Impacts of Brominated Flame Retardants on the Recycling of WEEE plastics.

Online launch event | 18th November 2020

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Context

Waste electrical and electronic equipment (**WEEE**): **11 million tons** in 2020 in EU

25% is plastic:

- many different **polymers** (ABS, PS, PP, etc.)
- wide range of **additives** (flame retardants, fillers, plasticizers, pigments, etc.)

Recycling of WEEE plastics could contribute to **Circular Plastics Alliance's** target: 10 million tons of recycled plastics by 2025

A large fraction of the total WEEE plastics potential does not reach European recyclers: sub-standard WEEE collection/treatment

Technical, economic and regulatory challenges negatively impact recycling yields (50-60%)

- Technological difficulties in **sorting**
- Strict **quality** requirements for recyclates
- Lack of **market** and/or inability to compete with virgin polymers
- Presence of "**legacy additives**"

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Objectives

Assess the impact caused by the presence of BFRs on the recycling of WEEE plastics

Estimate the **volumes and fate of BFR-containing plastics** arising in WEEE in Europe

Get a picture of the **trend in levels of legacy BFRs** in WEEE plastics

Review BFR plastics **treatment requirements and practices**

Understand impact of BFRs on recycling **yields** and recyclates **quality**, and compare with **alternative FRs**

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Estimate the **volumes and fate of BFR-containing plastics** arising in WEEE in Europe

Method:

- *Collection of data on **WEEE plastics composition** (>800 data points, from published studies as well as data provided by WEEE recyclers, WEEE plastic recyclers and take-back schemes)*
- ***Mass flow model** based on updated ProSUM data, other studies and information provided by various stakeholders*

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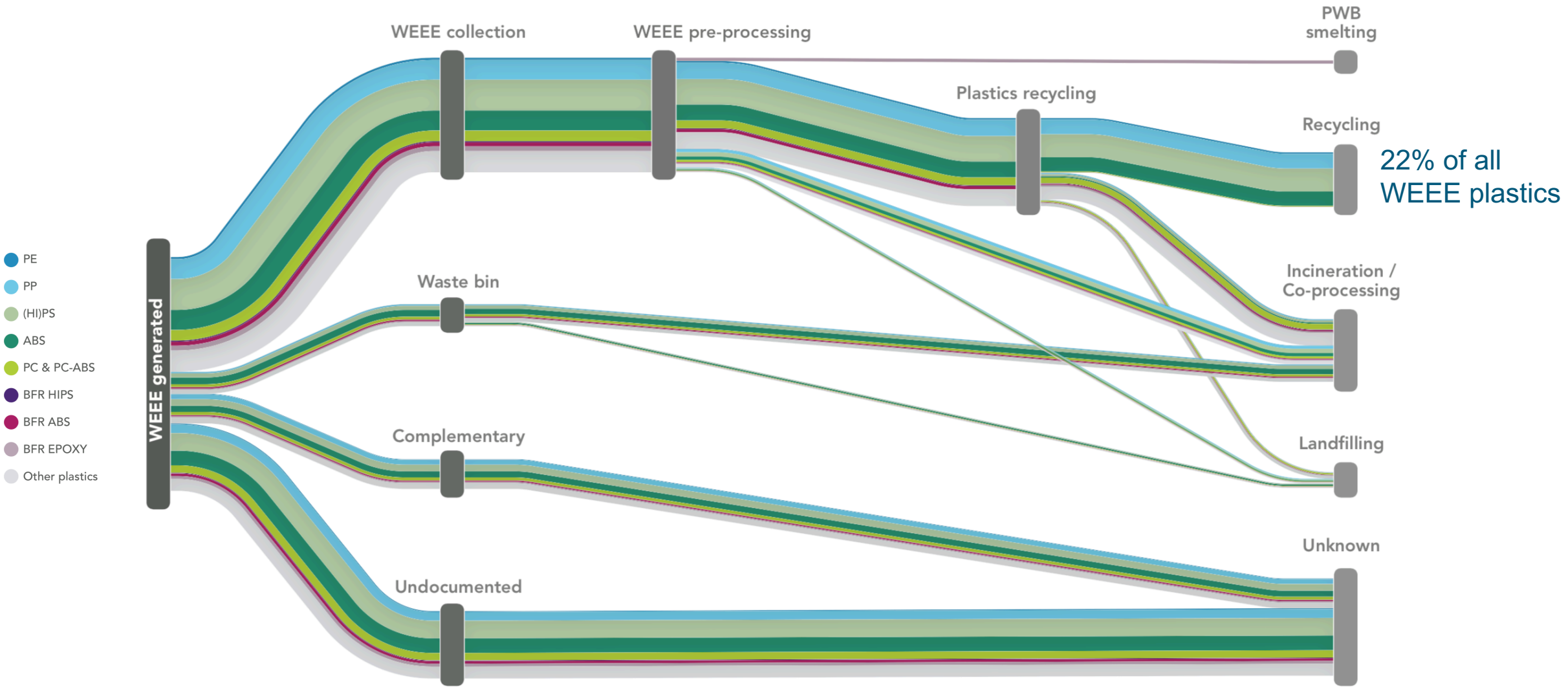
WEEE plastics mass flows (EU28+2, 2020)



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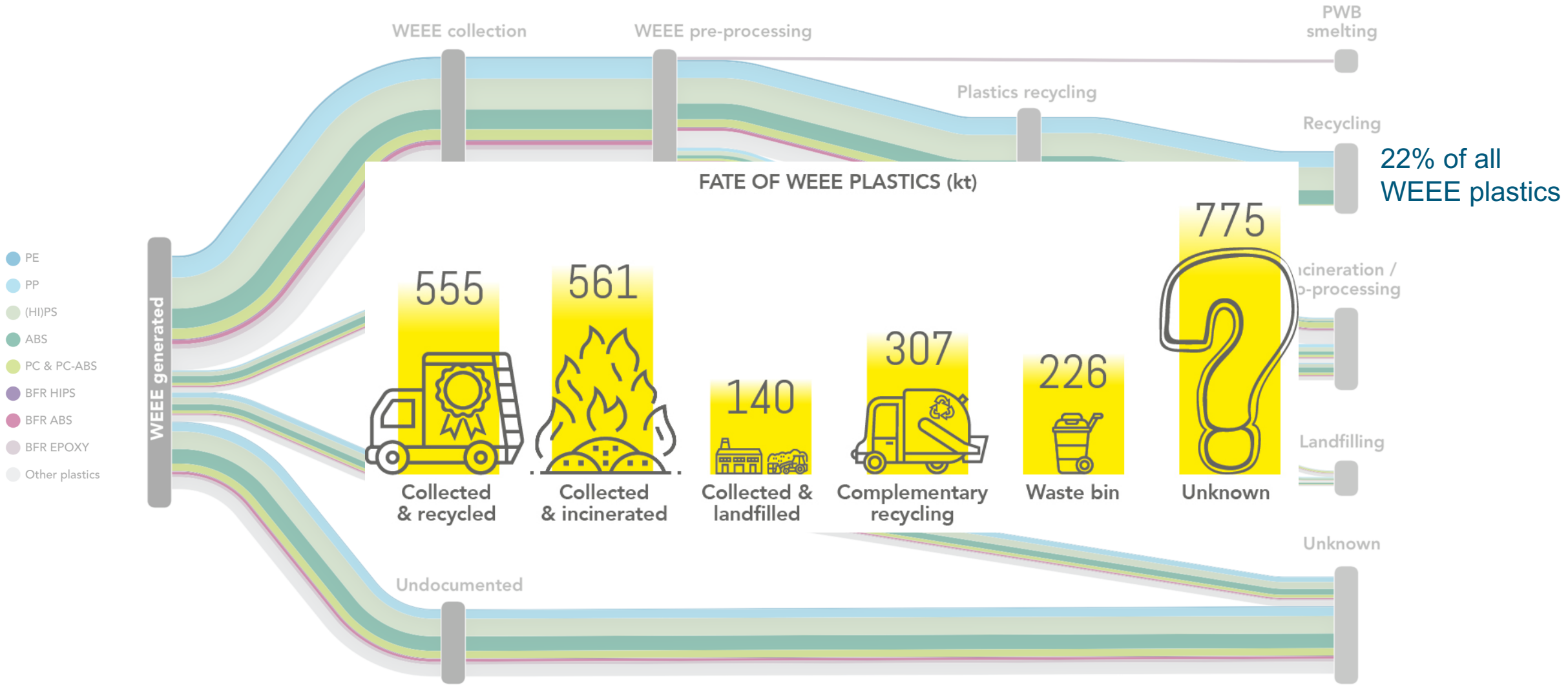
WEEE plastics mass flows (EU28+2, 2020)



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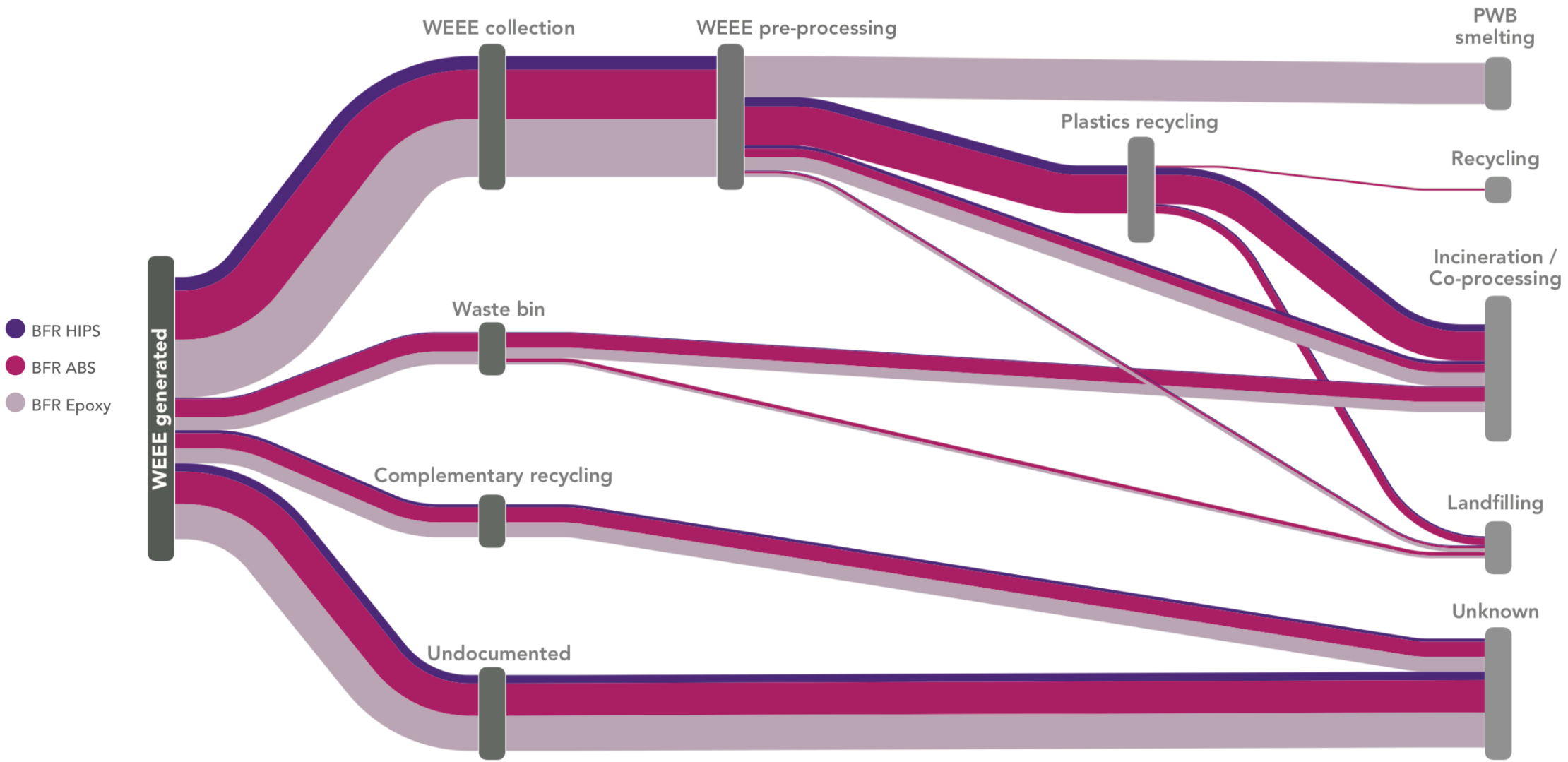
BFR plastics mass flows (EU28+2, 2020)



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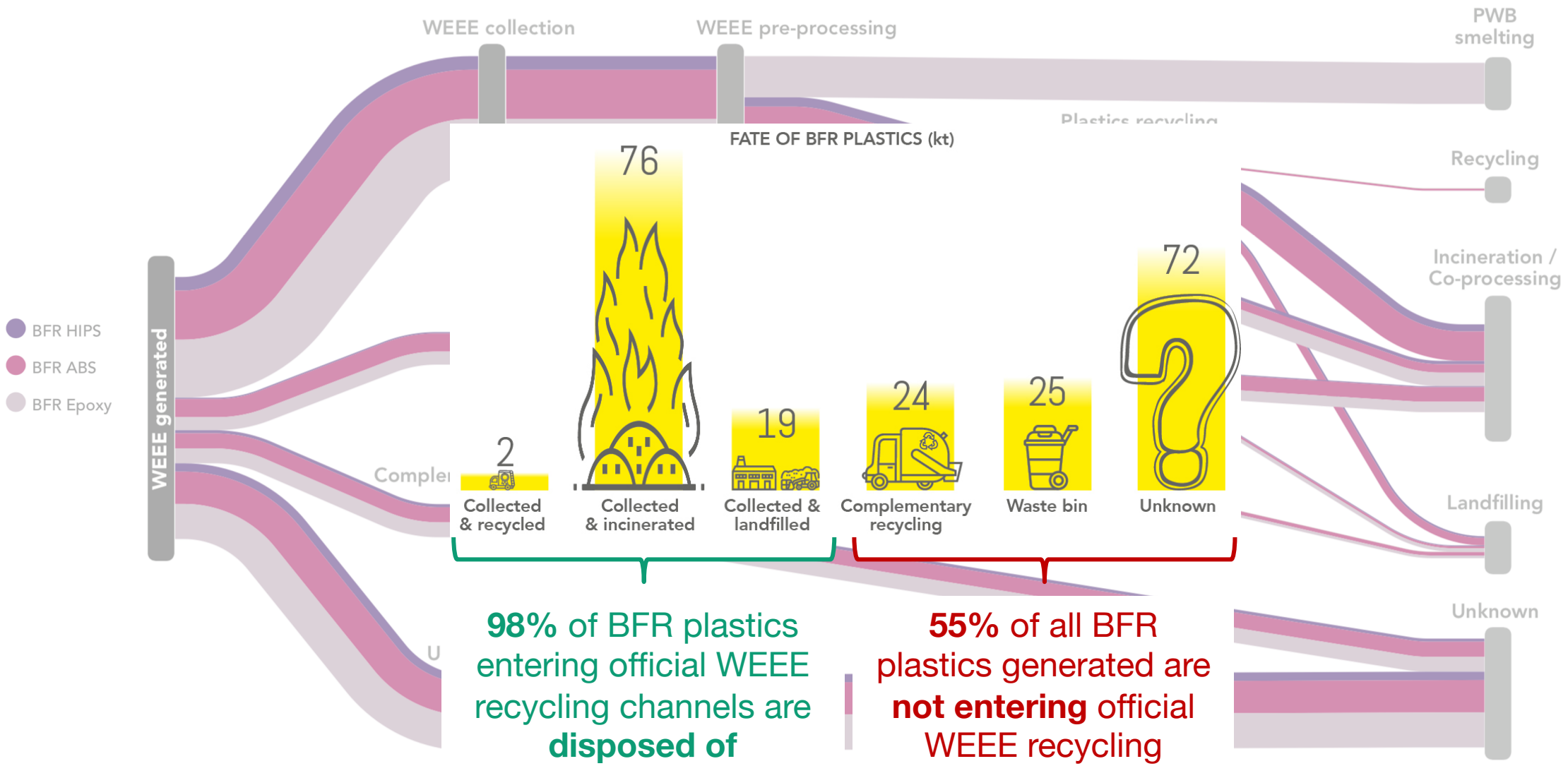
BFR plastics mass flows (EU28+2, 2020)



98% of BFR plastics entering official WEEE recycling channels are **disposed of**

55% of all BFR plastics generated are **not entering** official WEEE recycling channels

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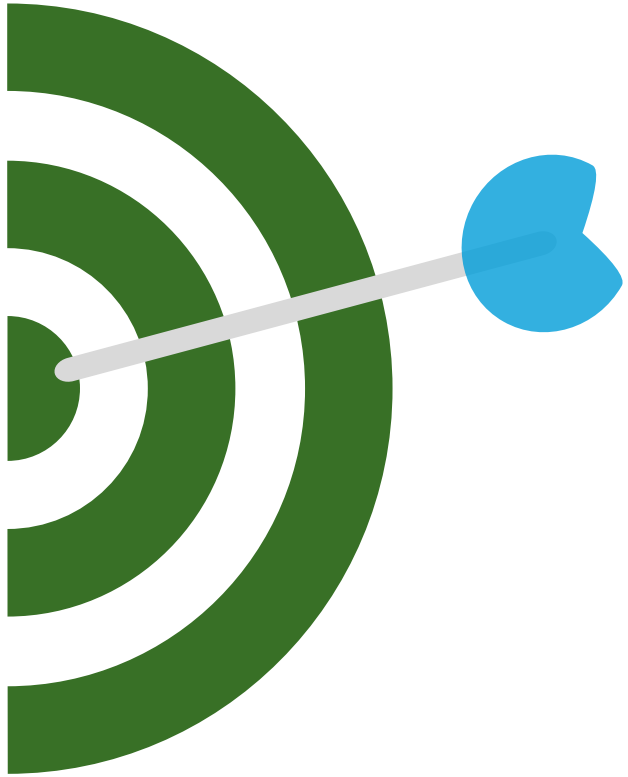

Get a picture of the **trend in levels of legacy BFRs** in WEEE plastics

Method:

- *Collection of data on **BFRs levels in WEEE plastics** (>400 data points, from published studies)*
- *Selection of data corresponding to **representative samples of unsorted WEEE plastic mixtures***

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Data on BFR levels

Category	Sampling year	# samples	Br		ΣPBBs		HBCD		Penta+OctaBDE		DecaBDE		ΣPBDEs		TBBPA		%PBDEs in total Br	%TBBPA in total Br	Reference
			Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median			
1 – Temp. exch. equipement	2010	12	245	210	BDL	BDL	BDL	BDL	BDL	BDL	92	BDL	92	BDL	5	BDL	31%	1%	Wäger et al. 2011
	2017	30	-	BDL	-	-	-	-	BDL	BDL	BDL	BDL	BDL	-	-	-	-	-	Drage et al. 2018
	2017	15	353	293	BDL	BDL	BDL	BDL	3	BDL	49	25	103	81	102	14	12%	17%	Haarman et al. 2018
2 – Screens	2017	43	-	320	-	-	-	-	38	BDL	1900	BDL	1938	-	-	-	-	-	Drage et al. 2018
2 - Screens (CRT)	2010	14	23571	15500	104	85	357	BDL	1486	665	3700	3450	5186	3995	16964	2975	18%	42%	Wäger et al. 2011
	2011	6	19167	19000	BDL	BDL	42	BDL	974	839	2600	2400	3574	3457	7553	6970	15%	23%	Taverna et al. 2017
	2014-2015	8	10394	-	34	34	552	276	574	-	1933	-	2507	-	3335	-	20%	19%	Hennebert et al. 2018
2 - Screens (FPD)	2010	6	8950	7900	BDL	BDL	BDL	BDL	32	BDL	67	BDL	98	BDL	1253	805	1%	8%	Wäger et al. 2011
	2011	6	8117	8150	BDL	BDL	BDL	BDL	11	12	1700	1500	1711	1511	2705	2375	17%	20%	Taverna et al. 2017
	2014-2015	8	10014	-	BDL	BDL	15	8	18	-	2708	-	2725	-	2100	1050	23%	12%	Hennebert et al. 2018
4 - Large equipment	2010	6	1083	1135	BDL	BDL	BDL	BDL	BDL	BDL	450	150	450	150	18	BDL	34%	1%	Wäger et al. 2011
	2017	57	-	0	-	-	-	-	BDL	BDL	19	BDL	19	-	-	-	-	-	Drage et al. 2018
	2017	21	1541	1300	BDL	BDL	8	BDL	17	BDL	147	48	201	170	222	52	9%	9%	Haarman et al. 2018
5 - Small equipment	2010	14	3258	1450	9	BDL	BDL	BDL	71	BDL	343	300	414	300	719	275	10%	13%	Wäger et al. 2011
	2017	29	-	1	-	-	-	-	BDL	BDL	170	BDL	170	-	-	-	-	-	Drage et al. 2018
6 - Small ICT	2010	6	11767	13000	8	BDL	BDL	BDL	450	295	883	700	1333	1575	3485	3675	9%	17%	Wäger et al. 2011
	2017	78	-	18	-	-	-	-	17	BDL	260	BDL	277	-	-	-	-	-	Drage et al. 2018
5&6 – Small equipement incl. ICT	2014-2015	8	3503	-	BDL	BDL	157	79	72	-	378	-	450	-	843	422	11%	14%	Hennebert et al. 2018

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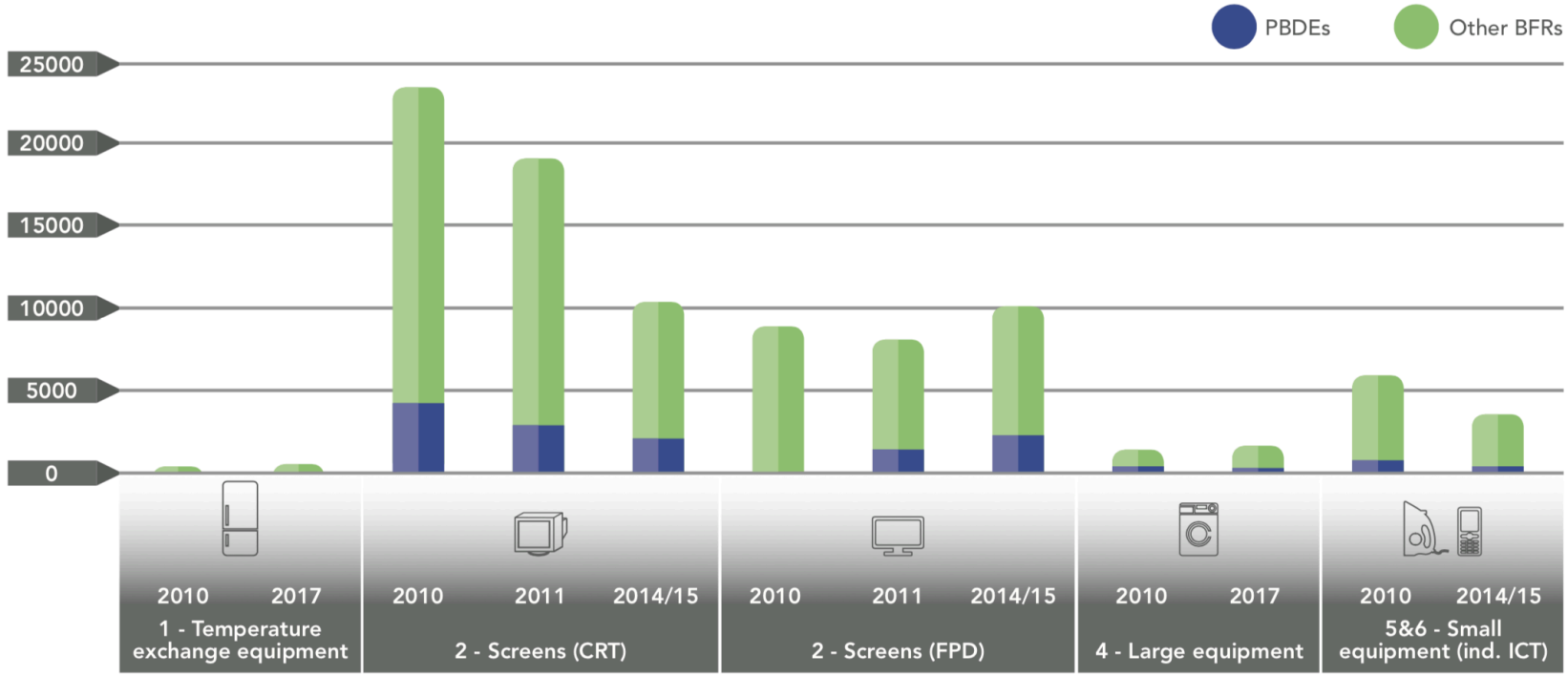
BFR levels over time

- Data collected from 5 studies, total of 367 samples
- Highest BFR levels in screens (esp. CRT), followed by small equipment
- Small and declining share of PBDEs in total Br content

Breakdown of total bromine content (ppm) in unsorted WEEE plastic samples, average values



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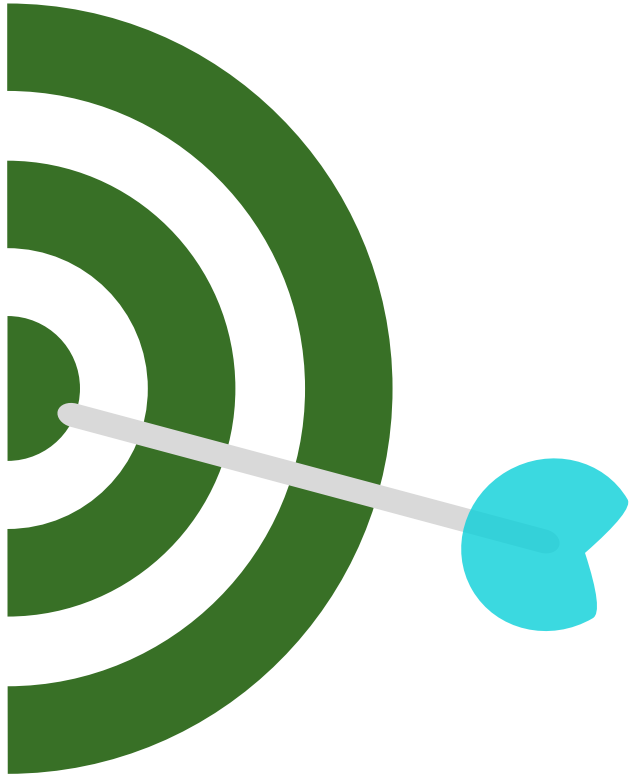
Data sources: Wäger 2010;Taverna 2017;Drage 2018;Haarman 2018;Hennebert 2018



Review BFR plastics **treatment requirements and practices**

Method:

- *Review of **normative requirements***
- ***Interviews** with take-back schemes & recyclers*

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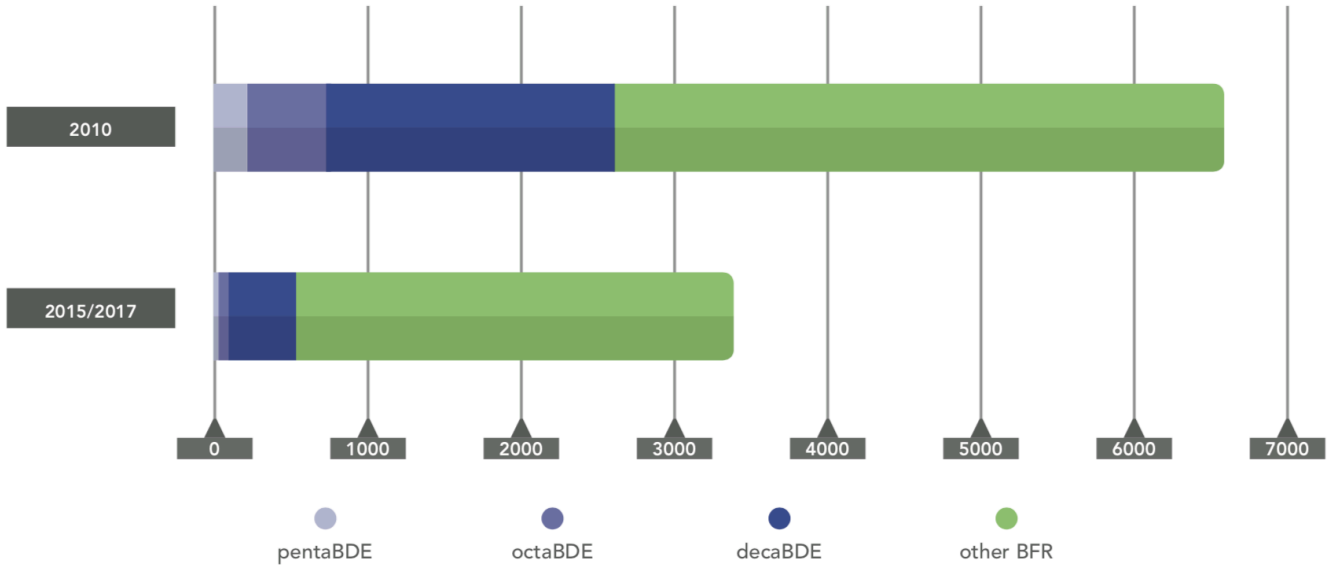
BFR plastics treatment requirements

- **WEEE Directive:** segregation of plastics containing restricted BFRs
- **CEN standard:**
  - Separate **Br-poor** fraction (to recycle) and **Br-rich** fraction (to dispose) for plastics from screens and small appliances
  - **Threshold of 2,000 ppm Br**

In 2010, 40% restricted BFRs of total Br content. 2,000 ppm Br threshold corresponded to a level below which **exceedance of the limit values for restricted BFRs was statistically unlikely**.

Nowadays, 15% restricted BFRs of total Br content. **Following the same logic**, threshold could be set at **6,000 ppm** (considering currently applicable limit values)



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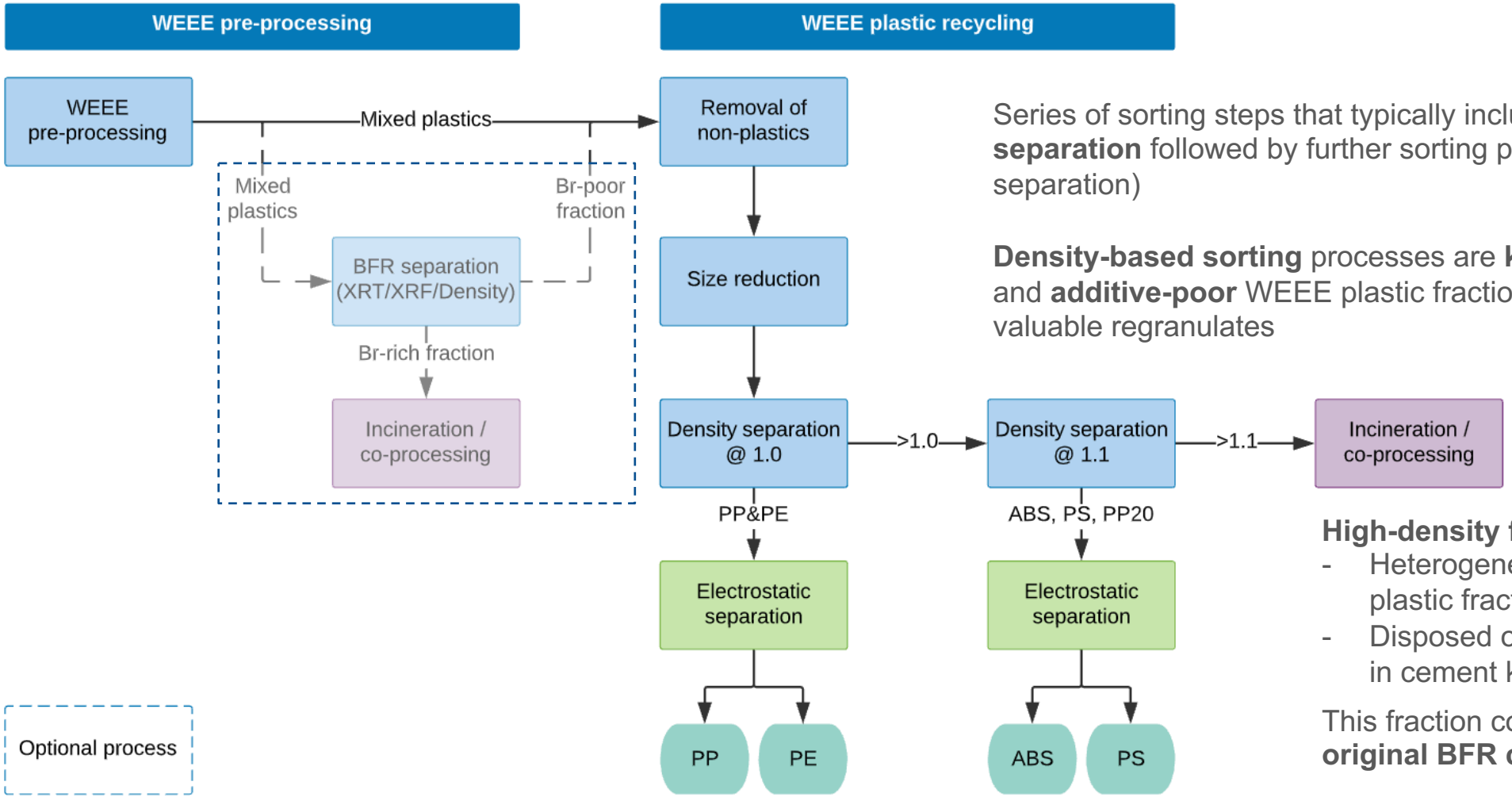
WEEE plastics recycling process



Series of sorting steps that typically include a stepwise **density separation** followed by further sorting processes (e.g. electrostatic separation)

Density-based sorting processes are **key** to obtain **homogeneous** and **additive-poor** WEEE plastic fractions that can be turned into valuable regranulates

High-density fraction or "**waste fraction**":

- Heterogeneity is too high to recover pure plastic fractions.
- Disposed of by incineration, co-processing in cement kilns or landfilling.

This fraction contains **more than 95% of the original BFR content**

Target polymers: pure, additive-poor fractions turned into recycled plastics for the manufacture of new products

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Method:

- ***Interviews** with recyclers*
- *Review of available **literature***

Understand impact of BFRs on recycling **yields** and recyclates **quality**, and compare with **alternative FRs**

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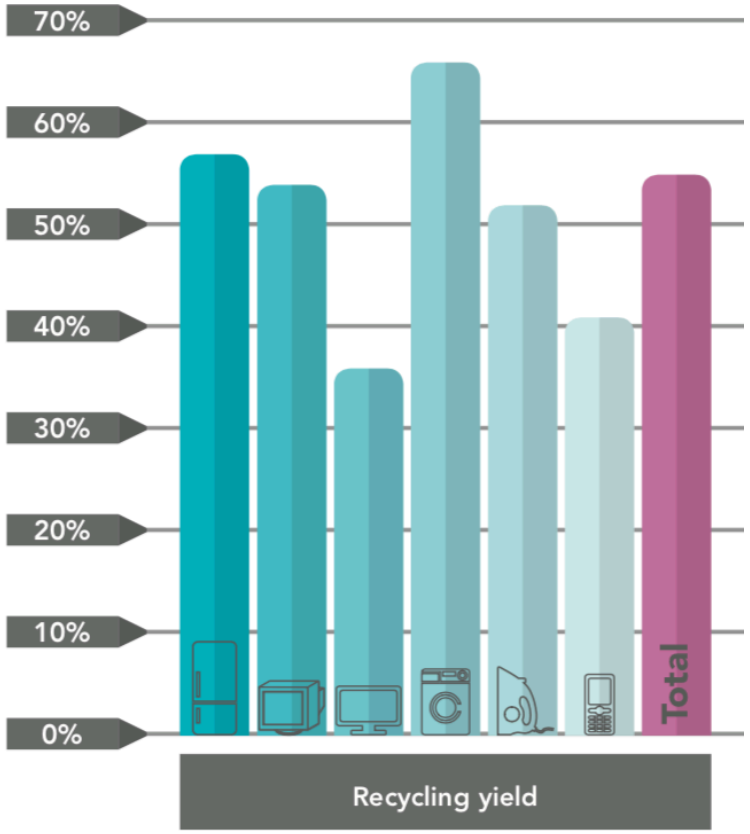
Impacts on recycling yields



(recycled plastics output / input to plastic recycling process)

Mainly influenced by

Share of target polymers

- Mainly PP, PE, ABS, PS (PC-ABS)
- Can be **easily separated** through density sorting

Additive loadings

- Plastics containing **high loads** of additives (fillers, flame retardants, stabilizers, etc.) are **not suitable for recycling**
- Removal of plastics with high loads of additives (through density sorting) therefore inherent to WEEE plastics recycling, **regardless of BFR content**
- Switch to **alternative FRs would not improve yields**, as PFRs and mineral FRs are **also sorted out** in recycling process
- Some **alternative FRs could even worsen recycling yields**, e.g. blend of PPE/PS polymer with RDP (PFR), which is listed in CoRAP list of substances but cannot be sorted out through density sorting (”**regrettable substitution**”)

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Impacts on recyclates quality

"degree to which a set of inherent characteristics of an object fulfils requirements"
WEEE plastics: mechanical, rheological and aesthetics properties

Purity

- Most plastics are **immiscible**, i.e. they will not form a single phase when melted
- Depends on polymers, e.g. HIPS can tolerate as much as 5% of ABS impurity but only 1% of PC or PC-ABS

Content in additives

- **Additives may adversely affect the quality** of recyclates (e.g. stiffness, brittleness, thermal stability, shrinkage, impact strength)
- Several studies compared impacts of FRs on recyclates quality*
- **BFRs** found to have remarkably **few negative effects**
- In contrast, **organophosphates (PFRs) are known to negatively impact quality** of recyclates (e.g. degrade into acid compounds causing **brittleness** of recyclates)
- **Little research on impacts of mineral FRs**, however considering the high functional loadings (>60%) brittleness is likely

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*Imai et al. 2003, Statler et al. 2008, Vahabi et al. 2015

Key findings & Recommendations

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Key findings

1

~2.6 Mt of WEEE plastics generated annually in Europe, **9% contain BFR**

2

Only ~1 Mt of WEEE plastics reach **specialized recycling facilities**, mainly due to low WEEE collection rates. Average recycling yield of **55%** → 550 kt **PCR WEEE plastic** produced annually (22% of total potential)

3

Restricted BFRs represent small and **declining** fraction of all BFRs. **2,000 ppm Br** sorting threshold should be reviewed considering decline in levels of restricted BFRs

4

State-of-the-art WEEE plastic recycling processes rely on **density sorting** to recover marketable homogeneous and additive-free recyclates (mainly PP, ABS, PS). Able to **remove >95% of Br** content.

5

High-density fraction, containing dense polymers + BFRs, PFRs, mineral FRs and other additives, cannot be recycled and is **disposed of**

6

Switch to **alternative FRs would not improve** WEEE plastics recycling, and could even lead to **detrimental impacts** on yields and quality (”**regrettable substitution**”)

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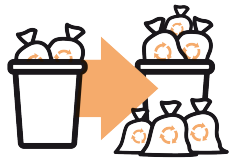
Recommendations

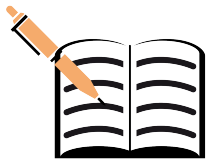
Policymakers



Increase quantities of WEEE plastics reaching recycling facilities by increasing **WEEE collection rates**, enforcing **compliance with EN 50625**, and facilitating **intra-EU cross-border shipments** towards state-of-the-art WEEE plastic recycling facilities

Investigate the **impacts of alternative FRs** on the recyclability of WEEE plastics to avoid “regrettable substitution” effects

Improve the **knowledge base** necessary for evidence-based policies and decisions by regularly collecting and analysing representative data on levels of BFRs and other additives in WEEE plastic streams



Review the **relevance of normative requirements** on treatment of BFR-containing WEEE plastics considering the reduction of restricted BFR levels over time (e.g. increase 2,000 ppm sorting threshold)

Harmonize and ensure stability of legislation of chemical, waste and products having a direct impact on WEEE plastic recycling, to facilitate **investment** in innovative recycling technologies

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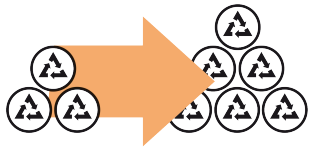
Recommendations

Producers



Adopt and implement recycled content targets to boost demand for WEEE plastic recyclates and decouple from virgin plastic prices

Exchange with WEEE plastics recyclers to understand how the **choice of polymers and additives** influence the recyclability of plastics, and select polymers (and additives) used in the manufacture of EEE considering the extent to which they are currently recycled

Recyclers

Develop **innovative** sorting and recycling methods to **recover a higher share** of plastics, enabling for instance the recovery of PC-ABS, PA, or PBT polymers.

Seek long-lasting **partnerships with producers** to optimize **design for and from recycling**

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Thank you for your attention!