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Circularity of EEE: legend or reality?

Current situation and Challenges

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June, 17th

SUSTAIN-E Summer School on Sustainable Electronics

What do you think?

Circular Electronics

A- A legend?

B- A reality?

C- An achievable goal?

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Circularity and EEE: current situation

(Towards Recycling Indicators based on EU flows and Raw Materials System Analysis data, JRC 2018)

(Adapted from ICT4S conference, Parry, Charbuillet, Sannier)

Circularity as a solution?

6,9% return of secondary materials to the global economy by 2024

Circle Economy. (2025). The circularity gap report 2025

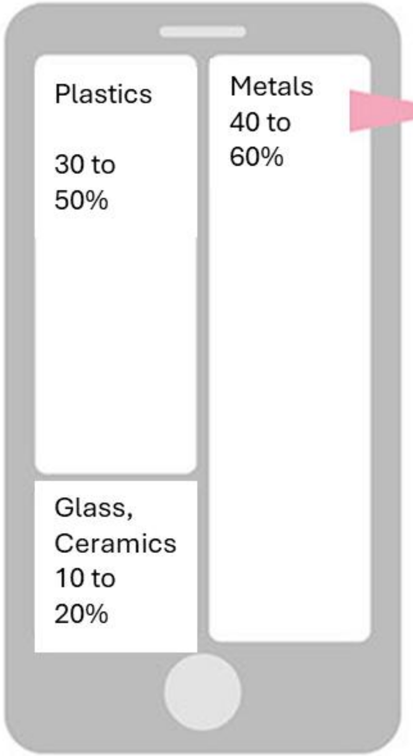
Circularity level of EEE?

Circularity and EEE: the European organisation

Waste from Electrical and Electronic Equipments (WEEE)
Extended Producer Responsibility System (EPR)
European Regulation (2002 rev 2019)
PROs (Eco-organisms)

e.g. The French organisation

Small devices and small IT devices (categories 5 and 6)



Metals distribution

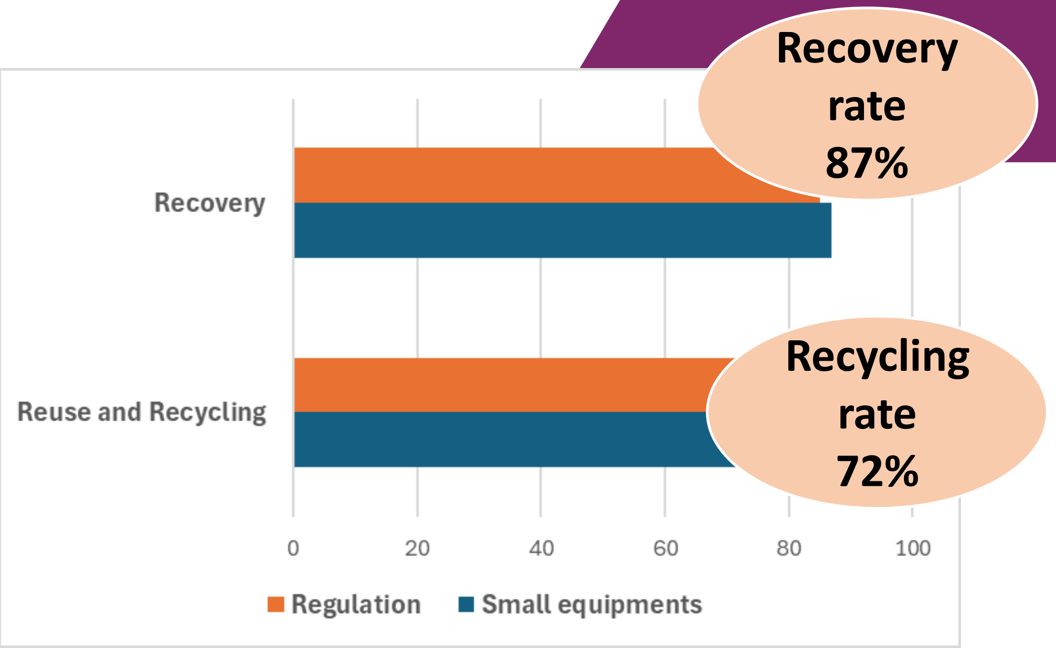
80- 85% ferrous and no ferrous metals (Cu, Al, Sn, Cr, Ni...)

0,5% Precious metals (Au, Ag, Pt....)

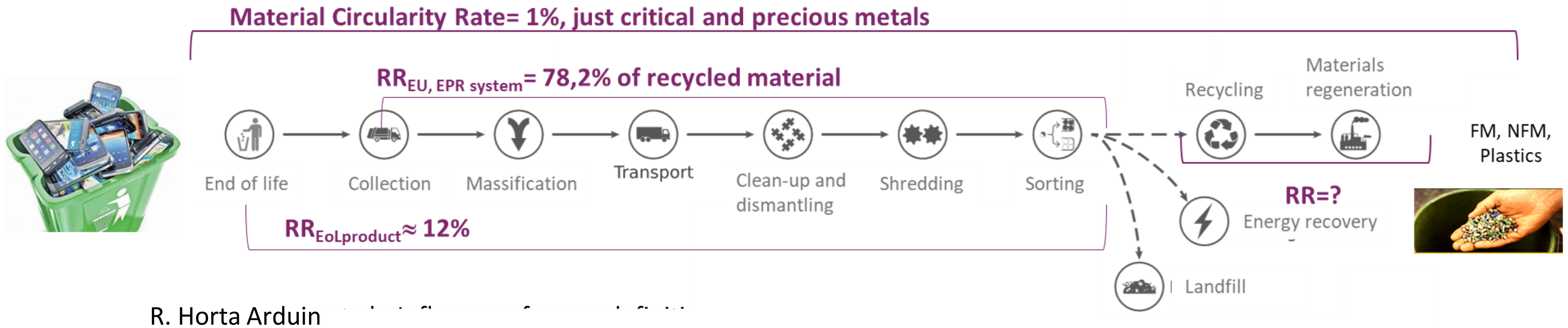
0,1% Rare earths (Y, Ga, In, Ta...)

15-20% Others (Co, Li...)

Source: Oeko-Institut, EcoInfo et Sénat



(ADEME 2022- Rapport annuel EEE- Données 2021 mis en ligne 10/2023)

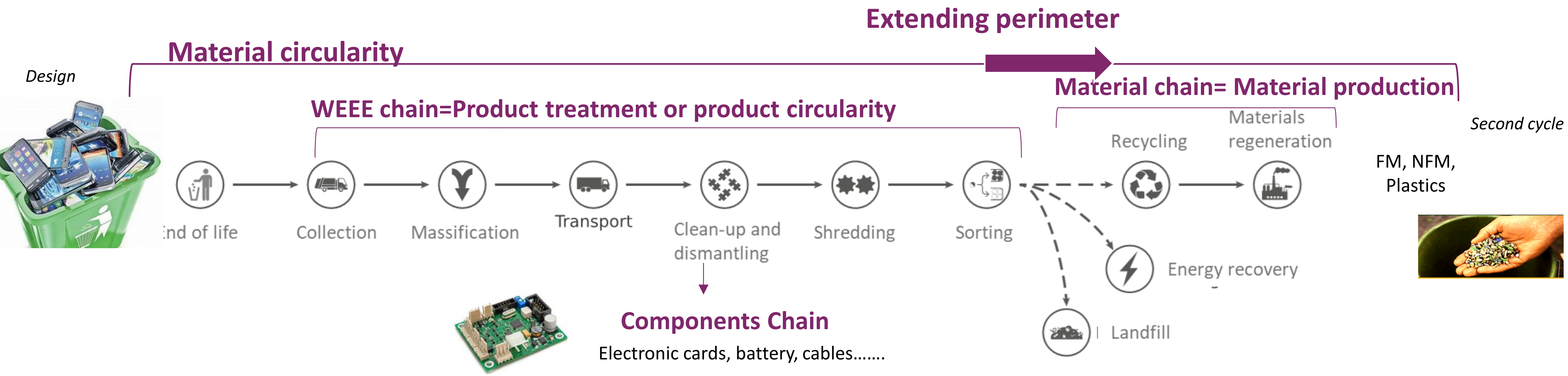


R. Horta Arduin
European e-waste extended producer responsibility - Waste Management, 84 (2019)

Why there is a difference?

Why there is a difference?

First Challenge = Rate calculation



weight of e-waste collected

material content per component

efficiency of the final recycling/regeneration

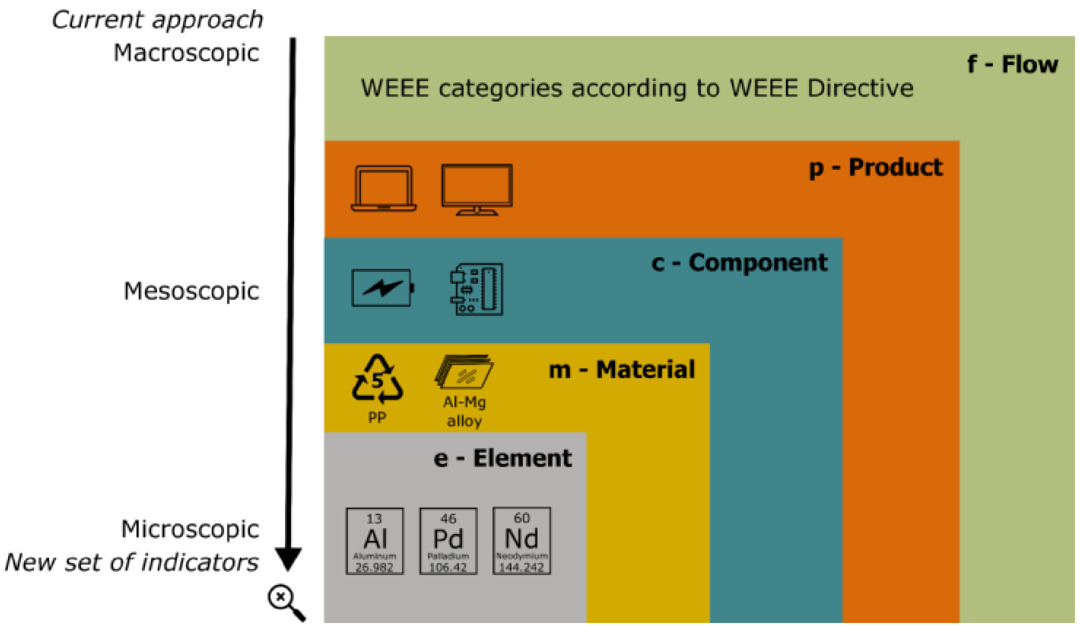
$$R_{COV} = \frac{\sum (m_i \times RVR_i)}{m_{EEE}} \times 100$$

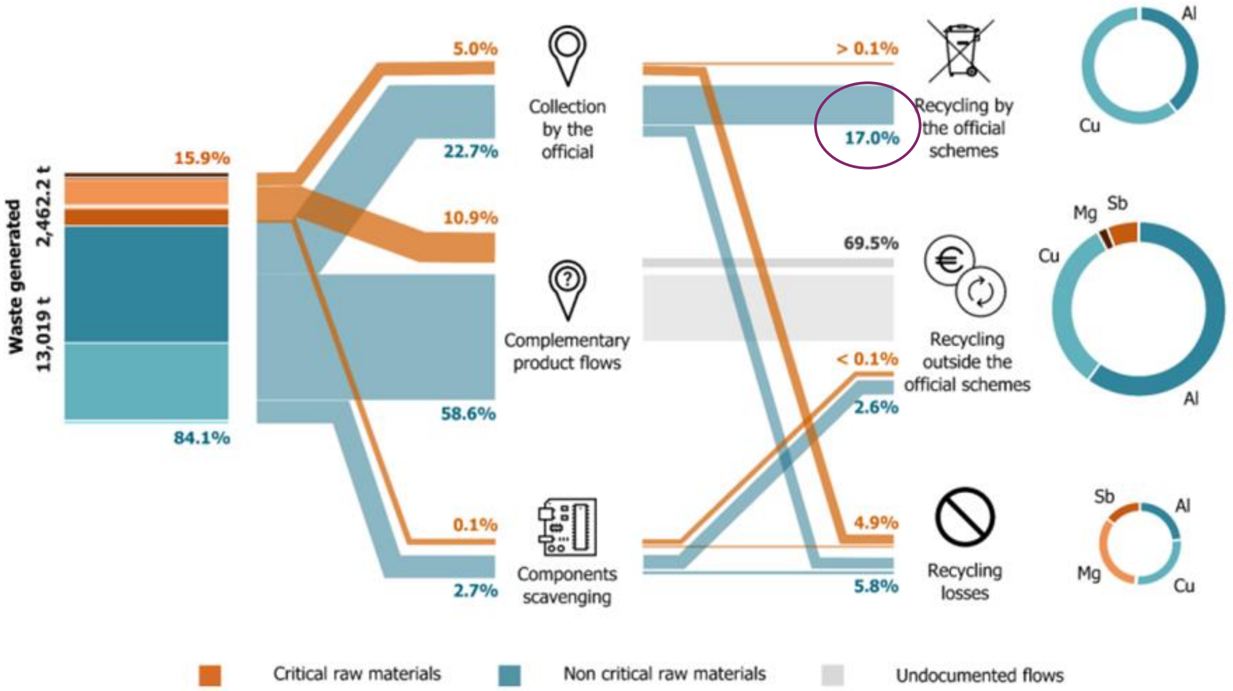
$$RR_e = \frac{\sum_{i=1}^{n} WC_i \times \sum_{j=1}^{n'} CH_{eij} \times (1 - SG_j) \times \sum_{k=1}^{n''} SR_{ek} \times PR_{ek}}{\sum_{i=1}^{n} WG_i \sum_{j=1}^{n'} CH_{eij}}$$

weight of e-waste generated

Why there is a difference?

Second Challenge=The calculation perimeter (Product/ material)- Recycling vs Circularity definition

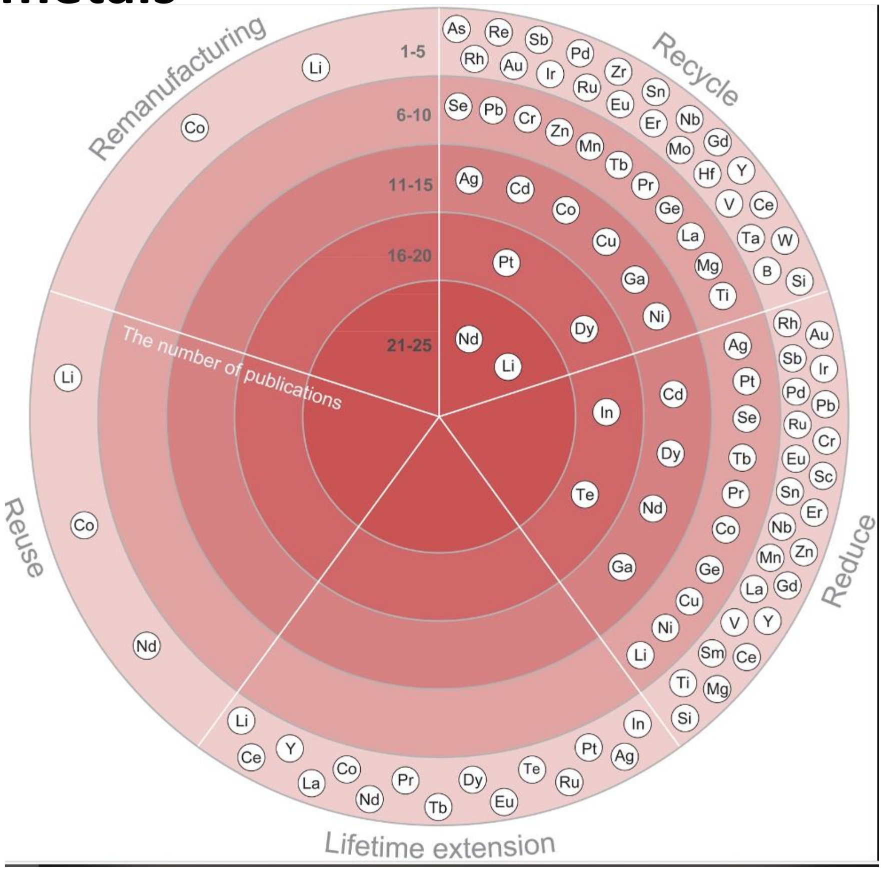




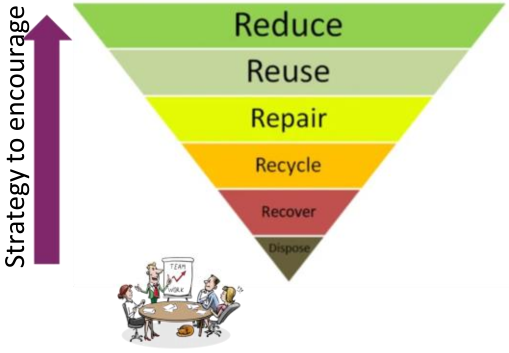
The screen recycling chain - from a product recycling rate of 55% to a material circularity rate of 17%. *(Travaux de Thèse Rachel Horta Arduin)*

Why is the circularity rate so low?

First Challenge=complex multi-material products with a focus only on critical metals



Review of critical metal dynamics to 2050 for 48 elements Takuma Wataria, Keisuke Nansaia,c , Kenichi Nakajimaa, Resources, Conservation & Recycling journal 2020



The main strategies studied on literature

- **Numerous publications on lithium, indium and platinum.**
- **Highlighting of materials of interest according to the environmental importance of their application**

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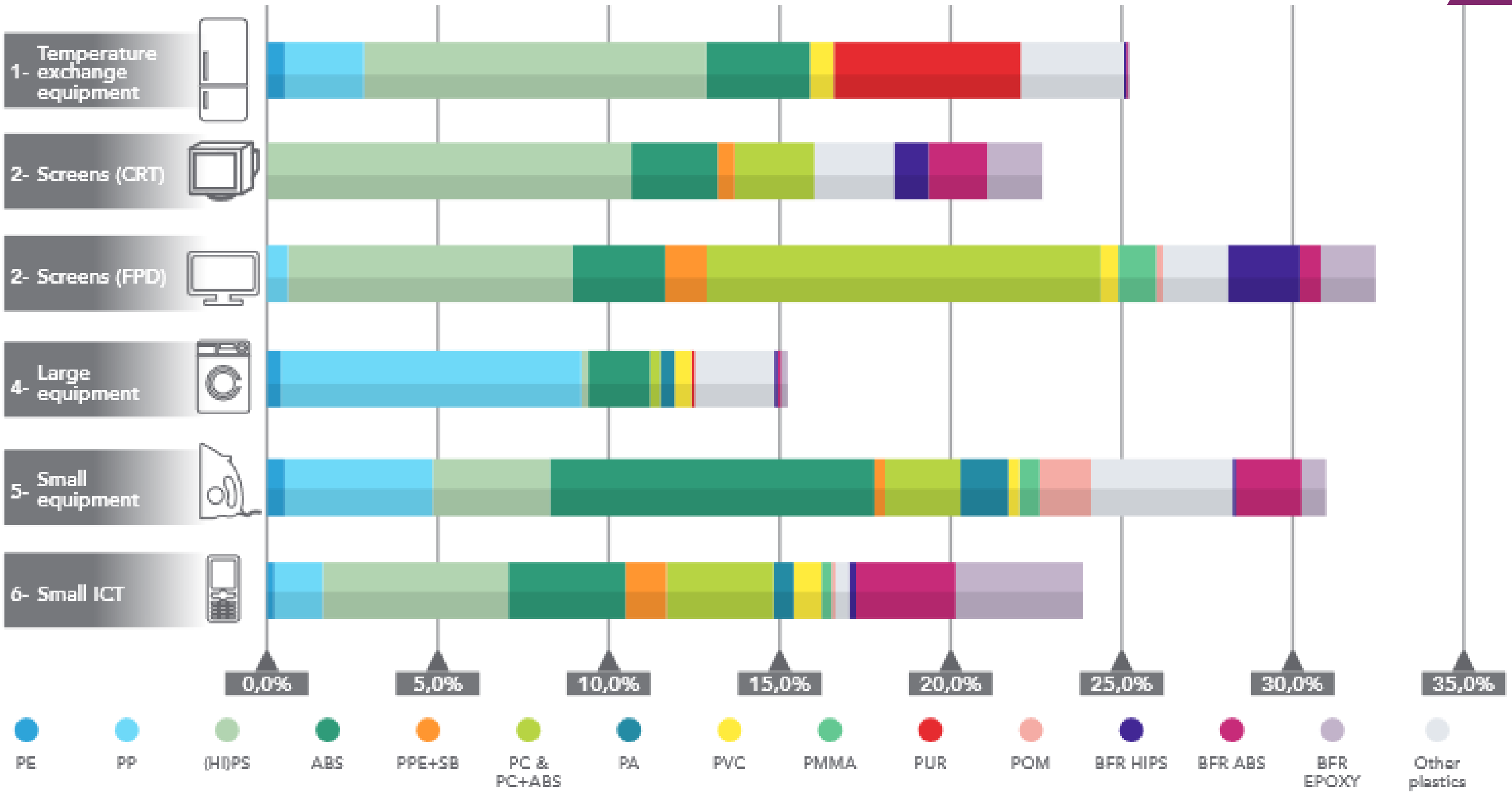
Why is the circularity rate so low?



Wide variety of plastics
Need to consider them for a circularity of EEE (recycling, design modification...)

(SOFIES EPR systems)

Why is the circularity rate so low?

Second challenge=physical, chemical and environmental limits

Lack of knowledge about the performance of these processes and their limitations

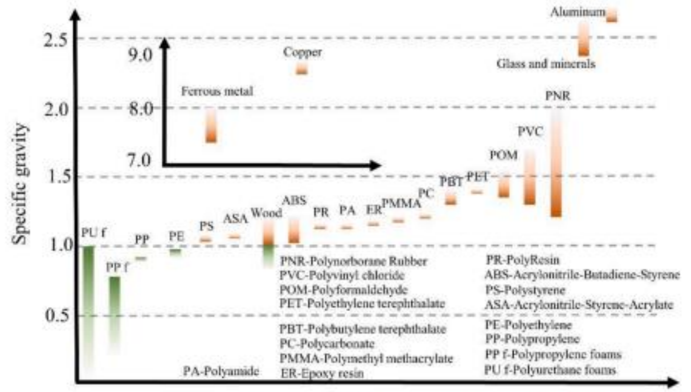


Fig. 3. The density ranging of waste plastics and associated materials (Gent et al., 2009; Bauer et al., 2018).

Numerous sorting technologies
Mainly float-sink, flotation
Limitations: efficiency, purity, material identification, degradation, diversity of resins

R&D → Design → Manufacturing → Use → End of life chains

End of life chains: Collection → Dismantling → Shredding → Sorting → Regeneration

Lack of match between treatment chain and design
Lack of confidence in RPM

Accessibility, Cost
Compatibility and marking of materials

Compatibility of materials

In France, the recycling rate for EEE PM is around 12% (ADEME +Plastics Europe + SRP)

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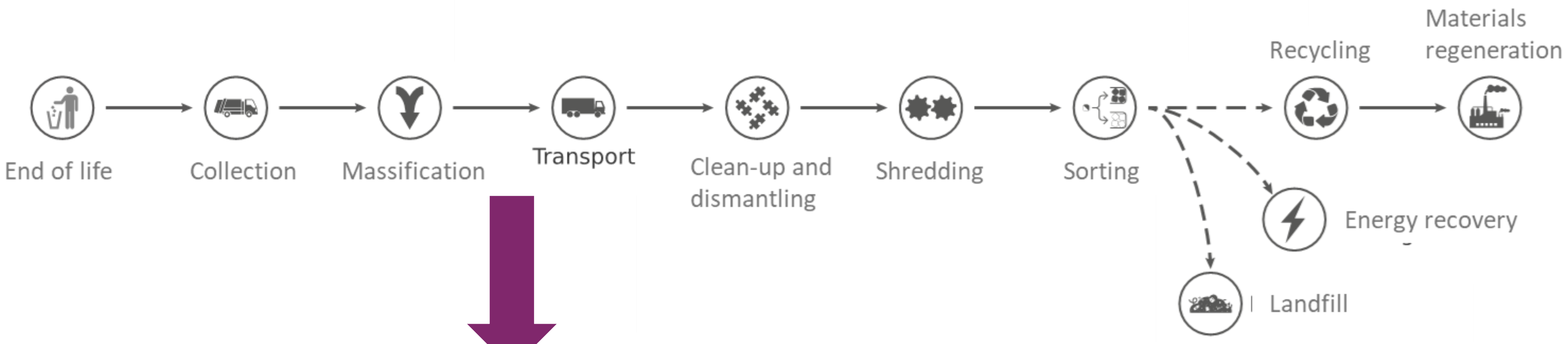
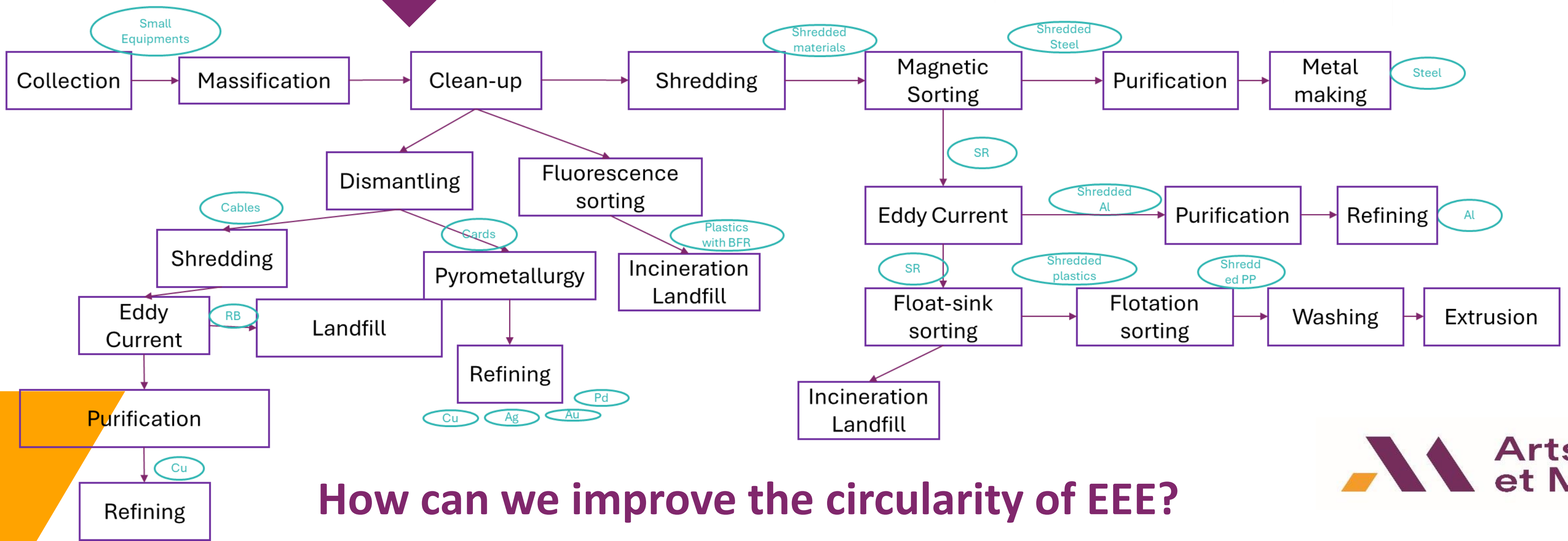
Why is the circularity rate so low?

Third challenge= a complex organisation to obtain regenerated materials, the lack of knowledge of the end of the chain, the lack of cooperation





How can we improve the circularity of EEE?

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The Urban Mines Chair

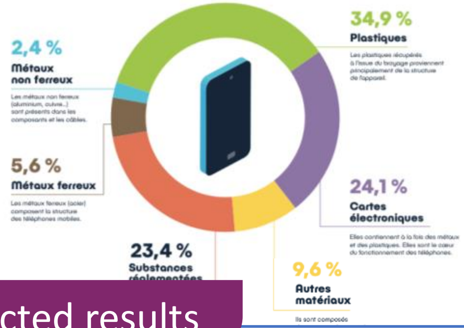
Research program funded by ecosystem

Towards more circular EEE

Background: why the Urban Mines Chair?

Goals

- Develop the circular economy for EEE
- Integrate circularity issues (materials, environment, channels) right from the design stage
- Encourage exchanges between producers and operators



Source et infographie ecosystem

Expected results

- Tools that can be used by operators
- Development of efficient treatment solutions
- Design indicators enabling real circularity on the first and second cycle

Chimie Paris ParisTech | PSL

Critical materials

ecosystem recycler c'est protéger

Mécène de la chaire

MINES ParisTech

Behaviour and change

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Polymers:

- **Circular economy and integration of RPM**
- **Design for a 5R strategy centred on reuse and repair**

I2M

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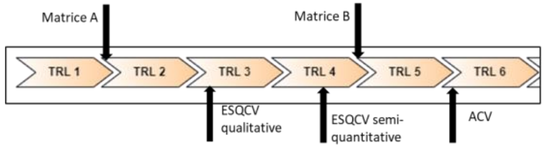
Tools developed for value chain actors (2019-2024)

Tools for greater collaboration and more circularity

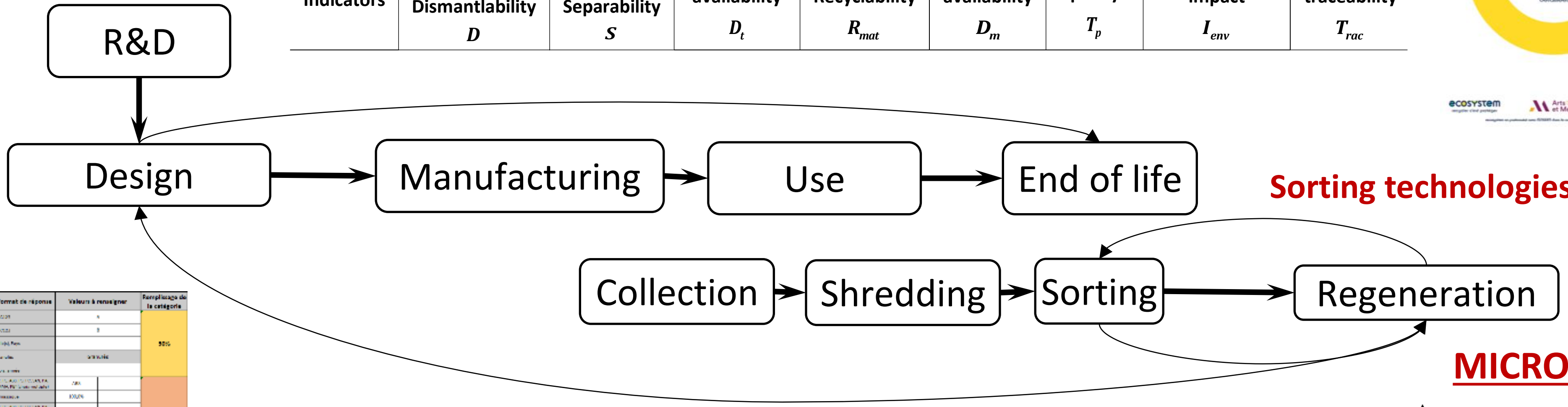
Tool for Low TRL processes



A tool for a design that takes circularity into account

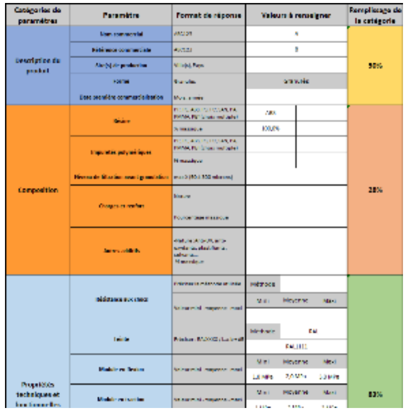
MESO

Indexes	Retreivability index I_{retr}				Re-integrability index I_{reint}			
Indicators	Dismantlability D	Separability S	Treatment availability D_t	Recyclability R_{mat}	Material availability D_m	Material purity T_p	Environmental impact I_{env}	Material traceability T_{rac}



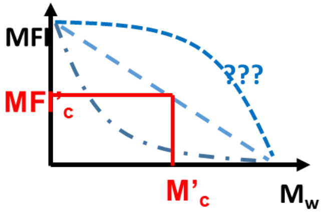
Sorting technologies guide

MICRO



RPM Sheet

Degradation Index



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Communication tools created in collaboration with stakeholders

Sorting technologies guide (28 Sheets)

Need: Identify technological gaps and provide support for decision-making on the choice of technologies to be developed
Workshops between producers and operators

Guide available on ecosystem website

00 Nom du procédé de tri		
Famille	Famille de procédé (voie sèche, humide, optique…) et type de séparation	
Type	Type d'analyse et de reconnaissance	
Niveau de développement	Niveau de maturité de la technologie. Précision du TR : Technology Readiness Level ou niveau de maturité technologique	
Description de la technologie	Présentation synthétique du procédé	
Caractéristiques techniques	Rendement	Degré de pureté du matériau ciblé en sortie de procédé
	Capacité	Débit moyen du procédé
	Nature de l'entrant	Cahier des charges requis pour la fraction entrant dans le procédé afin que le tri soit optimal
	Plastiques obtenus	Typologie de plastiques qu'il est possible d'obtenir en sortie
Données environnementales	Impact environnemental du procédé	
Forces	Avantages / Bénéfices de la technologie vis-à-vis du tri des plastiques de DEEE	
Faiblesses	Freins identifiés de la technologie vis-à-vis du tri des plastiques de DEEE	

(Bernard, 2023)

Recycled Material Sheet (76 parameters)

Goal: To facilitate the exchange of information on the characteristics of a RPM Workshops with regenerators (10 participants), plastics manufacturers and EEE producers (15 participants)

Categories	Parameter	Unit	Values	Category filling
Product description	Name	/		0%
	Product reference	/		
	Production site(s)	/		
	Form	/	Granules	
	First POM date	/		
Composition	Colour and external aspect	/		0%
	Main resin	/		
		%		
	Polymeric impurities	/		
		%		
	Filtration level before granulation	µm		
	Fillers, stabilizers	/		
		%		
	Other intentionally added additives	/		
		%		
	Proportion of minerals	% or ppm		
	Proportion of recycled materials	%		

Sheet in open access
(Neve, 2024)

Sciences et Technologies
et Métiers

(Neve, 2024)

Integrating the supply chain into the design process

Tool for a design that considers the circularity of plastics used in EEE

Indexes	Retreivability index I_{retr}				Re-integrability index I_{reint}			
Indicators	Dismantlability D	Separability S	Treatment availability D_t	Recyclability R_{mat}	Material availability D_m	Material purity T_p	Environmental impact I_{env}	Material traceability T_{rac}

Retrievability rate	
Indicators	**Sub-indicators**
Material separability	Material compatibility
	Material hazard
	Material contamination
Existence of treatment facilities	Existence of dismantling facilities
	Existence of recycling facilities
Recyclability	Potential recycling rate
	Material diversity
	Collection rate for the EoL category of the product

RPMs can be reintegrated into a new cycle

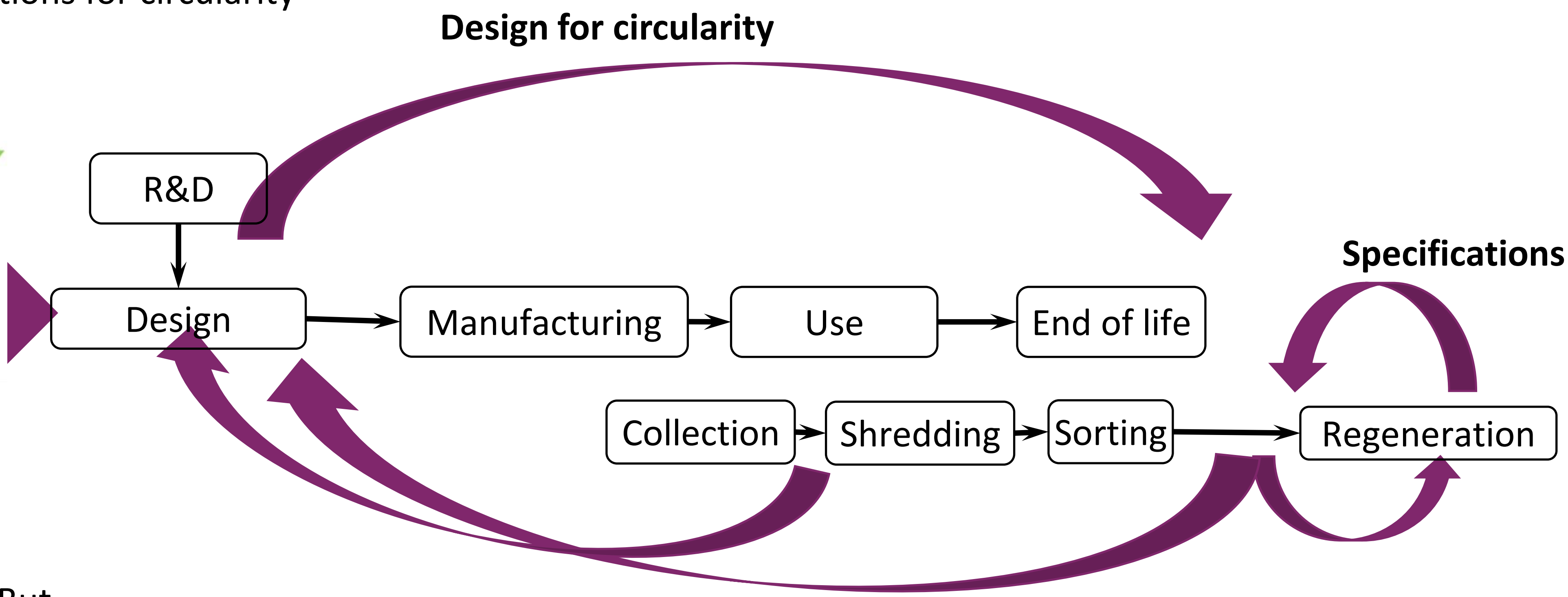
A systemic vision of circularity

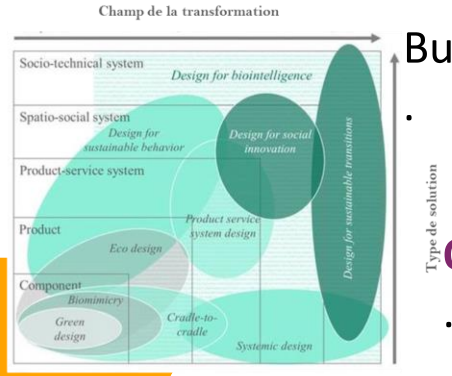
Re-integrability rate		
Sub-indicators		**Indicators**
Volume of the deposit		**Material availability**
Volume of production		
Proportion of main material		**Material purity**
Polymer contaminants	Proportion of contaminants	
Particle contaminants		
Additives, fillers		
Filtration level before extrusion		
Proportion of recycled material		**Environmental impact**
Carbon savings		
Raw material criticality		
Geographic origin of the materials		

(Neve, 2024)

New challenges for the development of circular strategies

Tools to encourage exchanges and cooperation between players
- Cooperation is essential for implementing circularity
- Knowledge of organizations for circularity

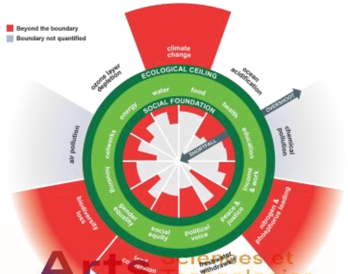




Ceschin et Gaziulusoy, 2020

But

- Defining the level of circularity of plastics and EEE
- Taking into account the number of loops by integrating a prospective scenario



Outlooks

- **Development of tools and methods to choose sustainable circular strategies for strategic materials**

Thank you for your attention

Questions?