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Expertise scientifique collective sur les plastiques utilisés en agriculture et pour l'alimentation

Paris, 23 mai 2025

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DE LA TRANSITION
ÉCOLOGIQUE,
DE LA BIODIVERSITÉ,
DE LA FORÊT, DE LA MER
ET DE LA PÊCHE
Liberté
Égalité
Fraternité

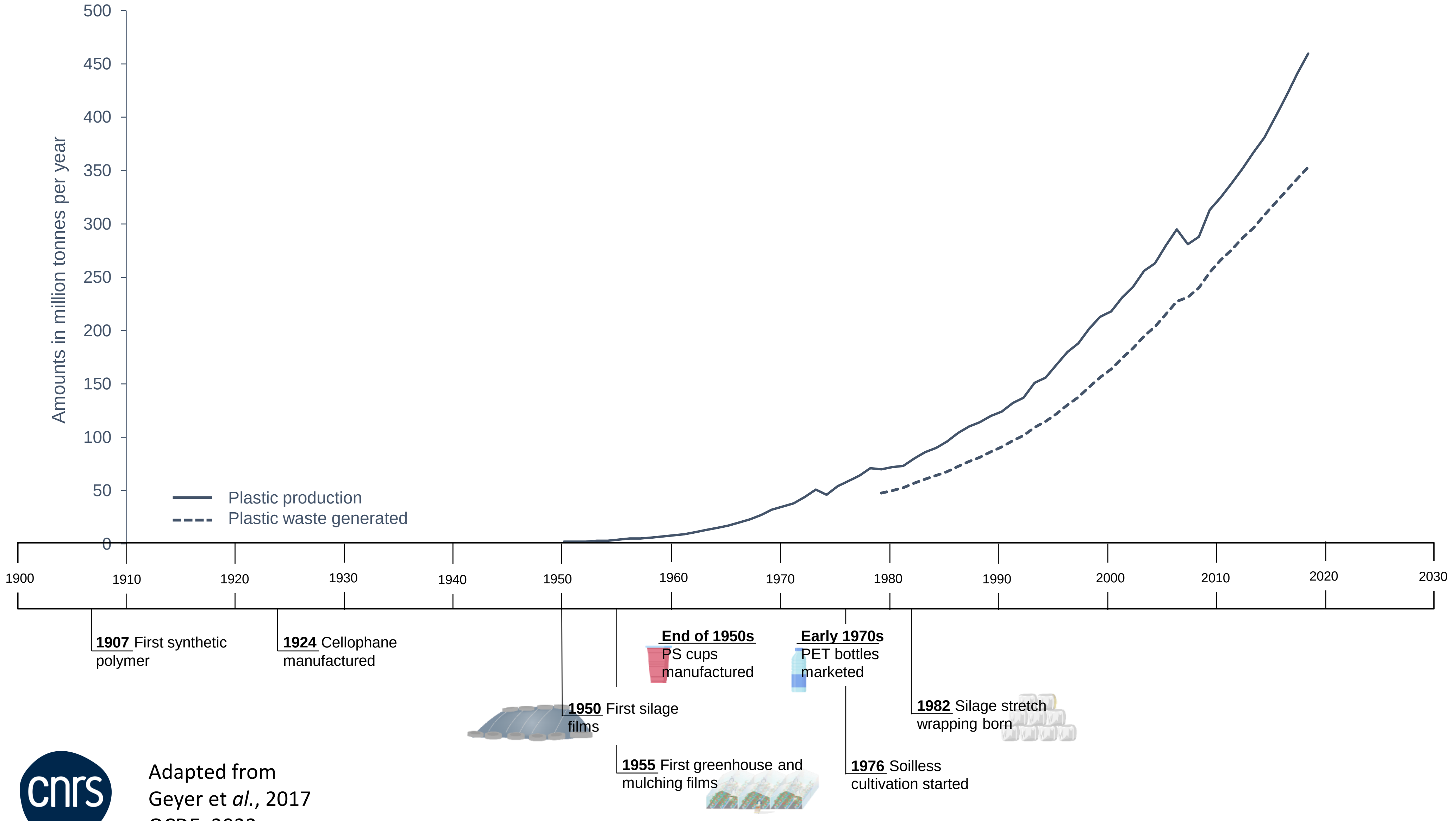
MINISTÈRE
DE L'AGRICULTURE
ET DE LA SOUVERAINETÉ
ALIMENTAIRE
Liberté
Égalité
Fraternité

ADEME
AGENCE DE LA
TRANSITION
ÉCOLOGIQUE

Introduction

1. Why a collective scientific assessment?
2. What are plastics, plastics used in agriculture and for food and the system under study?

Why a collective scientific assessment?



Adapted from
Geyer et *al.*, 2017
OCDE, 2022

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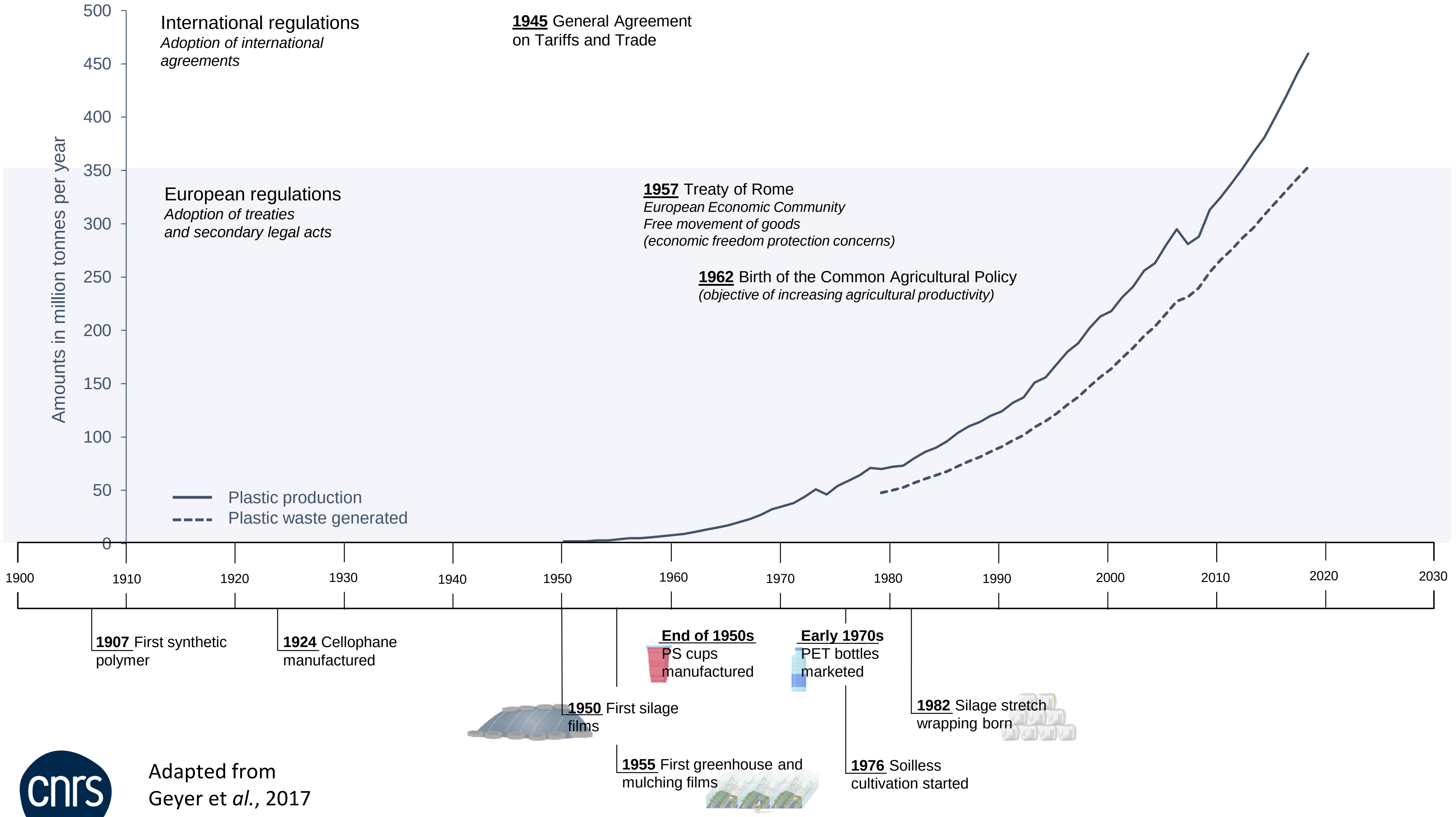

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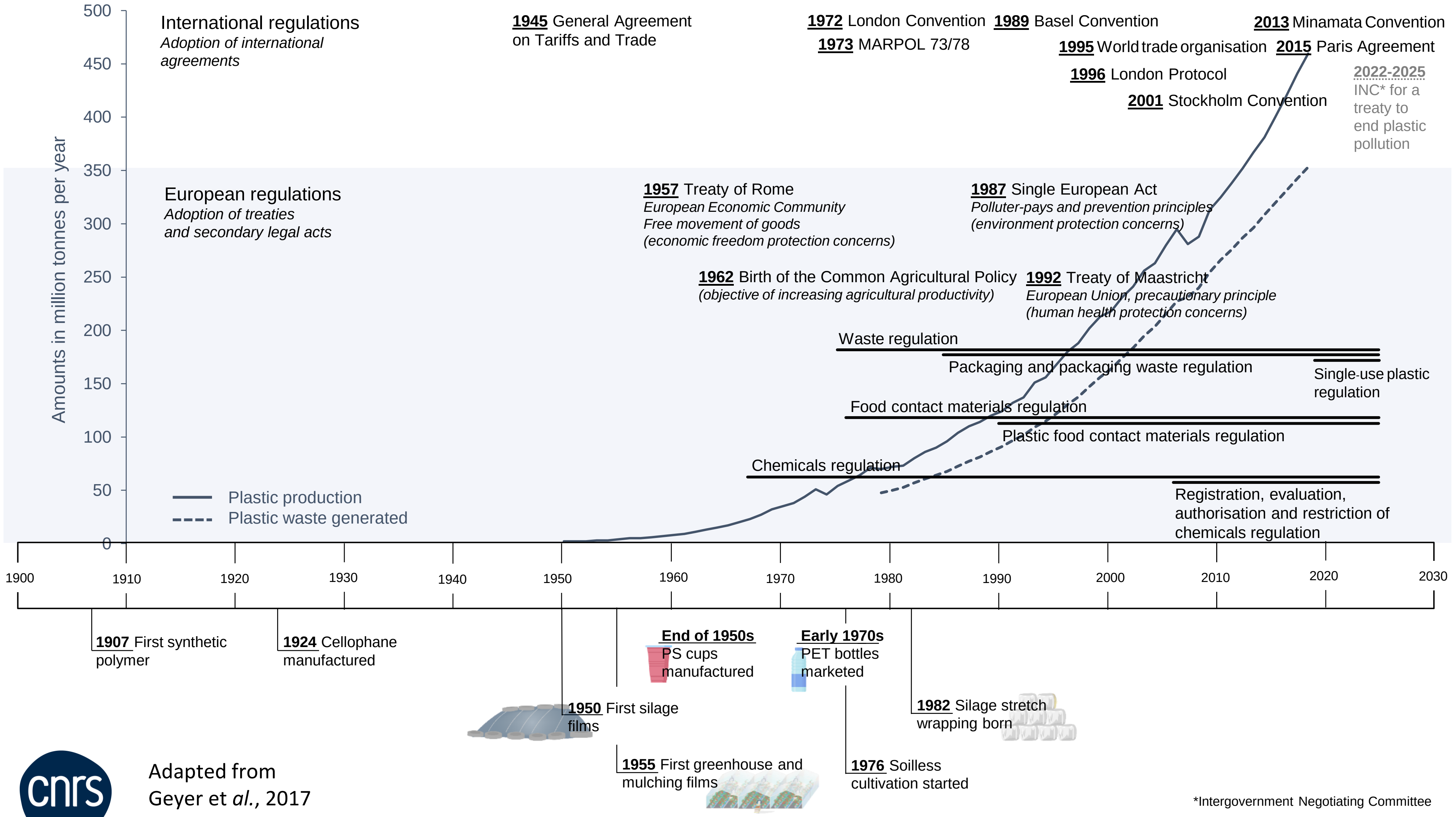

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*Intergovernment Negotiating Committee

Why a collective scientific assessment?

A review of the scientific literature on the sustainability of plastics used in agriculture and for food

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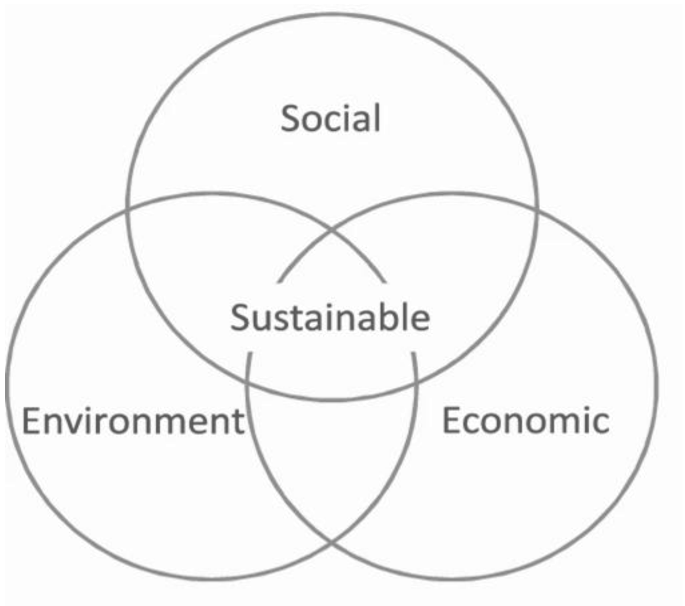

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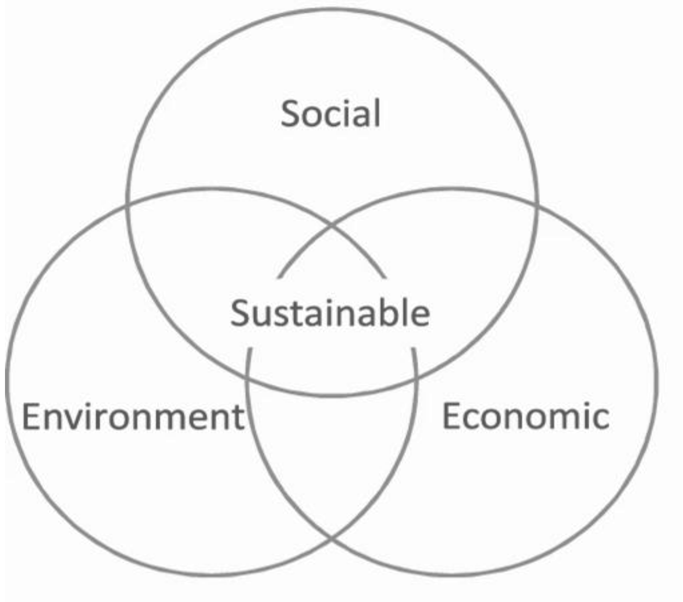
Why a collective scientific assessment?

A review of the scientific literature on the sustainability of plastics used in agriculture and for food

- Analysing trade-offs between benefits and costs, including human health and environmental costs



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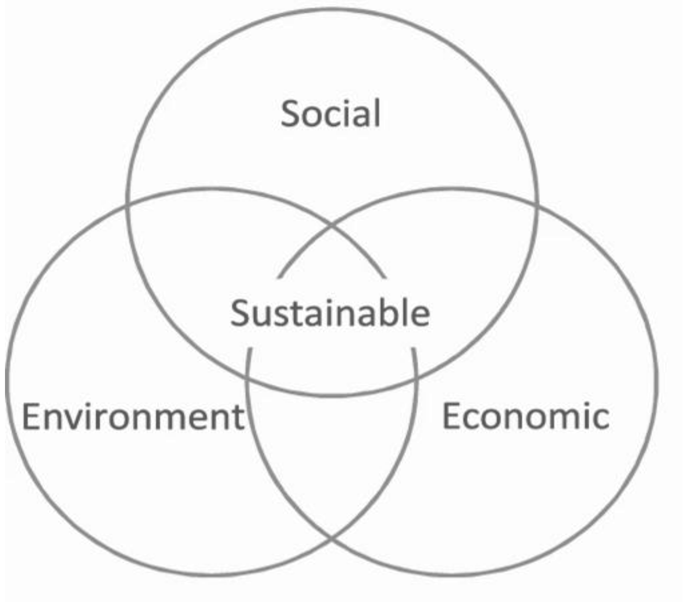
Following four core principles

- Competence
- Plurality of disciplines and approaches
- Impartiality
- Transparency



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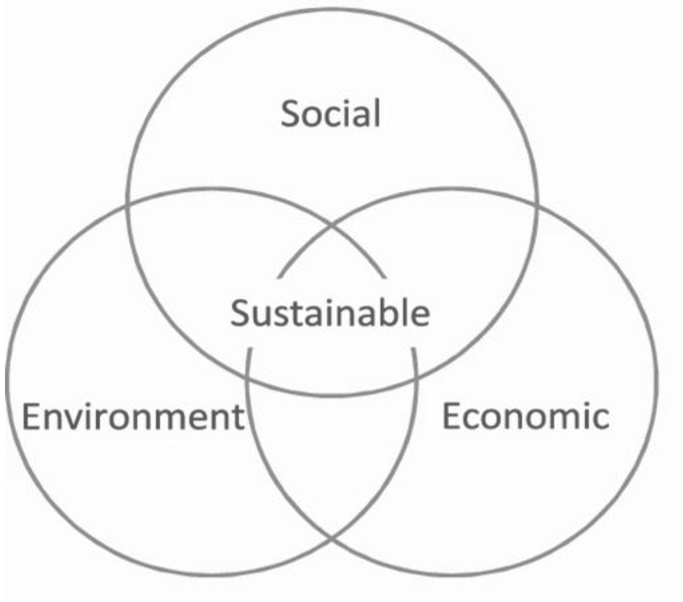
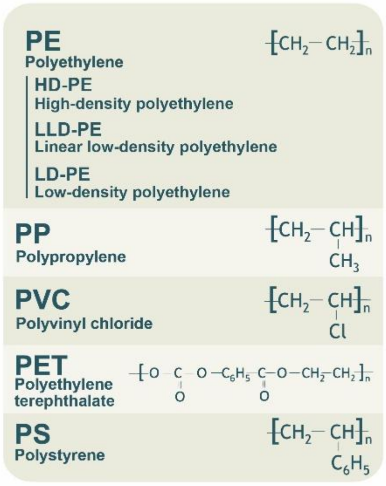


- A **multi-disciplinary group of 33 European experts from 24 public research organisations in 8 countries** involved
- Nearly **4500 publications** (published between 2000-2023) critically analysed, of which over 90% academic publications and about 100 legislative and regulatory texts.

What are plastics,
and plastics used in agriculture and for food?

Plastic constituents



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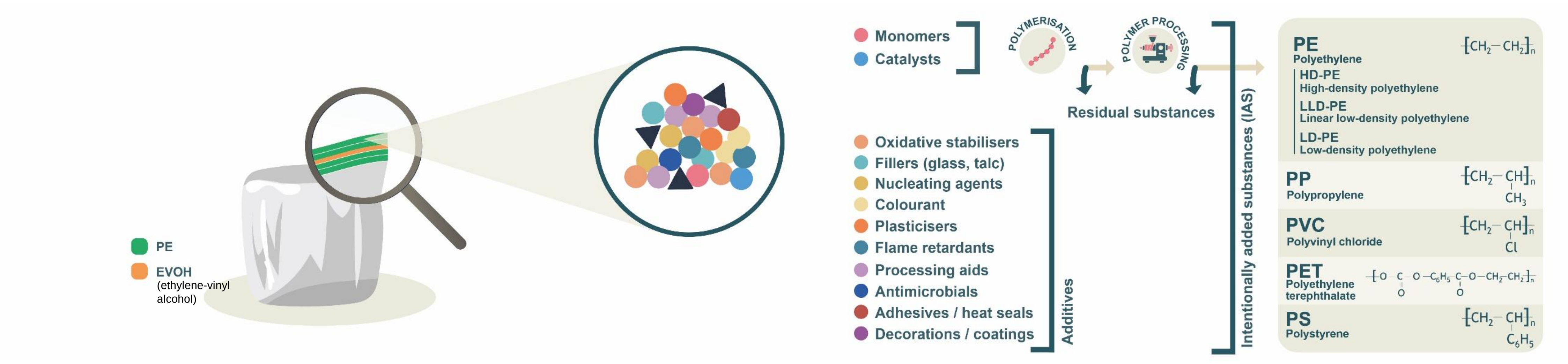

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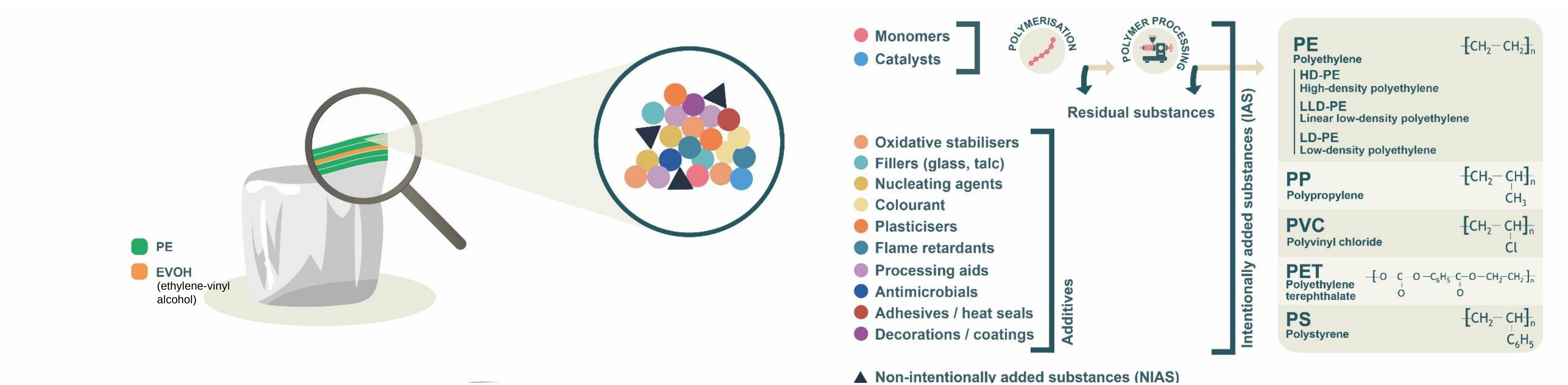

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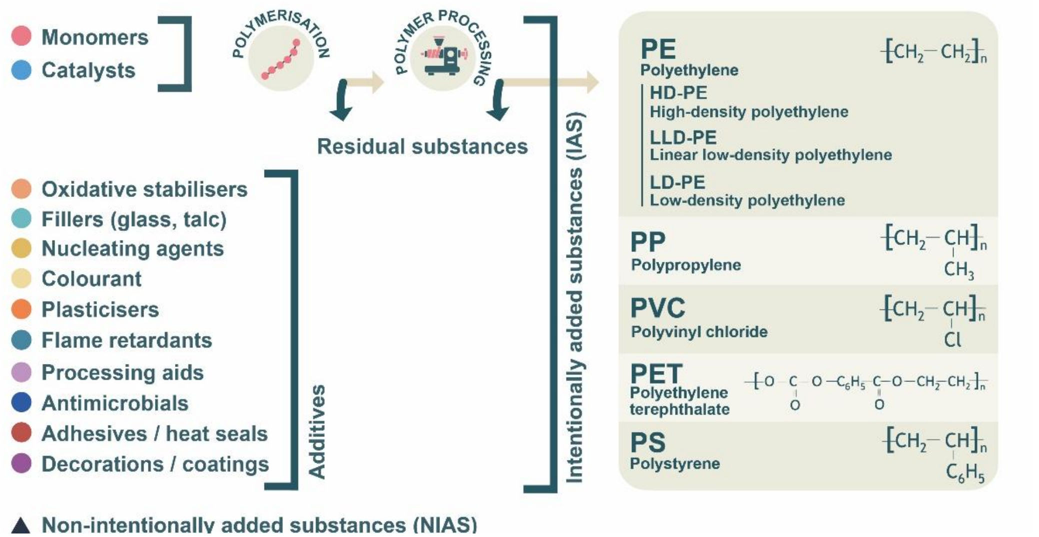

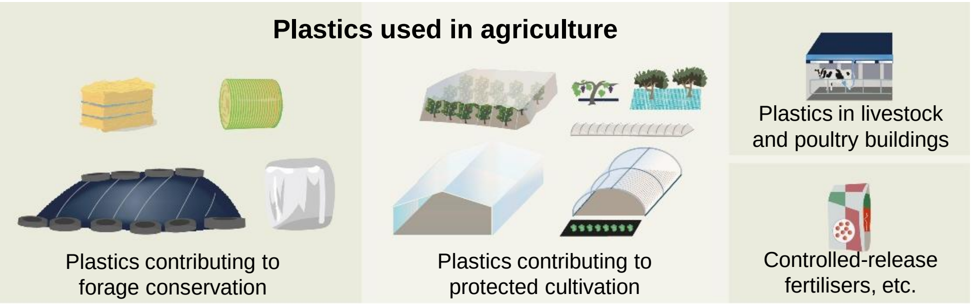

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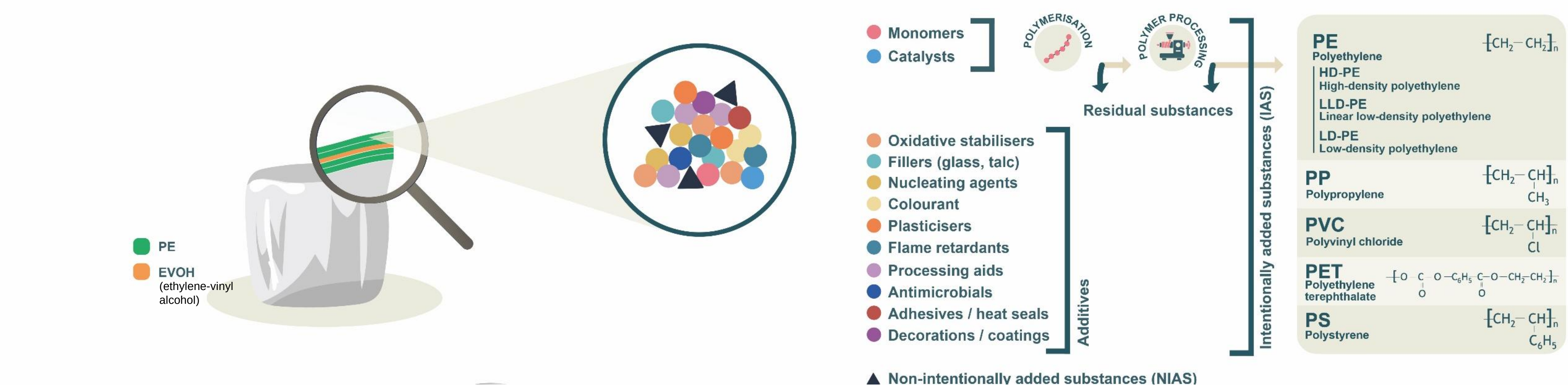

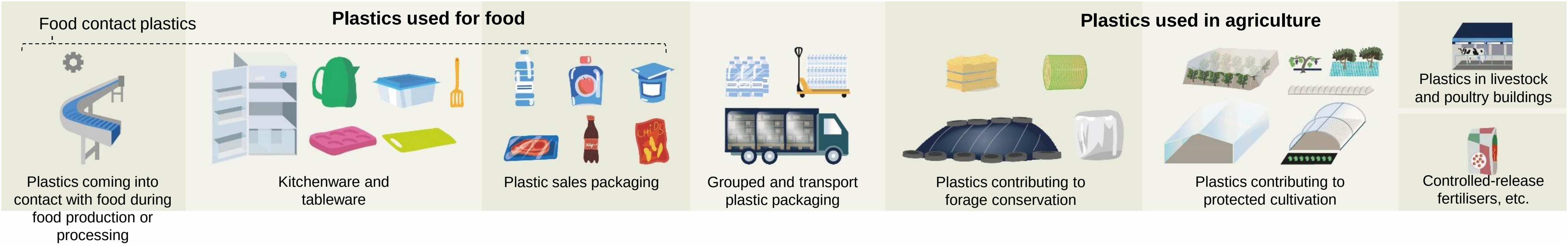

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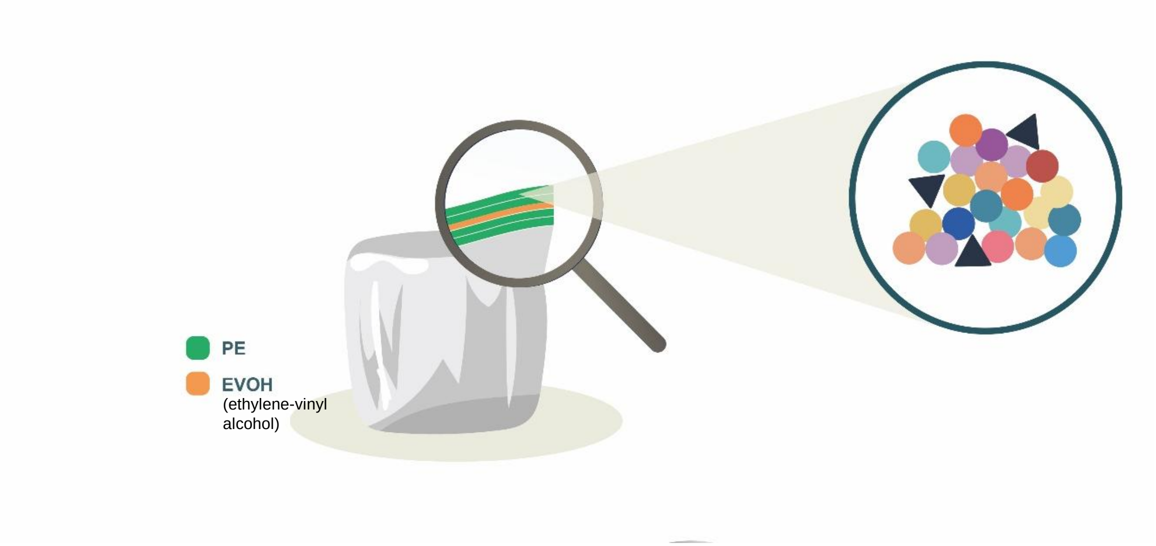
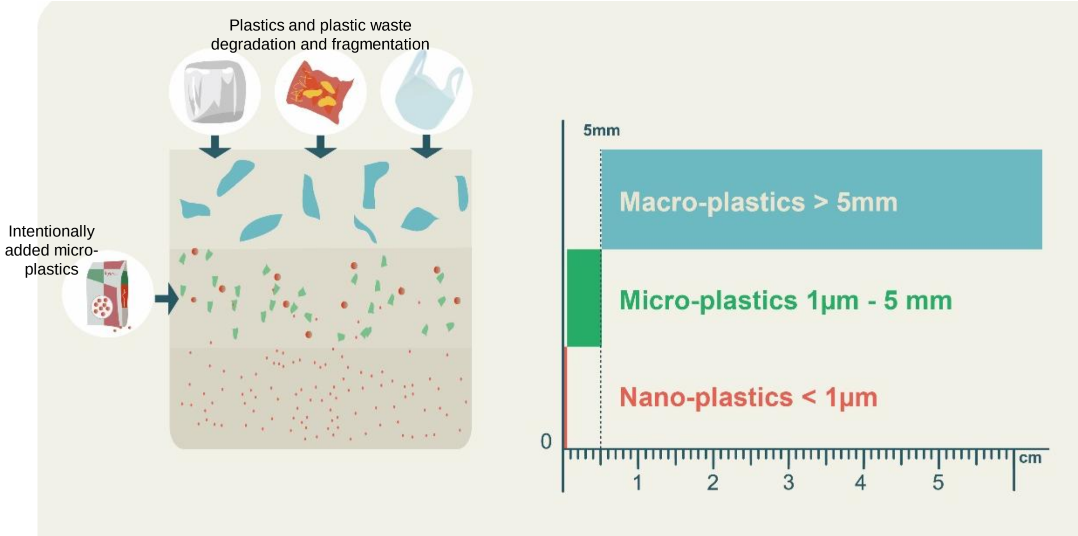
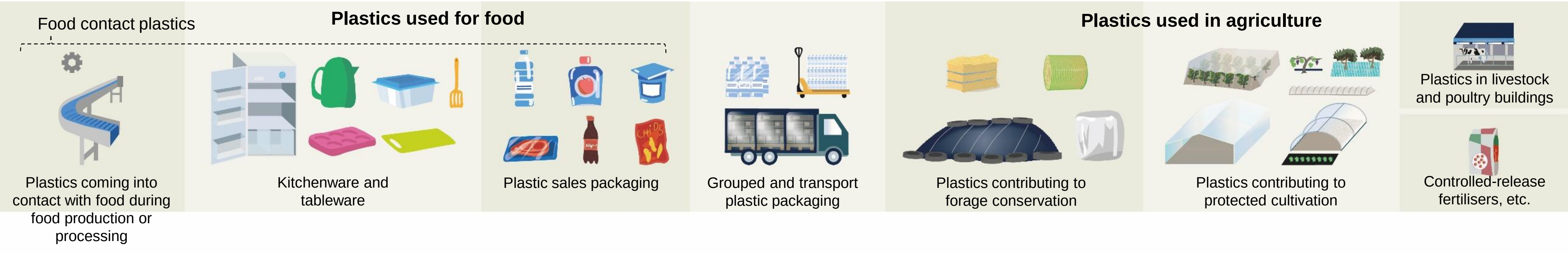


Plastic particles found in the environment





What is the system
of plastics used in agriculture and for food?

Production

What is the system of plastics used in agriculture and for food?

Uses

What is the system of plastics used in agriculture and for food?

Waste management

What is the system of plastics used in agriculture and for food?

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What is the system
of plastics used in agriculture and for food?

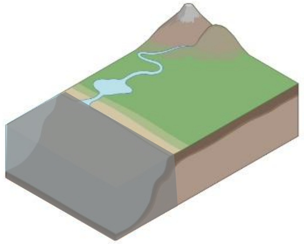
Focus on **uses** in Metropolitan France

What is the system of plastics used in agriculture and for food?

Broader geographical boundaries considered regarding **production**, **waste management**, and **impacts**

What is the system
of plastics used in agriculture and for food?

Impacts on continental (terrestrial & freshwater) ecosystems



marine ecosystems not considered

Key messages

Key messages

- Plastics have spread throughout food value chains
- The plasticity of plastics encourages their complexity
- Plastic waste management is difficult to monitor and implement in practice
- Plastics are ubiquitous, hazardous & have multi-scale impacts
- Is a sustainable system of plastics used in agriculture and for food possible?

Plastics have spread throughout food value chains

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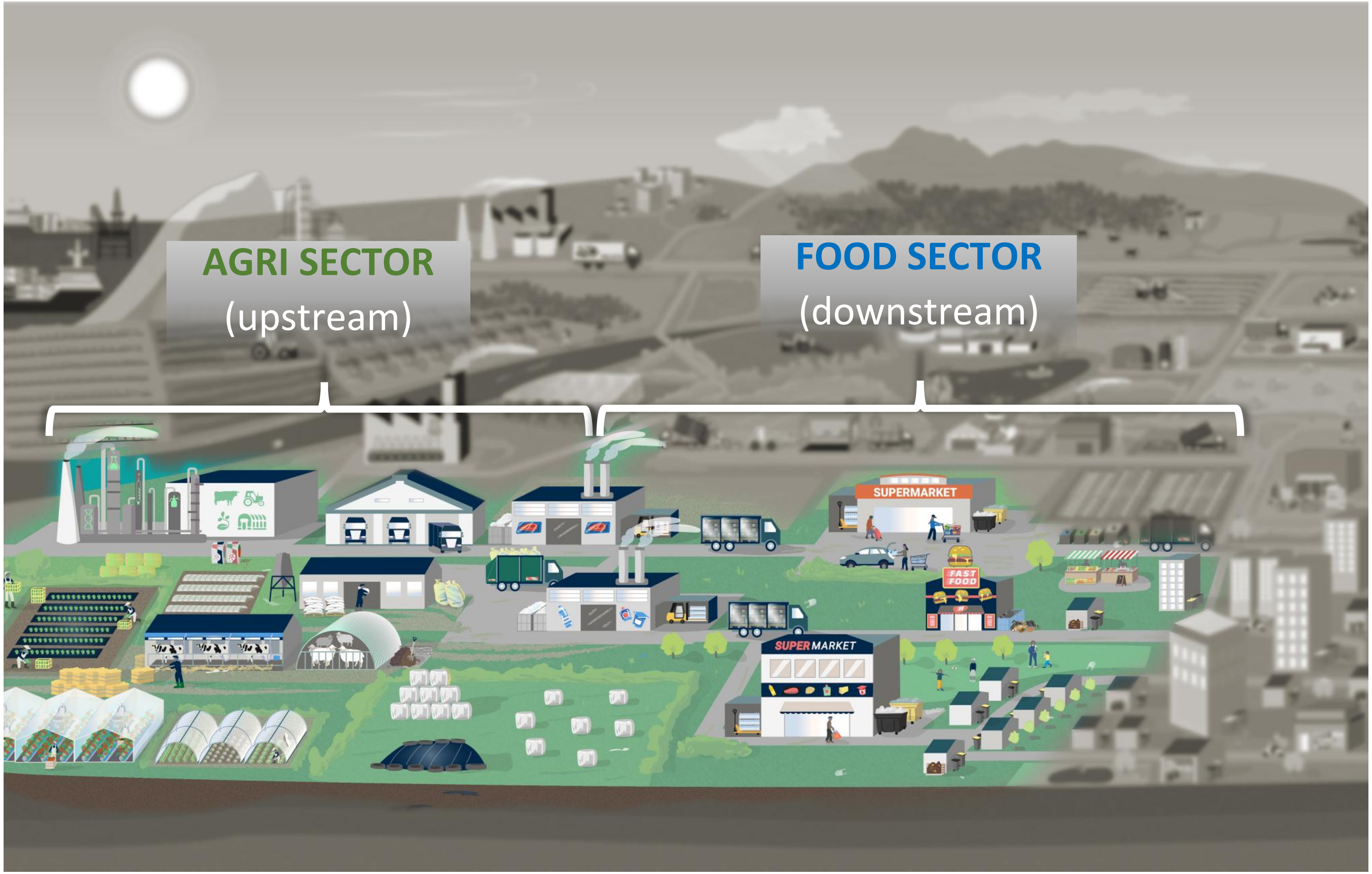
Plastics have spread throughout food value chains

Food value chain
overview



Plastics have spread throughout food value chains

Historical perspective: The Plastic Age

Mathieu Baudrin

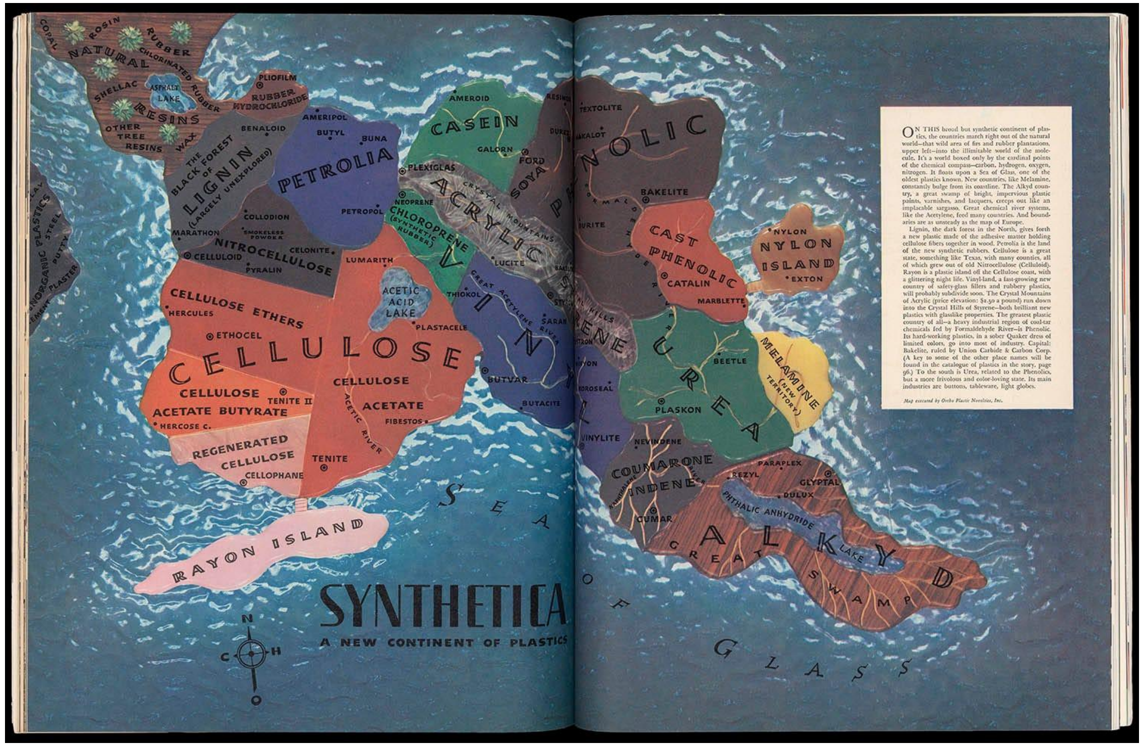
Based on a contribution by Mathieu Baudrin and Bernadette Bensaude-Vincent

Historical perspective. The Plastic Age

Plastics introduction into pre-existing agri-food systems changed the whole food value chain

- Plastics are **co-product of petrochemical industry**, looking for new markets after World War 1 and World War 2

- Plastics introduction not only **changed existing practices**, but also **created new ones:**
  - **In packaging (downstream)**
  - **Agriculture (upstream)**



Synthetica a continent created by Ortho Plastic Novelties [published in *Fortune* magazine, July 1940.]

A historical corpus focused on the north american context but still relevant for understanding the main socio-technical trajectories of plastics.

Historical perspective. The Plastic Age

Plastics changed food value chain starting with downstream

Couverture de Villermet, Jean-Marc (1965-) Auteur du texte. *Au Carrefour d'une révolution, la naissance de l'hypermarché : 1959-1963 / Jean-Marc Villermet ; préf. d'André Palluel-Guillard*, 1990. https://gallica.bnf.fr/ark:/12148/bpt6k3394942g.

- Plastic packaging appeared in the 1930s, coinciding with **refrigeration, storage and transport** advancements, later with the rise of **supermarkets** in the 1960s
- Plastic packaging became a **market device** in the 20th century, structuring the contemporary global food value chain (logistics, retailing and consumption)
- Plastics **changed the way we eat**, and contributed to **change the very nature of food**

Plastics made food **manageable**.

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Historical perspective. The Plastic Age

Petrochemical and packaging industries promoted a new way of life, based on plastics uses

- A pragmatic and profit-oriented **industrial research**

- **Role of marketing**

- After WW2, **single use**, or **disposability** of plastics were promoted as symbols of modernity, shaping **consumerist practices**

Life Magazine, 1955

Plastics as a factor of the **modern way-of-life.**

Historical perspective. The Plastic Age

Plastics changed agriculture

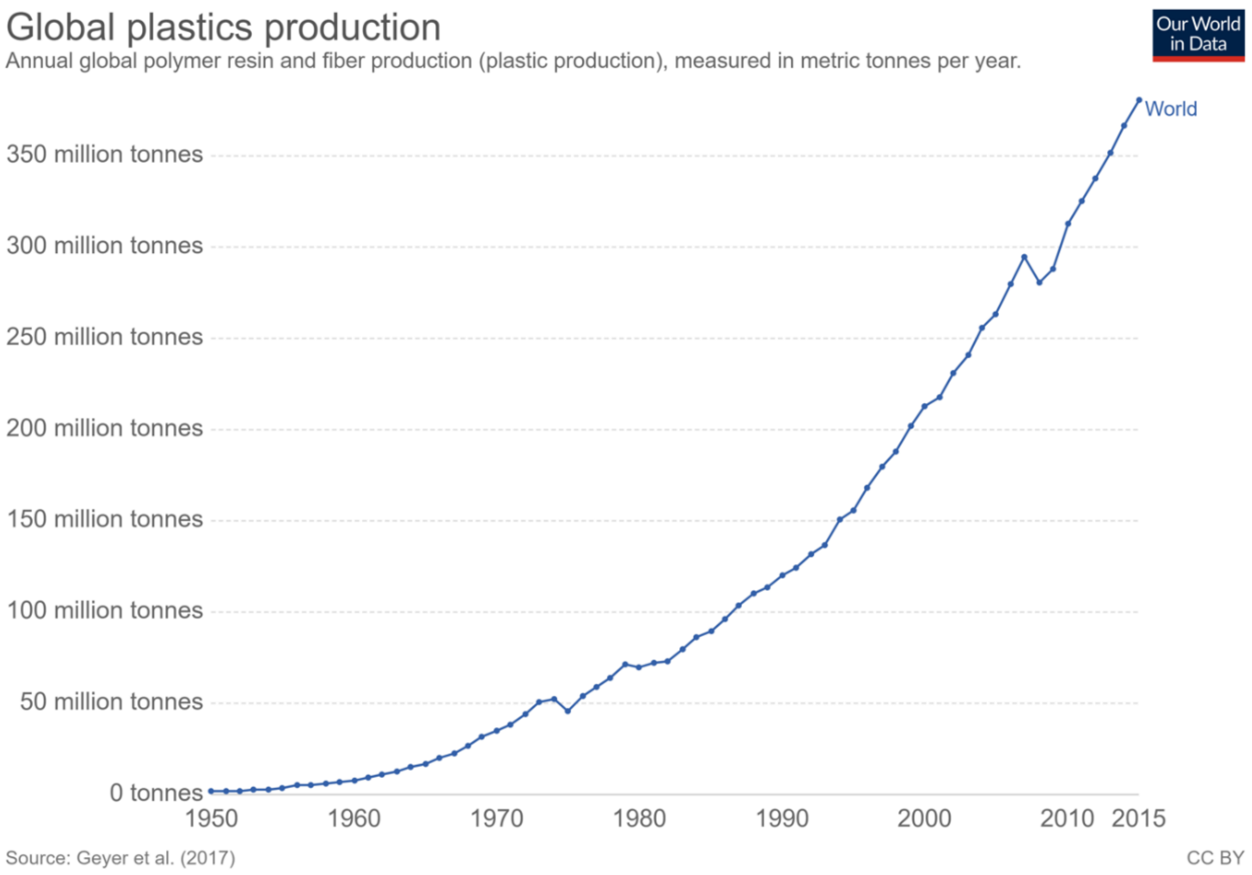
- Since 1962, **European Agricultural Policy** facilitated the adoption of plastics in agriculture, as technologies able to achieve its goals (greenhouses, tunnels or mulches).
- Plastics utilisation created **new agricultural practices**: in France, plastic mulches eased **intensive cultivation** of fruits and vegetable for the global market (esp. melon and strawberries).
- Plastics changed **agricultural labour** (more seasonal, thus precarious).

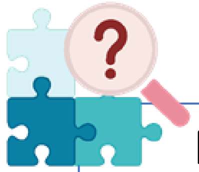
U.S. Department of Agriculture (Source)

Wikimedia Commons

Plastics contributed to **the emergence of industrial agriculture.**

Historical perspective. The Plastic Age





Research needs:

- Need to develop historical research on **plastics <u>uses</u> in agriculture**
- Need to document **history of plastics uses** in general (biography of objects as a stimulant methodology)

The **lockin** of the **sociotechnical** plastic system.

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Plastics have spread throughout food value chains

Today, downstream food supply chain and mainstream agriculture rely on plastics

Today, downstream food value chain and mainstream agriculture rely on plastics

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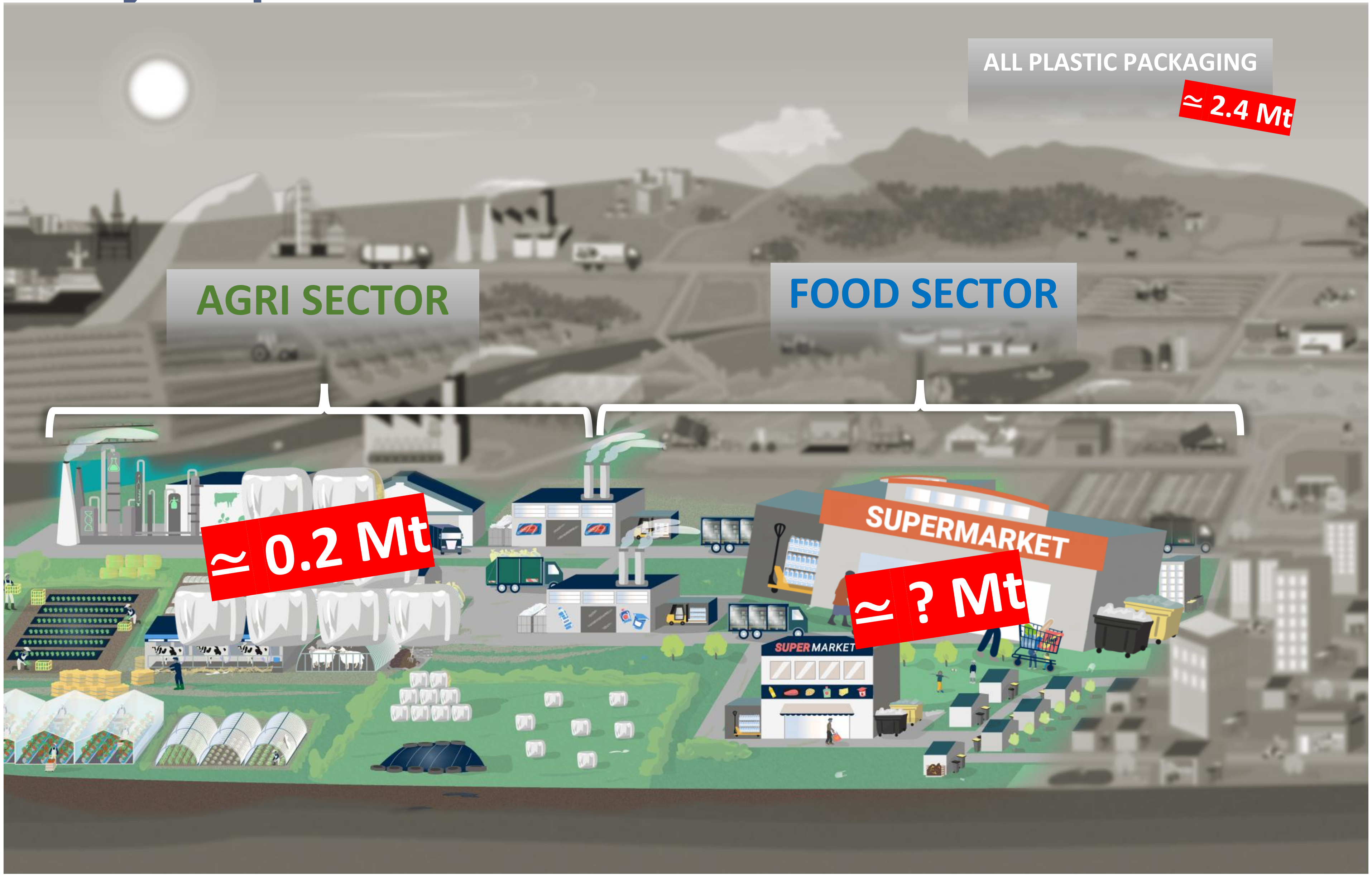
All plastics consumed in France:
2022 ≃ 6.4 Mt

Plastic consumption in food value chain – France – 2022 (Data, Plastic Europe, 2024)

Today, downstream food value chain and mainstream agriculture rely on plastics

Food value chain represents **about 20 % of all plastics consumed in France** (estimation)



Plastic consumption in food value chain – France – 2022 (Data, Plastic Europe, 2024)

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Today, downstream food value chain and mainstream agriculture rely on plastics

Downstream

food value chain

Today, downstream food value chain and mainstream agriculture rely on plastics

In downstream food value chain, plastics packaging are market devices that make food manageable

Downstream

food value chain

Today, downstream food value chain and mainstream agriculture rely on plastics

Plastic packaging is the **skin of commerce** as it is mainly used to **protect, preserve, transport and promote food products in line with regulation,** as well as it serves **practical purposes** that directly benefit supply chain actors.

In downstream food value chain, plastics packaging are market devices that make food manageable

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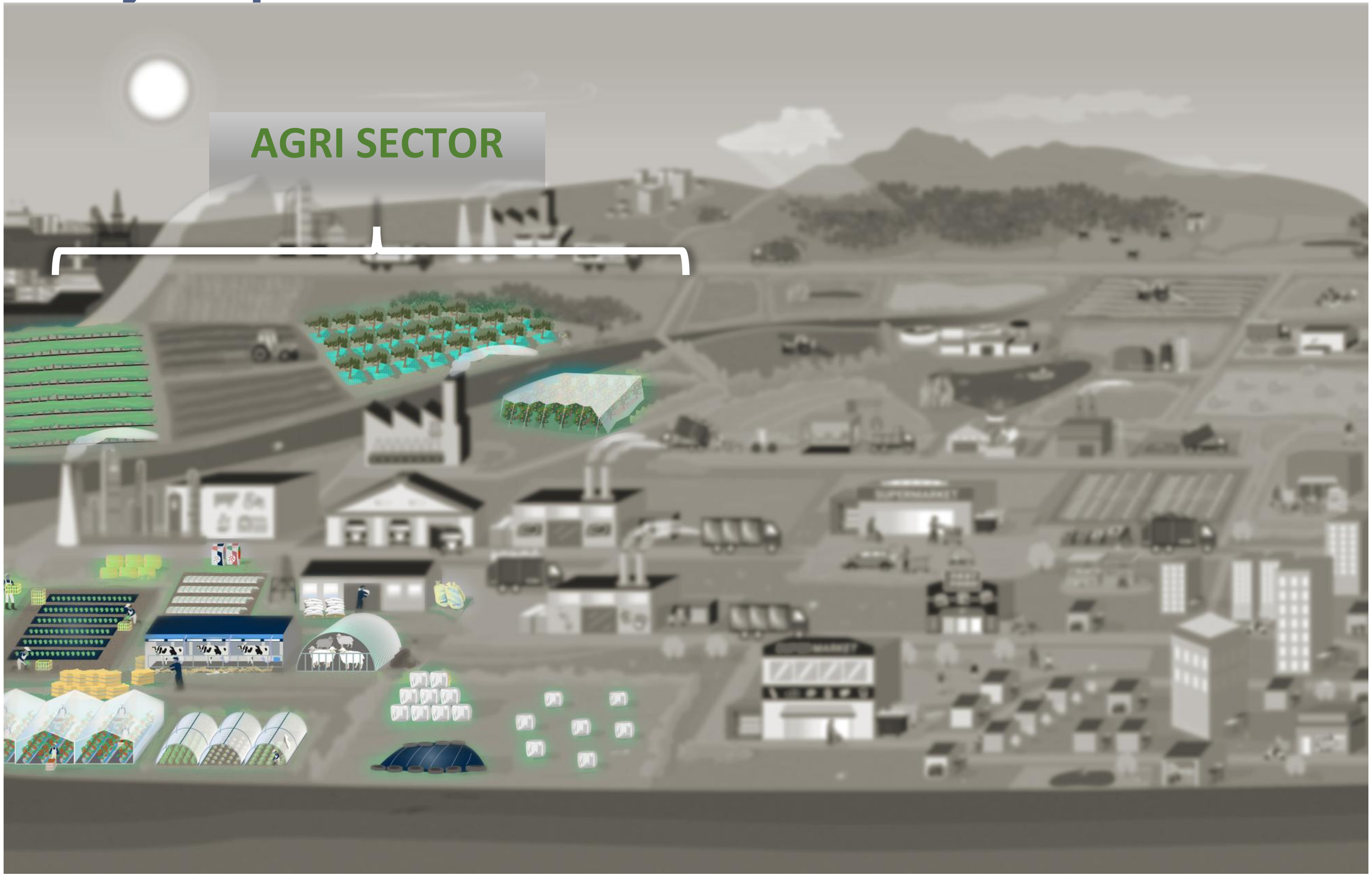
Today, downstream food value chain and mainstream agriculture rely on plastics

In downstream food value chain, plastics packaging are market devices that make food manageable

Distinction between objectives of use of **packaging in general and plastic packaging in particular is often blurred** in the literature.

Today, downstream food value chain and mainstream agriculture rely on plastics



Upstream

food value chain

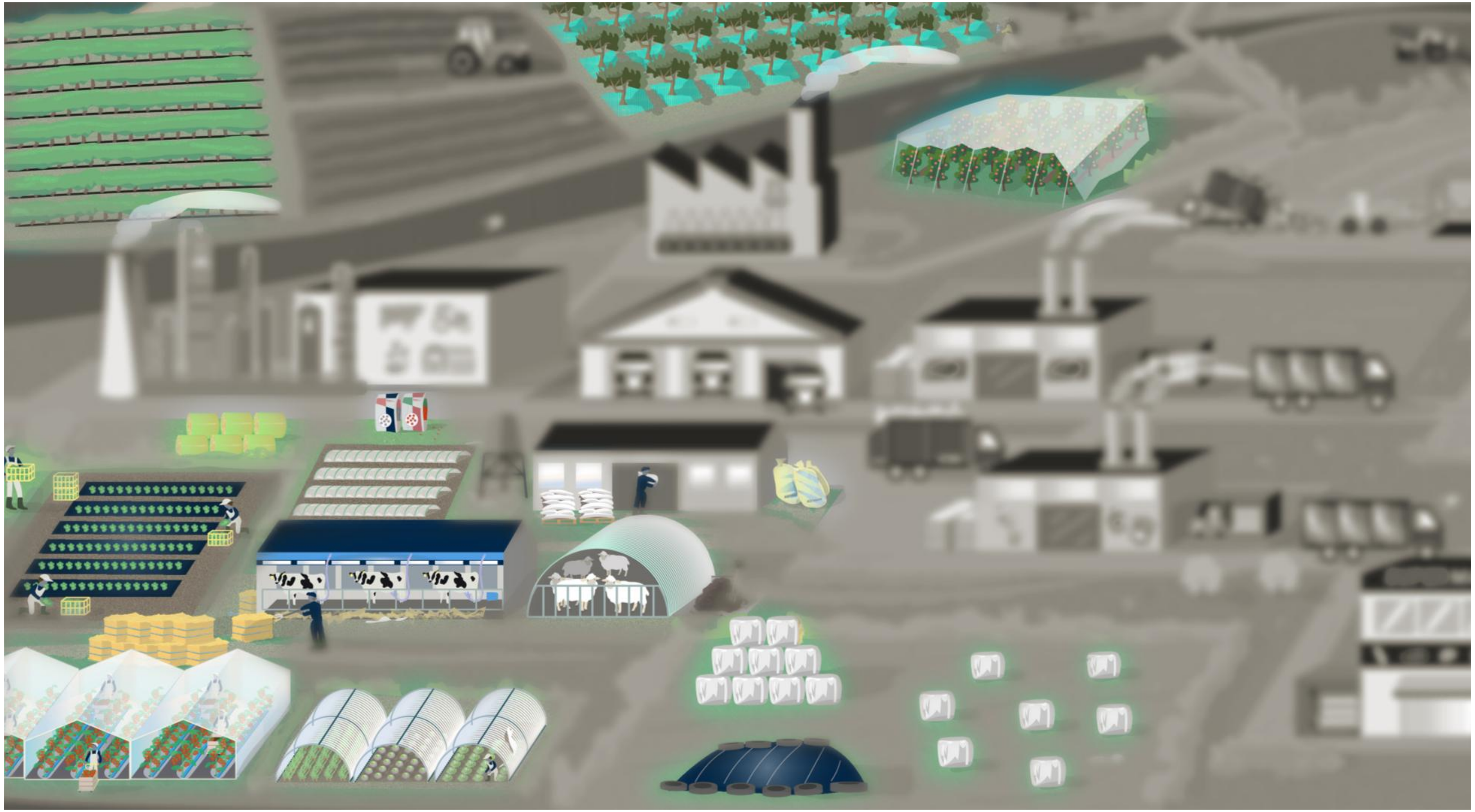
Today, downstream food value chain and mainstream agriculture rely on plastics

In upstream food value chain, among agricultural systems, cattle systems and mainstream horticultural practices rely on plastics

In agriculture, plastics are mainly used as **agrochemical inputs** and **infrastructure** to **optimise forage conservation and short-term yield.**

Upstream

food value chain

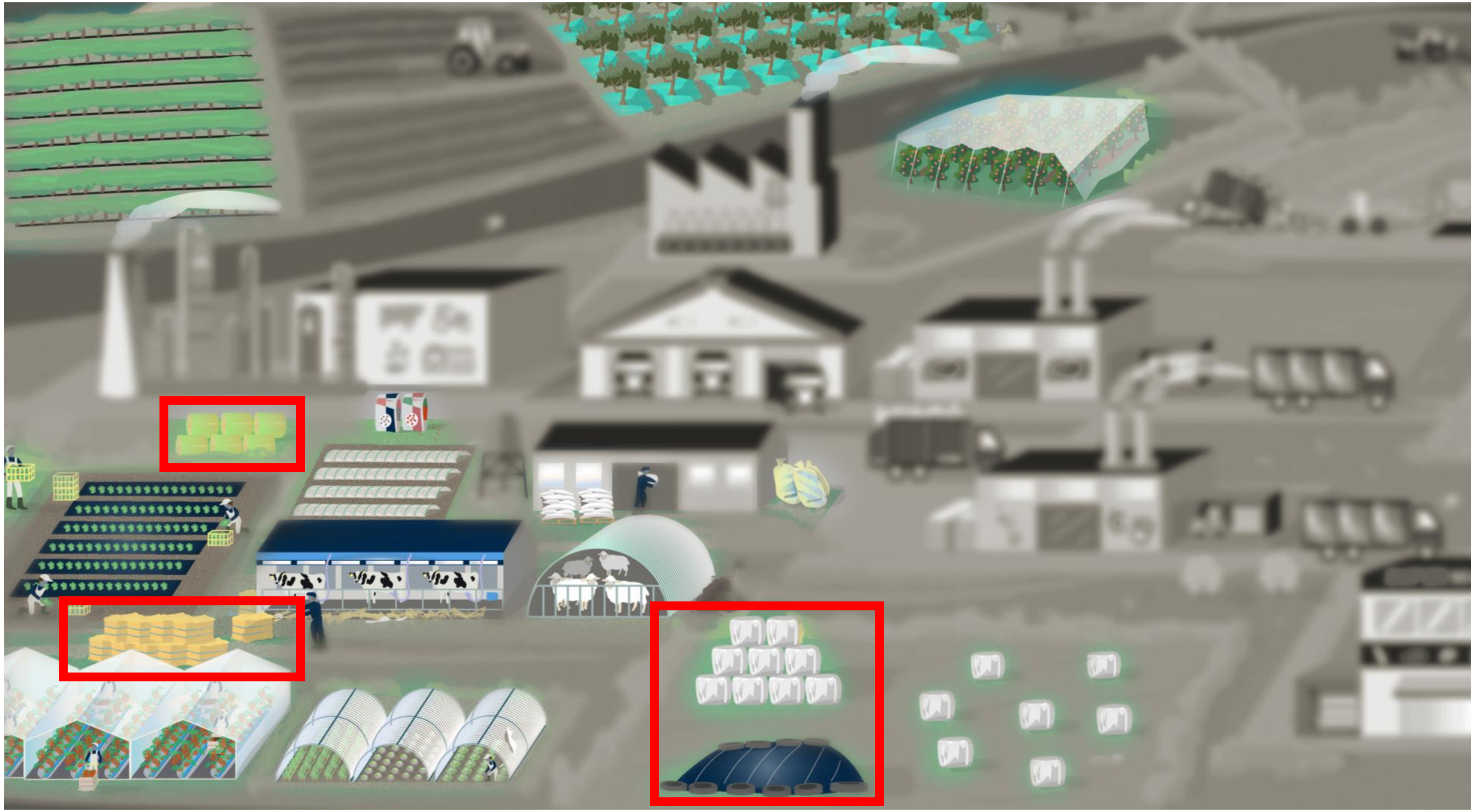


Today, downstream food value chain and mainstream agriculture rely on plastics

In upstream food value chain, among agricultural systems, cattle systems and mainstream horticultural practices rely on plastics

More than 50% of agriplastics = forage conservation
(APE, 2019)

France = 73%
(CPA, 2023)

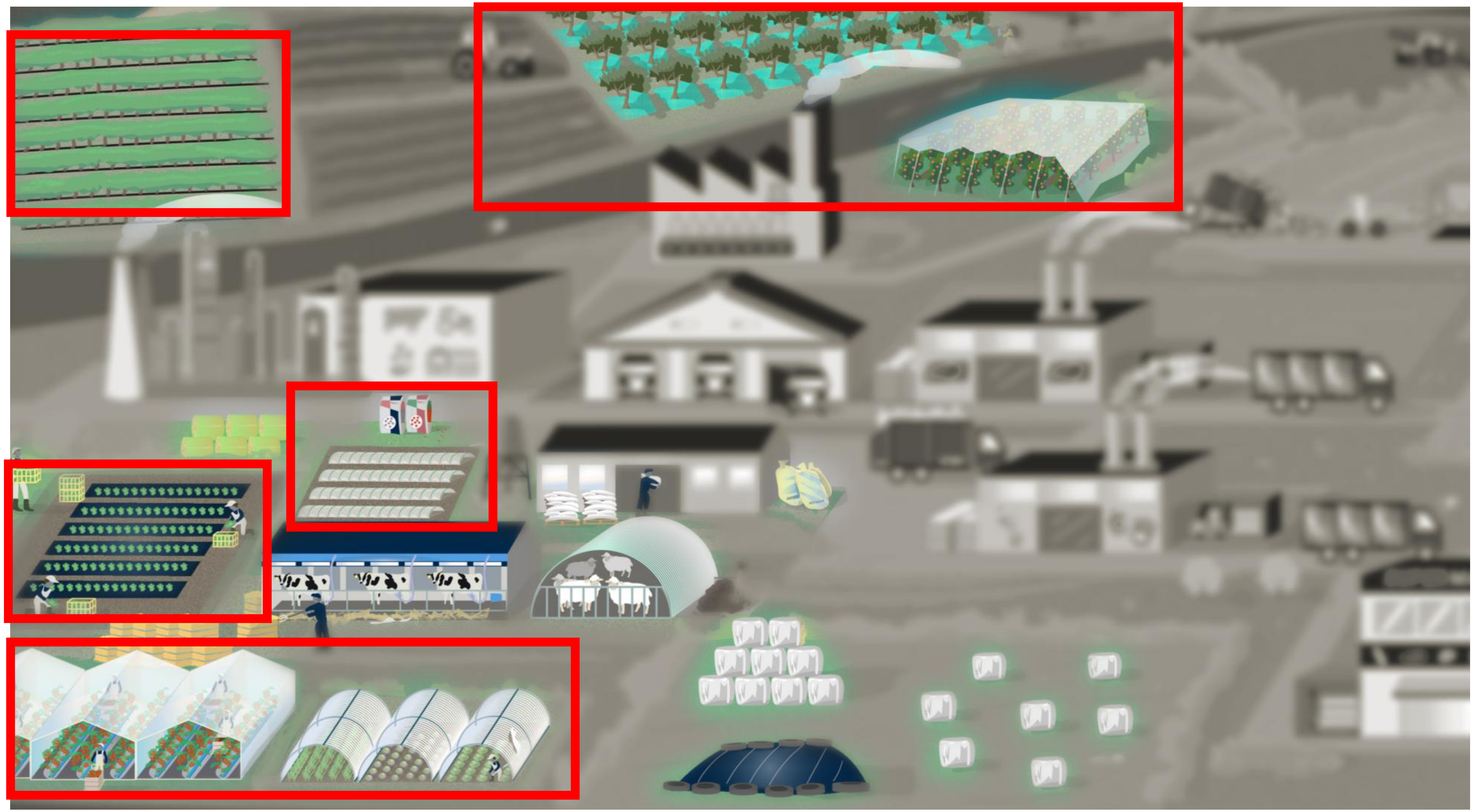


Cattle systems plastics uses

Today, downstream food value chain and mainstream agriculture rely on plastics

In upstream food value chain, among agricultural systems, cattle systems and mainstream horticultural practices rely on plastics as an agrochemical input and infrastructure

In agriculture, plastics are mainly used as **agrochemical inputs** and **infrastructure** to **optimise forage conservation and short-term yield**.

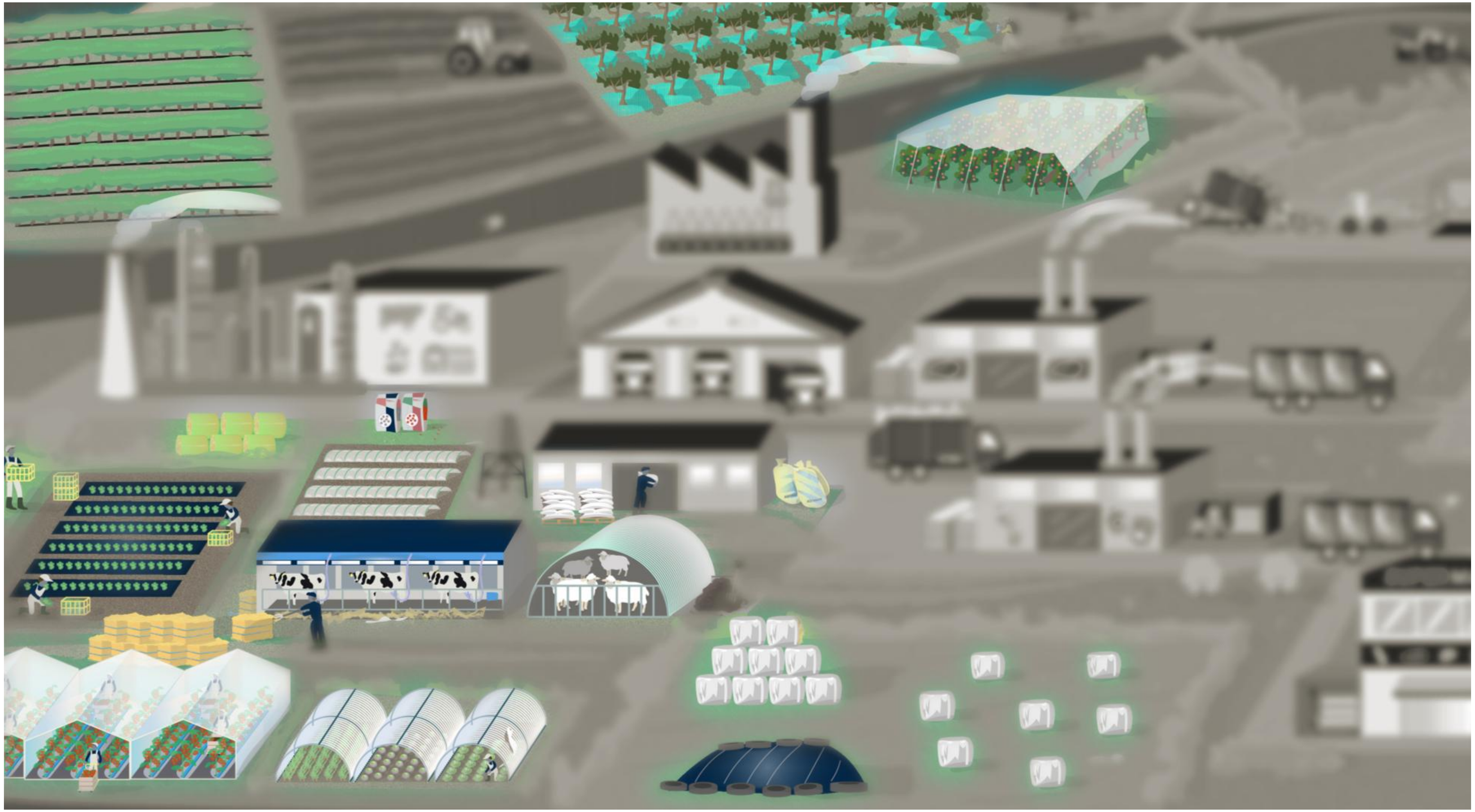


Mainstream horticulture plastics uses

Today, downstream food value chain and mainstream agriculture rely on plastics

In upstream food value chain, among agricultural systems, cattle systems and mainstream horticultural practices rely on plastics as an agrochemical input and infrastructure

Literature does not consider socioeconomic needs of farmers, their constraints and practices, **neither alternative system level solutions** to meet these needs.



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The plasticity of plastics encourages their complexity

Plasticity of plastics: lots of ingredients and processes to reach and balance various properties, functions and uses

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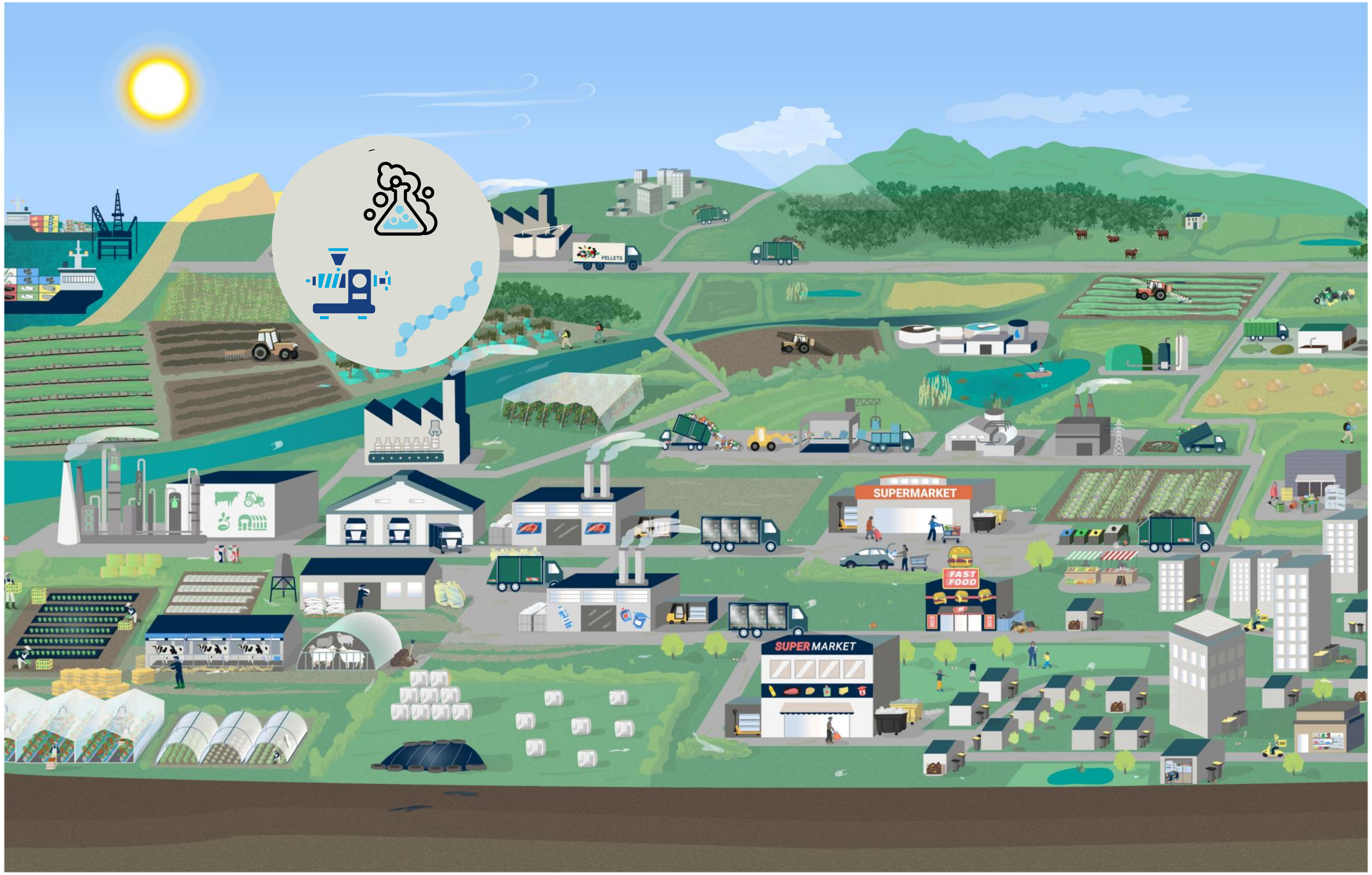

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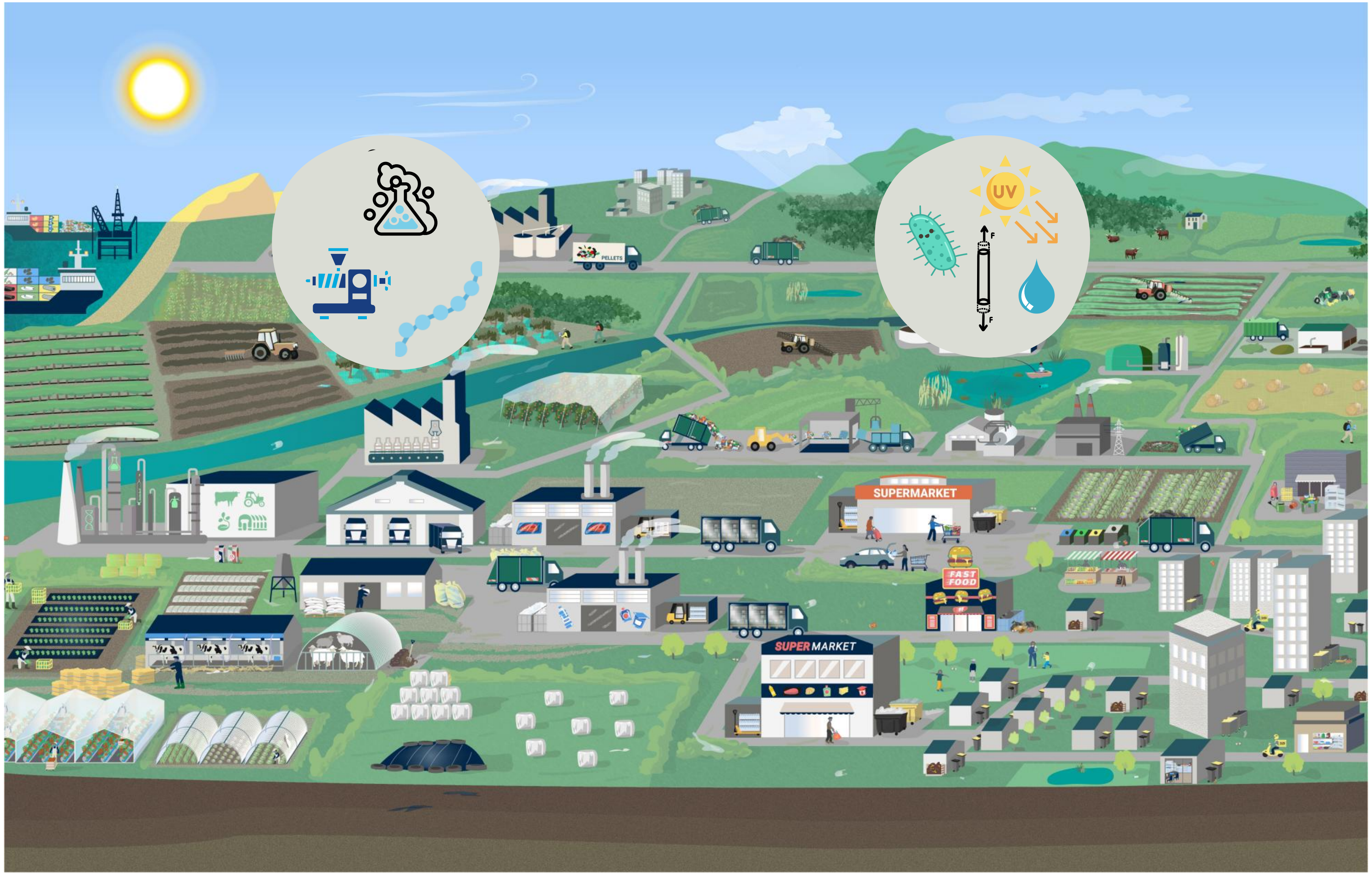

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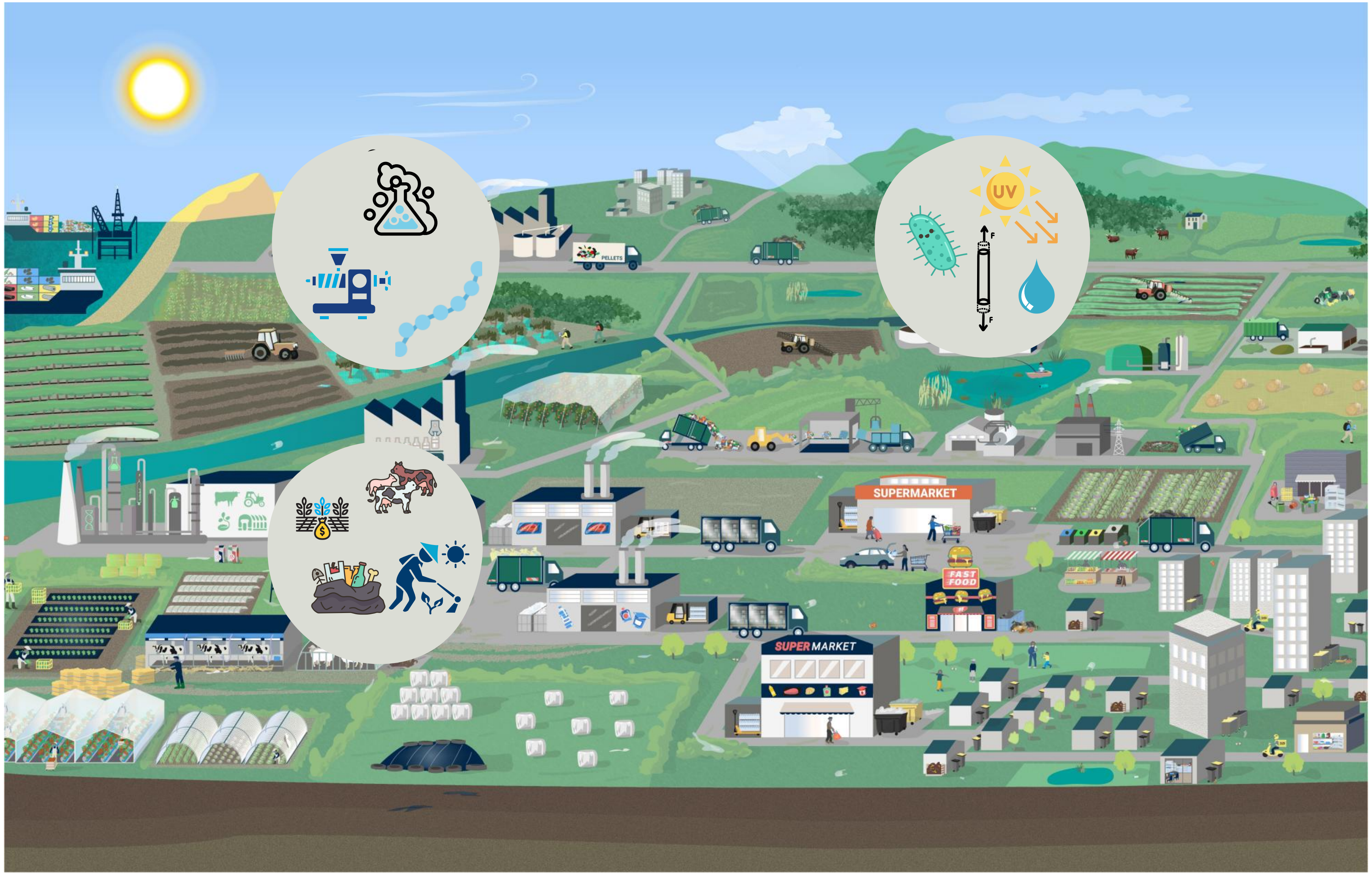

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Plastics are complex materials – many polymers, chemical substances in particular additives, formulations and processes

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The uses and objectives of use of plastic materials for agriculture and for food will impose the type of plastics and process to consider

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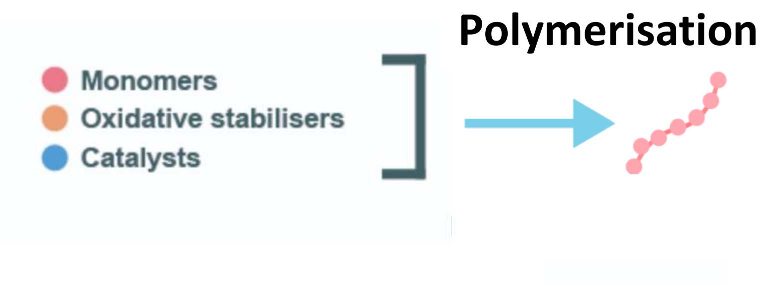

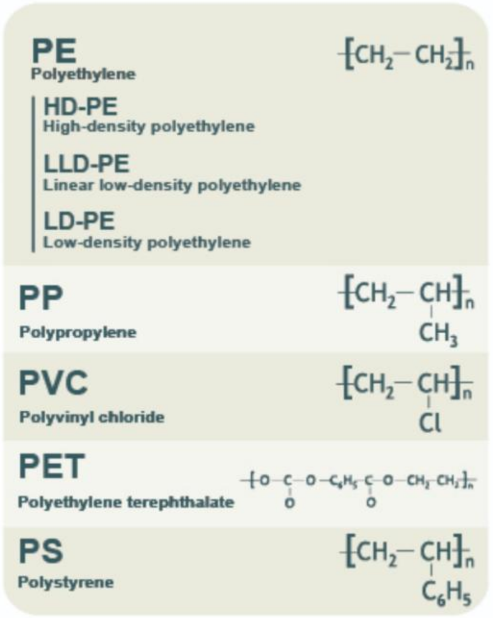

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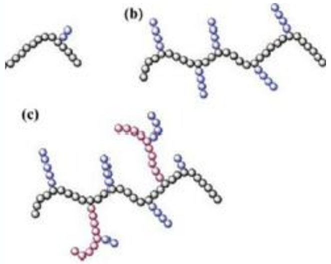
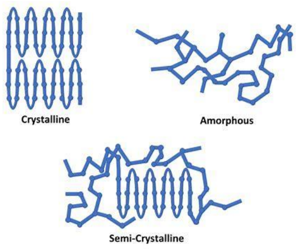
Polymerisation

PE	Polyethylene	$-[CH_2-CH_2]_n-$
HD-PE	High-density polyethylene	
LLD-PE	Linear low-density polyethylene	
LD-PE	Low-density polyethylene	
PP	Polypropylene	$-[CH_2-CH(CH_3)]_n-$
PVC	Polyvinyl chloride	$-[CH_2-CH(Cl)]_n-$
PET	Polyethylene terephthalate	$-[O-C(=O)-C_6H_5-C(=O)-O-CH_2-CH_2]_n-$
PS	Polystyrene	$-[CH_2-CH(C_6H_5)]_n-$





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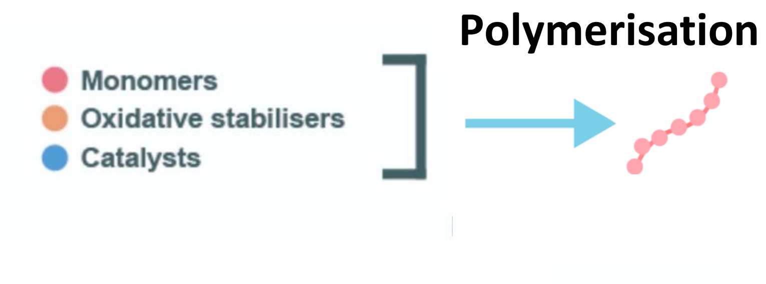

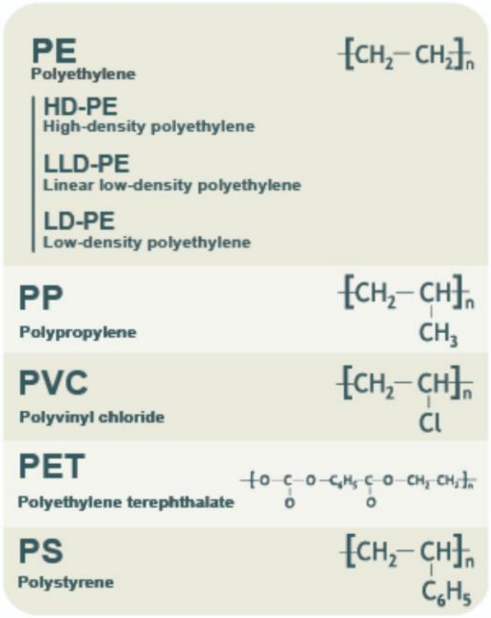

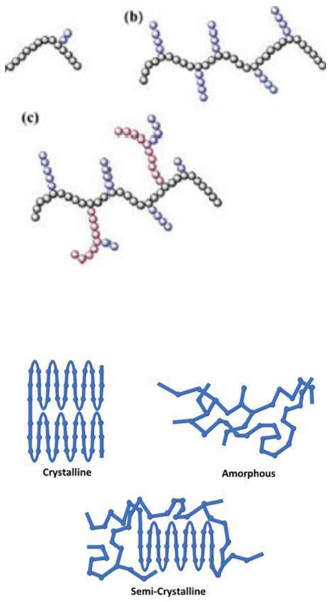

➲ **One polymer cannot easily replace another polymer**

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Plasticity of plastics: lots of ingredients and processes to reach and balance various properties, functions and uses

The uses and objectives of use of plastic materials for agriculture and for food will impose the type of plastics and process to consider

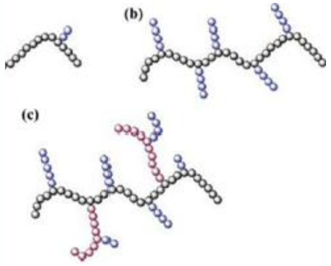
- Monomers
- Oxidative stabilisers
- Catalysts

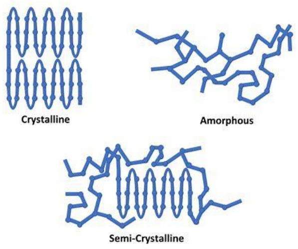
Polymerisation

Additives:

- Oxidative stabilisers
- Fillers (glass, talc)
- Nucleating agents
- Colourant
- Plasticisers
- Flame retardants
- Processing aids
- Antimicrobials
- Adhesives / heat seals
- Decorations / coatings

PE Polyethylene	$[CH_2-CH_2]_n$
HD-PE High-density polyethylene	
LLD-PE Linear low-density polyethylene	
LD-PE Low-density polyethylene	
PP Polypropylene	$[CH_2-CH(CH_3)]_n$
PVC Polyvinyl chloride	$[CH_2-CH(Cl)]_n$
PET Polyethylene terephthalate	$[O-C(=O)-C_6H_5-C(=O)-O-CH_2-CH_2]_n$
PS Polystyrene	$[CH_2-CH(C_6H_5)]_n$





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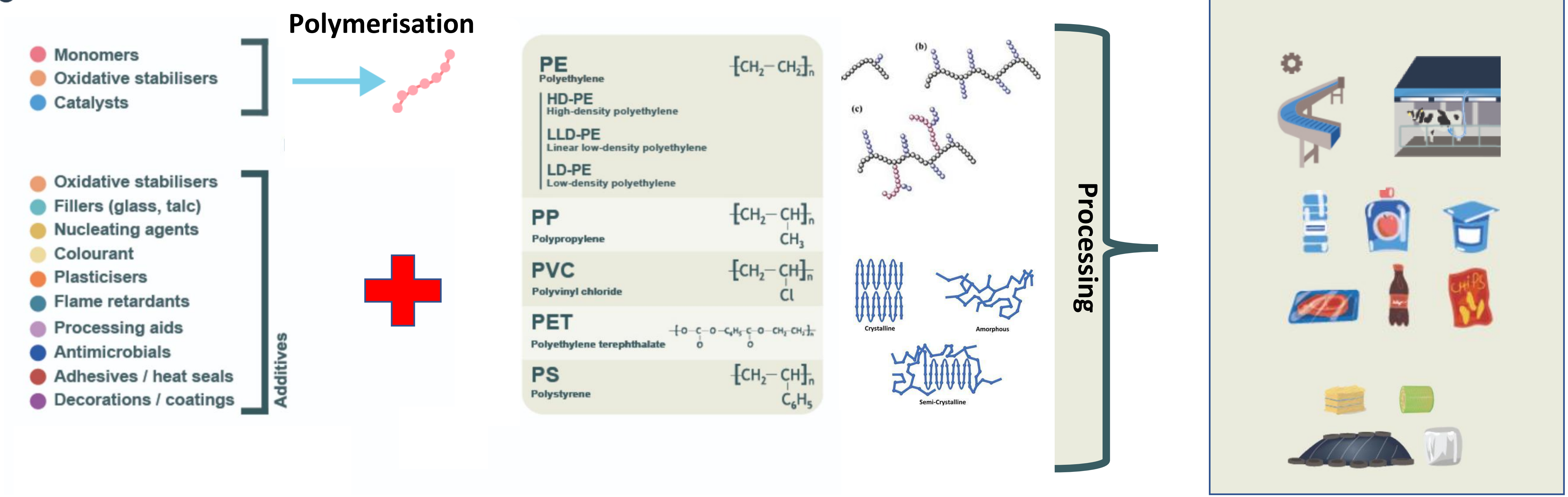

➲ **One polymer cannot easily replace another polymer**

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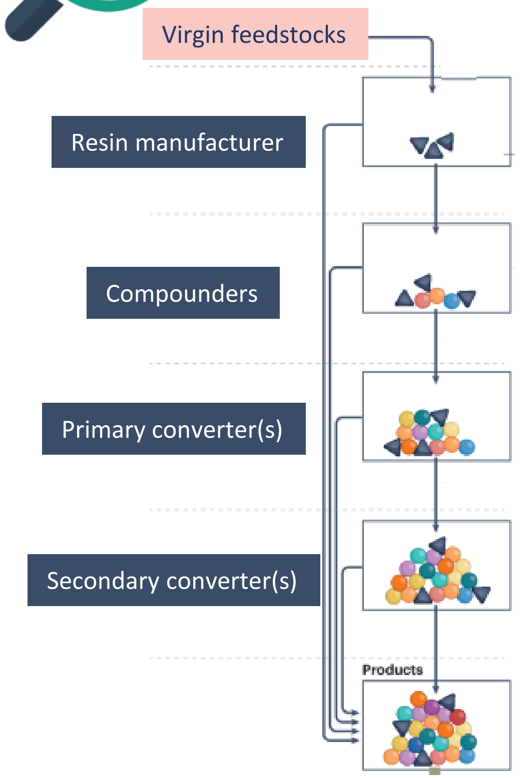
Plastics are complex materials : many polymers, chemical substances in particular additives, formulations and processes

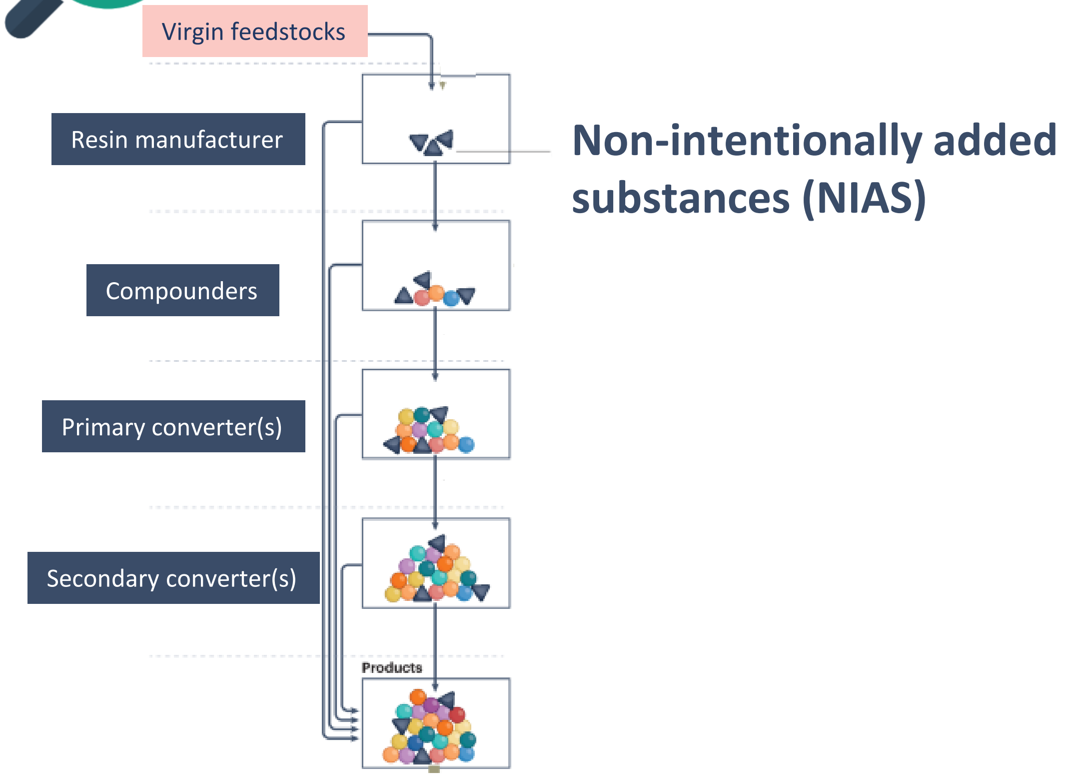
- **Additives are used during the whole life cycle of plastics**



Law et al., 2024

Plastics are complex materials : many polymers, chemical substances in particular additives, formulations and processes

- **Additives are used during the whole life cycle of plastics**
- **Plastics may also contain IAS and NIAS**



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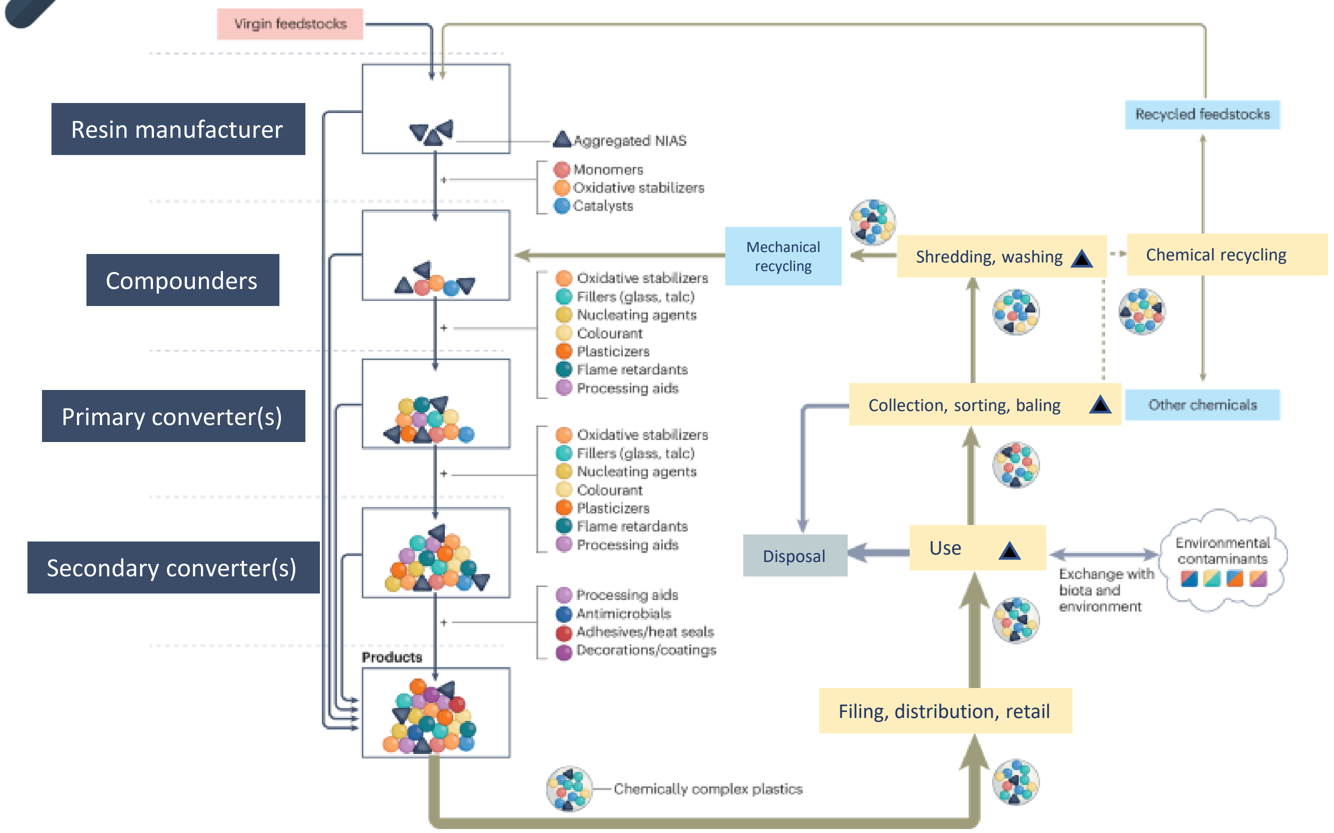

Law et al., 2024

Plastics are complex materials : many polymers, chemical substances in particular additives, formulations and processes

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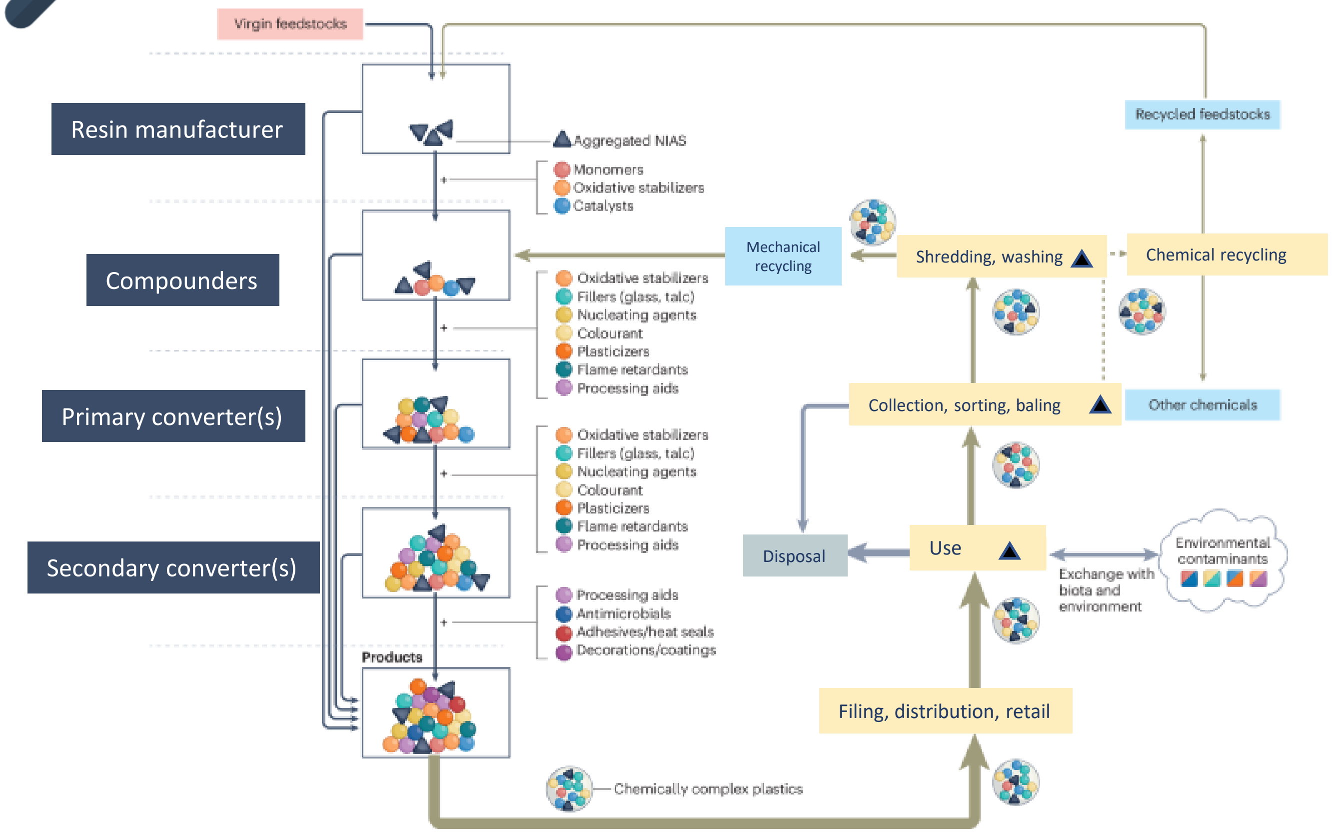

Law et al., 2024

➲ **The chemical substances composing a plastic are numerous and difficult to track along its whole life cycle**

Plastics are complex materials : many polymers, chemical substances in particular additives, formulations and processes

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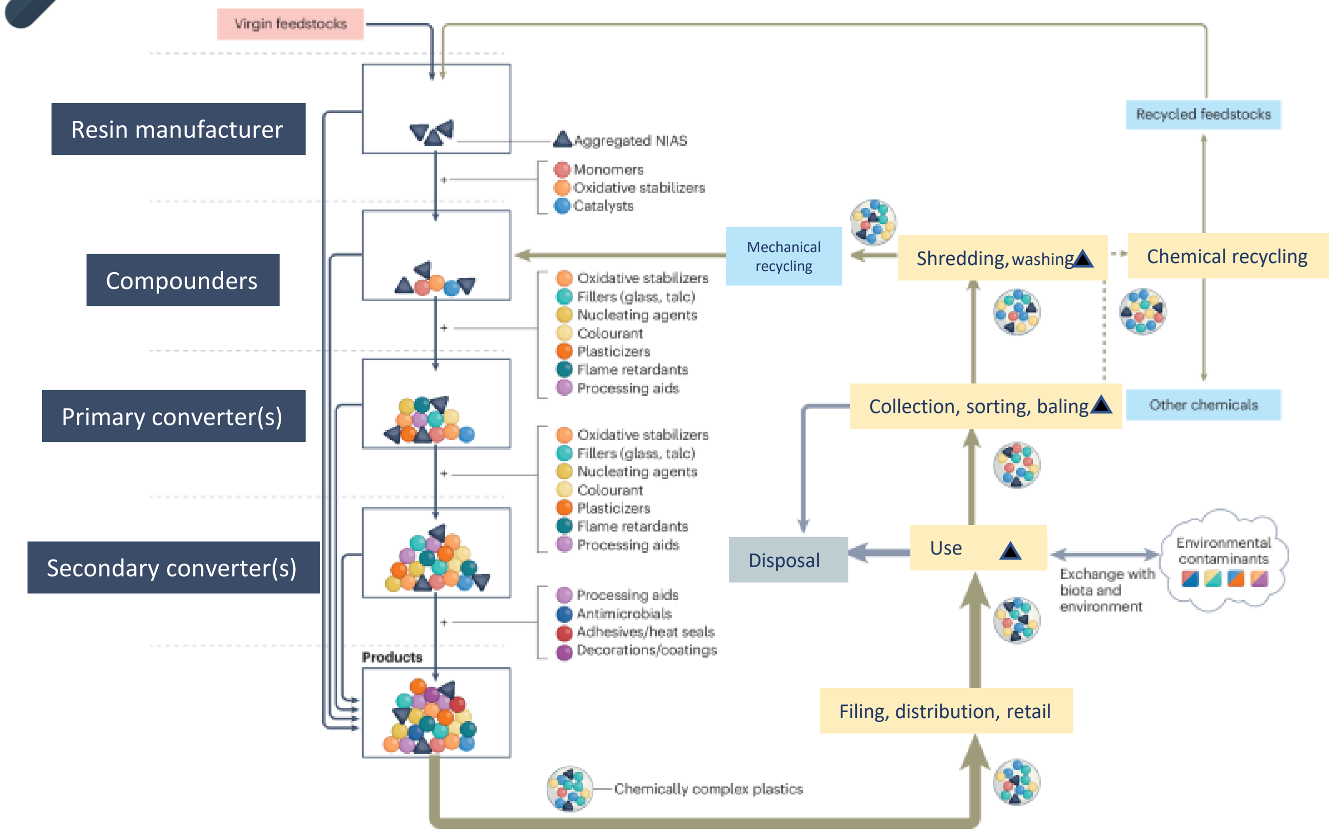

Law et al., 2024

Simplification: Pathways to simplify plastic formulations were not investigated in the literature

Traceability: Chemical complexity resulting from the formulation of plastics becomes even more complex, difficult to trace and less transparent throughout their life

➲ **The chemical substances composing a plastic are numerous and difficult to track along its whole life cycle**

Plasticity of plastics: lots of ingredients and processes to reach and balance various properties, functions and uses.

The existing literature in the field of polymers formulation is abundant and reports complex systems that are designed to reach specific functional properties.

Pierre Ovlaque

Plasticity of plastics: lots of ingredients and processes to reach and balance various properties, functions and uses

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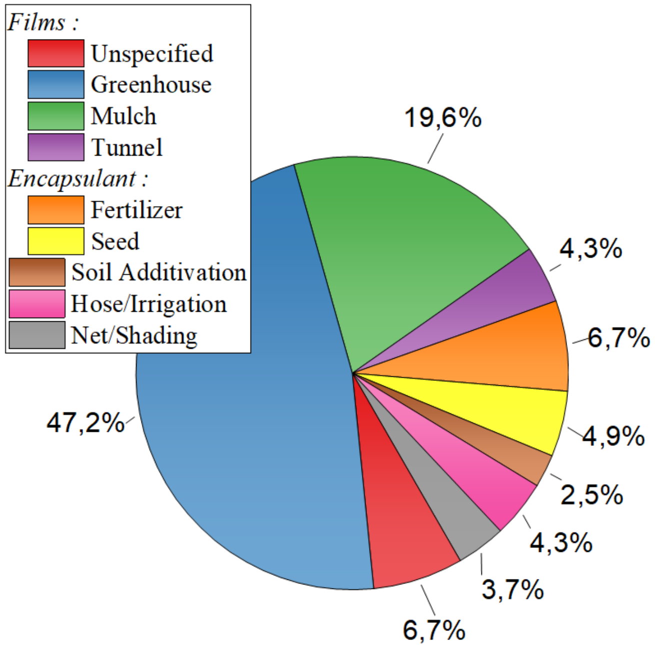
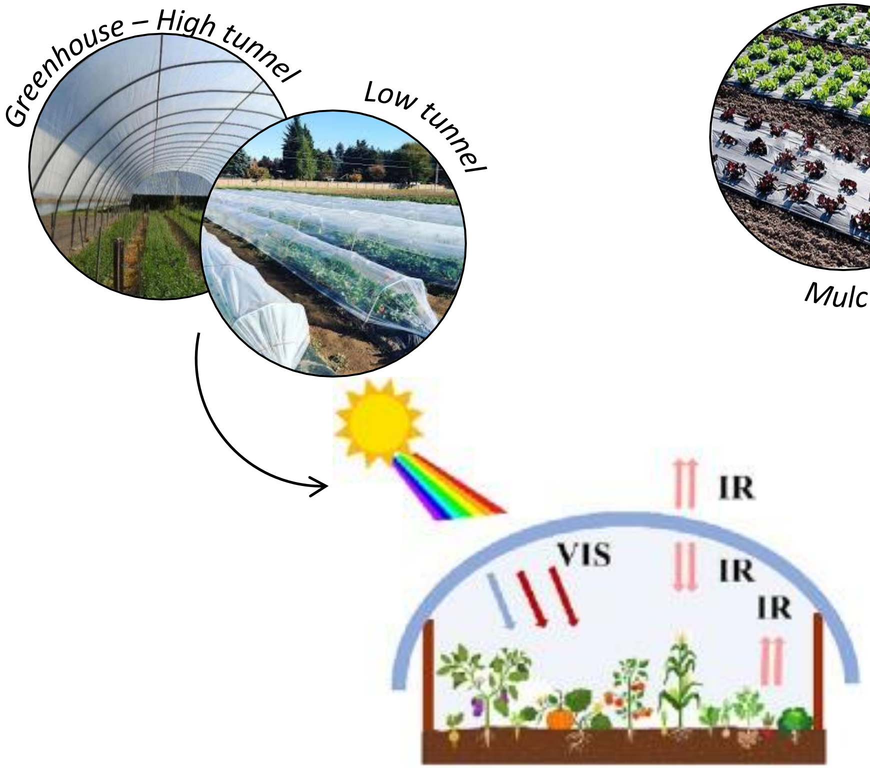
Complex systems that are designed to reach specific functional properties

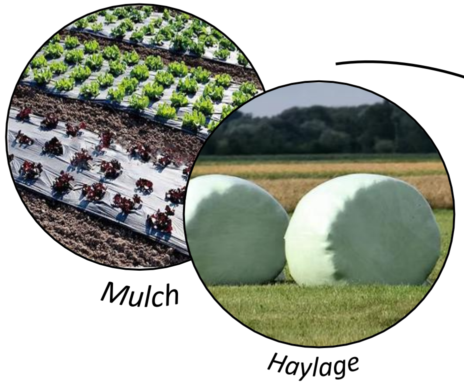
In the field of crop production, publications mainly considered films – Principal functions are related to radiometric properties, surface properties, mechanical properties, permeability.

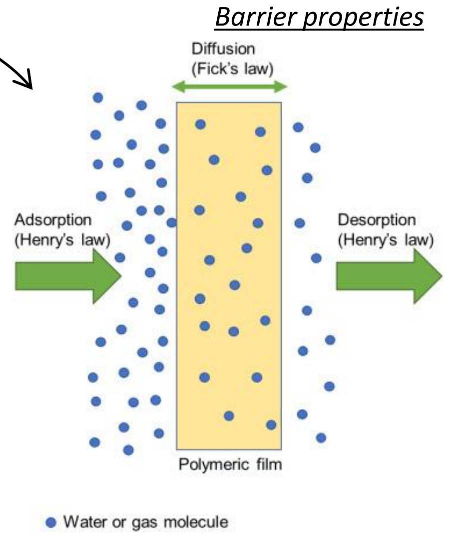
In the livestock production, plastics are widely used for forage preservation. The principal function of the film is to seal the forage and allows to establish anaerobic conditions.



Ovlaque – CSA extended report







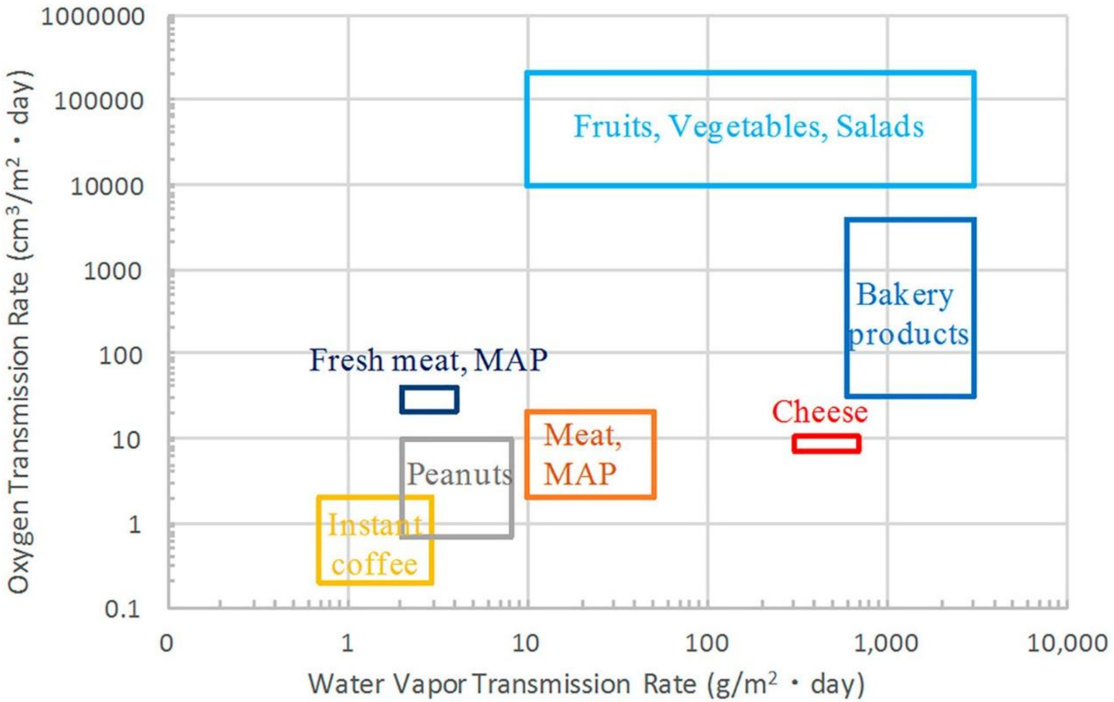
Adibi et al. 2023

Radiometric properties *Wang et al. 2023*

Complex systems that are designed to reach specific functional properties

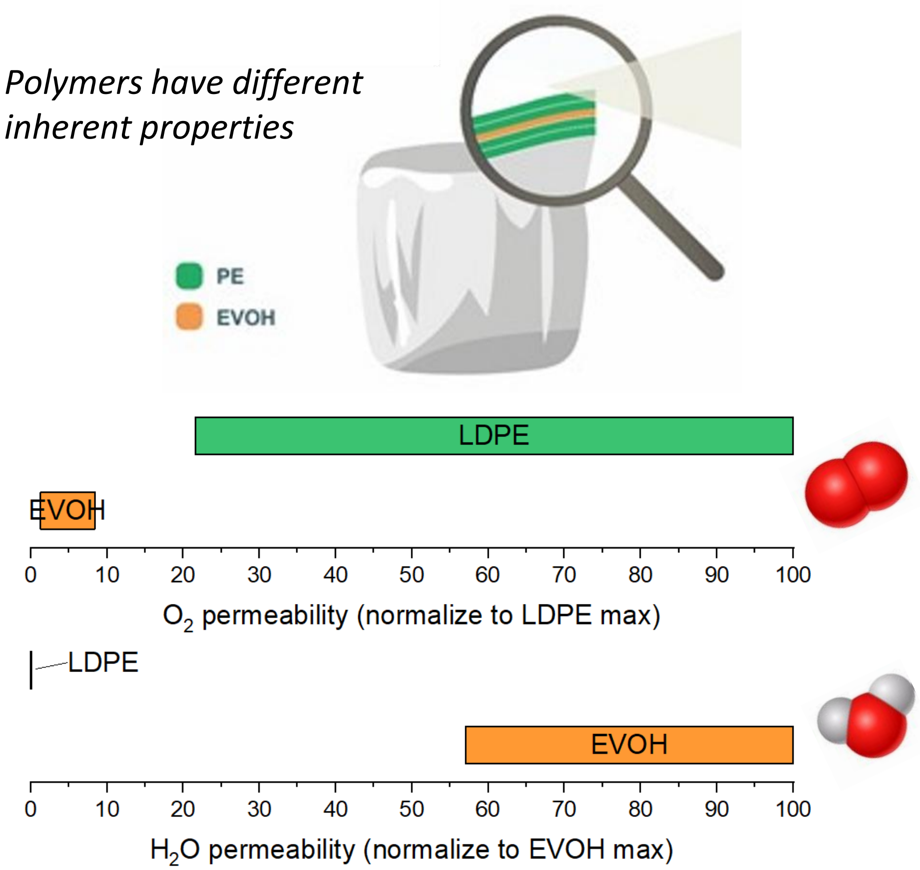
In the food sector, the main functional properties that have been studied are the thermal, mechanical, barrier and optical properties.

Properties are adapted to the use



Adibi et al. 2023

Polymers have different inherent properties



Adapted from Bai et al. 2024

INRAE cnrs

20 years of research focusing on bio-based and/or biodegradable plastics as well as on nanocomposites

Bio-based plastics

Literature focus on bio-based and/or biodegradable plastics presented as a sustainable alternative for petro-based plastics

- Bio-based plastics represent 1% of the plastics production in Europe - 20% of the scientific publications on agricultural plastic systems address the problematic's related to this 1%.
- Bio-based plastics require additives to reach the in-use properties expected for agricultural or food packaging applications – fate of the additives is not discussed.

Table 2. Main limitations of biobased polymer packaging materials [44].

Main Properties	Limitations of Biobased Polymers
Moisture and gas barrier	Low to moderate barrier compared to conventional synthetic polymers
Mechanical Resistance	Weaker mechanical resistance in some cases
Thermal properties	Insufficient thermal properties in terms of heat resistance and processing temperature range

Silva de Sousa et al., 2023

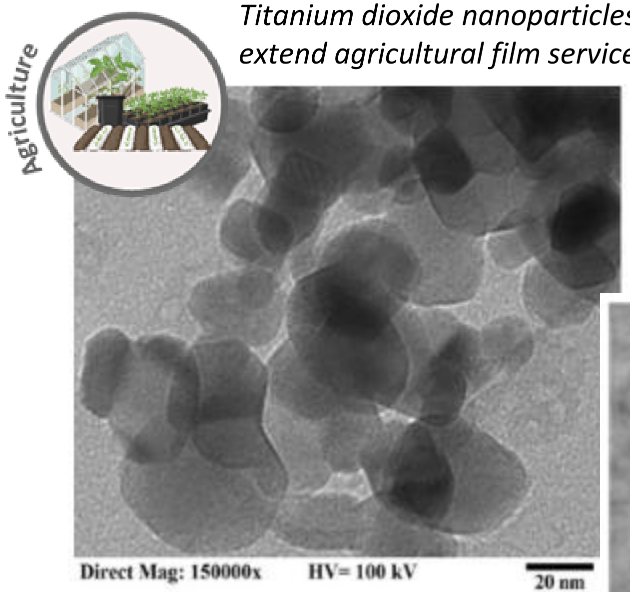
20 years of research focusing on bio-based and/or biodegradable plastics as well as on nanotechnologies

Potential risks they pose to humans and the environment are overlooked

Nanotechnologies

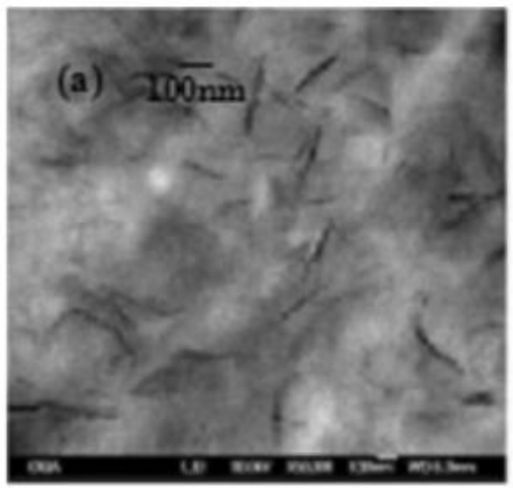
- Nanotechnologies were investigated in both agriculture sector and packaging

Titanium dioxide nanoparticles to extend agricultural film service life

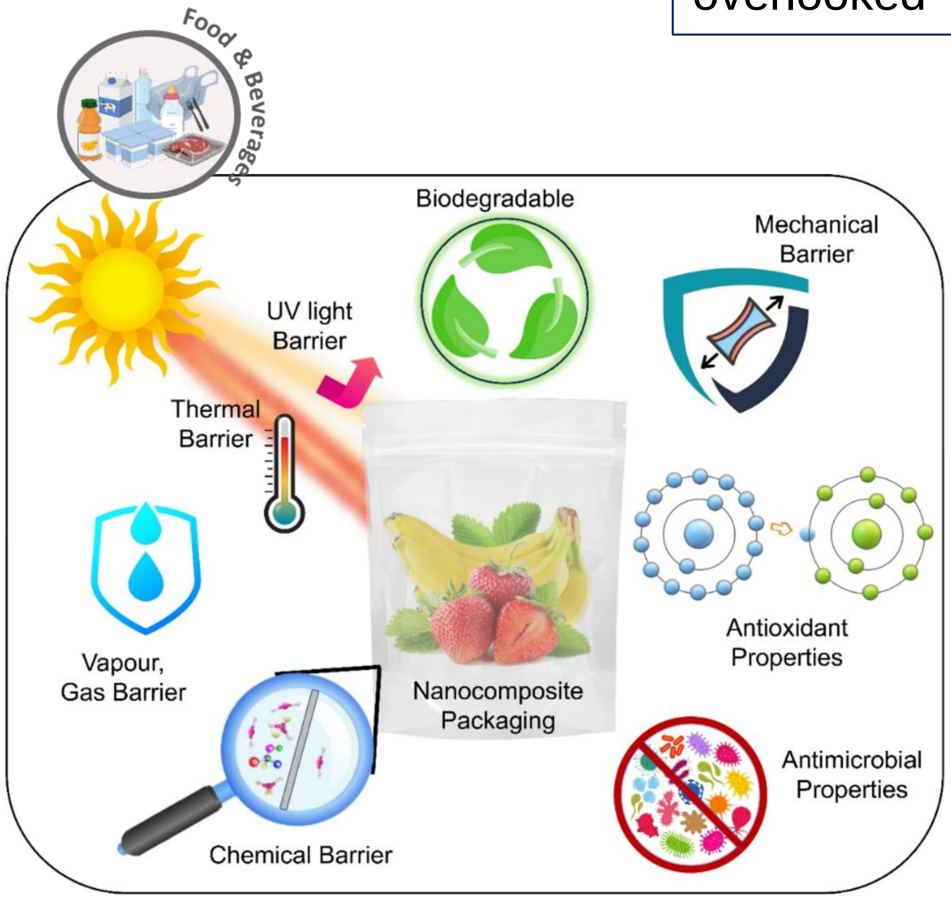


Apata-Tello et al. 2019

Nanoclay to modify radiometric properties of PE in greenhouse cladding applications.



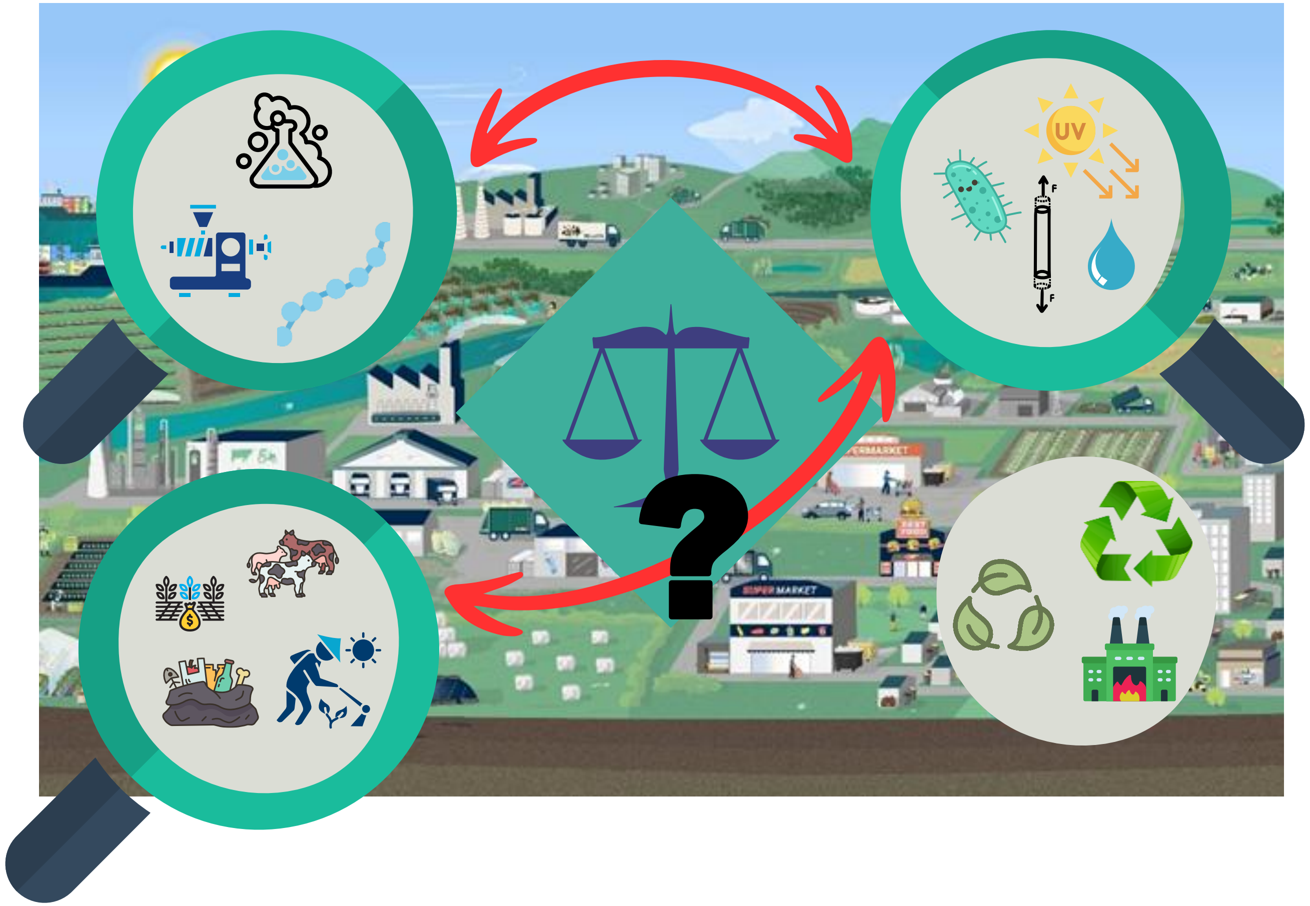
Sanchez-Valdes et al. 2010



Ghosh et al. 2025

Plasticity of plastics: lots of ingredients and processes to reach and balance various properties, functions and uses

Fit for properties of use ...
but not for objectives of use.

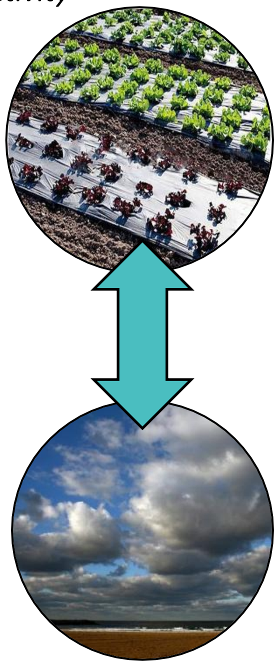


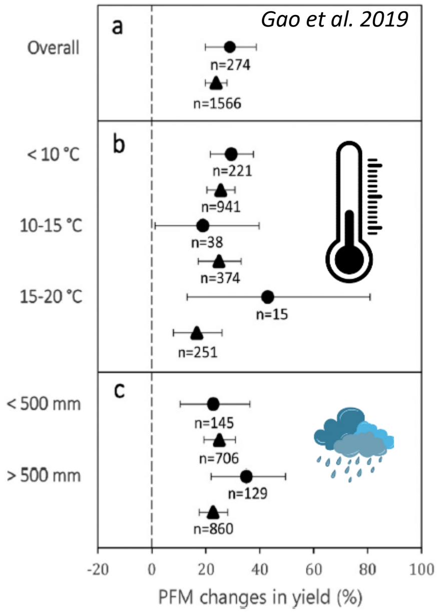
Fit for properties of use … but not for objectives of use

Publications that thoroughly explore the relationships between the chemical structure of macromolecules, the formulation of plastics, their properties, and their impact on the expected benefit of uses are rare

- ➢ Overlap multiple scientific fields
- ➢ Detailed formulations of industrial plastic products are unknown

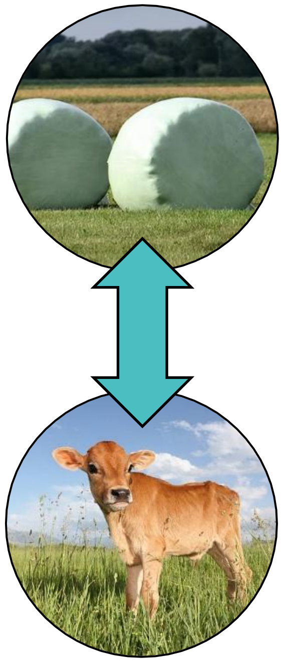
Even when formulations are known, there are no clear relationships between the film composition, properties and productivity

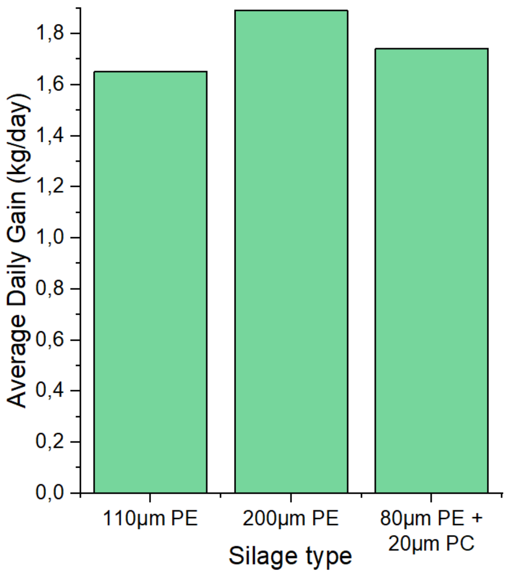




(●) *Black PFM* (▲) *Transparent PFM*
PFM = Plastic Mulching Film

In the field of livestock production, most publications consider the nutritional quality of the maize or grass silage





Adapted from Neumann et al. 2013

There is a need to consider the relationships between formulations or design and actual needs and associated benefits for users, whether they are farmers, food companies, retailers or final food consumers

INRAE cnrs

Trade-offs and adaptation strategies are needed along the life cycle of plastics

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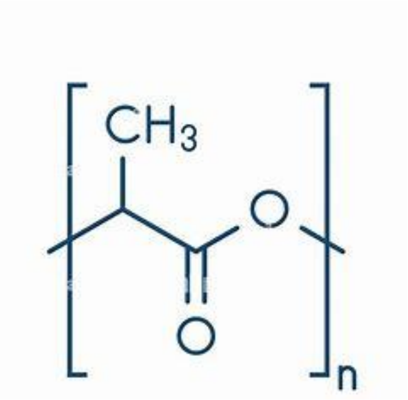

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PLA

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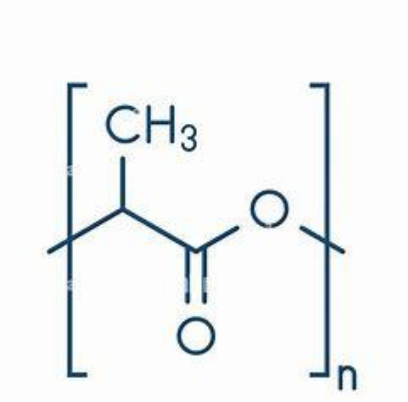

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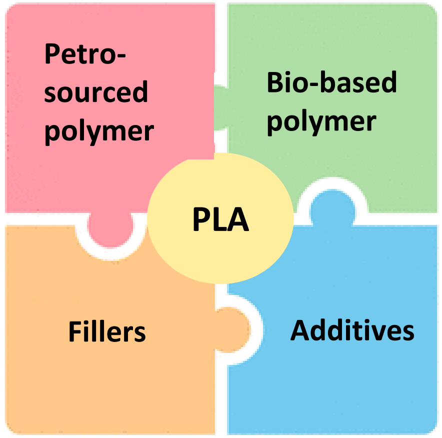

Adapted from Tripathi et al., 2021

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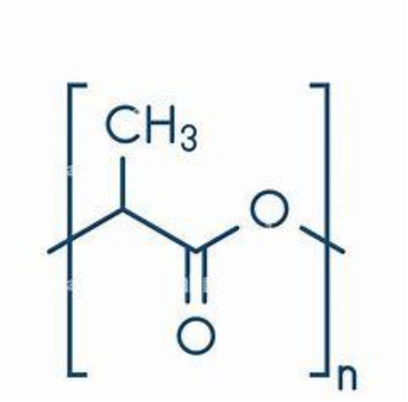

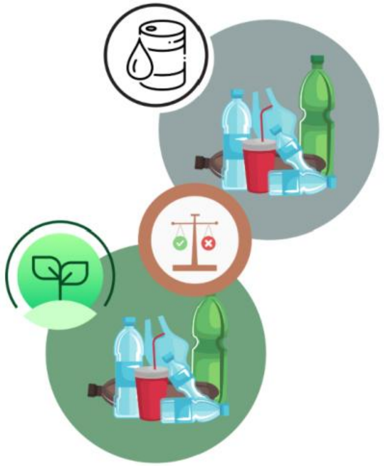

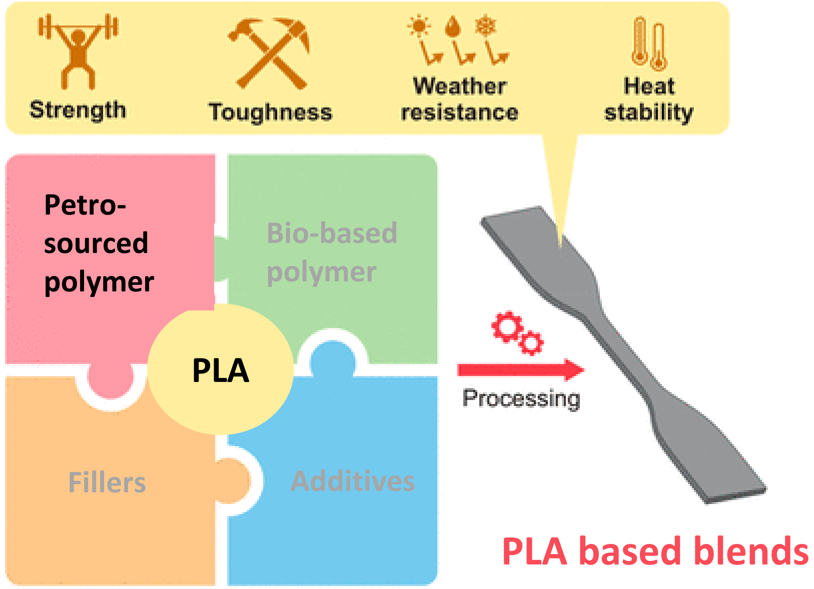

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INRAE cnrs

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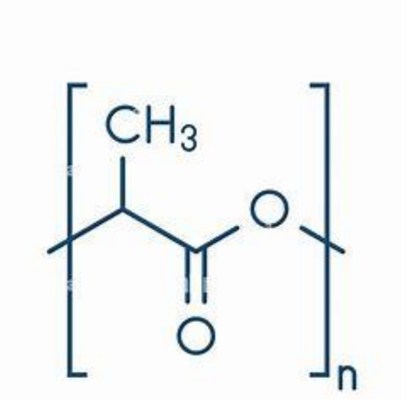

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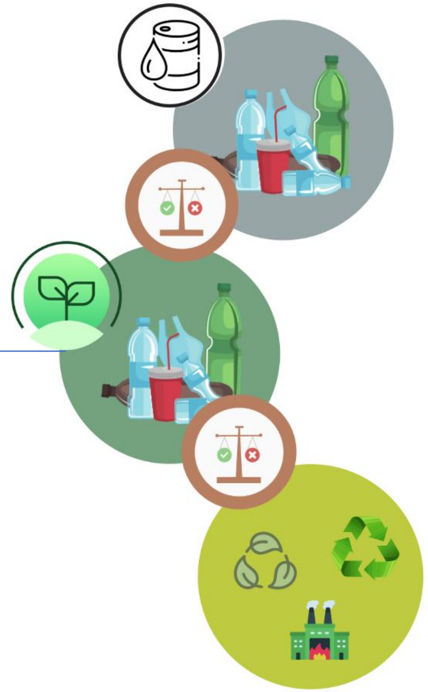

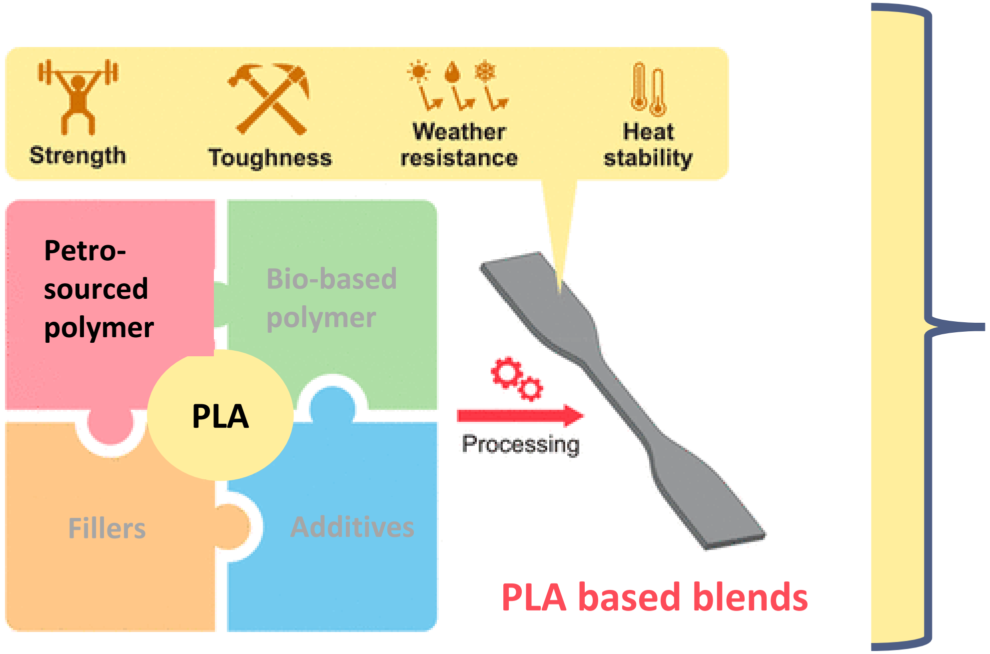

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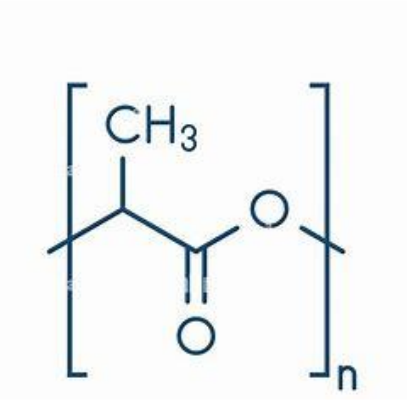

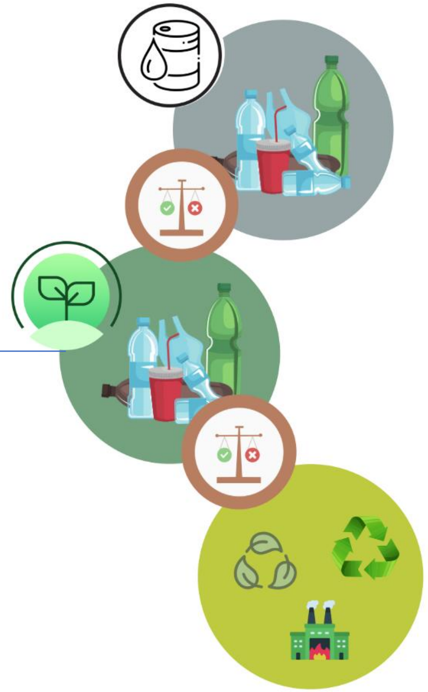

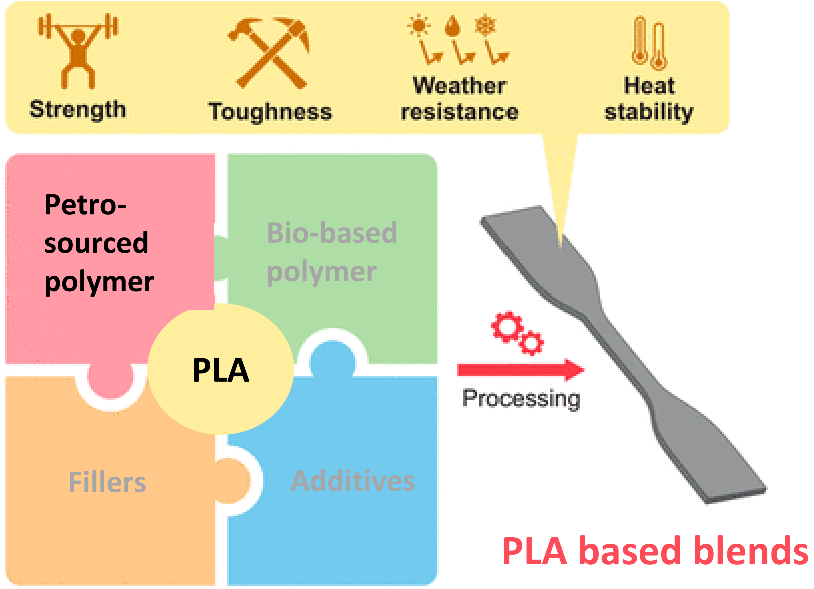

Adapted from Tripathi et al., 2021

Trade-offs and adaptation strategies have to be considered as global

Window of opportunities is broader when considering higher system level

Q&A session

Plastic waste management is difficult to monitor and implement in practice

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A picture of plastic waste management in France difficult to draw

INRAE cnrs

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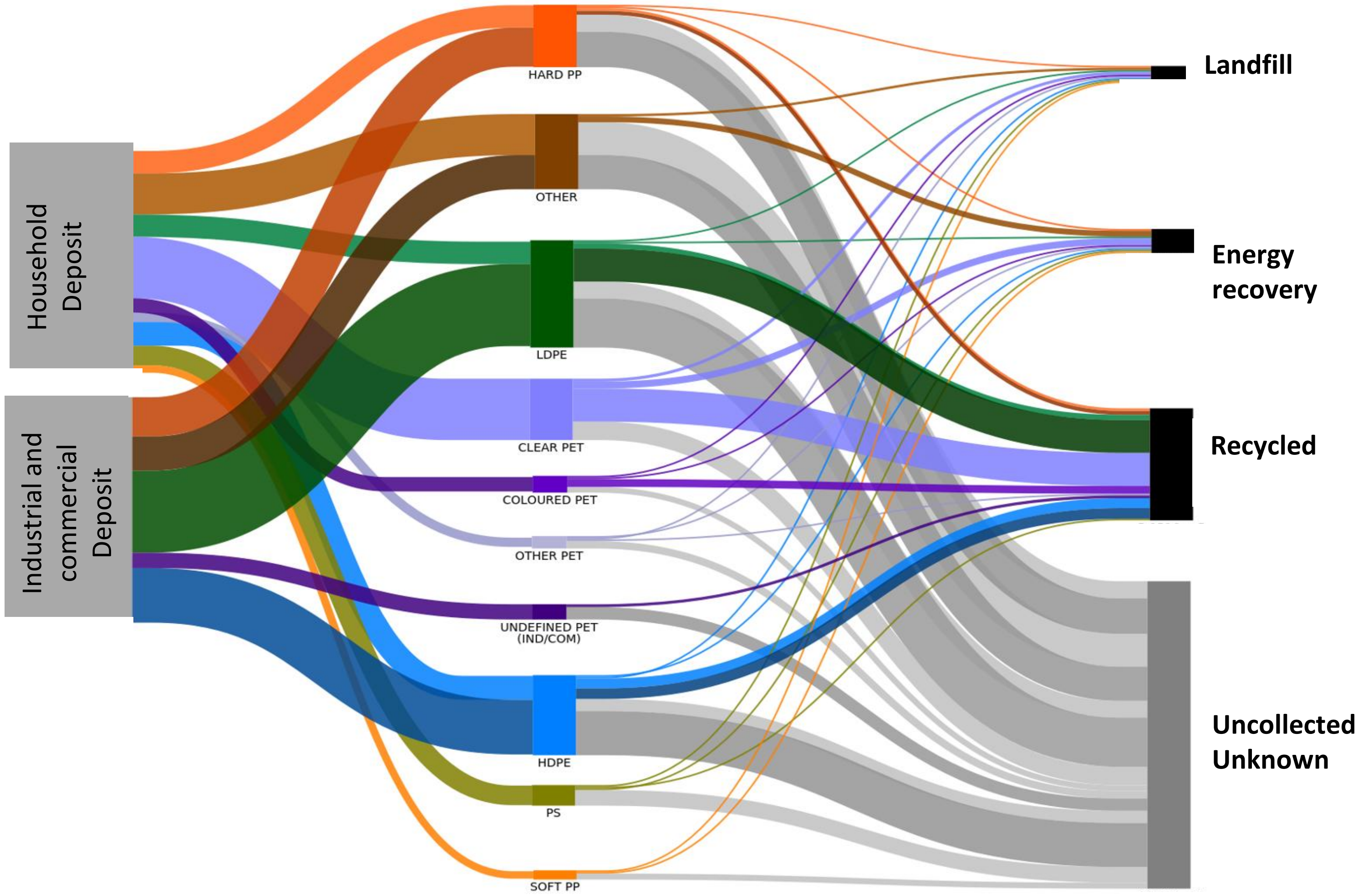

Plastic packaging waste flows by resin in France in 2022.

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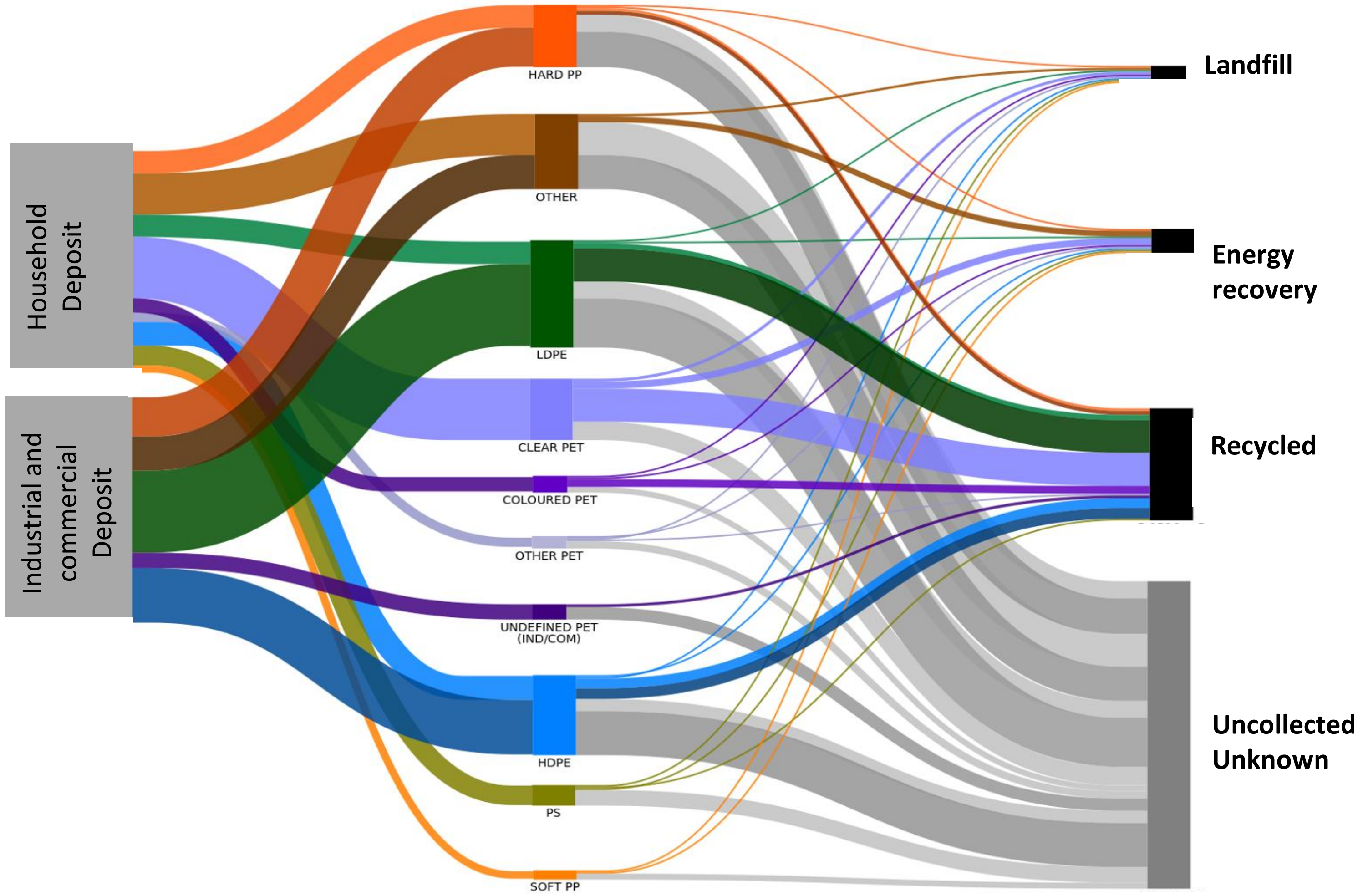

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- **The complexity of data collection**
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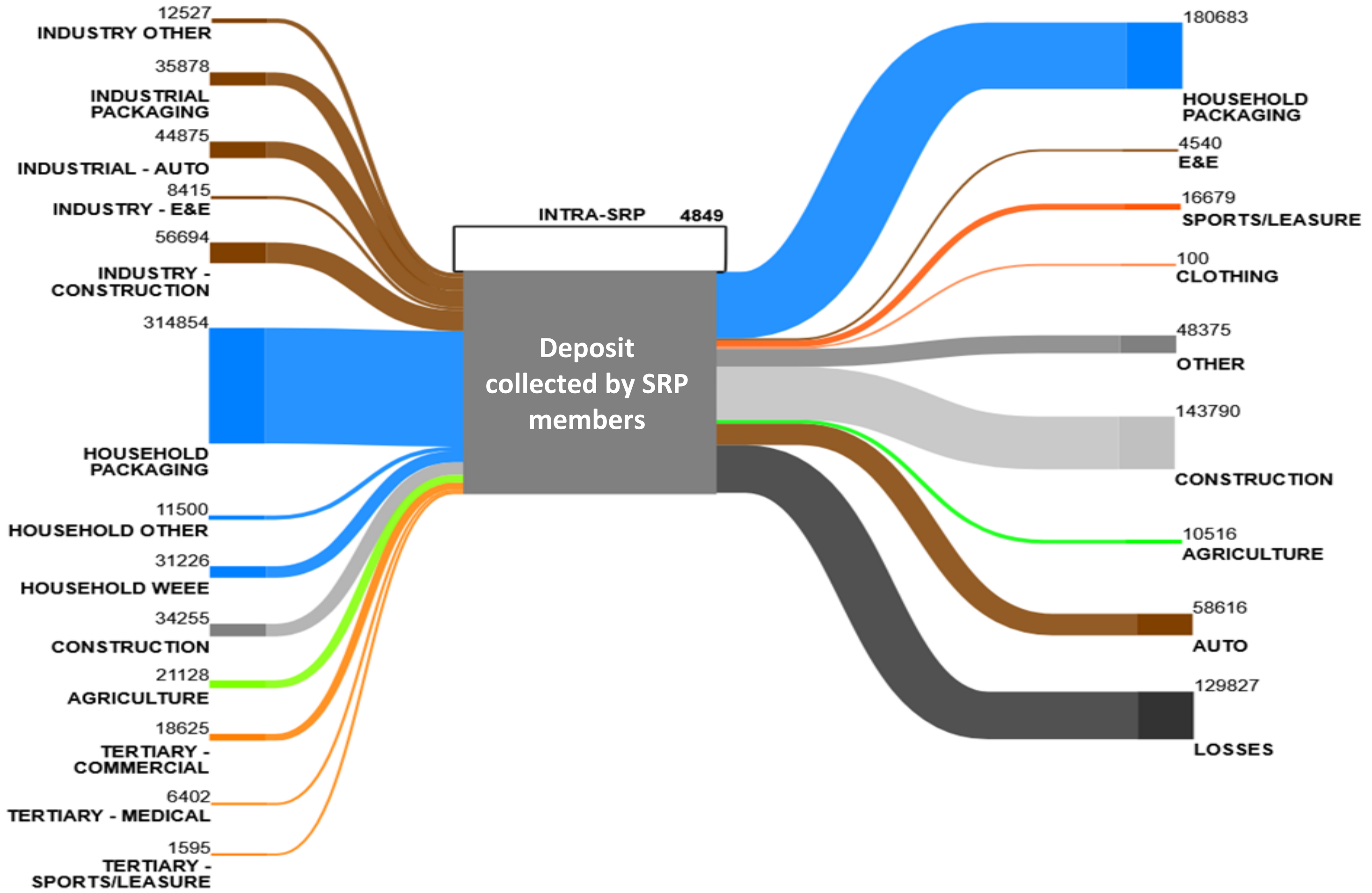
  - Fragmented and inconsistent data collection
  - Lack of transparency in data collection methods
  - Sector-specific issues
  - Challenges in cross-sectoral comparisons



Economic sectors of origin of plastic waste collected by SRP members and economic sectors of destination of recycled resins by SRP members

Plastic waste management is difficult to monitor and implement in practice

Collection and sorting : key steps with low attention

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Collection and sorting are scarcely studied by the scientific community but are essential

Roosen et al., 2022

Collection and sorting: key steps with low attention

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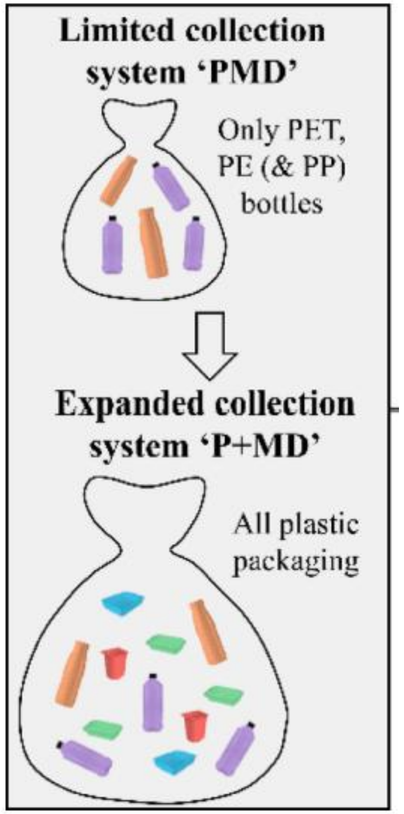

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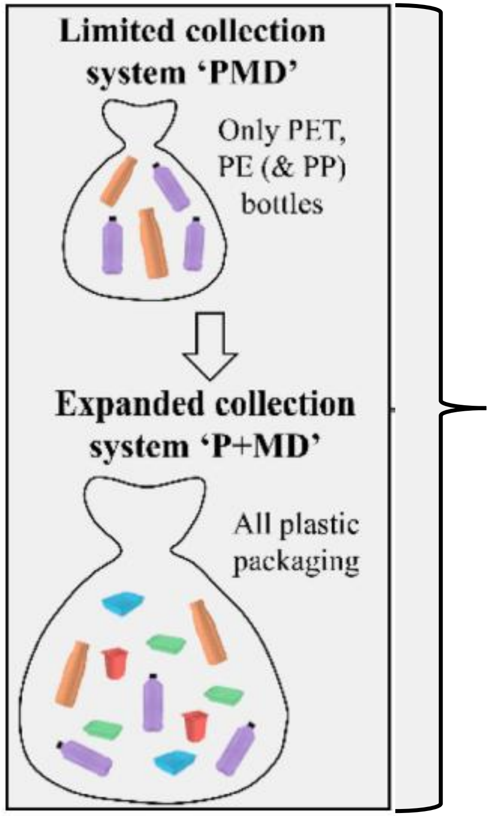

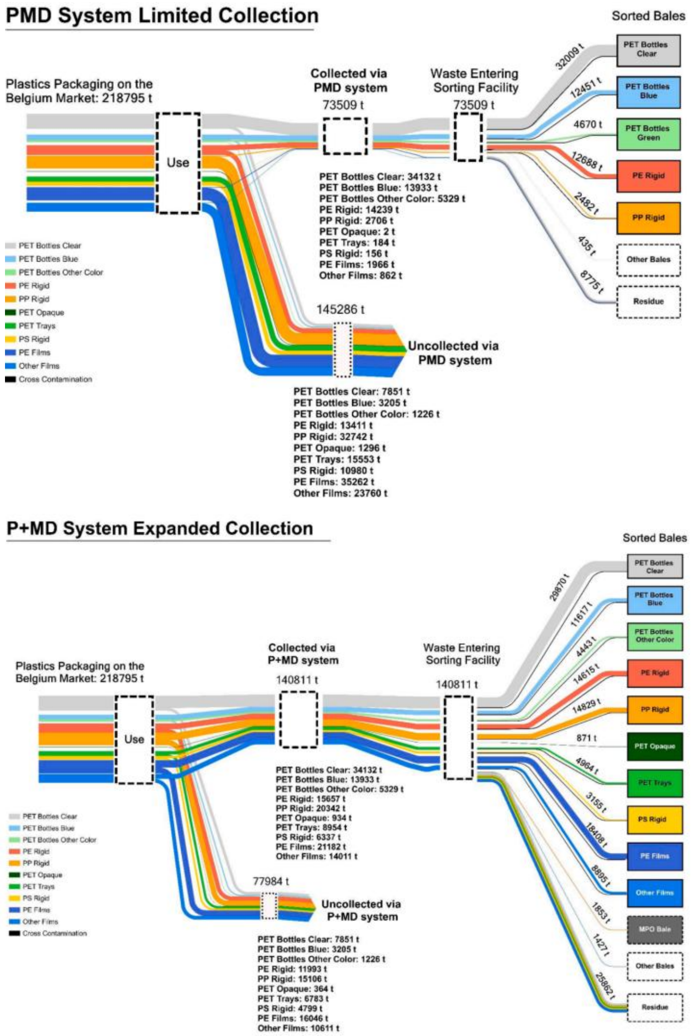

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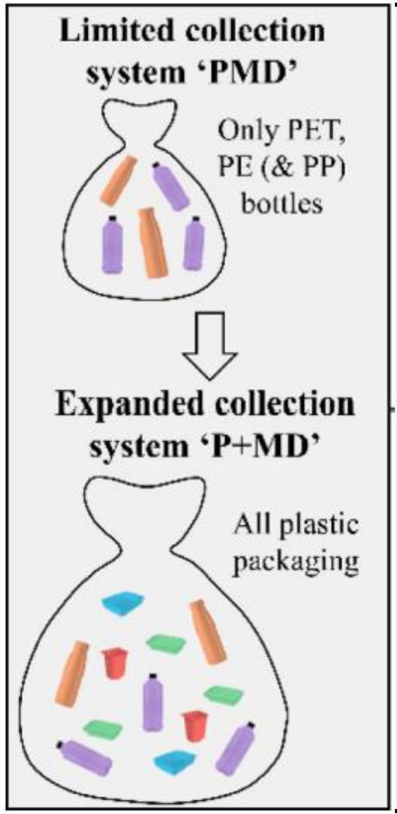

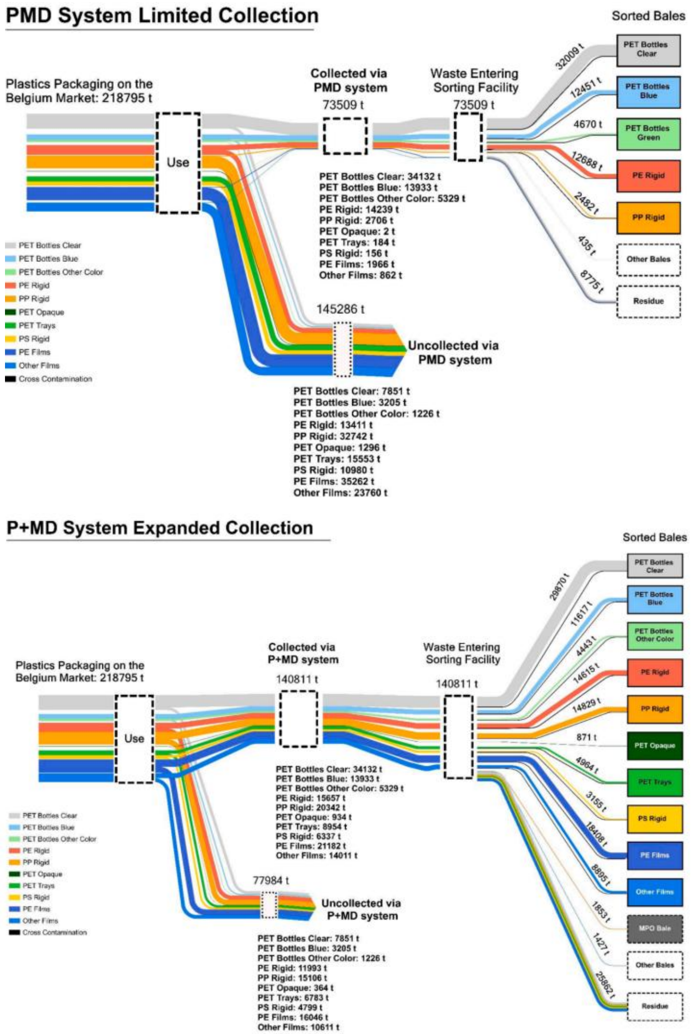

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PET bottles clear	92.9	87.0	75.5	70.7
PET bottles blue	88.5	83.3	72.0	67.7
PET bottles other color	87.4	83.3	71.1	67.7
PE rigid	89.0	91.0	45.8	51.5
PP rigid	90.0	72.8	6.9	41.8
PET opaque	–	*84.3*	–	*60.6*
PET trays	–	*53.0*	–	*30.2*
PS rigid	–	*49.8*	–	*28.3*
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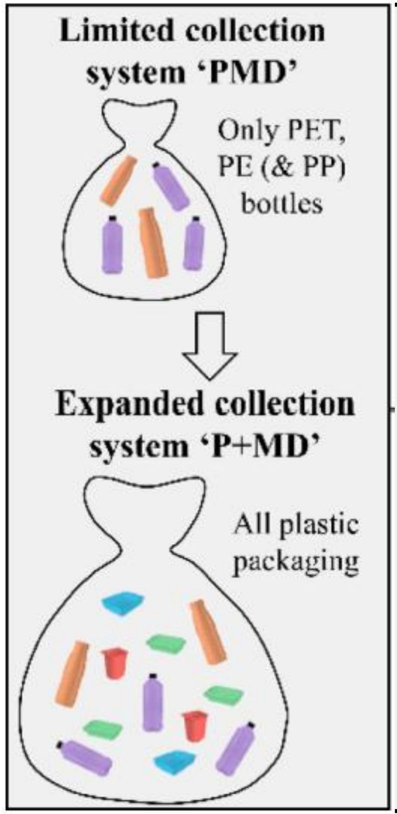

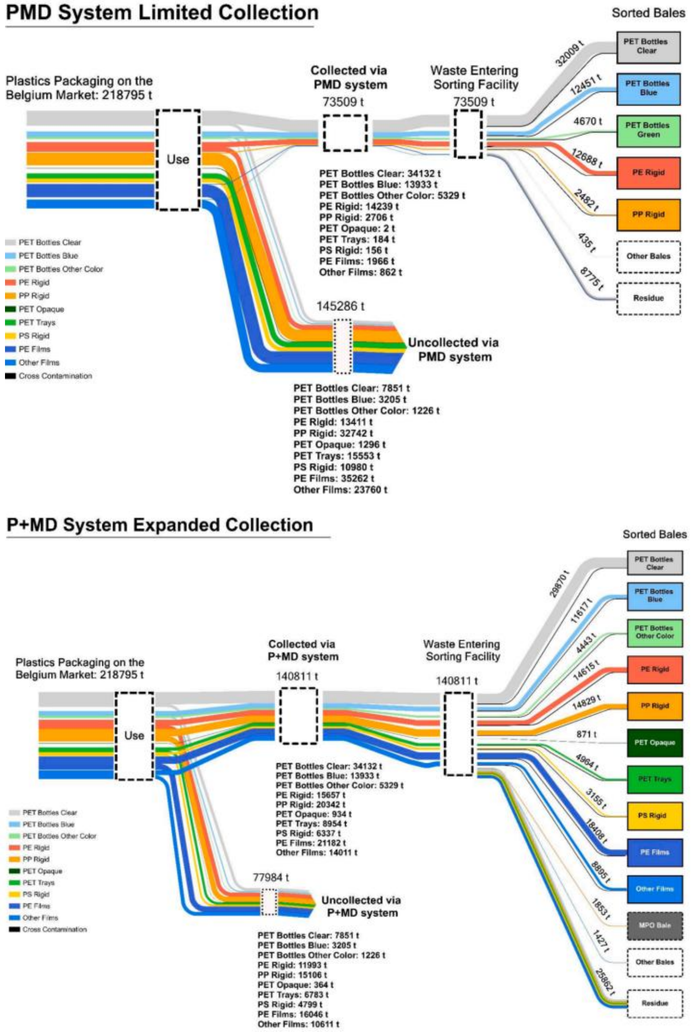

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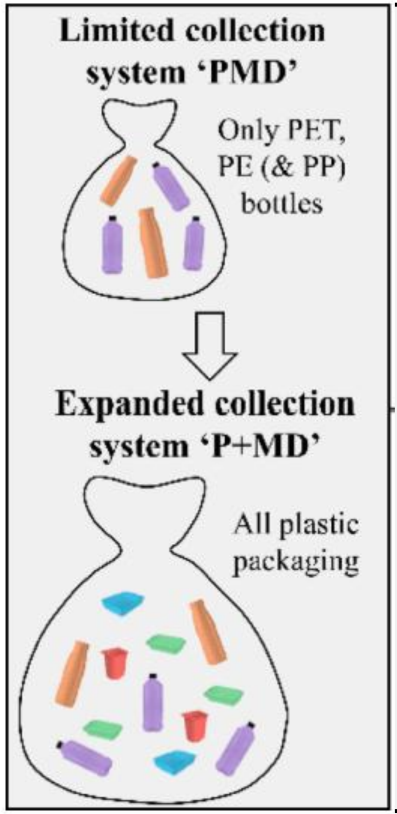

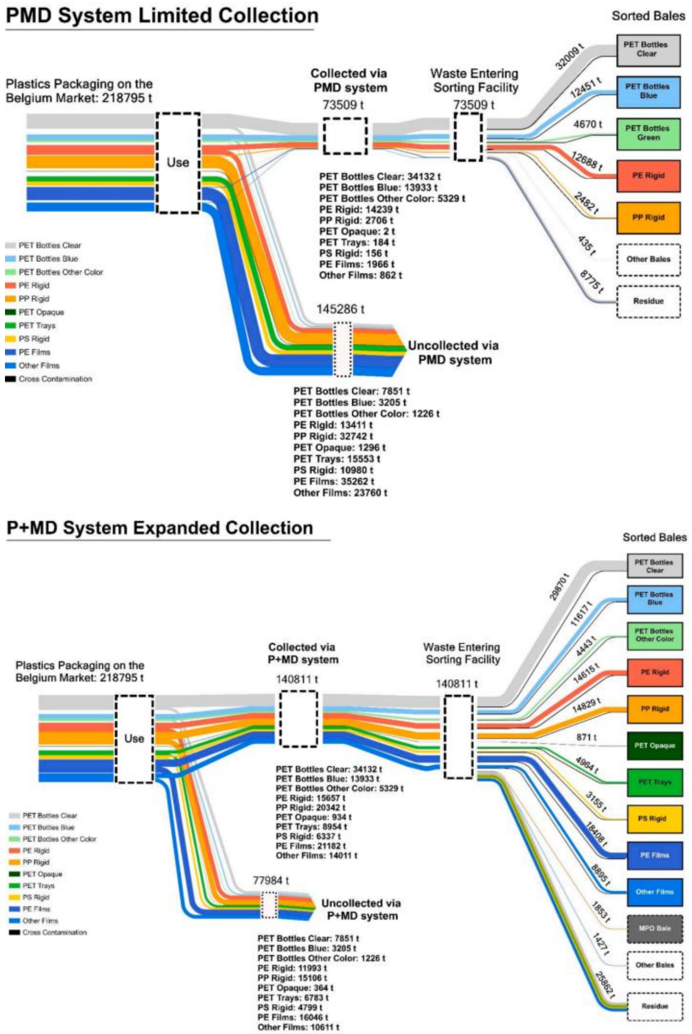

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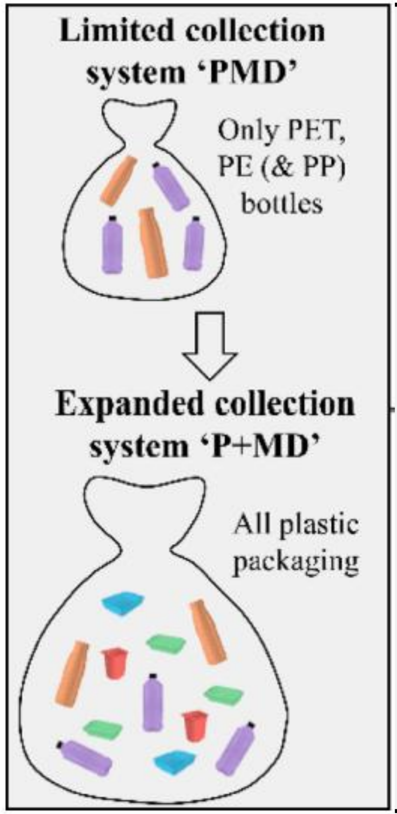

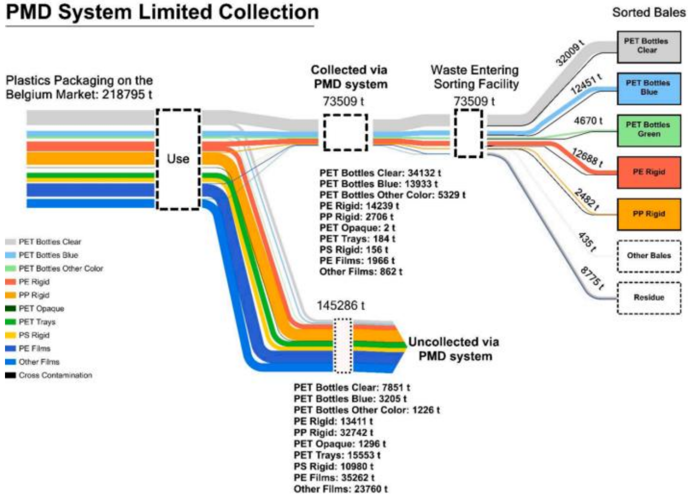

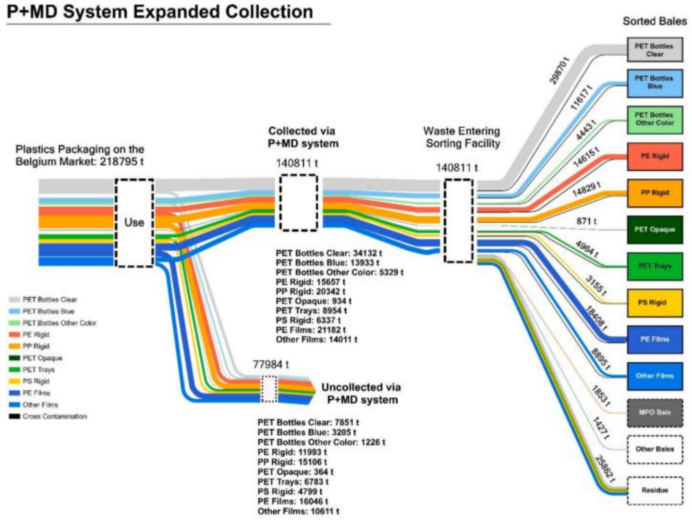

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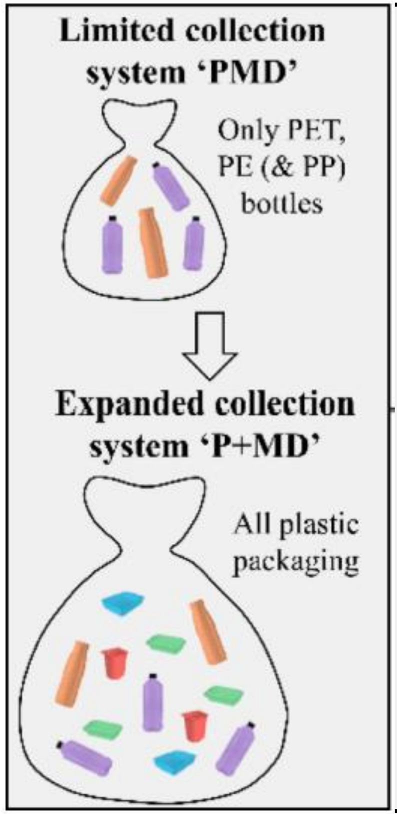

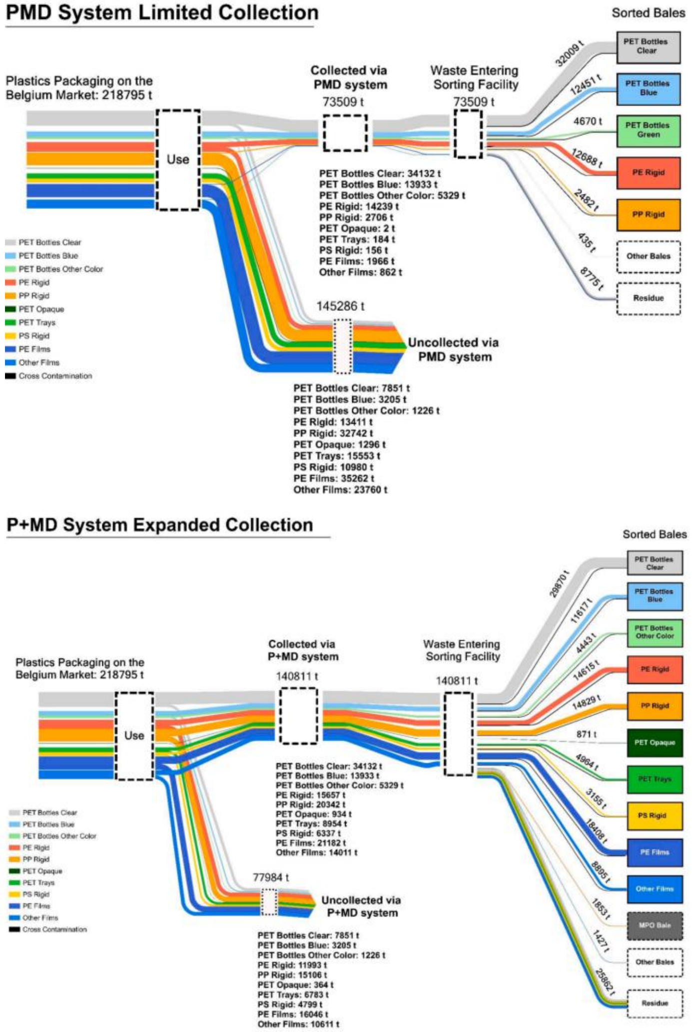

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PET trays	–	*53.0*	–	*30.2*
PS rigid	–	*49.8*	–	*28.3*
PE films	–	*79.0*	–	*45.0*
Other films	–	*52.2*	–	*29.7*
Total	86.8	77.3	29.2	49.7

➲ **Higher collection rates do not necessarily result in higher sorting rates**

Roosen et al., 2022

Collection and sorting: key steps with low attention

Collection and sorting are scarcely studied by the scientific community but are essential

➲ PET bottles, HD-PE and, in some cases, PP are the main sorted plastics sent to recycling

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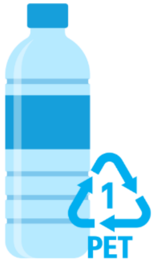
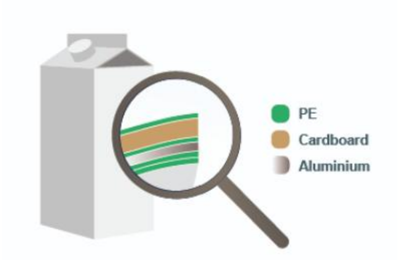


- ➲ Current sorting systems do not yet allow to sort complex objects (composite, multi-layered…)



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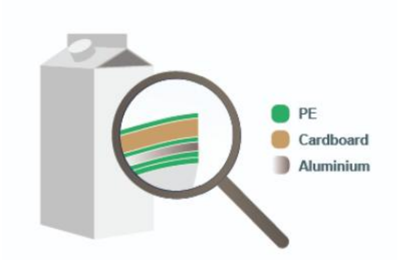
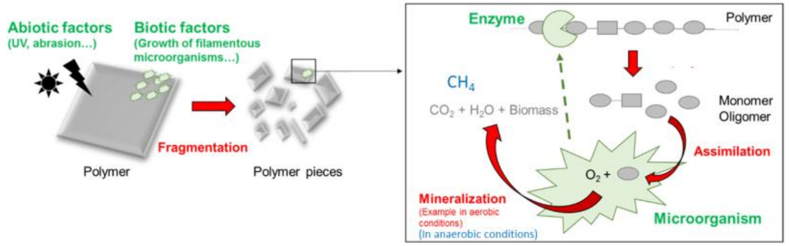
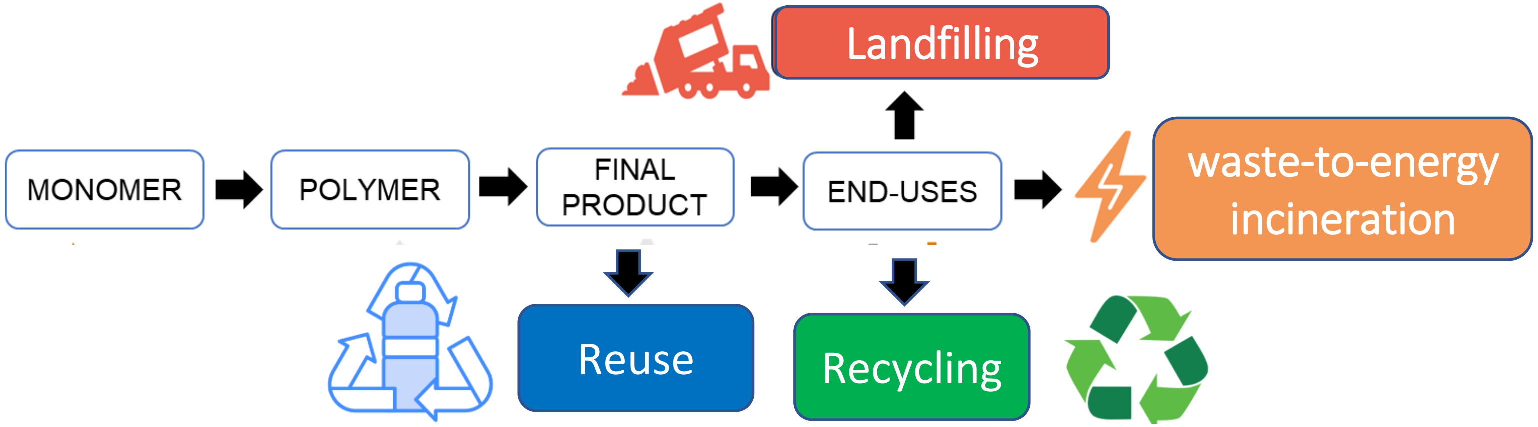


- ➲ Collection and sorting systems are not adapted or made specific to biodegradable plastics



End of life scenario

Subsequent treatment options include in descending order of quality, reuse, recycling and waste-to-energy incineration or landfilling



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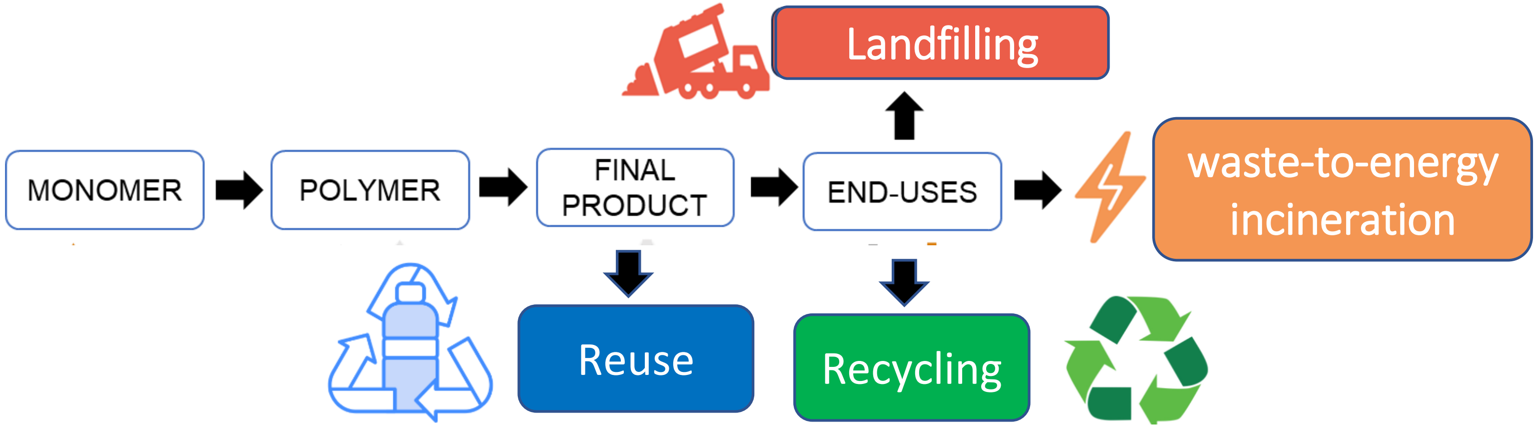
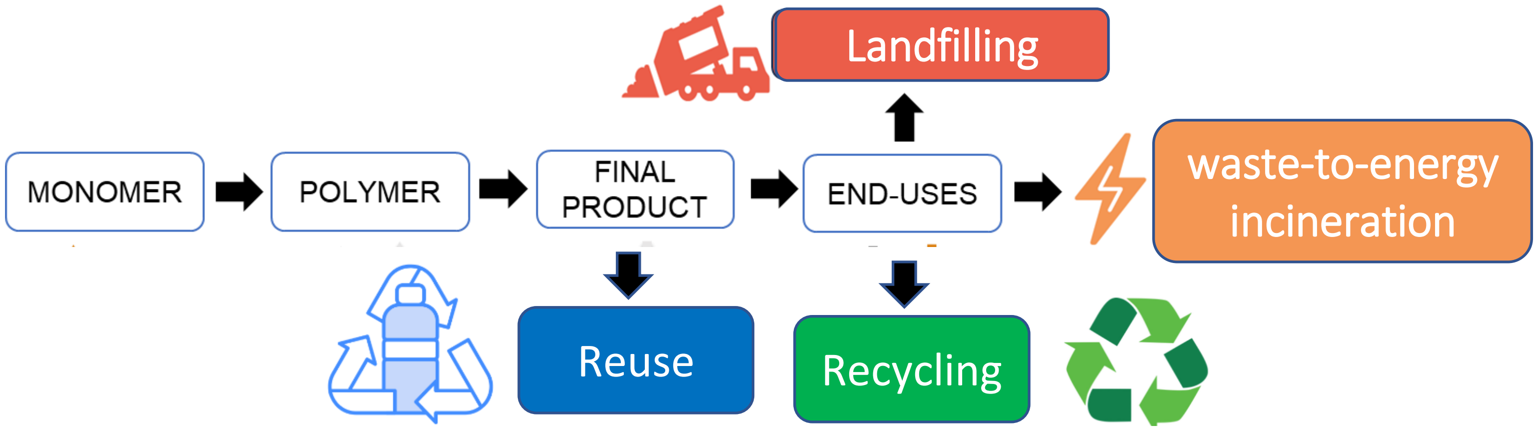


- **In France, collected for recycling (35%), sent to incineration (33%) or landfill (32%)**

Perez et., 2024

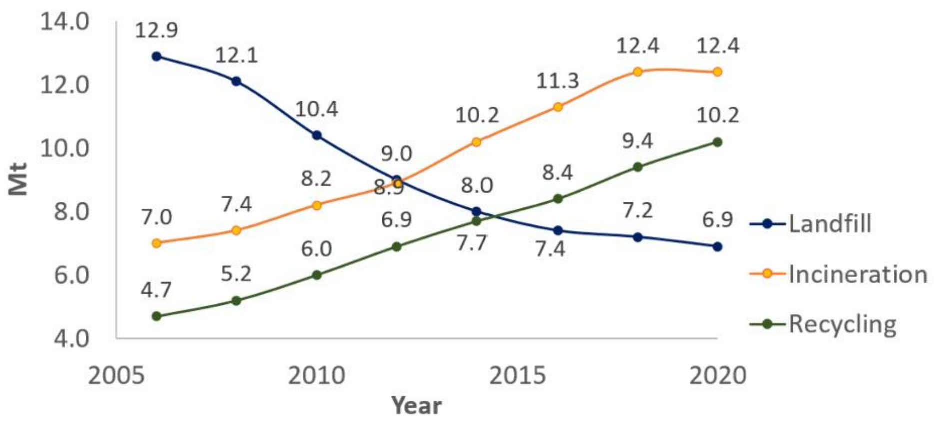
End of life scenario

Subsequent treatment options include in descending order of quality, reuse, recycling and waste-to-energy incineration or landfilling



- **In France, collected for recycling (35%), sent to incineration (33%) or landfill (32%)**

- **At the European level, the amounts of plastic waste sent to recycling have doubled in 15 years reaching**



da Costa and Desvaux– CSA extended report

Plastic waste management is difficult to monitor and implement in practice

Plastics may be recyclable but are scarcely recycled

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Mechanical recycling is the predominant recycling method

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Mechanical recycling presents some limitations

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➲ **Organisational and economic challenges**

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Mechanical recycling presents some limitations

- ➲ Organisational and economic challenges

- ➲ Contamination with other plastic waste or other waste and NIAS is further limiting

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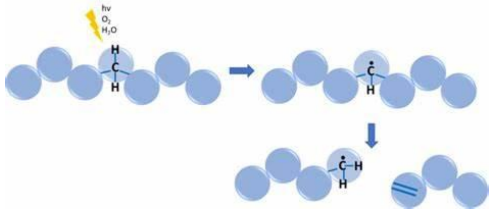
- ➲ Mechanical recyclability of plastics is limited by their degradation



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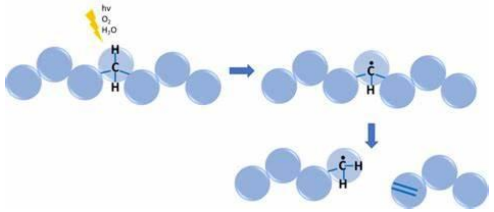
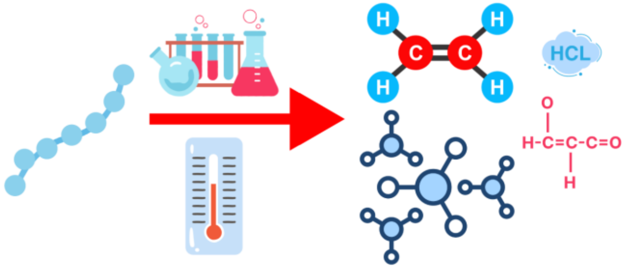
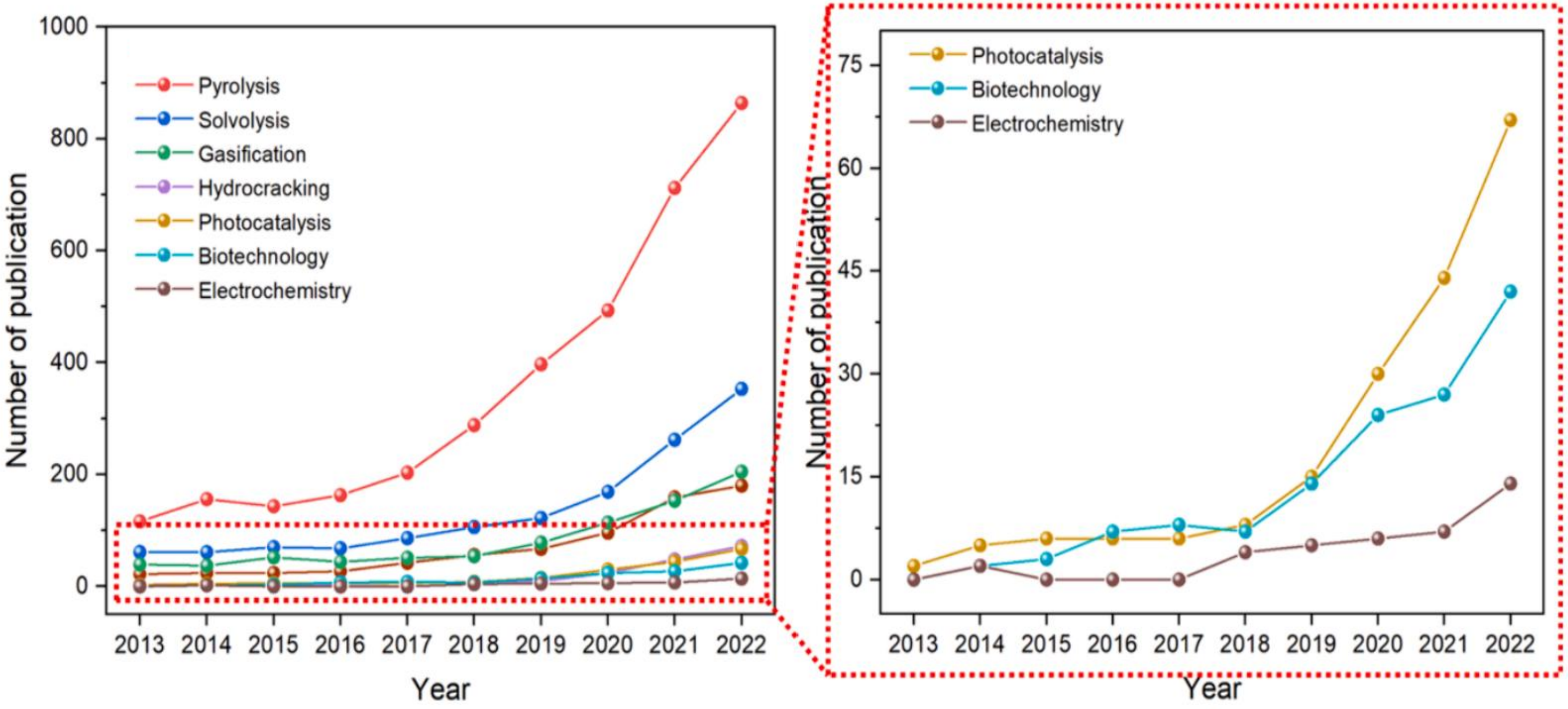


Research for technological solutions to overcome mechanical recycling limitations is very active, but only under laboratory conditions

Plastics may be recyclable but are scarcely recycled

Chemical and enzymatic recycling routes are at their early stage





Chen *et al.*, 2024

➲ **Chemical recycling becomes difficult when plastic waste are heterogeneous in composition and/or contaminated**

The difficult waste management of plastics

Plastics including the so-called biodegradable plastics are not biodegraded in soil environmental conditions

INRAE cnrs

Plastics including the so-called biodegradable plastics are not biodegraded in soil, compost and anaerobic digestion conditions

Patrick Dabert

What is plastic (bio)degradation?

A clear definition, but many misuses

INRAE cnrs

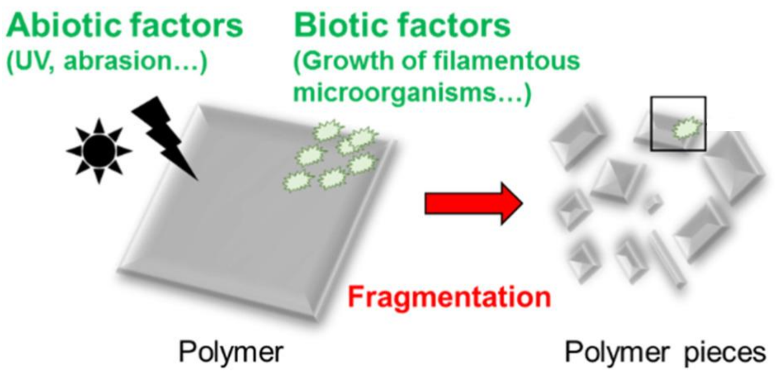
What is plastic (bio)degradation?

A clear definition, but many misuses

Deterioration
alteration of material properties

Fragmentation / Disintegration
microplastics release

Biodegradation
consumption by microorganisms



*Adapted from Magnin et al., 2020. Biotechnology Advances, **39**, 107457. INRAE / CNRS Universités de Strasbourg et Lille*

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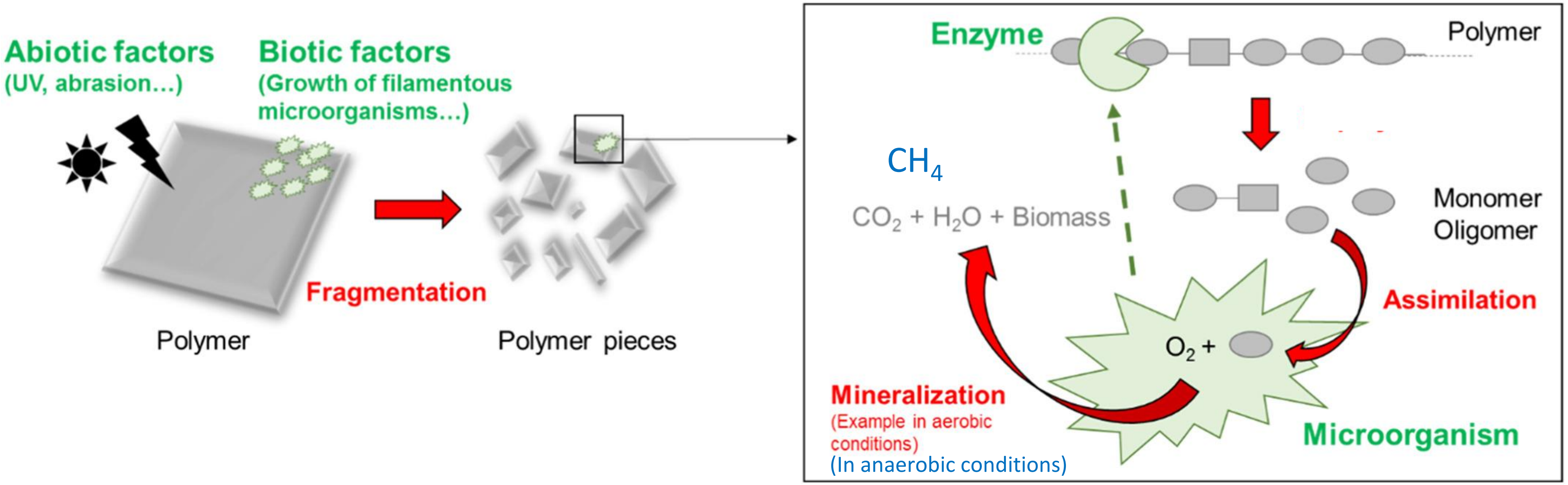

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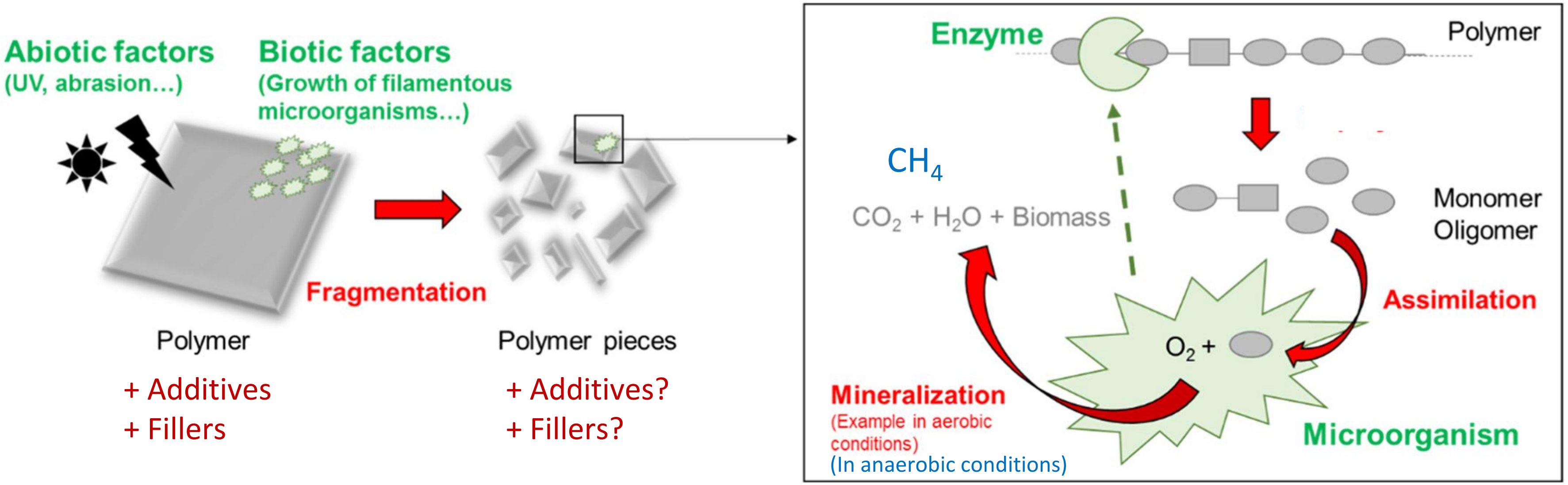

- Too many publications assum that disintegration means biodegradation => microplastics accumulation
- Biodegradation is very difficult to measure on real processes => Lab-scale studies
- Fate of additives and fillers is poorly reported

*Adapted from Magnin et al., 2020. Biotechnology Advances, **39**, 107457. INRAE / CNRS Universités de Strasbourg et Lille*

How biodegradable are today's plastics?

Conventional plastics

Polymers	Soil (6-24 months)	Mesophilic AD (60-90 days)	Thermophilic AD (60-90 days)	Home composting (12 months)	Industrial composting (6 months)
PE, PP, PS, PET, PVC, PUR, PA	Null or negligible degradation				

Conventional plastics do not biodegrade in composting and anaerobic digestion facilities
=> presence of microplastics in compost and digestate

P. Dabert, *CSA extended report*

Negligible = 0-15% / Low = 15-40% / Medium = 40-60% / Good = 60-90% / OK ≥ 90% degradation

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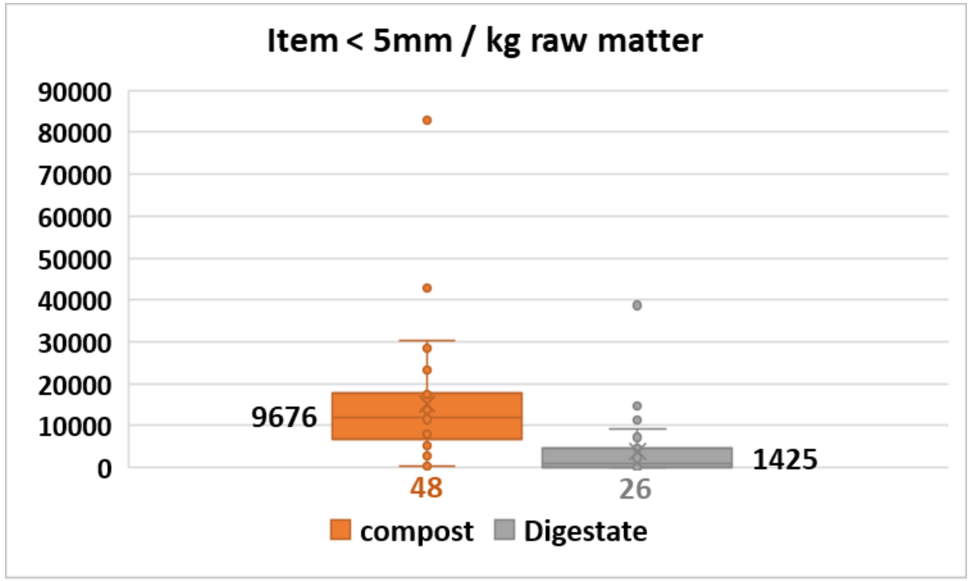

Coming primarily from:

- sewage sludge
- urban waste
- food packaging

P. Dabert, *CSA extended report*

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How biodegradable are today's plastics?

Fossil-based so-called "biodegradable" plastics

Polymers	Soil (6-24 months)	Mesophilic AD (60-90 days)	Thermophilic AD (60-90 days)	Home composting (12 months)	Industrial composting (6 months)
PBAT					
PBS					
PCL					

P. Dabert, *CSA extended report*

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PBAT	Controversial	Null or negligible		Controversial	OK
PBS	Null or negligible	Null or negligible	Low and slow	Controversial	OK
PCL	Medium to good	Low and slow	Good	OK	OK

The so-called "biodegradable" fossil-based plastics are only biodegradable effectively under industrial composting conditions

P. Dabert, *CSA extended report*

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Bio-based so-called “biodegradable” plastics

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PLA					
PHA (PHB, PHBV, etc.)					
Cellulose-based					
Starch-based					

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PHA (PHB, PHBV, etc.)	Medium to good	OK	Good	OK	**OK**
Cellulose-based	Usually good but depends strongly of the blend				
Starch-based	Usually good but depends strongly of the blend				

Only plastics based on bio-based PHA, cellulose or starch are effectively biodegradable under all composting and anaerobic digestion conditions

---

However

P. Dabert, *CSA extended report*

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However

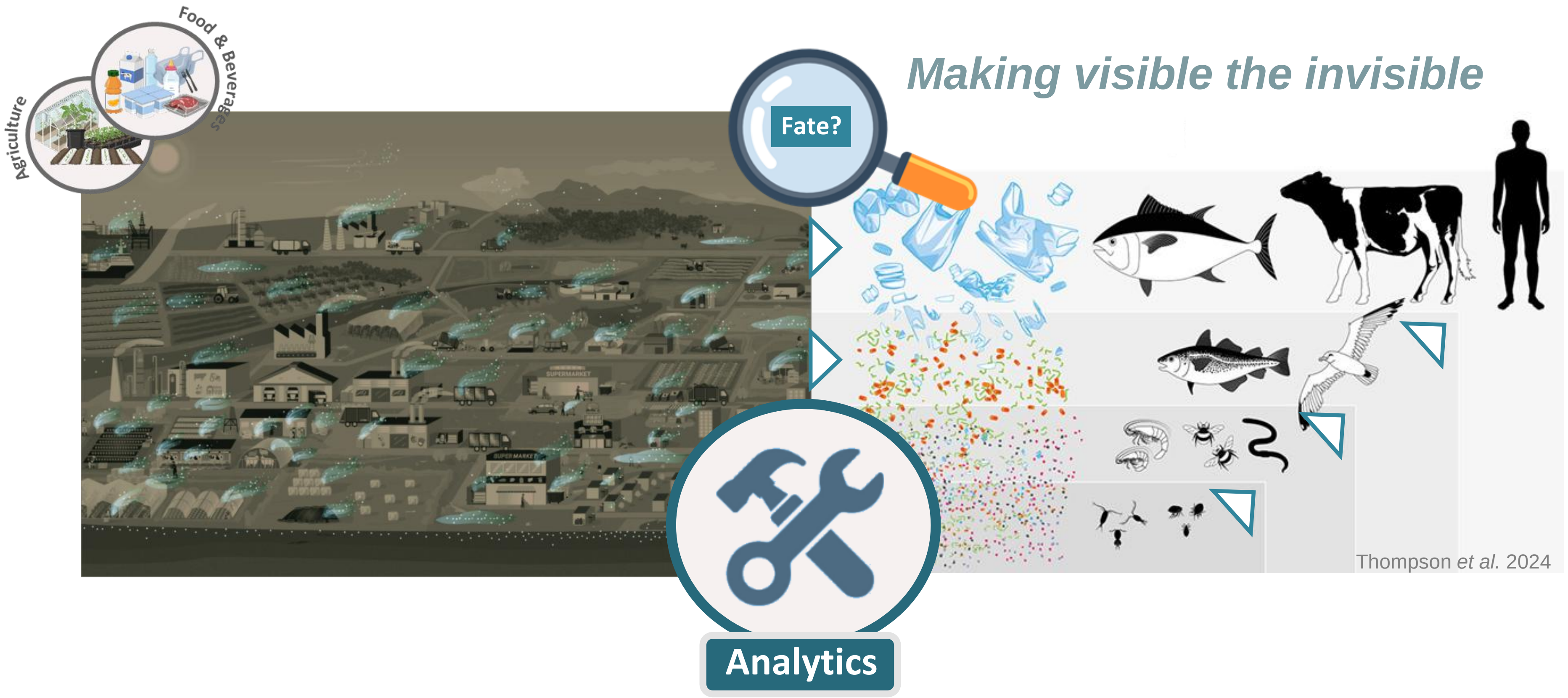
- They can lose their biodegradability when mixed with other polymers
- Little is known about the biodegradation of additives
- We need a better knowledge and transparency of the compounds present in plastics

P. Dabert, *CSA extended report*

Negligible = 0-15% / Low = 15-40% / Medium = 40-60% / Good = 60-90% / OK ≥ 90% degradation

Plastics are ubiquitous, hazardous & have multi-scale adverse impacts on living organisms, humans and continental ecosystems

Dispersion in the environment, living organisms and along food chains



Experimental analytical methods for plastics exist but need to be improved for the wide range of matrices and plastic forms being considered

Complementary analytical methods & tools available

Direct or differential approaches

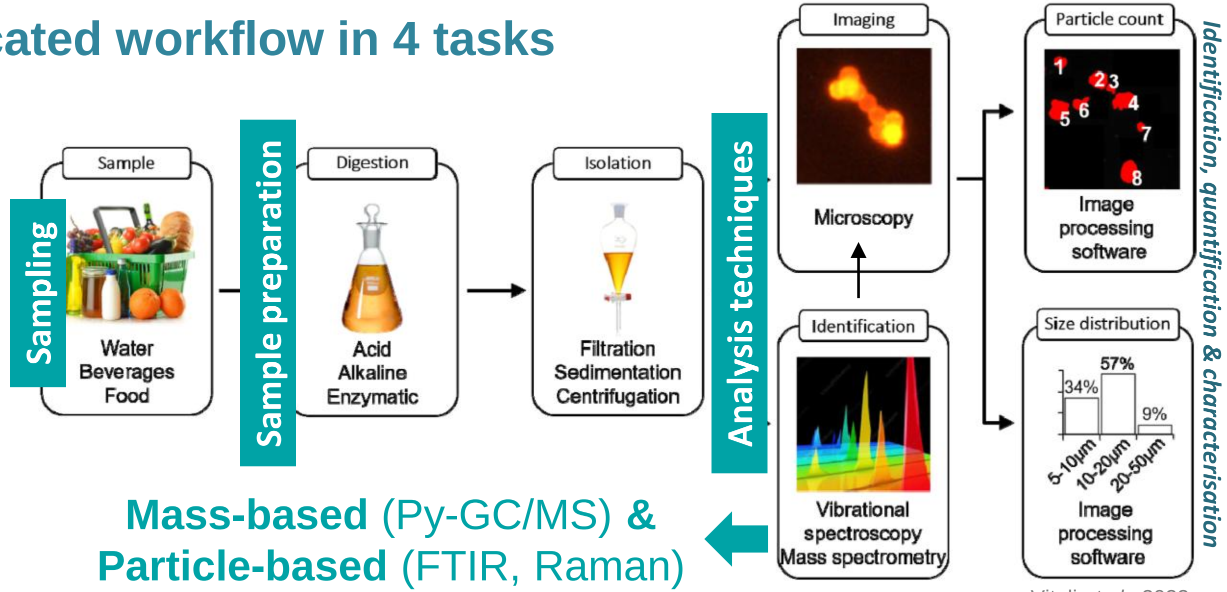
Organic molecules: GC and LC & **Trace metal elements**: ICP-OES/MS, X-ray Fluorescence, Atomic Absorption Spectroscopy

Accurate identification: HRMS (QTOF or Orbitrap)

Oligomers: LC or GC-MS for food samples, more challenging for environmental samples

A dedicated workflow in 4 tasks

Example of food & beverages



Vitali *et al.*, 2022

Mass-based (Py-GC/MS) **& Particle-based** (FTIR, Raman)

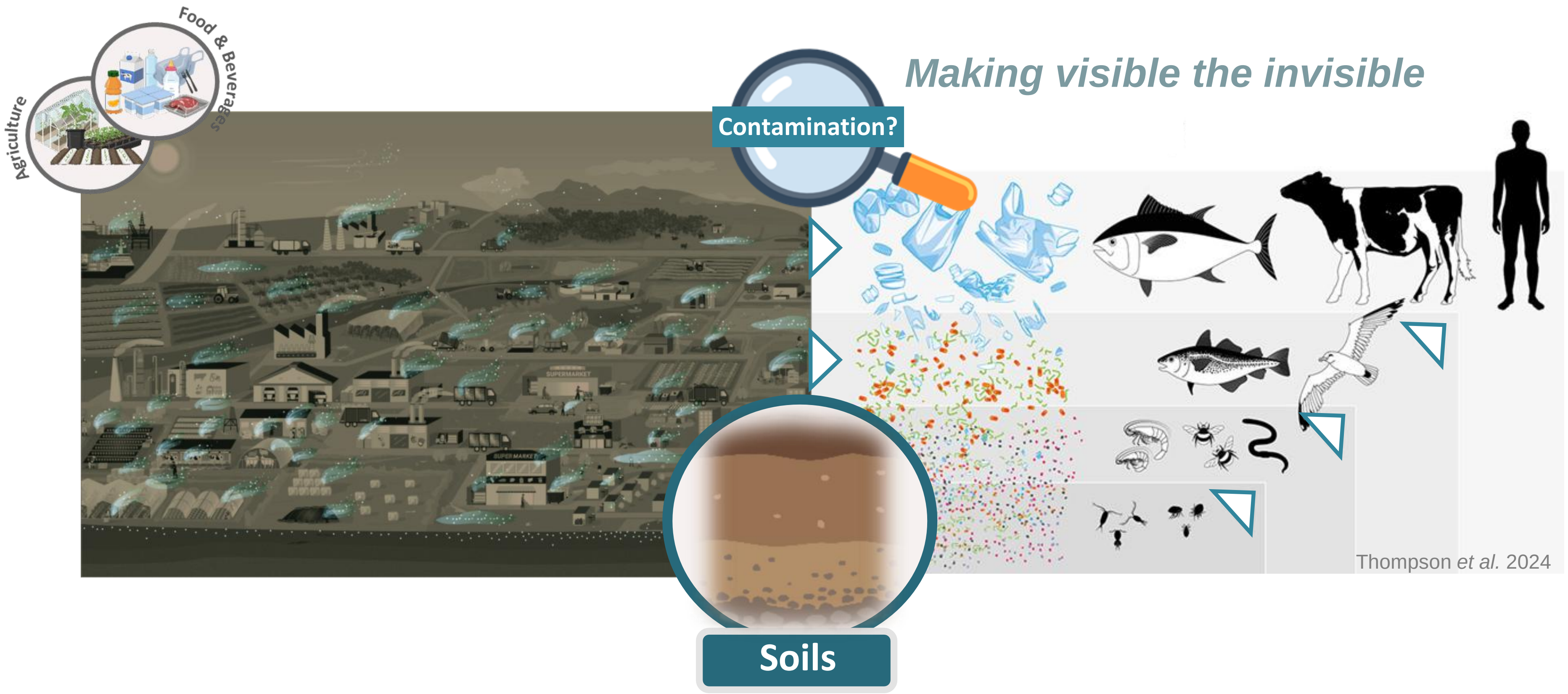
Method Validation, Quality Assurance & Quality Control (QA/QC)

For a wide range of matrices:

- Environmental compartments (atmosphere, hydrosphere, pedosphere)
- Food & Beverages
- Living organisms

➲ **Current lack of harmonisation and standardisation of methods & analytical issues** (interference with the matrix, analytical biais…)

Dispersion in the environment, living organisms and along food chains



Soil is the poor relation when it comes to studying plastic pollution in the environment, and yet...

Dispersion in the environment, living organisms and along food chains: the example of soils

Bruno Tassin

Soil contamination by plastics: a new area of research

Soils are contaminated by plastics

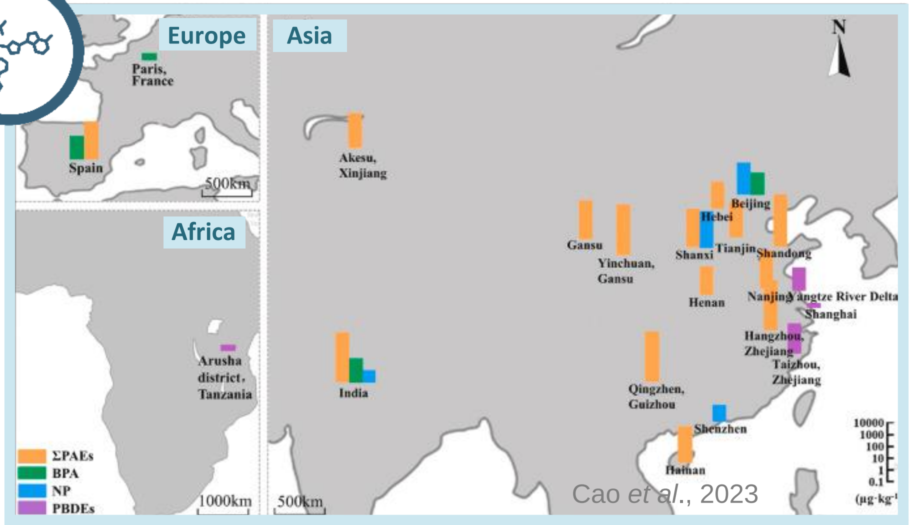
- **A wide range of sizes:** from macroplastics (MaPLs) to micro- (MPLs) and nanoplastics (NPLs)
- **A wide range of concentrations:**

Even remote areas (deserts) contaminated: 100 MPLs kg_{dw}^{-1}
➲ Agricultural soils: 1,000 MPLs kg_{dw}^{-1}
Dense urban areas: 10,000 MPLs kg_{dw}^{-1}

Heavy MPL contamination

- **Mass of MPLs in soils larger than in the oceans**

Estimate for French agricultural soils: 244 kg ha^{-1} (Palazot *et al.* 2024)



Cao *et al.*, 2023

Distribution in agricultural soils

Phthalates, BPA, NP & PBDEs:
most commonly detected

BPA concentration of **0.42 μg kg^{-1}** in Paris area

Soils: diverse human sources of plastic contamination

Soil sample from Mausud and Foan island reserve (Norway) (Cyvin *et al.* 2021)

Soil in Quevillon (Normandie, France). Former accumulation zone along the Seine estuary

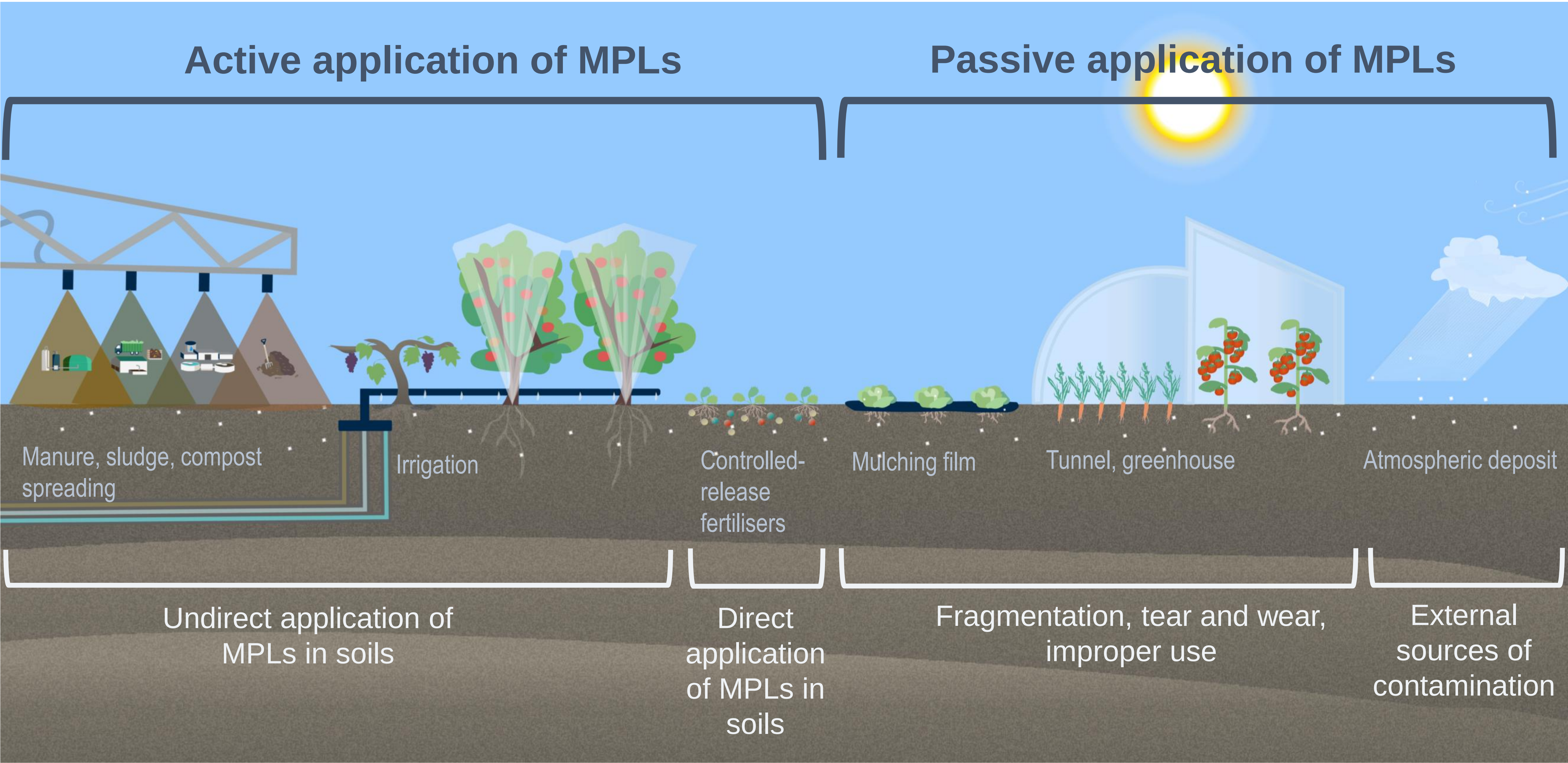
Macroplastics on agricultural soils in France: plastic mulch in Ustaritz (Basque Country, France)

Fragmentation into MNPLs

Fragmentation processes known <u>BUT</u> quantification of fragmentation still an open question

INRAE cnrs

Agricultural soils: diverse human sources of MPL contamination



Most at-risk contamination sources linked to agriculture

Capsule-suspension plant production products, coated seeds & polymer coated encapsulated fertilisers

Containers of pesticides

Mulching films

Bale knitted nets & silage nets

Bale wrap films

Bale netwraps & press films

Briassoulis, 2023

Quantification of contamination sources: an attempt

B. Tassin - CSA Extended Report

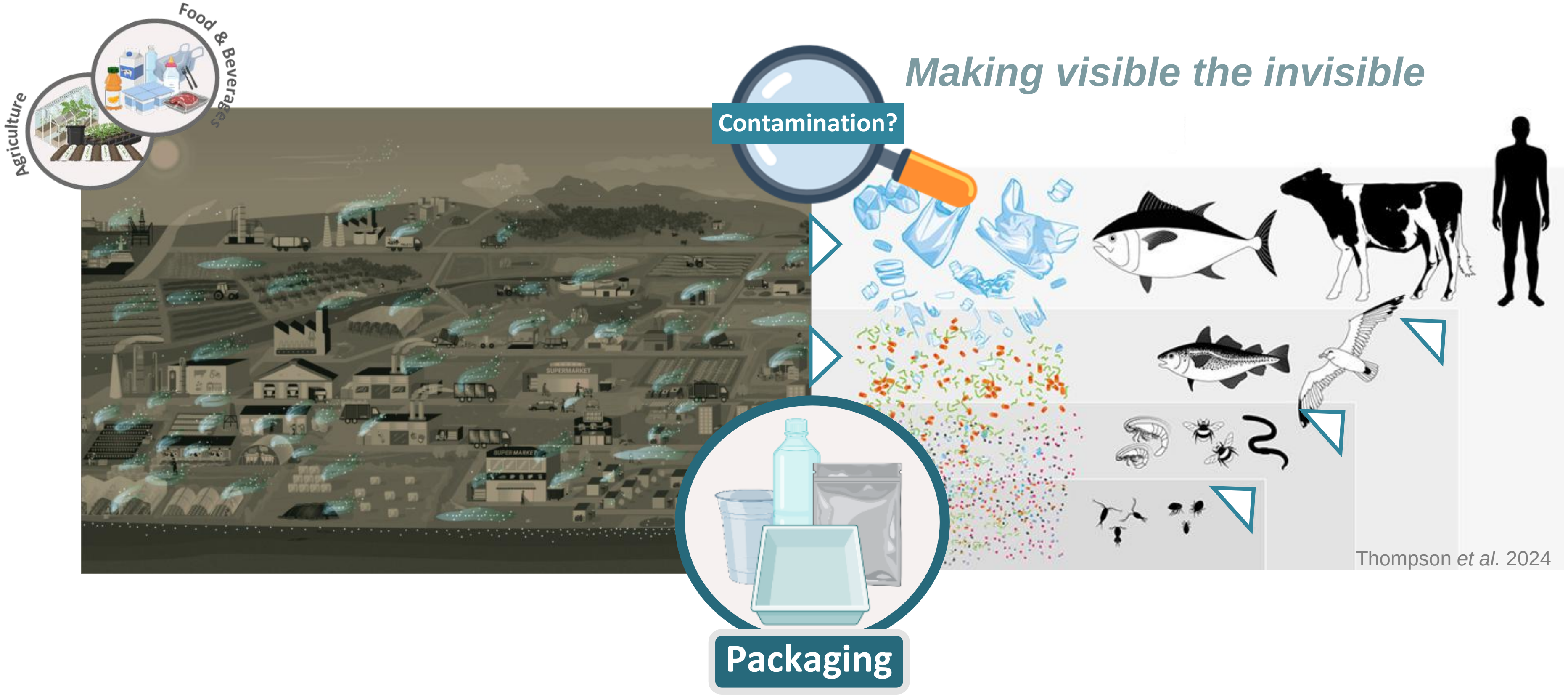
Origin of contamination	Order of magnitude of contamination ($MPLs \cdot ha^{-1} \cdot yr^{-1}$)	
	Minimum	Maximum
Irrigation (wastewater)	millions	thousands of millions
Atmospheric deposits	hundreds of millions	thousands of millions
Sludge application	tens of millions	hundreds of millions
Manure application	millions	tens of millions

Based on the sources most frequently cited in the literature

Numerous and cumulative uncertainties ❯❯❯ **Equivalent contamination sources?**

Quantification of fluxes between compartments

Dispersion in the environment, living organisms and along food chains



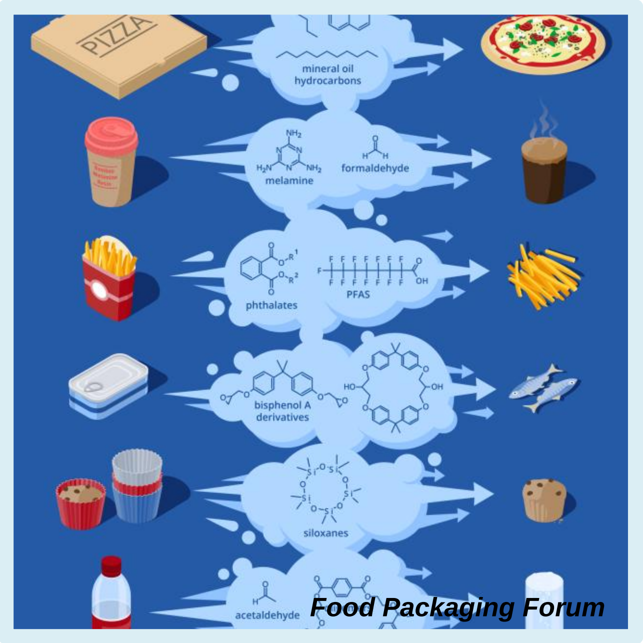
Food and drinks intended for human consumption are contaminated by plastics

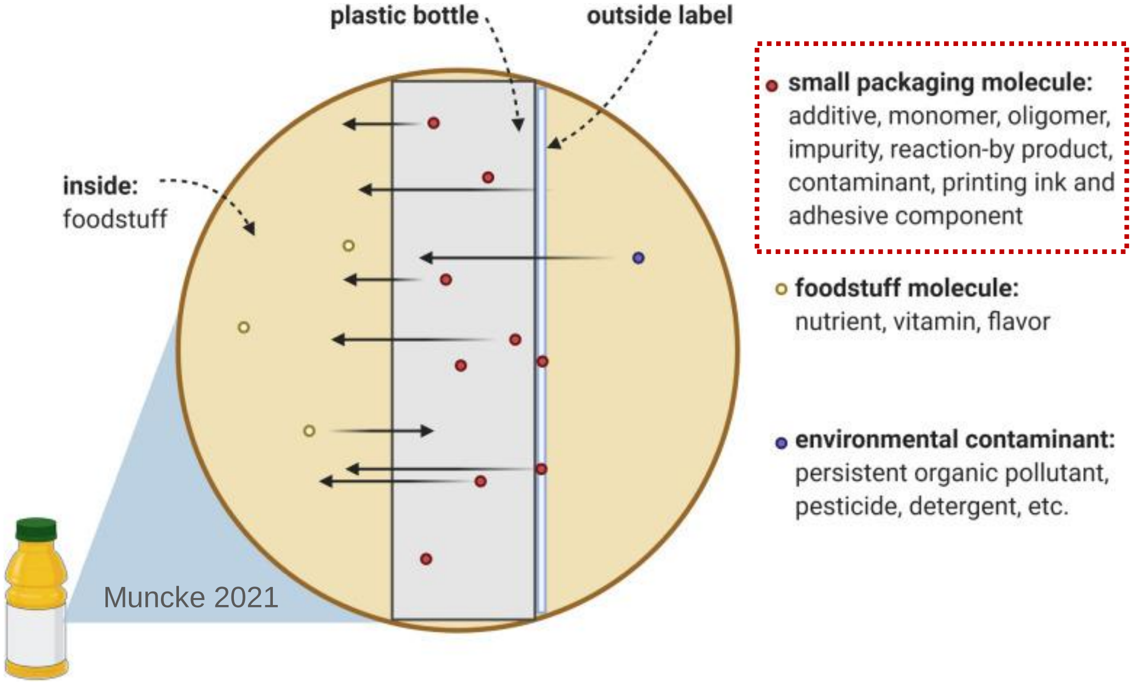
INRAE cnrs

Migration of chemical substances

Food contact materials (FCMs): chemical substances > 10,000

Positive List of Food Contact Substances (EU) & **Databases** e.g. Migrating and Extractable Food Contact Chemicals (FCCmigex)



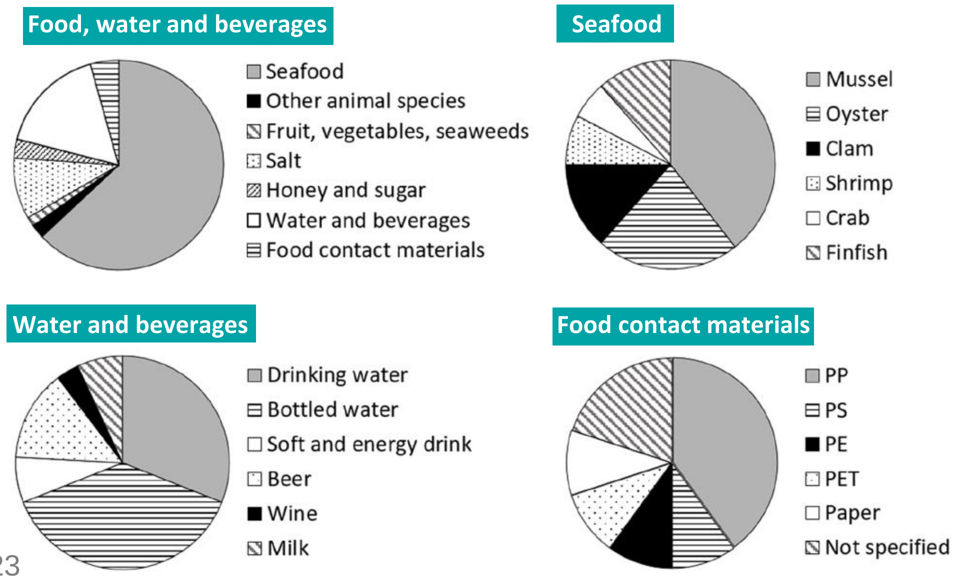


Food packaging and other food contact articles: migration of chemicals into food and drinks

- **Food packaging:** phthalates, antioxidants (BHT, BHA), oligomers and bisphenols
- **Tableware and kitchen utensils:** melamine derivatives and formaldehyde - role of heating or contact with acidic/fatty foods

Mainly **conventional petroleum-based plastics** compared to bio-based plastics (88% vs 12%)

MNPLs and possibly oligomer submicrometre particles



Vitali *et al*., 2023

MPL contamination in drinking water:

- Highly variable: 0 to 5.42E+07 MPLs/L
- Water sources, geographical locations, quantification methods, inadequate analytical procedures

Potential sources of contamination:

- Food chain, environment, airborne particles
- Practices and processing, transport, storage,
- Food preparation (cooking methods, choice of kitchen utensils)

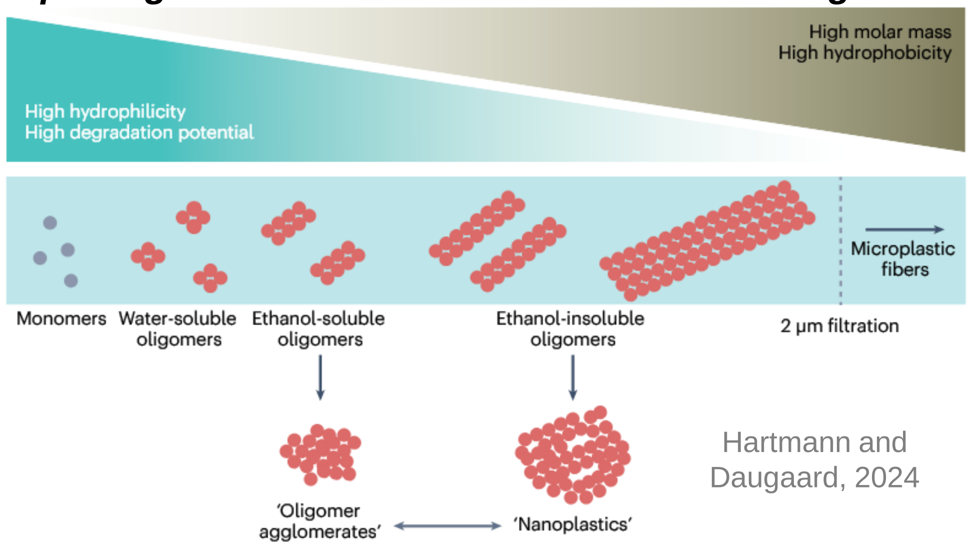
Release of MNPLs from packaging materials:

Mechanical stress (e.g. opening/closing of bottle caps) or thermal stress (heat, freezing)

Emerging problem with oligomer aggregates:

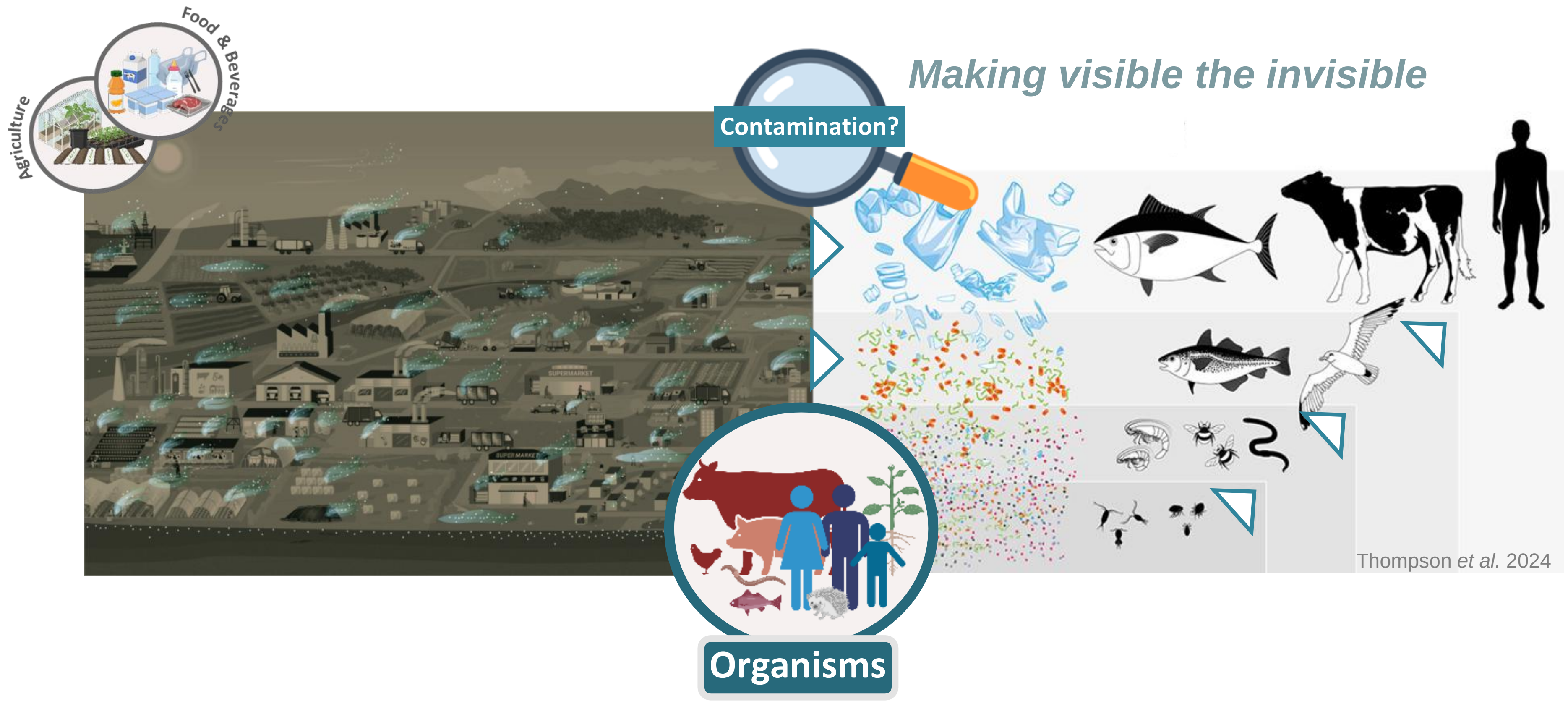
Chemical identification, distinction with NPLs (e.g. for PE and PET: ethanol pre-treatment)

Exploring the continuum between NPLs and oligomers



Hartmann and Daugaard, 2024

Dispersion in the environment, living organisms and along food chains



Biota are contaminated by plastics in their various forms and contribute to their dispersion

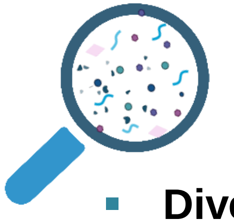
Contamination of living organisms by plastics

Ubiquitous contamination by plastics depending on e.g. their size

Mobile organisms: contribution to the long-range dispersion of MPLs following ingestion and subsequent egestion

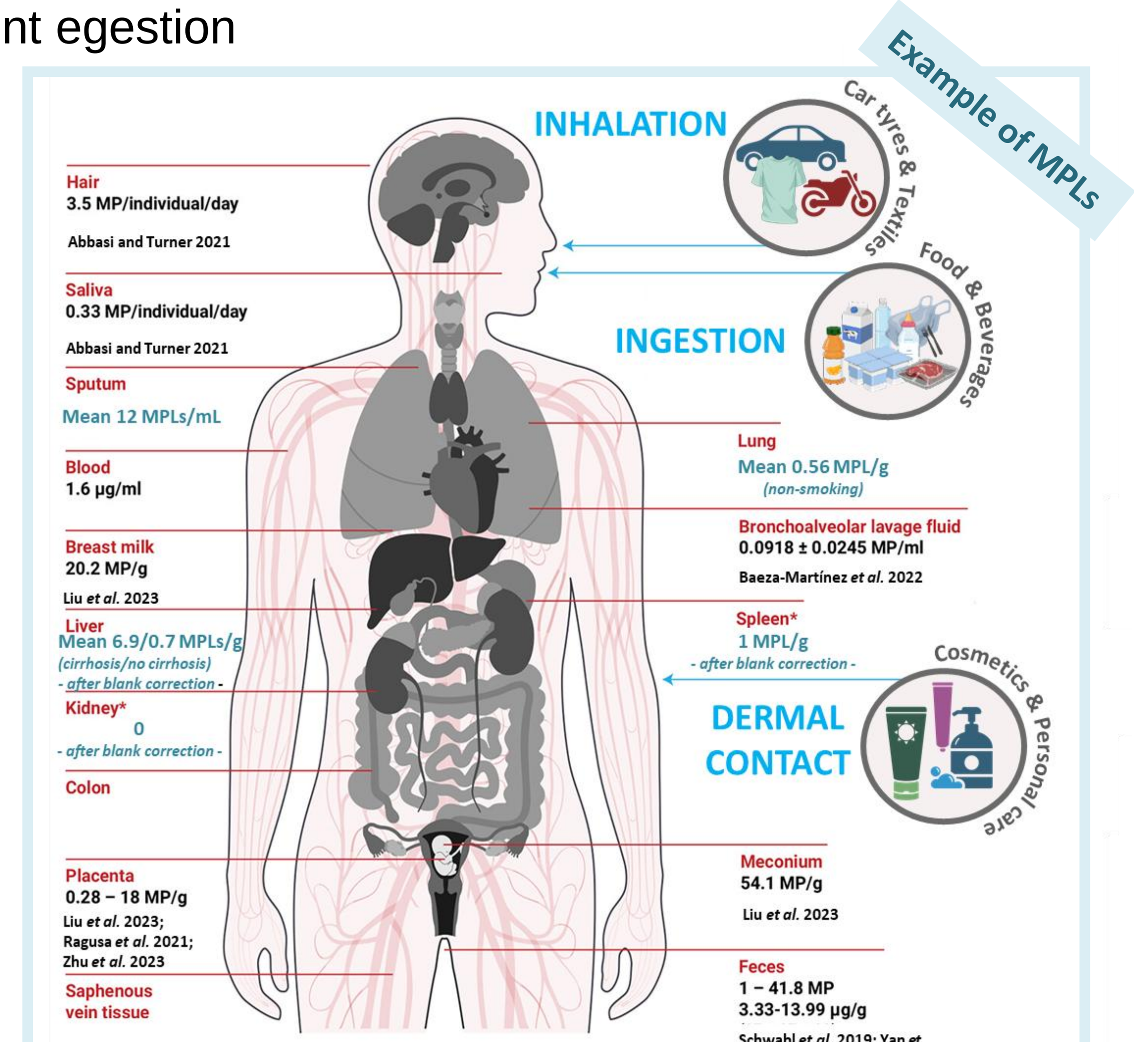
Food contact chemicals

- Presence in human samples for a total of **3601 (25%)** of the 14,402 known food contact chemicals



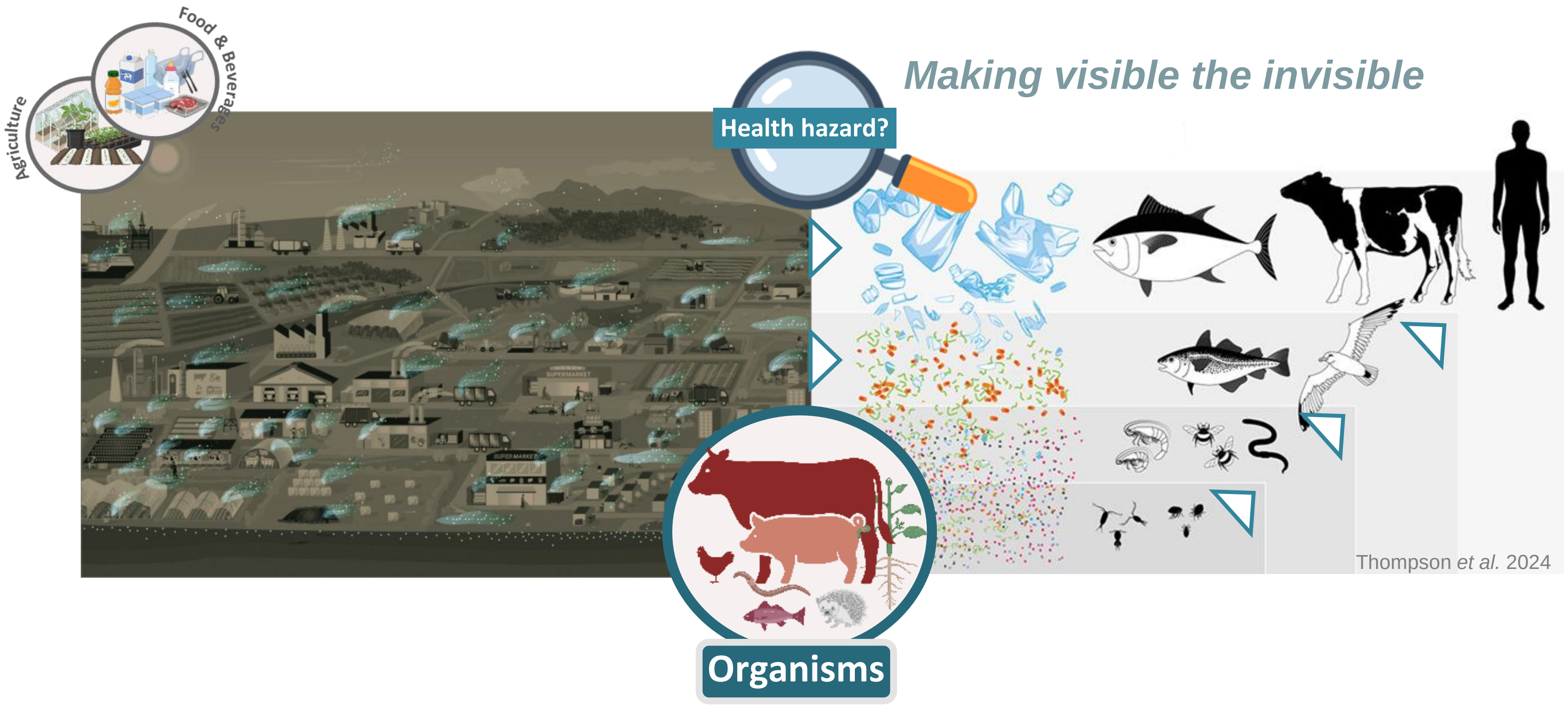
Main focus on MPLs

- **Diversity of polymer types found in human samples** (petroleum origin; lack of data on bio-based and/or biodegradable plastics)
- Sometimes linked to **lifestyle habits**
- Exposure data: **no consensus yet**



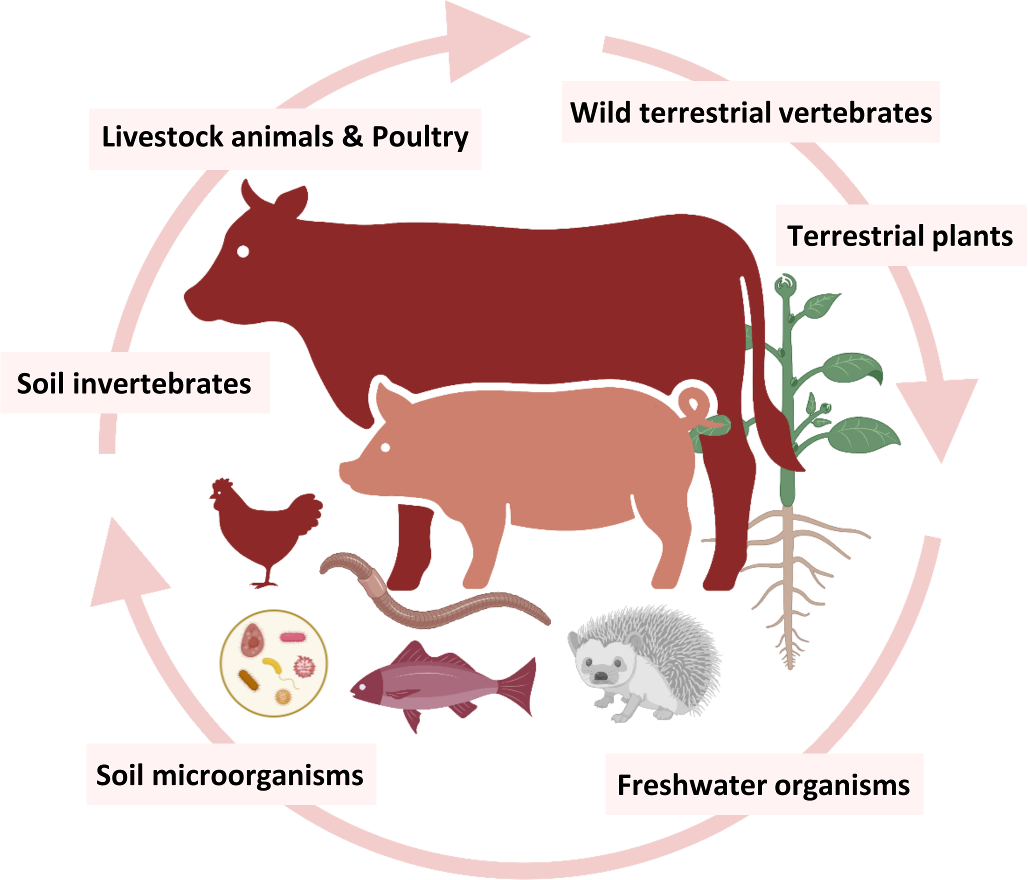
Adapted from Thompson *et al.*, 2024

Health hazard to living organisms & Impacts on ecosystems through widespread contamination



Plastics have (eco)toxicological effects on living organisms at multiple scales

Effects of plastics on living organisms

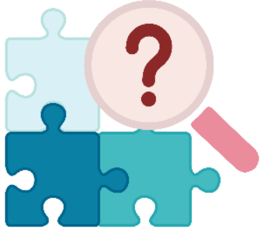


Most well known for a limited number of chemicals

Endocrine disruptors (phthalates, bisphenols): impact on **reproduction**

Main focus on MPLs

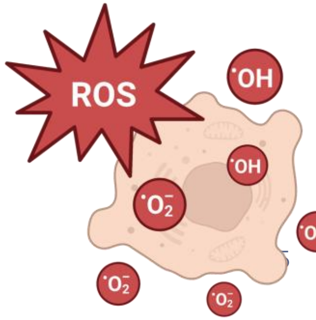
Soil organisms: few species, effects through **soil-food web**, **plastisphere**
Wild vertebrates: few (lab-scale) studies
Livestock animals & poultry: impact on **yield**, **growth** and **meat quality**



More in-depth research needed

LIMITATIONS: few types of polymers (over-representation of PS), use of monodisperse, spherical and pristine particles (commercial sources)

BUT: **adverse effects** on behaviour, biological activity, growth, reproduction, metabolism
WITH **common players** (microbiota) **AND** mechanisms of action (**oxidative stress**)



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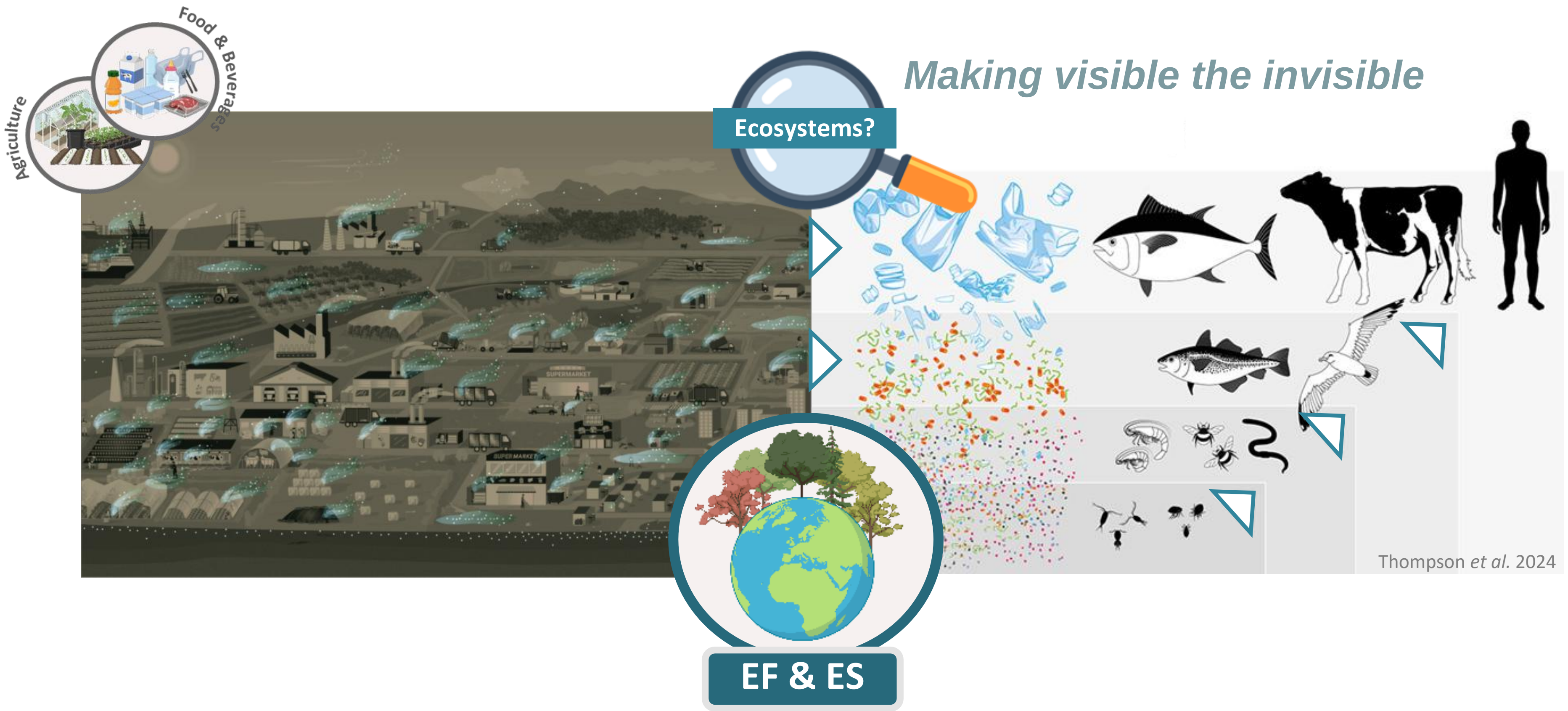

The accumulation of particulate plastics has an impact on ecosystem functioning and is likely to affect the provision of ecosystem services

Effects of plastics on ecosystem functions

Ecosystem functions	
EF1	Gas regulation
EF2	Dissipation and mitigation of contaminants and wastes in terrestrial and aquatic ecosystems
EF3	Resistance to disturbance
EF4	**Water retention in soil and sediment**
EF5	Water flow regulation
EF6	Albedo and reflection
EF7	**Production and input of organic matter in terrestrial and aquatic ecosystems**
EF8	Nutrient regulation in terrestrial and aquatic ecosystems
EF9	**Formation and maintenance of soil and sediment structure**
EF10	Dispersion of propagules in terrestrial and aquatic ecosystems
EF11	Provision and maintenance of biodiversity and biotic interactions in terrestrial and aquatic ecosystems
EF12	Provision and maintenance of habitats and biotopes in terrestrial and aquatic ecosystems

***12 EFs** considered based on a previous CSA*

(Pesce *et al.* 2023)

Recent, still fragmentary, knowledge

More in-depth research needed

EF4, EF7 and EF9 the most well documented

An illustration with EF4 'Water retention in SOIL and sediment'

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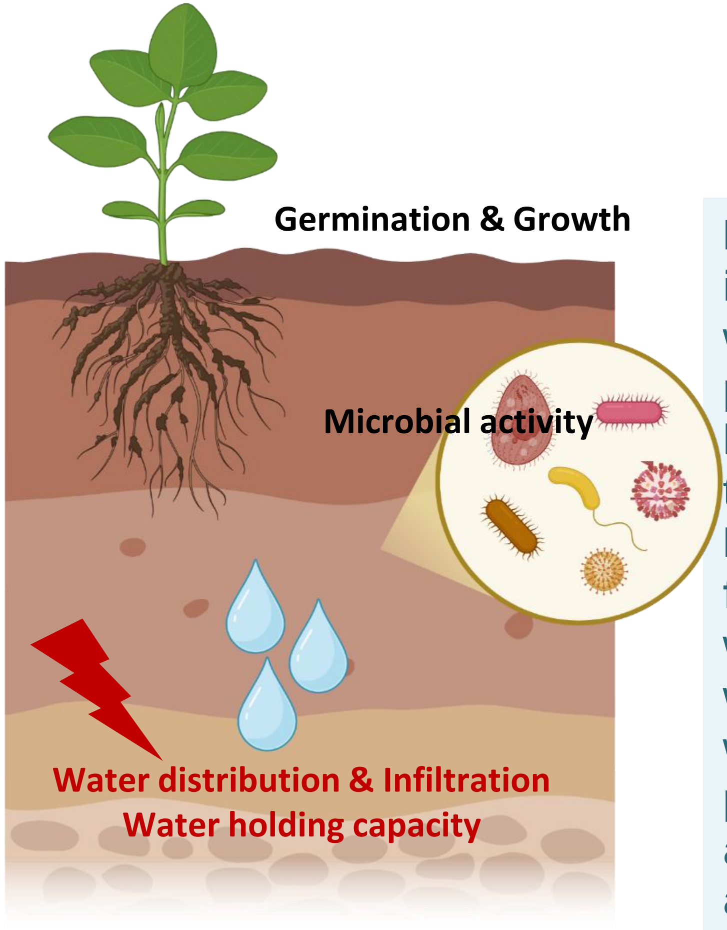
Effects of plastics on ecosystem functions: example of EF4

Ecosystem functions	
EF1	Gas regulation
EF2	Dissipation and mitigation of contaminants and wastes in terrestrial and aquatic ecosystems
EF3	Resistance to disturbance
EF4	**Water retention in SOIL and sediment**
EF5	Water flow regulation
EF6	Albedo and reflection
EF7	**Production and input of organic matter in terrestrial and aquatic ecosystems**
EF8	Nutrient regulation in terrestrial and aquatic ecosystems
EF9	**Formation and maintenance of soil and sediment structure**
EF10	Dispersion of propagules in terrestrial and aquatic ecosystems
EF11	Provision and maintenance of biodiversity and biotic interactions in terrestrial and aquatic ecosystems
EF12	Provision and maintenance of habitats and biotopes in terrestrial and aquatic ecosystems



Presence of plastic particles in soil systems: alteration of water distribution, infiltration pathways and subsequent water holding capacity, depending on the nature of the polymer

Plastic films, and probably fibres: potential alteration of water flow in soils by affecting water infiltration and absorption, with possible implications for plant germination and growth, and reduced soil microbiological activity

Effects of plastics on ecosystem services

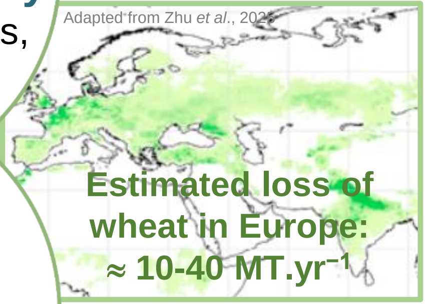
Common International Classification of Ecosystem Services

(Haines-Young and Potschin 2018)

Credit: Wilfried Sanchez

Crops
↘ biomass, productivity (rice, wheat and maize)

Livestock & poultry
Anorexia, weight loss, reduced growth



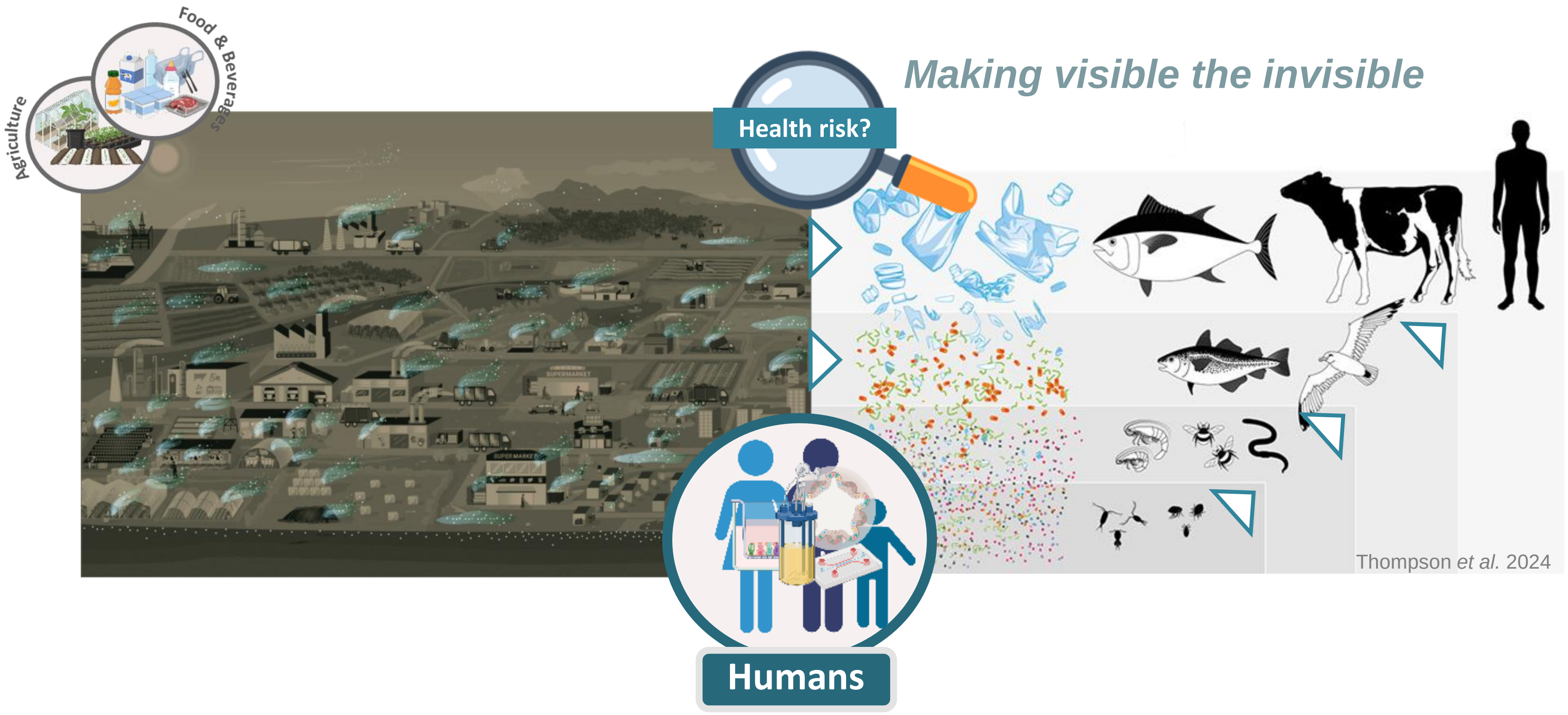
OM degradation
Soil alteration
Nutrient & energy reserves
Habitats for (micro)organisms
Disruption of the food chain

Plastics & their likely impact on human well-being to be further investigated (e.g. other anthropogenic stressors)

Human health & translational research for better risk assessment

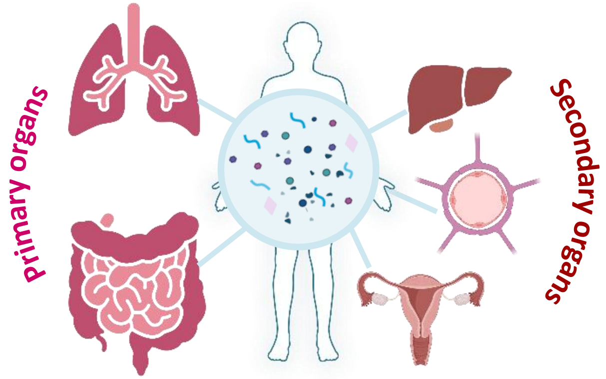
Mathilde Body-Malapel

Human health & Translational research for better risk assessment



In vitro *approaches are a step forward in the identification of common mechanisms of plastic toxicity to the gut, lung and secondary organs*

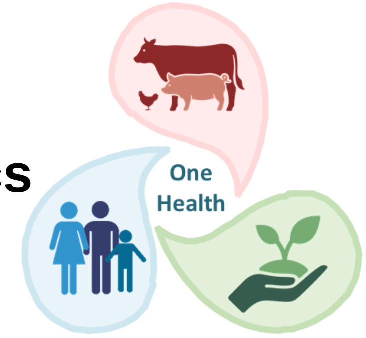
In vitro toxicity assessment

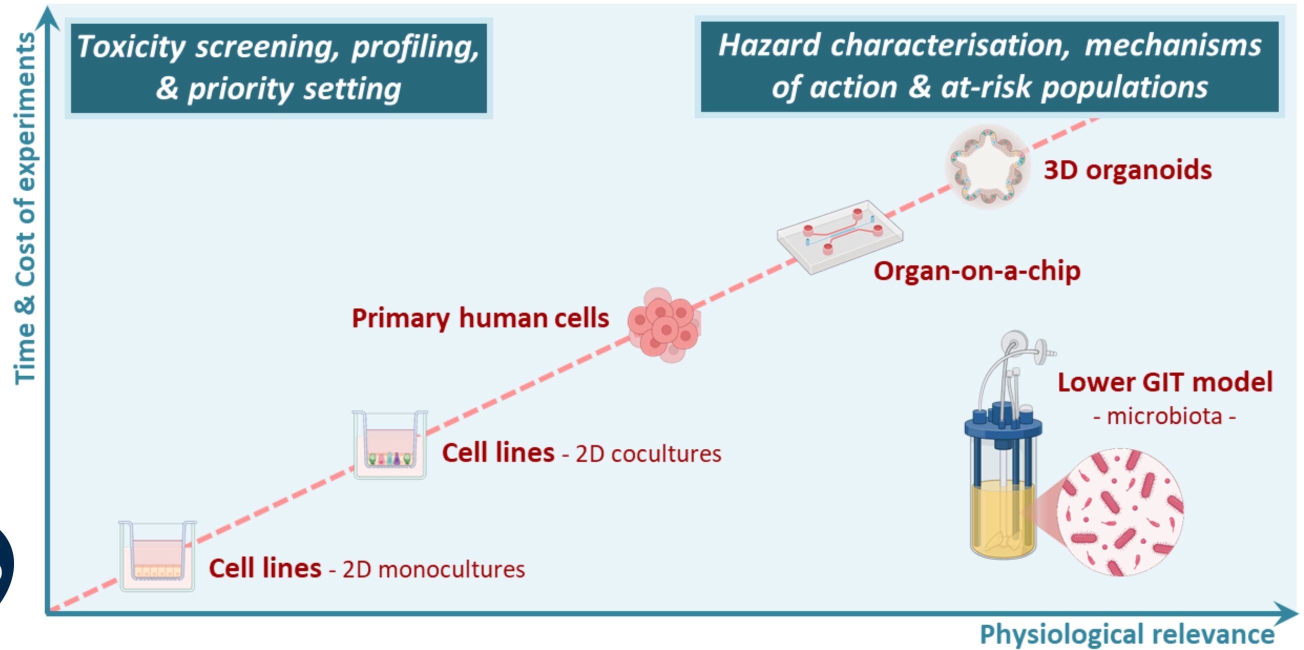


High doses & **variable** exposure scenarios

Mechanisms common to all organisms
Oxidative stress, cytotoxicity, genotoxicity, inflammatory response…

One Health for addressing the holistic adverse impact of plastics

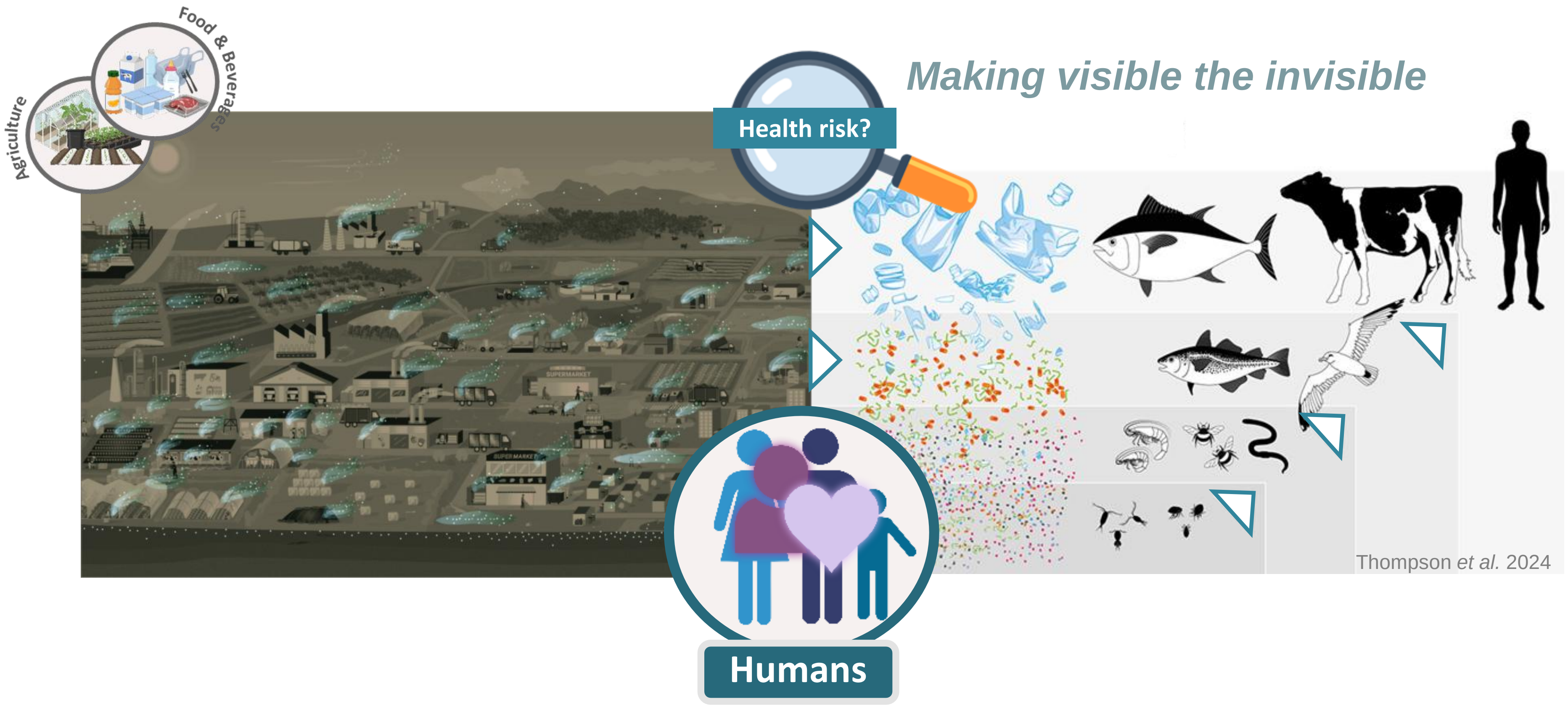




A necessary step from **basic** to more **advanced dynamic** *in vitro* models

Improved human health risk assessment

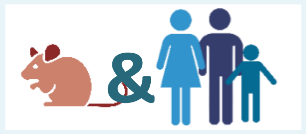
Human health & Translational research for better risk assessment



The role of plastics in promoting human disease is known to a different extent for plastic-related compounds than for particulate plastics

Plastic-related compounds & human disease: limited to additives

Only fully elucidated for bisphenol A and phthalates



	BPA		Phthalates	
	Preclinical level of evidence	Clinical level of evidence	Preclinical level of evidence	Clinical level of evidence
Asthma/allergy	Medium	High	High	High
Cancer	Medium	Medium	High	High
Cardiovascular diseases	Medium	High	Medium	High
Metabolic diseases	Medium	High	High	High
Developmental toxicity	High	High	High	High
Male reproductive toxicity	High	High	High	High
Female reproductive toxicity	High	High	High	High
Gastro-intestinal diseases	High	Low	Medium	Low
Hepatic diseases	Medium	NS	High	NS
Immune diseases	High	Low	Medium	Low
Neurological diseases	High	Medium	Medium	Medium
Pulmonary diseases	Low	Low	Low	Low
Renal diseases	Medium	High	Low	High
Thyroid diseases	High	High	Medium	High

***High**: toxicity recognised either by EFSA or by at least 1 meta-analysis*
***Medium**: toxicity recognised by at least 1 systematic review or by more than 3 consistent publications*
***Low**: toxicity found in 1 to 3 publications*
NS: not studied

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The burden of human diseases: an economic cost for the society

Estimates of the disease costs associated with phthalates and BPA for USA, Canada and European Union

Contaminant	Life stage of exposure	Outcome	USA		Canada		European Union	
			Disease burden (# cases)	Economic cost (billion USD)	Disease burden (# cases)	Economic cost (billion USD)	Disease burden (# cases)	Economic cost (billion USD)
Phthalates	Adult	Obesity	5,900	1.7	2,093	0.6848	53,900	20.8
	Adult	Type 2 Diabetes	1,300	0.0914	225	0.0258	20,500	0.8072
	Adult females	Endometriosis	86,000	47.0	10,151	5.7	145,000	1.7
	Adult males	Male infertility	240,100	2.5	1,395	0.017	618,000	6.3
	Adults	Cardiovascular mortality	90,800	39.9				
Bisphenol A	Prenatal	Childhood obesity	33,000	2.4	1,023	0.059	42,400	2.0

The Endocrine Society

➲ **Lacking a comprehensive view for other diseases and countries**

Tolerable daily intake limits: protection of European citizens

Phthalates & BPA: recognised as endocrine-disruptive chemicals

Updated group tolerable daily intake (TDI) of phthalates in food

2019

Group TDI for:

1. DEHP (Bis(2-ethylhexyl) phthalate)
2. DBP (Dibutyl phthalate)
3. BBP (butylbenzyl phthalate)
4. DINP (di-isononyl phthalate)
5. DIDP (di-isodecyl phthalate)

50 µg/kg bw/day

Updated tolerable daily intake (TDI) of BPA in food

2015

4 µg/kg
body weight per day
(temporary TDI)

2023

0.2 ng/kg
body weight per day
(full TDI)

BPA exposure is much higher than the new TDI*

BPA exposure
>>>
new TDI
=
health concern
for all age groups

*Based on 2015 exposure levels

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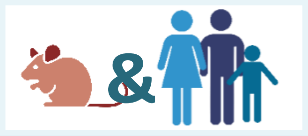
Particulate plastics & human disease: limited to preclinical studies



	Microplastics		Nanoplastics	
	Preclinical level of evidence	Clinical level of evidence	Preclinical level of evidence	Clinical level of evidence
Asthma/allergy	Low	Not studied	Not studied	Not studied
Cancer	Not studied	Not studied	Low	Not studied
Cardiovascular diseases	Low	Not studied	Low	Not studied
Metabolic diseases	Low	Not studied	Low	Not studied
Developmental toxicity	Medium	Not studied	Medium	Not studied
Male reproductive toxicity	Medium	Not studied	Medium	Not studied
Female reproductive toxicity	Medium	Not studied	Medium	Not studied
Gastro-intestinal diseases	Medium	Low	Medium	Not studied
Hepatic diseases	Medium	Not studied	Low	Not studied
Immune diseases	Medium	Not studied	Not studied	Not studied
Neurological diseases	Medium	Not studied	Medium	Not studied
Pulmonary diseases	Medium	Not studied	Medium	Not studied
Renal diseases	Medium	Not studied	Low	Not studied
Thyroid diseases	Not studied	Not studied	Not studied	Not studied

High: toxicity recognised either by EFSA or by at least 1 meta-analysis
Medium: toxicity recognised by at least 1 systematic review or by more than 3 consistent publications
Low: toxicity found in 1 to 3 publications

Wide toxicity of PS MNPLs from 20 µg/kg bw/day

Lowest Observed Adverse Effect Level (LOAEL)

	Spherical PS Microplastics	Spherical PS Nanoplastics
Asthma/allergy		
Cancer		
Cardiovascular diseases		
Metabolic diseases		
Developmental toxicity	20 **µg**/kg bw/day	20 **µg**/kg bw/day
Male reproductive toxicity	20 **µg**/kg bw/day	20 **µg**/kg bw/day
Female reproductive toxicity	20 **µg**/kg bw/day	20 **µg**/kg bw/day
Gastro-intestinal diseases	20 **µg**/kg bw/day	20 **µg**/kg bw/day
Hepatic diseases	20 **µg**/kg bw/day	
Immune diseases	80 **µg**/kg bw/day	
Neurological diseases	6.5 **ng**/kg bw/day	450 **µg**/kg bw/day
Pulmonary diseases	1.25 **mg**/kg bw/day	4.5 **mg**/kg bw/day
Renal diseases	20 **µg**/kg bw/day	

M. Body-Malapel - CSA Extended Report

Spherical shape & only one polymer (PS)

Bridging basic & clinical research
Bridging analytical developments & epidemiological studies

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Q&A session

Is a sustainable system of plastics used in agriculture and for food possible?

Plastics used in agriculture and for food are entangled in a complex plastic sociotechnical system

Plastics used in agriculture and for food are entangled in a complex plastic sociotechnical system

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Regulation of the plastics' sociotechnical system

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Regulation of the plastics' sociotechnical system

Pierre-Etienne Bouillot

based on a contribution by
Delphine Notelet, Pierre-Etienne Bouillot, François Dedieu, Eugenia Lampi, Anaïs Tibi, Lise Paresys

Regulation of the system of plastics: a difficult pathway towards sustainability

- A legal framework driven by:
  - economic freedom
  - health and environmental protection objectives
- divided into:
  - food contact material
  - waste
  - and chemicals regulations

	Plastic production	Plastic use				Plastic post-use			
	Monomers, additives, processing aids, polymers…	Food packaging (FCM)	Non-packaging FCM	Agri-food packaging	Agri-food objects	Food packaging (FCM)	Non-packaging FCM	Agri-food packaging	Agri-food objects
Food contact materials	✓ *if intended use for FCMs*	✓	✓			✓ *if recycled*	✓ *if recycled*		
Chemicals	✓								
Waste		✓		✓	✓ *If oxodegradable*	✓	✓	✓	✓

Notelet et al., *CSA extended report*

Legal areas applying to plastic ingredients, plastic objects and plastic waste

Regulation of the system of plastics: a difficult pathway towards sustainability

Plastics lately addressed as a specific object of regulation

- Plastics are defined as a mixture of chemical substances, as a material or as an object, depending on the legal area
- An evolving (plastic) definition of plastics, also depending on the legal area considered

Plastics in the scope of plastic FCMs regulations, from the first definition of plastics to the regulation in force.

	Directive 82/711/EEC	Directive 90/128/EEC	Directive 2001/62/EC	Directive 2002/72/EC	Regulation (EU) No 10/2011
Elastomers	–	–	–	–	? (except for silicones)
Silicones	+ Because not considered as elastomers at the time	+	– Because considered as elastomers	–	–
Paper and cardboard modified or not by the addition of plastic	–	–	–	–	?
Coatings derived from paraffin or micro-crystalline waxes and mixtures of these waxes with each other and/or with plastics	–	–	–	–	?
Multi-material multi-layer (one of which is not plastic)	–	–	–	–	+

Notelet et al., *CSA extended report*

(green)	In force
(grey)	Not in force
+	Regarded as plastics or in the scope of the text
–	Not regarded as plastics or not in the scope of the text
?	Not mentioned in the text

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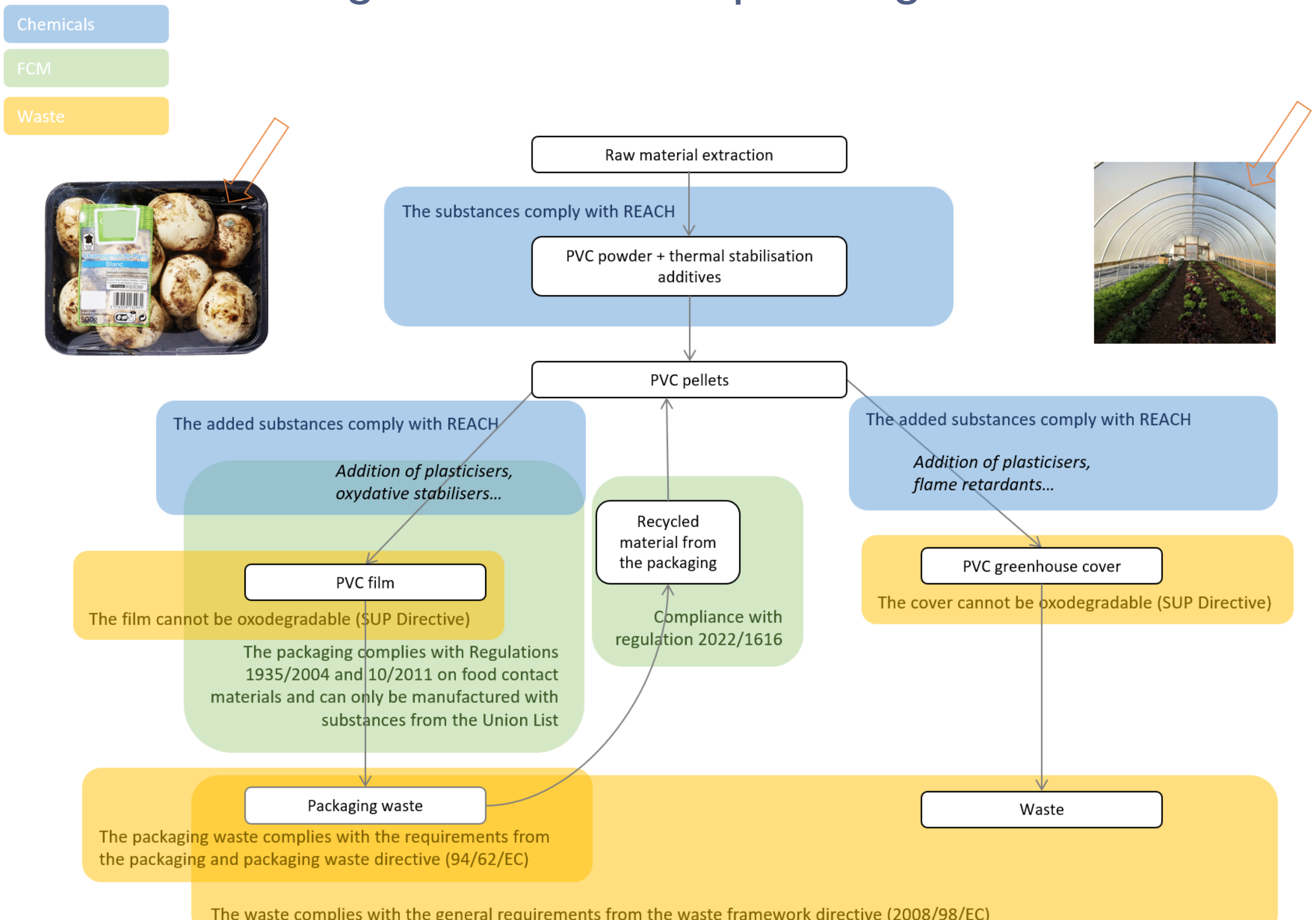
Regulation of the system of plastics: a difficult pathway towards sustainability

Diagram of the different legal treatment depending on use: case of PVC



Notelet et al., *CSA extended report*

Regulation of the system of plastics: a difficult pathway towards sustainability

Plastics regulation focuses on the tip of the iceberg

- A large proportion of plastic-related chemicals, including hazardous ones, are unregulated
  - regulations focus on certain molecules that are already relatively well known (e.g. phthalates, bisphenols)
  - Regulation overlooks the safety evaluation of polymers, for debatable reasons
  - Waste regulations focus on a handful of macroplastic objects, overlooking other macroplastics, other sectors and micro- and nanoplastics

- Regulations do not take into account plastics in the early stages of the food chain value, even though they may come into contact with food

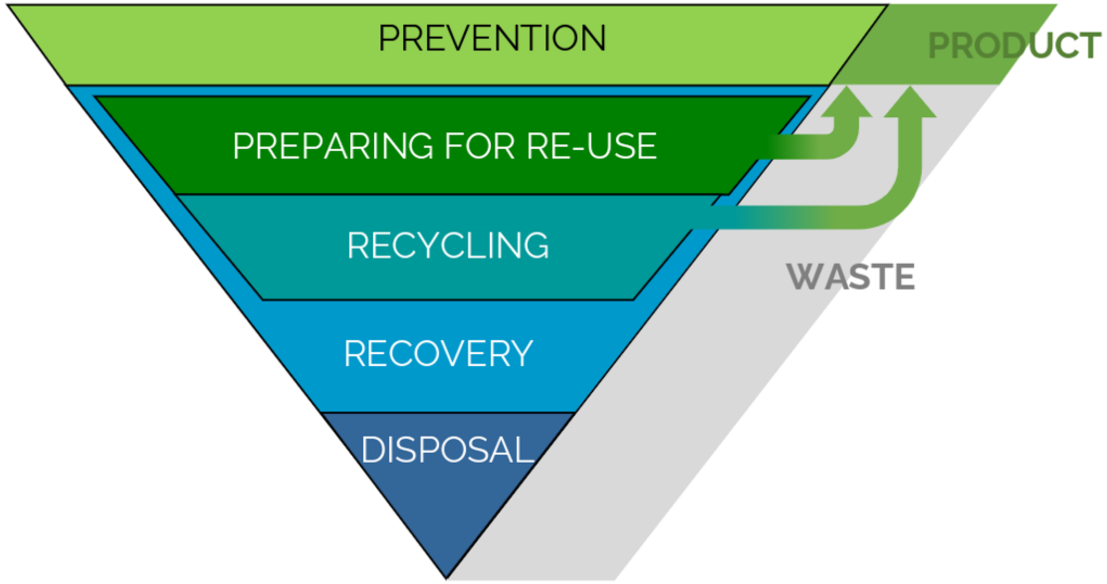
	FCM		**Waste**			**Chemicals**
	1935/2004	10/2011	94/62	2008/98	2019/904	REACH
Plastics used in agriculture	No	No	Yes (general)	Yes (general)	Yes for oxodegradable plastics	Yes (general + microplastics)

Notelet et al., *CSA extended report*

Regulation of the system of plastics: a difficult pathway towards sustainability

Plastics regulation is mostly curative

- Plastics regulation focuses on waste management, and plastics in particular
- No cap on the production of plastics
- Prevention and precautionary measures are limited

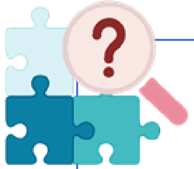


Hierarchy among prevention and waste management options

Regulation of the system of plastics: a difficult pathway towards sustainability

Corporate leverage on regulation

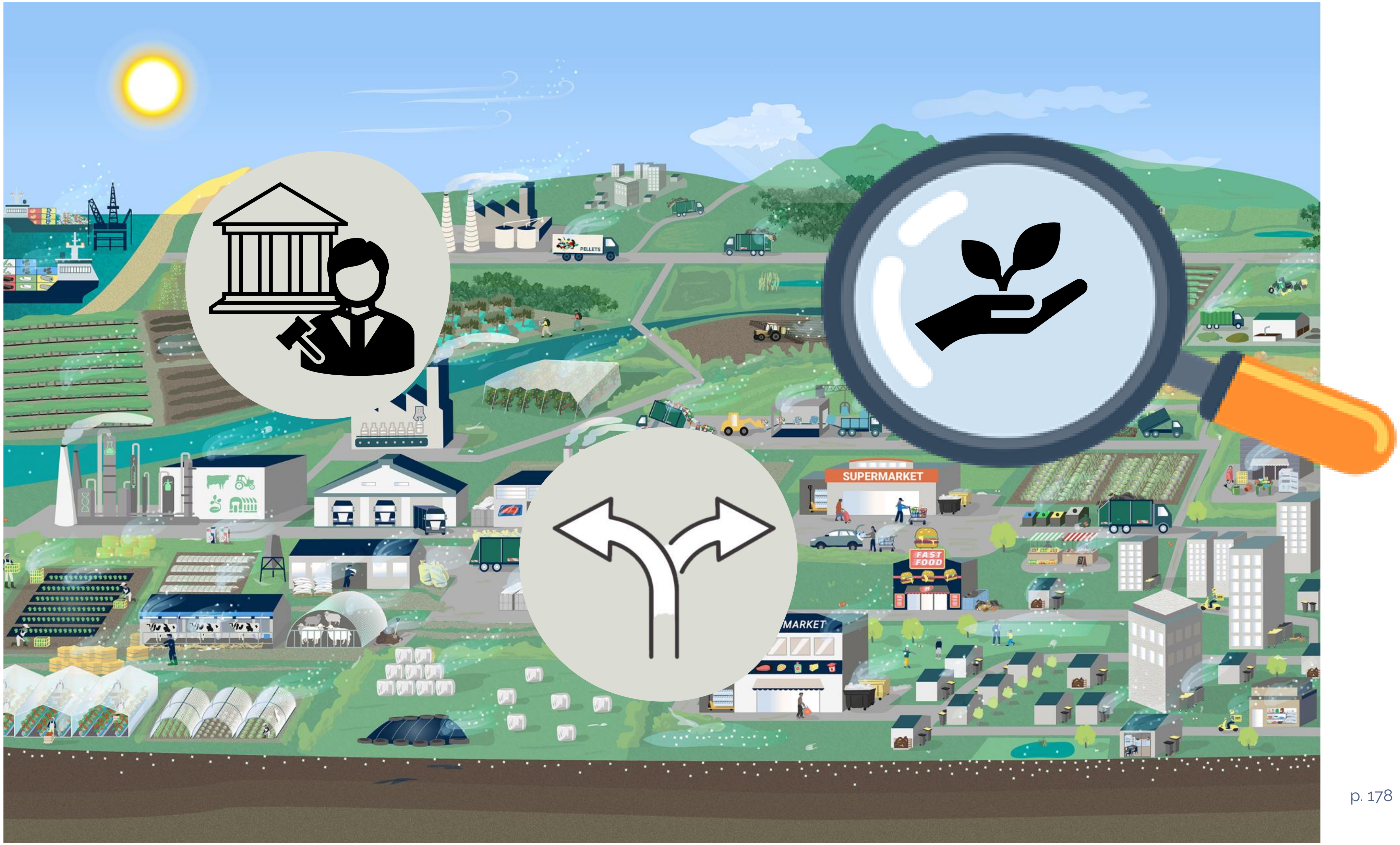
- Corporate **lobbying** uses tactics like **diversions**, **marketing**, and **opposing regulations**.
- Through promotion of circular economy, **industries emphasise consumer responsibility** and recycling, avoiding plastic production issues.
- **Public and corporate expertise interplay** in shaping plastic regulations.



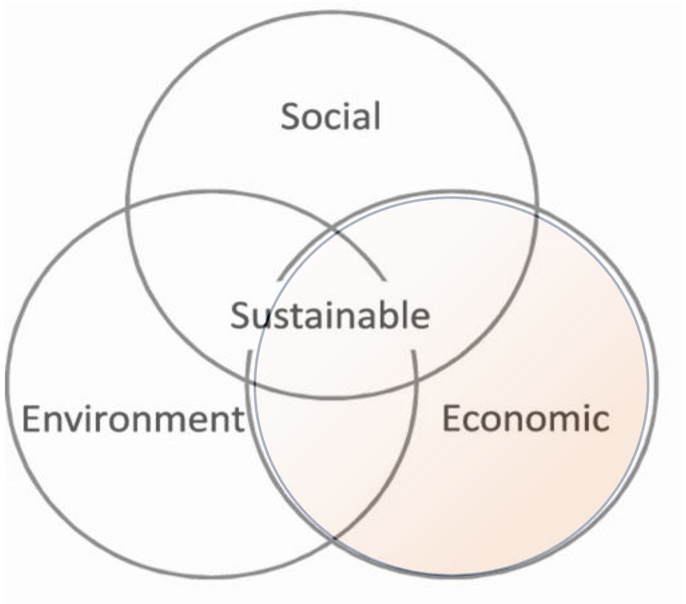
Research needs:

- **Expand legal research on plastics** to assess limitations of existing laws.
  - Focus on regulation of food contact materials (FCMs) for safety.
- **Explore regulatory measures** for micro- and nanoplastics.
  - F.i: MPL residues in organic fertilisers and address limitations in regulations concerning plastic residues in composting (MPLs<2mm).
- **Facilitate access to industrial archives**.

Assessment of plastics’ sustainability and mitigation strategies



Sustainability of the system of plastics is mostly reduced to a promise to improve the circularity in economy, through recycling processes



Sustainability ?
WCDE, 1987

The 4R scheme
source World Bank, 2012

Circularity of plastic system is mostly focused on recycling strategies, where scientific literature explains that **prevention/reduction should be prioritised**.

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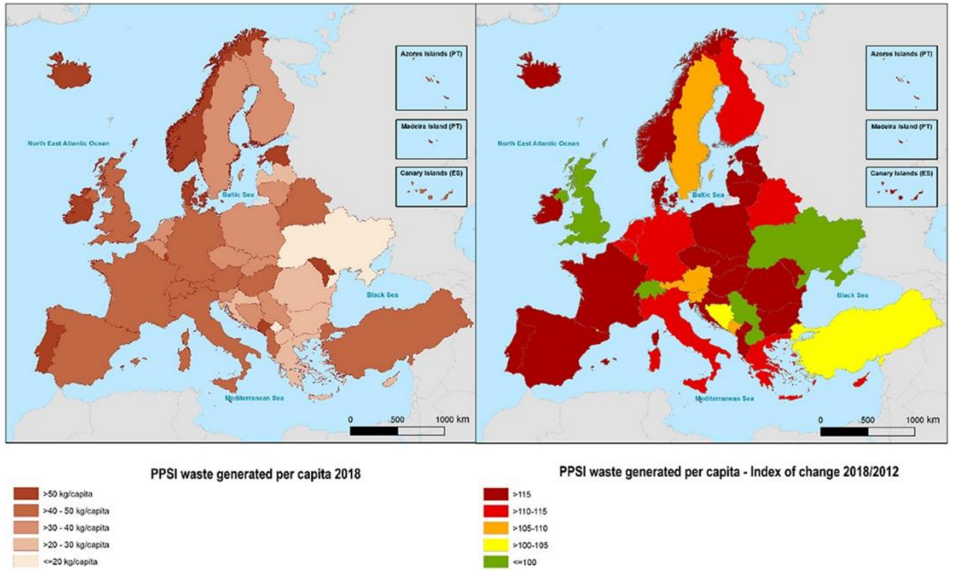
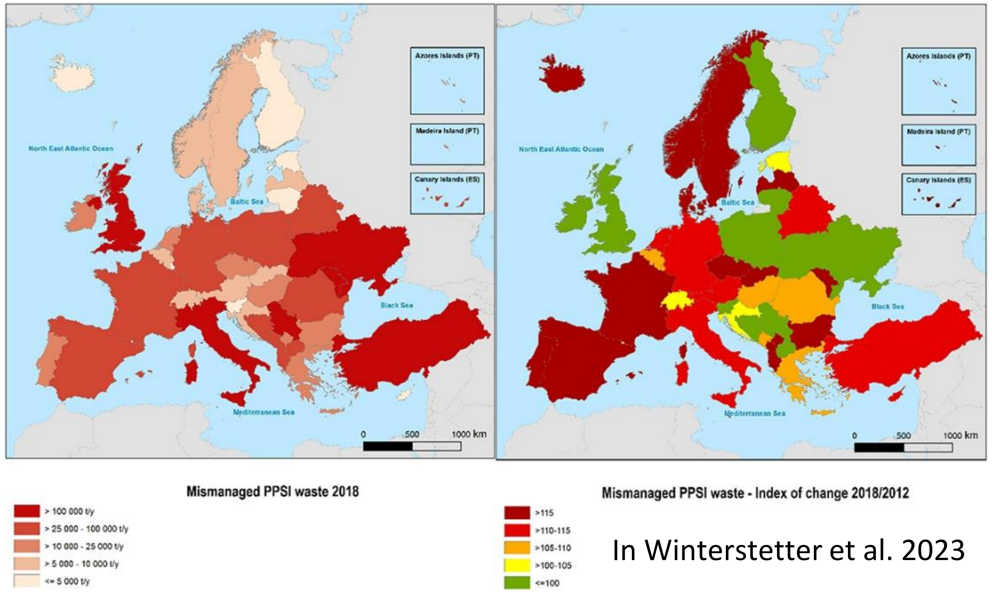
Prioritising plastic recycling over plastic production reduction is a counterproductive mitigation strategy as…



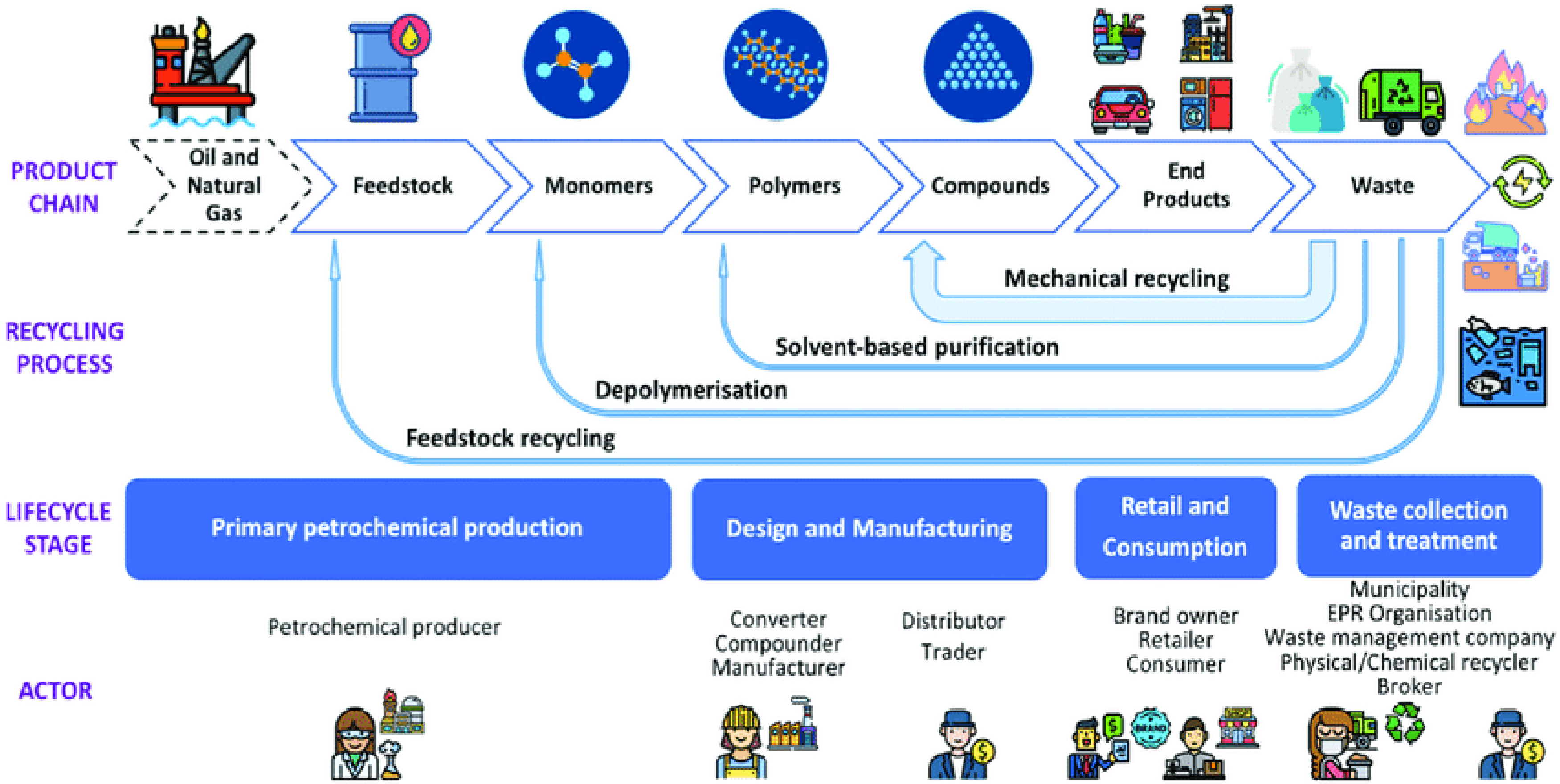


In Winterstetter et al. 2023

… plastic recycling alone cannot overcome the ever-increasing plastic consumption, mismanaged plastic waste and plastic pollution

Prioritising plastic recycling over plastic production reduction is a counterproductive mitigation strategy as…

Plastics recycling: many actors, many technologies, many materials



Hsu et al., 2022

Profitability of plastics recycling is globally debated…

…and appears non profitable for other plastics than rigid PET and PEHD

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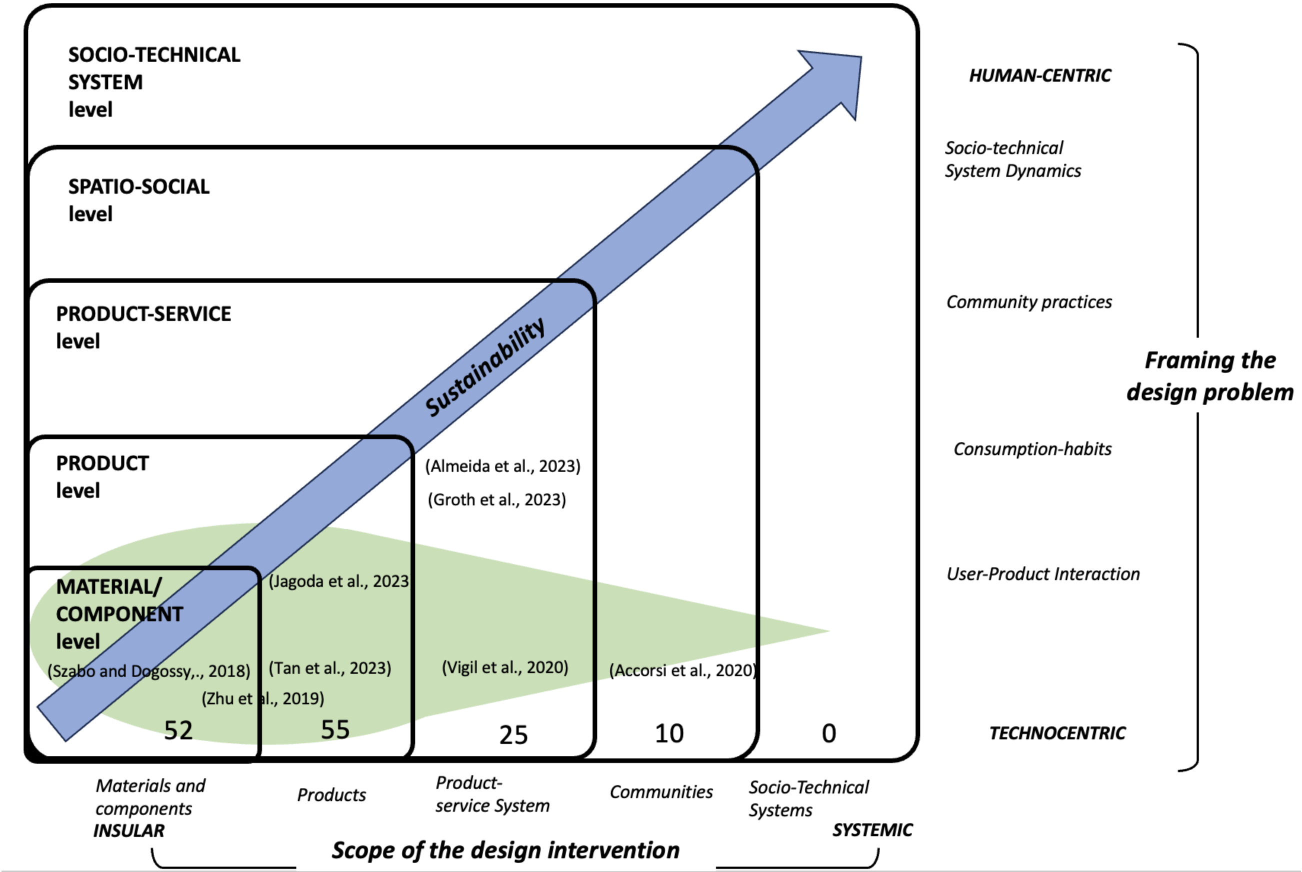
A reductive assessment of plastic sustainability in decision-making processes…

LCA is a hegemonic but limited tool…

… leading to the implementation of irrelevant mitigation strategies



The design levels and scope of the DfS field including paper from the corpus. Adapted from (Ceschin and Gaziulusoy, 2019)

LCA is the main tool to assess plastic sustainability in all its dimensions (including human health) as well as to develop eco-design strategies, but is **too reductive and leads to irrelevant mitigation strategies.**

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Alternatives: strategies of reduction

Strategies of reduction: reliable options have yet to be found

Substitution: most of the studied alternatives to plastics are…

… plastics and not alternative materials or practices

The scientific literature dedicated to approaches to sustainability **focuses on research for substitutes for conventional plastics** by looking for materials **with similar functional properties without questioning their objective of use.**
Because bio-based and biodegradable plastics are still **not economically viable** and because they pose **environmental issues**, they are not a reliable option.

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Strategies of reduction: reliable options have yet to be found

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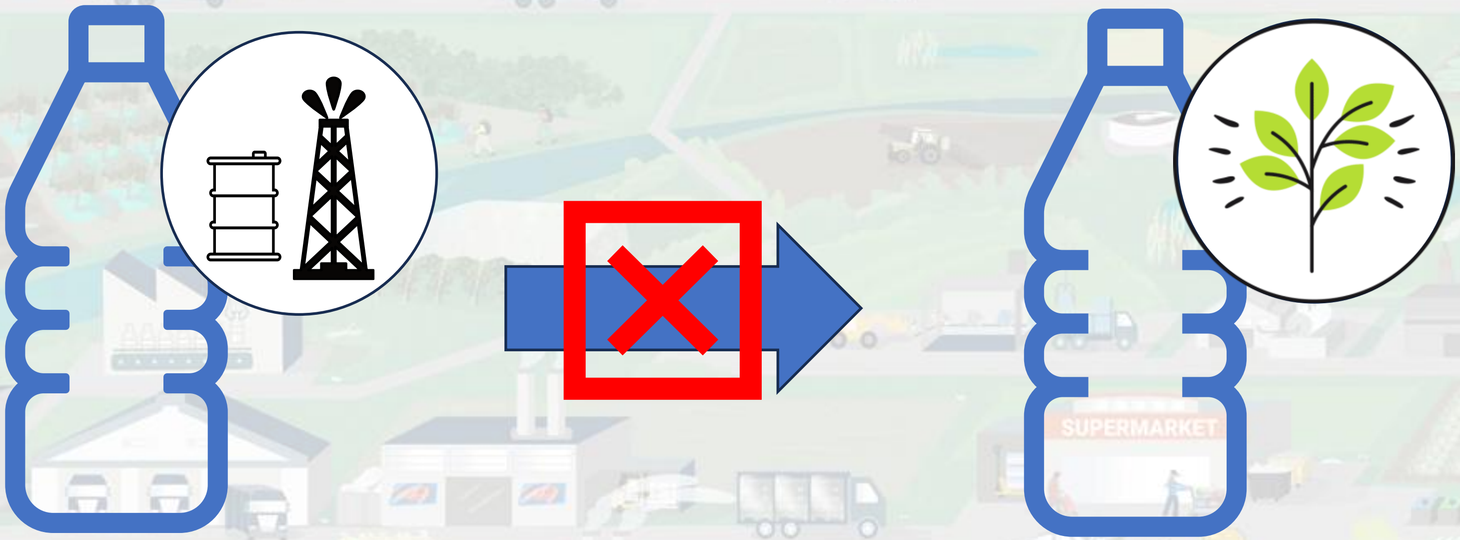

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Strategies of reduction: reliable options have yet to be found

Upstream strategies are a priority to reduce the production and consumption of plastics

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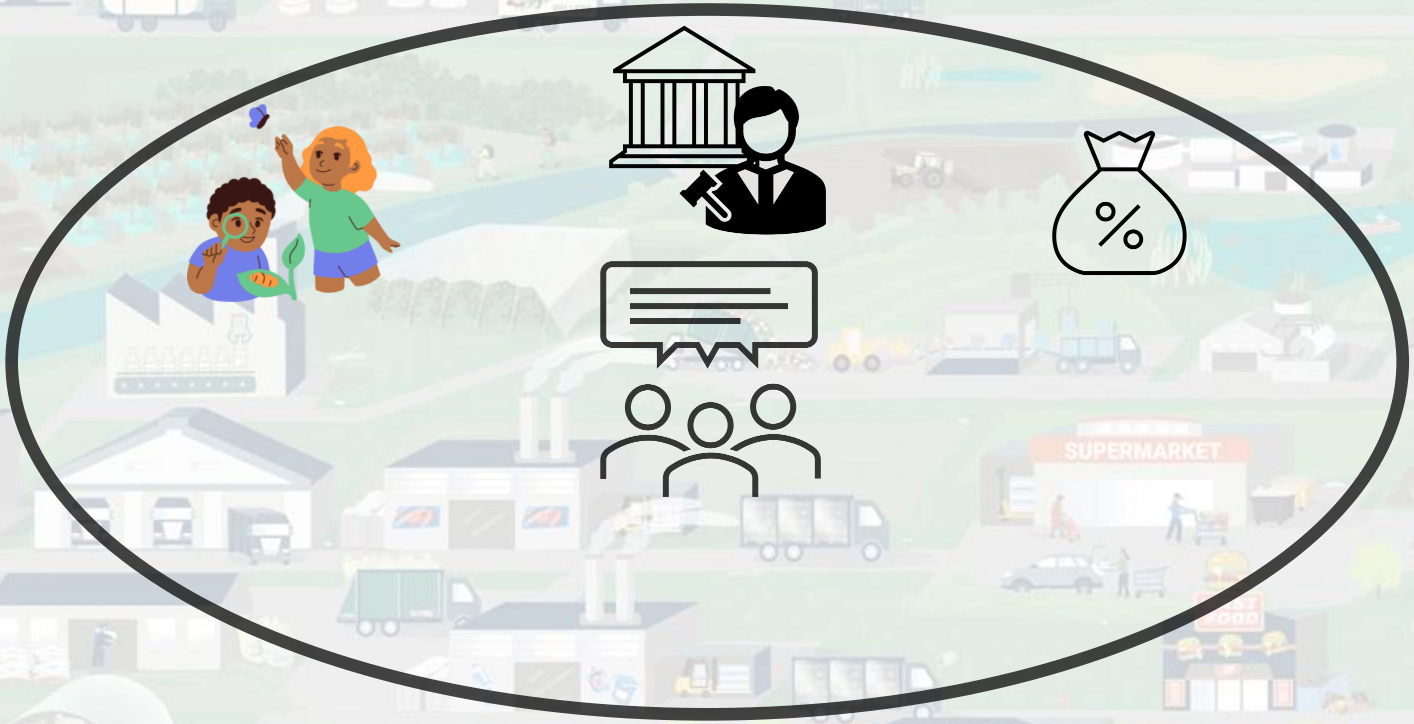

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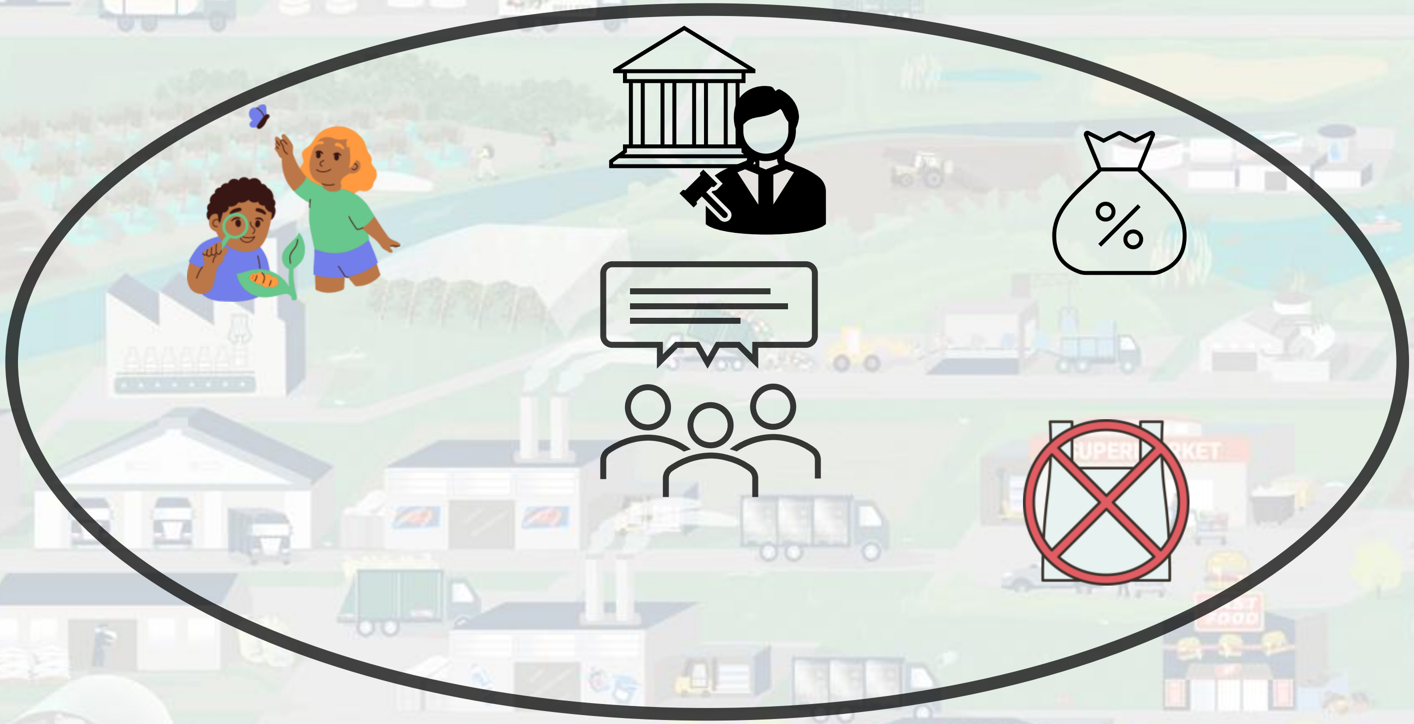

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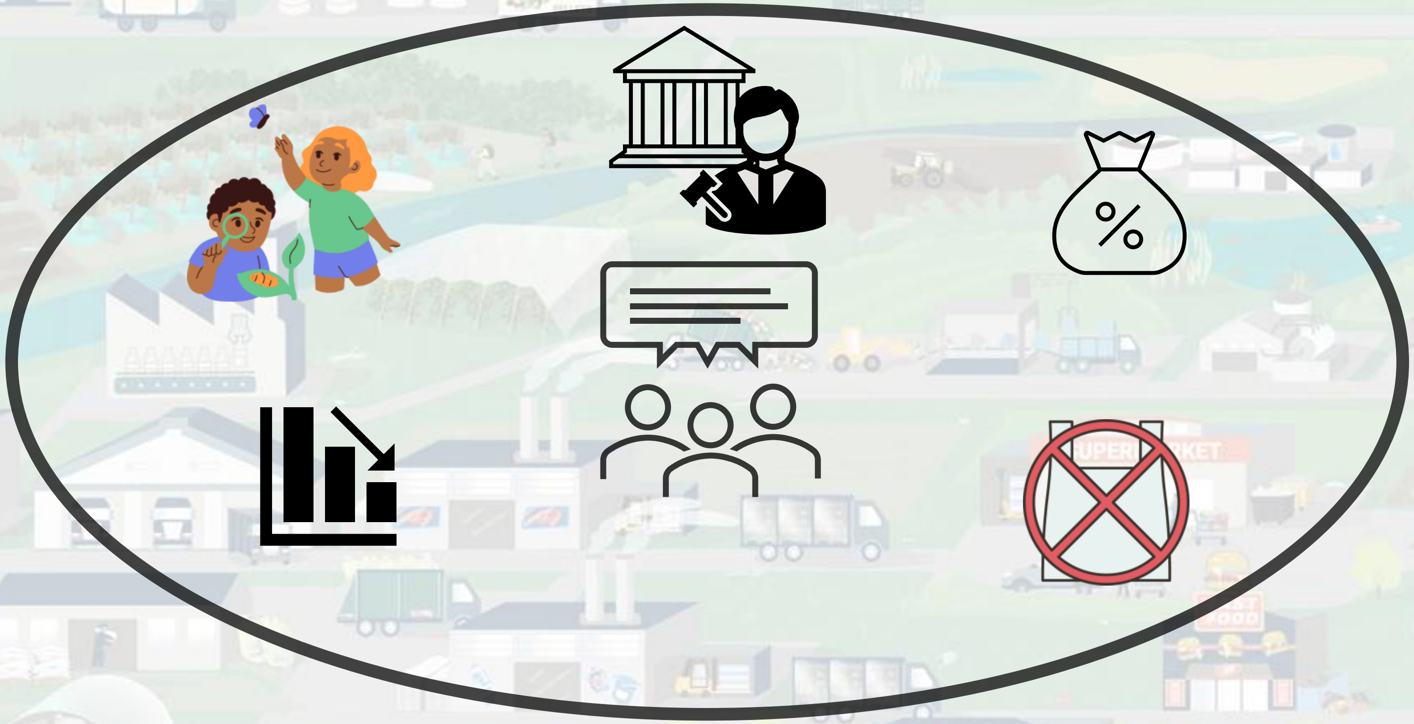

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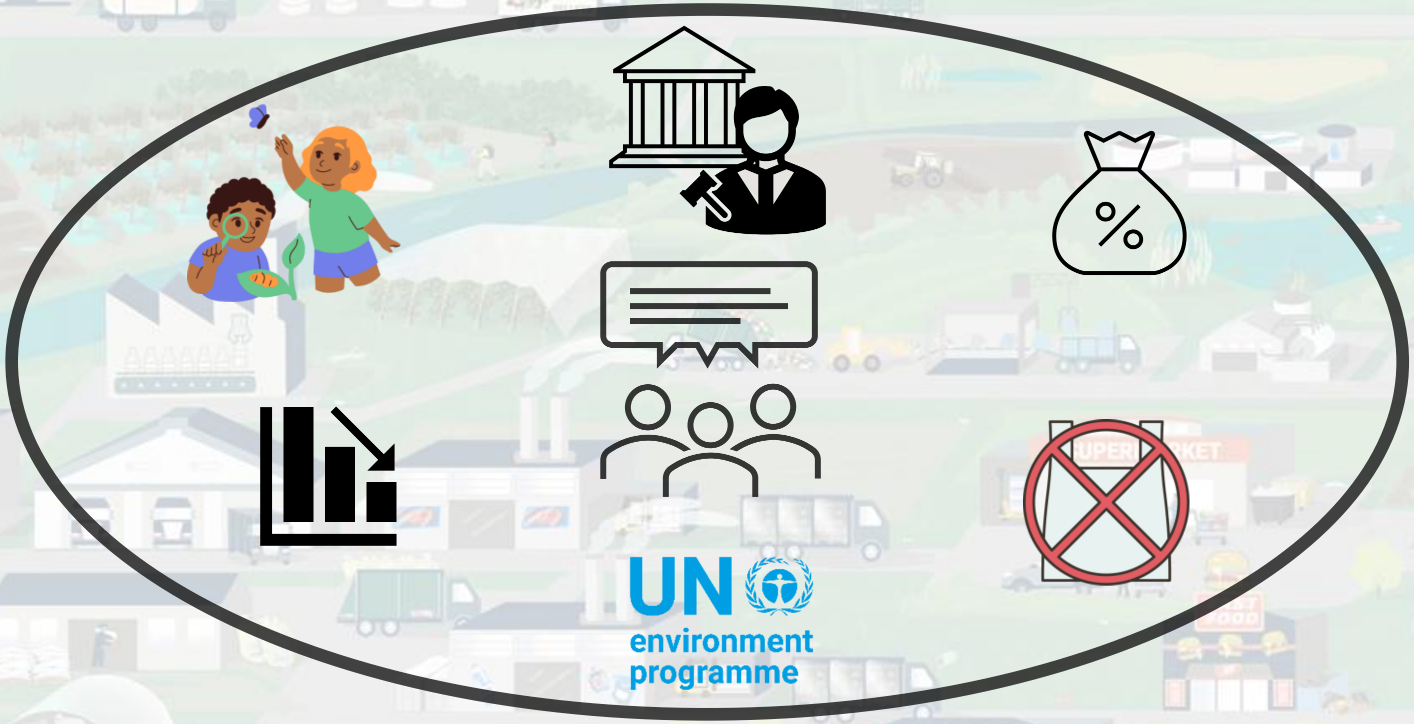

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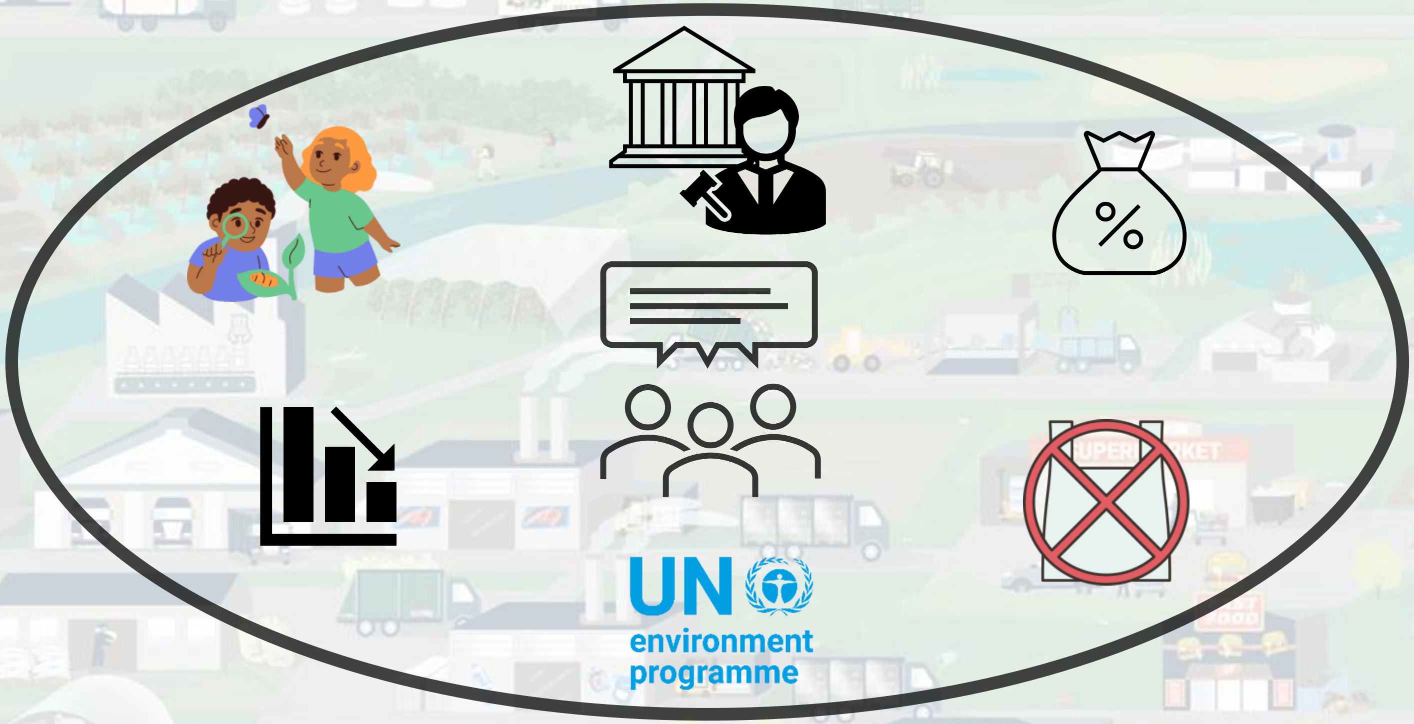

If the objective of **reduction of production and consumption of raw plastics** appears **consensual in scientific literature,** the research on actual means on how to achieve **reduction strategies remains limited.**

Conclusion

In brief

Because of their many uses, plastics are now structuring both technically and culturally the food value chains, particularly downstream: their versatility has encouraged greater complexity in their formulations, making their waste management very difficult.
Their omnipresence in continental ecosystems and in the human body, and their proven impacts at all levels, therefore call into question the very possibility of making the use of plastics in agriculture and food sustainable.

Du fait de leurs usages nombreux, les plastiques structurent aujourd'hui tant techniquement que culturellement les chaînes de valeur alimentaire, en particulier à l'aval: leur versatilité a encouragé la complexification de leurs formulations ce qui contribue à compliquer très largement leur gestion à l'état de déchet.
Leur omniprésence dans tous les écosystèmes continentaux et dans le corps humain et les impacts avérés à toutes les échelles viennent donc questionner la possibilité même de rendre soutenables les usages des plastiques dans l'agriculture et l'alimentation.

Knowledge gaps & Research needs

- Strengthen **field research** to **understand plastic usage** in food value chains.
- **Track plastic flows** from production to waste **to assess their impacts**.
- **Address the hazardous nature** of plastics using a **One Health** research approach.
- Develop **scenarios for reducing plastic** production and consumption.
- **Clarify implications of plastic use** in food value chains.
- Focus on **simplifying plastic systems and formulations**.
- Contribute to **scientific efforts for systemic transformation** in food value chains.

> More Interdisciplinarity

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Expertise scientifique collective sur les plastiques utilisés en agriculture et pour l'alimentation

Paris, 23 mai 2025

MINISTÈRE DE LA TRANSITION ÉCOLOGIQUE, DE LA BIODIVERSITÉ, DE LA FORÊT, DE LA MER ET DE LA PÊCHE
Liberté Égalité Fraternité

MINISTÈRE DE L'AGRICULTURE ET DE LA SOUVERAINETÉ ALIMENTAIRE
Liberté Égalité Fraternité

ADEME
AGENCE DE LA TRANSITION ÉCOLOGIQUE

Table ronde

Philippe Bolo, Député, rapporteur de l'OPESCT

Gilles Robillard, Président de Terres Inovia

Ronan Vanot, Directeur général d'ADIVALOR

Ariane Voyatzakis, Directrice de l'innovation et de la prospective de l'ANIA

Lauren Weir, Ocean Campaigner à l'EIA

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> More Interdisciplinarity

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La grande vague (2024) et Trash (2023), peinture éco-responsable sur herbe

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