Pinfa Sparks

Thursday 5 February 2026
14.00 – 14.45 CET

Recycling of Halogen-Free Flame Retarded Plastics :

Challenge or solution for high value applications?

Presented by

Dr. Michael Grosshauser
Scientific Expert, Central Project Acquisition
Fraunhofer Institute for Structural Durability and System Reliability LBF

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Cefic sector group

The European Chemical Industry Council, AISBL – Rue Belliard, 40 - 1040 Brussels – Belgium
Transparency Register n°64879142323-90

Welcome & Introduction

Thomas FUTTERER & Esther AGYEMAN-BUDU

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COMPETITION LAW

CHECKLIST FOR MEETINGS

DO

Ensure strict performance in areas on:

Oversight / Supervision

- Have a Cefic/Sector Group Secretariat representative at each meeting
- Consult with appropriate counsel on all questions which might be related to competition law
- Limit meeting discussions to agenda topics
- Provide each attendee with a copy of this checklist, and have a copy available for reference at all meetings

Recordkeeping

- Have an agenda and minutes which accurately reflects the matters which occur
- Ensure the review of agendas, minutes and other important documents by appropriate staff or counsel, in advance of distribution
- Fully describe the purposes, structures and authorities of the groups

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- Protest any discussion or meeting activities which appear to violate this checklist
- Ask for those activities to be stopped so that appropriate legal check can be made by counsel
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Contact: Quentin Silvestre, Senior Legal Advisor at qsi@cefic.be

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in fact or appearance, discuss or exchange information not in conformity with competition law, including for example on:

Prices, including

- Individual company/industry prices changes, price differentials, discounts, allowances, credit terms, etc
- Individual company data on costs, production, capacity (other than nameplates capacities), inventories, sales, etc

Production, including

- Plans of individual companies concerning the design, production, distribution or marketing of particular products, including proposed territories or customers
- Changes in industry production capacity (other than nameplates capacities) or inventories, etc

Transportation rates

- Rates or rate policies for individual shipments, including basing point systems, zone prices, freight, etc

Market procedures, including

- Company bids on contracts for particular products; company procedures for responding to bid invitations
- Matters relating to actual or potential individual suppliers or customers that might have the effect of excluding them from any market or influencing the business conduct of firms towards them, etc
- Blacklist or boycott customers or suppliers

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- Participants using AI tools/assistants must deactivate the tool and prevent it from calling in, transcribing, recording, or summarising any virtual or in-person meetings organised by Cefic or its sector groups.
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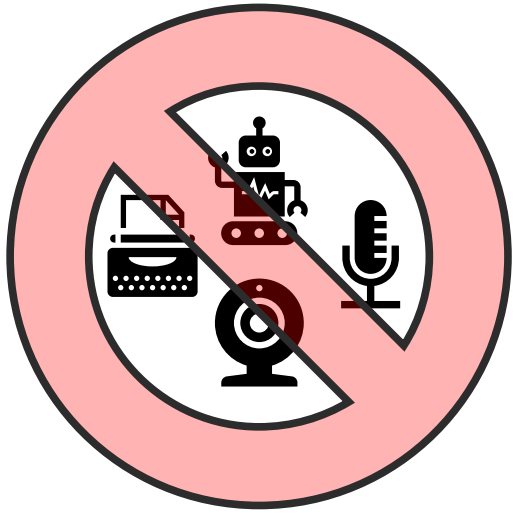

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- Submit your questions via the chat function during the session
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- This event will be recorded and posted on our website : www.pinfa.eu

Pinfa Sparks # 1

Recycling of Halogen-Free Flame Retarded Plastics

Challenge or solution for high value applications?

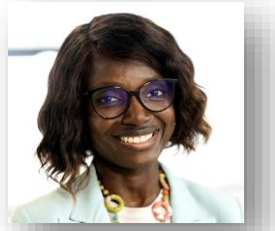
Speaker

Michael GROßHAUSER
Scientific Expert, Central Project Acquisition
Fraunhofer Institute for Structural Durability and System Reliability LBF

Moderated by

Thomas FUTTERER
Pinfa Chairman - Budenheim

Esther AGYEMAN-BUDU
Cefic Sector Group Manager



About us

Phosphorus, Inorganic and Nitrogen Flame retardants Association (pinfa)

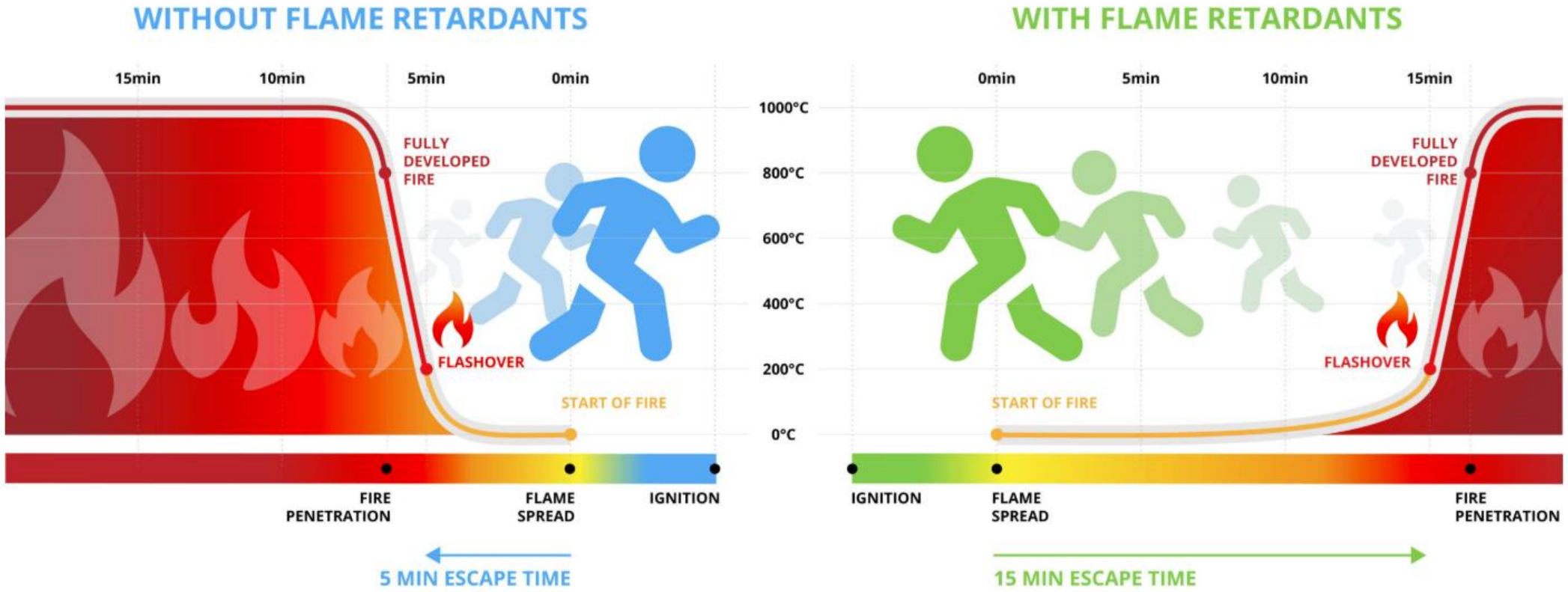
- Established in **2009** as a Sector Group within **Cefic**, the European Chemical Industry Council.
- Represents **26 members,** including **manufacturers and users** of the three major technologies of non-halogenated flame retardants.
- **pinfa-NA** and **pinfa China**, sister associations, established respectively in 2012 and 2018.
- Maintains mutual membership with **INEMI**[1] and partnership with **GTFI**[2], **EAPFP**[3], **EuroFSA**[4]

(1) International Electronics Manufacturing Initiative
(2) Groupement Technique Français contre l'Incendie
(3) European Association for Passive Fire Protection
(4) European Fire Safety Alliance

What are PIN Flame Retardants (PIN FRs)?

- PIN flame retardants are **phosphorus-, inorganic- and nitrogen-based** technologies designed to enhance fire safety in materials such as plastics, textiles, foams, and electronics.
- They contribute to fire protection by:
  - **Reducing flammability and slowing ignition**, helping materials resist or delay catching fire.
  - **Interfering with the burning process,** for example through char formation, heat shielding, or stabilising the polymer during exposure to heat.
  - **Limiting heat release and flame spread**, supporting improved fire performance across multiple applications.

How PIN FRs Support Increased Escape Time in Fires



- **PIN flame retardants slow down fire development, helping to delay ignition, reduce heat release and limit flame spread.**
- This slower progression can **extend the available time for people to escape,** which is critical for overall fire safety.

Pinfa members

Europe, China & North America

Meet the pinfa Europe team

Thomas Futterer
Chair

Adrian Beard
Vice-Chair

Zahra Fahimi
Vice-Chair

Sander Kroon
Vice-Chair

Esther Agyeman-budu
SG Manager

Francesca Filippini
SG Manager

Hannane Haddouch
Assistant

Myriam Goffin
Communications

Chris Thornton
Communications

pinfa members' shared vision

Vision: continuously improving the environmental and health profile of their flame-retardant products, offering innovative solutions for sustainable fire safety.

Commitment: to maintain high fire safety standards across the world, standards which minimize the risk of fire to the general public.

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Recycling of Halogen-Free Flame Retarded Plastics :

Challenge or solution for high value applications?

Dr. Michael GROßHAUSER

Fraunhofer Institute for Structural Durability and System Reliability LBF

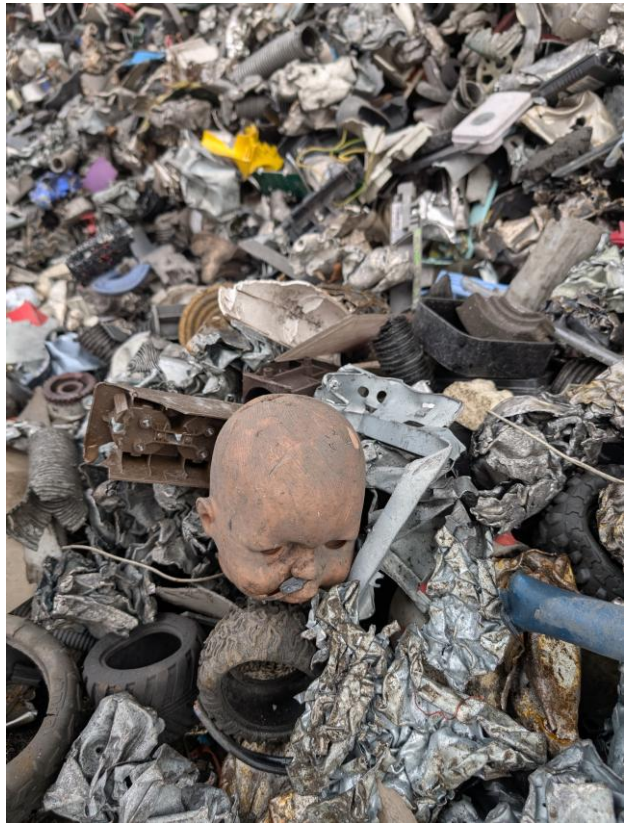
Cefic sector group

Recycling of halogen-free flame retarded plastics: challenge or solution for high value applications?

Dr. Michael Großhauser
Fraunhofer-Institute for structural durability and system reliability LBF

Agenda

- Fraunhofer LBF
- Motivation
- **Basics on material quality**
- **Projects in cooperation with Pinfa**
- Summary and take home massage



01

Fraunhofer LBF

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Fraunhofer LBF

Fraunhofer

Leading organization for application-oriented research in Europe

Fraunhofer focuses on transferring R&D from the lab into application, covering the key future-relevant technologies of today.

We assist our partners to commercialize our common findings in business and industry.

over **30,000**

employees

75

institutes and research facilities

€ 3.2 billion

financial volume
thereof € 2.6 billion contract research

funding mix: 70% orders from industry und public sector

30% base funding from Germany‘s state and federal governments

6200

customers from industry

Figures refer to the year 2022: Status as of May 15, 2023

Fraunhofer-Gesellschaft

International Network

- 8 Independent Fraunhofer affiliates
- Active with partners in approximately 80 countries
- Representative Offices and Senior Advisors worldwide leverage networks abroad

  Open

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Division Plastics

Synthesis and Formulation

- Synthesis in lab scale
- Upscaling in kg scale
- Formulation screening
- Lab scale compounding

Additivation and Durability

- Synthesis of additives in lab scale
- Formulation screening
- Compounding and material testing from gramme to kg scale
- Thermal ageing
- Artificial weathering

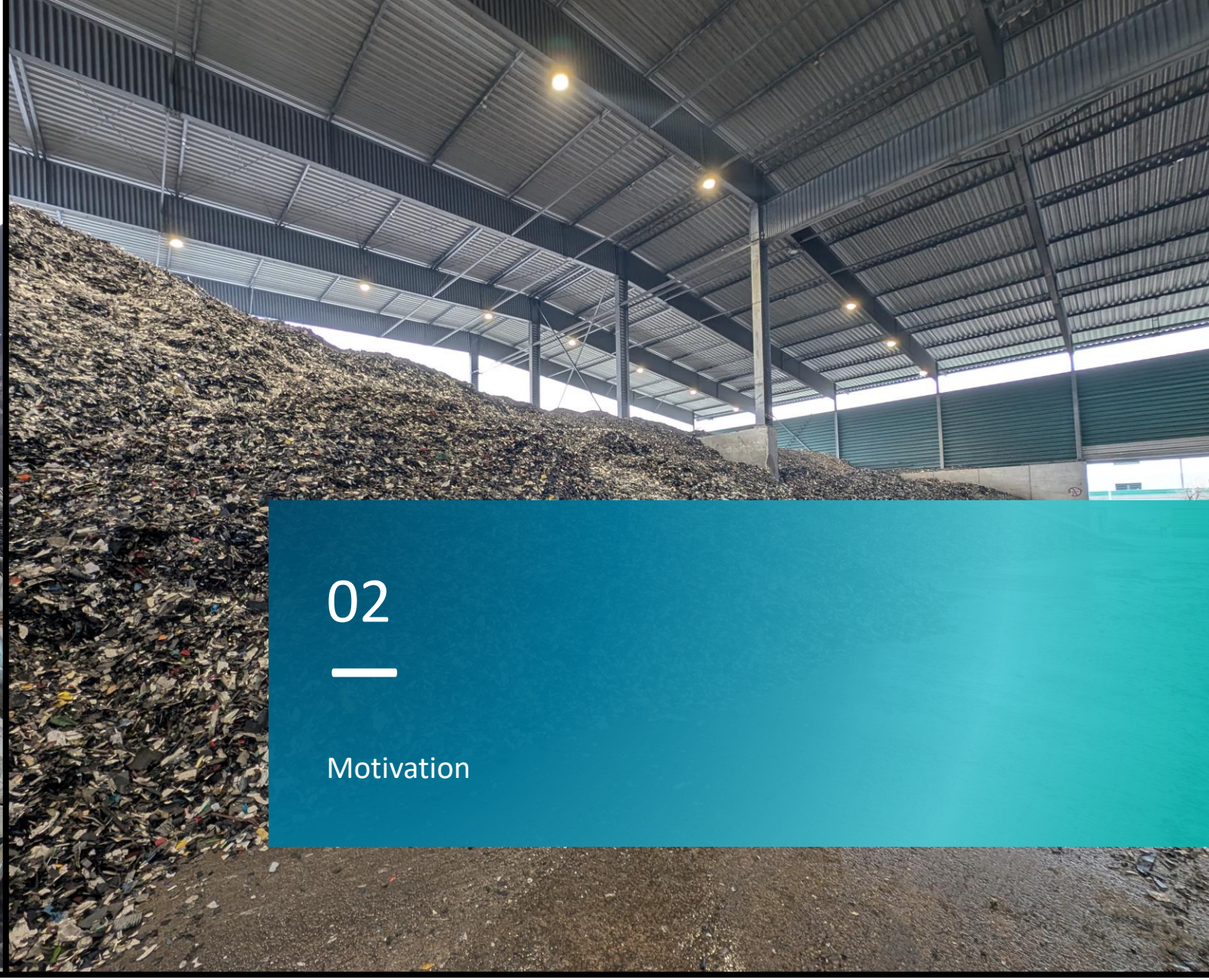
Material analysis and characterisation

- Chemical analysis
- Physical analysis
- Chemometrics
- Mechanical characterisation (static and dynamic loads, also under liquids and gases)
- Troubleshooting analysis for process- or material-related causes, critical operating loads, design

Plastics processing and component design

- Design and testing of components and their properties
- Integrative simulation and testing concepts
- Composite design: use of natural, glass and carbon fibres
- Process control

R&D along the plastics value chain: from the monomer to real-world applications



02

Motivation

European framework – A long way to the circular economy

Focus on waste prevention and disposal

- **1973** **First Environmental Action Programme (EAP):** First EU-wide environmental policy framework
- **1975** **Waste Framework Directive:** Established basic principles of EU waste management; Legal basis for future recycling legislation
- **1994** **Packaging and Packaging Waste Directive:** First EU rules targeting packaging waste; Introduced recovery and recycling targets
- **2000** **End-of-Life Vehicles (ELV) Directive:** Mandatory reuse and recycling targets for vehicles; Early product-specific recycling regulation

Clear transition to the circular economy

- **2008** **Revised Waste Framework Directive:** Introduced the EU waste hierarchy; Set binding recycling targets for member states
- **2015** **First Circular Economy Package:** Shift from waste management to material circularity; Starting point modern EU circular economy policy
- **2018** **EU Plastics Strategy:** First EU-wide strategy dedicated to plastics; Goal: all plastic packaging recyclable or reusable
  Revised Waste Framework Directive: Higher recycling targets for municipal waste; Reinforced circular economy principles

Targeted focus on plastics and recycling rates

- **2019** **Single-Use Plastics Directive:** Bans and restrictions on selected plastic products; Awareness and labeling requirements
  European Green Deal: Climate neutrality by 2050; Circular economy as a key pillar
- **2020** **Circular Economy Action Plan (CEAP):** Product design rules for durability and recyclability; Preparation for binding recycled content targets
- **2023** **End-of-Life Vehicles Regulation (proposal):** Mandatory recycled plastic content for vehicles, Stronger circularity requirements than ELV Directive
- **2024** **Packaging and Packaging Waste Regulation (PPWR):** Mandatory recycled content targets; Packaging reduction and reuse obligations
  Clean Industrial Deal: Supports competitive, low-carbon EU industry; Scaling up industrial recycling capacities

Development and status quo of the recycling industry

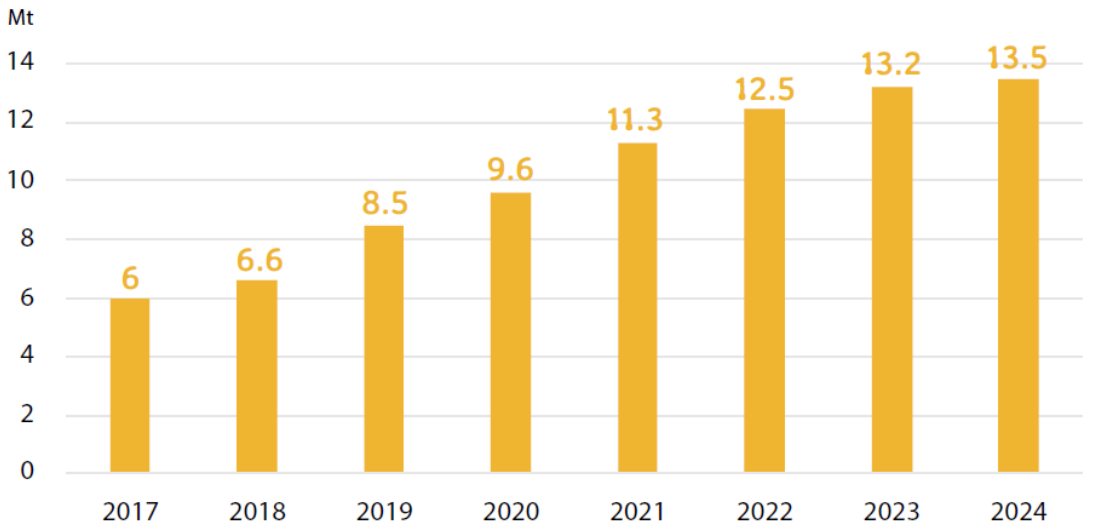
Status 2024:

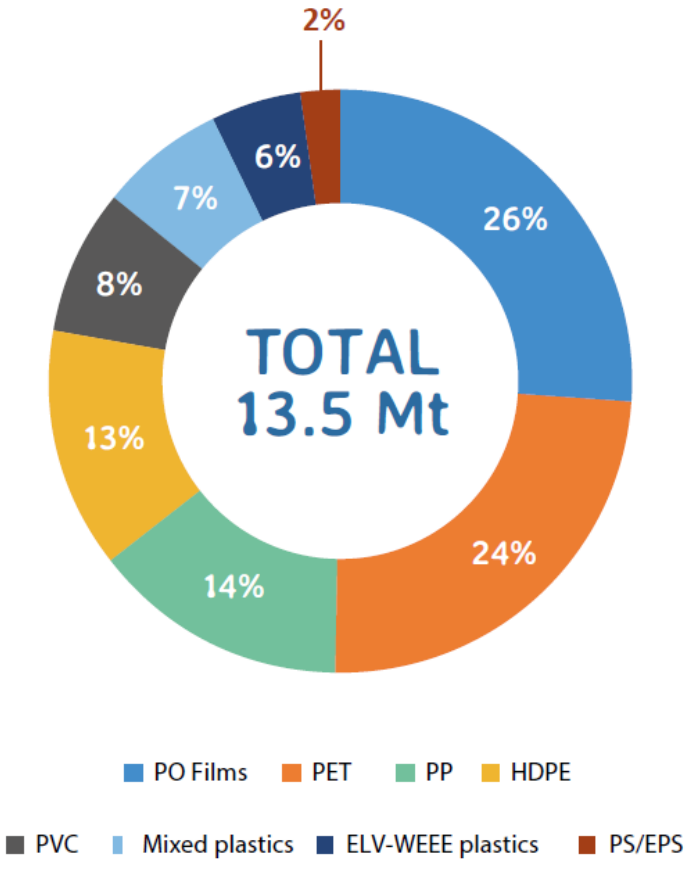
850 companies

13.5 million tonnes installed capacities

turnover: 8.6 bn€

30.000 employees

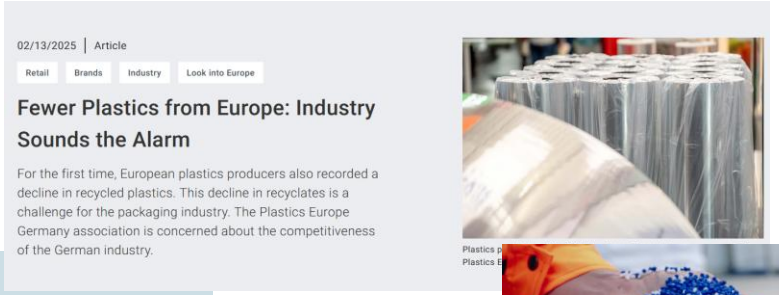




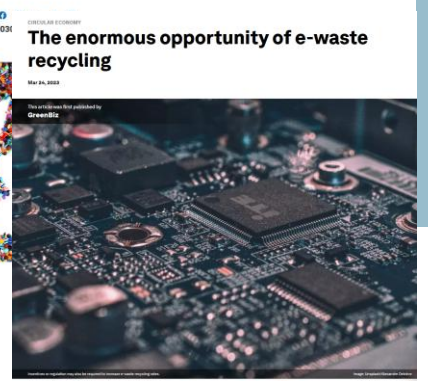
Source: **Plastics Recycling Industry Figures 2024 – Mapping of Installed Capacities** (Plastics Recyclers Europe PDF, *Statistics_2025_Final.pdf*)

Plastics Recycling in Europe: Pressure, Demand & Untapped Potential

Europe is losing recycling capacity despite rising regulatory demand.
For the first time, installed plastics recycling capacity declined, with significant plant closures across the EU.



The problem is not lack of potential, but lack of viable market conditions.
High-quality plastic waste streams exist, yet recyclers struggle to operate under pressure from low-priced virgin materials and imports.



High-value plastic streams remain largely underexploited.
Plastics from electronics, automotive and technical applications offer **substantial circularity potential**, but are insufficiently recovered and upgraded.

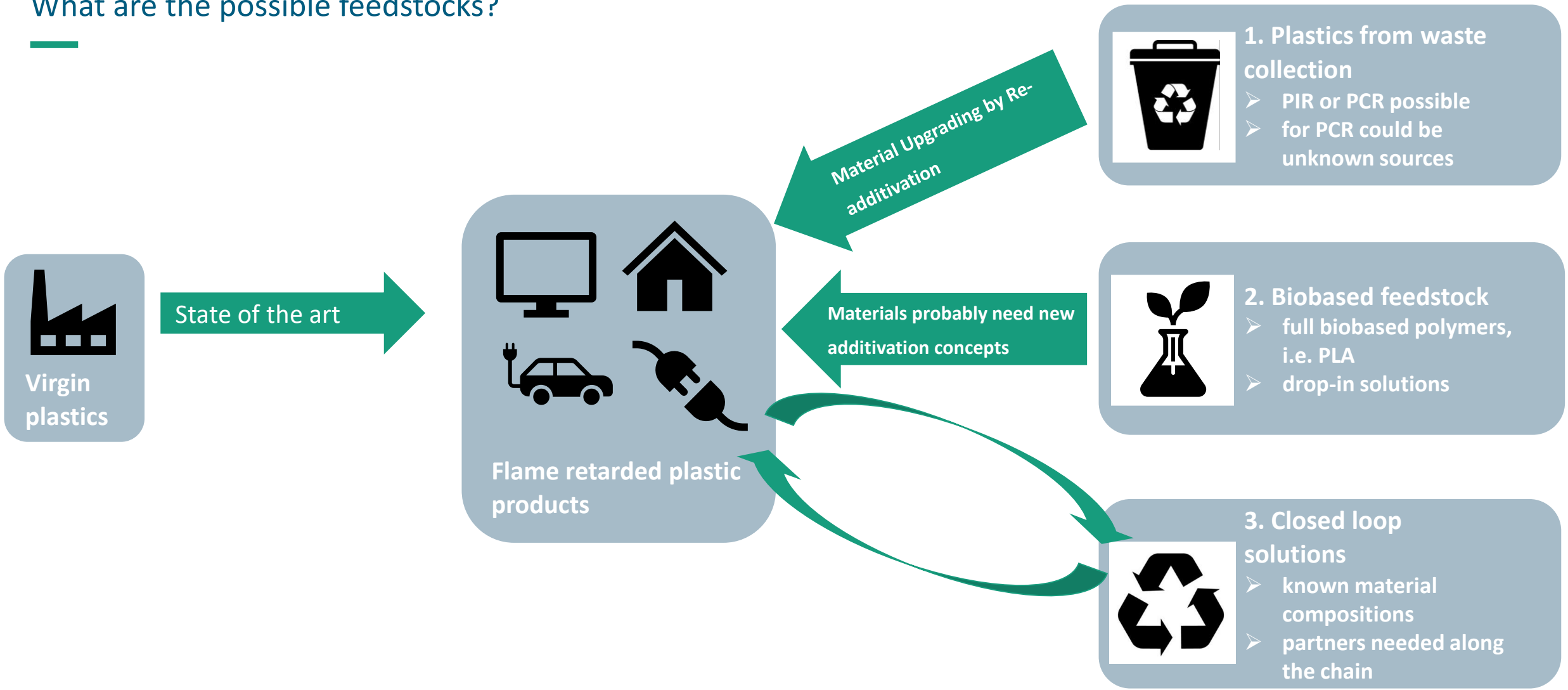
Policy ambition and market reality are structurally misaligned.
Recycled-content quotas assume scalable, competitive recycling – while current market dynamics actively undermine it.

Europe has the feedstock, the technology and the knowledge to scale plastics recycling — but without stabilising markets and unlocking high-value waste streams, this potential will remain unused.

From left to right:
https://knowesg.com/reporting-standards/eu-to-tighten-plastic-import-rules-in-2026-as-recycling-sector-struggles
https://waste-management-world.com/resource-use/plastic-recycling-the-future-of-recycled-material-availability-challenges-and-opportunities-to-2030/;
https://www.weforum.org/stories/2023/03/the-enormous-opportunity-of-e-waste-recycling/
https://www.fachpack.de/en/fachpack-360/2025-1/article/plastics-europe-fewer-plastics-from-europe-industry-sounds-the-alarm
https://erp-recycling.org/news-and-events/2025/04/germany-plastics-industry-warns-of-imminent-recyclate-gap/

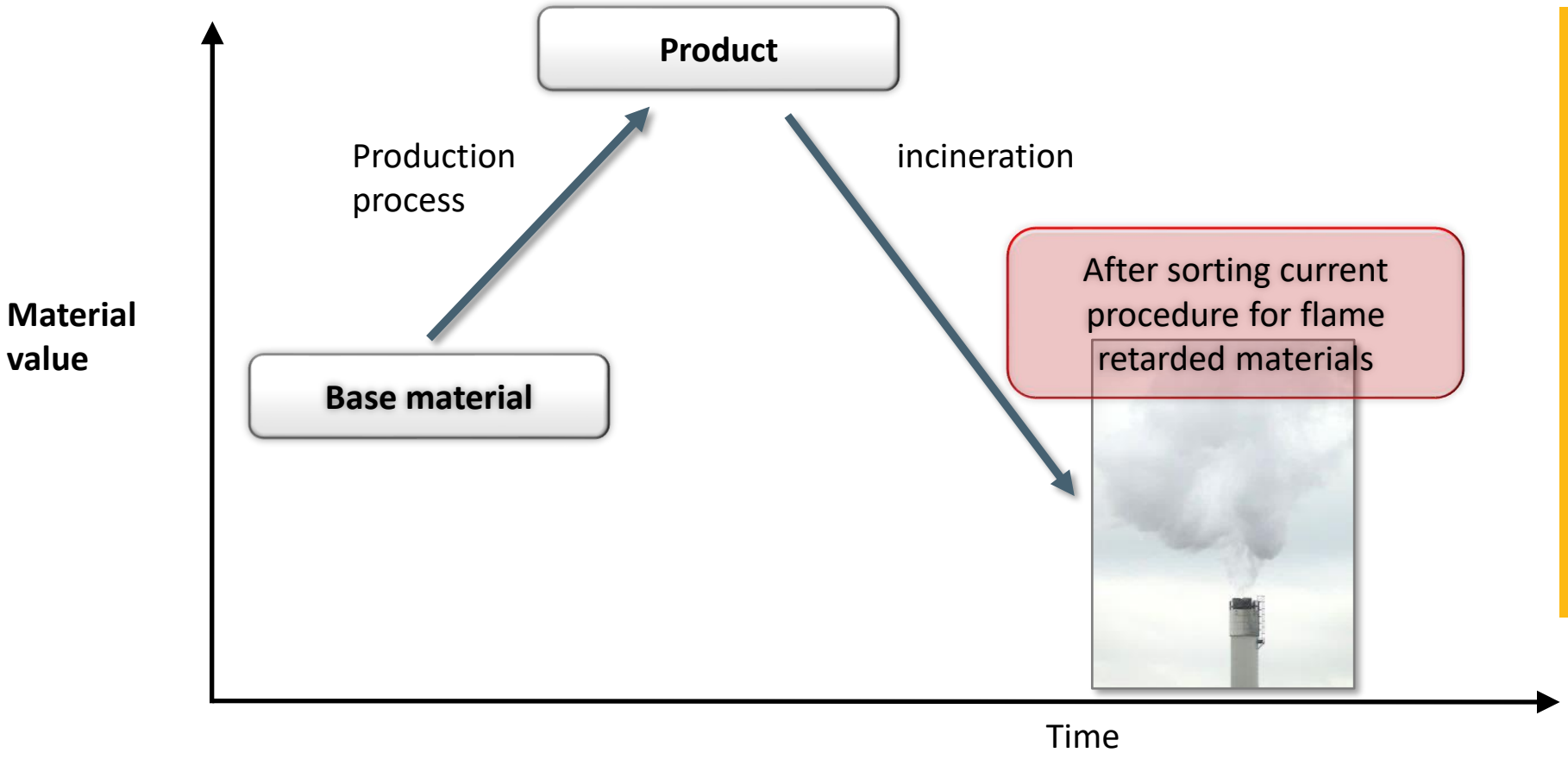
How to make flame retarded products more sustainable?

What are the possible feedstocks?



Fraunhofer LBF

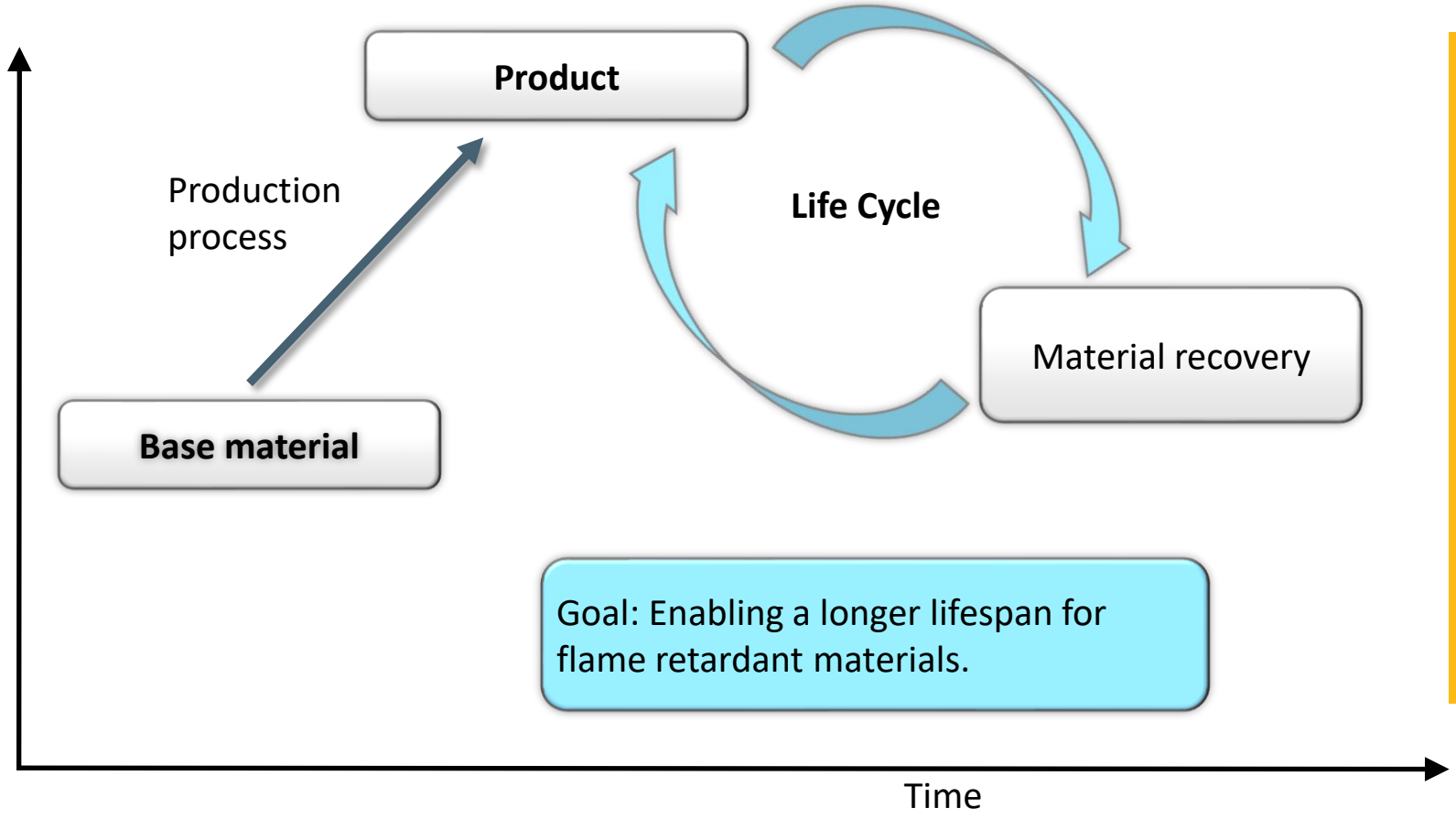
Recycling of high value plastics: Regaining independance



5 million tonnes of technical plastics
(from electronics, vehicles and construction)
enter waste streams in the EU every year.

A large share is incinerated after end-of-life, destroying material value that was produced.

Recycling of high value plastics: Regaining independance



This lost material value represents a major circular opportunity.

Through targeted recycling, material upgrading and R&D, technical plastic waste can be **transformed back into high-value products**.

Innovation unlocks value — not waste incineration.

03

Basics on material quality

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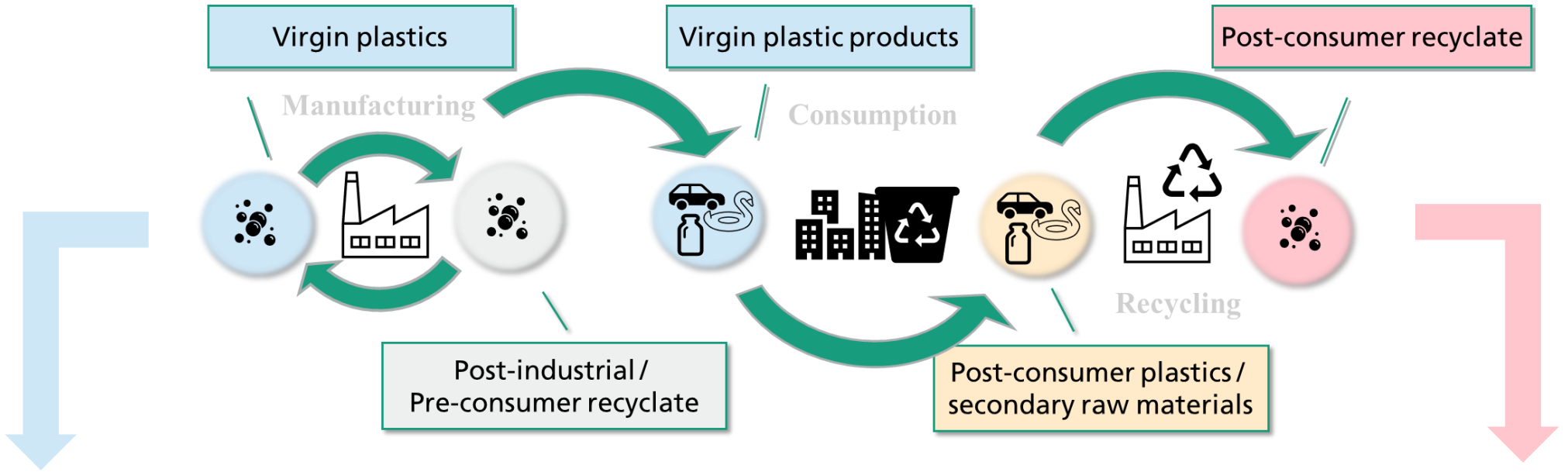
Difference between virgin and recyclate

Analysis: virgin vs. recyclate

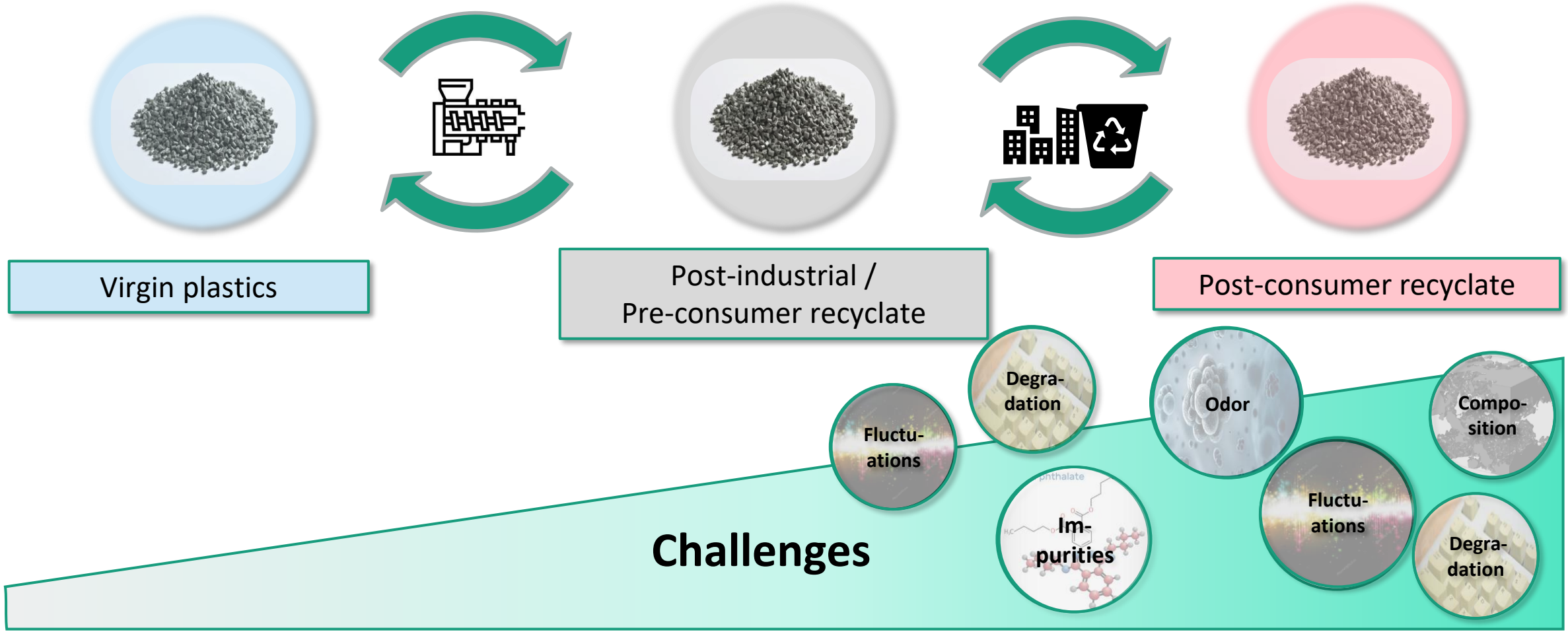


- Homogenity
- We know exactly what it is from the manufacturing process
- No external influences
- Characterization can be carried out without interfering factors

- Heterogenity
- Cannot estimate what is inside
- Many external influences
- Characterization must be carried out despite interfering factors

Challenges increase with material complexity

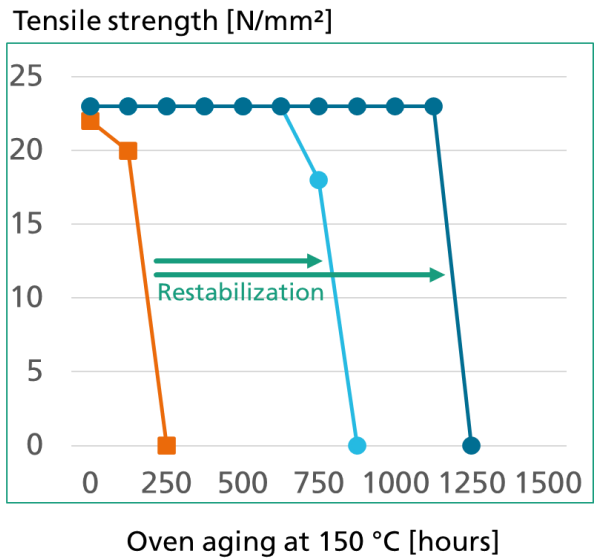
The use-phase complicates plastic's recycling



Giving plastics a new life: Re-additivation concepts

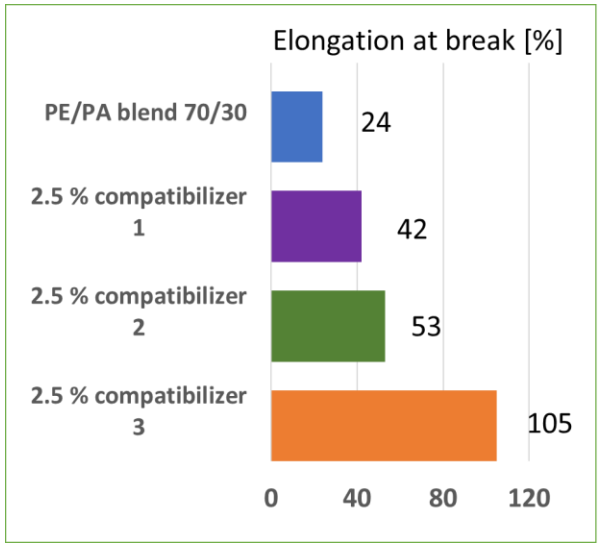
Formulation development on re-stabilization, compatibilization and chain extension

Re-stabilization



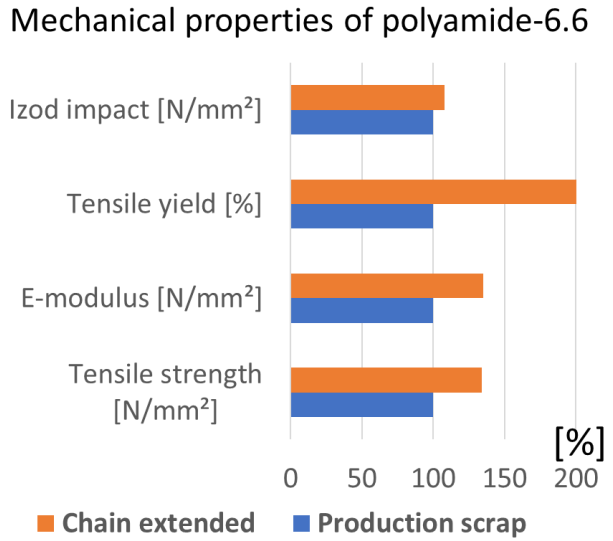
- All thermoplastic polymers
- Lifetime & recycling stability

Compatibilization



- Blends or PCR
- Composition-dependent

Chain Extension



- Polycondensates[4]
- Reactive extrusion, Repair

4 Herbst, H., Hoffmann, K., Pfaendner, R., & Zweifel, H. (1998). Upgrading of Recyclates—The Solution for High Value Applications: Restabilization and Repair. In Frontiers in the Science and technology of polymer recycling (pp. 73-101). Dordrecht: Springer Netherlands.

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04

Projects in cooperation with Pinfa

Fraunhofer LBF

IGF-Project: Recycling of halogen-free flame retarded plastics

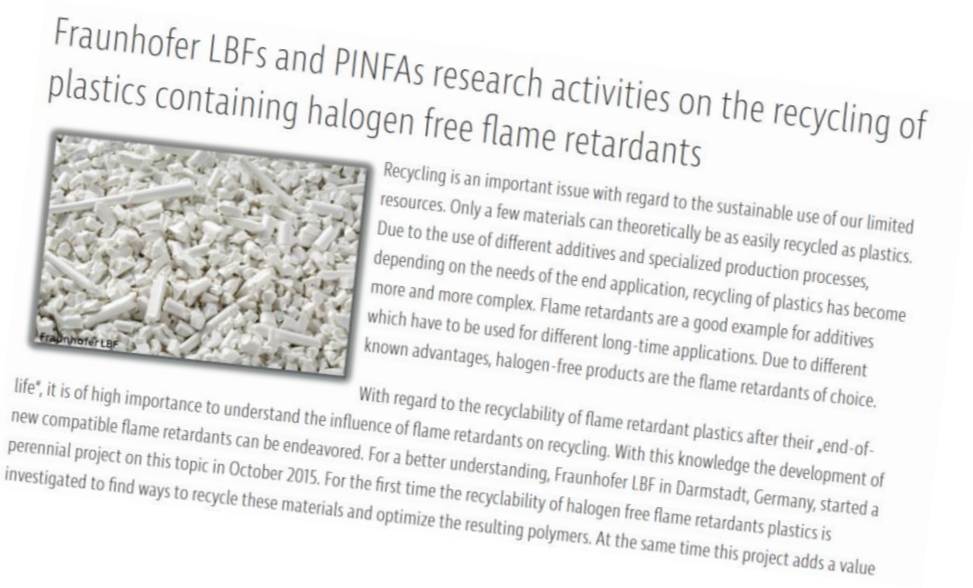
INDUSTRIELLE GEMEINSCHAFTSFORSCHUNG IGF
Bundesministerium für Wirtschaft und Energie
Fraunhofer LBF

IGF-Project: Recycling of halogen-free flame retarded plastics

Overview of selected HFFR model systems

Project scope: systematic investigation of 10 HFFR model systems

Applications	Plastics	Flame Retardants
E & E	PP PC/ABS	Piperazine pyrophosphate Phosphate ester
Films	PP	Alkoxyamine
E & E	PP PA-6	APP based system Melamine cyanurate
E & E	PA-6 / GF30 PA-66 / GF30	DEPAL + P-Synergist
Wire & Cable	PE/EVA, LLDPE	Aluminium hydroxide



Fraunhofer LBFs and PINFAs research activities on the recycling of plastics containing halogen free flame retardants

Recycling is an important issue with regard to the sustainable use of our limited resources. Only a few materials can theoretically be as easily recycled as plastics. Due to the use of different additives and specialized production processes, depending on the needs of the end application, recycling of plastics has become more and more complex. Flame retardants are a good example for additives which have to be used for different long-time applications. Due to different known advantages, halogen-free products are the flame retardants of choice.

With regard to the recyclability of flame retardant plastics after their „end-of-life", it is of high importance to understand the influence of flame retardants on recycling. With this knowledge the development of new compatible flame retardants can be endeavored. For a better understanding, Fraunhofer LBF in Darmstadt, Germany, started a perennial project on this topic in October 2015. For the first time the recyclability of halogen free flame retardants plastics is investigated to find ways to recycle these materials and optimize the resulting polymers. At the same time this project adds a value

„Fraunhofer LBFs and PINFAs research activities on the recycling of plastics containing halogen free flame retardants", FLAMERETARDANTS-ONLINE, https://www.flameretardants-online.com/news/?showid=18408, 02.03.2026

IGF funding number: 18246 N

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Bundesministerium für Wirtschaft und Energie

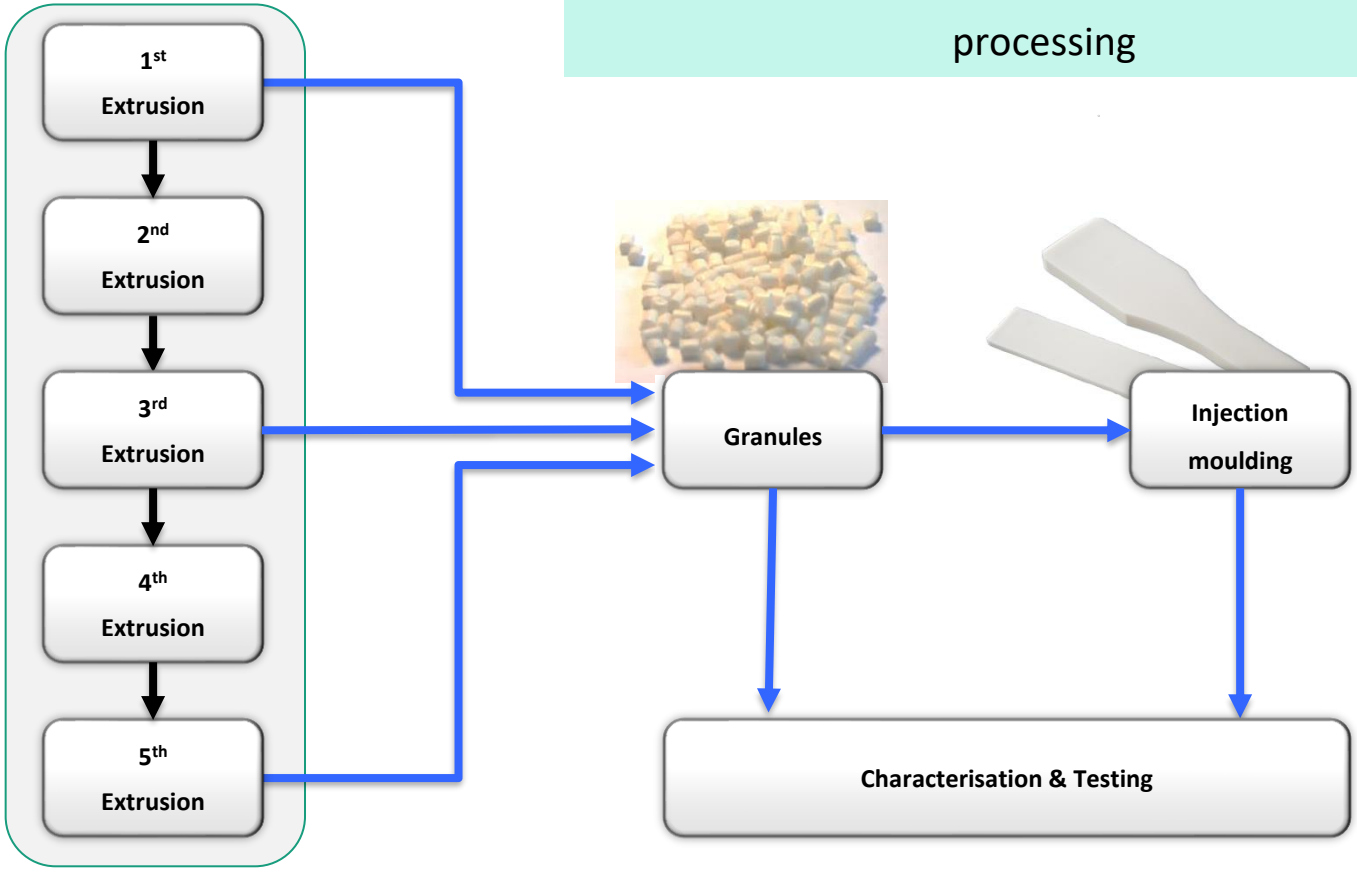
Fraunhofer LBF

IGF-Project: Recycling of halogen-free flame retarded plastics

Systematic Procedure I

Multiple extrusion

Simulation of mechanical exposure by multiple processing

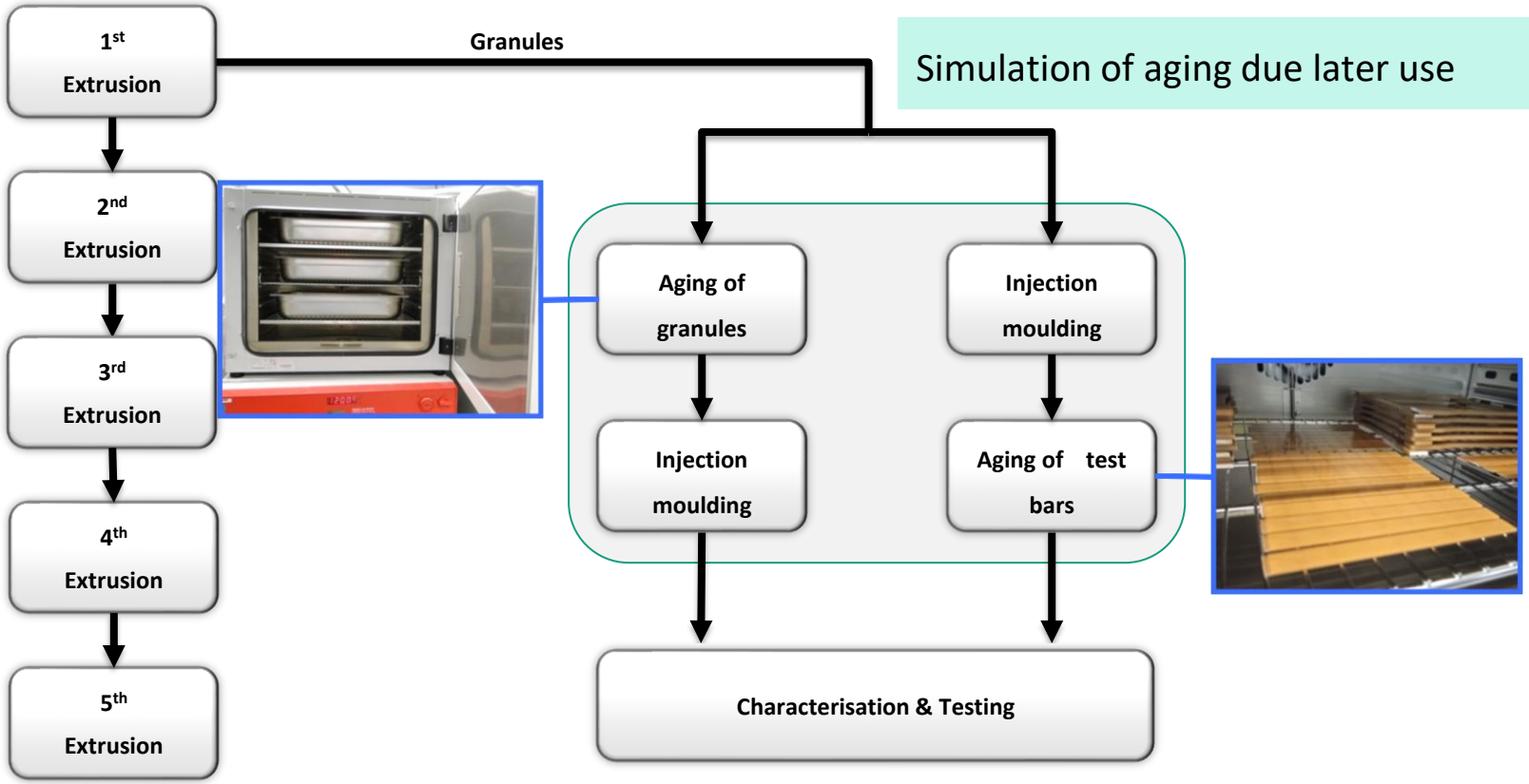


IGF-Project: Recycling of halogen-free flame retarded plastics

Systematic Procedure II

Multiple extrusion

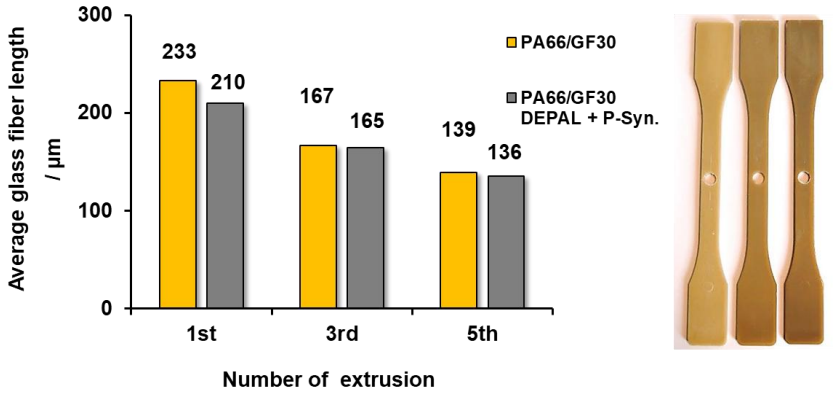
Accelerated oven-aging

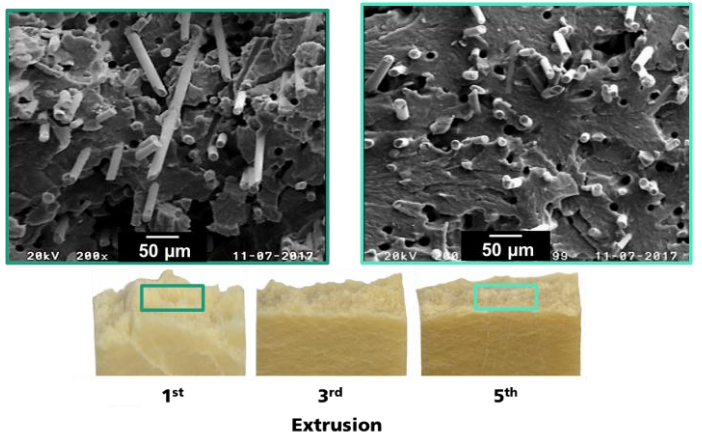


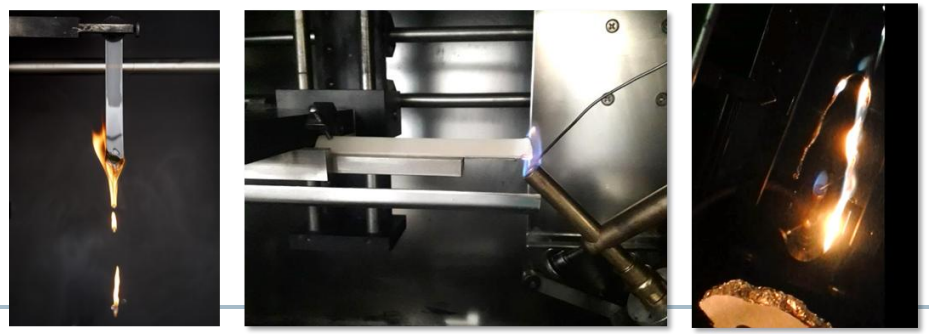
IGF-Project: Recycling of halogen-free flame retarded plastics

Project summary

- **Multiple Extrusion:** After 5 extrusion steps, flame retardancy was maintained for nine out of ten formulations.
- Glassfiber shortened over the extrusion steps.
- **Accelerated Aging:** For selected formulations flame retardancy was mainly maintained.
- Darkening/Yellowing during accelerated aging.
- **The project creates essential data sets for recyclability of HFFR plastics.**







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Bundesministerium für Wirtschaft und Energie

Fraunhofer LBF

Industrial joint project: Tailoring the hffr performance of recyclates

Industrial joint project: Tailoring the hffr performance of recyclates

Project plan

Project Setup

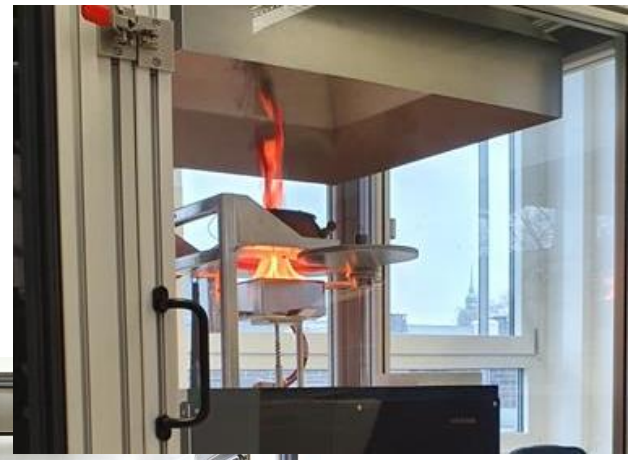
- Pre-competitive industrial joint project with 10 companies across the value chain
- Recyclate suppliers, compounders, flame-retardant producers and competitors collaborating

Objectives

- Validate PIR/PCR recyclates for upgrading into flame-retarded plastic compounds
- Assess need for adaptation of standard flame-retardant formulations
- Identify upcycling-suitable material flows and impact of recyclate quality
- Verify long-term performance and compliance with product standards

Methodology

- Multi-source recyclates, full material characterization (TGA, DSC, OIT, MVR, mechanics)
- Application-driven formulations for PP, PE, PA6, PA66, PET, PC/ABS
- Long-term thermal aging: 1,000–2,000 h up to 150 °C



Collaborative R&D enables high-performance, flame-retarded applications based on recycled plastics!

Industrial joint project: Tailoring the hffr performance of recyclates

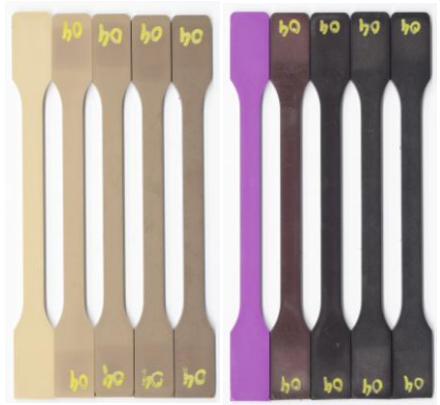
Material selection

Polymer-Type	Application	Material source
Polypropylene (PP)	➢ Trunking/Conduits ➢ Housings ➢ Construction film	➢ PIR Packaging waste ➢ Furniture foil ➢ WEEE-Plastics from household collection at recycling centers
Polyethylene (LLDPE)	➢ Cable ➢ Construction film	➢ PIR Packaging waste
Polyamide (PA6 and PA66)	➢ Injection moulding application (motor management)	➢ PCR-PA6 from Fishnets ➢ PIR-PA66
Polyethylene-therephthalate (PET)	➢ Coil bobbin/sensor cover ➢ Injection moulding	➢ PIR-PET packaging films
Polycarbonat/Acrylnitril-Butadiene-Styrene (PC/ABS)	➢ Housings ➢ Injection moulding	➢ WEEE-Plastics from household collection at recycling centers

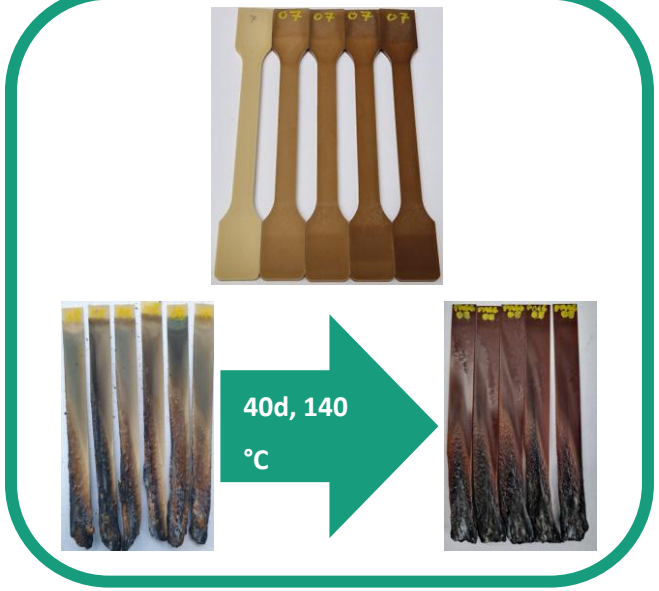
Industrial joint project: Tailoring the hffr performance of recyclates

Project methodology

- Best possible classification in UL94 was reached before and after ageing for PP, PA6&66, PET, PE
- GWFI @850 °C was reached for PP, up to 960 °C for PA6&66; GWIT up to 800°C for PA6&66
- CTI at 600V for PA6&66



- After Ageing stable flame retardancy can be tested
- Cone Calorimetry shows stable stable TTI and TTB, pHRR, THR and MARHE for almost all recyclates
- Tested were phosphorous, inorganic and nitrogenic flame retardants



IGF-Project: Upcycling HFFR

INDUSTRIELLE GEMEINSCHAFTSFORSCHUNG
Bundesministerium für Wirtschaft und Energie
Fraunhofer LBF

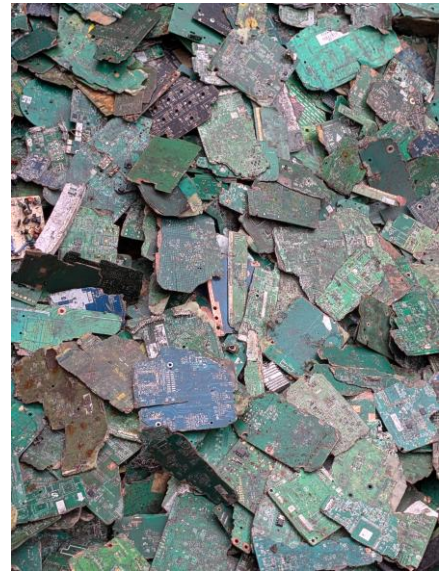
IGF-Project: Upcycling HFFR

Running project: Project plan

Project runtime from 2025 to 2028.

Main project questions

- Can specific waste streams, that are not used for high value plastics be upgraded?
- Focus is on „untypical“ recyclates for flame retarded applications, i.e. PE/PA or HDPE from multi layer films.
- Intense analysis of recyclates for characterization.
- Focus on restabilization of the basic polymers.



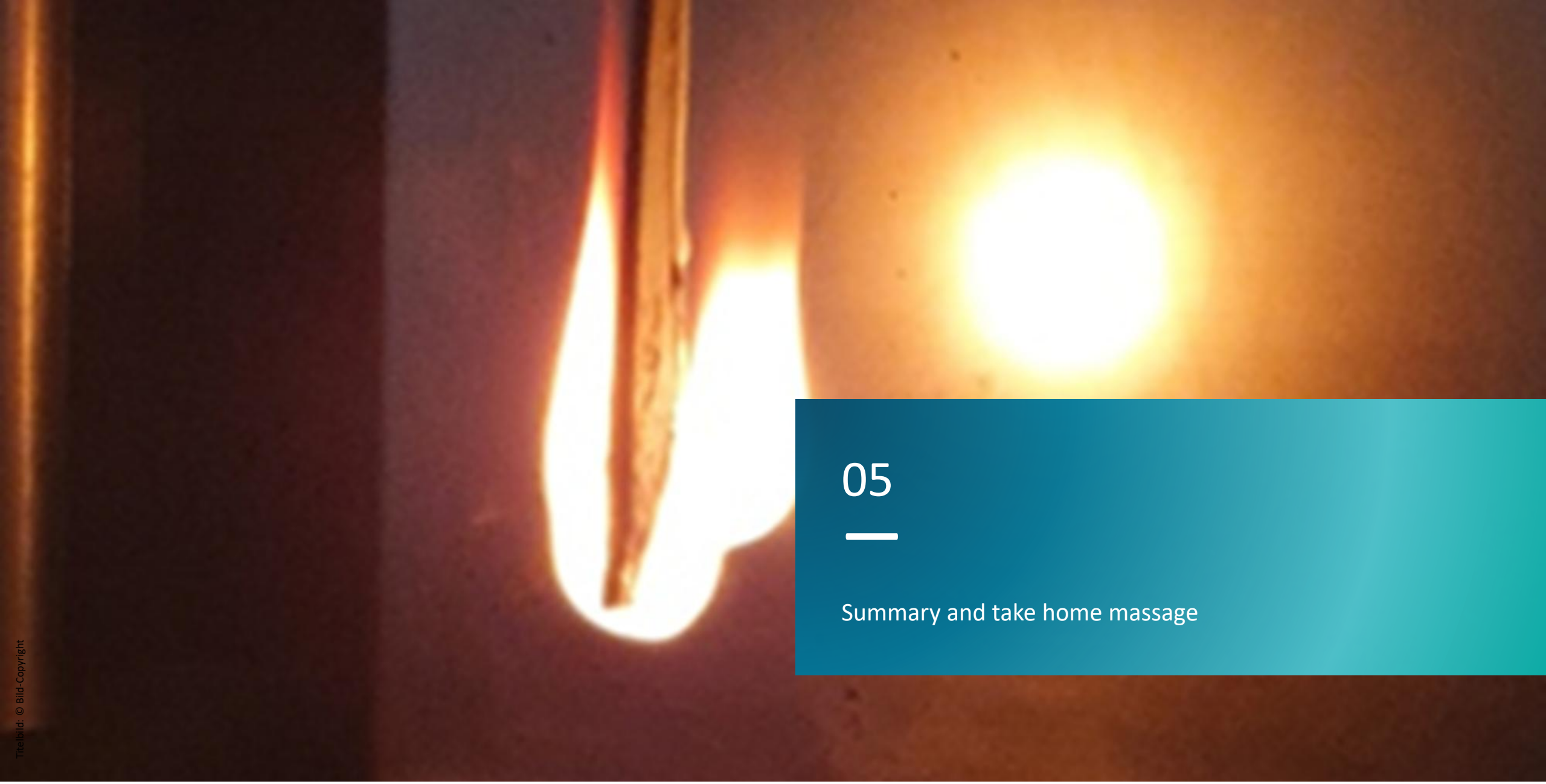
Methods and Goals

- Procurement of recylcates from PP, PA6&66 and PC/ABS (Currently over 30 different)
- Compounding of two sessions per polymer type
- Evaluation of the long-term stability via thermal ageing
- testing flame retardancy: UL94, Cone Calorimeter, GWIT, CTI
- Scientific publication of results (peer reviewed)

- Over 30 recyclates from different sources have been procured and characterized
- Currently compounding of typical flame retardant formulations (approx. 10) for each recyclate type

IGF funding number: 01IF23486N

Thank you for all the supporting companies since 2015!



05

Summary and take home massage

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Summary and take home massage

What did we learn?

- Recyclates can have large variations in their properties, characterization is necessary.
- Halogen-free flame retardants perform in recyclates similar to virgin materials, but recyclate quality, especially impurities need to can work antagonistically.
- Not every recyclate type is suitable for upcycling, long term stability should be tested and re-stabilization could be necessary.
- It is possible to fit formulations based on recyclates on current material specifications, but the variation of the material properties can be higher, i.e., for PCRs. Specifications probably need to be adjusted!

- To get a deeper knowledge into the categorization and analyzation of waste streams a broader study needs to be carried out.
- What happens when materials come back from closed loop systems, probably after a long usage time?
- A lot of topics regarding, interactions between additives, FRs, fillers are still unknown and will be handled in future projects. Very complex questions, that need more cooperation between all players alon the product chain!
- **The time to act is now, reach out to us and our partners to cooperate in the future!**

In initiation / Successfully realized Joint Industry Projects

hffr-Up2Cycle

The upcoming recycling targets present challenges for the industry to maintain material quality while ensuring compliance with regulations and securing reliable streams of recycled materials. This is particularly critical in high-value applications that require effective flame retardancy.

Key aspects of the collaboration

- Selection of PCR materials based on market availability and upcoming regulations.
- Detailed investigation and characterization of each waste stream.
- Upgrading of PCRs by halogen-free FR and testing of those materials by simulating closed-loop processes.
- Investigation of the process and long-term properties of the flame-retarded recyclates.

- ✓ Planned start and duration of the project: **01.04.2026 – 31.03.2028**
- ✓ Contribution to the project per partner: **11.999 € / Jahr**
- ✓ The project can commence when there are at least **8** participants

Register now

March 25-26, 2026 in Darmstadt

Forum Plastic Recyclates

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Questions & Answers

Thomas FUTTERER & Esther AGYEMAN-BUDU

Cefic sector group

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Survey

Esther AGYEMAN-BUDU

Cefic sector group

pinfa | sparks

Survey

What did you think of the pinfa sparks webinar? - 05/02/2026

More questions?

pinfa@cefic.be

...stay tuned for our next pinfa Sparks

About Cefic

Cefic, the European Chemical Industry Council, is the forum of large, medium and small chemical companies across Europe, accounting for 1.2 million jobs and 13% of world chemicals production.

On behalf of its members, Cefic's experts share industry insights and trends, and offer views and input to the EU agenda. Cefic also provides members with services, like guidance and trainings on regulatory and technical matters, while also contributing to the advancement of scientific knowledge.

Cefic sector group

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