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Use Case Needs Analysis and Circular Value Flow Mapping – Report v2

https://miro.com/app/board/uXjVOsBVNbk=/?share_link_id=450069542713

Deliverable number	D6.2
Deliverable name	Use case needs analysis and circular value flow mapping
Work package	WP6 – Industry use cases
Lead partner	Circularise BV
Contributing partners	+ImpaKT Luxembourg circular.fashion Concular GmbH Texon Lindner Group Ragn-Sells Recycling REIA
Deadline	2023-11-30
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Date	30/11/2023

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Project information

Project summary

Circular economy aims at maintaining and retaining the embedded value of products by creating continuous closed loops of materials or product parts and by phasing out waste. Today, lack of support for sharing data in a secure, quality assured, and automated way is one of the main obstacles that industry actors point to when creating new circular value networks. Together with using different terminologies and not having explicit definitions of the concepts that appear in data, this makes it very difficult to create new ecosystems of actors in Europe today. This project will address the core challenges of making decentralized data and information understandable and usable for humans as well as machines. The project will leverage open standards for semantic data interoperability in **establishing a shared vocabulary** (ontology network) for data documentation, as well as a **decentralized digital platform (i.e. Open Circularity Platform)** that enables collaboration in a secure and privacy-preserving manner.

The project addresses a number of open research problems, including the development of ontologies that need to model a wide range of different materials and products, not only providing **vertical interoperability** but also **horizontal interoperability**, **for cross-industry value networks**. As well as transdisciplinary research on methods to find, analyze and assess new circular value chain configurations opened up by considering resource, information, value and energy flows as an integral part of the same complex system. Three industry use cases, from radically different industry domains, act as drivers for the research and development activities, as well as test beds and demonstrators for the cross-industry applicability of the results. The developed solutions will allow for automation of planning, management, and execution of circular value networks, at a European scale, and beyond. The project thereby supports acceleration of the digital and green transitions, automating the discovery and formation of new collaborations in the circular economy.

Project start date and duration: 1st of June 2022, 36 months

Project consortium

No	Partner	Abbreviation	Country
1	Linköping University	LiU	Sweden
2	Interuniversitair Micro-Electronica Centrum	IMEC	Belgium
3	Concular Ug Haftungsbeschrankt	CON	Germany
4	+Impakt Luxembourg Sàrl	POS	Luxembourg
5	Circularise Bv	CIRC	The Netherlands
6	Universitaet Hamburg	UHAM	Germany
7	Circular.Fashion Ug (Haftungsbeschrankt)	FAS	Germany
8	Lindner Group Kg	LIN	Germany
9	Ragn-Sells Recycling Ab	RS	Sweden
10	Texon Italia Srl	TEXON	Italy
11	Rare Earths Industry Association	REIA	Belgium

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0.2		Eva Blomqvist	PC	LIU
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Table of Contents

Abbreviations

Abbreviation	Definition
B2B	Business to business relationship
B2C	Business to consumer relationship
CE	Circular Economy
EEA	European Environmental Agency
EoL	End-of-Life
ID	Identifier
ISO	International Organization for Standardization
IT	Information Technology
EOSC	European Open Science Cloud
MFM	Multi-Flow Metabolism
OEM	Original Equipment Manufacturer
PCDS	Product Circularity Data Sheet
REACH	Registration, Evaluation, Authorisation and restriction of Chemicals
SMEs	Small and Medium-sized Enterprises
UNECE	United Nations Economic Commission for Europe
WP	Work Package

Terms and Definitions

Below are listed the definitions of specific terms used in the scope of this document:

Business requirements vs. Functional requirements	Business requirements relate to a business' objectives, vision and goals. Business requirements relate to a specific need that must be addressed to achieve an objective. Functional requirements break down the steps needed to meet the business requirement or requirements. Whereas a business requirement states the 'why' for a project, a functional requirement outlines the 'what'.
Product Circularity Data Sheet (PCDS)	Product declaration which presents standardized and trustworthy information on the circularity characteristics of a product. It is based on a template containing pre-set true/false statements which describe circular economy properties of the product (ex.: design for reuse and disassembly, recyclability, recycled content, hazardous materials thresholds, etc.). The PCDS is not intended to be a scoring mechanism, but it could be used partially or entirely by other stakeholders (e.g., databases, platforms, or consultants) to enable an evaluation of the product circularity.
Traceability	"The ability to identify and trace the history, distribution, location and application of products, parts and materials, to ensure the reliability of sustainability claims in the areas of human rights, labour (including health and safety), the environment and anti-corruption"[1] and "the process by which enterprises track materials and products and the conditions in which they were produced through the supply chain"[2].
Transparency	"Requires relevant information to be made available to all elements of the value chain"[3] in a standardized way, which allows for common understanding, accessibility, clarity, and comparison.

[1] United Nations Global Compact Office, A Guide to Traceability: A Practical Approach to Advance Sustainability in Global Supply Chains (New York, 2014).

[2] Organisation for Economic Co-operation and Development (OECD), Due Diligence Guidance for Responsible Supply Chains in the Garment and Footwear Sector (Paris, 2017).

[3] DAI Europe and the European Commission, A Background Analysis on Transparency and Traceability in the Garment Value Chain (2017).

Executive Summary

This document gives an overview of the industrial needs from the perspective of the three use cases selected for the Onto-Deside project. It includes an analysis of the circularity compass, which aims to determine the material, information, energy, and value flows within the project. Further analysis, through the activity cycle, provides a detailed overview of the requirements to achieve ideal circularity scenarios. For them to become a reality, it is essential to engage and collaborate with the appropriate stakeholders. This deliverable identifies key participants who must be actively involved to ensure the successful implementation of circular practices. Furthermore, it outlines the specific information needs for each stakeholder category and highlights the critical activities that must take place to facilitate circularity.

Building on the previous deliverable D6.1 and including the latest outcomes from the related tasks within WP6, this version provides enriched perspectives and detailed insights into data needs and circularity analysis. The findings presented here pave the way for future actions in realizing the project's objectives of achieving traceability across supply chains and fostering circular practices. This deliverable serves as a valuable resource for stakeholders involved in the project, offering a comprehensive understanding of data requirements and circularity dynamics. It provides guidance on how to navigate the complexities of creating digital product passports and achieving optimal circularity. The information and analysis presented within this document are instrumental in shaping the project's roadmap and ensuring its successful outcomes.

1 Introduction

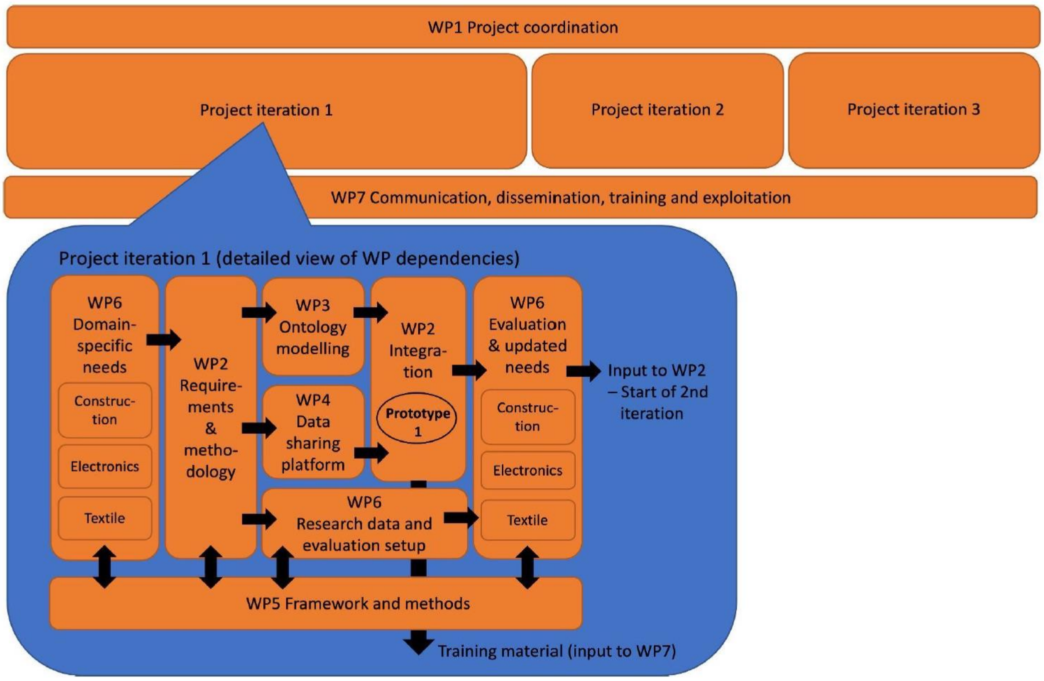
The Onto-DESIDE project applies an iterative methodology, inspired by the cycles of action research, where research and innovation are driven by industry needs identified in a set of industry use cases, and solutions become more mature with each iteration. Three project use cases, representing three distinct industry sectors (construction industry, electronics and appliances, and textile industry), will contribute to identify the needs and technical requirements of the Open Circularity Platform, but also act as test beds and evaluation scenarios for the novel solutions produced.

In this way, the project aims to show that results produced are concrete enough to solve specific problems, i.e. in three specific use case domains, but also that the Open Circularity Platform has potential to be widely applied, thus constituting a cross-industry solution for ontology-based data documentation that works together with other value network flows, as well as being connected to several European initiatives, such as the Industry Commons and its Onto Commons project, the EOSC and European Data Spaces.

The project consists of three iterations, where each Work Package (WP) contributes to all the iterations. WP dependencies are illustrated in Figure 1 through detailing the first project iteration. The duration of the first project iteration is Month(M) 1-18, while the second and third iterations are shorter, encompassing M19-27 and M28-36 respectively. Each iteration ends with collection of feedback from the industry use cases, which is analysed and reported in a WP6 deliverable (i.e., evaluation report).

This deliverable builds on the previous deliverable 6.1. It now includes further work on the circularity compass, through the energy and value flows, as well as an analysis of circularity strategies by means of the activity cycle. This analysis portrays how to achieve some of the ideal circular scenarios presented on the material and information flows.

Figure 1- Project outline and detailed dependencies between work packages exemplified by the first iteration



1.1 Tasks and deliverables

The WP6, led by CIRC, is divided into 3 tasks corresponding to the three industry use cases as outlined below:

- **T6.1 - Construction industry use case** - lead: CON – participants: UHAM, LIND, RS
- **T6.2 - Electronics and appliances use case** - lead: CIRC, participants: UHAM, REIA
- **T6.3 - Textile industry use case** - lead: POS, participants: UHAM, FAS, TEX

Three deliverables are being produced in WP6 during the project:

- **D6.1 Use case needs analysis and circular value flow mapping** (D6.1 - v1 M3, D6.2 - v2 M18, D6.3 - v3 M27) – report
- **D6.4 Research data** (D6.4 - v1 M12, D6.5 - v2 M24, D6.6 - v3 M33) - data (project internal)
- **D6.7 Evaluation report** (D6.7 - v1 M18, D6.8 - v2 M27, D6.9 - v3 M36) – report

The present document is the report for D6.1 version 2 (D6.2). It provides a description of the industrial needs from the perspective of each use case and a mapping of circular business opportunities and challenges in each use case. The D6.1 is divided into three major parts. D6.1 is used as a "living document" throughout the project. This is a revised version, issued at M18 (D6.2 - v2), to reflect new and changed needs identified after first and second prototype evaluation. A final version will be presented at M27.

- D6.1 - V1: use case and technology introduction (inventory on how the three providers collect and manage data), methodology definition, first flow model (in drawing), M4
- D6.2 - V2: use case and industry models refinement, and industry needs assessment, M18
- D6.3 - V3: detailed flow model and analysis, M27

2 Objectives and research methodology

2.1 Objectives

As mentioned previously, the industry use cases constitute a key part of the project, and will drive the technical development work, as well as validate the platform functionalities. In that way, the Work Package 6 aims to demonstrate the potential of the Open Circularity Platform with its semantic interoperability solution, i.e., ontology-based data documentation, for facilitating circular economy loops across industry domains. For that purpose, all three use cases (each a task of WP6) will:

1. **Define the business needs and requirements** from the specific perspective of their industry domain, which are generalized and integrated in **Work Package 2**.
2. **Provide research data**, both for technical development as well as validation and evaluation of results.
3. **Apply the tools from Work Package 5** (i.e., Circularity Compass and the Multi Flow Metabolism (MFM)) to map the business opportunities that are opened up through the ontology-based data documentation and related infrastructure, and to assess the potential gains in the life cycle of materials (e.g., reduced waste, reduction CO2, closing loops, etc.) including identifying incentives and quantifying the contribution of the ontologies.
4. **Perform evaluation experiments and provide feedback** of the intermediate releases of the ontology network and **open circularity platform developed in WP3 and WP4**, as well as validate and evaluate their final version.

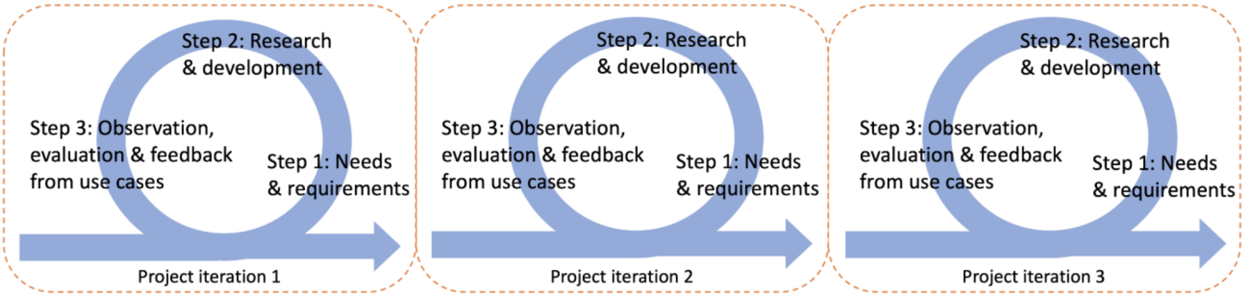
All three use cases will share the same technical infrastructure and method approach as how to apply and detail ontology artefacts. This is to ensure that the ontology building blocks that the project develops is industry-independent and usable across industry domains. Further, data will reside with the respective organization and will only be shared through the data-documentation vocabulary defined by the ontology, and by means of the secure and privacy-preserving data sharing platform. Each organization will add capabilities and data, i.e., specializing the semantic model, based on the type of business they are involved in.

2.2 Research methodology

The concrete research process will be divided into three iterations, each divided in 3 steps (cf. Figure 2):

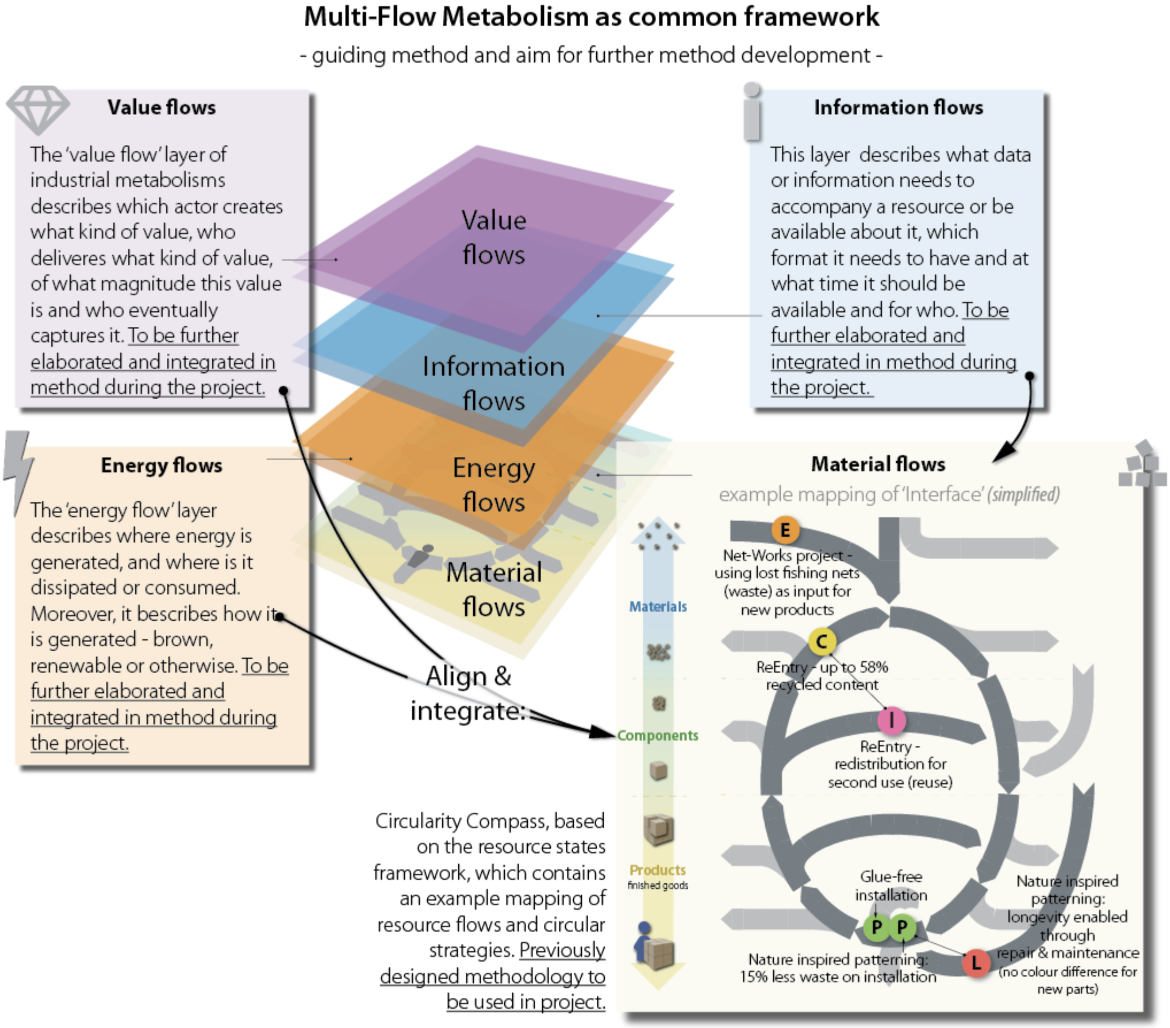
- Step 1: a needs analysis and requirements elicitation
- Step 2: research and technical development, including solution integration into a coherent prototype
- Step 3: use case-based observation and evaluation, providing feedback as well as revised and extended needs to start off the next iteration.

Figure 2 -The Onto-DESIDE research process, divided into 3 iterations, each consisting of three steps



For the steps 1 and 3, the existing tools and approaches of Circularity Thinking[4] (i.e., Circularity Compass and the Multi-Flow Metabolism (MFM)) are used as a common framework to align perceptions of current systems and explore possible new configurations of both resource flows and how different actors can collaborate in new ways (see Figure 3). In this sense, it offers a ready-made starting point for Onto-DESIDE use cases, both when mapping the details of each use case at the start of the project, analysing the industry needs and technical requirements (c.f. step 1 of each iteration), as well as a frame of reference when evaluating and assessing the potential contribution of the novel solutions developed in the project (c.f. step 3 in each iteration).

Figure 3 - Circularity Compass (bottom layer) and the Multi-Flow Metabolism as a common framework for analysing the use cases



Circularity Thinking – an approach for circular oriented innovation

Circularity Thinking is a method that enables identifying circular economy related opportunities, to explore possibilities and develop them into robust solutions, and to outline next steps. Circularity

[4] Circularity Thinking is an approach that enables innovators to identify circular economy related opportunities, to explore possibilities and develop them into robust solutions, and to outline next steps. It consists of a suite of tools that have been developed based on scientific research and experience with businesses. For more details, see the article Blomsma, F., Tennant, M., 2020. Circular economy: Preserving materials or products? Introducing the Resource States framework. Resour. Conserv. Recycl. 156, 104698. https://doi.org/10.1016/j.resconrec.2020.104698

Thinking draws on the experience of many businesses, as well as concepts of systems thinking, life cycle thinking, resource management, design, collaboration, and value creation. Waste – in all its different forms – is the starting point and source of value creation in this approach. At the time of writing, Circularity Thinking is used across Europe and a certification scheme allowing users to demonstrate their knowledge of this approach is under development at EIT Climate KIC (outside of this current project).

Circularity Thinking structures the analysis of circular economy complexities by 'following the flows,' finding the value for both companies and other actors by uncovering what waste is currently in the system, and by making sure that one is asking the right questions regarding scale, complexity, people, competences and technology.

Starting point of Circularity Thinking

The starting point for Circularity Thinking is to regard CE as an 'umbrella concept.' This means seeing CE as an approach that focuses on how different types of value can be created, through implementing a variety of circular strategies. This way of viewing means recognising that there is not one interpretation of CE that is 'right,' or that others are 'wrong,' rather that there are more or less appropriate circular strategies - depending on the context. For example: neither recycling nor reuse are assumed to be preferable *a priori* – rather it is the circumstances that determine which is best, or whether both have a role to play. To be able to critically assess what are appropriate circular strategies, it helps to understand how resources currently flow, and what waste – in all its different forms – are present. This allows for tying together many waste and resource management practices in strategic efforts for organisations as it is this waste that is a potential source of value. Viewing CE in this way gives those pursuing CE driven innovation the freedom to determine how they can (further) contribute to greater circularity, whilst imparting innovators with the responsibility to find solutions that truly address structural waste – so that solutions are not merely 'circular for circularity's sake', but truly tackle excessive and wasteful resource use.

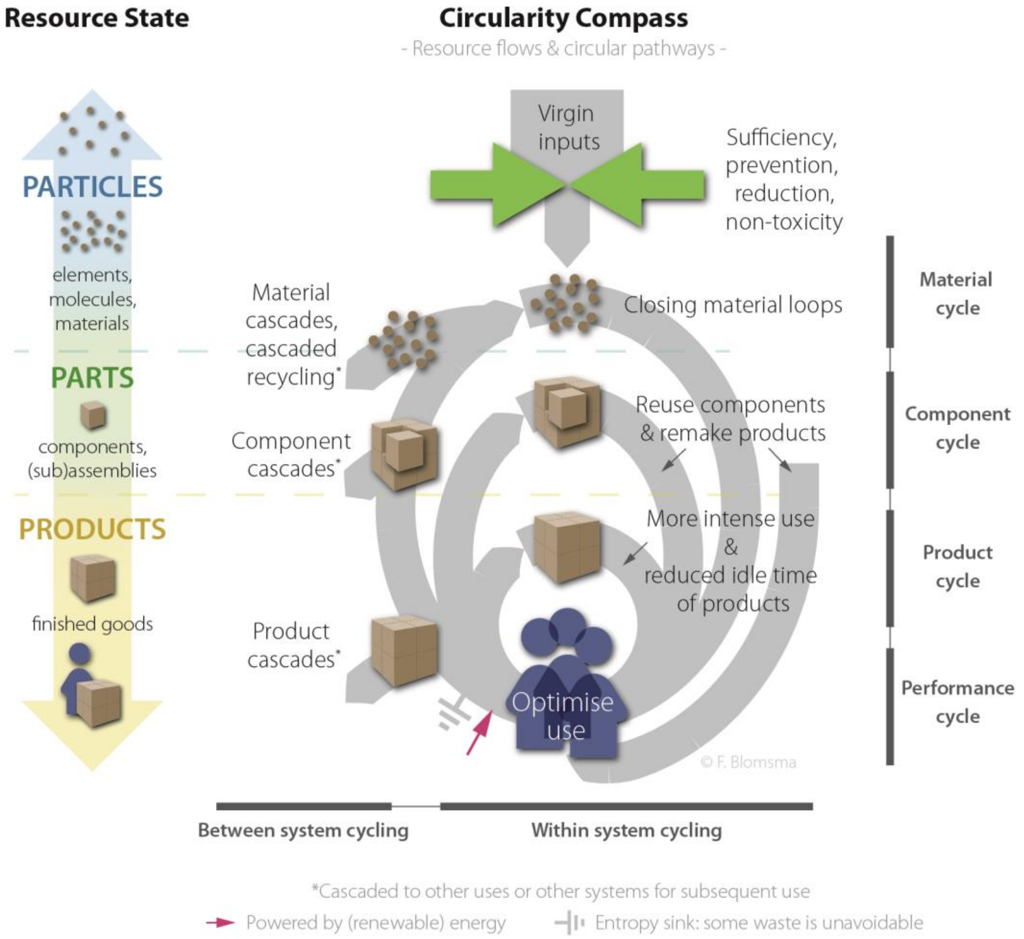
Circularity Thinking tool #01 - Circularity Compass

Circularity Thinking, see figure below, consists of a number of frameworks or tools, with which system mappings can be made to aid the analysis. The first of these tools is the Circularity Compass (Figure 4). The Circularity Compass, or simply Compass for short, can be used to understand resource flows. It consists of a visual template based on life cycle thinking that depicts common industrial processes, covering the beginning-of-life stages (sourcing, creation of bulk materials, creation of parts and subassemblies, finished products and distribution and retail), the middle-of-life stage (use phase), as well as the end-of-life (EoL) stages (collection and reverse logistics, operations that extend existing life cycles and that enable new life cycles for products and components, as well as EoL strategies for materials). Arrows indicate the direction of movement of the flows, much like in a Sankey diagram.
On this industrial life cycle the Compass superimposes three 'layers' that indicate the form a resource takes along its journey through the economy. These three layers are termed *resource states*, and the three most relevant states from a CE perspective are: particles, parts and products. The particles state indicates a phase where one would speak of resources in terms of elements, molecules, substances, or (bulk) materials. The operations in this state are primarily aimed at concentrating particles, purifying them and making them suitable for subsequent use. Think of, for example, the mining, smelting and manufacture of aluminium ingots and sheets. Next, particles are given an

intermediary form in the parts state. This is where parts or components, intermediates, (sub)assemblies, or modules are created. In the example of aluminium, this would be when it is used to create the various parts of a car, such as the chassis and the doors and other parts are added to it to create sub-assemblies. Lastly, parts are assembled to form finished goods that end users can extract value and utility from in the products state. This is when the complete car is assembled from the parts and sub-assemblies, it is sold or in some other way made accessible to the end-user. The resource state indicator on the left-hand side of the framework shows how the resource states relate to industrial processes.

This forward part of the industrial life-cycle can already contain several industrial cycling processes, such as pre-consumer recycling and rework for products that do not meet specifications. The remainder of the circular options are depicted as end-of-use and EoL processes: e.g. 'as-is' cycling or redistribution, operations such as refurbishment and remanufacturing that require (partial) disassembly, and material processing in the form of recycling. Note that these options are 'within-system' cycling, and that 'between-system' cycling can also take place when resources are cycled in a separate but connected system, such as through materials, component or product cascades or alternate use.

Figure 4 - Circularity Compass, providing an overview of the main cycling categories. From: Blomsma and Brennan (2022).



Circularity Thinking tool #02 - Big Five Structural Wastes

Thinking in terms of 'flows', with help of the Compass, allows for thinking about the larger system and in exploring what possible solution spaces are available – as sometimes solutions are unlocked by looking elsewhere in the system. However, as some types of waste are easier to identify than others, it is also essential to be able to examine where waste may be present in a more structured manner. This is what the 'Big Five' Structural Wastes allows: finding waste, wherever it may be present, in whatever form it is present.

Generally, it is agreed that waste is the loss and destruction of value - but this doesn't really help us distinguish between different waste types. Some forms of waste are clearly visible and identifiable, such as the materials in a bin or a product with a clearly visible breakage.

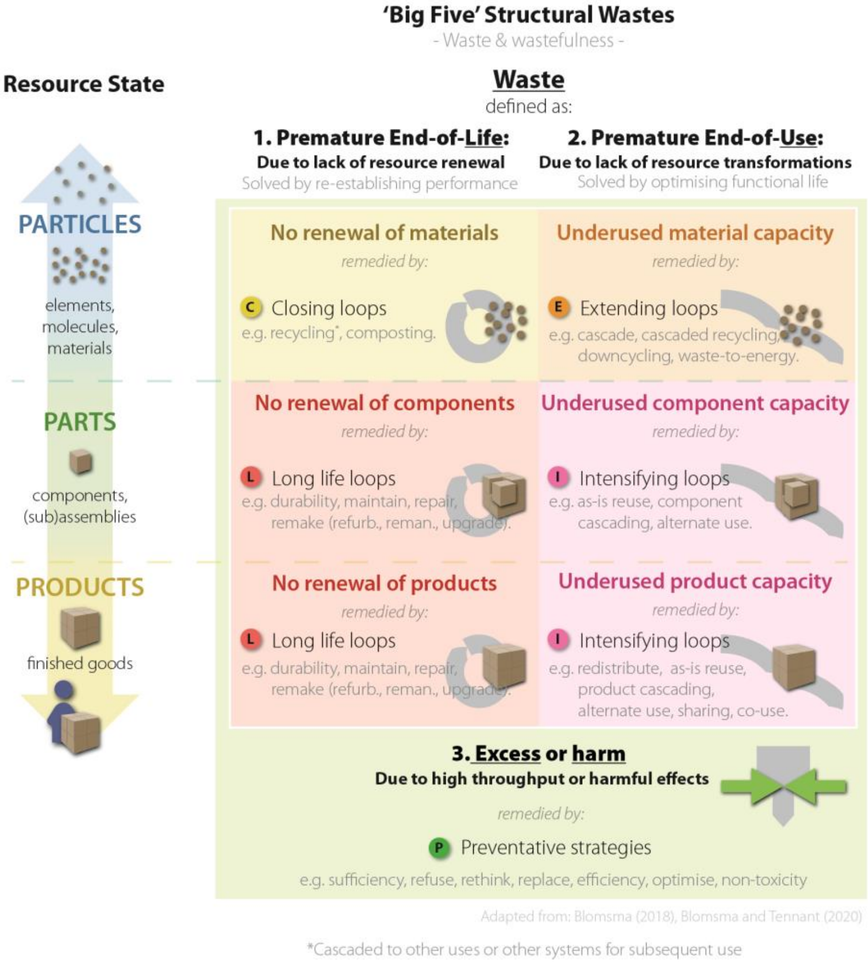
In contrast, other forms are inconspicuous, invisible and more difficult to point to. Think of products that are unused for a significant part of their life or products that are designed to fail after a certain amount of uses without outward signs or a clearly visible reason. Such situations lead to more resources being needed and a higher level of material throughput than would strictly be necessary to fulfil human needs - and they can therefore also be seen as 'wasteful.'

So what, exactly, do we mean by the loss and destruction of value and how this can be avoided? Preventing waste from being created usually means to 'preserve' or 'continue' something. There are three principal ways in which this can be achieved: 1) addressing premature EoL through re-establishing performance, 2) addressing premature end-of-use through optimising functional life, and 3) addressing excess or harm through prevention[5], see Figure below (Figure 5) for how this applies to the three resource states, and which circular strategies can be used to address the waste.

5 Blomsma, F. (2018). Collective 'action recipes' in a circular economy – on waste and resource management frameworks and their role in collective change. *Journal of Cleaner Production*, *199*, 969–982. https://doi.org/10.1016/j.jclepro.2018.07.145

Blomsma, F., & Tennant, M. (2020). Circular economy: Preserving materials or products? introducing the Resource States Framework. *Resources, Conservation and Recycling*, *156*, 104698. https://doi.org/10.1016/j.resconrec.2020.104698

Figure 5 - Example mapping of problem situation (identifying structural wastes) and a proposed solution (identifying circular strategies solving the earlier identified problems, offering opportunities for value creation).



Circularity Thinking in Onto-DESIDE

A similar (more extensive) analysis as described in the previous section, reaching increasing depth and detail in the project iterations, is proposed within Onto-DESIDE. In the first project iteration, the focus was on the problem situation. That is: the goal is to understand structural waste in the use cases, understand supply chain problems and difficulties, and to capture and describe barriers currently standing in the way of capturing value through circular strategies.

To support the initial phase of the project, the following materials were made available to those involved in this task, to learn about Circularity Thinking and the tools:

- **Overview video here**: LINK to short video on Circularity Thinking (13min)
- **Documents containing explanation (in folder or as link):**
  - **Resources, waste and a systemic approach to CE -** *Blomsma and Brennan*
  - **Making sense of circular economy - understanding the progression from idea to action -** *Blomsma, Tennant and Ozaki*
- **Explanation videos**
  - **Videos**: 3 videos from updated lecture series by Prof Dr Fenna Blomsma on Circularity Thinking:
    - 24 mins - The first explains about Resource States and the Circularity Compass.
    - 25 mins - The second covers Big Five Structural Wastes.

§ 31 mins - The third covers examples of how to use these concepts to understand circular configurations (incl. short company videos).

A Miro workspace was set-up for each use case. Further background materials were also made available. In addition to this, a presentation was given by Prof Dr Fenna Blomsma to provide an overview of this approach, also on-boarding those who didn't study the material yet, or who are not (yet) directly involved in the use case mappings.

Circularity Thinking tool #03 -Multi-Flow Metabolism

We also know, from previous research [6], that in circular economy-oriented innovation, additional flows besides the material flows play a role. That is: the industrial metabolism - the 'flows' that make up the lifeblood of systems such as economies - can be seen as consisting of resource- (e.g. physical), energy-, information- and value-flows. When large-scale metabolism changes happen, these 4 flows - together with the accompanying infrastructure and technology - change in an integrated manner to allow for new flow patterns to emerge. Within CE the relevance of these flows is also acknowledged: see, for value flows, for example, work by Bocken et al.[7] or Pieroni et al.[8]; for information flows see the work by Kristoffersen and colleagues[9], the call for a European Dataspace for Smart Circular Applications; and see for energy flows the work by Allwood and colleagues[10], Cullen or Bakker and colleagues[11].

So far, in CE, these 4 flows are studied with either an exclusive focus on one flow, or as a set, usually in relation to resources. However, Blomsma and colleagues [12] have recently shown that considerations regarding these 4 flows feature prominently and together in circular oriented innovation: they are usually designed together. For this reason, the Multi-Flow Metabolism (MFM) model was proposed to bring together these 4 flows (see Figure 3). However, at present, little

6 Blomsma, F., Tennant, M., & Ozaki, R. (2022). Making sense of circular economy: Understanding the progression from idea to action. *Business Strategy and the Environment*. https://doi.org/10.1002/bse.3107

7 Bocken, N. M., de Pauw, I., Bakker, C., & van der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering*, *33*(5), 308–320. https://doi.org/10.1080/21681015.2016.1172124

8 Pieroni, M. P. P., McAloone, T. C., & Pigosso, D. C. A. (2019). Business Model Innovation for Circular Economy and Sustainability: A review of approaches. *Journal of Cleaner Production*, *215*, 198–216. https://doi.org/10.1016/j.jclepro.2019.01.036

9 Kristoffersen, E., Blomsma, F., Mikalef, P., & Li, J. (2020). The Smart Circular Economy: A digital-enabled Circular Strategies Framework for manufacturing companies. *Journal of Business Research*, *120*, 241–261. https://doi.org/10.1016/j.jbusres.2020.07.044

10 Allwood, J. M., Ashby, M. F., Gutowski, T. G., & Worrell, E. (2011). Material efficiency: A white paper. *Resources, Conservation and Recycling*, *55*(3), 362–381. https://doi.org/10.1016/j.resconrec.2010.11.002

11 Bakker, C., Wang, F., Huisman, J., & den Hollander, M. (2014). Products that go round: Exploring product life extension through design. *Journal of Cleaner Production*, *69*, 10–16. https://doi.org/10.1016/j.jclepro.2014.01.028

12 Blomsma, F., Tennant, M., & Ozaki, R. (2022). Making sense of circular economy: Understanding the progression from idea to action. *Business Strategy and the Environment*. https://doi.org/10.1002/bse.3107

guidance exists as to what a robust circular metabolism looks like – and how these flows can be made into a coherent whole.

As a first step towards this, in the first iteration of WP6 – subtask D6.01 – the Compass was used to specifically identify and map current information flows and analyse where and how this enables or blocks circular flows in the future. In other words: it is a step towards identifying the information needs and with that for the ontology to be designed in Onto-DESIDE. This then also formed an important foundation for WP05 that further conceptualises, develops, validates and implements tools and approaches that transform the Multi-Flow Metabolism (MFM) model into a method for the accelerated development of systemic circular solutions by collating, expanding and validating relevant factors and value network dynamics for robust circular value chains.

Each of the organizations involved in the use cases is part of detailing the circular value networks, and related 'flows' according to the MFM. In particular, the actors within the use case analyse and enact a value network, specifically targeting the information flow, that was not feasible without data documented and shared through the ontology network defined in this project (by WP3 and WP4). The Open Circularity Platform should facilitate the digitalization and the automation of data exchange as far as possible at all interface points in the value chain, requiring minimal manual intervention. Making use of previously non-shared as well as open data, the capabilities of the ontology network and Open Circularity Platform will be evaluated, and its potential impacts assessed (e.g., economic impact such as time reduction and added value and sustainability impacts such as reduction of CO_2, reduction of virgin materials use, etc.).

For step 2, the technical development of the Open Circularity Platform including ontology-based data documentation (by WP3 and WP4) is performed in an agile approach. Based on the industry needs identified in the three use cases, a shared set of evolving technical requirements is iteratively built up (in WP2). It means that requirements are put in a backlog list and are prioritized for each iteration. Solutions are then built incrementally, i.e. extended and matured in each iteration, as well as evaluated in the three use cases. For the first iteration, a set of initial requirements was selected and agreed upon in WP2.

2.2.1 Methodology extension

The previous section presented the tools of Circularity Thinking that were used for the first version of this deliverable. The coming section now presents the methodologies used to extend the current mappings and analyses to develop a more detailed understanding of the use cases, i.e., Value Chain Activity Cycles and mappings of the use cases' energy and value flows.

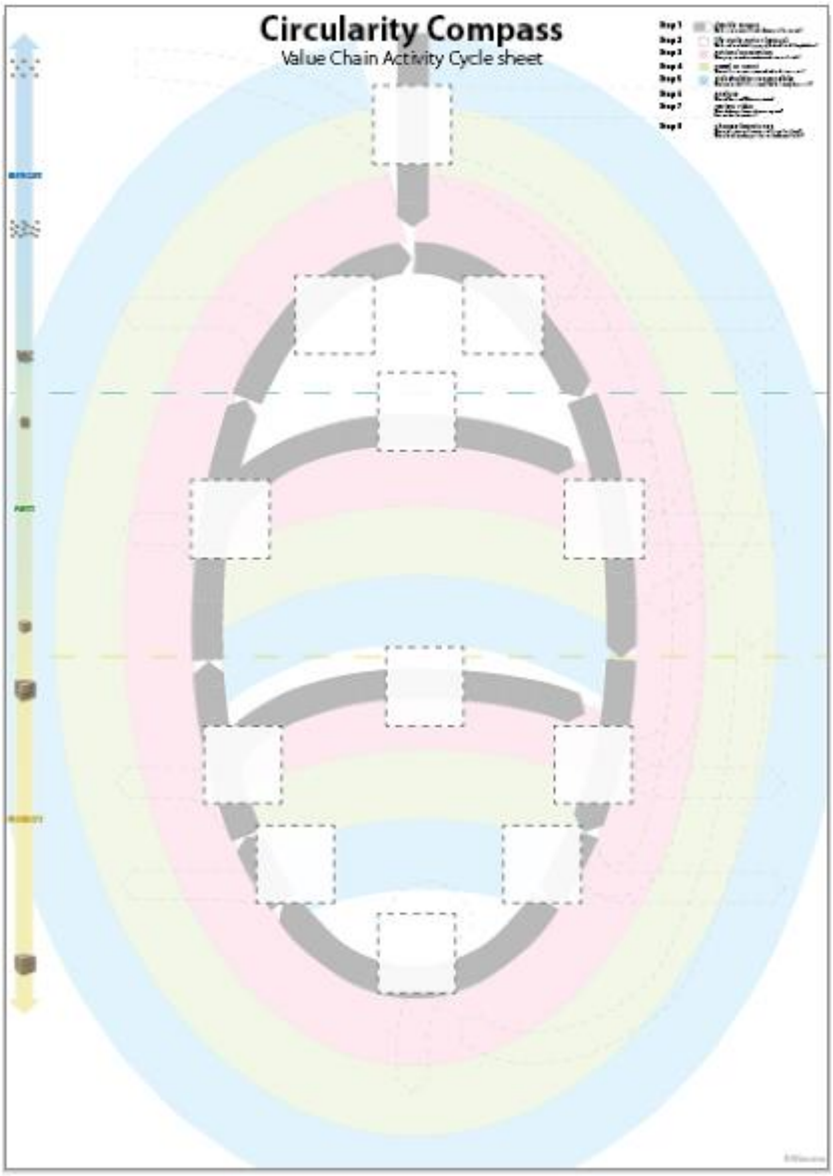
2.2.2 Value Chain Activity Cycle

Circularity Thinking tools described in the previous section were used in the first version of the Use Case Needs Analysis and Circular Value Flow Mapping (D6.1) to describe the needs from the perspective of the three use cases and to develop a detailed mapping of the targeted material flows in each use case. The goal of the deliverable at hand is to add greater detail to these use case analyses and to provide an opportunity to make revisions to the initial mappings. For that, another tool of the Circularity Thinking toolkit was used: the Value Chain Activity Cycle (VCAC). The VCAC –

also referred to as Activity Cycle – was developed by Prof Dr Fenna Blomsma and colleagues [13] as an extension of the Circularity Compass and as a tool to consider and organise actors, actions and stakeholders around the developed circular strategies (Figure 6).

The Activity Cycle is a great enabler to make complexity visible and keep it under control. For example, it helps to show which actors have which responsibilities, and how actors are connected and potentially dependent on each other. It is also a tool to help visualise the available or missing information and uncover hidden barriers, potentials, or insights.

Figure 6 The Value Chain Activity Cycle (by Fenna Blomsma and colleagues)



13 Blomsma, F., Jensen, T. H., Pigosso, D. C. A., & McAloone, T. C. (2020). Collaborating and Networking for a Circular Economy: CIRCit Workbook 6. Technical University of Denmark.

Within Onto-DESIDE, the Activity Cycle is used to refine and extend the use case mappings developed in D6.1. Each use case will use its existing material flow mapping as the foundation to work with the Activity Cycle. The existing case mappings visualise the as-is state and include (1) circular strategies that are already in place and (2) highlight where structural waste is still present. In the case of already implemented circular strategies, the Activity Cycle helps to add more detail and create specific questions. For those instances, where structural waste is present, the Activity Cycle exercise can be used to identify in greater detail what actions would be necessary to turn the identified structural waste into a circular strategy. The information flow mappings also serve as input for the VCAC. In D6.1, the use cases have developed a preliminary overview of the information requirements. These information pieces can now be integrated into the VCAC by allocating an information piece to the value chain actors who requires the information and identifying which stakeholder is responsible for providing the information. The use cases also have the opportunity to make adjustments or additions to their mappings.

The VCAC methodology follows five steps:

Step #1: Deciding the initial focus

As a first step, it has to be decided which of the circular strategies identified on the Circularity Compass should be examined first.

Step #2: Identifying the lifecycle actors

The actors or groups that are involved in each phase of the product lifecycle have to be identified. Names are added to the Compass in the relevant squares. External actors like public authorities, policy makers, trade associations, research institutes, as well as investors, often play a major role in supporting innovations like this and should be added below the compass.

Step #3: Listing the actions

In the pink band, the actions or steps each specific actor or group needs to take to implement the new way of working are listed. Actors may need to be involved in identifying waste, providing finance, managing customers, extending the product lifecycle or implementing specific circular strategies such as recycling.

Step 4: Identifying the needs

In the green band, the needs or wants that are associated with specific actions or steps are identified. A 'need' can be thought of as the support the actor requires to complete the action successfully. What information is needed? What format is the most useful to them? Where can it be found?

Step 5: Identifying the stakeholders

Finally, in the blue band, the stakeholders who are responsible for addressing specific needs are identified. The stakeholder can be internal to the organisation, an external stakeholder, or a combination of stakeholders.

In summary, the Activity Cycle is used to identify who key life cycle actors are, what actions need to be taken and which stakeholders will address these. It also helps to define roles and responsibilities of all actors.

For this deliverable, all use cases completed the VCAC for three circular strategies they had identified on their material flow mapping in D6.1. The findings of the three VCAC analyses were then compiled on one VCAC summary image. The summary image then served as the foundation to extend the use case analysis. Among the reflections that could potentially result from the VCAC cycle are:

- Are changes to the circular strategies required? Were any additional circular strategies implemented since the initial mapping?
- What are current uncertainties or barriers within the value network?
- What information remains or has become unavailable?
- Have any of the envisioned circular solutions become unfeasible?
- What responsibilities does each value chain actor have (e.g., manufacturers, retailers, users)?
- Are additional stakeholders required?
- What may be key actions or needs?

The list of these possible reflections only serves the purpose to showcase what insights could result from the VCAC exercise.

As the VCAC exercise can be time-intensive it was agreed within WP6 that each use case carries out the exercise and analysis for three circular strategies from the material flow mapping. The analyses of these mappings thus represent only a part of each use case's circular value network. The summary images of each use case and their analyses are presented by each use case in their respective chapter.

2.2.3 Extension of the MFM: Energy and Value Flows

All tools and methodologies that have been used so far are part of the Circularity Thinking toolkit by Prof Dr Fenna Blomsma. However, while the existing tools serve as a ready-made starting point for Onto-DESIDE use cases, it is the objective of WP5 to further develop this methodology. The Multi-Flow-Metabolism (MFM) – which is a visual representation of an industrial metabolism comprised of material-, energy-, value-, and information flows – is the conceptual starting point for the methodology extension (see Figure 7). Current Circularity Thinking tools focus primarily on material flows, however, previous research shows that energy-, value-, and information flows also need to be considered carefully in the development of circular value networks. Therefore, it is the objective of WP5 to turn the MFM into a strategic tool beyond the project. While this work is ongoing in WP5 at the point of writing, WP5 initiated first discussions on energy- and value flows within the use cases. These discussions are recorded as part of the work for D6.2.

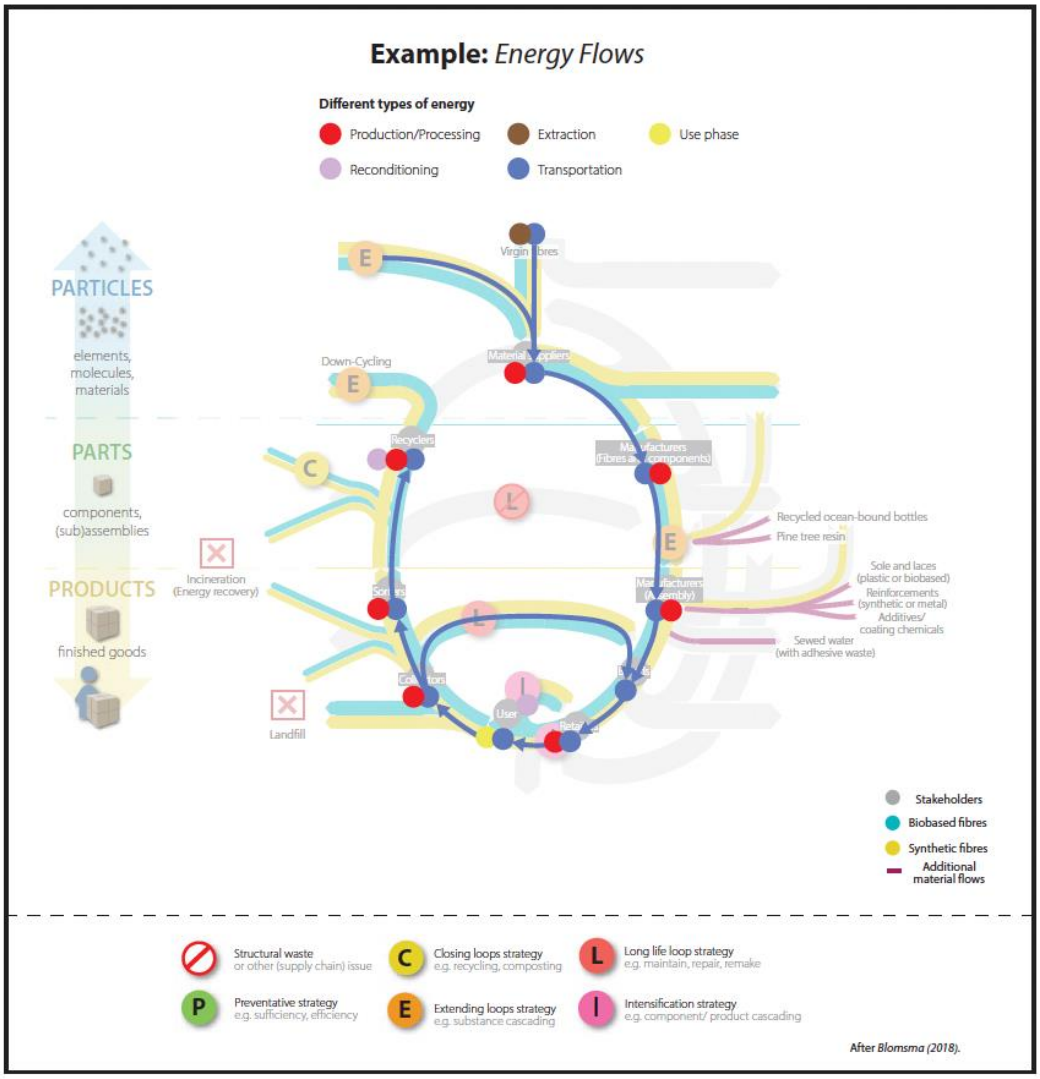
The material flow mappings of each use case carried out for D6.1 were used as the starting point for the preliminary – and high-level – analyses of the energy- and value flows. All use cases were asked to map their energy and value flows through the following steps.

For energy flows

- To start the conversations on energy flows in each use case, five different types of energy were pre-defined by WP5: Extraction, production/processing, transportation, reconditioning, use phase. These different types of energy present a starting point and are subject to change.
- Each kind of energy, with the exception of transportation energy, is visualised through different colored circles. Transportation energy is illustrated through the use of an arrow to illustrate that it "connects" different parts of the circular value chain.

- The use cases were asked to assign the different types of energy to the different circular strategies and processes as indicated on the D6.1 material flow mapping. The partners placed either a circle or an arrow (in the case of transportation) on the material flow mapping.
- This mapping did not capture the element of relative energy consumption, i.e., when one process is more energy intensive in comparison to others; instead, the focus was to understand what different kinds of energy are present.
- This exercise allowed for an initial overview of the different types of energy required for each use case scenario and provided first insights. See Figure 7 for an example of such a mapping.

Figure 7. Example of an energy mapping

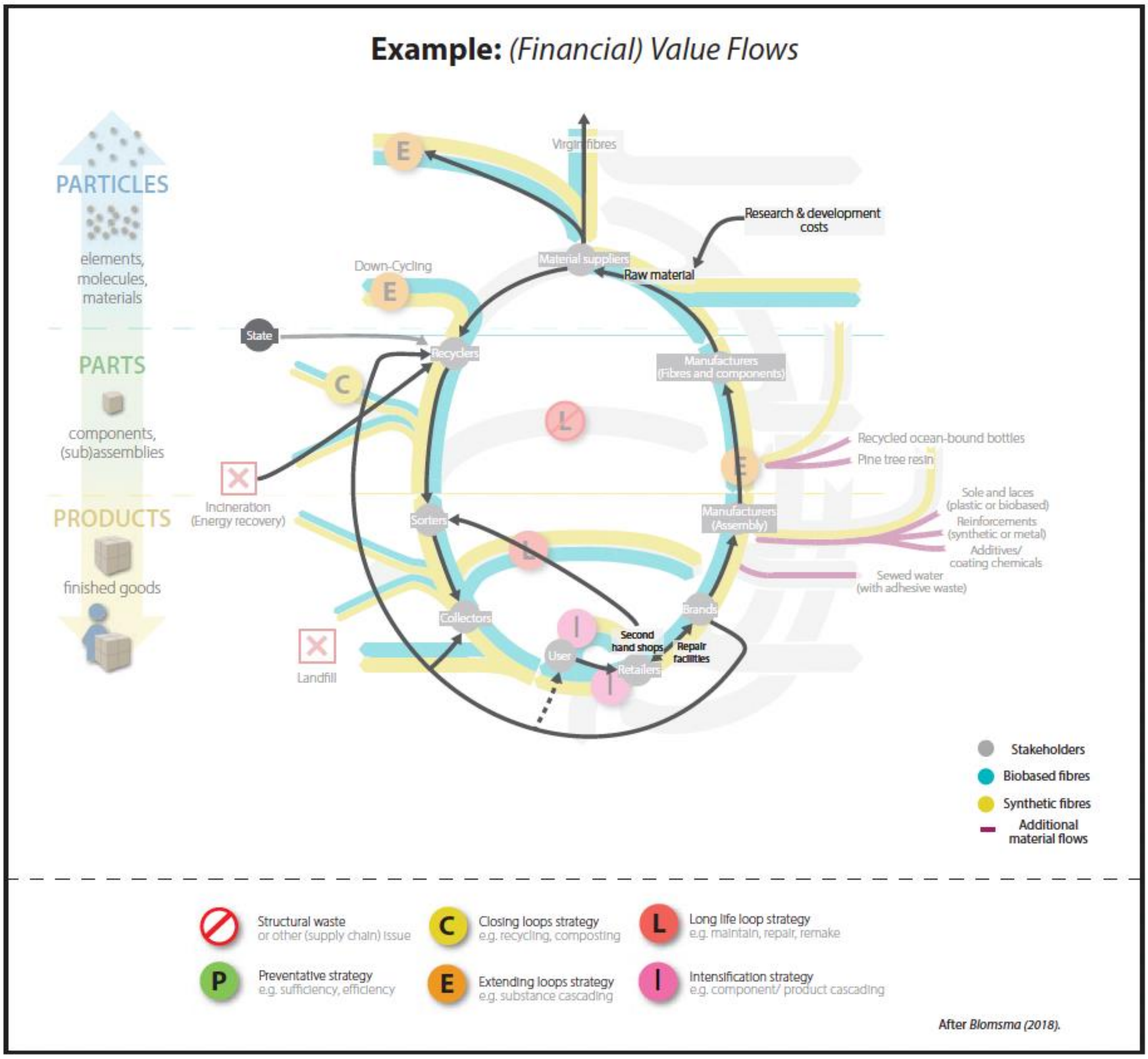


Looking at the example mapping starting at the top, it can be observed that energy is required for the extraction of virgin fibres (brown circle). Energy is then used for the transportation of the virgin fibres and the secondary raw materials to the material suppliers as indicated through the two blue arrows that lead to the material suppliers. Energy is then used in the processing of these materials (red circle) before these are transported to the manufacturers (indicated by a blue arrow again). Given that the methodology development is still at its very beginning, some of the observations may seem rather obvious; nevertheless, these initial mappings are a starting point to understand energy flows and provide the foundation to compare between the use cases.

For (financial) value flows

- The definition of value for a circular value network is still ongoing within WP5. Therefore, the focus of this exercise was placed on financial value only.
- That is, the partners were only asked to map the financial value flows for the respective material flow mappings by drawing arrows representing monetary exchanges.
- In the financial value flow mappings, the flow of financial value is indicated through a black arrow between value chain actors. See Figure 8 for an example.

Figure 8 Example of a (financial) value mapping



The black arrows show the flow of financial value. Similar to the energy mappings, some of the arrows may appear obvious, e.g., that material suppliers have to pay for the virgin and secondary fibres, or that brands pay manufacturers. Nevertheless, these mappings also show first use case specific features. For example, the brand may incentivise the user to return the product by paying a small fee or by selling new items to the user at a discounted rate. A retailer may also pay money to sorters to receive items directly from them, as may be the case when a second-hand shop sources products which do not need additional repair or refurbishment from the sorter.

Given the early development status of this methodology, the use cases were instructed to not spend more than 30 minutes to an hour on these mappings. The following questions were posed as thought-provoking suggestions for possible reflections on the exercise. It was upon the use cases to decide how to structure their analysis.

- Which types of energy flows are present the most? What part of the value chain is the most energy intense for respective types of energy?
- What patterns can you identify?
- Where does value flow differently due to your circular strategy?
- Which actors capture the most values flows?
- Where are large value flows between actors?

To draw conclusions for the development of the MFM into a methodology, this exercise will be followed up by WP5 to receive feedback:

- How was your experience in mapping these flows?
- Where did you start?
- What made it difficult?
- How was it helpful to initiate conversations?

Overall, these analyses present a first version of each mapping and are done at a high-level due to the early stadium of the methodology. It is important to note that particularly the mapping of financial value is just a starting point for the discussion on value flows. Other types of circular value will be integrated in the method development moving forward. The main objective of this activity was to start discussions on each flow in the respective use cases and to lay the groundwork for the third and final version of this deliverable (to be submitted in the third iteration). Additionally, the initial energy and (financial) value mappings build the foundation for the method development in WP5. WP5 will analyse the results of this deliverable with respect to the applicability and usefulness of the methodology, and will collect feedback from each use case. These first results will feed into the method development in T5.2 and will be part of D5.2 – a report on the "Multi flow circular value network design & development method".

3 Construction Use Case

3.1 Objectives of the use case

As described above, the objectives of the use case are to define the business needs and requirements from the perspective of the construction industry. The research data for this use case will be provided by the different partners in the construction use case team. Furthermore, we will map out the business opportunities for raised floors using the tools from Work Package 5 (i.e., Circularity Compass and the Multi Flow Metabolism (MFM)). Additionally, the insights from the second iteration are supplemented and applied in the Value Chain Activity Cycle.

3.2 Introduction to the construction industry

Of all the industries that require sustainable transformation to help us succeed in achieving the UN's Sustainable Development Goals, the construction sector is perhaps the most influential. Construction alone contributes to 23% of air pollution, 50% of climate change, 40% of drinking water pollution, 50% of landfill waste, and 40% of worldwide energy usage. Accounting for nearly 50% of annual global CO2 emissions, the built environment poses an existential threat to our planet.
The main reason is the "take-make-waste" model of construction materials. They are produced, put in a building and then - after sometimes just 5-6 years - are disposed.
While decision-makers and industry leaders are eager to adopt new technologies to address these problems, the development of necessary solutions is still emerging, and sustainability isn't integrated into the beginning stages of the construction process.
A promising scenario could be to empower all professional actors in the construction industry with the tools and resources they need to succeed in circular construction practices. The most measurable and achievable way to do this is by leveraging the data we have to help guide decisions towards a closed-loop "take-make-reuse" mentality.
In the construction industry use case, the objective is to design a circular value network for reuse based on semantically linked data that makes it possible to reuse construction components from a building. The use case will account for the following two scenarios in supplying components back to the manufacturer; the construction component is (1) reusable in its whole, or (2) as secondary raw-materials.

3.3 Partners and Contributors

Three organizations will be part of completing this use case;

- Lindner Group (https://www.lindner-group.com/), who is the producer of inner ceilings and floors.
- Restado & Concular (https://restado.de/, https://concular.de/), who assess material values in buildings and make secondary construction components and material available for reuse.
- Rang-Sells (https://www.ragnsells.com/), who collects and treats waste streams to turn waste into valuable raw materials.

These organizations will provide data, information and knowledge in the following domains: supply chains, product information, capabilities in collection/deconstruction, treatment and transportation of waste streams and materials.

For this use case one product from Lindner Group was selected and used as the object from which to elicit ontology requirements and apply the Circularity Thinking framework and the Circularity

Compass to identify, among other things, the information needs. Rang-Sells will establish with Concular a take-back system and outline ways to integrate that system into a new building, using the ontology-based data documentation.

3.4 Workplan - Methodology for determining the user story

In a first step a non-exhaustive list of actors and partners in the construction industry was established. These are professional companies and institutions that impact and shape the construction industry. Accordingly, we looked at the information these actors can provide on and/or need from a product.

Actors that can be distinguished and their possible needs defined

- Raw material supplier
- Recycling material supplier
- Building waste Disposer
- Manufacturer
- Planer
- Legislator
- Building Owner
- Building User
- Dismantling Company
- Refurbishment Company
- Recycling Company
- Permit Institution
- Reuse Market
- Etc.

In a shared information data system, one can expect the following information to be searched, needed, retrieved and provided:

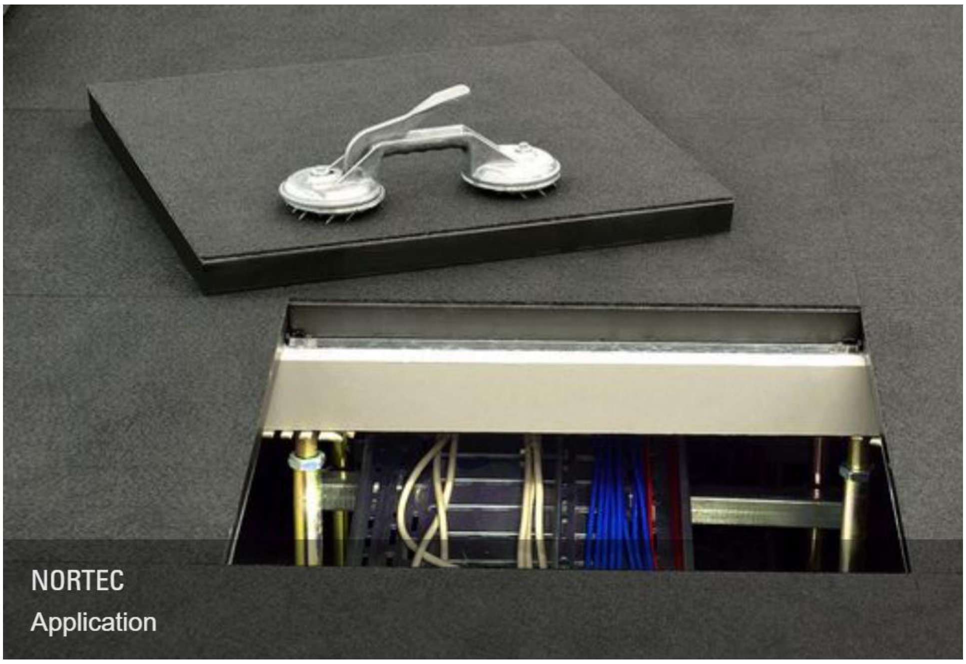
- composant ID
- quality
- product ID
- composants
- production date
- take back program
- circularity possibilities
- policy on treatment
- state
- use span (installation date)
- dismantling costs
- reuse potential
- local availability
- costs
- recycling potential
- market value

- reuse potential
- Etc.

3.5 Use case description

The product we are studying in this user case is a raised floor manufactured by Lindner in 2022. The floor tiles are installed in an office building in Mannheim at the end of 2022. Ten years later the tenant moves out and the building owner decides to change the floor system. This means that the floor tiles will no longer be of use in the building (see Figure 9).

Figure 9 - Nortec Application



3.5.1 User's motivation to search for information

The building owner now wants to make a decision on what to do with the raised floor based on economic and environmental costs. Economic aspects includes also the factor time. The building owner wants a clear overview in terms of the different and realistic scenarios, such as:

- Bringing the raised floor elements into a take back system by the manufacturer
- Selling the floor tiles for reuse
- Selling the floor tiles for recycling of their components
- Disposal of the raised floor elements
- Etc.

In order to enable the building owner to make a decision, it will be crucial to feed information into these scenarios, such as costs, time and environmental impact of the scenario.

3.5.2 User's needs for information

The building owner needs information concerning all different scenarios. This concerns both financial, practical and environmental data. This information can be provided by different actors in the construction industry, being Manufacturer (take back system, information on components), Dismantling Company, Refurbishment Company, Recycler or Reuse Market:

- Take back system
    - Is there a take back system in place and how does it work?
    - Does the manufacturer dismantle the raised floor?
    - Does the manufacturer pick up the parts?
    - Who packs the material?
    - What are the costs and benefits of the take back system?
    - How much CO_2 and waste is saved through the take back system?
    - What does the manufacturer do with the collected material?
- Dismantling
    - What are the costs for a selective dismantling of the raised floor?
    - Which dismantling companies guarantee a professional dismantling?
    - How do I ensure that the tiles are not damaged by the chosen deconstruction company?
    - How do I include the dismantling in the tender?
    - How do I make sure that the deconstruction company has the skills for a selective dismantling?
- Demolition
    - What are the costs for a conventional demolition?
    - Will the material be sorted by the chosen demolition company according to the raw material of the components?
    - How is the waste treated after demolition by the chosen demolition company?
- Disposal
    - What are the costs for a disposal as mixed waste?
    - What does it cost to separate the components and dispose of them separately?
    - What happens to the waste after disposal?
- Refurbishment
    - What needs to be done to reuse the tiles?
    - What are the costs for repairing the tiles?
    - Are there adhesive residues? Do they need to be removed and if so, how?
    - Can the steel pedestals be saved and reused? (see Figure 10)
- Recycling
    - What is the residual market value of the raw materials?
    - What are the costs for a selective deconstruction and separation of the raw materials?
    - What are the transportation costs to the next recycling facility?
- Reselling value
    - What is the pricing for similar reuse products?
    - What is the pricing for similar new products?
    - On which platform can this material be sold?
    - Does the seller need to give a warranty for the product?
    - Does the buyer pay for the dismantling and the transportation?
    - Does the manufacturer provide a potential buyers list?
- Request on market

- Statistics on offer and demand for this product in the past 2 years
- Shortage of raw materials
- Shortage of skilled workers in the manufacturing industry
- Delivery delays
- Number of requests on online marketplaces
- Inside Information about new building projects

Figure 10 – Pedestals.

Pedestals
Overview over pedestals

3.5.3 Product description

The specific raised floor product that we will use for this use case is Nortec by Lindner. Nortec floor panels are manufactured from calcium sulphate (gypsum): a non-combustible material with good structural and physical properties.

Technical Information

PANEL

fibre-reinforced calcium sulphate panel, with galvanised steel sheet at bottom side on request, optionally with surrounding edge trim protection against damage and humidity

PANEL THICKNESS

16 - 38.5 mm

DIMENSIONAL DEVIATION ACCORDING TO EN 12825

class 1

SYSTEM WEIGHT

32 - 62 kg/m²

STANDARD PEDESTAL HEIGHTS

25 - 2,000 mm

PEDESTAL GRID

600 x 600 mm

RESISTANCE TO EARTH

≥ 1 x 106 Ω (depending on covering)

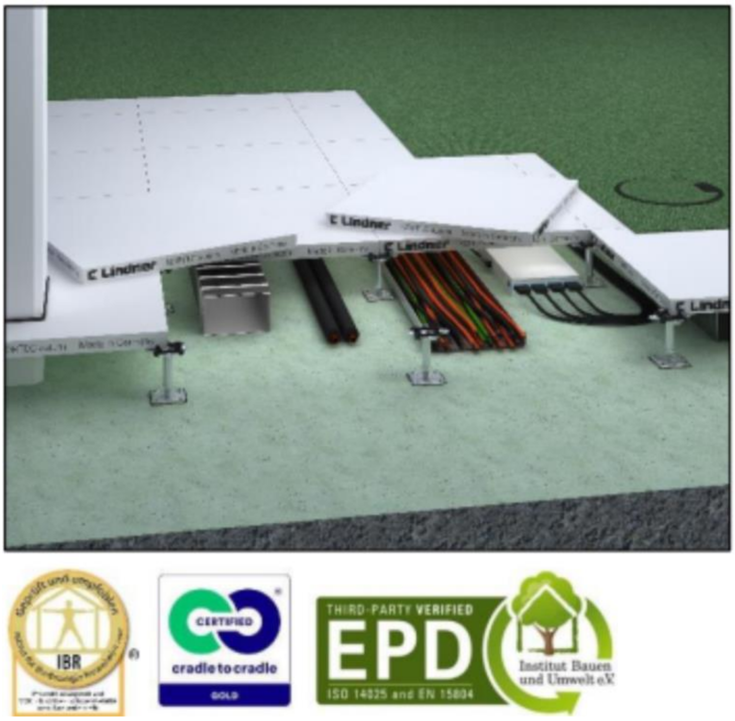
Material Health

The parts of the floor system have to be secure and not harmful for health and environment. Lindner develops raised floor systems which are environmentally friendly and also not harmful for the human being from the production up to the usage and reuse. The composition of the chemical components is known. Emission tests according to national and international standards (e. g. AgBB scheme) assure low-emission and harmless materials.

Material Recycling

The raised floor Nortec is a product with good reuse and recycling possibilities. A separation of all components is possible at the end of the usage phase (see Figure 11). The carrier panel from calcium sulphate can be recycled to 100 % and be returned to the production cycle. The steel pedestals can also be recycled after conversions or demolition.

Figure 11 - Demo case

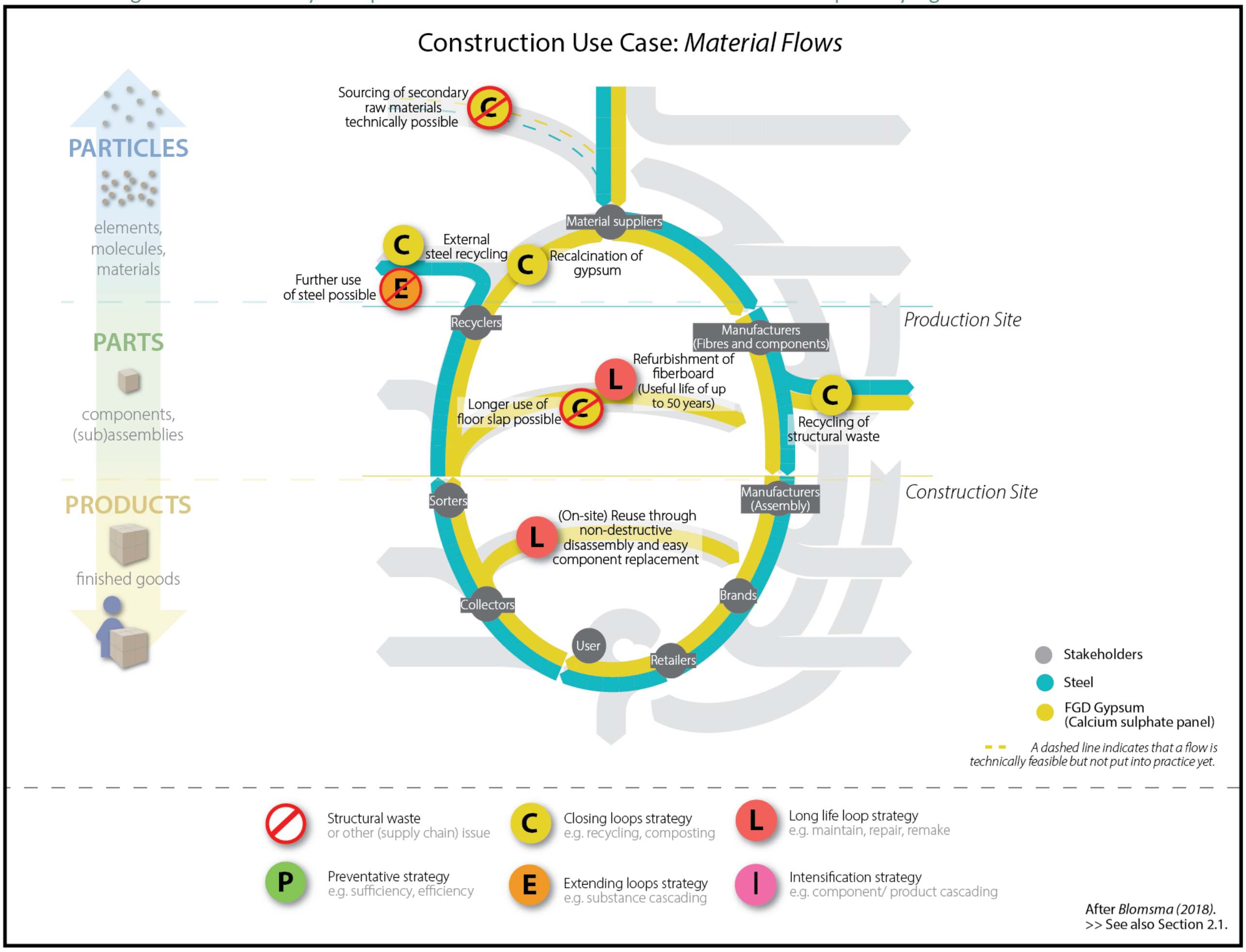


3.5.4 Material flows

Structural waste

With a water circulation concept, water consumption is systematically reduced. The necessary process water can circulate in the circuit due to sedimentation and cleaning of the solids. Waste that cannot be avoided during production is fed into recycling processes via specialist disposal companies. The NORTEC raised access floor has a material reuse value of 72.11, which is calculated from the proportion of recycled materials and the proportion of materials that can be recycled (see Figure 12).

Figure 12 Circularity Compass of the construction use case value chain portraying the material flows



Further use / Refurbish:

Due to the functional longevity of the gypsum fiberboard, the panel can be resold 100% technically complete as a NORTEC raised access floor panel. Thanks to the take-back guarantee and rental models, further use of the access flooring is possible without any problems. After the non-destructive dismantling the product's components are returned to production.

The components that may need to be replaced are the top application (all flooring variants), the statically effective steel sheet on the underside of the panel and the side edge band. If necessary, the edges and surfaces will be reformatted. The removal of the applications and the preparation of the surfaces can be carried out directly at the Lindner plant. The reconditioned panels are put back on the market as "ReUsed Products".

Increased service life:

The useful life of raised floors is more than 50 years (according to BBSR table, code no. 352.911, as of 02/2017, published by the Bauinstitut für Bau-, Stadt- und Raumforschung).

Reuse / Multiple use:

Through a single and non-destructive disassembly of the raised floor panels, the system can be easily reused. The reuse of the product can then take place in the same building or in another building.

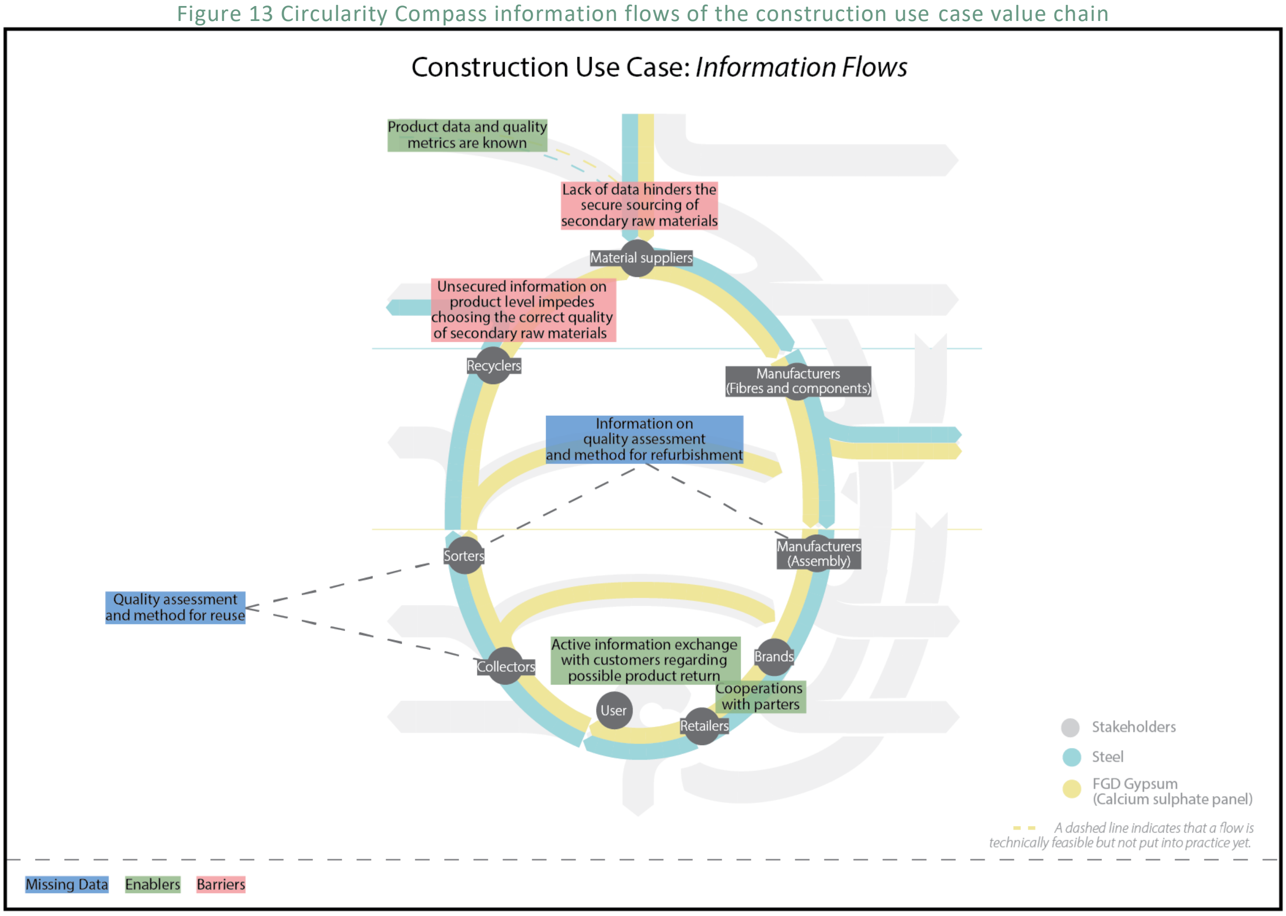
Recycling:
If the gypsum fiberboard no longer meets the technical requirements after it has been taken back, it can be processed into a reactive raw material gypsum in the factory's own processing plant by means of recalcination. This serves as a starting material for the production of further gypsum fiberboards.

- Steel pedestals are fed into an external recycling process after removal from the building
- Soil application -> Waste or material recycling

3.5.5 Information flows

From Linder's perspective, all product data and quality metrics are known. On the other hand, Lindner does not have information on dismantled NORTEC raised floor elements: where to find them, how many can be found, when will these elements be available? Therefore, procuring secondary raw materials in a secure way is hard due to lack of data on those materials. Access to more data, and at increased granularity, would increase the usage of those materials (see Figure 13).
Additionally, an active exchange with customers regarding a possible return scheme of the product would further increase the reuse and also produce less waste. But creating such a scheme would require that the product could be identified with the correct quality metrics and that the required logistics could be arranged for it to be returned in a reusable state.
Information on product level are not registered throughout the lifecycle of the product which makes it hard to securely assess the quality and secure the correct handling of the product, either for reuse or to transform it into secondary raw materials.

Figure 13 Circularity Compass information flows of the construction use case value chain

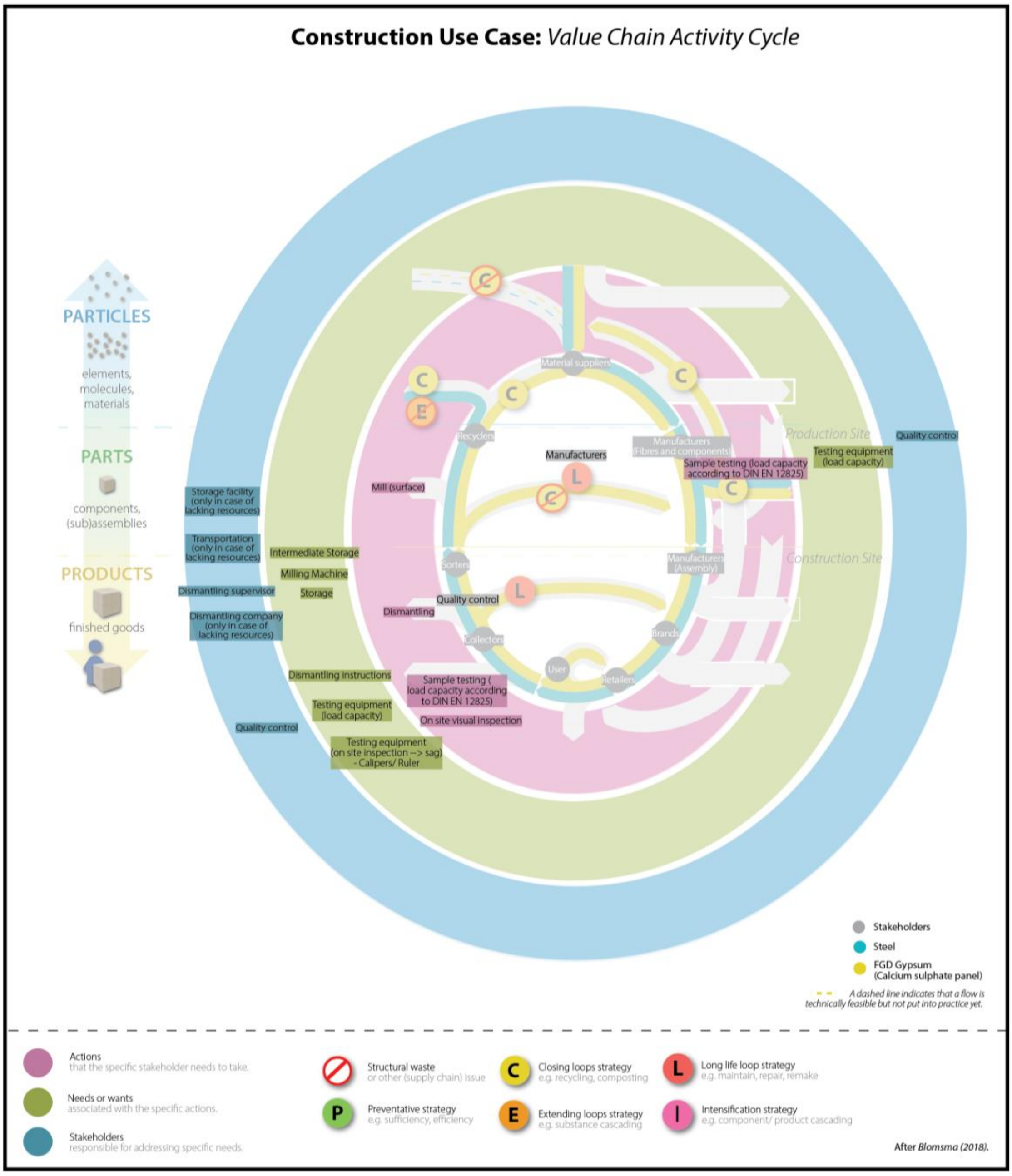


3.5.6 Activity cycle material flow

Upon revisiting the Circularity Compass (as documented in D6.1) for an iterative update and prior to its expansion with the Value Chain Activity Cycle, it became evident that the recycling of dust, cutouts, and construction site leftovers had not been integrated into the Circularity Compass. These materials can be transported back to the factory's processing plant, where they could undergo recalcination to yield reactive raw material gypsum.
Furthermore, users have the option to independently reuse the flooring panels within their property, bypassing Lindner's prescribed reuse procedure, thanks to the panels' straightforward dismantling process.

In the course of elaborating the Activity Cycle, three distinct strategies were delineated for more thorough investigation (see Figure 14).

Figure 14 Activity cycle analysis for the construction use case



On-Site Reuse

To enable the on-site reuse of flooring panels, an initial visual inspection of the panels is imperative. This inspection is overseen by a factory supervisor who evaluates the panels' condition. If the inspection confirms their suitability for further use, the panels must be dismantled non-destructively. Before these panels can be reintegrated, a specific number of them must undergo testing in accordance with DIN EN 12825 standards. The testing is carried out at the factory's dedicated testing facility located on its main campus. Unfortunately, the selected panels are sacrificed during this testing process. However, if the testing results align with the required standards, the dismantled panels can be confidently reintroduced on-site.

To effectively execute these actions, various prerequisites must be met. The visual inspector should have access to necessary testing equipment, including tools such as calipers and rulers, for identifying issues like panel sagging. For non-destructive dismantling, clear instructions must be readily available for on-site workers. Depending on the project's timeline, proper storage is crucial to safeguard the panels from damage and ensure the construction work can progress without hindrance. Additionally, equipment is essential for load capacity testing during the panel assessment process.

In the course of this process, various stakeholders come into play. These include the factory itself, which is responsible for quality control and overseeing the dismantling process. In instances where Lindner lacks the necessary capacity or resources, the involvement of storage facilities, dismantling companies, and transportation companies becomes equally essential.

Refurbishment
In the refurbishment process, there are two key stages: one after use and another one after refurbishment. When refurbishing after the use phase, several steps mirror those of on-site reuse. This includes an initial visual inspection and sample testing, followed by the dismantling of the tiles. Even when refurbishing as leftover materials, sample testing is essential. For the refurbishment process, the tiles need to be transported back to the factory's plant for surface grinding and repreparation, as on-site methods are currently unavailable. After refurbishment another sample testing is necessary to guarantee the products compliance with standards.

Facilitating this process necessitates the provision of testing equipment for the visual inspector and sample testing at the testing facility, along with clear dismantling instructions. Unlike on-site reuse, machinery for grinding and repreparation is indispensable. Additionally, an intermediate storage solution is required to bridge the gap between the refurbishment process and the subsequent use of the tiles.

In this context, Lindner assumes a more pivotal role compared to the stakeholders involved in the reuse process, as refurbishment primarily occurs at the factory.

3.5.7. Activity cycle information flow

In addition to the aforementioned information flows, there is a pressing requirement for panel tracking and localization, which currently lacks a viable solution. The implementation of such a solution, if feasible, would facilitate the anticipation of material flows and provide the necessary data for potential reuse or recycling processes.

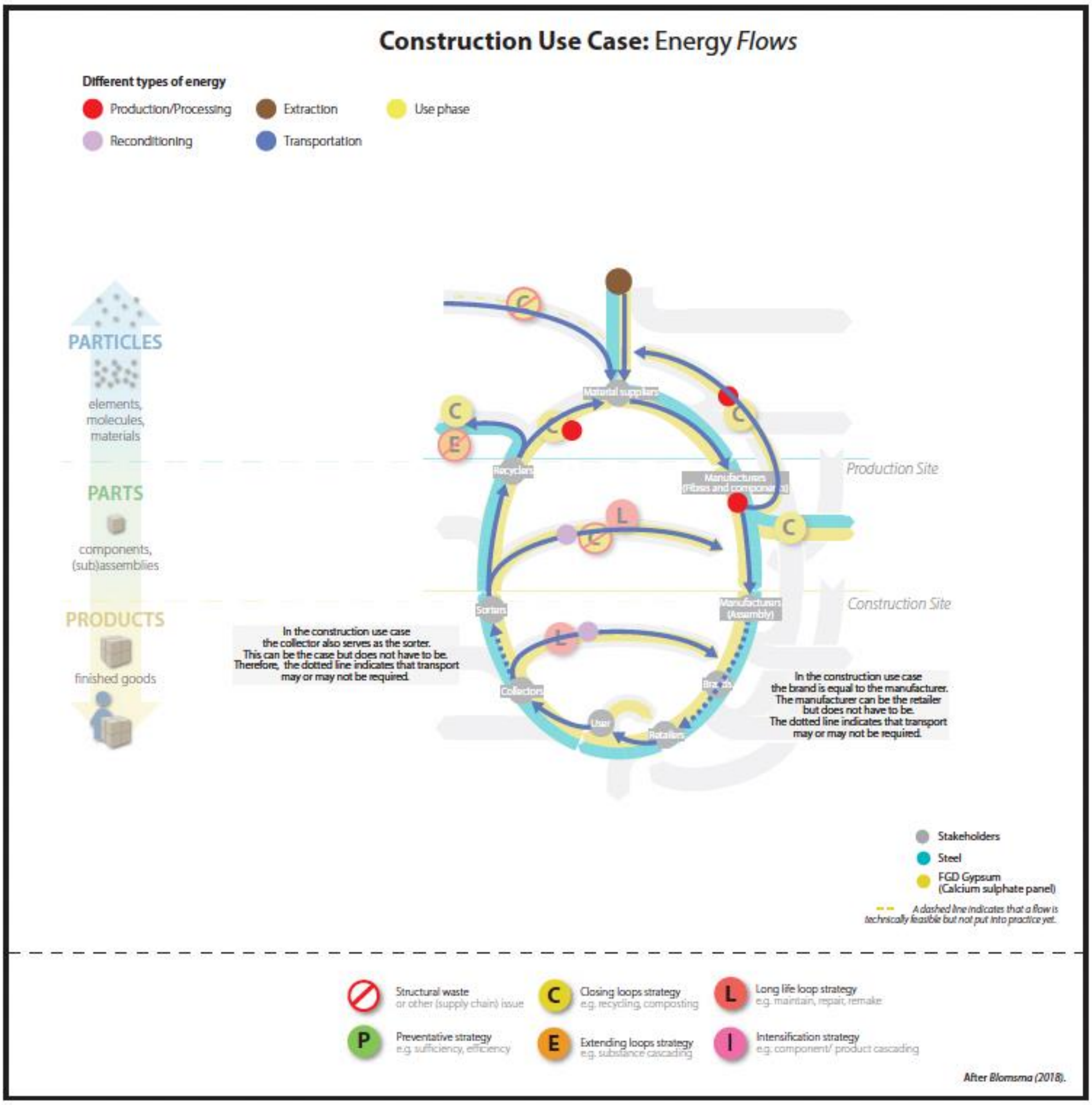
3.5.8. Energy flows circularity compass

For the initial mapping of energy flows we focused on three types of energy related activities: Production/processing, Reconditioning and Transportation (see Figure 15). No work was put into assessing the magnitude of energy, rather we focused on mapping out where these three energy types occur. In this initial mapping, transportation is the most frequently occurring energy type for the construction use-case.

Furthermore, we observed that on-site material reuse plays a pivotal role in minimizing the need for transportation. By reusing materials on-site, construction projects can significantly reduce their reliance on external transportation, leading to both energy and cost savings.

Another notable aspect we discovered is the dynamic and varying nature of energy flows. Energy consumption in these three categories exhibits different intensities and fluctuations, highlighting the need for adaptable strategies in energy management and conservation.

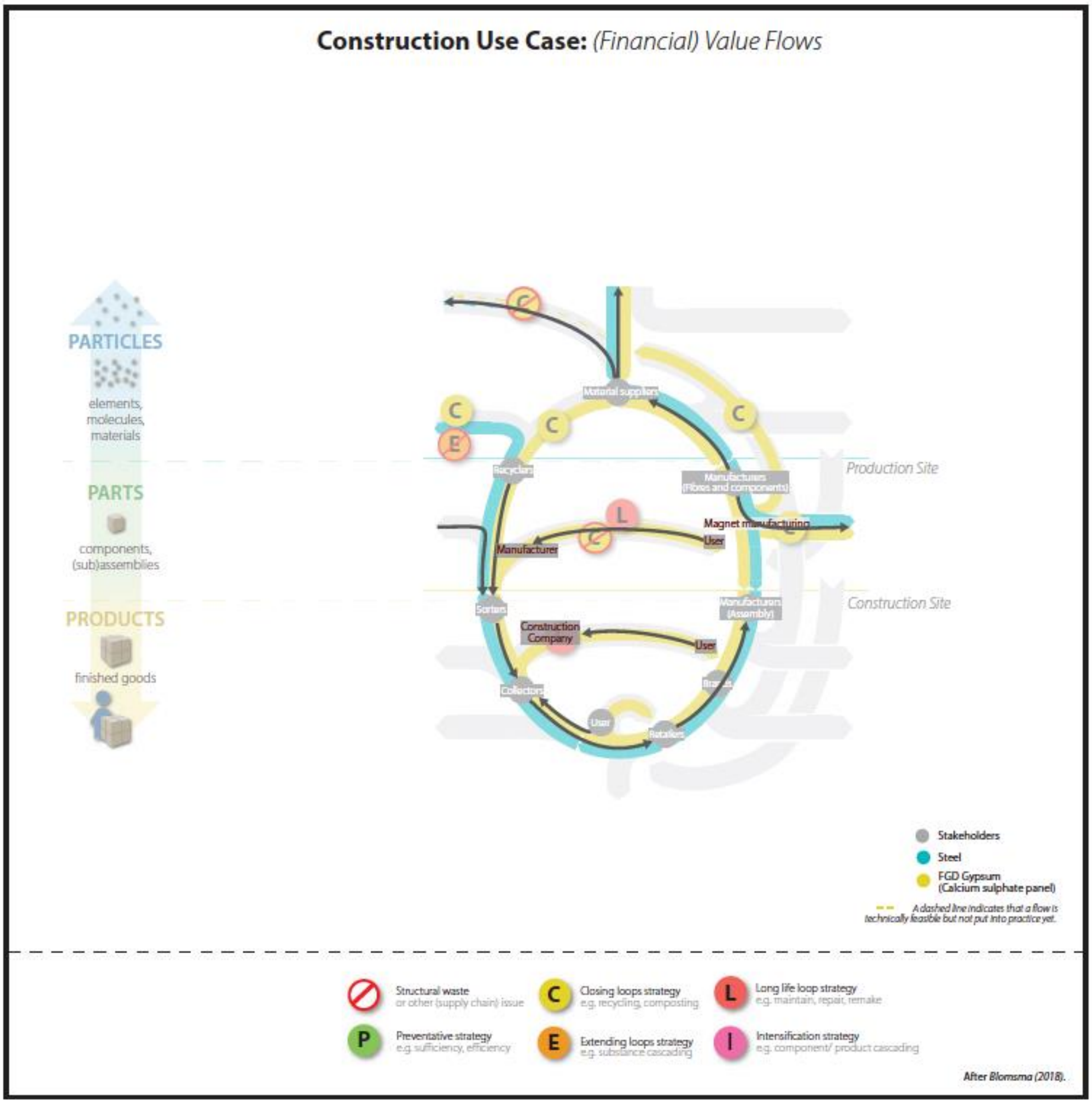
Figure 15 Circularity Compass energy flows of the construction use case value chain



3.5.9. Value flows circularity compass

The initial mapping of value flows was done with financial value in focus. The exercise proved to be challenging even only considering the financial flows. Actors can have different roles depending on where in the cycle they are working. For certain actors, this means that they could be inclined to pay for a certain service and at the same time get paid for something else. In further extending the value flow mapping, this will be more clearly defined as value are not always monetary and some flows will be replaced by other forms of value. Additionally, the value flow can go both ways. For example, collectors sometimes pay to obtain the product from the user, while in other scenarios, the user has to pay the collector to take the product (see Figure 16).

Figure 16 Circularity Compass value flows of the construction use case value chain



3.6 Main challenges

The challenges in this use case will be the following:

- Many actors are involved which makes it complex to get a clear picture of what is the essential steps in the handling of the product and how these should be described and defined.
- How and who checks if the provided data is correct? For further modelling of the ontology, we need to take into account that real world actions need to be in place to validate what is used as input.
- How is the communication between the actors organised? To some degree there will be an agreeable consensus in what will later be defined in the ontology as a result of the use case,

but at least initially, there will not be a complete flow and that will require more communication between actors to make up.

- Data security will need to be taken into account in every aspect of the work. As per design, we are aiming for the possibility to share sensitive product and process data at source.
    - Manufacturers might not want to provide information on the composition and manufacturing process of their building products to competitors.
    - Building owners might not want to make their demolition projects public.
- How can data about the products be retained over an extended period? Floor tiles are typically used in buildings for over 10 years before they are replaced.

4 Electronics And Electrical Appliance Use Case

4.1 Objectives of the use case

The electronic use case will demonstrate the implementation of the ontology-based supply chain communication technology in order to decentrally and confidentially connect many supply chain stakeholders and communicate material data along the supply chain. This approach is meant to fulfil several functions within the Onto-DESIDE project and specifically Work Package 6.

First and foremost, the developed ontology of the project is being tested and validated. This testing and validation process identifies whether 1) the ontology enables generalisation that is broad enough to function across three different sectors and 2) the ontology allows for the communication of material information without any mislabelling of materials that are not applicable to industry standards.

Furthermore the testing and validation identifies what concretisations are necessary for the specific sector and what industry standards and pre-existing data formats are to be taken into consideration and integrated. This entails for example proprietary classifications of data by big CRP system providers, the applicability of generic standards like CAS numbers, as well as the availability of different types of data around the product, production process and recycling process.

Furthermore, the electronics use case will demonstrate the combination of Circularise's supply chain communication technology and the developed ontology. In order for this assessment to take place, the ontology will be used to determine the data format on the Circularise system, which is then tested with real material data of components and the final product of a magnet containing speaker. This demonstration also specifically analyses the applicability of the ontology and the communication software for the electronics industry with the example of a selected group of suppliers to the demonstration product.

4.2 Partners and Contributors

4.2.1 Circularise

Circularise is a scale-up that enables value chain transparency without disclosure of material data or supply chain partners. The solution uses decentralised, encrypted data to track material and product characteristics, e.g. what chemical composition a product has and what sustainability characteristics it fulfils. The technology decreases auditing costs and scaled standards, certification schemes and transparency. This B2B software-as-a-service (SaaS) technology allows companies to adhere to government regulations and policies relating to the circular economy, sustainability and recovery and recycling of materials. The insights that can be shared and collated using the B2B SaaS can support companies to advance their circular economy innovation strategies and implementation.

Circularise's "Smart Questioning" technology enables companies to monetise data in 3 ways. Firstly, Circularise's technology provides real time monitoring of material flows through complex supply chains to better understanding the composition of the materials used and manufacturing impacts so that they can:

1. prove the source of materials used,
2. verify the materials are conflict or hazardous material free,

3. provide data on the content of their products and materials that can be recovered under Extended Producer Responsibility (ERP) regulations, and
4. prove the percentage of recovered or recoverable materials they are using.

As there is an increasing focus on providing “Life Cycle Assessment” (LCA) data, such as carbon emissions or water usage, companies are required to assess their supply chains beyond Tier 1 and 2 suppliers to include the full supply chain. Circularise’s technology allows companies to incorporate data from end to end of the supply chain to include and report on Scope 1,2 & 3 to aggregate the embodied energy of materials and products.

Finally, companies use Circularise’s technology to:

1. Drive growth by charging a premium for a digitalised version of their products,
2. Mitigate risks by identifying anomalies and risks before they become a problem,
3. Identify and reduce CO2 emissions within their supply chains
4. Perform Mass Balancing and Traceability operations
5. Reduce costs by using an automated system, which in turn removes the potential for fraud or human error, and
6. Drive collaborative innovation to implement new circular business models such as product lifetime extension, closed loop materials, or product take-back etc.

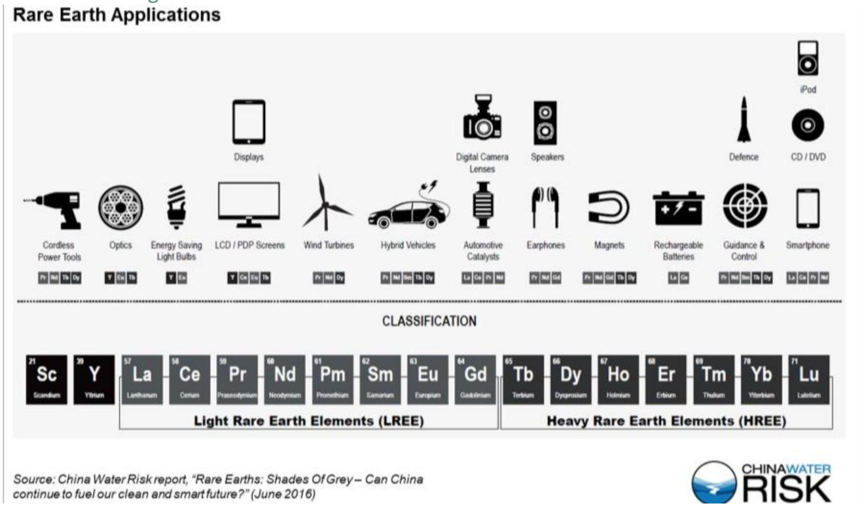
Currently, because many companies use manual auditing methods that lack visibility and real time data, the information they have is often insufficient and ineffective, flawed and sometimes corrupt, and doesn’t have real substance in driving change within a supply chain.
The pressure from NGOs, regulators and consumers mean more transparent data is becoming a necessity.

Circularise solves these problems by enabling clients to monitor and record in real time current material and product flows throughout their whole supply chain, enabling them to create a circular economy and reduce their environmental impact. Additionally, as substantial amounts of data are collected this means companies can monetise this to increase profits.

4.2.2 Rare Earths Industry Association (REIA)

REIA is a global association with a European foundation which aims to enable sustainable, responsible, collaborative and transparent Rare Earth Value chains, from mine to recycled sources. REIA provides a platform for stakeholder networks, conducts research and develops strategies, and supply chain standards. In the project, REIA will provide knowledge on the supply chain stakeholders and processes. Furthermore, it will further develop its own standard and engage stakeholders in the demonstration. REIA’s global network with 80 active and committed members on REE sustainability representing all spectrum of the value chain along with a large network of stakeholders from downstream. This large network will enable the consortium to commercialise the services and realize the project objective in a timely manner. REIA identified two stakeholders within the membership or professional network of REIA, who will inform the demonstration of the electronic use case on Circularise Technology. The stakeholders form part of the supply chain of a typical speaker system for end-users or as subcomponent for larger products like e.g. a car or a smart device (Figure 17).

Figure 17 Overview of materials with rare earth materials



4.3 Workplan

The electronic use case demonstration entails preparatory steps of a) understanding the data needs of the industry in terms of material and supply chain data needed (e.g. chemical composition, Lifecycle inventory data, chain of custody etc.) as well as the data formats that are inherent to the sector. Afterwards, the relevant adjustments are being made to the Circularise dashboard in order to reflect the industries and specific use case's needs. This assessment process also entails further research into the supply chain steps and circularity of the supply chain via the circularity compass model described in chapter 2. This mapping process of circular value flows identifies improvements towards circularity. The in-depth understanding of the challenges and opportunities of the electronics industry will be developed in cooperation with the Rare Earth Industry Association and its members.

The demonstration of the use case will entail the creation of a digital twin on the decentralised communication platform of Circularise employing the new semantic models designed in Work Package. This data-sharing demonstration will entail the involvement of several stakeholders of the electronics industry in order to determine great fit of the technical solution with the challenges of circularity in the industry. Several itineration between the demonstration and the ontology research in WP3 will result in a feedback and validation process for the ontology and respective improvements.

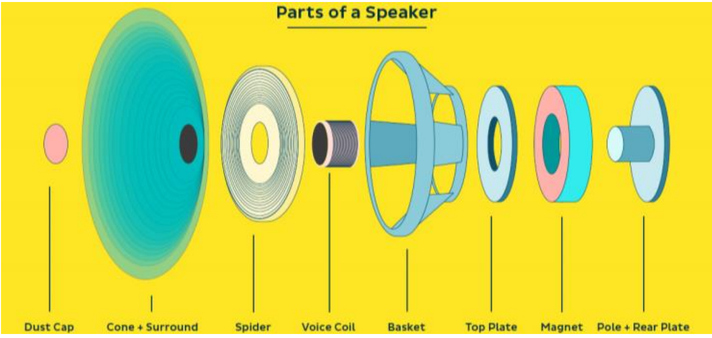
Use case description

The use case selected for the demonstration are speakers for typical smart devices sold on the B2C market. The demonstration entails typical components of speakers with a specific focus on the magnets and magnet materials used for the production of speakers.
A speaker typically contains the following components (Figure 18):

Speaker components:
- suspension
-basket
-spider
-voice coil
-dust cap

-diaphragm/ Cone + Surround
-magnet

Figure 18 Components of a typical speaker



The component which this product is specifically focusing on is the magnet. The latest developments especially in the renewable energy sector and its related energy storage systems has also reflected on the typical composition and production of magnets. The most common magnet components which the material flow analysis preceding the demonstration will focus on is as follows:

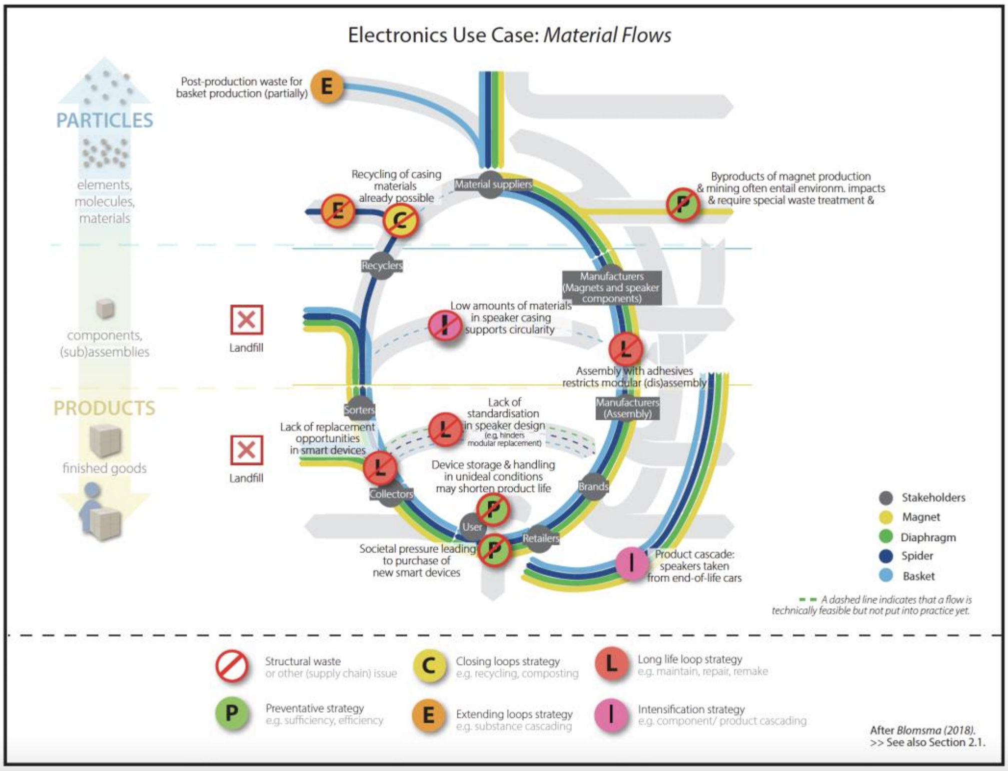
- Magnet materials:
- NdFeB
-SmCo
-Ferrite
-AlNiCo

3.4.1 Material Flows

The material flows along the supply chain of the speakers are specifically interesting for the biggest components of the speakers, the basket, Diaphragm, Spider and Magnet. Most of the material used in the production process entails raw materials, with a small amount of post-production scrap material (Figure 19). The possibility to increase the share of this post-production or even post-costumer material flow increases with the use of certifications and traceability solutions that provide further information on the material content ensuring quality and the opportunity to use the sustainable practise as a marketing opportunity. The material circularity within the supply chain on speakers varies a lot. The components with a simple composition and small amount of materials e.g. the spider and basket, containing mostly polymer-based materials are more easily reusable or recyclable. However, the low material value requires regulatory adjustments or sustainability certification in order to increase in frequency.

The component with the highest material value is the magnet. The proprietary recipe of the magnet and the small amounts of rare earth materials decrease the possibility to recycle the material of the magnet. In newer product-designs involving small amounts of glue and aiming for eco-design the opportunities to repair or refurbish a speaker is higher. This is especially true in B2B business relationships, e.g. the equipment of cars with a standardised speaker system. The high volume of products and the rather centralised repair shops (usually contracted automotive partners) increases the feasibility and likelihood of extension of the lifecycle of the product. The shorter lifecycle of speakers in B2C sales, e.g., in smart devices or as components of other devices such as smartphones, decreases the opportunities for circularity not only due to the lack of individual repairing capacity, but also due to the cultural expectations of a frequent replacement of smart devices.

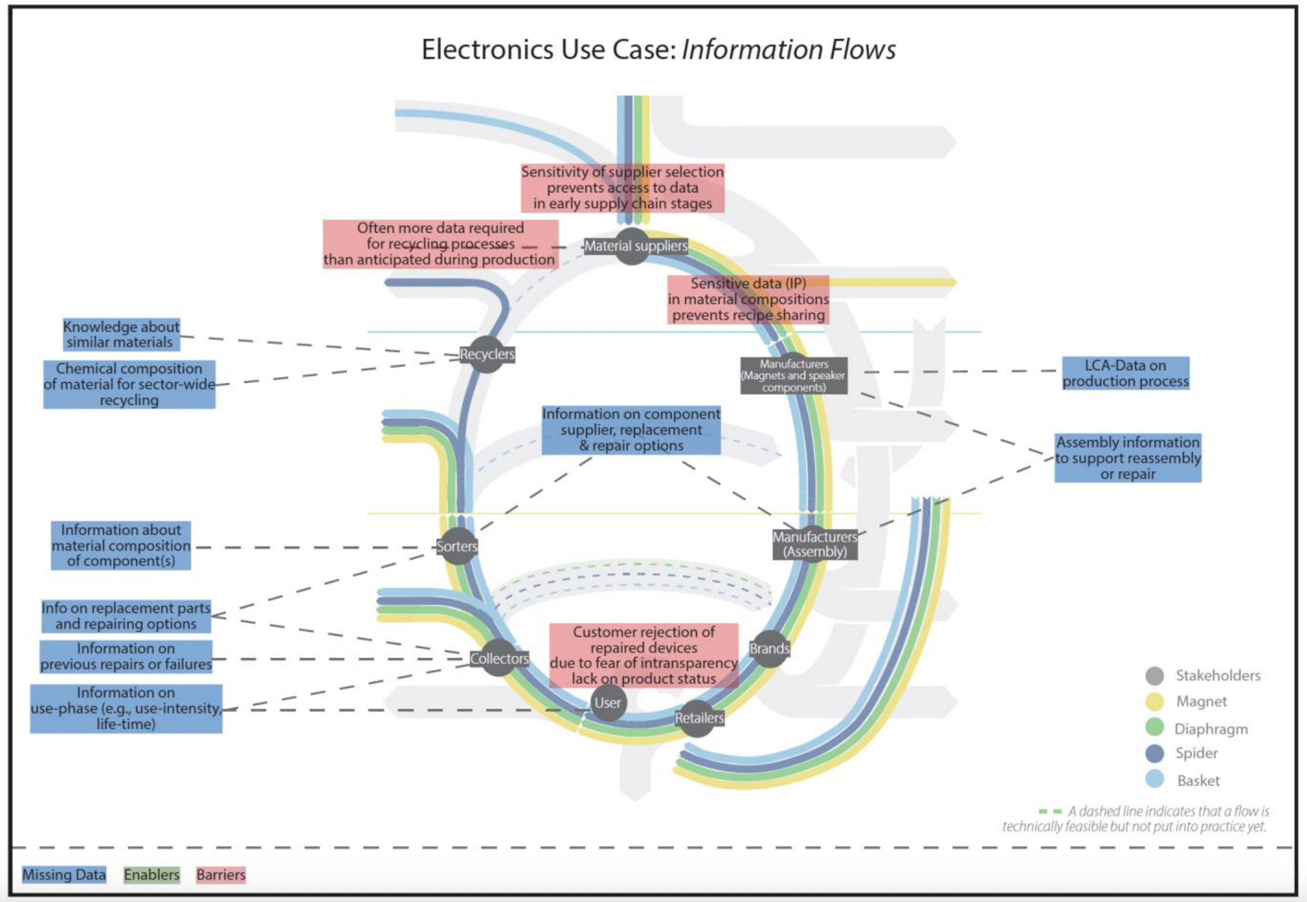
Figure 19 Circularity Compass material flows of the electronics use case value chain



3.4.2 Information Flows

In order to assess the potential for circularity and the role of data towards this end, the information flow along the supply chain is being mapped and analysed (Figure 20).

Figure 20 Circularity Compass information flows of the electronics use case value chain



The information flows along the supply chain of speakers and its components is characteristic for the general information flow along long supply chains containing different categories of materials (in this case metal-based, polymer-based and cellulose-based components). The re-use, repair, refurbishment and recycling process within the supply chain of speakers requires information about:

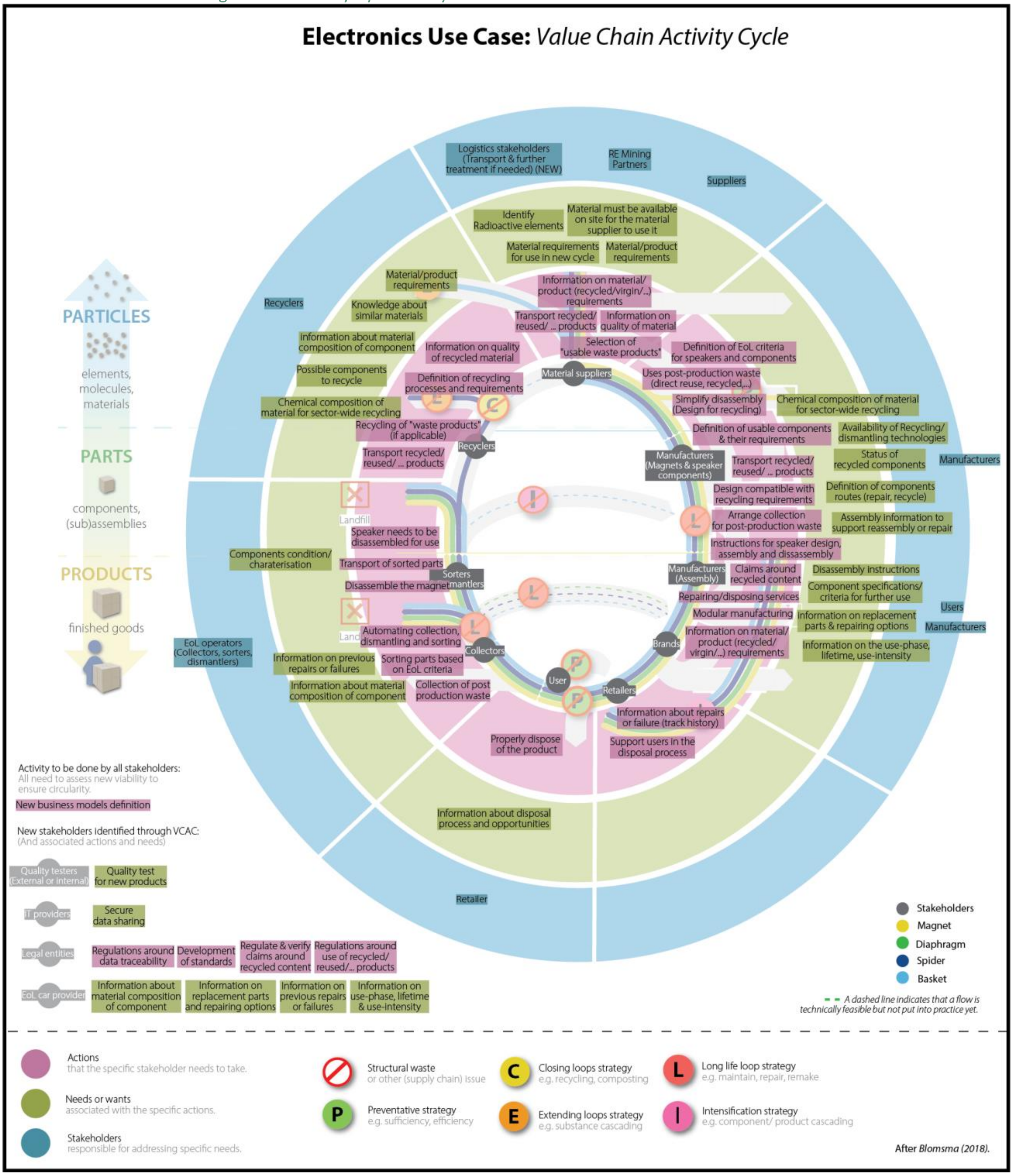
a) the status of the product (quality of product and material)
b) the material composition (chemical composition)
c) the chain of custody (which stakeholder held the material, components and product)
d) the sourcing composition and quality/ hazardous/ recycled/restricted substances

The information flow analysed for the example product shows missing information across all levels of circularity due to a) the ignorance of supply chain stakeholders on the type and detail of data required for circularity, and b) the sensitivity of data linked to material compositions and recipes involving intellectual property and customized production processes that involve sensitive data confirming suppliers unique selling point in the supply chain.

3.4.3 Activity cycles

Some of the scenarios from the circularity compass material flow were selected for a more in-depth analysis based on the activity cycle. In this case, actions, needs and stakeholders involved were defined, to have a better understanding and clarity of the impact and feasibility from these strategies, on the electronics' use case (Figure 21).

Figure 21 Activity cycle analysis for the electronics use case value chain



Post production waste

In a circular economy, waste should be transformed into usable input. One attractive scenario to explore is the use of post-production waste as raw materials. To accomplish this, manufacturers must collect and analyse their waste to determine its potential for use in the same or different value chains.

The waste needs to undergo quality and characterisation tests, conducted by relevant institutions, to establish new material routes and identify stakeholders involved in waste transformation and product utilization.

Suppliers receiving this waste as raw material should be aware of its characteristics and instructions for use. They also need to assess how these new inputs replace existing ones, considering the impact on quality and quantity. It is crucial to determine if additional amounts of recycled/reused material are required compared to using only virgin materials. Additionally, certifications and safety measures must be addressed, alongside other relevant criteria.

The use of post-production waste introduces new raw materials for current and potential value chains, resulting in the emergence of new business models. These models necessitate the definition of component streams, processes, and involved actors, such as those facilitating transportation, sorting, treatment, and logistics. Evaluating the economic viability and technical feasibility of these business models is essential for their successful implementation. Maintaining product quality standards remains crucial for companies, as it helps sustain and enhance market competitiveness. Legal entities will monitor claims regarding the use of recycled content and ensure compliance with existing standards while updating documentation to reflect any new or adjusted products.
Similar considerations can be applied to strategies centered around the utilization of by-products generated during mining and other upstream activities. By-products derived from such activities can be incorporated into different value chains, depending on their condition and potential. These products must also undergo testing and characterization by responsible parties to determine their applicability in various manufacturing processes.

Product cascade
Expanding on the previous strategy, the concept of incorporating EoL products from adjacent value chains can further maximize circularity. In this case, exploring the inclusion of speakers from EoL cars presents an attractive opportunity. Similar measures to those mentioned earlier need to be taken into account. Manufacturers involved in the new value chain must actively collaborate with EoL operators to exchange disassembly information, enabling the recovery of components relevant to the current value chain. Sharing information about the chemical composition and other properties that influence performance and potential for reuse is essential. This information should be securely shared with relevant stakeholders to protect intellectual property and preserve competitive advantage. Defining criteria for the use of EoL components by downstream partners and subsequent upstream actors (as recycling outputs become inputs for suppliers and manufacturers) is also necessary. Legal entities should regulate this process, establishing standards for product quality and guidelines for the safe reuse, ensuring sustainability claims related to recycled content and environmental impact reduction are accurate.

The utilization of EoL parts as input or raw materials for value chains creates new business opportunities and streams that need to be evaluated for viability and feasibility. Incorporating these components into daily activities necessitates the definition of new actors and activities involved in processing EoL components from previously isolated or separate value chains. Strengthening relationships between industries is crucial, and the responsibility for building circular value chains should be shared among all actors in the value chain. Implementation of processes to ensure the collection, disassembly, testing, repairing, recycling, and even design that supports multiple uses and a circular economy is essential.

Speaker design standardisation

Recycling plays a vital role in a circular economy, by transforming waste into raw materials. However, the lack of information about components poses challenges to effective recycling, impacting resource recovery. Standardized speaker design can help automate and scale recycling processes by providing a uniform option that applies to all products, eliminating the need for individual assessment. Recyclers must define recycling process requirements, including prohibited materials or substances. Manufacturers and suppliers need to identify suitable materials for existing or new processes and determine the required properties and quality. This brings possibilities for new component flows and business models, enabling the utilization of recycled products with reduced capabilities or different properties. To ensure circularity and maintain quality while reducing impacts, regulations must be established to standardize processes.

Standardization of design enables the automation of recycling and EoL activities, as stakeholders already possess knowledge about product composition and characteristics, allowing the establishment of defined processes. This reduces the reliance on extensive laboratory assessments to determine chemical composition and eliminates ambiguity during the allocation of possible routes at the EoL phase. It is crucial to implement systems that trace products and components from the early stages of the value chain until their EoL, providing lifecycle details for informed decision-making. These systems should prioritize data security to protect intellectual property while ensuring accessibility for relevant stakeholders. Additionally, regulations should be defined to facilitate effective communication and guidelines for standardization. These guidelines can include instructions for assembly and disassembly that promote modular manufacturing, enabling specific component replacement when needed without the disposal of the entire product. Consequently, this requires the establishment of component flows, along with new processes and actors, to ensure circularity within a modular approach.

Overall analysis

Analysing the strategies collectively reveals common elements across all of them. Assessing the viability and feasibility of new businesses appears to be crucial for successful implementation. These evaluations should take into account the necessity of establishing new value streams, processes, actors, and even legislations that support the transition towards more circular opportunities. Ultimately, actors will only adopt processes that align with their operational needs, considering the benefits they bring in terms of cost reduction, competitive advantage, and market positioning. Certifications and claims related to sustainability outcomes, such as reduced life cycle analysis (LCA) in the overall value chain, must be certified and approved by reputable institutions to prevent deceptive disinformation and greenwashing practices.

Data plays a vital role in defining these processes, with transparency and traceability supporting effective decision-making for resource allocation. It is important to note that data availability is a collective responsibility among all actors involved in the value chain. Materials and processes utilized at one stage have implications for subsequent steps and even those further downstream. Decisions made by manufacturers regarding substance usage will influence the recycling processes chosen by recyclers to maximize resource recovery. Additionally, data on product usage, repair history, and applications are criteria used by EoL operators and suppliers to determine the possibility of reintroducing EoL components into new cycles, either as they are or after repairs, further treatments, or recycling. Efforts should be made to ensure that only the necessary information is communicated to relevant actors, reducing the risk of data breaches and safeguarding companies' competitive advantage.

Effective circular strategies go beyond the mere collection of data; they also require a focus on product design with recycling possibilities in mind. When products are designed with circularity as a goal, manufacturers aim to create items that can be easily dismantled, enhancing recycling processes and efficiency. By incorporating considerations of potential value flows, encompassing both existing and new ones, during the design phase, manufacturers ensure that all constraints and requirements of downstream processes are considered. This holistic approach maximizes the circular value of products, promoting a more sustainable and efficient system overall.
Overall, these strategies promote closer collaboration among stakeholders within a value chain and even across adjacent ones, wherein the outputs or waste of one industry can serve as inputs for another. For example, value chains related to the automobile industry can contribute to the value chain of the speaker market. Likewise, mining byproducts find applications in various value chains, fostering increased cooperation among stakeholders and the exploration of new partnerships and business models.

3.4.4 Energy flows circularity compass

The energy flow enable to have an analysis of the energy expenditures throughout the speaker and magnet value chain (Figure 22). The most expensive and energy intensive component in a speaker is the Rare Earth Permanent Magnet. It plays an essential role in converting electrical signals into audible sound waves. Rare earth magnets, specifically NdFeB magnets, have become increasingly popular in modern speaker design due to their exceptional magnetic properties. These magnets provide a stronger magnetic field with a smaller size, contributing to the overall efficiency and compactness of the speaker system.

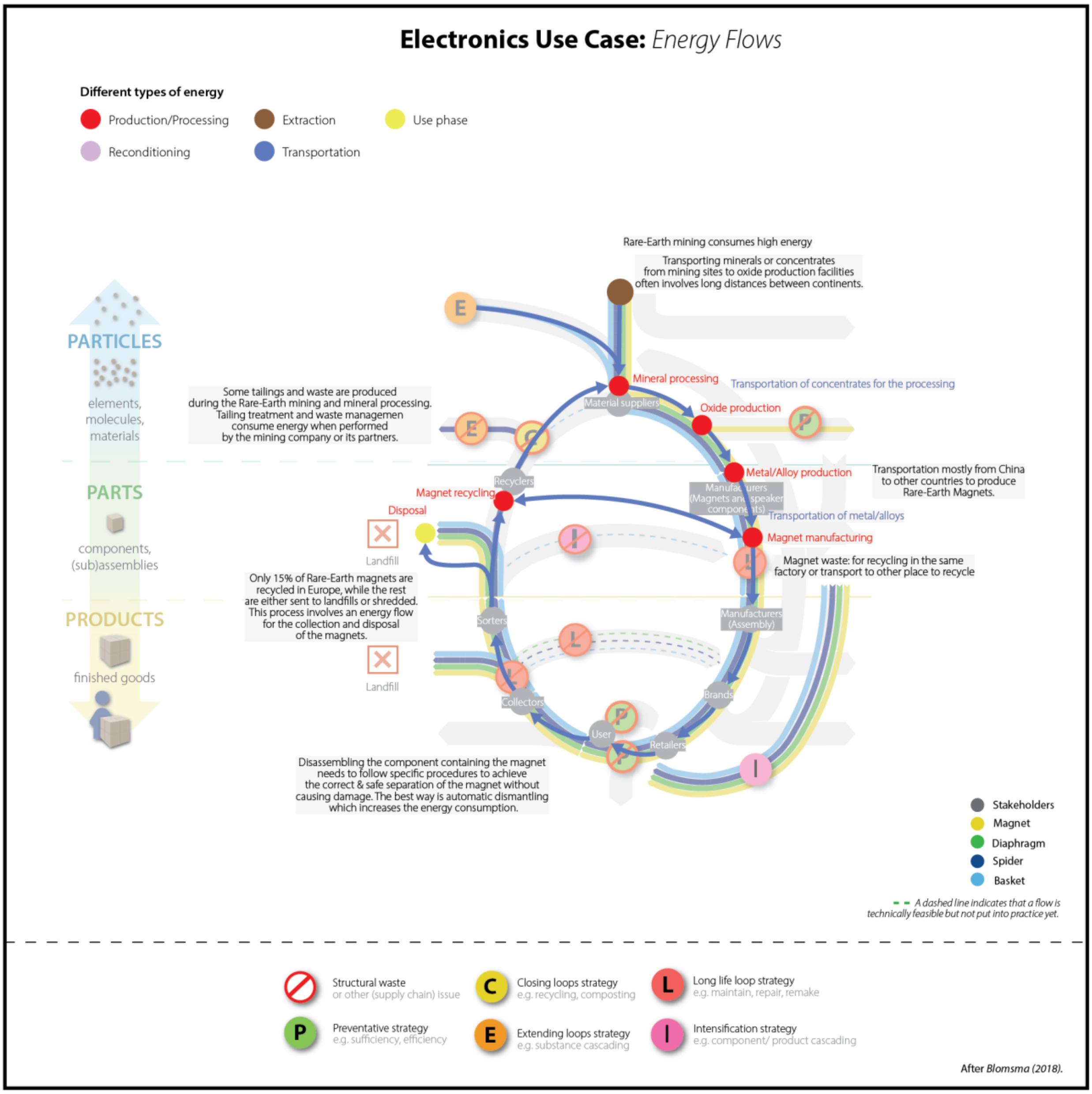
The production of rare earth elements (REE) involves complex processes that are energy-intensive and time-consuming. The extraction, mineral processing, and separation of REE encompass numerous stages. Typically, the REE percentage in the host mineral is less than 5%, necessitating several steps to separate REE from the gangue and host mineral. REE have very close chemical and physical properties, requiring the repetition of separation processes numerous times, often exceeding 100 iterations.

Moreover, from oxide to magnet and magnet to final products there are a number of processing steps in the value chain that require energy. In rare earth value chain, metal and alloy making is the most energy intensive process, which is done often by the traditional process of molten salt electrolysis. There has been R&D developments in this sector but could only achieve incremental improvements so far.

On the other hand, transportation within the REE supply chain is extensive due to China's dominance in REE production. Consequently, 90% of REE products are transported from China to global markets, leading to heightened energy consumption.

Another important segment within the REE supply chain, concerning energy flow, is the recycling process. The energy consumption varies depending on the recycling method, but generally, the recycling process omits only the mining and mineral processing stages of REE production. The separation stage is still carried out to produce individual REEs. Moreover, collecting RE magnets and disassembling the component containing the rare earth magnet is challenging and requires either automated processes or accurate manual disassembly, which is time and energy-consuming.

Figure 22 Circularity Compass energy flows of the electronics use case value chain



3.4.5 Value flows circularity compass

A major step in the REE value chain is the processing stage rather than the mining stage where the main value-adding activities happen. Though initial beneficiation is done at the mining locations, the majority of the valuable waste stream is generated at the processing stage. Often mined and concentrated REE ores are transported to a different location and, the mining and separation companies are often different, generating financial flows between different business entities. This are reflections made based on the value flow circularity compass for the speaker use case (Figure 23).

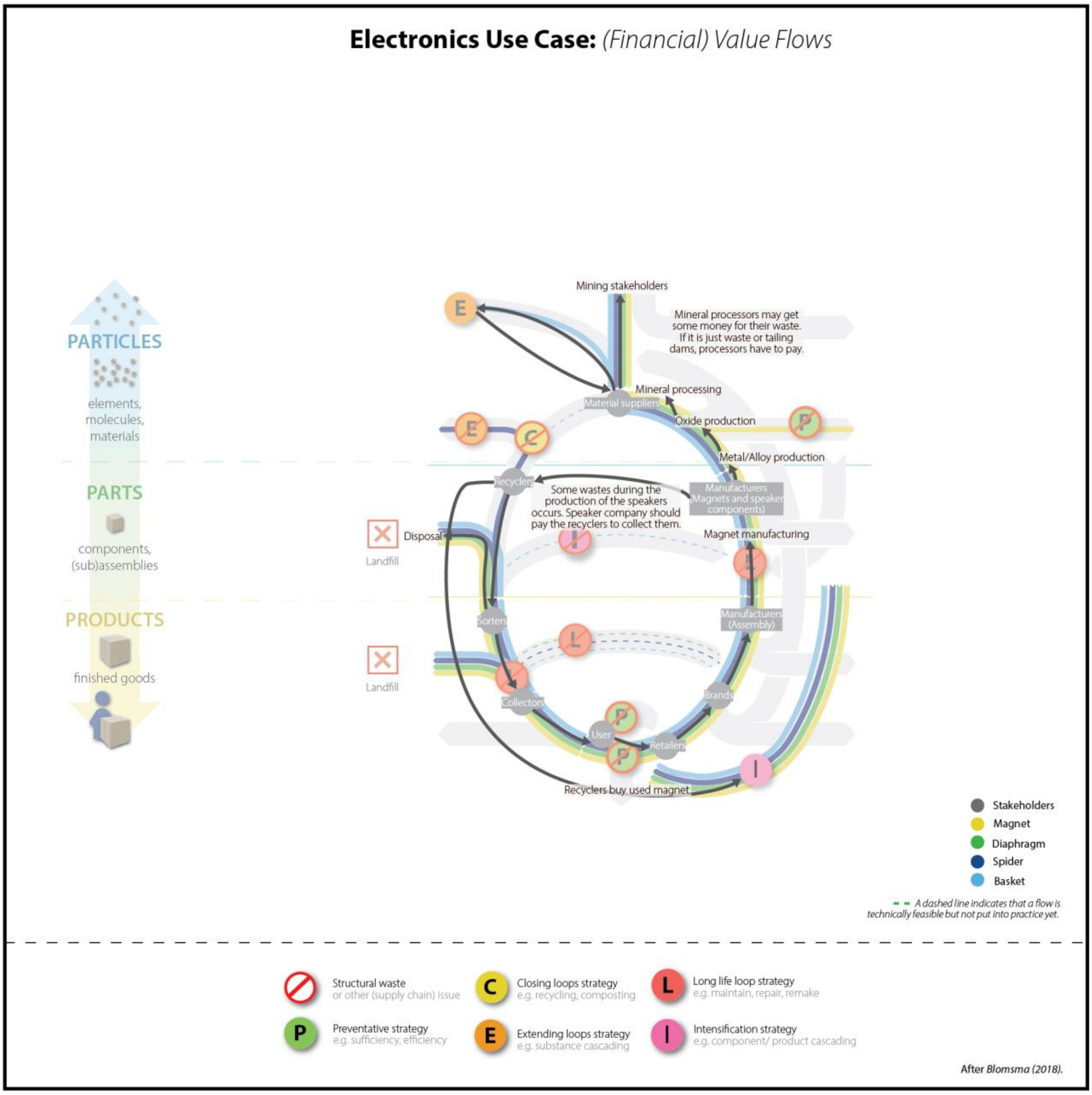
In the electronics value chain, the first transaction is marked between a mining company and a processing company or it could be a trading company and a mining company, followed by a trading company and a processing company. At the processing stage, the processing company usually bear the cost of waste disposal including the radioactive materials storage as some REE ores contain radioactive materials.

In recent years, there have been efforts to recover REEs as by product from waste streams of other base metals, from phosphate tailings or as bi-product of heavy mineral sand extractions. For example, the major source of rare earth in China is a byproduct of iron ore mining in Bayan Obo, Inner Mongolia. Also, the major Iron producer in EU LKAB is planning to recover REEs from its Iron ore mine tailings in Sweden. Heavy mineral sand producers like Iluka and Tronox who process Zirconium, Titanium etc have announced their plans to recover REEs from waste streams. In some cases, these waste streams are transported to a third company for further processing or shipped to subsidiary companies creating value flows between companies.

As indicated before, during the magnet processing stage, a considerable amount of magnet scrap and swarf is generated. Often these wastes are sold to a recycling entity, creating a value flow and financial transactions or REE processing company or processed further internally.

In case of EoL recycling, the OEMs, the final producer might have to pay to a collection company. If the products are sorted enough, the recycling companies may have to pay to the collection companies. The business around CRM recovery from EoL products is still in infant stage and a viable commercialisation strategy for each products categories are yet to develop.

Figure 23 Circularity Compass value flows of the electronics use case value chain



4.4 Main challenges

Table 1 List of challenges related to data exchange throughout the electronics value chain

Nr.	Topic area	Challenge statement
1	Data security	Supplier selection and material recipes are sensitive data types which often form part of the intellectual property of a company. This is to be taken into account.
2	Standardisation of Data	A first analysis of the electronics industry has shown many different data formats including sector-specific databases on material classifications like e.g. the IMDB database detailing speaker materials used in the automotive sector with a classification numbers which is only used within the automotive sector
3	Transparency is an investment	The adoption of a supply chain-wide traceability system entails financial and time investments. In order to ensure such approaches are being taken up

		industry-wide, regulatory arrangements can be conducive and eliminate the problem first-movers would otherwise face.
4	Data availability and regulatory differences	Especially the electronics entailing REE are subject to intransparent upstream supply chains. This is often linked to the sourcing of materials outside the European Union and the different regulatory requirements especially for the materials with Chinese provenance.
5	Interoperability	One of the challenges in supply chain data communication is the harmonization of different data formats and communication systems or software.
6	Ownership	Companies are inclined to only store data on their own databases and to keep the ownership of data whenever possible. This points to the necessity of a peer-to-peer or decentralised solution.
7	Accountability	Material data is often collected by a centralised entity e.g. the original equipment manufacturer. This centralised accountability does however not reflect the fragmentation of data and its dispersion across the whole supply chain.

5 Textile Use Case

5.1 Context

Textiles are fundamental to our society and used in everyone's daily lives, providing us with clothing, shoes, carpets, curtains, furniture, etc. for homes, offices, and buildings. However, according to the European Environment Agency (EEA), clothing, footwear and household textiles in EU are together the fourth highest pressure category for use of primary raw materials and water (after food, housing, and transport), the second highest for land use and the fifth highest for greenhouse gas emissions[14]. Furthermore, the complex and highly globalised textile value chain is also faced with social challenges like child labour, in part driven by pressures to minimize production costs to meet consumer demand for affordable products. Furthermore, textile production processes use a significant amount and variety of chemicals (about 3500 substances), of which, 750 have been classified as hazardous for human health and 440 as hazardous for the environment. The release of microplastics from synthetic textiles and footwear adds to the environmental impacts of the sector. According to the EEA, half a million tonnes of synthetic fibres are released annually in the effluent of washing machines[14].

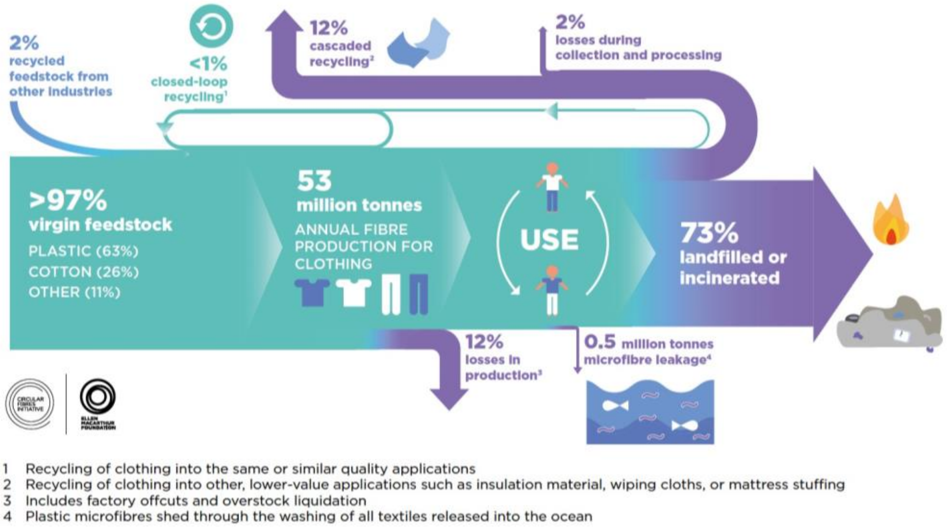
The negative impacts of the textile industry have their roots in the linear model characterised by low rates of use, reuse, repair, and fibre-to-fibre recycling of textiles, and that often does not put quality, durability, and recyclability as priorities for the design and manufacturing of products. For example, while EU consumers buy on average 26 kg of textiles per person per year, they discard about 11 kg of textiles per person per year[15]. Every second somewhere in the world, a truckload of textiles is landfilled or incinerated. Globally, less then 1% of textile fibres are recycled into new fibres, as illustrated in Figure 24. Finally, a recent screening of sustainability claims in the textile, garment and shoe sector suggested that 39% could be false or deceptive[16].

[14] EEA (2019) Textiles in Europe's circular economy. https://www.eea.europa.eu/publications/textiles-in-europes-circular-economy/textiles-in-europe-s-circular-economy

[15] EEA (2019) Textiles and the environment in a circular economy. https://www.eionet.europa.eu/etcs/etc-wmge/products/etc-wmge-reports/textiles-and-the-environment-in-a-circular-economy

[16] https://ec.europa.eu/info/live-work-travel-eu/consumer-rights-and-complaints/enforcement-consumer-protection/sweeps_en

Figure 24 - Global material flows for clothing in 2015. Source: Ellen MacArthur Foundation (2017) A New Textiles Economy: Redesigning fashion's future.



To achieve higher sustainability and circularity in the textile industry, traceability and transparency throughout the supply chain are essential according to the United Nations Economic Commission for Europe (UNECE). In that regard, in recent years, an increasing number of initiatives started to work on achieving better traceability and transparency, coming from a variety of organizations and with slightly different focus. Among some of the leading ones, one can name the UNECE initiative to improve Traceability for Sustainable Garment and Footwear[17], Trustrace[18], EonGroup's Circular ID protocol[19] and circularity.ID® Open Data Standard[20] developed by circular.fashion. Most of these initiatives developed Product Passports as a mechanism to capture and share relevant data across value chains. Some look at increasing the quality of textile recycling via smarter sorting solution, some at increasing product and material data transparency and others at increasing trust in the data collection from the supply chain. More recently, in line with the European Green Deal ambition, the EU Commission published the EU Strategy for Sustainable Textiles[21], which includes policy measures such as applying new sustainable product framework, eco-design requirements, empowering choices of sustainable textiles, providing incentives and support to textile circular business models. In particular, to achieve these objectives, the EU Commission will introduce a Digital Product Passport (DPP) as part of the measures under the new Ecodesign for Sustainable Products Regulation (whose requirements for textiles are not fully defined at the time of this report).

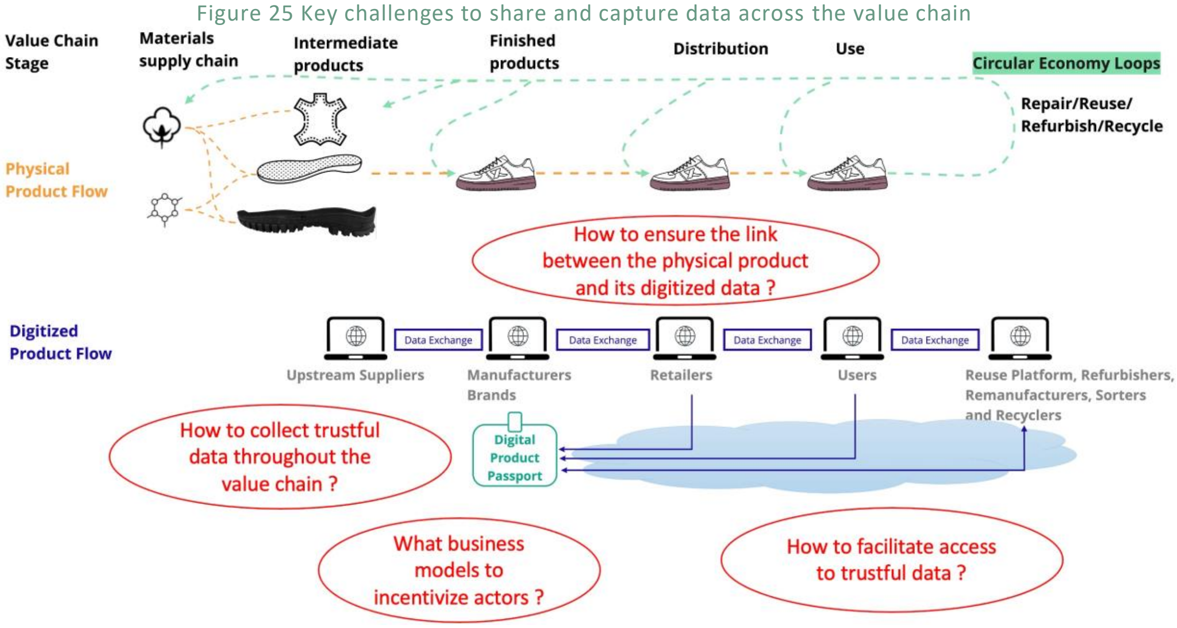
All these initiatives consume and produce data, which does not necessarily become available outside the immediate stakeholder context and in a format facilitating interoperability. In addition, they all are facing the challenge to access and collect trustful data from the supply chain, which currently requires a lot of too much human and financial resources. One the one hand, many companies have a limited view of the network of business partners within their value chain and do not get the full story behind their products. On the other hand, manufacturers are reluctant to share confidential

[17] https://unece.org/trade/traceability-sustainable-garment-and-footwear
[18] https://trustrace.com
[19] https://www.eon.xyz
[20] https://circularity.id
[21] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12822-EU-strategy-for-sustainable-textiles_en

information and are concerned with disclosure of intellectual property and the details on the chemical composition. Finally, while several proven tracking technologies exist (e.g. RFID, QR Code, NFC, etc.), ensuring and maintaining a link between the physical product and the digitized product throughout the product lifecycle remains a key challenge.

These challenges, summarized in Figure 25, call for more systemic solutions to capture and share standardized and fundamental data to establish a reliable and interoperable flow of information across industry value networks. In this context, the ontology network and the open data sharing platform developed in this project will specially aim at increasing sharing efficiencies of trustful product data throughout the supply chain from suppliers to the end of use of product and recycling. Thereby facilitating increased traceability and transparency, and thus the project results will be a crucial step towards a more circular and sustainable textile industry.

Figure 25 Key challenges to share and capture data across the value chain



5.2 Objectives of the textile use case

The textile use case aims to:

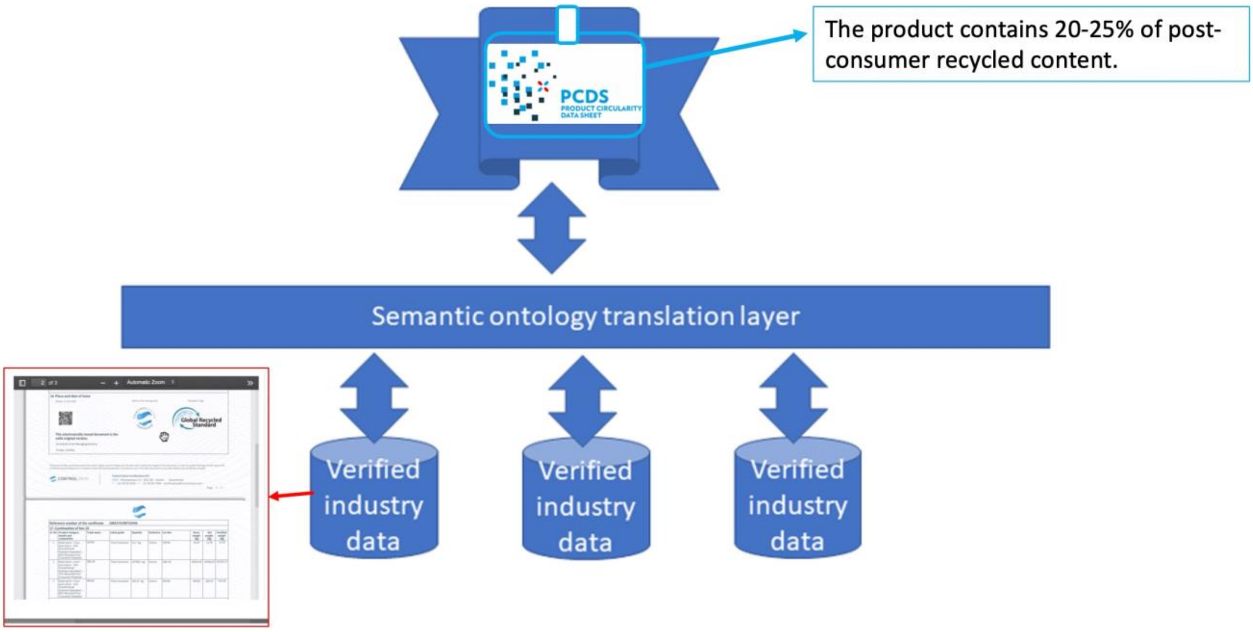
1. **Define the business needs** (product data and data sharing platform) to support the establishment of **circular economy loops** through the analysis of case scenarios in the **footwear industry.** These business needs will be shared with WP2 as inputs for defining the requirements for the development of Ontology and the Open Circularity Platform.
2. **Design and test a translation layer**, making use of the Open Circularity Platform, to enable automatic data exchange between manufacturers’ product data, a sustainability data scheme (i.e. Product Circularity Data Sheet (PCDS)) and a product passport (i.e. circularity.ID)
3. **Evaluate and demonstrate the potential of the Open Circularity Platform** (developed in WP4) to support business circular opportunities through the ontology-based data documentation.

The objective of the translation layer is to automate data exchange and access throughout the value chain. In particular for the textile use case, sustainability and circularity data related to a selected product will be translated to map the set of statements in the PCDS and the set of data in the circularity.ID. Through this mapping:

1. Claims entered in the PCDS can be automatically verified in real time against external data sources stored at the manufacturers. For example, the Figure 26 illustrates the case of one PCDS statement related to post-consumer content which is publicly available and the proof supporting the claim (i.e. Global Recycled Standard certificate) which is stored in the manufacturer's IT system.
2. Actors providing traceability solution such circular.fashion will gain the ability to pull verified data from the textile supply chain and make them accessible via their circularity.ID platform for consumers through a digital product site and for textile sorters and recyclers through the intelligent sorting stations.

In addition, mechanisms for authorization and validation of access to data will be accounted for through the Open Circularity Platform established by the project. Finally, when designing the Translation Layer, we will evaluate the potential of the True/False statements approach used by the PCDS as a mechanism to ensure interoperability across sectors and to solve the conflict between confidentiality of information and the need for transparency to enable circular material loops.

Figure 26 Ontology-based translation layer concept

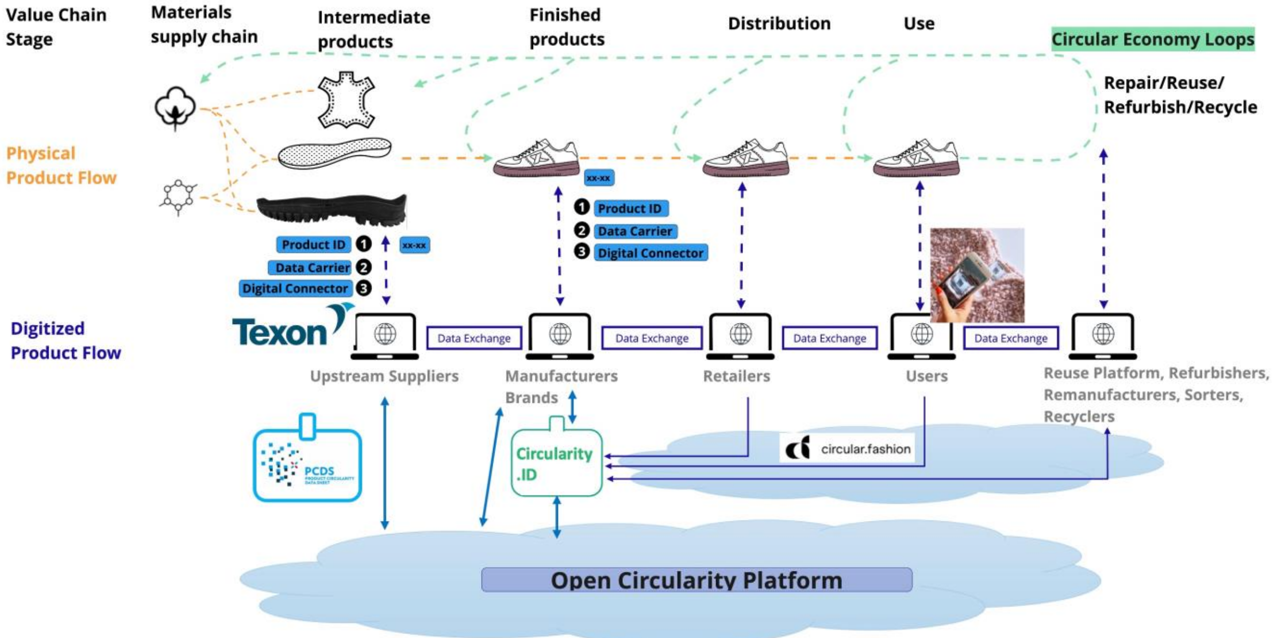


5.3 Involved partners and contributions

Three organizations contribute to the Textile Use Case. They provide data, information, and knowledge in the following domains: supply chains, product information, and criteria for sustainability, circularity and recyclability claims as well as their evaluation. A brief description of these organisation, their technology and expertise are presented below.

The Figure 27 indicates the position of the partners within the value chain and how the interactions with the Open Circularity Platform are envisioned. Texon provides insights on the data needs in the footwear industry and supports the data collection from supply chain stakeholders. +ImpaKT provide their expertise on the Product Circularity Data Sheet standard and how it can be used to support uniform circular metrics and to ensure interoperability across industries. circular.fashion provides their expertise on circular product design and traceability solutions for closing (including data carrier and product passport). Finally, the Open Circularity Platform with the ontology-based data documentation will be designed to enable automatic data exchange between manufacturers' product data, the circularity data scheme Product Circularity Data Sheet (PCDS) and the product passport circularity.ID.

Figure 27 Role of the Open Circularity Platform and its interactions with the partners in the textile use

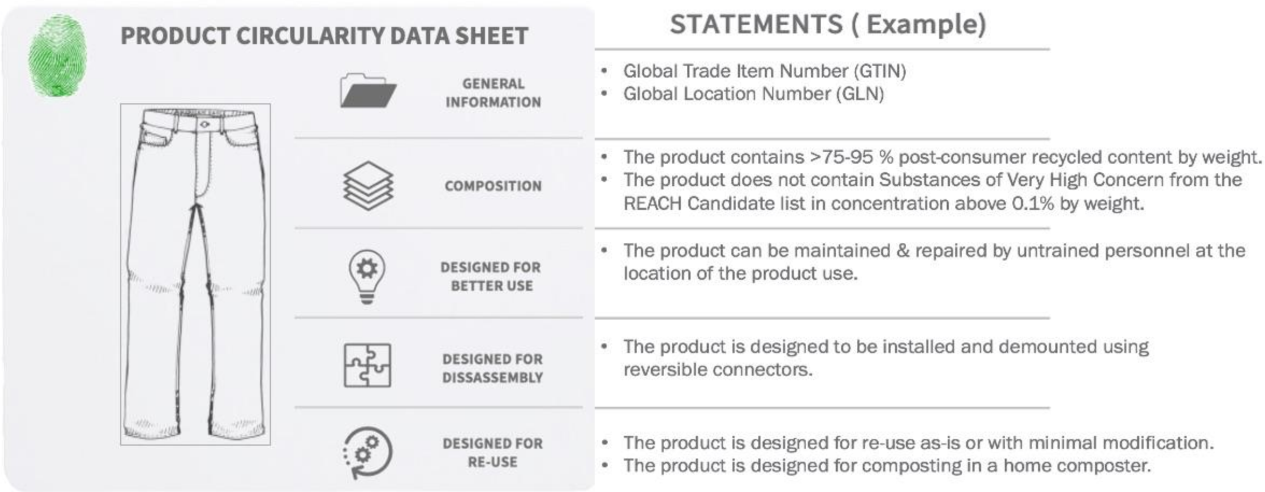


1. **+ImpaKT Luxembourg** (http://positiveimpakt.eu/en/pcds/), which stands today among the most experienced Cradle-To-Cradle & Circular Economy experts in EU and Luxembourg. It has done extensive work on the topic over the last years in Luxembourg, contributing to several national strategies (e.g. National Circular Economy strategy, National Zero Waste Strategy, Supporting Emerging Circular Business Models and Roadmap for A Sharing Economy). Since 2018, +ImpaKT has been leading since 2018 the development of the international standard **Product Circularity Data Sheet (PCDS)** (https://pcds.lu/), an initiative funded by the Luxembourgish Ministry of the Economy. Working with more than 50 international organizations from 12 EU countries and USA, +ImpaKT has developed an open standardized data format to facilitate product data sharing of circular economy characteristics across value chain networks[22]. The PCDS will be an ISO standard in the next 2-3 years (https://www.iso.org/standard/82339.html) and it is currently being piloted by companies and data aggregation platforms in several key supply chains.

[22] Mulhall, Ayed, Schroeder, Hansen, and Wautelet (2022). "The Product Circularity Data Sheet—A Standardized Digital Fingerprint for Circular Economy Data about Products" Energies 15, no. 9: 3397. https://doi.org/10.3390/en15093397

The PCDS is a product declaration in a machine-readable format that provides standardized and verifiable data about the circularity characteristics of a product. To solve the conflict between confidentiality of information and the need for transparency when implementing a true circular approach, the PCDS is using "true/false statements" to describe a certain set of features that can be transparently stated as true or false without having to disclose to every party the manufacturer's production secrets. By doing so, this helps manufacturers to take the first step in transparency and product circularity practice. To ensure trustworthy content and reliability, the originating data are verified by an independent audit and authentication mechanisms combined with unique ID per created PCDS are being developed.
As shown in Figure 28, PCDS standardized statements include information about chemical substance thresholds, design for reuse and disassembly, recyclability, recycled content, biocompatibilities, hazardous materials thresholds, and actively positive impacts. The PCDS is not a scoring or rating mechanism. Instead, its data are inputs for other product schemes and platforms to do that.

Figure 28 Content of the Product Circularity Data Sheet (PCDS)



2. **circular.fashion** (https://circular.fashion/en/index.html), is a sustainable design agency creating product and system innovation for a circular economy in fashion and textiles. The company develops services and software for circular design and closed loop recycling to enable a transparent flow of information between material suppliers, fashion brands, consumers and recyclers. At the centre of the circular.fashion system is the circularity.ID including the Open Data Standard (https://circularity.ID/open-data-standard.html), which holds material and product data, along with a product's entire story. This ensures future reuse, reselling and recycling at the highest possible level of sustainability. Through this system, data becomes accessible to stakeholders in the fashion ecosystem at any point in time to assess and handle products in a circular economy. The rationale for developing the circularity.ID is based on the identification of three main challenges that need to be overcome to realize a circular economy for fashion:

- fashion needs to be designed for circularity,
- product life must be extended and consumers need to know where to return clothing for reuse and recycling, and

- sorting facilities need to identify products and their materials for fibre-to-fibre recycling.

To enable a reverse supply chain for fashion and textiles, sorting companies play a key role. The process of sorting is primarily manual today, based on a sorter's optical impression and sense of touch and smell. The specific feedstock requirements of innovative fibre-to-fibre recyclers bring current sorting processes to their limit as many requirements are not recognizable in a manual decision process. ID-based sorting of post-consumer garments has the potential to optimise the process, reaching a higher-quality level output to serve fibre-to-fibre recyclers and make the operations commercially viable. To test ID-sorting in a relevant environment, circular.fashion developed a working prototype of an intelligent sorting workstation, featuring different scanners mounted below and on a table with a screen above. When moving a garment over the table in the sorter's usual workflow, the screen displays crucial information to support the sorting decision-making, based on possible sorting fractions such as fibre-to-fibre recycling or valuable second-hand fractions. The workstation can read and process all products with IDs identified as potentially suitable.

3. **Texon** (https://www.texon.com/), which designs, manufactures and supplies high quality, high performance, sustainable material solutions used in footwear applications. They have deep knowledge and accumulated expertise in the footwear supply chain and the challenges related to circular product design and product data exchange from raw materials to final product assembly.

5.4 Methodology

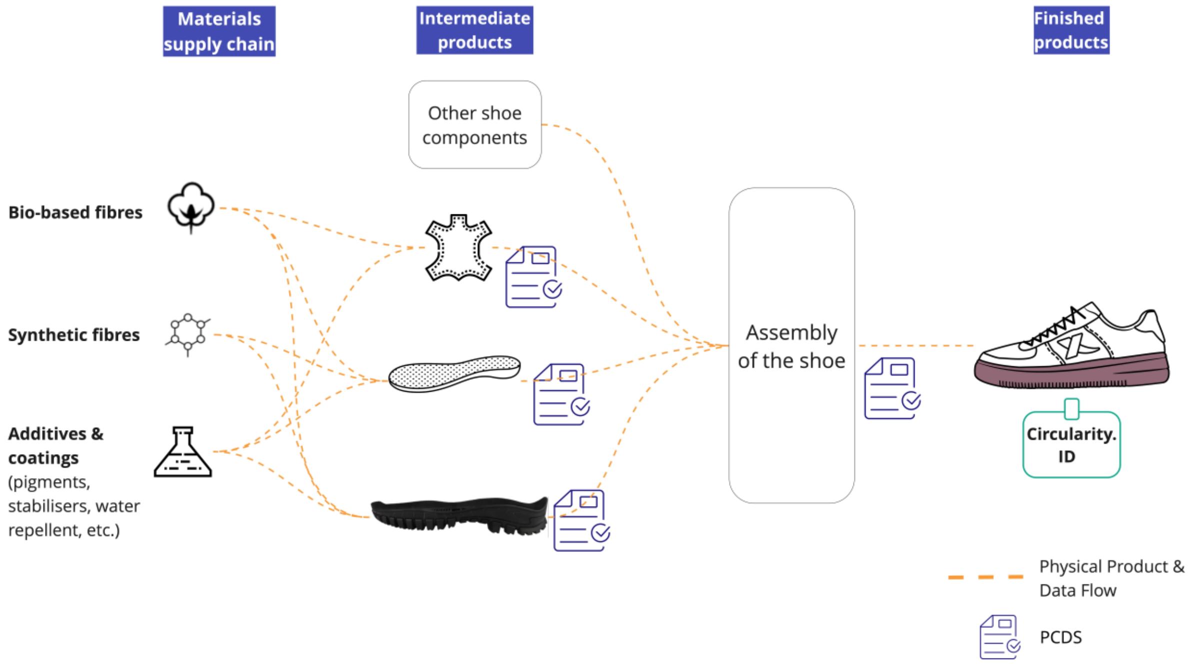
Due to the complexity of the footwear supply chain, it was agreed between the partners and WP leaders to focus on only one circular economy action (i.e. **fibre-to-fibre recycling**) for a selected existing footwear product, to ensure getting meaningful results within the timeline envisioned by the project. Fibre-to-fibre recycling is one of the top priorities of the EU Commission mentioned in its EU Strategy for Sustainable and Circular Textiles[23]. Therefore, footwear recycling is a prominent opportunity, albeit a formidable challenge, within the broader textile industry scope.

As specified earlier, the Onto-DESIDE research process is divided into 3 iterations. The focus of the first iteration was to evaluate the *state of play* in terms of product data sharing, based on a first set of requirements. In a first step, +ImpaKT Luxembourg and circular.fashion established a list of product data for footwear products based on the standard PCDS and the circularity.ID Open Data Standard 4.0, and including requirements for traceability, sorting and recycling. A set of business needs for the data sharing platform (data security & privacy, storage, access, etc.) have been elaborated based on an analysis of leading initiatives and leveraging the accumulated knowledge of the partners. Then, in a second step, we collected and documented the data of three typical materials used in the production of an existing footwear product selected by Texon (cf. Figure 29). As a typical shoe is manufactured with around 40 different materials which are assembled using diverse types of processes (stitching, gluing, etc.) and multiple additives and coatings, the scope is limited on a number of footwear components and not the whole shoe. The received product data were verified, missing data were identified, and potential ways of getting the data needed from suppliers are analysed.

[23] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12822-EU-strategy-for-sustainable-textiles_en

The second iteration design and test a translation layer, making use of the Open Circularity Platform, to enable automatic data exchange between manufacturers' product data, a sustainability data scheme (i.e. Product Circularity Data Sheet (PCDS)) and a product passport (i.e. circularity.ID®). The third iteration focuses on testing the closed-loop data exchange from suppliers to recyclers by creating a mock-up with circular.fashion of the footwear product equipped with a data carrier.

Figure 29 Data collection process for a specific footwear product



5.5 Use case description

To describe and analyse the use case needs, it was agreed among the WP leaders and partners to use the tools from Work Package 5 (i.e., Circularity Compass and the Multi Flow Metabolism (MFM)). In the first iteration, the MFM was used to describe the current realities in terms of circularity of materials and to highlight the barriers and enablers for the implementation of circular strategies, with a focus on fibre-to-fibre recycling. The analysis of material and information flows provided insights on what is already there and what is missing. For the updated report (version 2), the analysis of use case was extended to energy and value flows and the Value Chain Activity Cycles. These mappings are used to assess and analyse the implementation of circular economy strategies at a more granular level.

5.5.1 Material flow and circular economy practices

The Figure 30 provides a high-level description of the key material flows in the footwear sector and the circular pathways which are currently happening. The Table 2 provides a description of the key business partners involved in the footwear sector. For illustration purpose, the example of Texon Reform 2.0 solution (https://www.texon.com/reform-2-0/) was selected. And for the visibility of the diagram, only the two main material flows, bio-based fibres and synthetic fibres, are represented. Texon's structural solution is designed to be 100% recyclable and it contains up to 59% recycled content (i.e. 49% of recycled PET bottles and 10% of post-industrial content) plus an additional 7% renewable content (i.e. pine tree resin). In the next stage of the supply chain, the fibres-based components such as heel counter, toe reinforcement, foam, midsole cushioning systems, outsoles, footbed, etc. are supplied to B2B distributors which are in charge to ensure a continuous supply of components to shoe assembly manufacturers. At this stage, additional materials and substances are used during the assembly process to create the finished shoe product. In general, brands do not own these final assembly production sites which create some barriers for supply chain traceability.

In terms of circular economy actions, the current practices in the footwear sector include:

1. **Reuse and repair**, e.g. replacement of shoelaces or soles.
2. **Redistribution and second-hand** sales are also a common practice, but to a very limited extent in comparison to garments.
3. **Refurbishment and remanufacturing** of shoe is not occurring.
4. Used footwear products are generally collected via a **dedicated textile waste stream** or via **take-back schemes** handled by retailers.
5. Finally, footwear recycling faces several challenges described below, which limits the current practice to downcycling for a very limited volume, the rest being landfilled or incinerated.

Figure 30 Circularity Compass of the footwear value chain showing the state of play in terms of resource flows and circular pathways

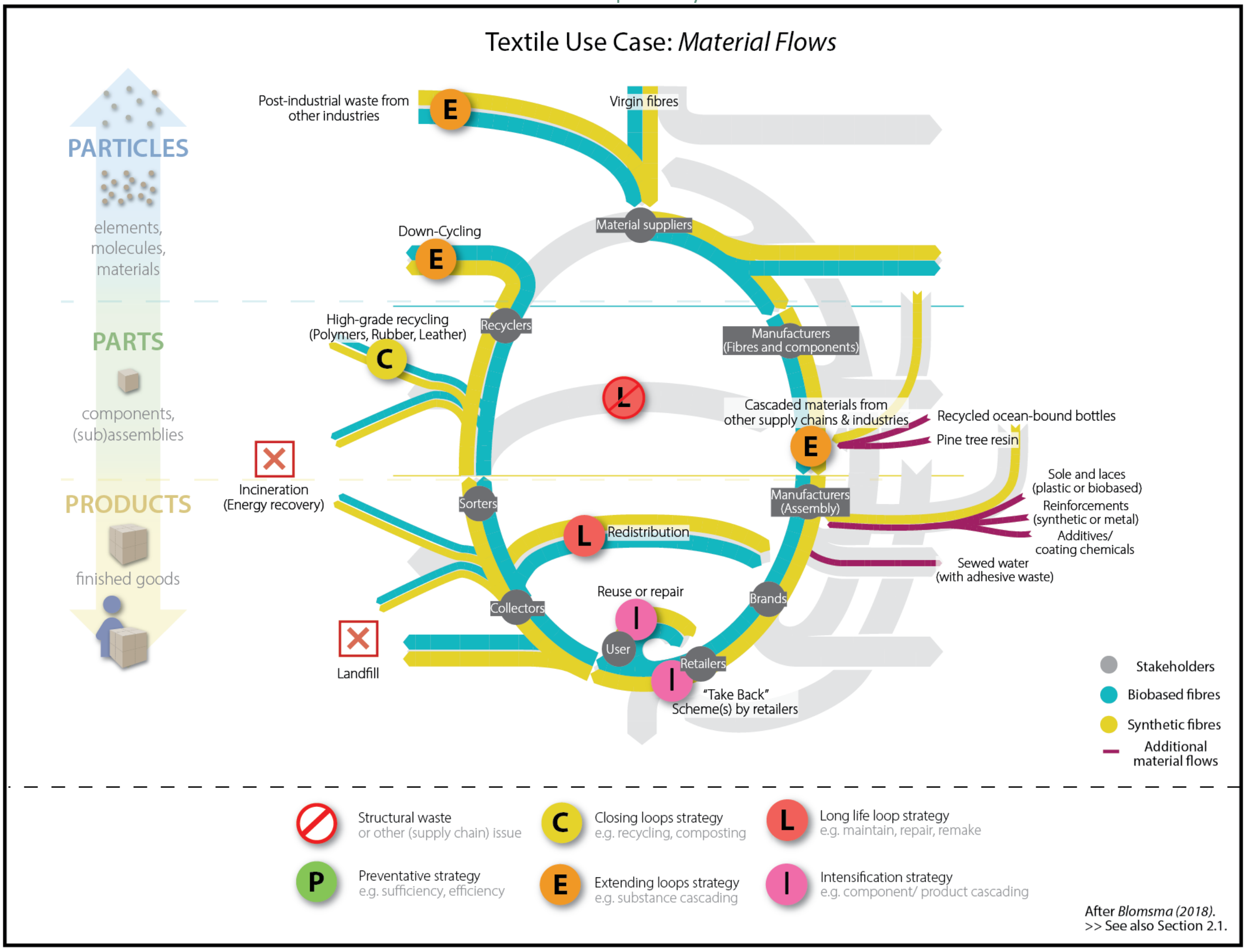


Table 2 Key business partners in the footwear sector

	Business partner	Definition	Comment	Updated definition
A.1	**Consumer**	A person who purchases goods and services for personal use.	Since there are two definitions of consumer roles, further the following meaning is kept for user and aligned with ISO 59004	Organisation or individual member of the general public purchasing or using goods or services purchased for commercial, private or public purposes
A.2	**Customer**	A person or company who buys goods or services from a company.		
A.3	**Auditor/Certifier**	A person or company who inspects something, such as a product, process, or organization, to ensure that it complies with requirements or regulations.	The role of the actor is limited from the perspective of facilitation of collaboration across a supply chain and implementing CE, so not further considered	
A.4	**Suppliers**	A person or company that provides something needed in the manufacturing stages such as feed, equipment, materials, intermediary and finished products, chemicals or a service etc. Suppliers also include those who supplies data carriers.	Any actor within the supply chain has the potential to be a supplier. To avoid confusion in the identification, the role won't be further used.	
A.5	**Transformation actor**	A party that processes or changes one or more inputs to create different outputs (i.e. Farmer, Slaughterer, Ginner, Spinner, Tanner, Weaver, Dyer, Finishing Provider, Manufacturer, Subcontractor).	Further: Manufacturer, definition is not modified	A person or company that performs the transformation of material input to create a different output and interacts with other manufacturers of the supply chain.
A.6	**Product guardians**	A party, such as a Transporter, Warehousing Party, Agent/Trader, Distributor, Wholesaler that makes no changes to a product or raw material; they only store, transport, sell, or purchase it. Product Guardians also include those who undertake redistribution and resales activities for reusing the product. Their possession of the product can be recorded in order to establish the chain of custody, since product contamination or	These actors have different functions, located in different stages of life cycle. Their role of information requestor is limited at this point of the project, so they won't be further considered	

		substitution could take place during their custody. They may also perform the role of Information Requestor.		
A.7	**Brand owner**	A person or company who sells any commodity under a registered brand label.	The definition is extended by the design functionality	A person or company who sells any commodity under a registered brand label. Additionally, a function of design is added to the role of the brand because the implementation of circular economy principles requires a systemic approach to the design products/services, business models and processes. Brand is selected because it can influence customer behavior, gather information/interact with supply side (material selection, product design).
A.8	**Retailer**	A person or company that sells goods to the public in relatively small quantities for use or consumption rather than for resale.	No modifications	A person or company that sells goods to the public in relatively small quantities for use or consumption rather than for resale
A.9	**Life-extension actor**	A person or company that perform repairing or refurbishing activities on an existing product in order to extend its lifetime. Since product modification or replacement of components could take place, these transformation activities must be recorded with the newly product data in order to establish the chain of custody.	Definition extended according to ISO 59004	Actors ensuring the following activities: - Repair - action to restore a product to a condition needed for the product to function according to its original purpose. It includes renewal or replacement of worn, damaged, or degraded parts. - Reuse – use of a product after its initial use for the same purpose for which it was originally designed. - refurbish – process by which an item, during its expected service life, is restored to a useful condition for the same purpose with at least similar

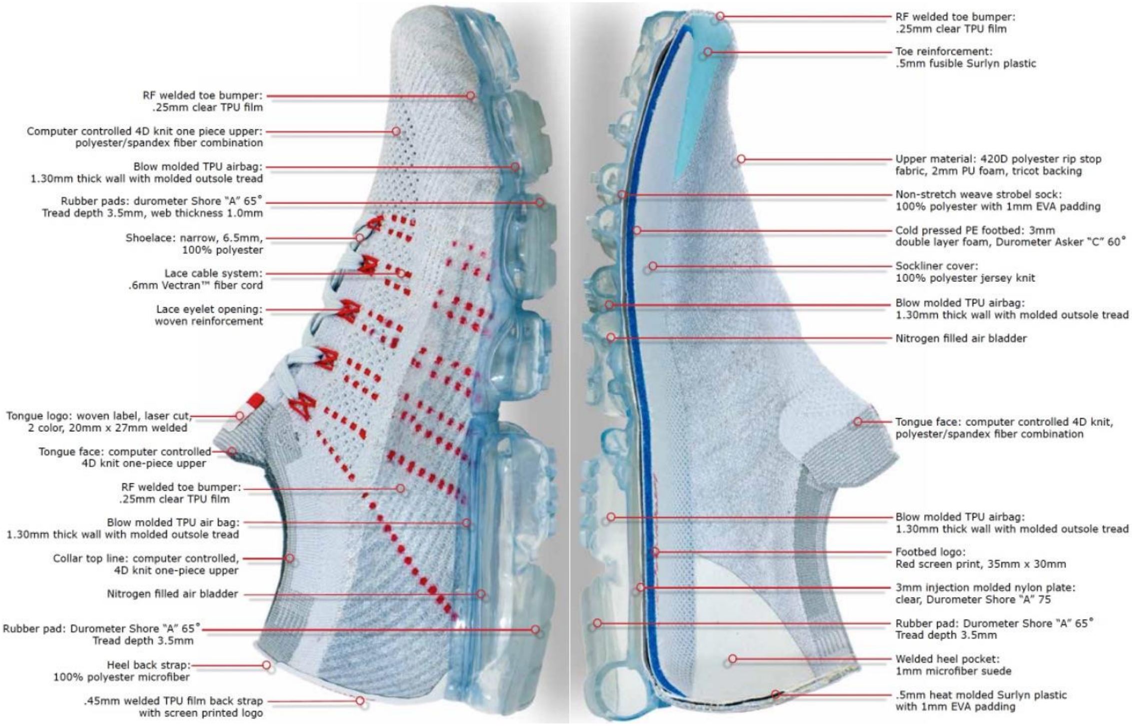
				quality and performance characteristics. Refurbishing can include activities such as repair, rework, replacement of worn parts, and update of software or hardware but does not include activities that result in the need of a new certification of the product. It does not include restoration after the expected service life. - remanufacturing – industrial process by which an item is returned to original condition from both a quality and performance perspective. The item can be previously sold, leased, used, worn, remanufactured, or be non-functional. - Repurpose – adapt a product or its component parts for use in a different function than it was originally intended for without making major modifications to its physical or chemical structure
A.10	**Provider of IDs**	A party that supplies identifiers and data carriers. For a product or component to be traced, it must have a unique identifier that cannot be duplicated or moved from one (compliant) product to another (which may not be compliant). Parties and locations in the value chain also need to have unique IDs. This value chain partner's role is to provide the identification. The role can be carried out by a Transformation Partner, but it could also	The role of the actor is limited from the perspective of facilitation of collaboration across a supply chain and implementing CE, so not further considered	

		be done by a certifier or an inspection organization or an association that specializes in identifiers (such as GS1) or a government (for example, if a company is identified by its tax ID).		
A.11	**Information requestor**	A person, organization or authority needing traceability and transparency information about product(s) for their sustainability statement(s) (claims) regarding environmental, health, human rights and socio-economic impacts. If the products being traced are regulated, the data could also be used to verify compliance and enforce laws. Information Requestors can also include those who aggregates product data into traceability system or platforms.	Any actor within the supply chain has the potential to be an information requestor. This role is not limited to direct stakeholders; even indirect stakeholders can take on this responsibility. Therefore, it is crucial for the platform to enhance information traceability and transparency as a core feature, rather than considering it a unique characteristic of a specific actor.	
A.12	**Waste disposal provider /Collector**	A person, company or body having a role in waste disposal; the collection, processing, or deposition of the waste materials of human society. The waste disposal provider may also perform the role of sorter and recycler.	Collection of textiles can be performed by different actors (brand, retailer, municipality collection system, social economy actor), so its role must be separated from waste disposal. Waste disposal has no contribution to CE, so not considered for this iteration	
A.13	**Sorter**	A party that is dividing all textile post-consumer waste deciding whether a garment is resold or recycled. Sorters can also be waste disposal provider and recycler.	No modifications	A party that is dividing all textile post-consumer waste deciding whether a garment is resold or recycled
A.14	**Recycler**	A person or company who recycles or uses machines to recycle.	Modified according to the definition of ISO 59004	Actor performing activities to obtain recovered resources for use in a process or a product, excluding energy recovery

5.5.1.1 Exploring the barriers to fibre-to-fibre recycling

While the worldwide consumption of footwear is estimated to be more than 21 billion pairs of shoes per year[24], less than 5% of EoL shoes are being recycled, with most being disposed of in landfill sites around the globe[25]. To date, very little work has been done to develop material recycling solutions for mixed footwear products. According to Texon, fibre-to-fibre recycling in the footwear industry is nearly 0% due to the product design as showed in Figure 31. In fact, most modern footwear products are made of a complex mixture of more than 40 different materials which are assembled using different types of processes (stitching, glueing, dyeing, etc.) and multiple additives and coatings. Figure 31 illustrates this complexity by showing the components breakdown of a typical sports shoe. Commonly used materials include bio-based fibres (e.g. leather, cotton, wool), synthetic fibres (e.g. polyethylene terephthalate (PET), nylon, polyurethane (PU), rubber, poly vinyl chloride (PVC), ethylene vinyl acetate (EVA)), metallic materials (e.g. steel, brass, aluminium).

Figure 31 Typical sports shoe with main parts and used materials. Source: Wade Motawi (2018) SHOE MATERIAL DESIGN GUIDE.



This material complexity combined with the diversity of shoe types and construction techniques poses significant challenges to achieve high-quality closed-loop recycling with cost-effective processes. Even with the use of highly mechanised recycling systems[26] (currently employed by other industries such as electronics and automotive), the extensive use of additives and coatings pose additional barriers to fibre-to-fibre recycling as they affect the recycling process and the quality of its outcome. For example, the use of water repellence coating poses great barriers to fibres' recyclability

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[24] https://www.centreforsmart.co.uk/projects/footwear-recycling

[25] M. James Lee and S. Rahimifard (2012) *An air-based automated material recycling system for postconsumer footwear products*. Resources, Conservation and Recycling. Volume 69, December 2012, Pages 90-99.

[26] These recycling processes typically involve shredding or granulation, and subsequently separation machines which exploit the differences in material properties (such as material size and density) to provide automated separation into different material streams.

and protective and stabilizing chemicals added to natural biodegradable materials such as leather, natural rubber, etc. disable them to degrade naturally[27]. Finally, due to the intrinsic shortening of the fibres at each recycling cycle, the recyclability is limited to an average of 8 recycling cycles for synthetic fibres and an average of 5 cycles for natural fibres.[28] These effects require then the addition of virgin fibres to reach the desired performance level.

5.5.1.2 Enablers for high quality closed loops of fibres

The above-described barriers to fibre-to-fibre recycling show the crucial role of product design in achieving cost-effective closed loop system and high-quality recycled fibres. At the same time, there is also a clear need to boost visibility and to reward the efforts of companies which design 100% recyclable fibres solutions for footwear. These design options include better materials selection (as detailed by the Better Shoes Foundation https://www.bettershoes.org/home/material-selection#common) and circular design strategies such as:

- **Minimal design** which means removing unnecessary components without compromising the basic function of a shoe and reducing the number of different materials. For example, to achieve 100% footwear recyclability, Adidas has completely rethought their design process and came up with the running shoe FUTURECRAFT.LOOP[29] which is made of only one material and using no glue.
- **Alternative manufacture and assembly methods:** for example, choosing processes that minimise the amount of energy needed or using a glue less construction.
- **Bio-sourced materials:** 60% of textile fibres are synthetic and polyester is the most commonly used fibre, produced from carbon-intensive processes requiring more than 70 million barrels of oil each year[30]. In that regard, bio-sourced materials represent a key opportunity to mitigate climate change and resource scarcity. Microplastics released in the environment during the use phase of footwear are also a key challenge that bio-sourced and biodegradable materials can tackle. For example, PUMA recently experimented a biodegradable version of its most iconic shoe, called RE:SUEDE[31].
- **Modular Design and Design for disassembly**: this is one of the key design strategies to enable cost-effective fibre-to-fibre recycling. This strategy considers how shoes can be easily broken down into clean components once they wear off, in order to minimise waste and promote repairability, recyclability, and durability / product longevity.
- **Easy-care / Repairable**: Enable features to freshen up tired shoes and increase their lifespan. For example, resoling expands the lifespan of a shoe.
- **Multipurpose use**: Enable the user to wear one pair of shoes for a range of occasions.

5.5.2 Activity cycle material flow

Three scenarios from the circularity compass material flow (longevity, improment of sorting and design for recycling) were selected for a more in-depth analysis based on the activity cycle. In this

[27] Rahimifard, S., & Staikos, T. (2006). End-of-life management of shoes and the role of biodegradable materials. … University, UK.
[28] Celep, G., Tetik, G. D. , & Yilmaz, F. (2022). Limitations of Textile Recycling: The Reason behind the Development of Alternative Sustainable Fibers. In (Ed.), Next-Generation Textiles [Working Title]. IntechOpen. https://doi.org/10.5772/intechopen.105118
[29] https://news.adidas.com/running/adidas-unlocks-a-circular-future-for-sports-with-futurecraft.loop--a-performance-running-shoe-made-t/s/c2c22316-0c3e-4e7b-8c32-408ad3178865
[30] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12822-EU-strategy-for-sustainable-textiles_en
[31] https://about.puma.com/en/newsroom/corporate-news/2022/04-21-2022-start-re-suede

case, actions, needs and stakeholders involved were defined, to have a better understanding and clarity of the impact and feasibility from these strategies, on the textile use case. The activity cycle material flow for three strategies is illustrated in Figure 32.

Material producers must engage in thorough research and investigation, focusing on developing durable materials through high-quality manufacturing processes. Establishing strong connections with other material suppliers is crucial for sourcing reliable and hight quality materials.

Brands play a central role in influencing consumer choices and behaviours. To promote longevity, brands should consider the following actions:

- Neutral colors and versatile designs: opting for neutral colors and versatile designs ensures that products remain timeless and can adapt to changing consumer preferences over time.
- Function-first approach instead of fast fashion: prioritizing function over fashion in the design process ensures that products serve their intended purpose effectively and incorporate timeless aesthetics. This action requires design for easy maintenance or service by the user, implement a modular design,
- Guidance on Product Care: Providing guidance on product care, maintenance, and potential upgrades empowers users to extend the lifespan of their purchases

The end-users play a crucial role in the longevity strategy by prioritization of repair over replacement and by taking proactive steps in maintaining and repairing their purchases.

Improving the **sorting** process in the shoe and textile sector requires the active involvement of various stakeholders. The key players in this strategy are material producers, manufacturers of fibres and components, assembly manufacturers, brands, retailers, users, and sorters. Each actor has specific actions contributing to the overall objective of efficient sorting and recycling.

The key action expected from material producers and manufacturers of fibres and components revolve around providing comprehensive material data. This demands technical, financial, and human resources. Collaborating with assembly manufacturers is imperative, as these actors utilize the information in their processes and transfer it further.

For assembly manufacturers, ensuring the traceability of the final product with unique identifiers (IDs) is essential. Additionally, they play a vital role in providing data for the disassembly process. This actor must collect all relevant data and incorporate it into data carriers, collaborating closely with brands and ID providers.

Brands contribute to improved sorting by promoting the recyclability of their products. This involves establishing a reverse supply chain setup and devising strategies to collect products, in collaboration with collectors and sorters. Retailers, in turn, should furnish clear instructions on product recycling. To achieve this, they need to gather information and support from the brand. Users also play a role in sorting by following instructions on where to send components and how to perform separation, aligning with guidance from retailers and brands.

Sorters, with the aim of achieving high-quality sorting, require detailed and reliable material composition data for products. This information should be easily accessible. Agreements with recyclers are necessary to discern recyclable materials, and a reliable sorting method, such as scanning RFID tags or using spectroscopy, is crucial. Brands, assembly manufacturers, and recyclers are the key collaborators for sorters to achieve these actions and fulfil their requirements effectively. This collaborative strategy ensures a comprehensive approach to sorting in the textile sector, encompassing various stages of the supply chain.

In implementing the **"Design for Recycling"** strategy, various actors within the supply chain play pivotal roles. Manufacturers of Fibres and Components focus on creating recyclable materials, necessitating the minimization of material mixing and ensuring material quality and compliance. Collaborative efforts with brands, other manufacturers, and suppliers are crucial for the success of this strategy. This necessitates an effort to minimize material mixing, uphold material quality, and ensure compliance with legislation and standards. It involves fostering collaboration with brands, other manufacturers, and suppliers.

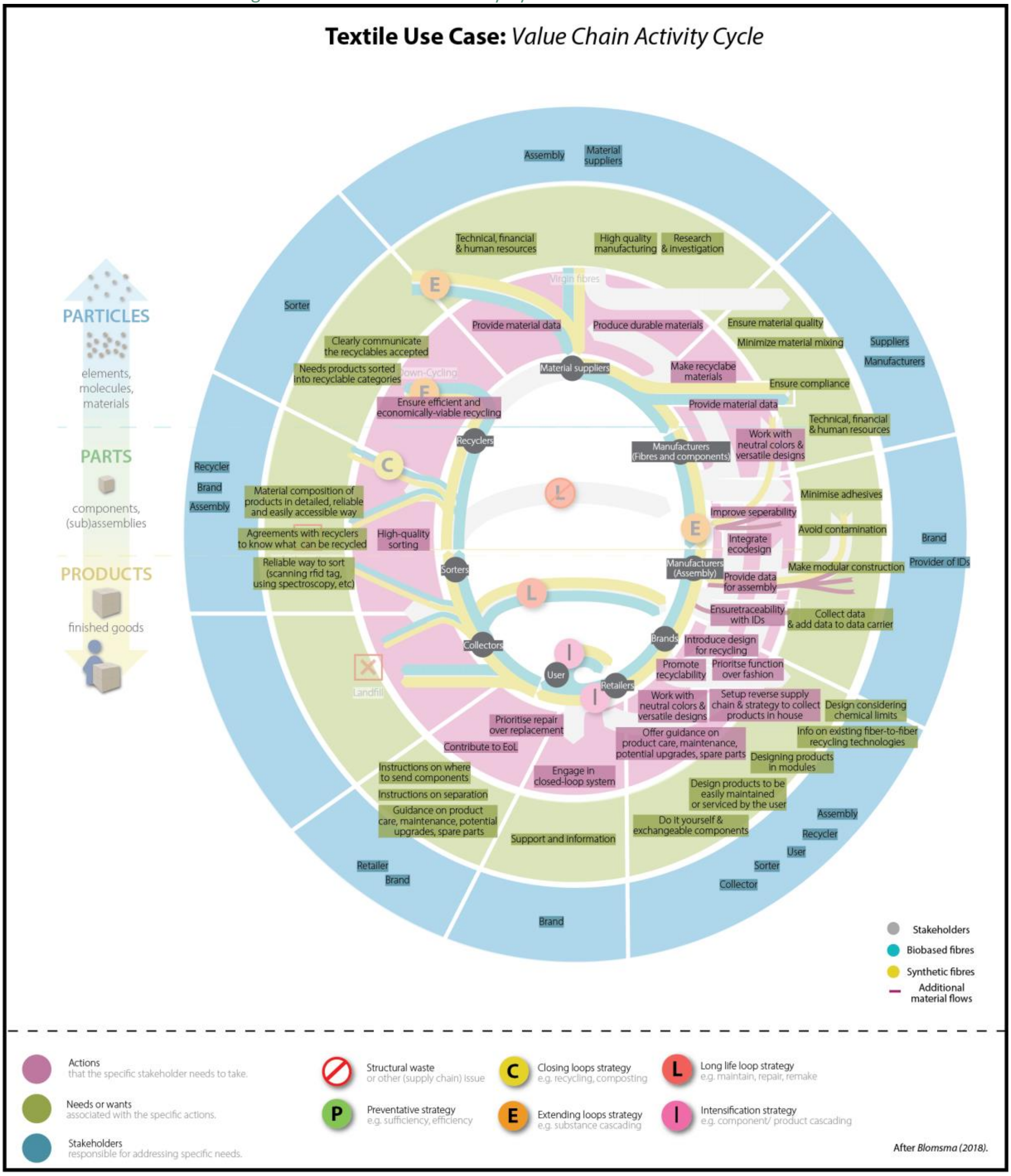
For assembly manufacturers, adopting a modular construction approach is central to the design for recycling strategy. This involves minimizing contamination, reducing the use of adhesives to simplify EoL separation. This design choice simplifies the separation process at the end of the product's life cycle.

Brands, as key actors, contribute to the strategy by incorporating design for recycling principles into their product development. This involves considering allowed chemical limits and seeking information on existing fibre-to-fibre recycling technologies from recyclers. Collaboration with retailers is also essential for the integration into the closed-loop system.

Retailers, within this strategy, could engage in the closed-loop system by collaborating closely with brands. Their involvement ensures that the products they handle can enter the recycling loop. End users could contribute through separation at home. Clear instructions from retailers and brands are essential, guiding users on where to send components and providing insights on effective separation methods. Sorters' actions and needs aligns with the sorting strategy described above, emphasizing the need for collaboration with manufacturers, brands, and recyclers.

Recyclers, at the end of the supply chain, contribute by ensuring efficient and economically viable recycling processes. Clear communication is key for recyclers, indicating the materials they can recycle and necessitating products to be sorted into categories that align with their recycling capabilities.

Figure 32 Value chain Activity cycle for the textiles use case



5.5.3 Energy flows circularity compass

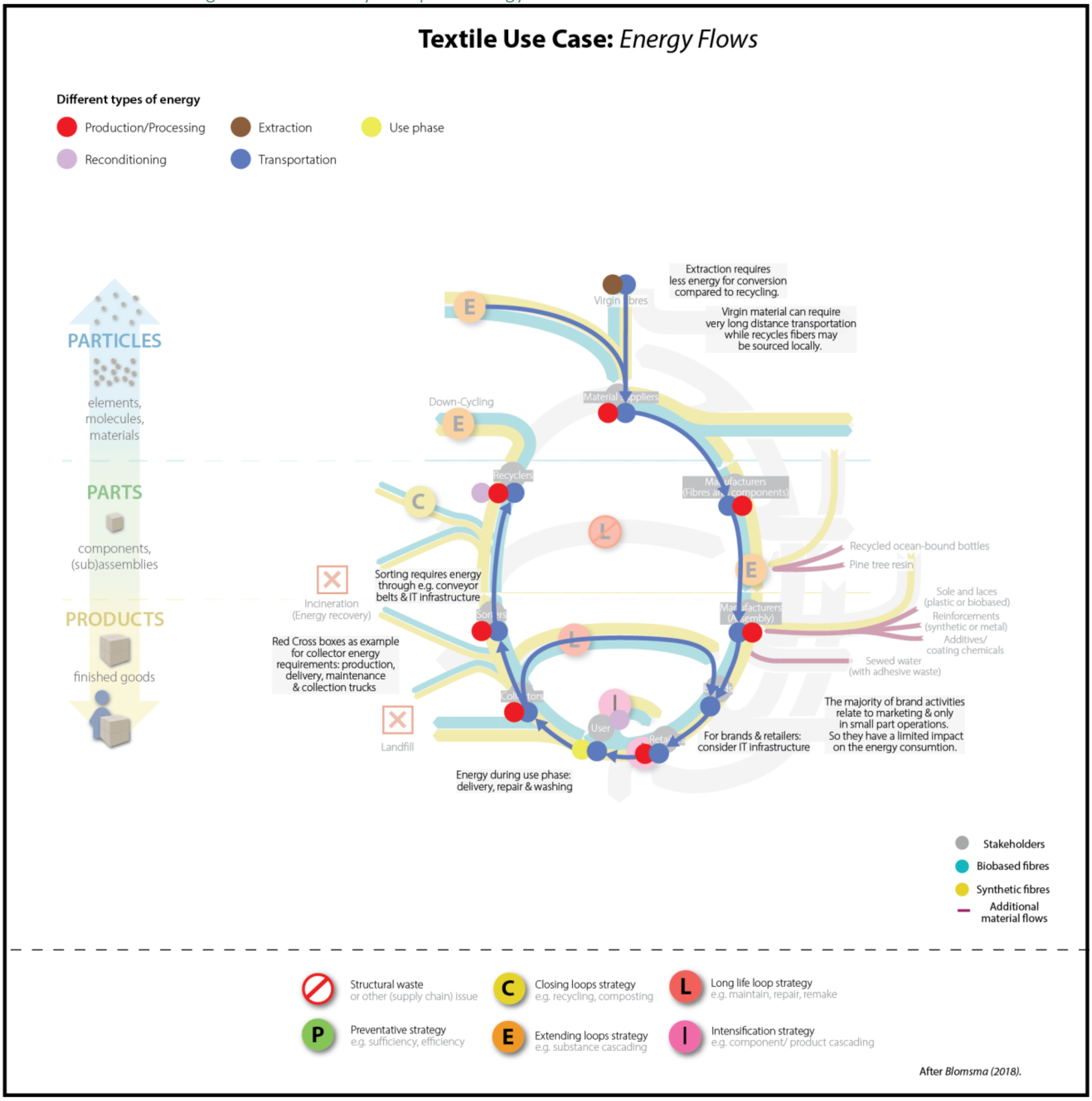
Energy consumption along the textile supply chain manifests at each stage in various forms. The energy usage encompasses routine operational activities as well as the transportation of goods between different actors within the supply chain (Figure 33).

- Virgin Fiber Producers: This stage involves energy requirements for the extraction, production, and processing of virgin fibers. The energy demand in this phase typically surpasses that of secondary fibers. Additionally, the transportation of virgin fibers often involves long distances, contrasting with locally sourced recycled fibers.

- Material Suppliers, Fiber, and Component Manufacturers, and Assembly Manufacturers: Energy is used both in the production processes and transportation at these products further contributes to the energy consumption.
- Brands: Brands predominantly focus on marketing activities and have a relatively smaller share of operational activities. Their energy consumption is primarily associated with office activities, goods transport to retailers, and the IT infrastructure necessary for business operations.
- Retailers: Similar to brands, retailers require energy for IT infrastructure, goods transport, and in-store energy consumption.
- Use Phase: During the use phase of textile products, energy is expended for washing and transportation, such as the purchase or delivery from a shop, or transporting items for repair. Actors involved in repair or reuse activities also require energy for their reconditioning processes.
- Collection: Textile products often reach collection points for voluntary disposal, such as Red Cross boxes. Collectors incur energy costs for producing and maintaining these boxes, as well as utilizing trucks for box delivery and clothing collection.
- Sorting: Sorting operations involve energy consumption for equipment, such as conveyor belts, and IT infrastructure, including servers. Additionally, energy is used for transportation.
- Recyclers: Recyclers consume energy for their equipment, the recovery of secondary materials, and transportation.

In conclusion, the analysis of energy consumption along the textile supply chain reflects that each stage of the supply chain, from virgin fiber production to recycling, contributes to energy consumption. The extraction and processing of virgin fibers, often coupled with long-distance transportation, result in important energy demands at the initial stage. As the materials progress through the supply chain, energy consumption persists in production processes. Activities of brands and retailers are predominantly centred around marketing, office functions, and product transportation. The collection phase involves energy consumption for transportation, production and maintenance of collection points, while sorting and recycling demand energy for the equipment, transportation and, eventually, IT infrastructure. The examination of energy flows reveals the utilization of various energy sources throughout the value chain, yet it falls short of pinpointing the highest energy consumption. While this qualitative review offers valuable insights, its effectiveness could be enhanced through a quantitative analysis to identify the most significant contributors to energy consumption. By including quantitative data, a more accurate understanding of energy usage can be achieved to further optimize energy efficiency.

Figure 33 Circularity Compass energy flows of the textiles use case value chain



5.5.4 Value flows circularity compass

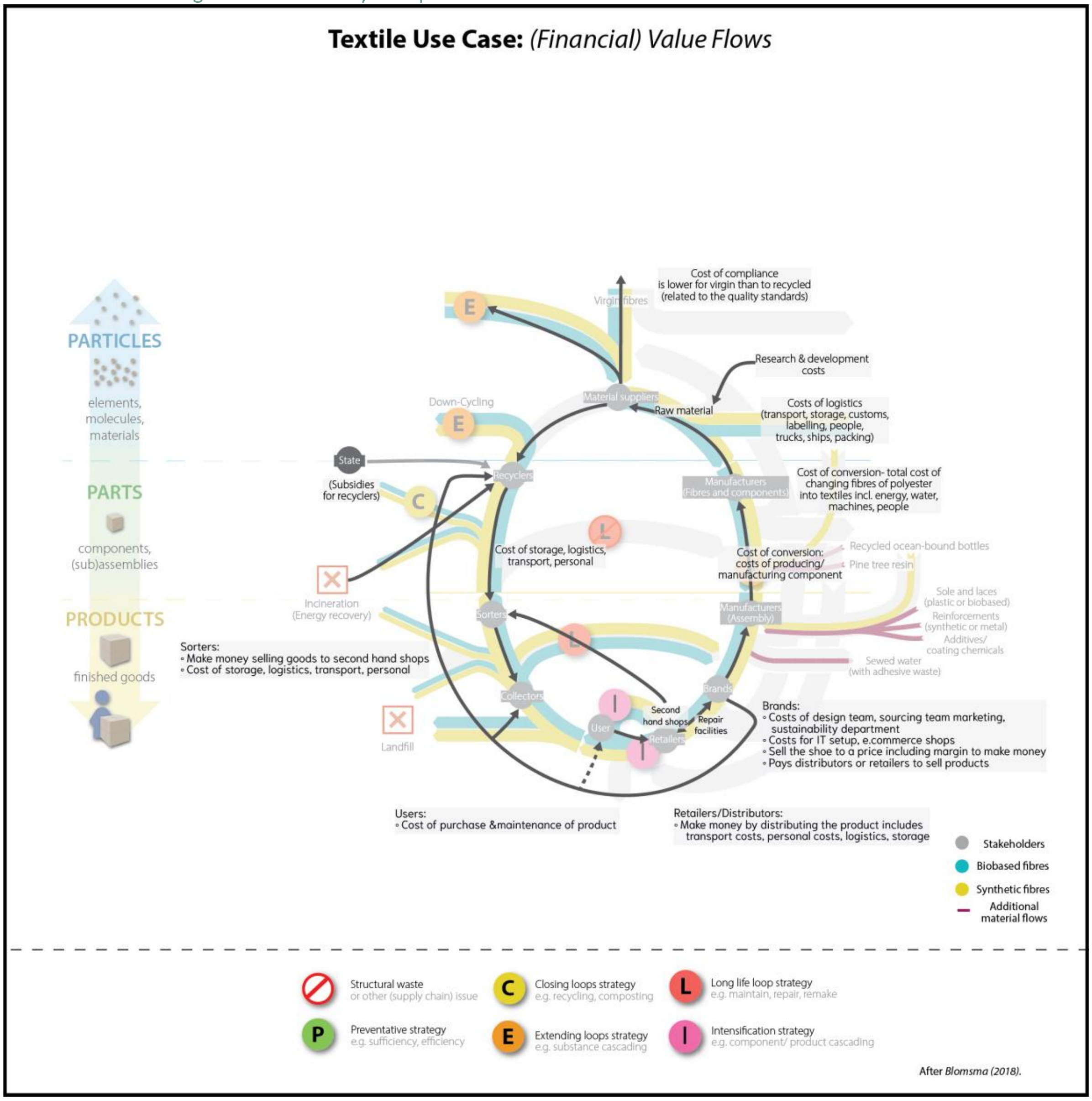
Financial flows along the supply chain in the textile and shoe industry involve various stages and costs (Figure 34):

- Material Suppliers: Depending on the material produced, material suppliers pay virgin fiber suppliers, recyclers for recovered secondary fibers, and/or other industries supplying post-industrial waste. Additionally, material suppliers incur costs related to research and development for new materials or processes.
- Manufacturers of Fibers and Components: These manufacturers bear the cost of conversion, encompassing the total expenses involved in transforming fibers, such as polyester, into textiles. This includes energy, water, machinery, labor, and more. Moreover, they incur logistics costs for transportation, storage, customs, labeling, personnel, trucks, ships, and packing.

- Assembly Manufacturers: Actors involved in assembling products face costs related to the manufacturing process (energy, water, machinery, labor, etc.).
- Brands: Brands incur costs related to its functioning, including those associated with design teams, sourcing teams, marketing, sustainability departments, IT setups, and e-commerce shops. In some cases, brands may pay distributors or retailers to sell their products.
- Retailers: Retailers sell products at a price that incorporates a margin for profit. This price covers various expenses, including transport costs, personnel costs, logistics, and storage.
- Users: End-users cover the cost of purchasing and maintaining the product.
- Sorters: Sorters may generate revenue by selling goods to second-hand shops. However, they must also cover costs such as storage, logistics, transport, and personnel.
- Collectors and recyclers: are paid by brands or importers, because In Europe, the responsibility for the collection of discarded textile products falls under Extended Producer Responsibility (EPR) schemes. Under EPR, the principle is that producers or importers of products are held financially and operationally responsible for the collection and proper management of the waste generated by their products. The implementation of EPR can vary by country as each European Union (EU) member state may adopt its own regulations and programs. In some cases, producers are required to collaborate with waste management systems or set up their collection and recycling systems.

The circular economy within the textile and shoe industry offers a potential for additional income throughout the supply chain. The financial flows illustrated in the various stages of production and consumption demonstrate that different actors within the industry can benefit economically from embracing circular practices. Material suppliers, manufacturers of fibers and components, assembly manufacturers, brands, and retailers have the opportunity to optimize their resource use, and subsequently lower certain costs. Moreover, the circular model introduces the potential for generating revenue through reuse and resale. Sorters also may find a source of income by selling goods to second-hand shops. Additionally, the implementation of Extended Producer Responsibility (EPR) schemes further emphasizes the financial responsibility of producers and importers in managing the life cycle of their products. While complying with EPR regulations may involve costs, it also creates opportunities for collectors and recyclers to be paid by brands or importers for their services.

Figure 34 Circularity Compass value flows of the textiles use case value chain



5.5.5 Information flows and main challenges related to data sharing

In a circular economy, it is not only resources that need to circulate but also information. The Open Circularity Platform should facilitate the digitalization and the automation of data exchange as far as possible at all interface points in the value chain, requiring minimal manual intervention. The Figure 35 describes the key challenges related to the data exchange hindering footwear recycling. The lack of data on materials, additives and coatings, production methods and assembly techniques, and the (unstable) quality of materials does not currently allow for a closed fibres cycle in the footwear sector. In particular:

- The lack of information on additives and assembly processes does not allow for transparency and product knowledge that would favor the implementation of disassembly protocols to improve product repair and fibre-to-fibre recycling.

- The absence of traceability process for materials does not ensure their quality and therefore does not allow for a proper assessment of their real potential for recovery (e.g. addition of chemical substances, like water repellent).

In terms of enablers, two main solutions to be explored in future work are:

- Reward mechanisms to boost visibility of the sustainability and circularity efforts made by companies on their product/materials. This would create incentives for manufacturers to share product data and for brands to design shoes made to be 100% recyclable.
- Traceability mechanisms to ensure that the product is made of the claimed materials and that this information can be made available to authorized parties. This would make it possible to match footwear products with appropriate recyclers, so that they are recycled to best knowledge and method according to the current state of technology at EoL.
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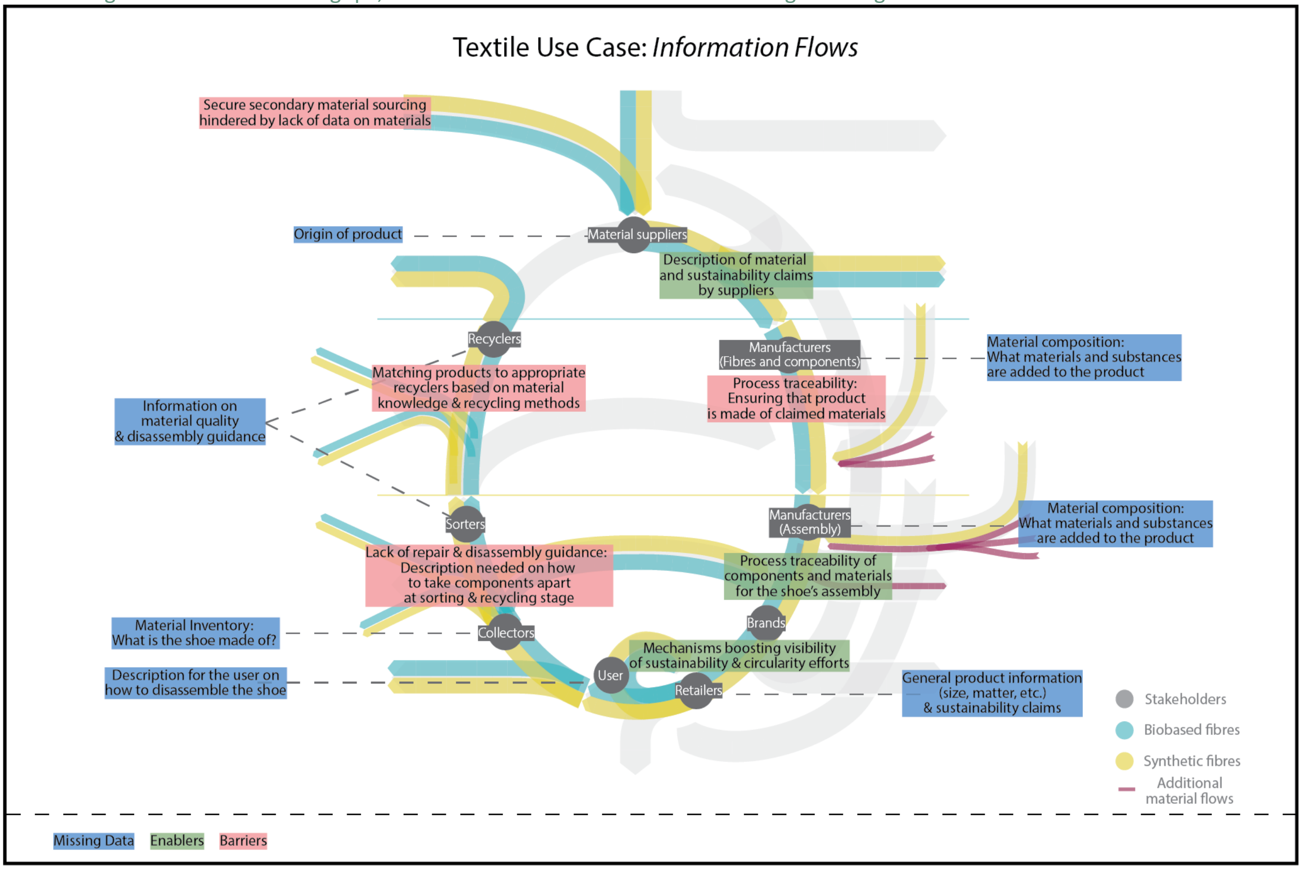
Figure 35 Current data gaps, barriers and enablers for data exchange throughout the footwear value chain



The Table 3 provides a list of the challenges related to data exchange that shall be addressed to ensure a successful implementation of the Open Circularity Platform.

Table 3 - List of challenges related to data exchange throughout the footwear value chain

Nr.	Topic area	Challenge statement
C.1	**Value proposition**	How to value the efforts made by companies to achieve sustainable and circular products? So, it can be translated into the final price. The Open Circularity Platform shall support companies by boosting the visibility on their sustainable practices and efforts.

C.2	**Global reach and inclusive for SMEs**	- Textile value chains are complex and international with a lot of subcontracted generating of products with short life cycles and by small and smallest companies, often with poor IT capabilities and competences. - For a high adoption by the market actors, the platform must be easy to use in terms of costs (training, IT implementation, etc.) and interoperable (i.e. compatible with the organizations' IT systems). - Socio-cultural factors and regional regulations and policies may influence the understanding of a same concept/ statement/ etc., which may to various interpretations of the same elements. It is crucial to create a globally harmonized product data model for circular material flows. The platform shall provide the data creation methods for each key stakeholder in the value chain to minimize human and technical costs related to data creation and exchange.
C.3	**Lack of digitalization**	There remains today an existing lack of digitalization of many companies in the textiles sector leading to heterogeneity of IT-related capability of companies, especially for SMEs which often lack IT capabilities. The platform shall be easy to use in terms of IT competences and ensure interoperability.
C.4	**Product Traceability**	The platform shall address the following challenges: - Lack of standardized product classification systems, like e. g. ETIM in electronics - Lack of traceability of the manufacturing process to ensure that the product is made of the claimed materials. The footwear industry is extensively using chemicals at the different stages of the manufacturing process (dyeing, coatings, glues, etc.). These chemicals have a huge impact on the recyclability. In addition, for cost reason, it is common practice to mix low-quality fibres with high-quality fibres without considering the impact on recyclability. Technical issues in identifying the material types and the appropriate recycling streams when sorting textile and footwear products at the end of their life cycle (which is currently a highly manual task).
C.5	**Security and privacy**	The platform shall ensure that sensitive data is not displayed and not shared with third parties without authorized permission, as manufacturers are highly reluctant to disclose detailed product data such as product composition. For example, the manufacturers may agree to provide access to some details about their product composition to a list of authorized recyclers.
C.6	**Trust**	Trust in the Open Circularity Platform occurs at different level: 1. Between the stakeholders using the system (e.g. authenticate method to ensure that stakeholders using the data exchange platform are trusted parties) 2. In the integrity of the data shared via the platform 3. In the accuracy of the product data and claims
C.7	**Verification of sustainability and circularity claims**	As highlighted in the EU Strategy for Sustainable and Circular Textiles, the accuracy of green claims made on using recycled content is a specific growing concern by the EU Commission. In particular, the common practice of brands to use recycled plastic polymers from sorted PET bottles (and not from fibre-

		to-fibre recycling) is "not in line with circular model for PET models" and is misleading for consumers[32]. The platform shall facilitate the access to the valid proofs (e.g. certificates, audit report, etc.) of circular/sustainable claims (e.g. recycled/renewable content, etc.)

[32] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12822-EU-strategy-for-sustainable-textiles_en

6 Conclusion

The project was initiated through the identification of fitting example cases for the testing and validation of the technology and ontology created within the Onto-DESIDE project. The three demonstrators identified three supply chains of different length and regulatory circumstances. The example products have been well-chosen to span as many types of materials as possible in order to portray circularity and data communication across different industries. The presented circularity compass identified a methodological framework of analysis that enables the comparison of the use cases on circularity terms and information flow with the possibility to describe and analyse the processes conducted in the demonstrations after this first assessment of the status quo. Despite the differences of the use cases, the first assessment revealed interesting similarities.

This deliverable introduces a tool known as the Activity Cycle, which promotes circular thinking. By employing this methodology, one can effectively address the challenges outlined in the circularity compasses for each specific use case. The Activity Cycle assists in determining suitable actions required to achieve the desired state, the necessary information, and the involvement of relevant stakeholders. Within this report, each use case thoroughly examines significant scenarios related to material flows and explores associated information flows.

When assessing the material flows along the supply chain, the demonstration products reveal usually initial and in the case of the textile case even advanced circularity practises in relation to the reuse and recycling of generic material types. All example cases show serious limitations whenever materials get more complex, supply chains get longer and information about material composition and production processes are not traceable yet.

The information flow along the three supply chains portrays a first analysis of the availability and detail of information available to the manufacturer. The assessment will have to be detailed further as per the assessment of raw data on materials, chain of custody and production process throughout the demonstration activities with supply chain stakeholders. The initial overview showed similar limitations in information availability whenever supply chains got very long, or international and material compositions got advanced. Furthermore, the availability of data showed improvement whenever products were for the B2C market and subject to regulations, like the textile industry. In addition, the complexity of a product and its intellectual property rights on compositions correlates with difficulties in accessing reliable and detailed material data. All information flows show a bias towards recycling practices with little to no existing efforts in refurbishment or remanufacturing of products.

The analysis of energy and value flows provides valuable insights for identifying opportunities to enhance the cycle. Organizations are greatly incentivized to tackle energy consumption issues and improve efficiency as it directly translates into reduced costs and competitive advantages. Moreover, comprehending the value flows allows for a better understanding of financial values, key activities, and stakeholders involved. This knowledge helps identify areas where heightened motivation is needed and where decision-making power lies.

The version 3 of this report (D6.3) will intensify the analysis in line with more engagement with the demonstrating manufacturers and detail the industry-related needs in data standards and data needs.