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The role of additives in a circular plastics economy

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Agenda

1. Motivation
2. The role of additives
3. Opportunities & challenges
4. Conclusion and outlook

1 Additives enable functionalities – can they enhance a sustainability transition?

The purpose of additives is increasingly focused on **sustainability, including circular solutions.**

BASF
We create chemistry

BASF introduces VALERAS™, a new brand for its plastic additives portfolio that enables customers to achieve their sustainability goals

Sustainability

EVONIK
Leading Beyond Chemistry

EVONIK AIMS TO GENERATE ADDITIONAL SALES OF AT LEAST €350 MILLION BY 2030 WITH SOLUTIONS FOR CIRCULAR PLASTICS

Sources: left: https://www.basf.com/global/en/media/news-releases/2021/06/p-21-243.html
right: https://www.infinam.com/en/sustainable-3d-printing-materials

1 (Toxic) additives threaten recyclability – can they hinder a sustainabiltiy transition?

Recent headlines convey **recyclability concerns** related to (toxic) additives.

c&en CHEMICAL & ENGINEERING NEWS

Recycling of plastics threatened by toxic additives, environmental and health advocates say

February 20, 2022

Environmental Health News

Recycling plastics "extremely problematic" due to toxic chemical additives: Report

June 01, 2023

IPEN

The Hidden Hazard of Toxic Additives in Plastics Impacts a Circular Economy

29 September 2020

Sources: Top left: https://cen.acs.org/environment/recycling/Recycling-plastics-threatened-toxic-additives/100/i7
Top right: https://www.ehn.org/plastic-recycling-2660739413.html
Bottom: https://ipen.org/news/hidden-hazard-toxic-additives-plastics-impacts-circular-economy

1 What is the role of plastic additives in a circular plastics economy?

Additives as **Opportunity**

Functionality optimization

Sustainability enabler

Additives as **Threat**

Negative effects on Human Health and Environment

+

Transition towards a more **circular plastics economy**

? **Additives in a circular plastics economy – Enabling or hindering a sustainable transition?**

2 Common ground: What are «additives»?

"Additives are **substances intentionally added to plastics** to provide a function fit for purpose to provide, improve, modify, or retain plastic properties […] **during the plastic life cycle**[1]"

Properties

- Substance type
- Size
- Mass
- Vapour pressure
- Boiling point
- Soluability
- …

Functionalities[2]

- Plasticizers
- Lubricants
- Blowing agents
- Antistatic agents
- Slip additives
- Antioxidants
- Light/UV stabilizers
- Heat stabilizers
- Biocides
- Flame retardants
- Fillers
- Reinforcements
- Colorants
- …

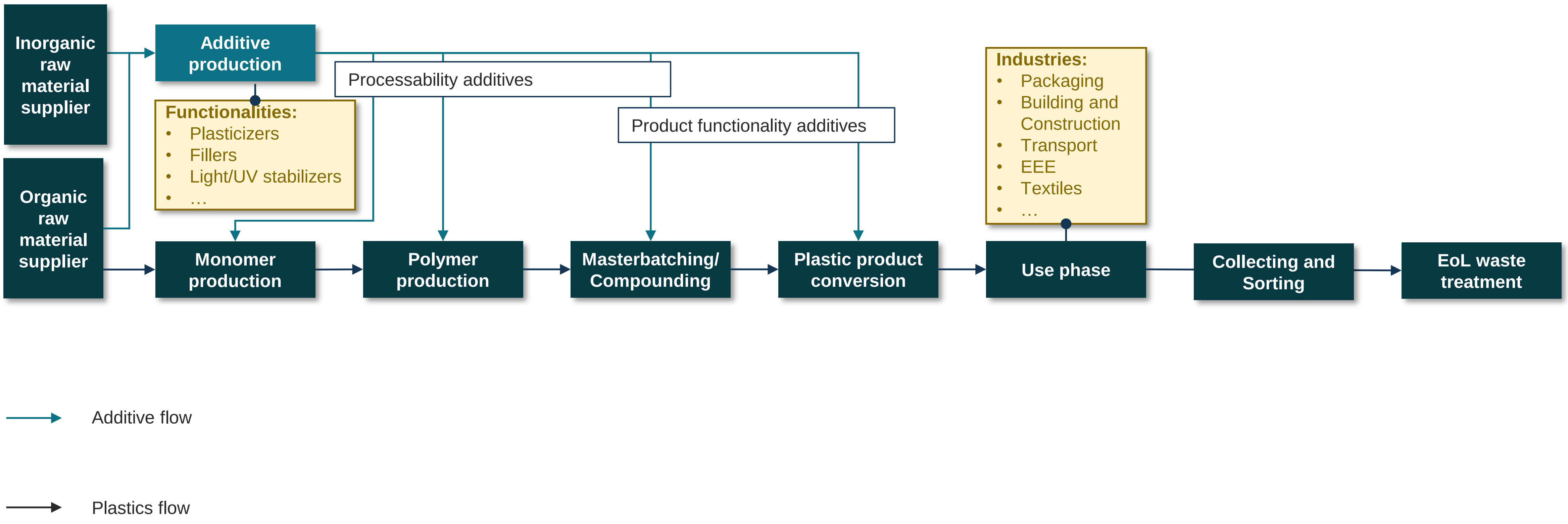
Industries

- Packaging
- Building and Construction
- Textiles
- Transportation
- …

Additives are substances with **individual properties**, which are intentionally added during the plastics life cycle to **enable** a broad range of product **functionalities** for **application in different industries.**

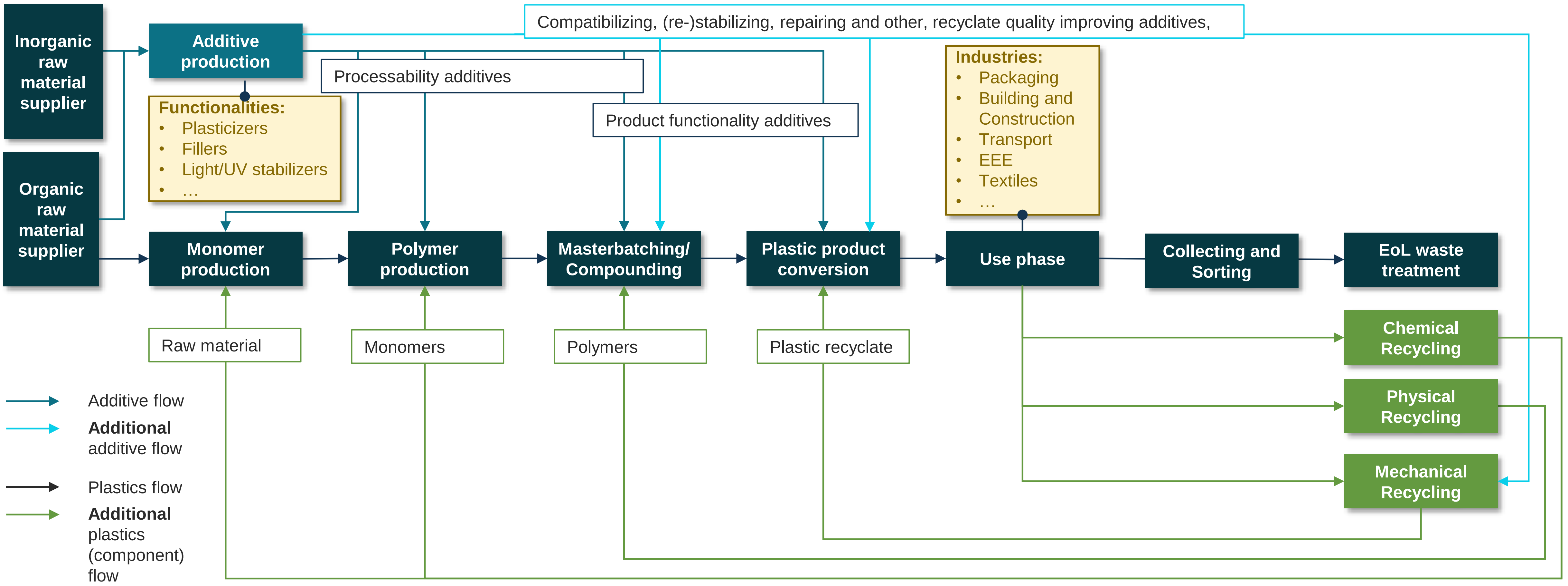
(1) Schiller et al (2009) (2) Combined sources: ECHA 2019; Hansen 2013; OECD 2019; Wiesinger et al. 2021

2 The **LINEAR** plastics value chain requires different additives at different stages



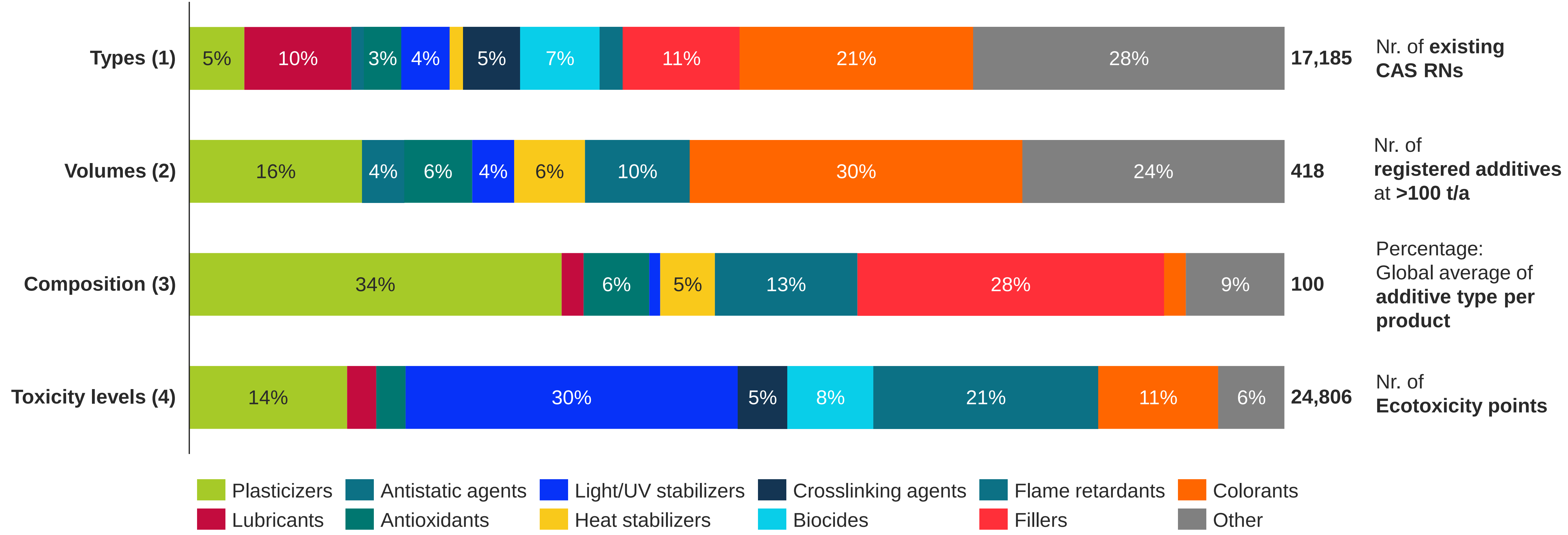
*Note: Additive **functionality, quality and quantity** requirements vary depending on the **industry application***

2 The **CIRCULAR** plastics value chain has additional additive flows



*Note: Additive **functionality, quality and quantity** requirements vary depending on the **industry application before and after recycling***

2 Types, volumes, compositions, and toxicity levels of additives – 4 incompatible perspectives*



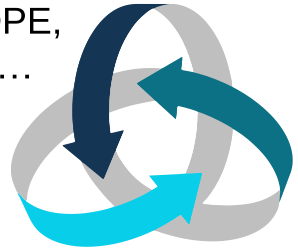
Sources & Comments:
(1) Wiesinger et al. 2021: One CASRN may serve multiple functions
(2) ECHA 2019: Without fillers and lubricants; Crosslinking agents and biocides may be included in “Other”
(3) Geyer et al. 2017: Antistatics, Crosslinking agents, Biocides may be included in “Other”
(4) Barrick et al. 2021: Without fillers; Ecotoxicity; Antistatics, Heat stabilizers may be included in “Other”

*Due to knowledge gaps and differing classifications a direct comparison across units is difficult. This presentation shall only convey that the additive relevance may depend on the selected unit (and classification). It is not suitable for further interpretation.

2 The combination of additives and polymers varies across industries

Status Quo: Additives are selected to optimize for **application requirements, not circularity**

Polymers
LDPE, HDPE,
PP, PS, …



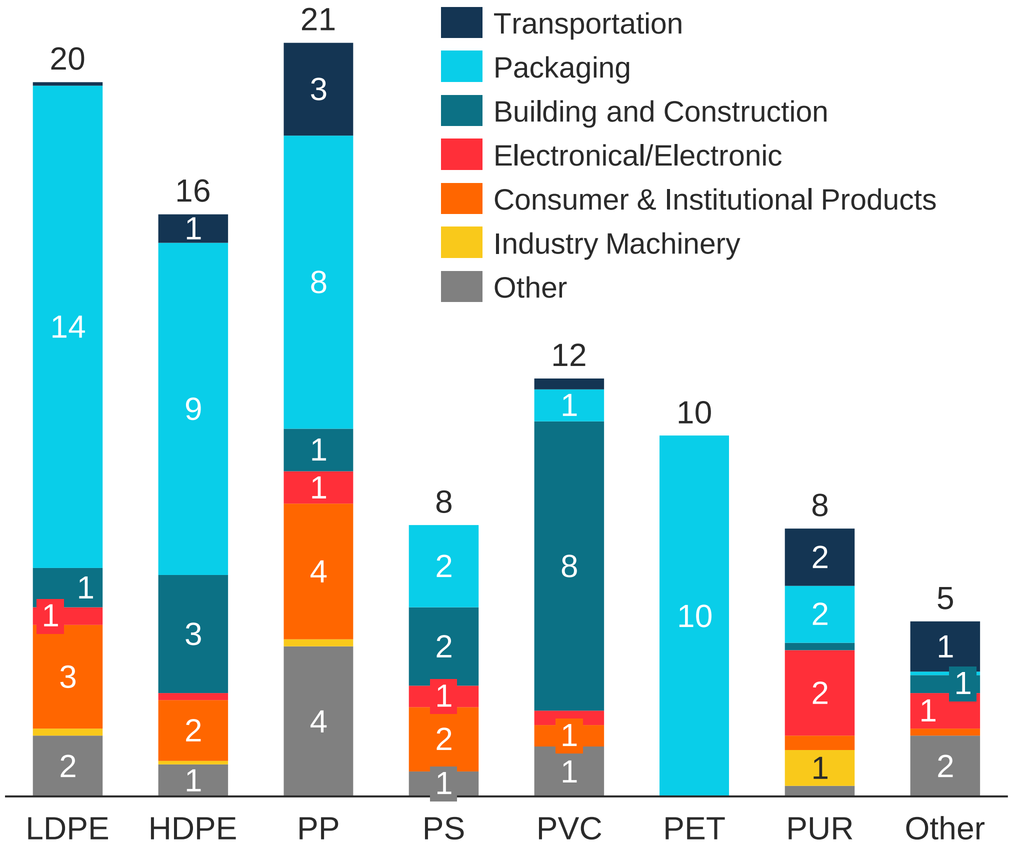
Additives
Plasticizers, Stabilizers,
Fillers, Colorants,…

Application requirements
- **Cost**
- **Functionality** (lifetime, fire resistance, food contact approval)

Status quo:
The optimization for functionality in different applications led to a **large bandwidth** of possible **polymer and additive combinations**

Challenge:
Different material/additive combinations potentially require **different circular strategies** for different industry applications

Global shares (%) of polymer consumption per industry



Source: Geyer et al. 2017

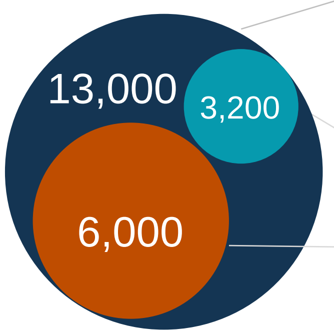
3 Additives as CE Enabler: Support for the recycling stage

	Compatibilizer	Repair additives	Stabilizer
	Improve the **compatibility** of immiscible **polymers**	**Restore original material properties** by elimination of damages	**Prevent the degradation** of polymers during processing or use from external impacts (e.g. heat, UV, …)
	Reactive groups on either end of the polymer chain that **connect different polymers by reacting with them**	Chemical reactions **restore polymer chains** and therefore molecular weight	Additives are used as **polymer (re-)stabilizer**
+	**Enable recycling** of "contaminated" materials	Reach **high recyclate material properties**	Improve recyclate material properties to **reach quality requirement**
−	• **Limited applicability** • The **costs** compete with those of sorting and cleaning technologies	**No plug and play additives** → additives and process need to be **aligned carefully** → Residues may **react with DNA**	**Risk of overdosing** stabilizer in multiple recycling loops

Additives can **enable/support plastics recycling** and therefore **contribute** to a **transition towards a CE.**

3 Lack of transparency as CE barrier

Lack of transparency



Identified plastic chemicals (incl. additives)[1]

Chemicals with ≥1 hazardous property[1]

Poorly characterized chemicals[1]

schematic visualization

(1) UNEP 2023

The current lack of transparency applies for **chemical identity, quantity, functionality** and **hazard information.**

Reasons

(1) Limited public accessibility to available data[2]
(e.g., producer's IP)

(2) Data incompleteness[2]
(e.g., reduced requirements for low production chemicals)

(3) Limited data availability[1]
(e.g., understudied chemicals)

(2) Wiesinger et al. 2021

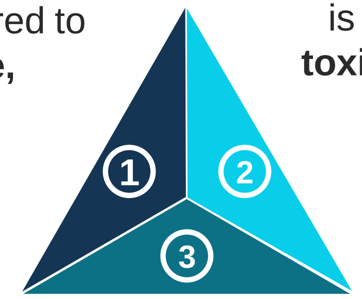
Affected stakeholders*

Downstream actors

Information on types and compositions of chemicals is required to produce **toxic free, high quality recyclates**

Research

information on chemical identities and applications is required to **assess toxicity of chemicals/ chemical groups and their combinations**



Policy makers

information on chemical identities, quantities and particularly impacts is required to **develop effective regulations for a safe and sustainable circular system**

*not exhaustive

The current lack of transparency **hinders the transition** towards a safe and sustainable CE **from an industry, research and regulatory perspective.**

3 Additives as CE threat: New additive-related risks caused by the recycling stage

	Contamination	Cross-contamination	Mixture effects	Legacy additives
	Unintended usage leading to contaminators entering the recycling stream	Additives react with each other in mechanical recycling process and **contaminate the recycling stream**.	Mixing of substances at dosage levels of no concern may lead to **effect multiplication**	Banned additives which still are found in today's products may enter additional life cycles
	• Potential recycalte **quality downgrading** • **Efficiency reduction**	Unproblematic additives **may generate problematic reaction products**	Additives of little concern **may become problematic in combination**	Substances of **high concern**. May **contaminate recycling streams** in transition phase
	• Unintended use of e.g. PET bottles (rat poison storage)	Certain flame retardants and UV stabilizer might react when processed together	Effect multiplication from mixing endocrine chemicals of individually non concernable quantities (Silva 2002, Kortenkamp 2007)	• Flame retardants (e.g. HBCD) • Plasticizer (e.g. Phtalate) • Stabilizer (e.g. Cadmium)
	How to ensure there is no contamination?	How to circumvent undesired reaction products?	Which substances multiply in what conditions to what problematic effects?	How to eliminate the risk from legacy additives in recycling streams?

Plastic recycling brings up **new, additive-related risks.** The **scope and impact levels** are **unclear.**

3 Lack of knowledge and methodology as systemic challenge

Lack of **knowledge:** Additive's **impacts**

General

- **Life cycle impacts** from chemicals
- **(Eco)toxicity**
  [Note: Some additives have been studied intensely (e.g. Bisphenols, Phtalates, Brominated flame retardants) – limited to a few]

Circular system

- Impacts from **additive accumulation and (unintentional) combination in recycling**
- Additive **behaviour in recyclate material** and modified **impacts** (compared to virgin material)

Lack of **methodology:** Globally harmonized **impact assessment**

Assessment strategy

- **Criteria for grouping** of chemicals
- Assessment **prioritization**
- …

Assessment guidelines

- Procedural standards, Transparency
- **Independency** requirements
- **Result classification** systems
- …

Chemical database

- Documentation and sharing of knowledge globally
- E.g., IDs, **assigned groups**, functionalities, impacts, **(in)compatible chemicals**

The impacts of additives are **neither understood** sufficiently **nor assessed** strategically on a global level.

4 We know, that we don't know a lot

1

Additives **generate both, many challenges but also opportunities** to enable a shift towards a circular plastics economy.

2

The **relevance** of both, challenges and opportunities **is difficult to determine** due to major knowledge gaps.

3

Joint efforts of research, policy makers and value chain actors are needed to take advantage of the opportunities while simultaneously overcoming the challenges.

4 Demand drives innovation: Existing ideas to address additive-related challenges

Rethinking Product design

Sustainable alternatives

- More sustainable types, e.g., Bioadditives
- Reduced quantities, e.g., highly efficient additives

Design for Recycling

- Today: Additive optimization for **cost and functionality**
- Future: Additive optimization for **durability and recyclability**

Redesigning Value chain

Closed Loop systems

- Reduced material combinations
- Reduced additive-related concerns
- Increased recycling rate

Value chain integration

- Generate knowledge about material composition for efficient recycling
- No external information sharing

Generating / Sharing Information

Digital tracking solutions

(Secure) data sharing along the Value Chain:

- Watermarks
- Product passports
- Blockchain technologies

Analytical methods

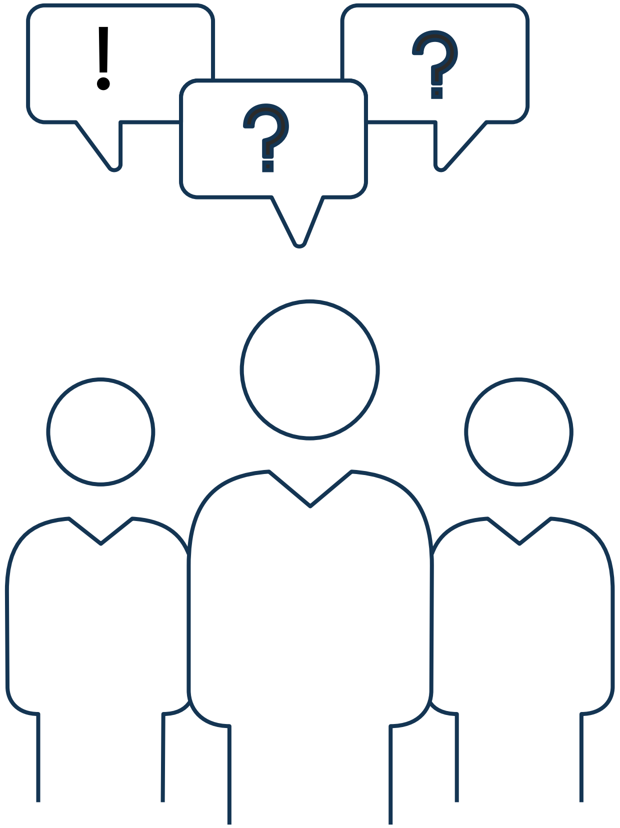
- In-process methods → operational adjustment
- Laboratory methods → strategical adjustment

4 The role of additives in a circular plastics economy is a two sided medal

	Opportunities		CE demand		Concerns
Upstream	Enabler of durability and recyclability; (Additive) business model innovation	←	**Design for recycling**	→	Overstabilization
	Additive innovation	←	**Sustainable additive solutions**	→	«Alternatives for the worse»
Down-stream	Additives for recycling; Technology innovation	←	**High recycling rates**	→	(Cross-)contamination; Mixture effects; Legacy additives
System	Technology innovation; Safe circular plastics systems	←	**Material Transparency**	→	Publishing additive producers IP
	Informed decision making and strategy development	←	**Scientific evidence**	→	Time and resource capacities; Result comparability
	Elimination of toxic substances; Incentivize innovation	←	**(Stricter) regulation of additives**	→	Overregulation as innovation barrier; «Alternatives for the worse»

Thank you for your attention

Questions and comments?



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