RECYCLING OF FLAME RETARDED PLASTICS

pinfa
Phosphorus, Inorganic & Nitrogen Flame Retardants Association

E-Mobility Workshop

Fire Safety Challenges in Automotive Plastics

12. November 2019

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www.lbf.fraunhofer.de

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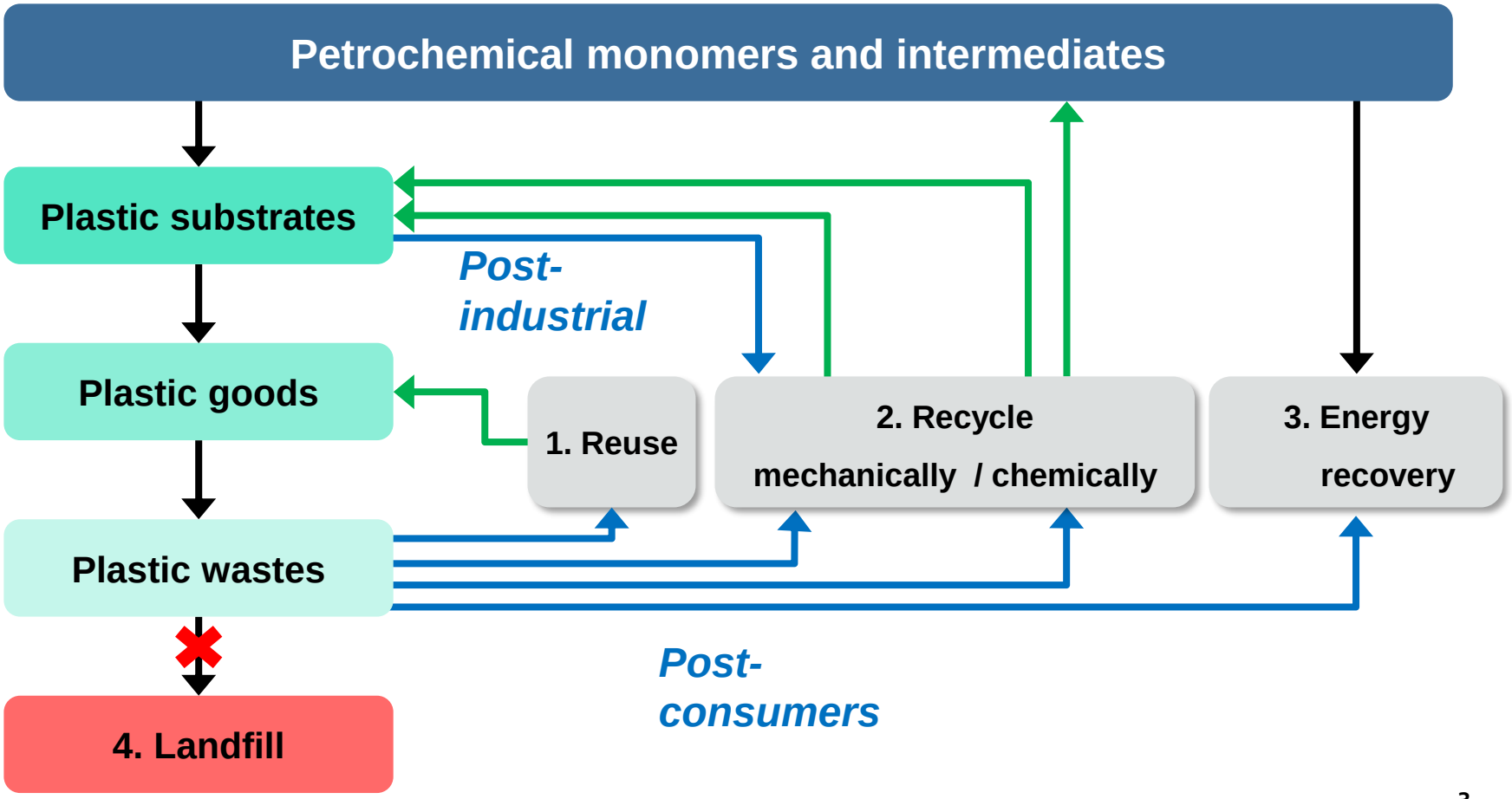
Outline

- Plastics recycling
- Recycling of FR polymers
- Recycling of end-of-life vehicles
- Conclusions

Plastics recycling
Linear economy → circular economy



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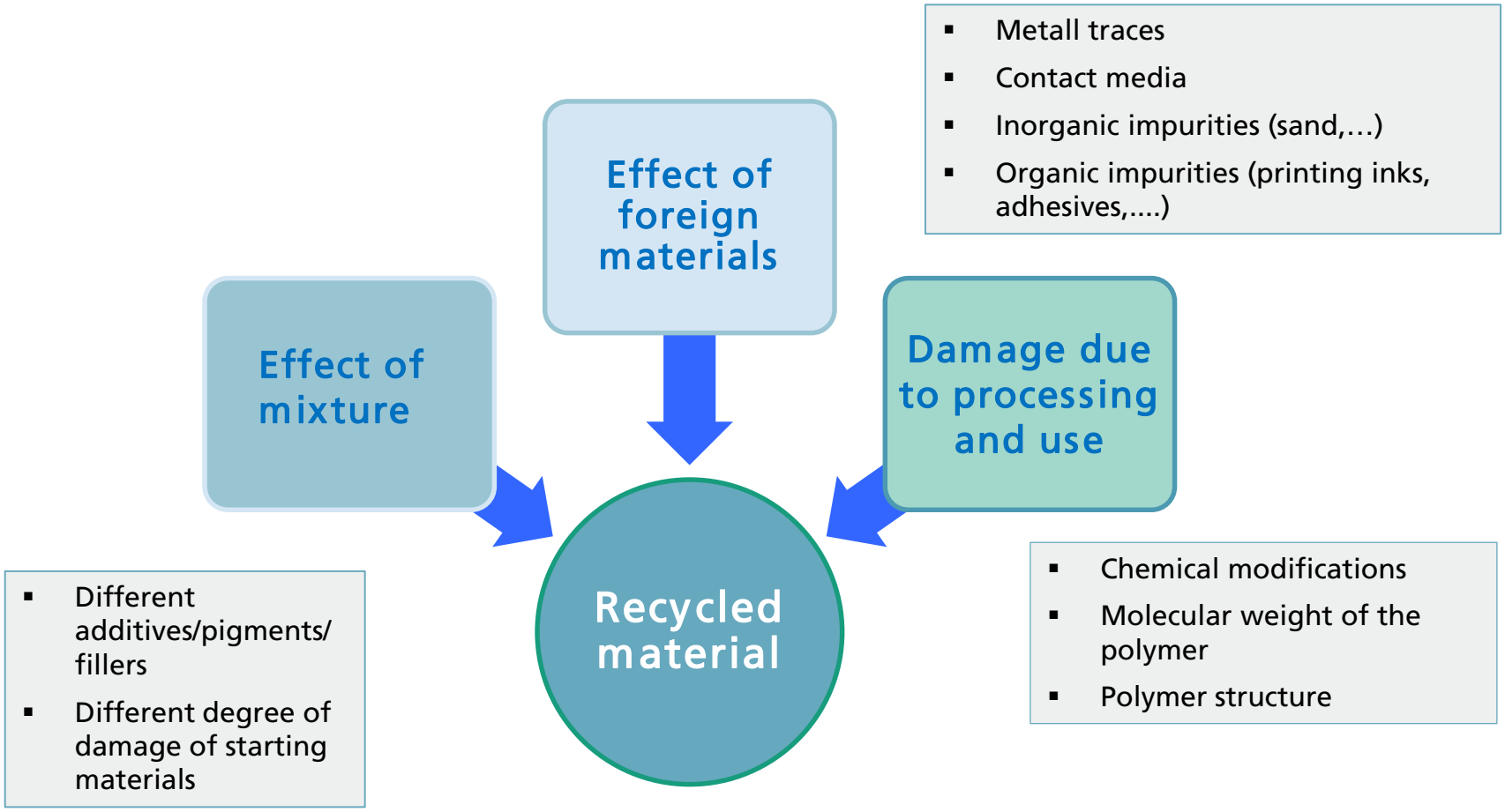
Plastics Recycling
-When does mechanical recycling makes sense?

- **Conditions for mechanical recycling are:**
  - defined composition of material flow
  - sufficient material flow
  - only small amount of impurities
  - suitable size of the sorting good
  - presence of sorting and separation systems
  - relatively low logistical effort
  - polymers and additives must be easily recyclable

Plastics Recycling
Differences between virgin materials/aged materials



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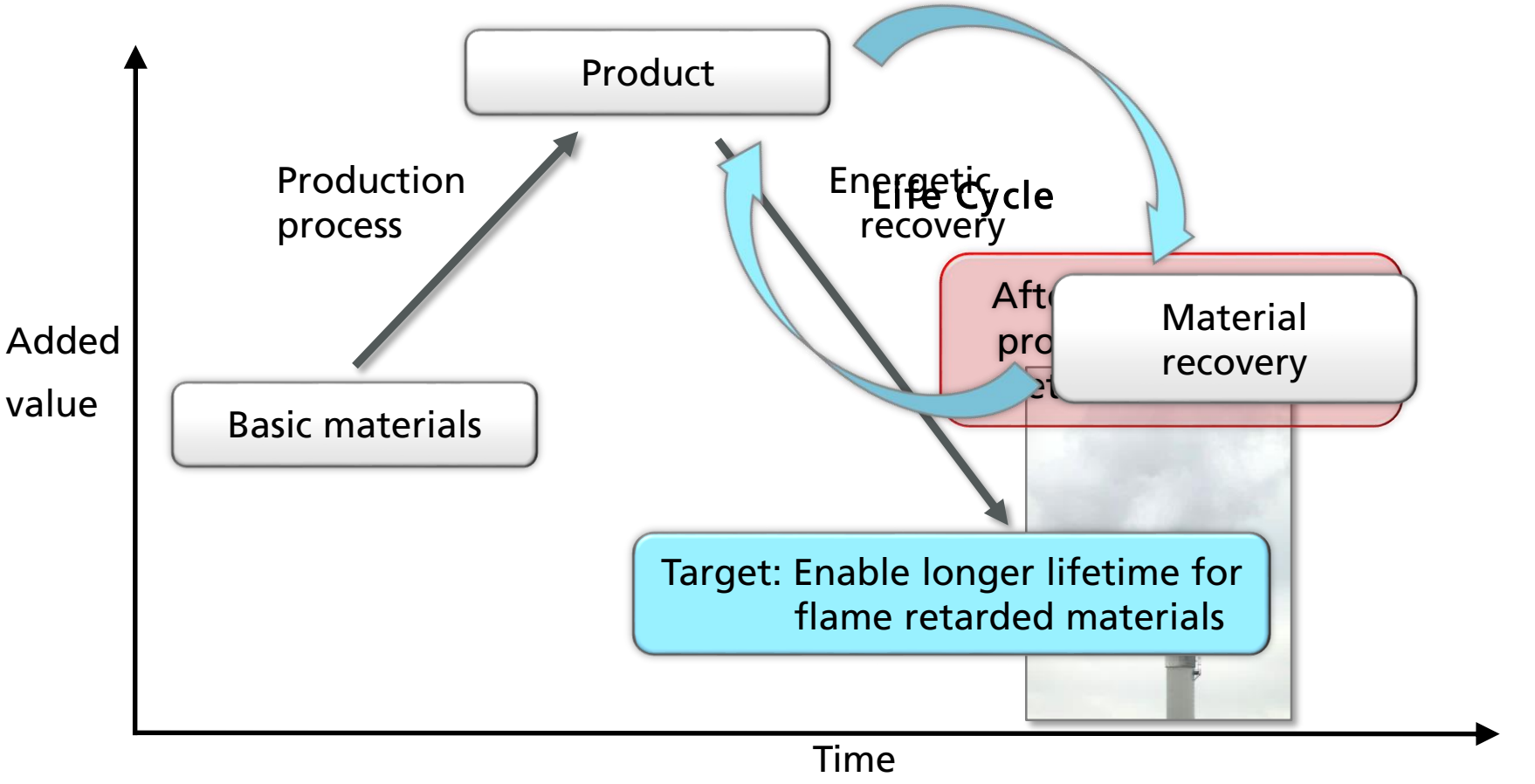
FR Plastics Recycling
Challenge of flame retarded materials in circular economy



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FR Plastics Recycling
Solving the problem

- Chemical recycling of brominated flame retarded plastics (e.g. CreaSolv process)
- REWARD, a 3 year project in the Eco-Innovation program. Title: “Recovery of Electronic Waste through Advanced Recycling And Demonstration”
- Fraunhofer LBF project: recycling of HFFR plastics

HFFR Plastics Recycling Project

RECYCLING

HF flame retardants: the recycling challenge

Fraunhofer LBF in Germany is leading a project to boost mechanical recycling of plastics containing halogen-free flame retardants. By Amanda McCormack

The project aims to plug into a €3bn market for flame retardant plastics

The Fraunhofer Institute for Structural Durability and System Reliability LBF, the Germany-based application-oriented research organisation, has launched a new research project focused on the recycling of halogen-free flame retardant plastics.

The project has been developed against a backdrop of growing European ambitions for "zero waste to landfill". In December, the European Commission released its revised Circular Economy Package with proposals including common EU targets for recycling 65% of municipal waste and 75% of packaging waste by 2030, and a binding target to reduce landfill to a maximum of 10% of all waste by 2030.

Fraunhofer LBF says the project could lead to an annual saving of €150m from processors using flame retardant production waste. The value of re-using end-of-life plastics will be even higher.

In Europe, Fraunhofer LBF estimates that around 70% halogen-free flame retardants based on phosphorus, inorganic substances and nitrogen are already in use in a market with a value of around €3bn. These additives are mainly used in plastics for the electrical and electronics, construction and transportation industries.

The use of flame retardants can prevent the fire spreading or slow down its development, so are extremely important in stopping injury or loss of life in the case of an accidental fire, when used in areas such as household items. But the institute highlights there is very little knowledge about the mechanical recycling of these plastics.

It is hoped the research project into mechanical recycling of halogen-free flame retardant plastics will lead to enhanced quality products with high safety standards. It is intended to identify potential hazards of degradation products which can then be eliminated from the process.

Another aim is to minimise risks such as product liability when using recyclates, due to the data compiled during the project.

Fraunhofer LBF states that although the research is part of an ongoing multi-year project, the findings should be able to be used immediately by participating companies. The research will save companies money by recycling process waste and allow them to build new business areas concentrating on recycled materials, along with limiting the amount of raw materials used.

Pinfa members

The investigation will be partly funded by the Industrial Community Research of the AiF in Germany, which promotes projects with a maximum requesting amount of about €250,000 per delivery point, said Fraunhofer LBF. The project will take place with the participation of member companies of Pinfa (Phosphorus, Inorganic & Nitrogen Flame Retardants Association). Pinfa's membership includes: A. Schulman, Adeka, BASF, Budenheim, BYK, Clariant, CTF 2000, Dartex, DSM, DuPont, Everkem, FRX Polymers, Italmatch Chemicals, Lanxess, Metadynea, Nabaltec, Perstorp, Presafer, Schill & Seilacher, Solvay, Thor, William Blythe and Inemi.

The members of Pinfa work to continuously improve the environmental and health profile of their flame retardant products. Pinfa currently has working groups and research projects in the areas of fire safety, environment and ecolabels, recycling, and communications and outreach.

The halogen-free retardant plastics research being carried out by Fraunhofer LBF will be of particular use to polymer, flame retardant and additive manufacturers, compounders, masterbatch producers, producers of plastic parts, recycling companies and consulting firms, the institute says.

It also points out that small and medium-sized companies should benefit from the results of the research, as they will be able to reduce costs and, at the same time, produce new high quality products that meet safety standards.

Fraunhofer LBF says its plastics division is constantly extending its knowledge of recyclates and states that with the addition of customised stabilisers, compatibilisers and reactive additives, recycled materials can achieve qualities that can really compete with those of new material. Although the number of recyclates is increasing, the current problem faced is how to develop the best technical and economic solution for the property profile.

Fraunhofer LBF's customers come from automotive and commercial vehicle construction, shipbuilding, aviation, machine and plant construction, power engineering, electrical engineering, construction, medical engineering, the chemical industry and other industries. The research organisation has around 400 employees. Its technology is housed in more than 11,560 square metres of laboratory and experimental space at locations in Bartningstrasse and Schlossgartenstrasse in Germany.

Plastics News Europe 24 APRIL 2016

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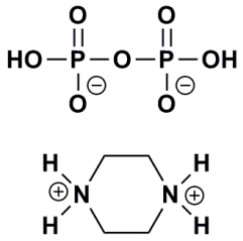
HFFR Plastics Recycling Project
Overview of selected HFFR model systems

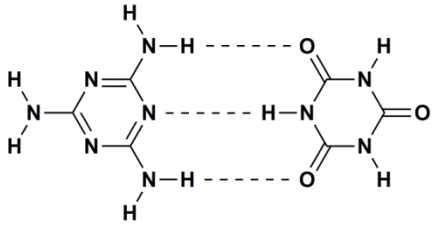
Project scope: systematic investigation of 10 HFFR model systems

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

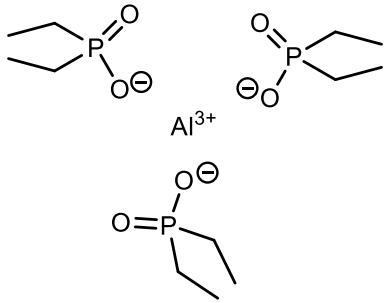
HFFR Plastics Recycling Project
Chemical structures of the used flame retardants



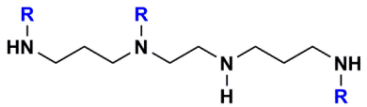
Piperazine pyrophosphate

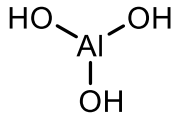


MC

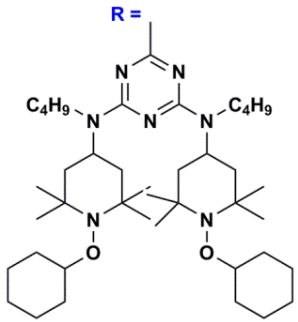


DEPAL

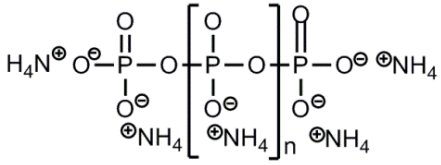




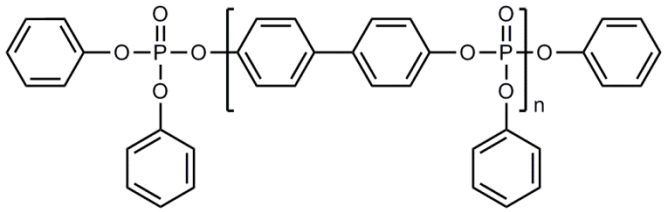
ATH



Alkoxyamine



APP



Phosphate ester

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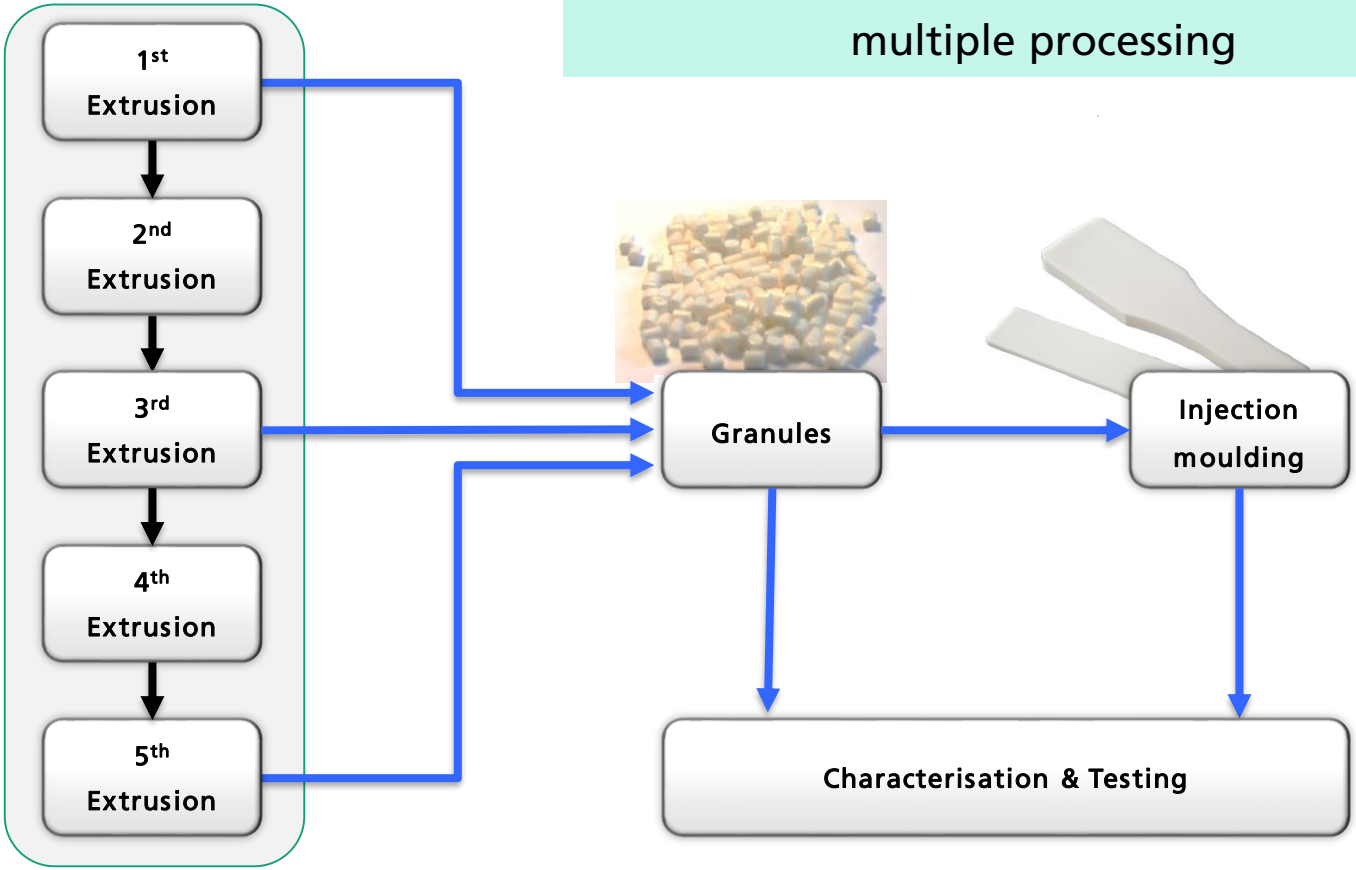
HFFR Plastics Recycling Project
Systematic Procedure I

Multiple extrusion

Simulation of mechanical exposure by multiple processing



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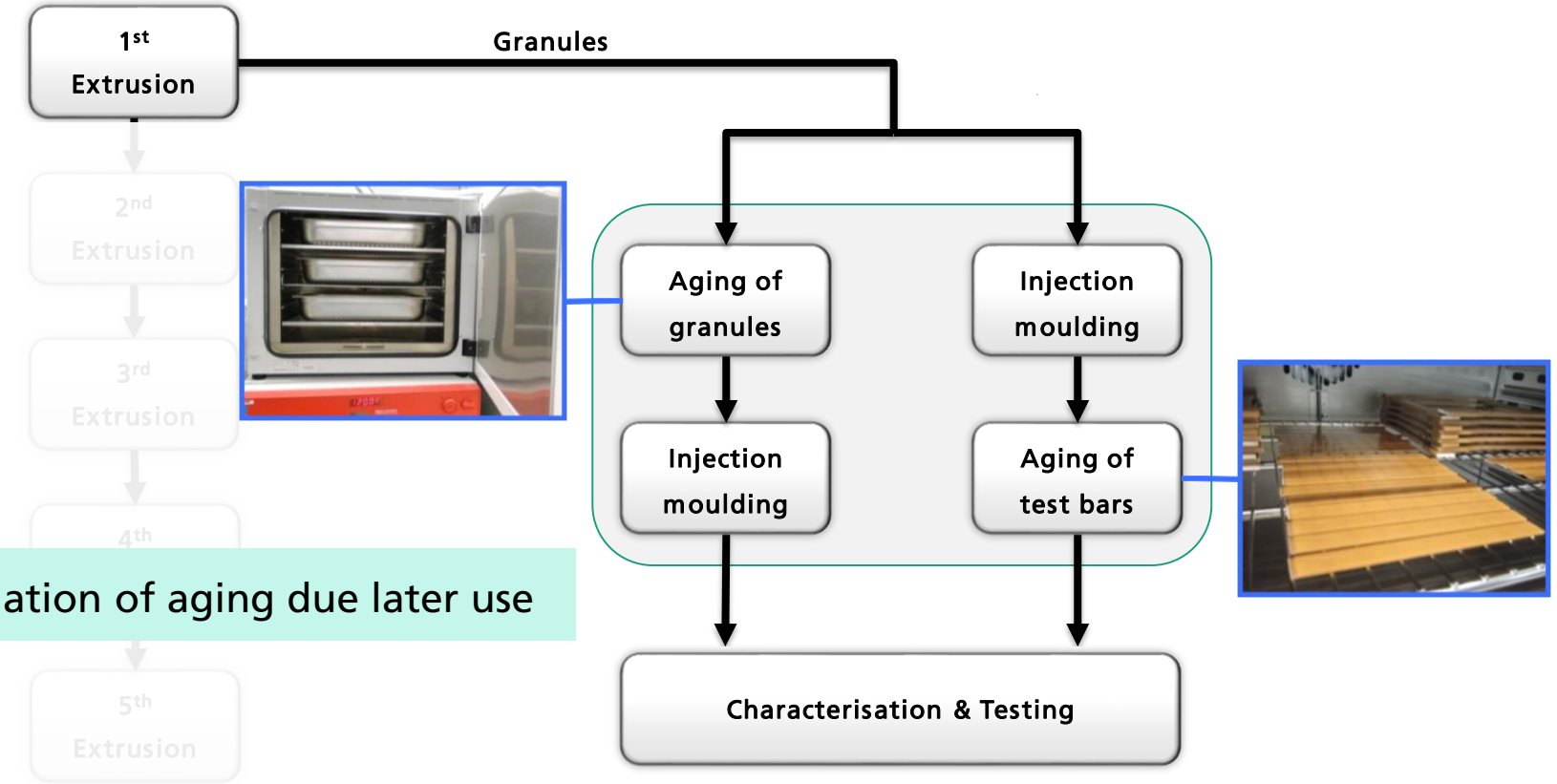
HFFR Plastics Recycling Project
Systematic Procedure II

Mehrfachextrusion

Accelerated oven-aging



Simulation of aging due later use

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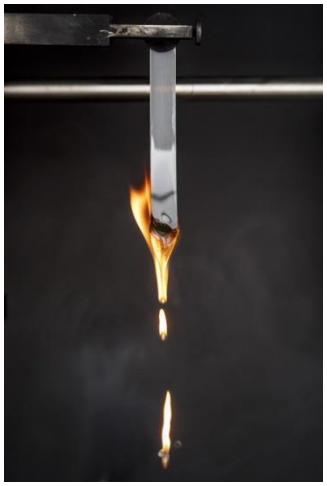
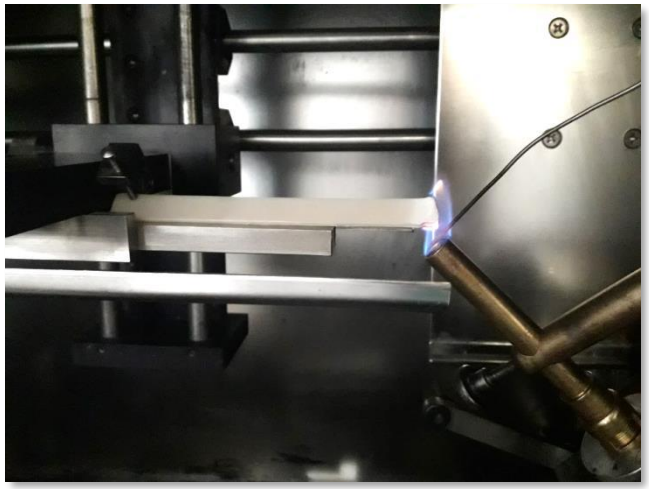
HFFR Plastics Recycling Project
Starting values

- Best possible fire classification
  - E+E: UL94 V-0 (1.6 mm and 0.8 mm)
  - cable: UL94 (HB) (1.6 mm and 3.2 mm)
  - films: 4102-1 (B2) (150 µm)





HFFR Plastics Recycling Project
Material properties after multiple extrusion

CZ	Polymer type / HFFR	T (Extr.) / °C	Burning behaviour	Mechanical properties		
				Young's modulus	Tensile strength	Elongation at break
1	PP / APP based system	230	V-0	↑	↗	↑
2	PP / piperazine pyrophosphate	200	V-0	—	—	↓
3	PP / 0,5 % alkoxyamine	210	B2		—	—
4	PP / 1,0 % alkoxyamine	210	B2		↘	—
5	PE / ATH (I)	150 – 160	HB		—	↗
6	PE / ATH (II)	150 - 160	HB		—	↗
7	PA66 / GF30/ DEPAL HFFR	290	V-0	↘	↓	↘
8	PA6 / GF30/ DEPAL HFFR	270	V-0	↘	↓	↓
9	PA 6 / MC	270	V-0	↗	↗	↓
10	PC/ABS / phosphate ester	260	V-2	—	—	—

% relative change normalised to the respective initial value

— unchanged

↘↗ < 25 %

↓↑ < 50 %

↓↑ > 50 %

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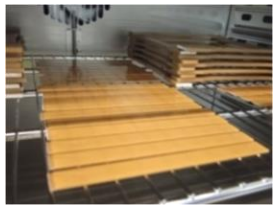
HFFR Plastics Recycling Project
Material properties after accelerated oven-aging



Oven-aging of test specimens

CZ	Polymer type / HFFR	T (oven) / °C	Storage time in days	Burning behaviour	Mechanical properties		
					Young's modulus	Tensile strength	Elongation at break
1	PP / APP based system	135	10, 20, 30, 40	2x V-0 3x V2	—	—	—
4	PP / 1.0 % alkoxyamine	120	20, 40, 60, 80	B2		—	↓
5	PE / ATH (l)	100	5, 10, 15, 20	HB		—	↑
7	PA66 / GF30/ DEPAL	120	10, 20, 30, 40	V-0	—	—	—
8*	PA6 / GF30/ DEPAL	120	10, 20, 30, 40	V-0			
9*	PA6 / MC	120	20, 40	V-2			
10	PC/ABS / phosphate ester	100	10, 20, 30,40	V-0	—	↗	—

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HFFR Plastics Recycling Project
Material properties after accelerated oven-aging

Oven-aging of granules with subsequent injection moulding

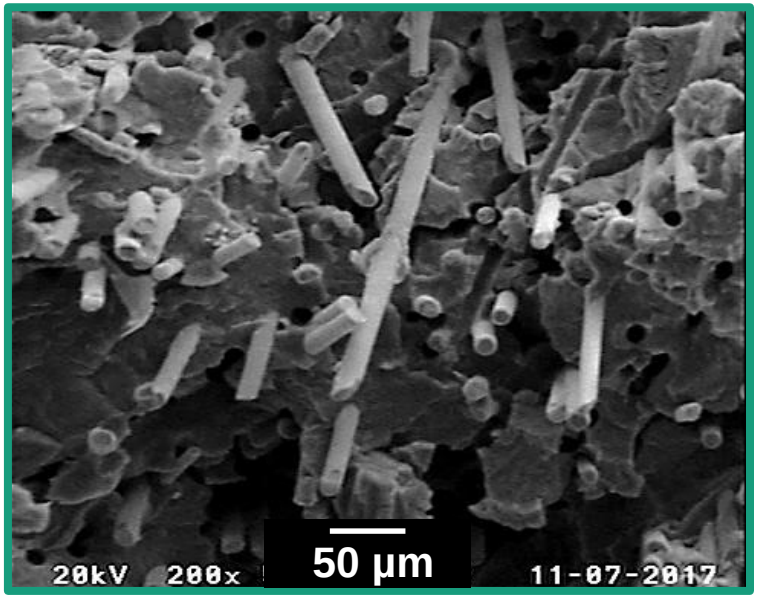
CZ	Polymer type / HFFR	T (oven) / °C	Storage time in days	Burning behaviour	Mechanical properties		
					Young's modulus	Tensile strength	Elongation at break
1	PP / APP based system	135	20, 40	V-0/V2	—	—	↘
4	PP / 1.0 % alkoxyamine	120	20, 40	B2		↗	—
5	PE / ATH (I)	100	10, 20	HB			
7	PA66 / GF30/ DEPAL	120	10, 20	V-0	—	—	↘
10	PC/ABS / phosphate ester	100	20, 40	V-0	—	—	—

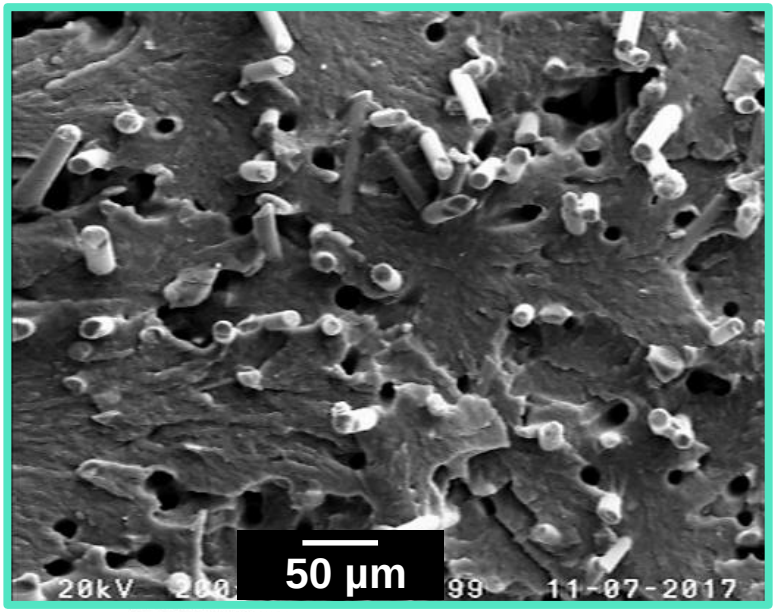
Conclusions after multiple extrusion and accelerated aging

- **Multiple extrusion**
  - After 5 extrusion steps, flame retardancy was maintained for nine out of ten formulations

- **Accelerated aging**
  - For selected formulations flame retardancy was mainly maintained.

HFFR Plastics Recycling Project
SEM of PA66/GF tensile test bars





1st 3rd 5th

Extrusion

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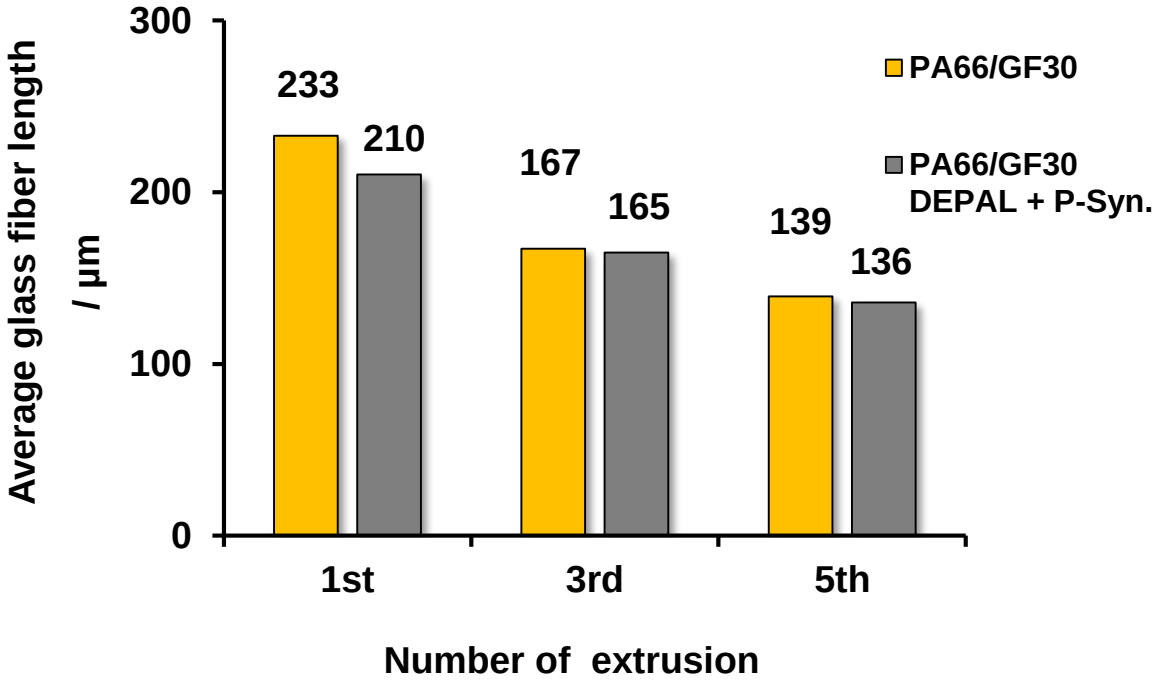
Average glass fibre length



- Manufacturer specifications (CS 7928, Lanxess)
  - Fibre diameter (nom.) 11 µm
  - Average fibre length (nom.) 4.5 mm

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HFFR Plastics Recycling Project

The project creates essential data sets for recyclability of HFFR plastics.

Thanks

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BASF SE

Adeka Europe