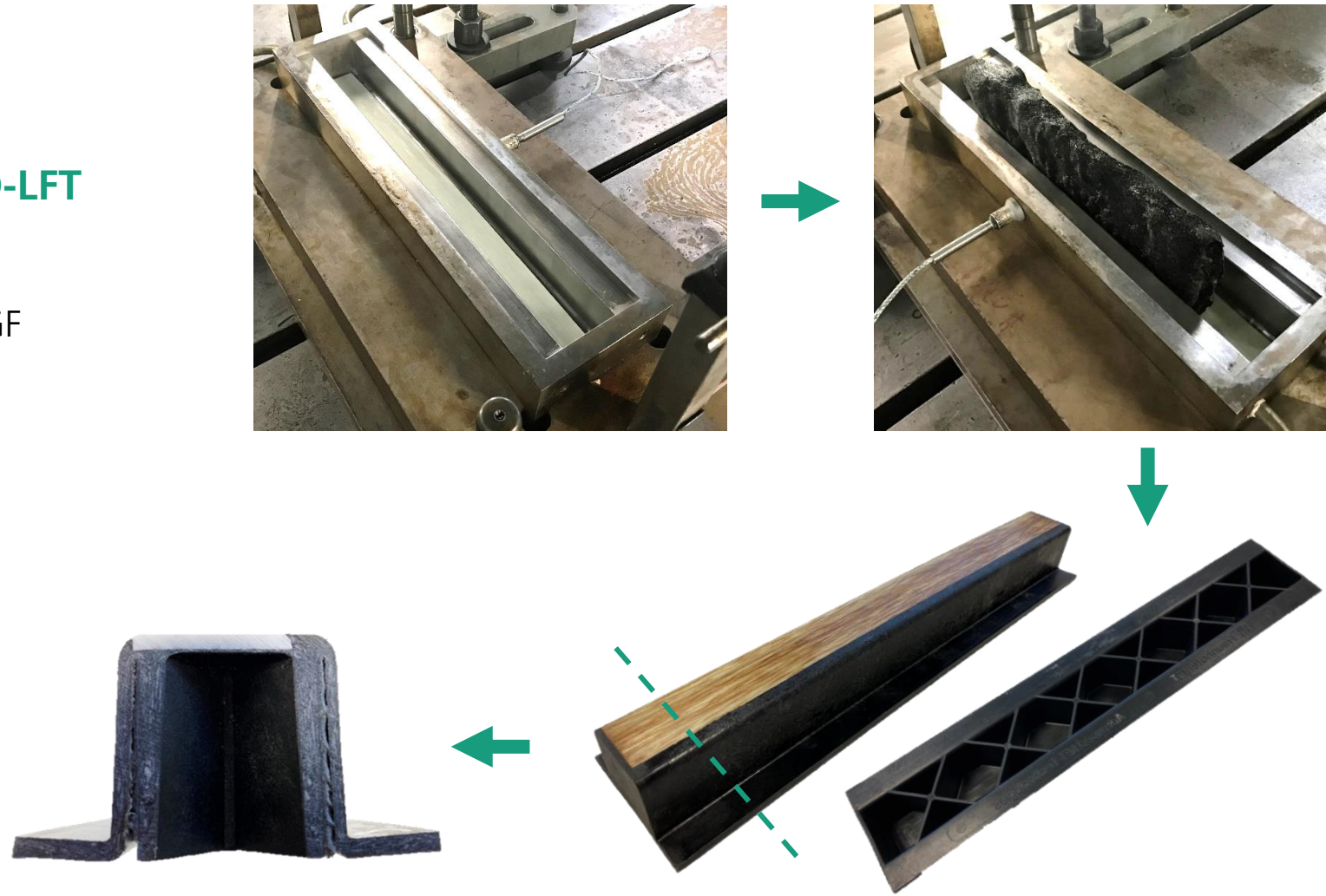
Key benefits



Functionalization

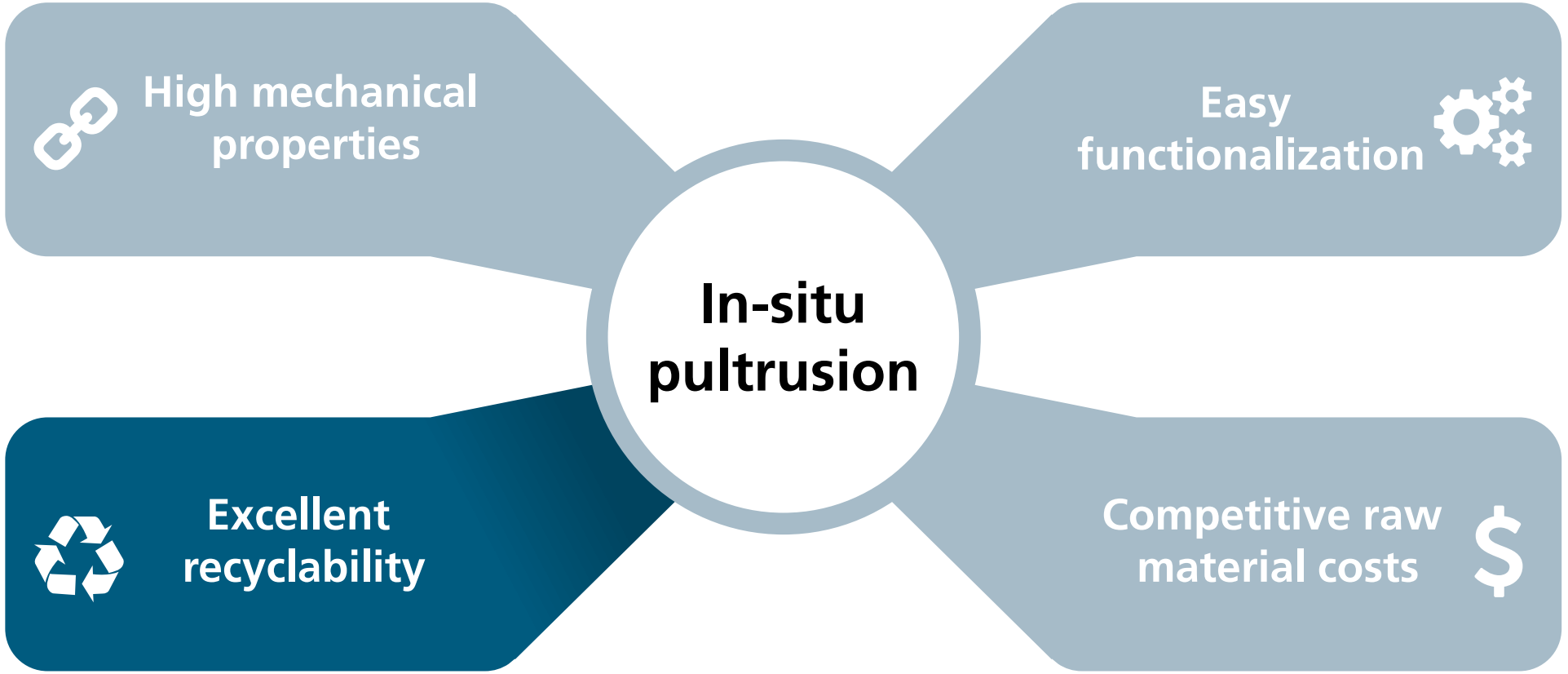
Demonstrator example

- **Co-molding of in-situ-pultrusion profiles and D-LFT**
- **“Erlanger Träger”**
  - PA6 profiles with 65 vol.% GF
    - t = 2 mm/ 3 mm
    - PA6 GF45 D-LFT



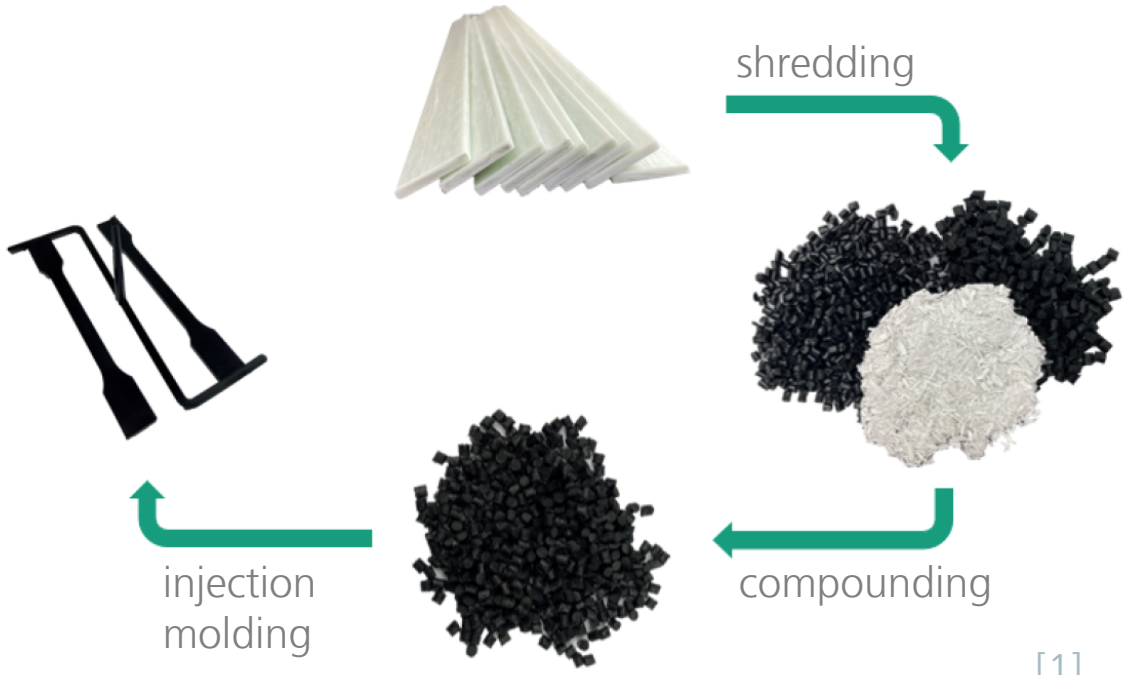
In-situ-Pultrusion

Key benefits



Recycling

- **Different options for recycling routes**
  - Mechanical recycling
  - Chemical recycling
- **Benchmark with virgin PA6GF30:**
  - Only 10% less tensile strength and stiffness
  - Impact strength strongly depends on amount of recyclate
  - No need for variation of injection molding parameters
  - No need for separation of coarse and dust fraction after shredding



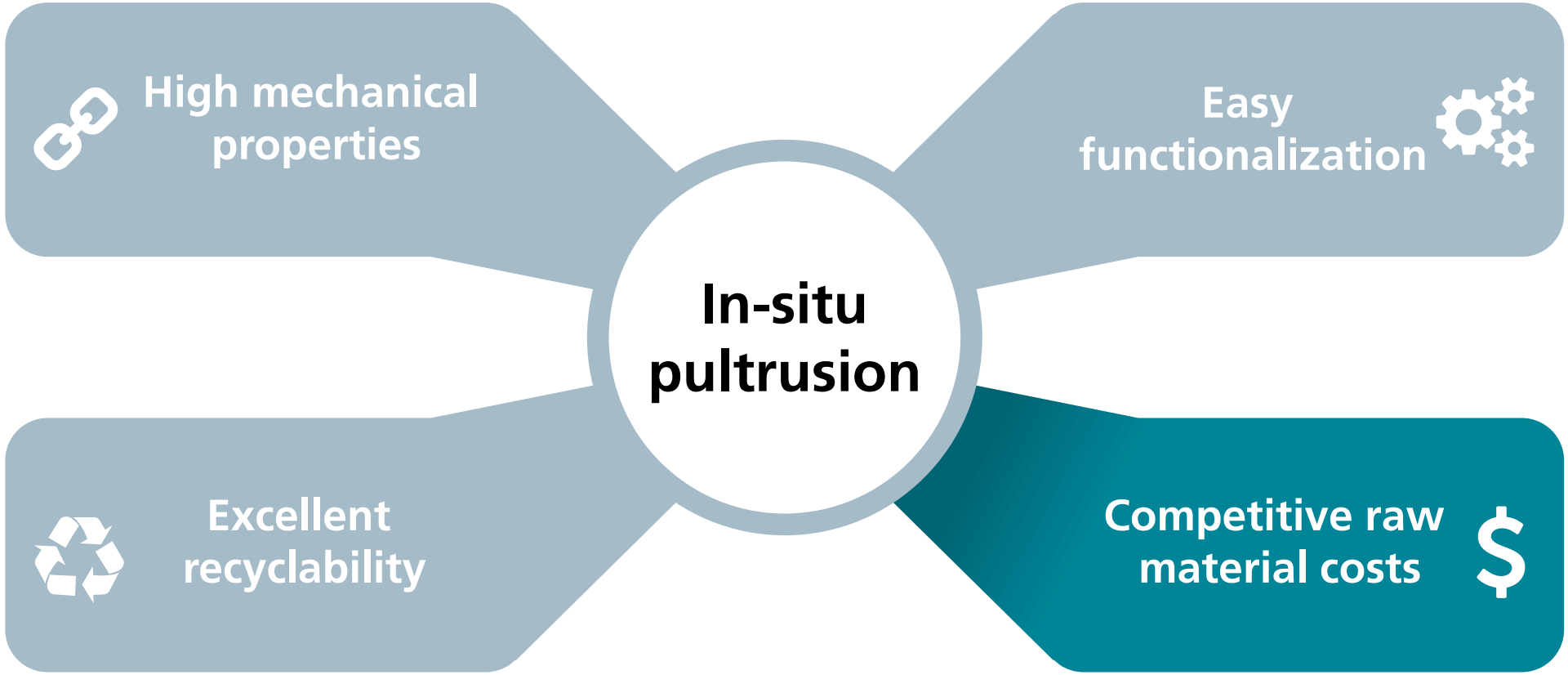
[1]

Detailed results will be published soon

[1]: Henrik Kummert, Bachelor thesis, „*Mechanisches Recycling von In-situ-Pultrusions-Profilen am Beispiel der Materialkombination PA6 und Glasfaser*“, 2022

In-situ-Pultrusion

Key benefits

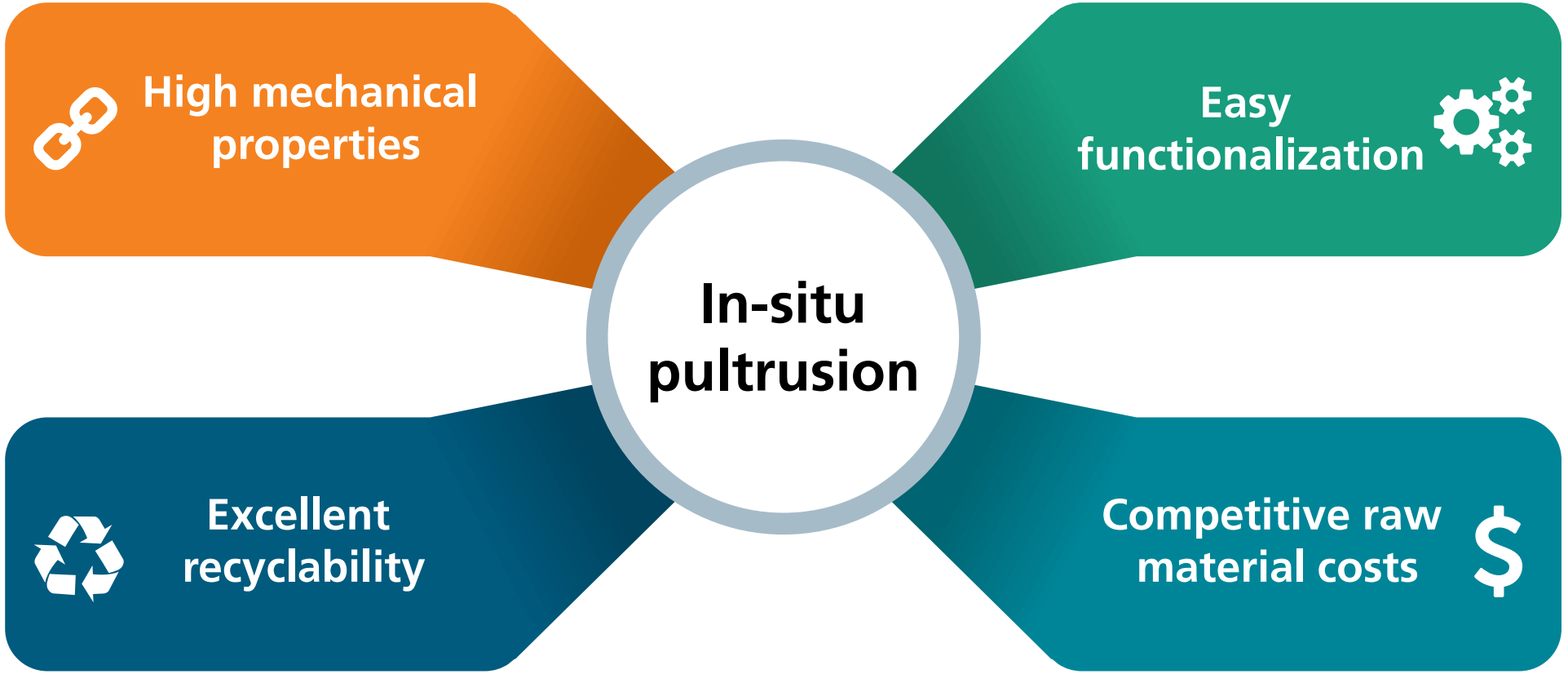


Competitiveness
In-situ-Pultrusion

- **Machinery**
  - Similar machinery invest compared to thermoset
    - Dosing machine and injection + impregnation box
  - Additional fiber drying and preheating unit necessary
- **Processing**
  - Haul off speed up to 1.6 m/min for flat profiles successfully demonstrated
  - More complex profiles are currently under investigation
- **Materials**
  - Matrix system costs are comparable to VE with <5 $/kg
  - Slightly higher fiber costs
  - No need for fillers

In-situ-Pultrusion

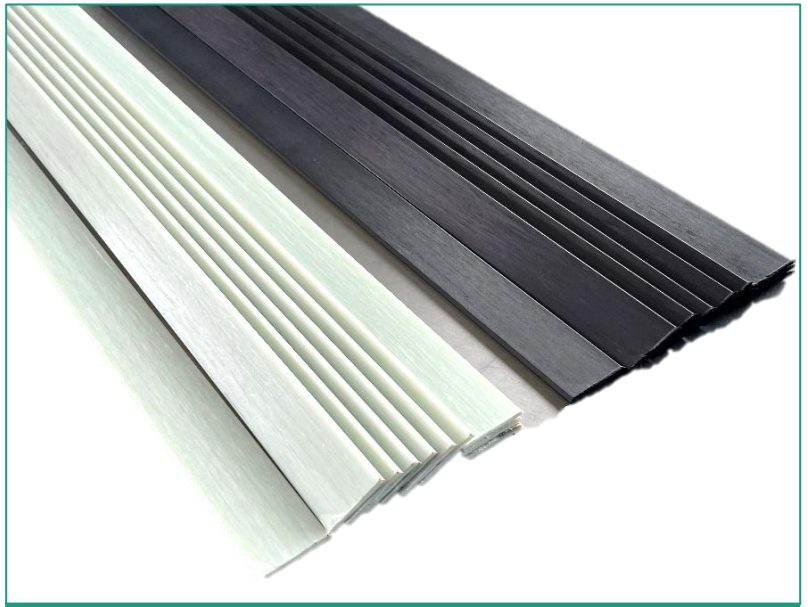
Key benefits



Our research topics
for in-situ-Pultrusion

Research focus:

- Evaluation and optimization of process parameters and materials
- Design and comparison of different injection chambers
- End-of-Life processes / Recycling
- Process digitalization
- Development of methods for fast and cost-efficient characterization (quality management)
- Implementation and evaluation of newly developed reactive thermoplastic matrices

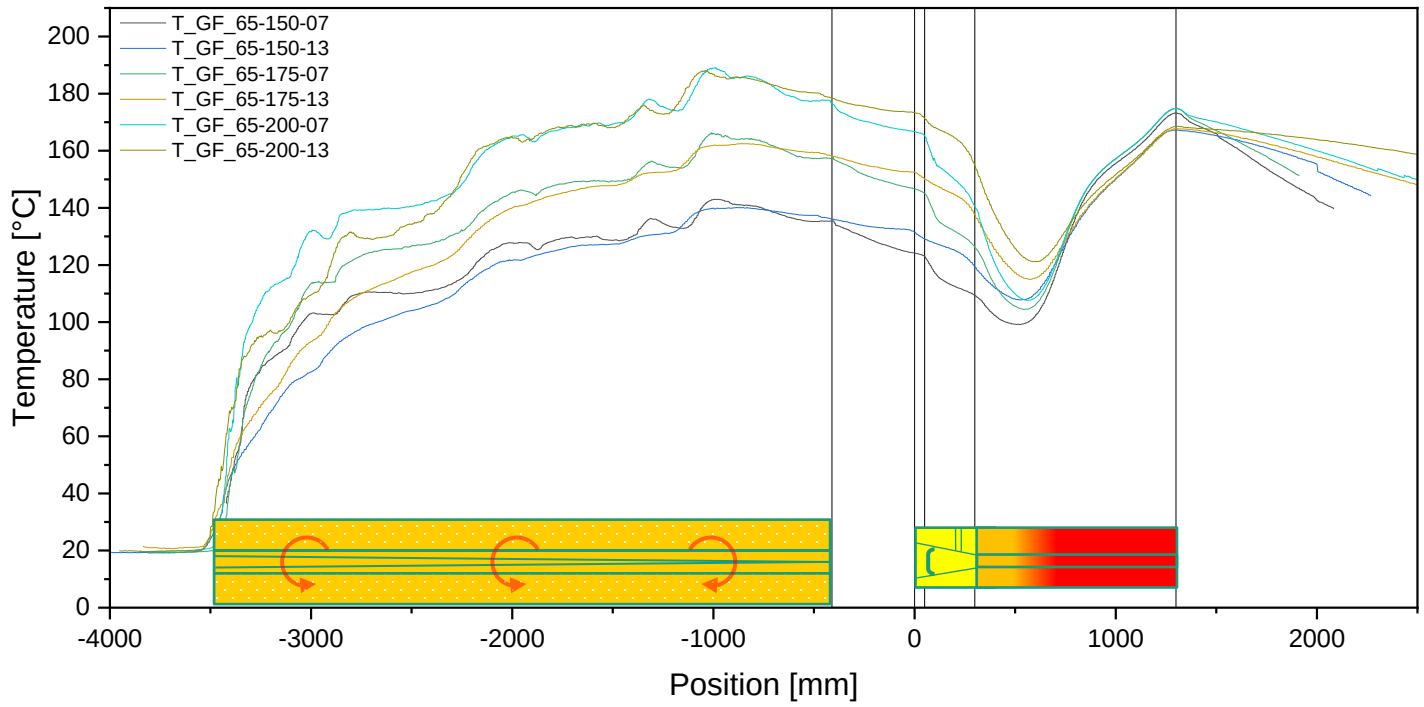


Flat profiles made with
in-situ-Pultrusion
30 x 4 mm^2
Matrix: Brüggemann Chemicals
Fibers: Johns Manville/ Zoltek (65-71% FVC)

Latest research

Temperature evolution of glass fibers moving through the preheating & drying unit

- Necessary to adjust haul off speed
- Significant difference within drying unit at different heater temperatures
- Nearly no speed dependence visible in the die (0.7 – 1.3 m/min)
- Parameters:
  - 65% FVC
  - Temperature: 150 – 200°C
  - Speed: 0.7 – 1.3 m/min

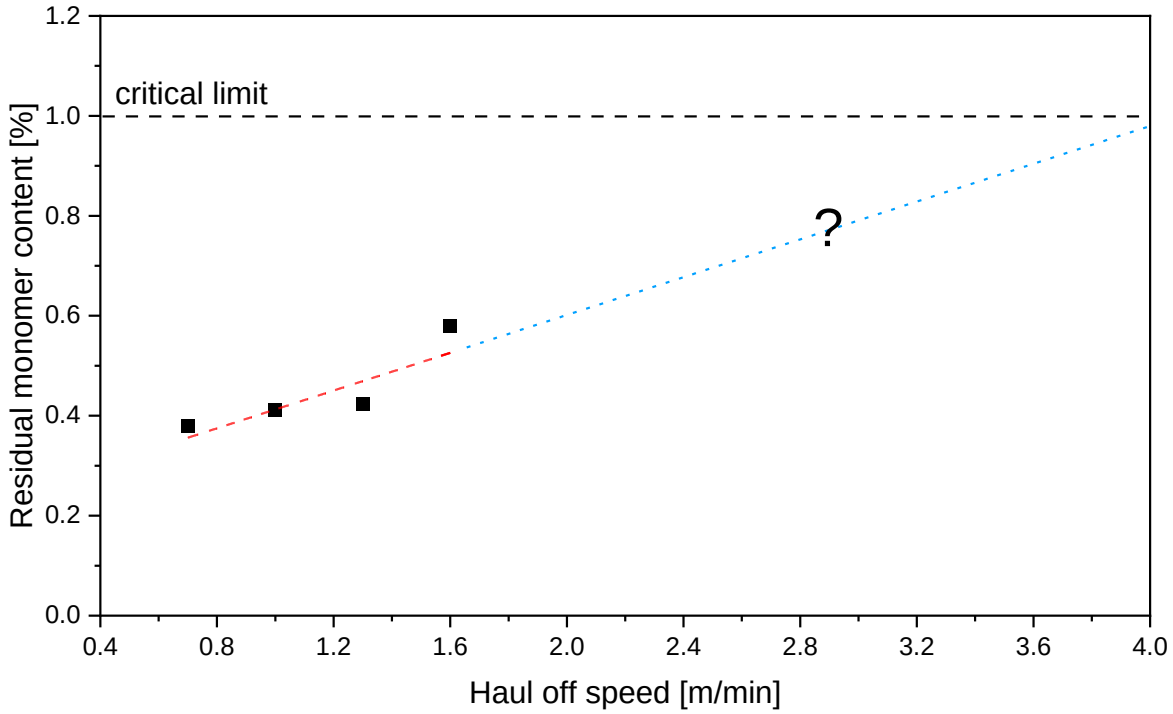


…and finally, the happy and promising ending…

Latest research

Residual monomer content dependent on the haul off speed

- Residual monomer content (RMC) is the critical quality parameter of in-situ polymerized FRPs
- Most important factor for economic production
- Current process window with haul off speed up to 1.6 m/min is still far below 1% RMC
- Even more potential for reduction is under investigation



Thank you for your attention!

Contact

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