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ONTO-DESIDE

DELIVERABLE

Use Case Needs Analysis and Circular Value Flow Mapping – Report v3

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Deliverable name	Use case needs analysis and circular value flow mapping
Work package	WP6 – Industry use cases
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Contributing partners	+ImpaKT Luxembourg circular.fashion Concular GmbH Texon Lindner Group Ragn-Sells Recycling REIA Universität Hamburg
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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 GmbH	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
12	Prague University of Economics and Business	VSE	Czech Republic

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Document approval

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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. For understanding and analyse the use case, different methodologies were used, such as 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 deliverables D6.1 and D6.2 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 realising 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 developing systems that enable information sharing throughout value chains and achieving 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 **Error! Reference source not found.** through detailing the first project iteration, but which applies to all iterations. 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 deliverables 6.1 and 6.2. It now includes further work on the different flows, as well as the ecosystem itself, providing a holistic viewpoint. It uses the steps and follows the structure of the circular value chain development method (including both design and improvement) developed as part of WP5, which supports strategic thinking towards building plans for achieving a circular economy in the different use cases – but which will have broader applicability beyond these cases also.

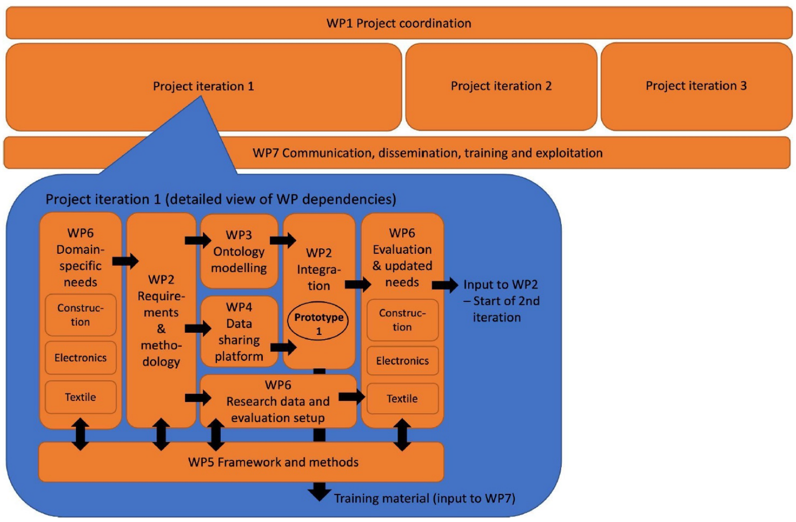


Figure 1- Project outline and detailed dependencies between work packages exemplified by the first iteration

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:

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

Three deliverables are being produced in WP6 during the project:

1. D6.1 Use case needs analysis and circular value flow mapping (D6.1 - v1 M3, D6.2 - v2 M18, D6.3 - v3 M27) – report
2. **D6.4 Research data** (D6.4 - v1 M12, D6.5 - v2 M24, D6.6 - v3 M33) - data (project internal)
3. **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 3 (D6.3). It provides a description of the industrial needs from the perspective of each use case and a mapping of circular opportunities and challenges in each use case. The D6.1 is divided into three parts and is used as a "living document" throughout the project. This current version is a revised version, issued at M27(D6.1 - v3) - and we refer to this as D6.3 from here on out. This current report focuses, as opposed to previous iterations which centered on mapping flows, on how barriers and enablers shape these flows and the possibilities to improve levels of circularity and sustainability. Specifically, it focuses on how the behaviour of circular value chains as a whole can be influenced. This ultimately serves to identify how data and computing can support developing circular value chains and therefore culminates in an overview of the themes that featured across the cases – and offers reflections on how these can be carried over and featured when further specifying the circularity requirements developed as part of WP2 (*Requirements, integration and standardisation*). As such, this work serves to explore and understand the role of systemic features of circular value chains and if and how these can or should feature as part of the ontology (WP2 & 3) as well as the Open Circularity Platform (WP4) developed within Onto-DESIDE. As such, this and the previous reports build on each other and each advance the previous work:

- 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: updated flow models, with an emphasis on systemic barriers and enablers and acquire or use the capacity to shape the course of such flows, M27

Where for these previous deliverables the focus was on understanding the material, energy and value flows and the associated information flows that support better understanding their properties; for this current deliverable the focus lies on identifying actions that can be taken to (further) grow and mature the value chain. As such, the current deliverable moves from the focus of D6.1 and D6.2 which looked at the 'what' of circular value chains, to the 'how' of advancing them – to ensure that not only descriptive information is captured by the ontology, but that the developmental and the systemic perspective that is necessary for this, is also considered.

2. Objectives and research methodology

This chapter presents an overview of the objectives and research methodology for the analysis done on each of the use cases in WP6.

2.1 Objectives

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, WP6 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 this purpose, all three use cases will:

- **Define the business needs and requirements** from the specific perspective of their industry domain, which is generalised and translated into technical requirements for ontology and platform development in **WP2**.
- **Provide research data and insights into their value chain**, both for technical development as well as validation and evaluation of results of the technical and scientific WPs (2-5)
- Apply existing methods (1st half of the project) and help to develop and test the extension of this method (2nd half of the project) as part of WP5 (respectively: the Circularity Compass and Value Chain Activity Cycle, and the Multi Flow Method) to map the business opportunities that are opened up through applying a systemic perspective on value chain development, and the potential implications for data collection, storage and computing.
- **Perform evaluation experiments and provide feedback** on 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 to how to apply and detail ontology artefacts. This is to ensure that the ontology building blocks that the project develops are industry-independent and usable across industry domains, thus also facilitating cross-industry circular flows. 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 confidentiality-preserving data-sharing platform. Each organization will add capabilities and data, i.e., specializing in the semantic model, based on the type of business they are involved in.

2.2 Research methodology

This chapter on the research methodology gives an overview of the general research approach and outlines which frameworks and methods have been used in the three iterations of the “Use Case Needs Analysis and Circular Value Flow Mapping” report, respectively. The chapter then continues to introduce Circularity Thinking - and one of the fundamental frameworks used in it: the Circularity Compass. This is to ensure that the reader is informed about this fundamental part of the methodology used within WP6, as it serves as the basis for all mappings conducted. Since these mappings are essential for the work involving the Multi Flow Method, it is important to understand the concepts behind the Circularity Compass. Readers that are already familiar with Circularity

Thinking and the Circularity Compass may skip Chapter 2.2.2, and continue with 2.3, which introduces the Multi Flow Method used for the development of the current deliverable (D6.3).

2.2.1 General Research Approach and Methods Used

The project research process is divided into three iterations, each divided in 3 steps (cf. **Error! Reference source not found.**):
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.

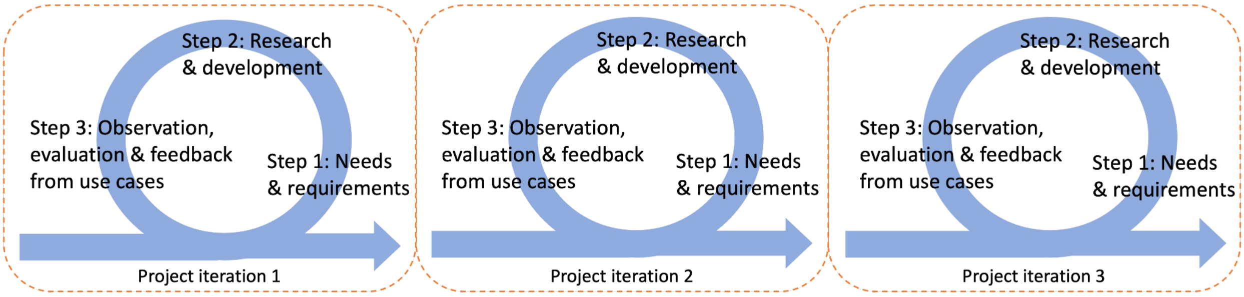


Figure 2 -The Onto-DESIDE research process, divided into 3 iterations, each consisting of three steps

For each project iteration for steps 1 and 3, Circularity Thinking[4] (i.e., Circularity Compass and the Multi-Flow Metabolism (MFM)) was used – in the first half of the project the existing tools and methods, and in the second half of the project new additions - as a common framework to align perceptions of current value chains as well as explore possible new configurations of both resource flows and how different actors can collaborate in new ways (see **Error! Reference source not found.**). In this sense, there existed a reciprocal relationship between the use cases and Circularity Thinking first, Circularity Thinking offered a ready-made starting point and later the use cases served to advance the method and therefore support the objectives of WP5. That is, Circularity Thinking served to map the details of each use case, 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).

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.

[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

Solutions are then built incrementally, i.e. extended and matured in each iteration, as well as evaluated in the three use cases.

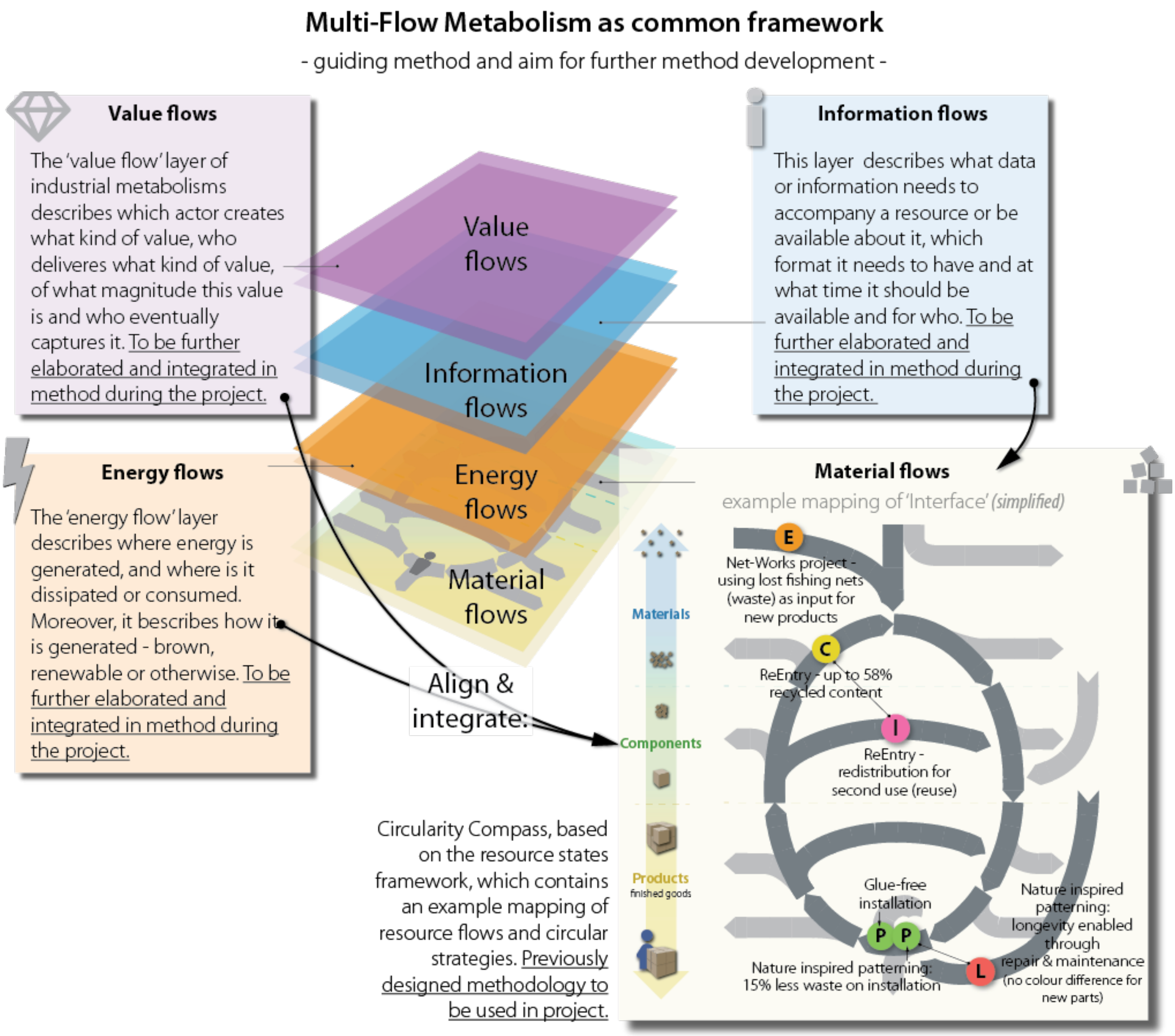


Figure 3 - Circularity Compass (bottom layer) and the Multi-Flow Metabolism as a common framework for analysing the use cases

Circularity Thinking consists of several frameworks or tools, with which system mappings can be made to aid analysis. Many of these frameworks have already been used within the previous iterations of this deliverable (D6.1 and D6.2), i.e., the Circularity Compass, the Big Five Structural Waste and the Value Chain Activity Cycle. Additionally, the MFM has served as a guiding conceptualisation of circular value chains for Onto-DESIDE. As part of the third project iteration, WP5 has developed a method that turns the MFM into a method for the accelerated development of circular solutions – the Multi Flow Method (first draft). This method is used by the use case partners to further interrogate their value chains within the current deliverable (D6.3). Table 1 provides an overview of the methods and tools used within the three iterations of the report, and where to find further descriptions of the respective methods used.

Table 1 - Methods used within the three "Use Case Needs Analysis and Circular Value Flow Mapping" Reports

Report Version (Date submitted)	Circularity Thinking Tools Used (and Location of Method Description)
Version 1 (09/22)	• Circularity Compass (see Chapter 2.2.2 and Appendix 1 – Circularity Thinking - Continued) • Big 5 Structural Waste (see Appendix 1) • Results: **1.** Mappings and analysis of resource and information flows
Version 2 (11/23)	• Circularity Compass for energy and (financial) value flows (see D6.2) • Value Chain Activity Cycle (see D6.2) • Results: **2.** Updated mappings of resource and information flows (where applicable) **3.** Preliminary mapping of energy and (financial) value flows **4.** Extended analysis through VCAC
Version 3 (08/24)	• Multi Flow Method (Version Beta 1) (see Chapter 2.3) • Results: **5.** Updated mappings: for the four flows, for infrastructure and enabling assets, and for the system environment (Differs between use cases) **6.** Analysis of improvement opportunities for circular value chains

The next chapter now provides an overview of Circularity Thinking and a brief description of the Circularity Compass. Please refer to Appendix 1 – Circularity Thinking - Continued, for further explanations on the Big Five Structural Waste and the MFM.

2.2.2 Circularity Thinking – An overview

Circularity Thinking – an approach for circular oriented innovation

Circularity Thinking is a method that enables identifying circular economy-related opportunities, exploring possibilities developing them into robust solutions, and outlining the next steps to make these solutions a reality. Circularity 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 available 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.

The Circularity Compass (Circularity Thinking tool #01)

The Circularity Compass, or simply Compass for short, is the first of the Circularity Thinking tools and can be used to understand (physical) resource flow (Figure 4). 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.

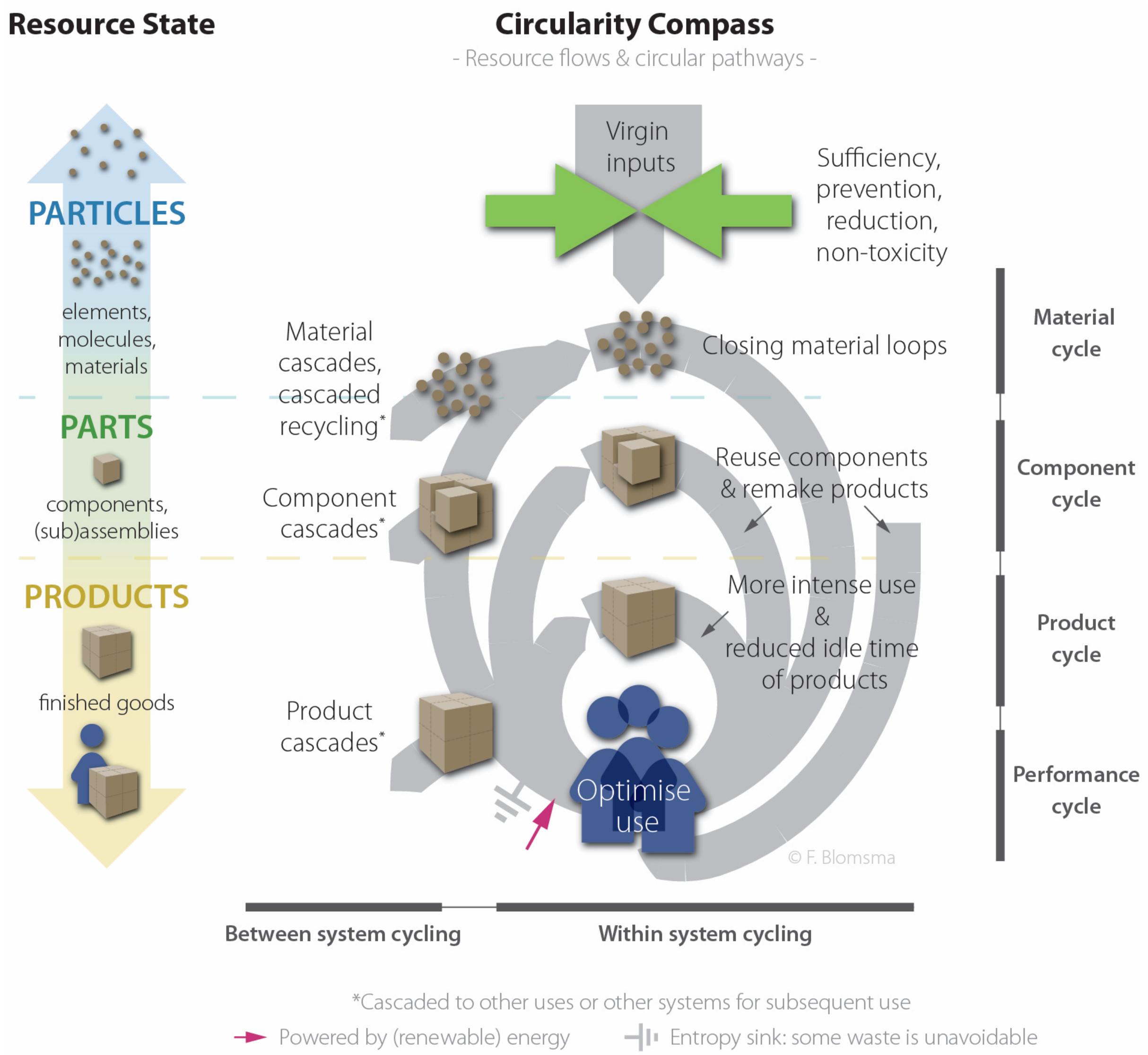


Figure 4 - Circularity Compass, providing an overview of the main cycling categories. From: Blomsma and Brennan (2022).

Circularity Thinking contains a range of other tools that can be used depending on the stage of the innovation process and the objectives. Here, and for the purposes of this deliverable, we continue with a focus on the Multi Flow Metabolism framework, which is turned into the Multi-Flow Method as part of D5.2 and used for the current mappings that are the main outputs of D6.3.

2.3 The Multi-Flow Method

As the Multi Flow Method is under development, here we present the version that was used for the current value chain interrogation (Version Beta 1 - Bv1) - including how it was facilitated. The chapter starts with a method introduction (2.3.1) which includes the purpose of the method and relevant prior work. It continues with an overview of the method and the general instructions (2.3.2). The individual steps and instructions for Part 1 and Part 2 of the method are then introduced separately, in 2.3.3 and 2.3.4, respectively. Images of the method are included in this chapter where appropriate, yet a full version of all method steps can be seen in Appendix 2.

2.3.1 Method Introduction

Method Purpose

Circular value systems differ from linear systems in that all components must work together for the system to function effectively and remain robust. After all, circular value chains are unique in the sense that feedback loops exist: their output is also their input. It is because of this that weak links within the system pose a threat to the entire circular system and each actor involved in creating and capturing circular value. Despite this, systemic thinking and analysis has been minimally applied in the circular business realm. It is this gap, that the method aims to address: to strengthen the innovation capacity for circular value chains The goal of the method is to support value chain actors in developing – including both design and improvement opportunities - circular economic value chains by applying a systems perspective and understanding how the circular value chain can function better as a whole. That is: instead of focusing on a small set of local phenomena, the method helps to examine the relationships between different points of interaction and how the sum of this creates the behaviour of the value chain. The Multi Flow Method guides practitioners in their exploration of: What works well and what problems have been already solved? What does not function well and where do problems remain? What should the value chain look like and function instead – and what actions can be taken to get there?

Prior work

Within the processes of D6.1 and D6.2, the use cases generated mappings for each of the four flows – material, energy, value and information – within their circular value network. These mappings offer a visual representation of how the flows flow within their value network, providing a descriptive overview. The work completed in D6.1 and D6.2 lays the groundwork for each use case. The analytical approach of the Multi-Flow Method now enables partners to shift from a descriptive overview to a more detailed comprehension of their circular value chain and its relationships, aimed at uncovering shortcomings that prevent the value chain for further developing and scaling – and the value chain participants to create and capture circular value.

2.3.2 Method Overview and General Instructions

The method is facilitated on an online collaboration whiteboard (Miro). Figure 5 offers an overview of the method and shows how the online whiteboard for each use case looks. This subchapter gives an overview of Parts 1 and 2. Detailed instructions will be provided in the subsequent chapters.

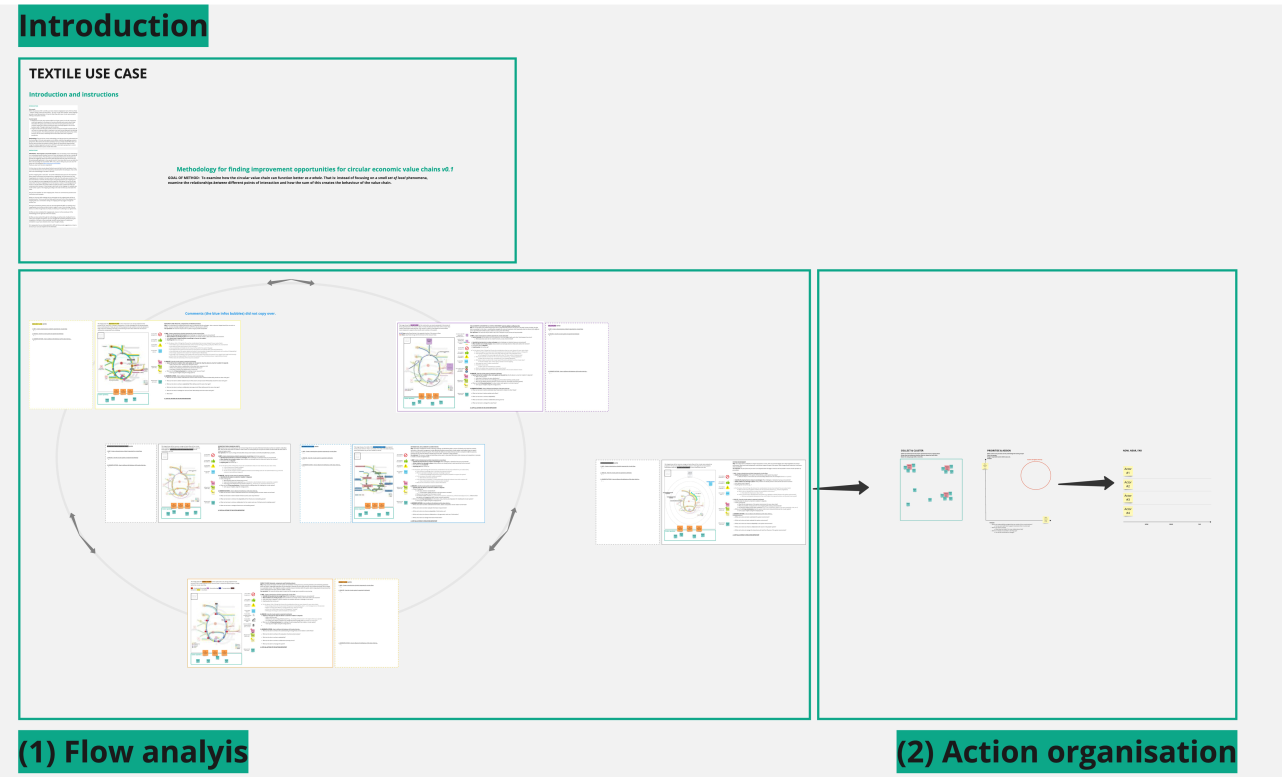


Figure 5 - Overview of Online Collaboration White Board used for Facilitation

Overview

When participants first access the online whiteboard, they are automatically directed to the "Introduction" section. This section includes 1) an introduction to the method, covering relevant prior work, the background of its development, and the purpose of the methodology; and 2) offers a set of instructions for each mapping task. As an initial step, participants are encouraged to familiarise themselves with the workspace, i.e., to zoom in and out on the board to locate all elements within the workspace and take a first look at the method to understand its contents.

The process of the Multi-Flow Method consists of two parts: 1) the flow analysis and 2) the action organisation. Part 1) includes six individual boards, called *mapping tasks*, for:

- Resource flows
- Value flows
- Energy flows
- Infrastructure and enabling assets
- Information flows, data, memory & computation
- System environment.

The purpose of these mapping tasks is to create a shared understanding of barriers and enablers for the respective flows and generating relevant actions to address shortcomings. Whilst a barrier or enabler may feature in multiple mapping tasks, these different tasks serve to highlight different dimensions or aspects of it – and thus to gain a deeper insight into the respective topic.

The result of each mapping task is the identification of actionable items that are then used in the second part of the method, the action organisation. The purpose of this subsequent step is to condense and organise the actions in a way that helps participants to take initiative and ownership, but also see where they can collaborate (e.g. have shared responsibilities and mutual interests) The following is written from the perspective of self-facilitated sessions, because this will be the format of the training guides (WP7) - even though for this phase of the method development it was still facilitated by WP5).

The general steps for the Multi Flow Method are the following (Table 2):

Table 2 - Multi Flow Method - Process Steps for participants

1) Choosing the first mapping task As a group, choose one mapping task to start with. Even though it is not required to start with the resource flow mapping task, it can be helpful to start with this mapping task. While all mapping tasks follow the same general structure (1. Map, 2. Analyse, 3. Generate actions), each task also includes prompts and questions specific to the task. Use these prompts to conduct the analysis. Then, copy all generated actions to the action repository. Additional information: • All mapping tasks include a mapping area (i.e., the image of the pre-mapping from D6.1 and D6.2) and an adjacent space for notetaking. You are free to take notes either on the pre-mapping (in form of the post its and icons) or in the designated text section. Either way, please make sure that you have a system that helps you understand which answers / notes belong to which part of the mapping. For example, you could number a part on the mapping according to the order of which you have taken the notes.
2) Continuing the mapping tasks After completing the first task, choose another mapping task, follow the mapping task instructions and use the respective prompts. Additional information: • While you may approach the completion of the mapping tasks in order, it is likely that the mapping tasks will be an iterative process. That is: you will most likely switch back and forth at times between the mapping tasks as a conversation during one mapping task may trigger a thought for another one.
3) Completing sufficient number of mapping tasks Even though all flows as well as the system environment and infrastructure tasks are considered to be important for gaining a detailed understanding of the circular value network as a whole, the completion of four mapping tasks may already be considered sufficient to fulfil the requirements of the first part of the method. Select the tasks that are most relevant to the value chain. Additional information:

- (For D6.3 and D5.2 specifically) During the introductory session, each use case agreed on a specific set of mapping tasks to prioritise and which tasks to neglect in case of time shortage.

4) Copying *all* actions to Part 2

After you have finalised the mapping tasks, copy over *all* actions from the respective action repositories to the *collect and cluster* task. This starts the second part of the Multi Flow Method. Please follow the instructions given in each step of Part 2, i.e., the *collect and cluster* step, the *prioritise and assign* step, and the allocation to the *now, near, and far* future to complete Part 2.

2.3.3 Part 1: Flow Analysis

Each mapping tasks consist of three parts: 1) a short introduction/overview of what the mapping tasks pertain to, 2) the instructions and guiding questions 3) a mapping area (and respective notetaking space). Figure 6 shows the value flow mapping task and serves as an example of all mapping tasks.

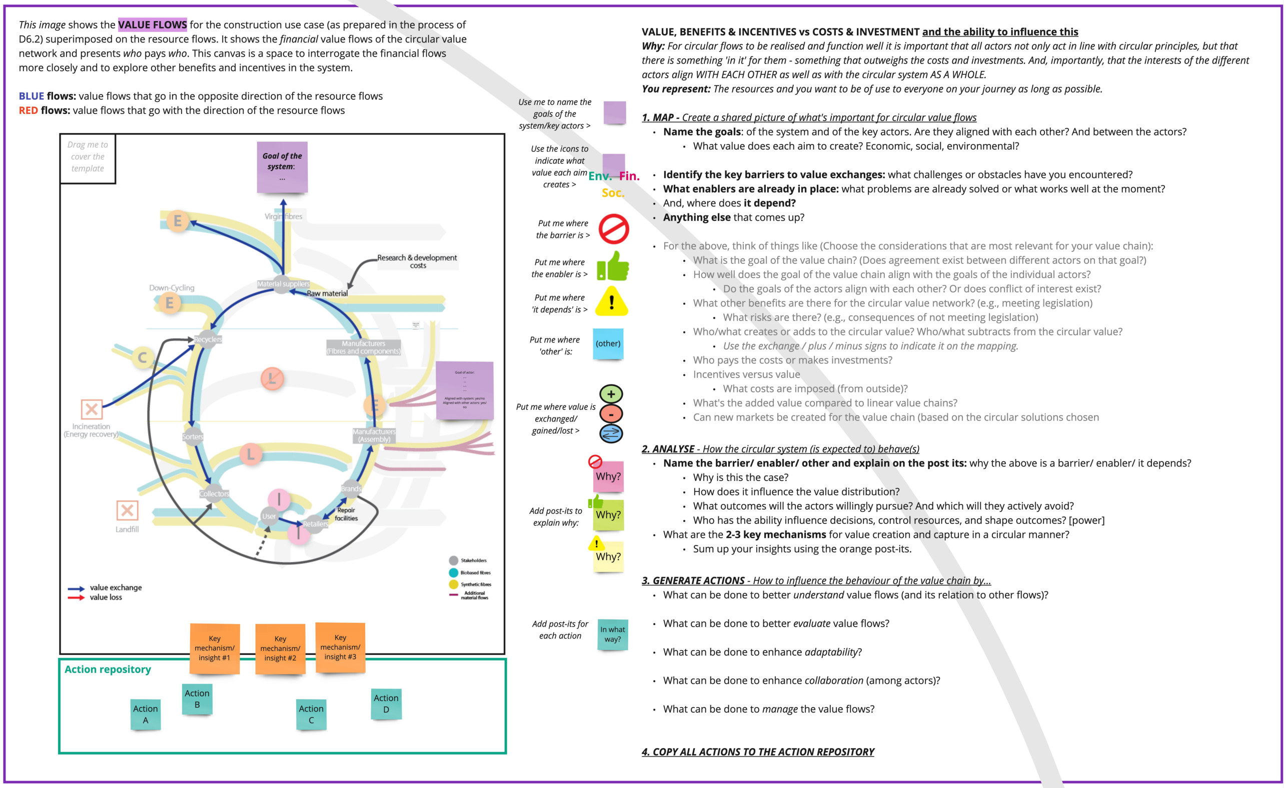


Figure 6 - Mapping Task Example (notetaking space not pictured here to increase the readability of the image.)

The mapping tasks start with a short description of what is included in the respective task and why it is important for circular value chains. For example, while the task is generally called value flow mapping task, it is meant to facilitate discussion around “value, benefits & incentives versus costs & investment and the ability to influence this”. The description continues with the reasons for why these topics are important for the development of circular value chains. To support participants in shifting their perspective from the usual actor-centric perspective to a systems approach, a prompt is included to make participants aware of the perspective they should take, e.g., for value flows, one should think about barriers, enablers and actions from the perspective of the resources (i.e, the prompt: “you represent the resources and you want to be of use to everyone on your journey as long as possible”). This shall emphasise that the focus is not on how the value chain can work for the individual actor but rather how the flow of the flows can be enabled.

The first step is the mapping – “to create a shared picture of what's important for circular value flows”. Within this step, participants are asked to identify key barriers for the respective flow (i.e., what obstacles they have encountered) and what enablers are already in place (i.e., what problems are already solved or what works well at the moment). To guide the conversation, guiding questions are provided. Examples of value flows include:

1. What is the goal of the value chain?
2. Does agreement exist between different actors on that goal?
3. How well does the goal of the value chain align with the goals of the individual actors?
4. Do the goals of the actors align with each other? Or does conflict of interest exist?
5. What other benefits are there for the circular value network? (e.g., meeting legislation)
6. What risks are there? (e.g., consequences of not meeting legislation)
7. Who/what creates or adds to the circular value? Who/what subtracts from the circular value?
8. Who pays the costs or makes investments?
9. What costs are imposed (from outside)?
10. What's the added value compared to linear value chains?

Different coloured post its and different icons are provided to facilitate the transfer of discussions onto the mapping space so that discussions can be documented, and a shared picture and understanding emerges. For example, green post its and a green thumb for enablers, or red post its together with a red crossed-out circle for barriers The mapping tasks may also include additional icons specific to its topic. For example, the value mapping task also includes icons to indicate whether environmental, social, or financial value is discussed, and icons to show where value is gained or lost.

The second step is the analysis of “how the circular system (is expected to) behave(s)”. This step is based on the findings from the previous mapping step – and is in reality often combined with step 1. Participants are asked to name the barriers or enablers and explain on the post its why it is a barrier, an enabler or why it depends. Example questions from the value flows include:

- How does it influence the value distribution?
- What outcomes will the actors willingly pursue? And which will they actively avoid?
- Who has the ability to influence decisions, control resources, and shape outcomes?

To summarise the discussion and enable a focused conversation moving forward, participants will then summarise their insights into the key mechanisms (or root causes) of the flow. For value, the question to be answered is: What are the 2 – 3 key mechanisms for value creation and capture in a circular manner? The key mechanisms are recorded on the orange post its.

The third step is *generating actions* and understating "how to influence the behaviour of the value chain". To guide the conversation about action development, five guiding questions are proposed. The guiding questions are based on the Circular Metabolism Factors developed by WP5 in D5.1. The five factors (i.e., the capability to understand the system and its relations, to evaluate actions and processes, to adapt, to collaborate and to manage the system) reflect critical aspects of designing circular value chains. Therefore, they were chosen to guide the conversation on creating actions. All five *generate actions* questions remain the same for all mapping tasks, yet topic specific examples were provided within each mapping task. These examples were integrated in the method in the form of comments on the online white board and are not visible in Figure 6. Examples of the guiding questions for value include:

- What can be done to better *understand* value flows (and its relation to other flows)?
- Examples for value flows – You may think of: if the creation of other types of value be of interest (e.g., easier (dis)assembly, health for workers or users (non-toxicity), simplified logistics, local employment, etc.)
- What can be done to better *evaluate* value flows?
- Examples for value flows – You may think of understanding value created, destroyed, value missed; measuring financial, environmental & social value each; combining all value forms for one comprehensive evaluation; identifying activities for value creation, capture and delivery

The actions are noted on teal post its and placed with the respective barrier. After the completion of the action development, all post its are copied and placed in the action repository of each mapping task, the fourth and final step of the mapping tasks. This way, both a record exists of which barrier it pertains to as well as where in the system, and the actions are collected for ease of aggregation in Part 2 of the method.

2.3.4 Part 2: Action Planning Process

The second part of the method, the action planning process, begins by copying all actions from all action repositories and placing them below the *Collect and Cluster* step.

Collect and Cluster

The goal of this step is to condense the created actions and define key actions. Given the iterative process and the interconnectedness of the different mapping tasks, some actions may occur in multiple action repositories. The first step is thus to remove any duplicates. But also: to further specify and develop actions that are not yet distinct or clear enough. The second step is to group the actions according to whether they are related to each other. Then, rename the action group with a new title that captures the commonality of the topic (Figure 7).

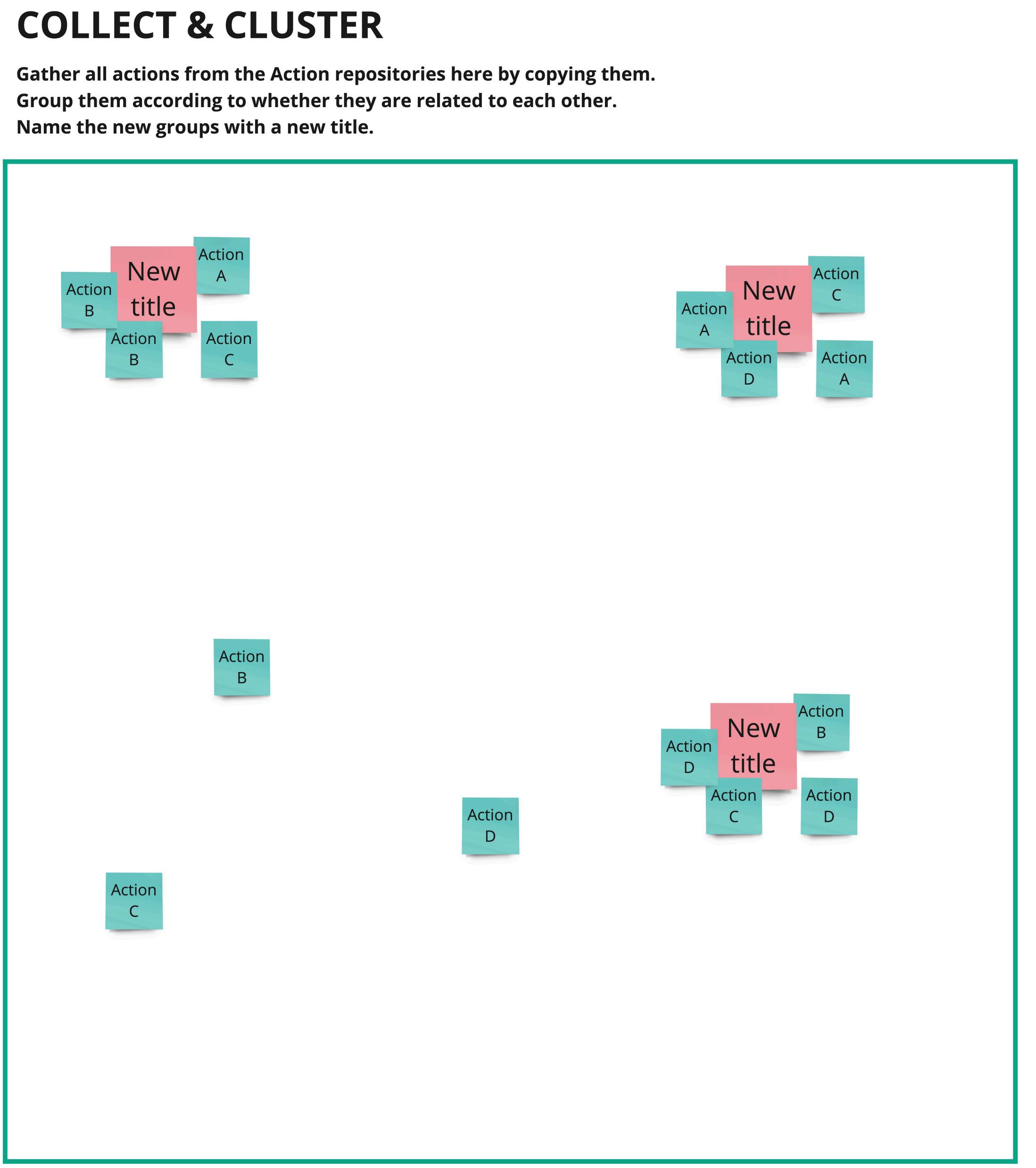


Figure 7 - Method Part 2: Collect & Cluster

Prioritise and Assign

The second step of Part 2 is the prioritisation of the actions (Figure 8). First, participants must identify two criteria according to which they will prioritise the action groups. The action groups from the previous step are then copied over to the prioritisation workspace and placed on the graph according to their categorisation based on the criteria. This step may also help participants identify actions of highest priority. Where possible, responsible actors should be assigned to the action clusters.

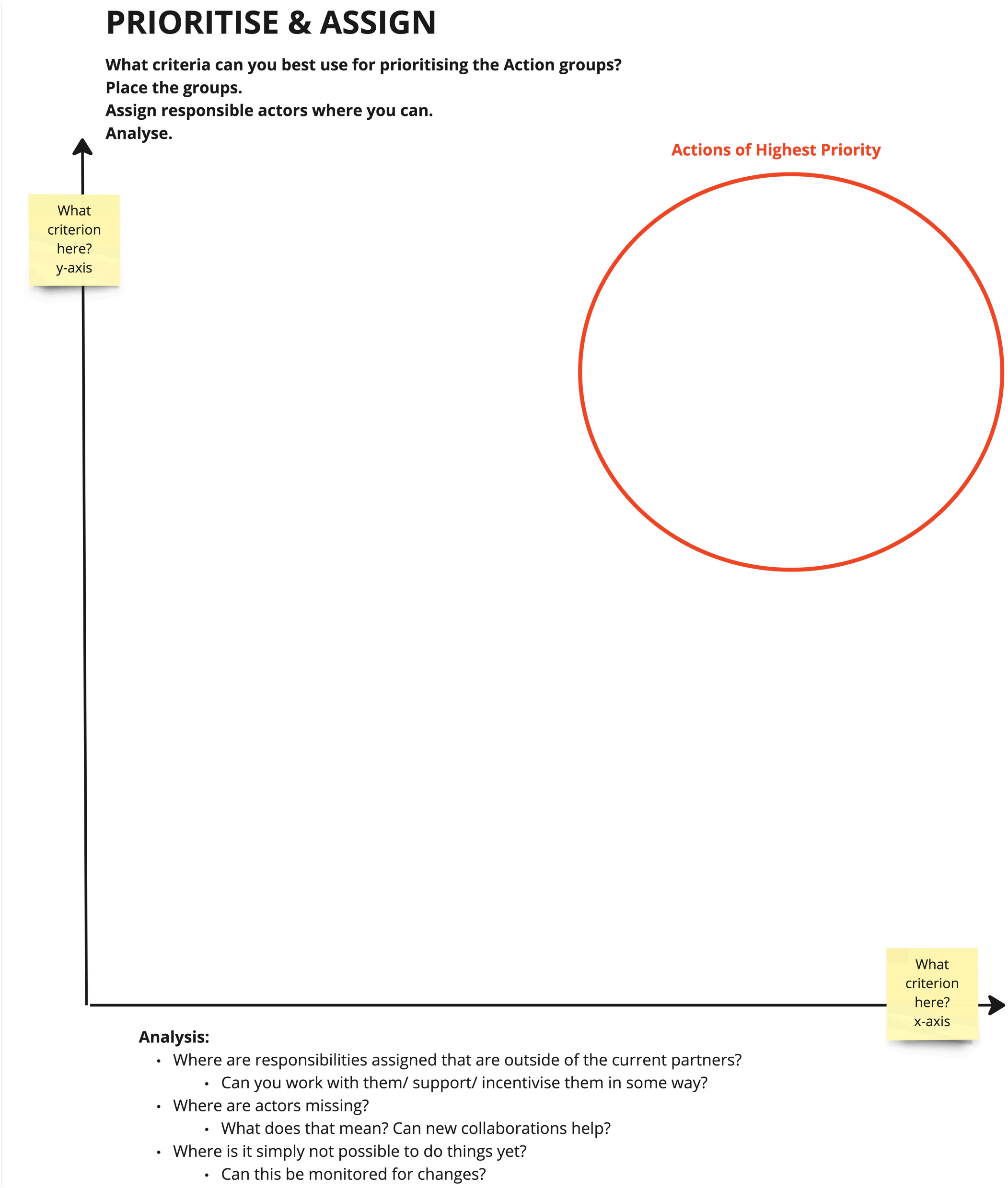


Figure 8 - Method Part 2: Prioritise and Assign

Allocation to *now, near and far* future

The final step of the action organisation process is the allocation of the actions according to timing and actors (Figure 9). Relevant actors are listed on the yellow post its. The action groups are copied over from the previous steps to this workspace and then allocated 1) to the respective actor, and 2) according to when this action shall be addressed. These two steps are done with the help of the insights from the prioritisation and actor assignment done in the previous step. For example, the prioritisation, and the identification of the actions of highest priority, may influence the timing considerations, i.e., whether an action shall be addressed, now, near or far. This step concludes the Multi Flow Method and results in an overview of actions to be taken for each actor, as well as an indication

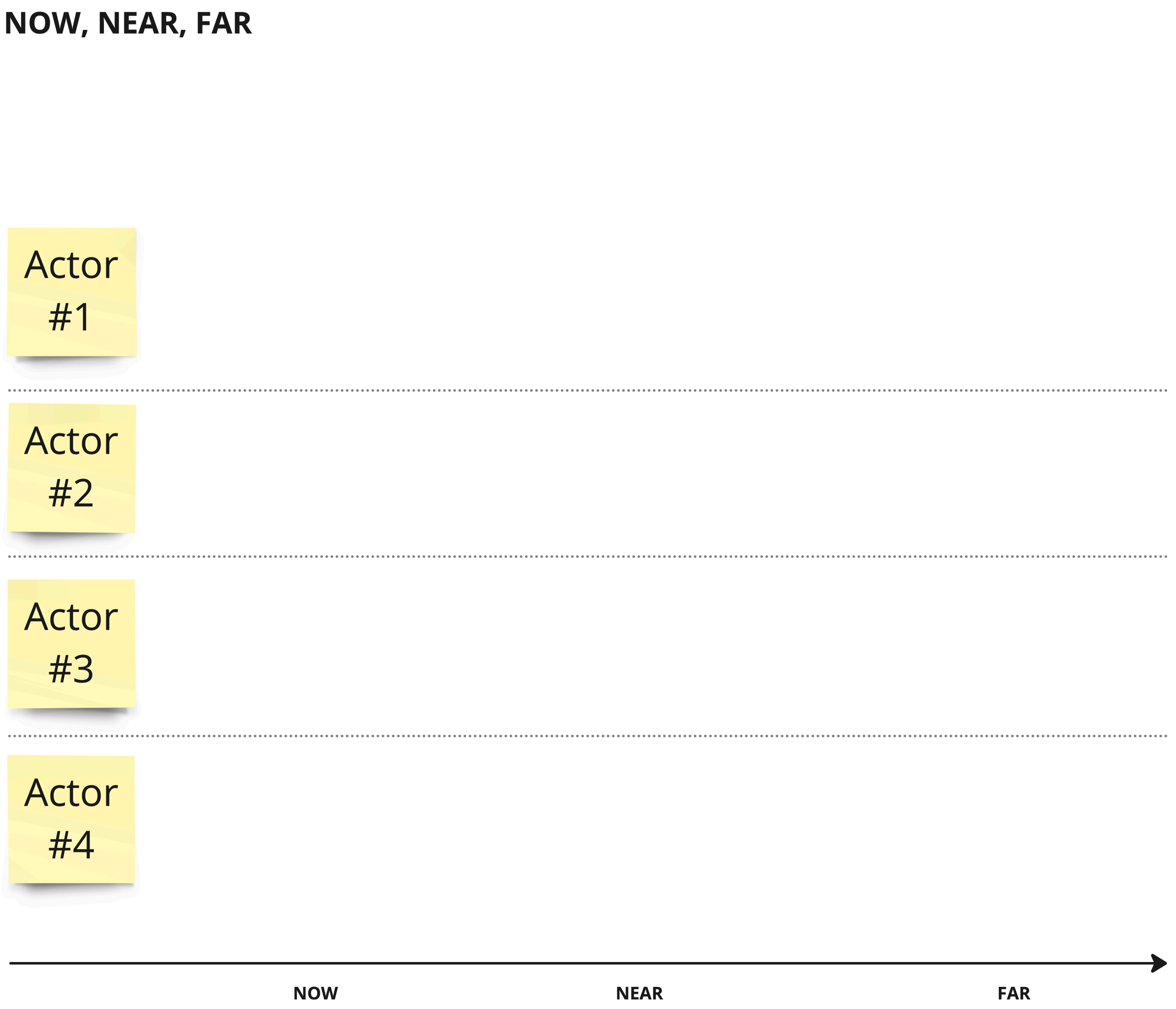


Figure 9 - Method Part 2: Allocation to Now, Near and Far Future

These steps were broadly followed in all three use cases. Depending on the use case, however, some steps were skipped or executed differently. Reflections on what was effective, what needs improvement or elements to be added can be found in D5.2, which was based on the researcher's observations as well as formal feedback from the participants collected through a survey.

In the following chapters, the results of the application of this methodology for each use case will be explained. As described above, the objectives of the use cases within the project are to define the business needs and requirements for the ontology from the perspective of each of the corresponding industries (construction, electronics and textile). To define what those needs are, it is key to understand how the value chain will operate the circular strategy or strategies that are being considered for (further) development – and how data and analysis can support this. Therefore, the focus here is on the value chain development: how the value chain will function as a whole, what barriers and enablers are present, and what actions can be taken to overcome these. Reflections will then be offered with regards to what this means for support from the ontology being developed as part of the project, and – more generally - what other data- and analysis support may be needed.

The input for these use cases will be provided by the different partners in each use case team (see Partners and Contributors section in each chapter for the construction, electronics and textile cases). The process followed and tools used for this are, as described in above, developed and provided by WP5 – building on but expanding on the mappings that were done as part of D6.1 and D6.2.

3. Construction Use Case

3.1 Objectives of the use case

As per the product description below, this case focuses on metals and gypsum – the main materials of the floor tiles that are the object of study. As well as recycling these materials, the objective was to expand on the remanufacturing and reuse that is currently taking place – and to understand what actions were necessary for these circular strategies to grow and work in unison.

3.2 Partners and Contributors

Three organizations are part of 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.

For this use case, one product from Lindner Group was selected for which a reuse scenario is already in operation: raised floor tiles. This product was used as the object from which to elicit not only insights into the construction industry in general but to also have a concrete example to be able to understand specific circumstances. The ambition is that Rang-Sells establishes, together with Concular, a take-back system for these tiles and to establish a process to integrate them into a new building, using ontology-based data documentation. As such, these organizations provide knowledge in the following domains: supply chains, product information, capabilities in collection/deconstruction, and the treatment and transportation of waste streams and materials.

3.3 Use case description

Introduction to 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 CO_2 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.

In the construction industry use case, therefore, 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 (e.g. recycling).

Scenario for use case

As well as broader sector outlook, the focus of study in this user case was a raised floor manufactured by Lindner in 2022. The scenario: 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 10).

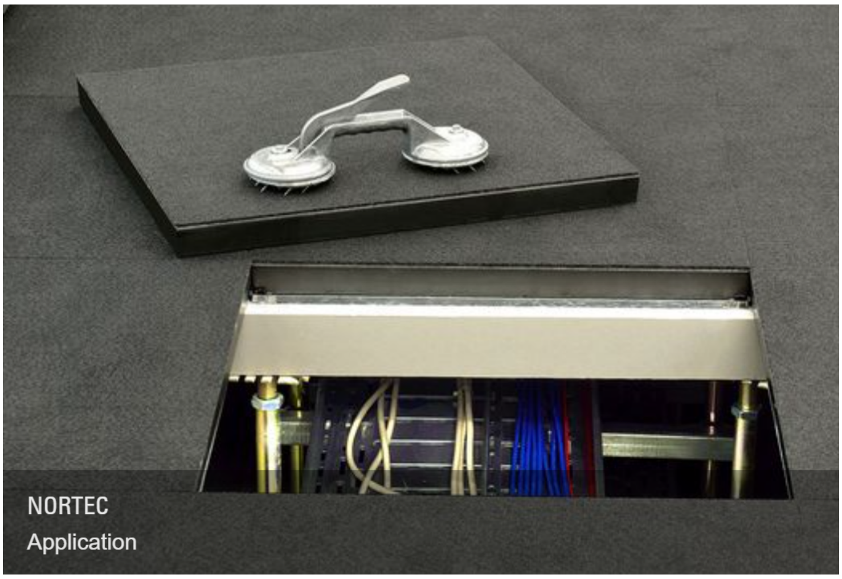


Figure 10 - Nortec Application

Figure 11 - Pedestals.

Product information

The specific raised floor product used 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 12). The carrier panel from calcium sulphate can be recycled to 100 % and returned to the production cycle. The steel pedestals can also be recycled after conversions or demolition.

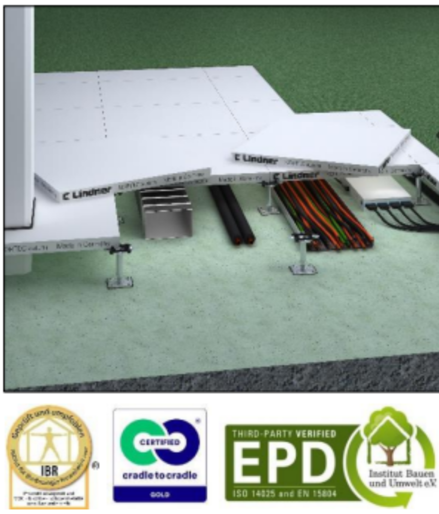


Figure 12 - Demo case

3.4 Investigating value chain improvement opportunities

For the construction use case, a summary and the highlights of the discussions will be provided for the following mapping tasks: resource flows, energy flows, value flows, infrastructure & enabling assets, and systems environment. This section closes with a reflection and considerations for further ontology development.

3.4.1 Resource flows

Understanding the dynamics of resource flows is critical to effectively implementing circular economy principles. Currently, there are significant challenges, including a lack of information regarding the dismantling and availability of Nortec raised floor elements. For instance, Lindner does not have precise data on where these elements are located, how many are available, or when they can be accessed. This uncertainty in timing, quantity, and quality poses a challenge to optimizing resource flows within the system (D6.1).

Moreover, securing secondary raw materials remains a substantial hurdle. The process of procuring these materials is complex and fraught with uncertainties, as noted in project discussions (D6.1). While virgin materials are still sourced reliably, there is a growing concern about the sustainability of this approach in the face of environmental and economic pressures. From a technical standpoint, the proposed solutions for a circular approach seem ready for implementation. However, readiness varies depending on the context. A significant area that requires further development is the return scheme. Improved communication and logistics processes are needed to facilitate an effective return system. Engaging in active exchanges with customers about potential return schemes could significantly enhance reuse rates and reduce waste (D6.1).

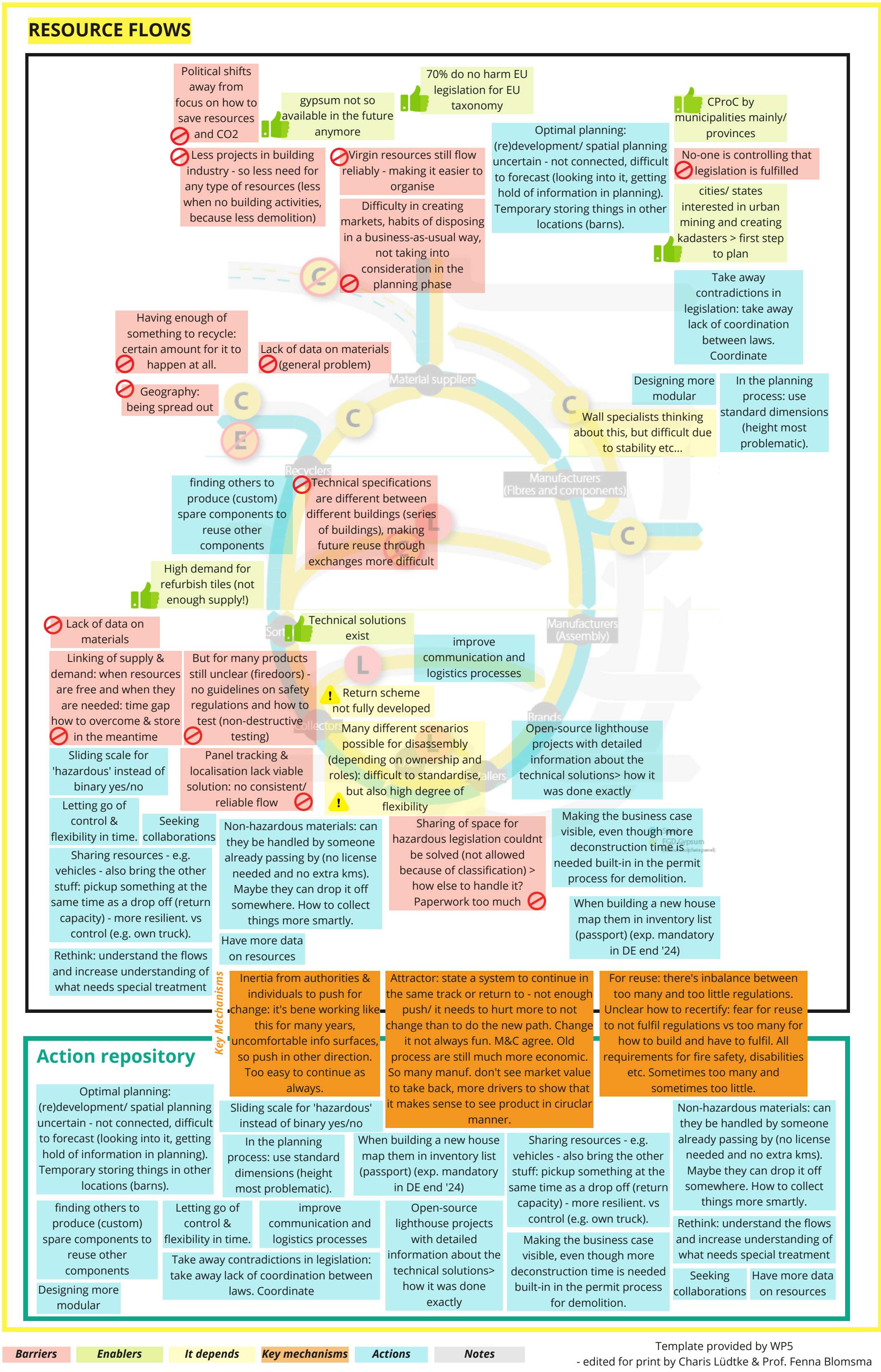


Figure 13 Construction Use Case - Resource Flow

Mapping of barriers & analysis for resource flows

One major barrier to the system's effectiveness is the lack of uniform technical specifications across different buildings, which disproportionately affects the potential for future reuse through exchanges. This issue is particularly pronounced for products like fire doors, where the absence of clear guidelines on safety regulations and non-destructive testing creates additional complications. Another critical challenge is the synchronization of supply and demand for reusable materials. The time gap between when resources are available and when they are needed poses a significant obstacle, exacerbated by inadequate storage solutions. This barrier is closely linked to the broader problem of insufficient data on materials, hampering the ability to plan and execute effective reuse strategies.

Despite these barriers, there are also enablers that could help improve the system. For example, there is high demand for refurbished tiles, though supply is currently insufficient. This demand-supply mismatch suggests that while technical solutions exist and are ready for implementation, the current system is not fully capitalising on these opportunities. Addressing communication and logistics issues could help to ensure that resources flow more effectively through the system. The choice between selling and leasing tiles significantly affects the functionality of the value chain. Selling tiles may reduce communication and obligations for customers, simplifying the process in the short term. However, a leasing model could better support feedback mechanisms and improve tracking and resource management over time. The impact of these barriers and enablers on the value chain is substantial. Barriers such as the lack of data, technical discrepancies, and poor synchronization of supply and demand can severely limit the system's efficiency and sustainability. Conversely, enablers like the high demand for certain reused products and the availability of technical solutions present opportunities for improving the value chain if properly leveraged. Addressing these interconnected barriers and enablers could lead to more robust and efficient resource flows, ultimately enhancing the overall effectiveness of the circular economy model.

Generating actions for improving resource flows

To address the barriers identified in the group discussions several key actions can be taken to improve resource flows and enhance the overall efficiency of the value chain.

Optimal Planning and Temporary Storage Solutions: One of the significant barriers identified was the lack of synchronization between supply and demand for reusable materials, exacerbated by inadequate storage solutions. To mitigate this, an action could involve **temporary storage of reusable materials** in alternative locations, such as unused barns or warehouses. This would allow for better coordination between when materials become available and when they are needed, helping to bridge the time gap that currently hinders efficient resource flow. Additionally, integrating this approach into spatial planning processes could ensure that materials are not only stored but also readily accessible when required, thereby reducing delays and enhancing overall system efficiency.

Standardization and Modular Design in Planning: The lack of uniform technical specifications across different buildings was identified as a significant barrier to reuse. An action to address this could involve incorporating standard dimensions and modular designs into the planning process. By standardizing aspects such as the height of components, it becomes easier to reuse materials across different buildings and projects. This would simplify the exchange and reuse of components, reducing the technical barriers that currently prevent materials from being reused effectively. Modular design also allows for easier disassembly and reassembly, which is crucial for promoting a circular economy.

Shared Resources and Smart Collection Strategies: To improve logistics and reduce inefficiencies in material collection, an action could focus on sharing resources like vehicles and optimizing collection routes. For instance, if a vehicle is already scheduled to drop off materials, it could also be tasked with picking up materials at the same time, thus maximizing vehicle usage and reducing the need for additional trips. This approach not only enhances the resilience of the system but also reduces transportation costs and carbon emissions. For non-hazardous materials, the action could involve identifying opportunities for collection by individuals or entities already in the vicinity, thereby minimizing extra kilometres and simplifying the collection process.

Enhanced Communication: Enhancing communication could involve improving the visibility of the business case for deconstruction—by building this into the permit process for demolition, stakeholders could better understand the financial and environmental benefits of resource reuse.

3.4.2 Energy flows

In the analysis of energy flows, there was a more intensive discussion about the consideration of transport energy than before. Depending on the actor, transport energy has a varying impact—when it comes to transporting reused components (Concular perspective), the environmental impact of transportation is quite significant (in a Life Cycle Assessment reuse components are considered to have zero impact, only refurbishment processes are taken into account), even though it represents only a small portion compared to production (Lindner’s perspective).

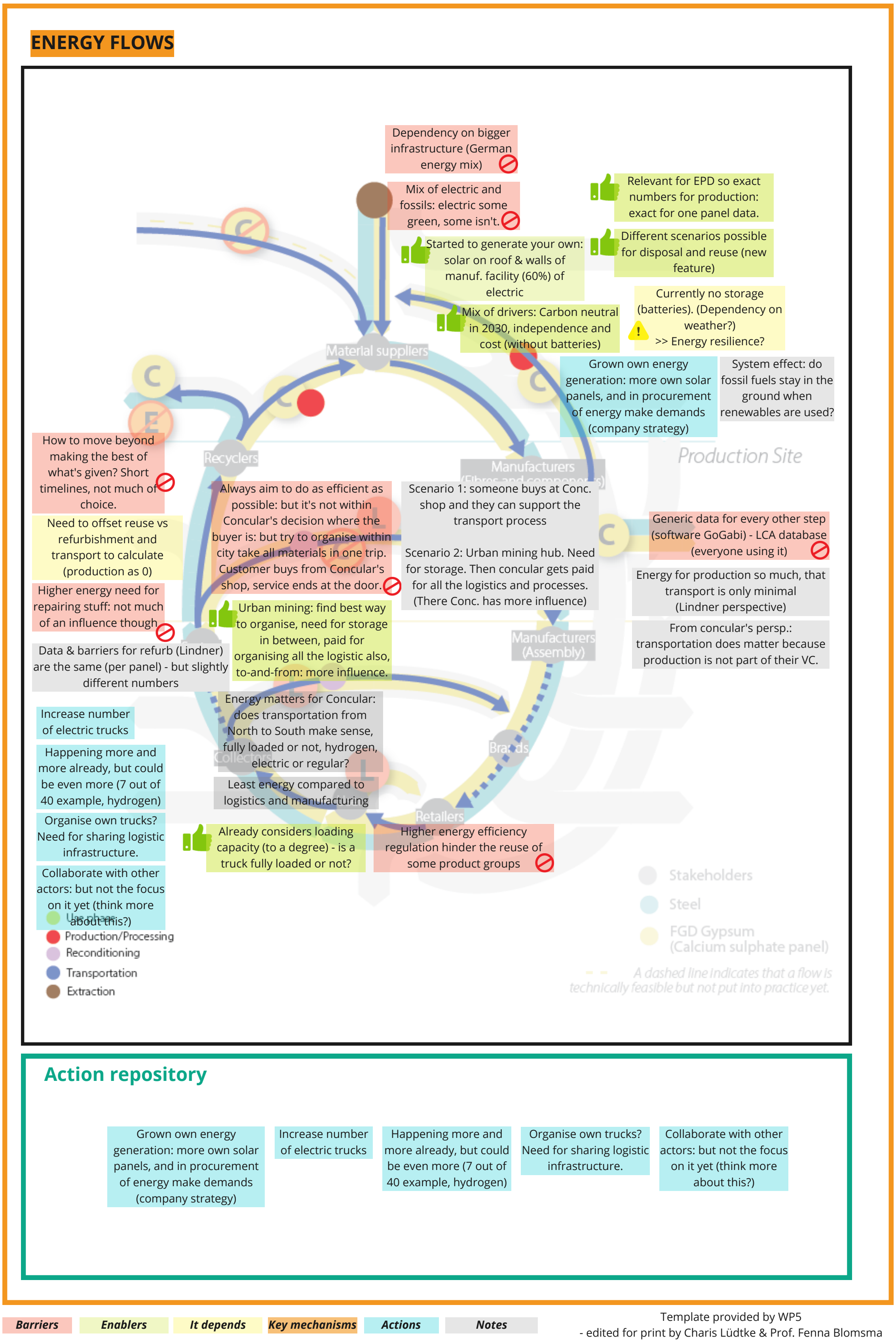


Figure 14 Construction Use Case - Energy Flows

Mapping of barriers & analysis for energy flows

One significant barrier is the dependency on larger infrastructure and the national energy mix, which affects the sustainability of production processes. The variability in electricity sources—some being green and others not—complicates efforts to achieve consistent energy efficiency especially for manufacturer like Lindner. Another challenge arises from differing priorities within the value chain. Manufacturers like Lindner, including those involved in refurbishment, are primarily concerned with energy efficiency during production. In contrast, reuse partners focus more on the logistics of transporting and managing reused components. This divergence can create alignment issues across the value chain. Moreover, stricter regulations aimed at improving energy efficiency can sometimes hinder the reuse of certain product groups, as these regulations may not always accommodate the nuances of reuse.

Despite these barriers, there are notable enablers that support the advancement of circular economy practices. For instance, Lindner has successfully implemented solar panels on their manufacturing facility's roof and walls, generating 60% of their electricity from renewable sources. This initiative not only contributes to their goal of carbon neutrality by 2030 but also enhances energy independence and reduces costs, even in the absence of battery storage. The diverse drivers for change, including environmental goals and cost considerations, lead to various scenarios for material disposal and reuse, introducing new features and opportunities for optimization. Urban mining is another promising approach, emphasizing the need for effective interim storage solutions and efficient logistical planning. By optimizing loading capacities and ensuring that transportation resources are used efficiently, the system can better manage the flow of materials.

Generate actions for improving energy flows

Discussing the energy flows and the linked barriers and enablers following action to influence the behaviour of the value chain were identified.

Collaborate with Other Actors: While not yet the primary focus, there is a need to explore and enhance collaboration with other stakeholders. This could involve sharing best practices and resources to optimize logistics and energy management.

Share Logistic Infrastructure: Instead of organizing solely owned transportation, there's a need to consider sharing logistic infrastructure. This approach can reduce costs and improve efficiency through collective use of resources.

Increase Electric Truck Fleet: Expanding the use of electric trucks is crucial for reducing carbon emissions associated with transportation. Investing in a larger fleet of electric vehicles can contribute significantly to sustainability goals.

Enhance On-Site Energy Generation: Increasing the installation of solar panels and other renewable energy sources on-site is a strategic move. Additionally, making specific demands in energy procurement to align with the company's sustainability goals can further enhance energy management and reduce reliance on non-renewable sources.

3.4.3 Infrastructure & other enabling assets

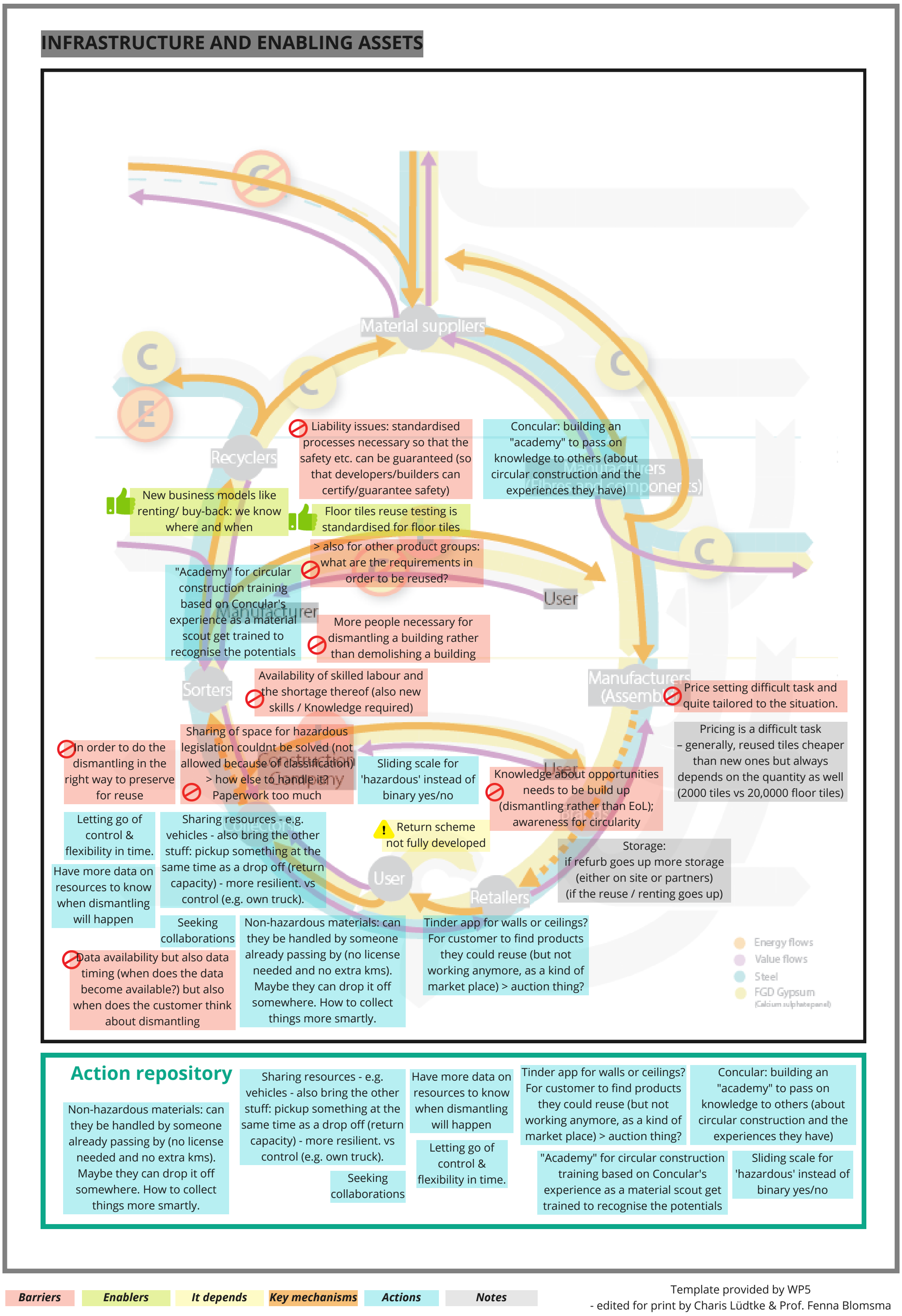


Figure 15 Construction Use Case - Infrastructure & Enabling Assets

Several barriers and enablers significantly impact the effectiveness of resource management in dismantling and reusing building materials.

One of the primary challenges is the shortage of skilled labour. The dismantling of buildings requires specialized knowledge and skills that are not widely available, making it more complex compared to traditional demolition. This shortage impedes efforts to dismantle buildings in a way that preserves materials for reuse. Additionally, there is a need to build up knowledge and awareness about the advantages of dismantling versus end-of-life processes. Many stakeholders lack awareness of the benefits of dismantling and the principles of circularity, which hampers the broader adoption of these practices. The availability and timing of data pose another significant barrier. Effective dismantling requires timely access to data on when materials become available and when customers plan their dismantling activities. The current gaps in data availability and timing create challenges in planning and executing dismantling processes. Moreover, price setting for dismantling services is often complex and tailored to specific situations, making it difficult to establish consistent pricing structures. Liability issues further complicate the process, as there is a need for standardized procedures to ensure safety and guarantee that dismantling meets safety and certification standards.

On the positive side, standardized testing for floor tiles facilitates their reuse by ensuring consistent quality and suitability. This standardization helps streamline the process and supports the wider adoption of reuse practices. New business models such as renting and buy-back schemes are also beneficial. These models provide clearer information on the availability and timing of materials, improving planning and resource management. Furthermore, the use of mobile reprocessing plants for materials like chipboard (though not specifically for Nortec tiles) presents an innovative solution. These plants enable on-site processing of materials, especially beneficial during renovations, and help optimize the reuse of materials by adapting to the specific needs of the site.

Generate actions for improving infrastructure & enabling assets

To enhance the infrastructure in the circular value chain several key actions can be implemented:

- **Optimize Resource Sharing and Logistics:** Implement a strategy to share transportation resources, such as vehicles, to increase efficiency and reduce costs. For example, coordinate pickups and drop-offs to maximize return capacity and resilience. By using shared logistics, the overall efficiency can be improved and decrease the need for dedicated trucks, balancing control with cost-effectiveness.
- **Enhance Data Availability for Dismantling:** Develop and maintain comprehensive databases to track when and where dismantling activities will occur. This data will enable better planning and coordination, ensuring that resources are managed more effectively and that materials are available for reuse when needed.
- **Implement Smart Collection for Non-Hazardous Materials:** Establish a system to collect non-hazardous materials from locations that are already on nearby routes, eliminating the need for additional travel and licensing. This approach could involve creating convenient drop-off points or coordinating with passing vehicles to handle materials efficiently, reducing unnecessary kilometers and simplifying the collection process.

- **Develop a Marketplace for Reusable Products:** Create an online marketplace or auction platform where customers can find and acquire products intended for reuse. This platform would facilitate the exchange of items that are no longer in use but still have potential value. By providing a space for these transactions, the platform encourages the reuse of materials and products, supporting a circular economy.

3.4.4 System environment

Mapping of barriers & analysis for system environment

A significant challenge is the reduced project activity in the building industry. With fewer construction and demolition projects, there is less need for resources and fewer opportunities for material reuse. This downturn limits the flow of materials available for recycling and reuse. Additionally, political shifts have led to a decreased focus on resource conservation and CO2 reduction. This change in priorities reduces the emphasis on sustainability and hinders efforts to implement effective resource management practices.

Creating markets for recycled materials also remains difficult. Established habits of disposal and a lack of consideration for reuse during the planning phase contribute to this challenge. The industry continues to operate under business-as-usual practices rather than integrating circular economy principles.

Furthermore, there is a lack of enforcement to ensure compliance with resource management legislation. Without effective oversight, adherence to regulations related to recycling and sustainability is inconsistent, undermining efforts to promote a circular economy.

Despite these challenges, there are several positive factors that support progress in resource management. The EU's legislation mandates no harm to the environment and aligns with the EU taxonomy, providing a regulatory framework that encourages sustainable practices and supports the circular economy. Cities and states are increasingly interested in urban mining and creating cadasters, which are essential first steps in planning for material recovery and reuse. Additionally, the Circular Public Procurement involves municipalities and provinces to promote sustainable practices and to support the circular economy.

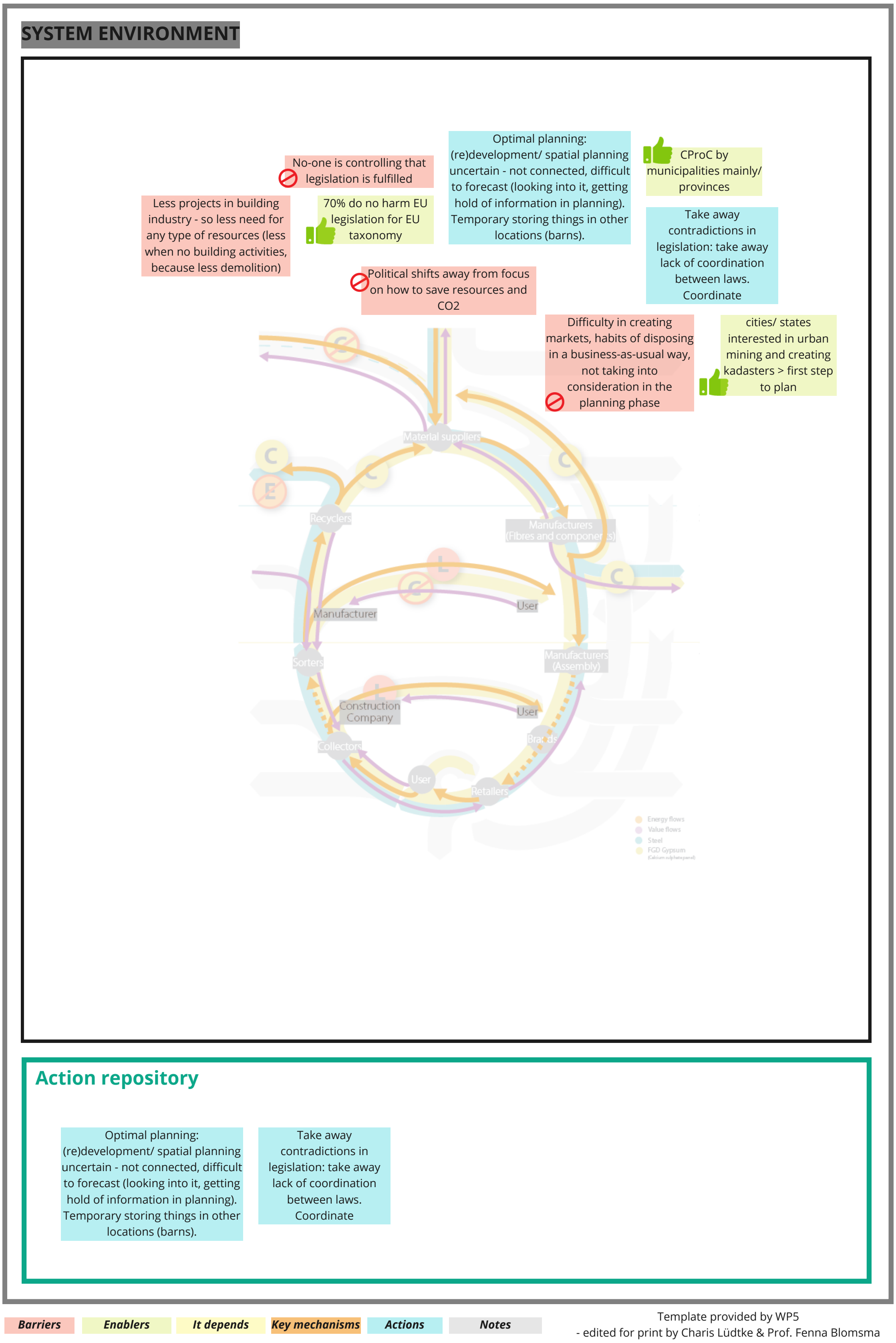


Figure 16 Construction Use Case - System Environment

Generate actions for improving system environment
Discussion the system environment several actions were generated to influence the behaviour of the value chain:

- **Enhance Spatial and Redevelopment Planning:** Develop a more integrated and connected approach to spatial and redevelopment planning. Implement systems to improve forecasting and access to planning information. This could involve establishing centralized databases and platforms for sharing information about upcoming projects, enabling better coordination and preparation for material reuse. Additionally, consider creating temporary storage solutions, such as using barns or other facilities, to manage materials that are not immediately needed but are available for future projects.
- **Streamline Legislation Coordination:** Address the contradictions and gaps in current legislation by coordinating between different laws and regulations. Create a unified framework that ensures consistency in environmental and resource management regulations. This could involve forming cross-sectoral committees or working groups to align policies, clarify legal requirements, and reduce the complexity of compliance. By removing conflicting regulations and improving legal coherence, the process of implementing circular economy practices can be simplified and more effective.

3.4.5 Value flows

Any updates on the value flows since D6.2

During the discussions about value flows, it became particularly evident that defining the value for reuse and high-quality recycling is complex and depends on many components. It is clear that the perspective of the observer or user within the value chain significantly influences how this value is perceived. For Lindner, the implemented measures, such as the introduction of refurbished tiles, represent a significant step forward, with other processes still receiving more focus. In contrast, for Concular, the current implementation of Circular Economy (CE) practices is deemed insufficient and does not fully exploit the potential.

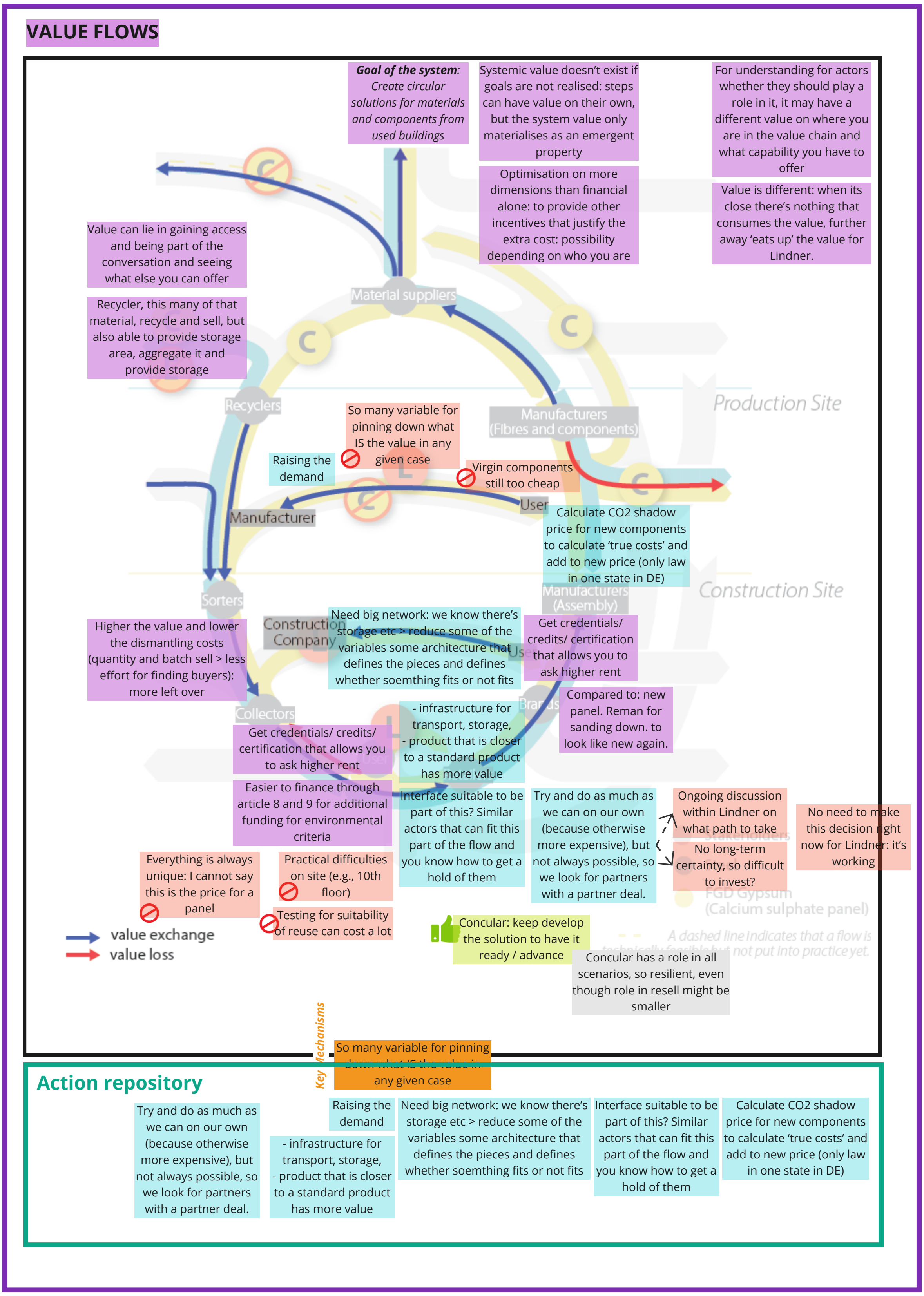


Figure 17 Construction Use Case - Value Flows

Mapping of barriers & analysis for value flows

A major barrier is the lack of long-term certainty, which makes it difficult to commit to investments in circular solutions. The absence of stable conditions and predictable outcomes complicates planning and financial commitment. Additionally, testing for the suitability of reuse can be costly, further deterring investment. Practical difficulties on-site, such as those encountered at high elevations like the 10th floor, add to the complexity of dismantling and reuse processes. Furthermore, manufacturers often see no immediate need to adopt circular practices, as their current linear models remain effective. The low cost of virgin components also discourages the shift towards recycled or reused materials, as virgin materials are still relatively cheap.
On the other hand, there are several enablers that support progress in this area. Ongoing development of circular economy solutions is crucial, ensuring that they are ready for implementation when conditions become more favorable. There is a growing sense of urgency to address sustainability challenges, driving efforts to advance circular practices. Additionally, the discussion and partial implementation of CO2 shadow pricing are starting to influence decision-making, promoting more sustainable practices by factoring in environmental costs.

Generate actions for improving value flows
Discussing the value flows several actions were generated to influence the behaviour of the actors.
Increase Demand for Reused Products: Actively work on raising the demand for reused materials and products. This involves creating awareness and fostering market demand to support the transition towards circular economy practices.

- **Build a Comprehensive Network:** Develop a robust network that includes storage and transport infrastructure. By knowing where resources are stored and understanding the requirements for their handling, you can reduce uncertainties and ensure smoother integration into the supply chain.
- **Standardize Products:** Focus on producing or using products that are closer to standard specifications. Standardization can increase the value of reused products and make them more adaptable and easier to fit into existing systems.
- **Utilize Suitable Interfaces:** Ensure that products and processes are compatible with existing systems and interfaces. This involves collaborating with similar actors who are part of the value chain and establishing effective connections to streamline the flow of materials.
- **Self-Sufficiency and Partnering:** Aim to perform as much work in-house as possible to manage costs. When in-house efforts are not feasible, seek partnerships with other organizations to share resources and reduce expenses through collaborative deals.
- **Calculate CO2 Shadow Price:** Incorporate CO2 shadow pricing into the cost calculation for new components. This approach, which is mandated by legislation in certain regions (e.g., some states in Germany), helps in determining the true environmental cost and integrating it into the pricing of new components.

3.4.6 Generating actions

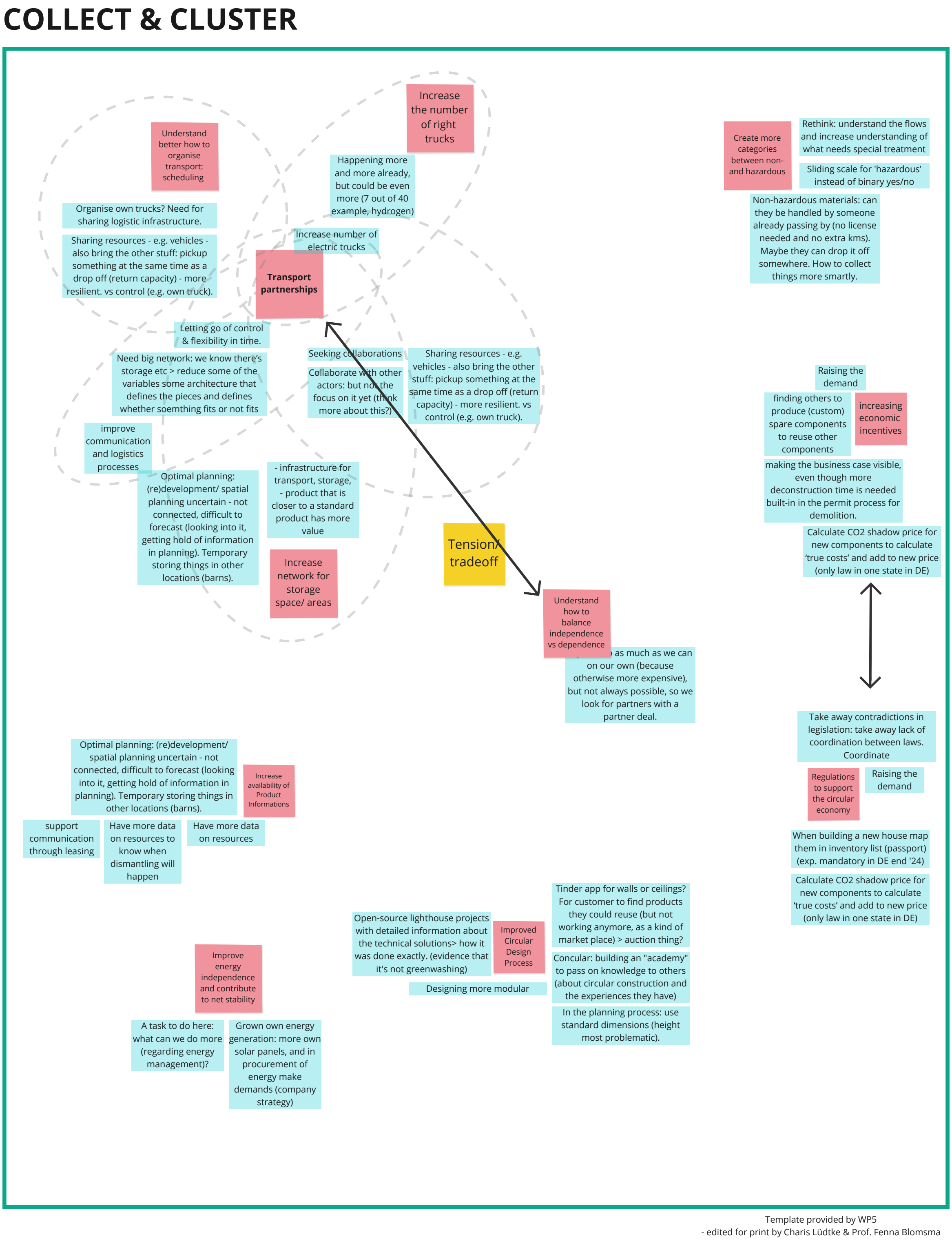


Figure 18 Construction Use Case - Collect & Cluster

From the clustering of the defined actions, eight distinct thematic action groups have been identified. The majority of actions were grouped under "Transport Partnerships," leading to the development of the following sub-actions: understanding how to better organize transport scheduling, increasing the number of appropriate trucks, assessing the impact on operations, defining actor profiles for integration, and expanding the network for storage spaces and areas.

In addition to these, the remaining actions were clustered in seven action groups during discussions on value chains, approximately four actions per group:

- Balancing Independence vs. Dependence
- Improving Energy Independence and Contributing to Net Stability
- Increasing Availability of Product Information
- Enhancing the Circular Design Process
- Regulations to Support the Circular Economy
- Increasing Economic Incentives
- Creating More Categories Between Non-Hazardous and Hazardous Materials

Among these, the actions related to regulations and economic incentives are interconnected, potentially creating synergies. Conversely, the demand for "Transportation Partnerships" contrasts with the action to "Understand How to Balance Independence vs. Dependence."

When prioritizing the actions, it became evident that the criteria for categorization are complex and cannot be fixed to two static axes. It was agreed that the Y-axis represents "The degree to which it removes barriers or friction from the system to achieve circularity," reflecting the impact or overall significance of the action. The X-axis is still under discussion but has initially been defined as "Degree of Collaboration Required."

Overall, the use case partners agreed that the action groups can be clustered into two categories: F Future/Strategic and Operational Actions. Future/Strategic Actions, derived from legislation, regulations, and the strategic objectives of stakeholder, significantly influence the operational actions of those stakeholders within the value chain. In this context, it is also possible for a stakeholder to influence their own operational actions through their own strategic directive.

When grouping the actions by the use case partners, it became clear that many of the actions can be assigned to Lindner as a representative for manufacturers. However, some actions are relevant to multiple stakeholders or need to be addressed by all parties involved. Examples include increasing economic incentives, applying and advancing circular design, and improving the availability of product data, one of the most frequently mentioned barriers. Additionally, it is noticeable that the time horizon for nearly all actions was categorized as "now" or "near." This reflects both the urgency felt towards the implementation of the Circular Economy (CE) and the current opportunities for change.

3.4.7 Use case conclusion

Implications for ontology development and information support

In the context of the ontology developed in this project, the method helped to highlight that the lack of valid data and information regarding the whereabouts of components after their installation is crucial for enabling a functioning Circular Economy (CE) in the construction sector. It was one of the

main barriers discussed in the use case. Addressing this gap can facilitate the creation of a simple, cross-actor platform that enhances data accessibility and supports effective CE practices.
Another challenge which can be addressed with an ontology is when data from the circular economy (CE) value chain is linked to life cycle assessments or other impact analyses. In this case, the distance travelled becomes crucial for marketplace actors. This is because it directly influences the value and energy flows and thus the overall environmental impact. This assessment cannot be made in a general or aggregated way but must be evaluated on a case-by-case basis. A major challenge is to determine who enters this data when it benefits another partner or actor in the value chain rather than the person entering the information. This leads to the question of whether the provision of such data can be incentivized. For example, could someone be rewarded for providing accurate and detailed data? This is where the development of an ontology could play a crucial role. The ontology could be designed to facilitate such incentives, perhaps through mechanisms such as microtransactions that reward data providers.

Furthermore, the evaluation of the value chain improvement opportunities showed that different parts of the value chain have different data needs, which emphasizes the need for a flexible and adaptable data ontology. For marketplaces like Concular the transportation of the materials has a major impact on the LCA while for Lindner transportation plays a minor role. For manufacturers, the energy consumption and provision for production have more impact on their assessments. This is just one example of how the players require different data in relation to the energy flow.

4. Electronics And Electrical Appliance Use Case

4.1 Objectives of the use case

As further explained in the product description below, the electronics use case focuses on rare earth elements (magnets) and metals. Due to the importance of rare earths for our economy, recycling these materials is a major focus for this case. Different possible routes and their value chains to accomplish this are explored, across different geographical scales – and actions are identified that are necessary for these recycling scenarios to be further developed.

4.2 Partners and Contributors

Two organizations were in charge of this use case;

- **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.
- **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 provides knowledge of the supply chain stakeholders and processes. REIA's global network with 80 active and committed members on REE sustainability representing all spectrums of the value chain along with a large network of stakeholders from downstream.

Together, these entities brought their expertise and knowledge regarding the electronics value chain, to provide an overview of the current status, the challenges and enablers for achieving a Circular economy. Furthermore, the electronics use case demonstrated the combination of Circularise's supply chain communication technology and the developed ontology. In order for this assessment to take place, the ontology is used to determine the data format on the Circularise system, which was then tested with real material data of components and the final product of a magnet-containing speaker. This demonstration also specifically analysed the applicability of ontology and communication software for the electronics industry with the example of a selected group of suppliers to the demonstration product.

4.3 Use case description

Introduction to electronics industry

The electronics industry is the backbone of modern society, powering everything from smartphones to electric vehicles. Central to this sector are rare earth elements, crucial for producing powerful magnets essential for numerous electronic devices. Rare earth elements have been mainly found and exploited in countries outside of Europe, which in recent years have raised the alarms given the initiatives towards a resilient European economy. To support this, the European Union has implemented a robust regulatory framework to address environmental challenges and secure critical resources. Key initiatives include the Critical Raw Materials Act (CRMA), aiming to reduce dependency on third-country imports for essential materials, and the Ecodesign Directive, which enhances the environmental performance of products throughout their lifecycle. These regulations, alongside others focusing on waste management, vehicle recycling, and battery regulation, contribute to the EU's broader circular economy goals.

With all these regulations, the electronics sector has been taking some initial steps towards compliance. However, the industry faces significant challenges. A key issue is the lack of transparency in the supply chain. This makes it difficult for companies to get information on their value chain activities and even on the components they are receiving. This in turn doesn't allow them to for example make sure that their products do not contain certain hazardous substances, or that they are not sourced from areas of conflict, or even the amount of recycled content. Companies are not able to trace the origin of critical raw materials, raising concerns about ethical sourcing and environmental impact. Given the growing demands from government and public entities to meet the regulations, and the increasing importance of sustainability and sustainable practices, as well as the classification of many rare earths as critical raw materials, this lack of traceability is a major hurdle.

Additionally, while actions are being taken to address circular economy practices and recycling, the electronics industry still has a long way to go. Building resilient supply chains, reducing reliance on specific regions, and developing effective recycling processes are critical steps to ensure the industry's sustainability and future growth. Moreover, measures need to be taken around providing systems that enable a secure and trustworthy environment for data sharing, and thus traceability. These should consider the international and complex setting of the electronics value chain, where there are no current practices or standards for data (e.g. no clear "worldwide" guidelines for LCA calculations) and governments' approaches, mindset and legislations can interfere with traceability, or even with circularity (e.g. control over the number of exports).

In general, the evolving landscape of resource management for the manufacture of electronic components, especially those containing rare earths, is becoming increasingly complex and relevant. As regulations tighten and the global push for sustainable practices strengthens, the focus shifts towards mapping the speaker manufacturing process - from initial material extraction to eventual recycling.

Scenario for use case

For this use case, the discussion focused on the flow of rare earths and a general sector perspective was mainly used. However, specifics of the following use case also featured: the manufacturing of a speaker, and evaluating the value chain from the mining, up to the recycling of EoL products. It considers multiple stakeholders upstream, such as the mining actors, the material suppliers, and the components suppliers (e.g. magnet producers), all going to the final speakers' manufacturers. It also considers multiple routes as speaker manufacturers are not always the "end of the value chain", as speakers could be a part of other products (e.g. cars). Finally, this use case involves the EoL stage of products, where collectors, sorters, and recyclers are involved, in processing products after use and exploring possible repairs, reuses or recycling of these products for the creation of raw materials and their "re-use" in a new cycle.

Product information

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 19):

Speaker components:
- Suspension
- Basket
- Spider
- Voice coil
- Dust cap
- Diaphragm/ Cone + Surround
- Magnet

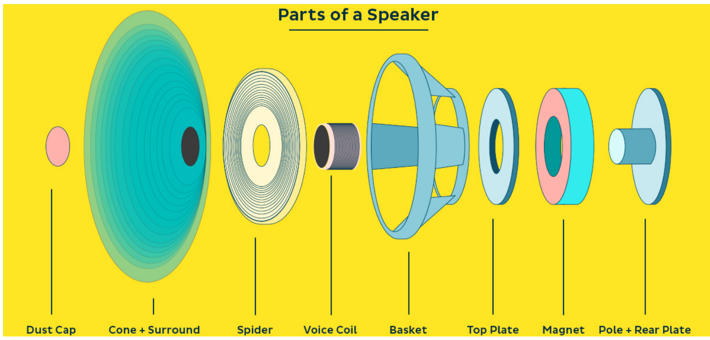


Figure 19 - Components of a typical speaker

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

4.4 Investigating value chain improvement opportunities

For the electronics use case, a summary and the highlights of the discussions is provided for the following mapping tasks: resource flows, information flows, value flows, infrastructure & enabling assets, and systems environment. This section closes with a reflection and considerations for further ontology development.

4.4.1 Resource flows

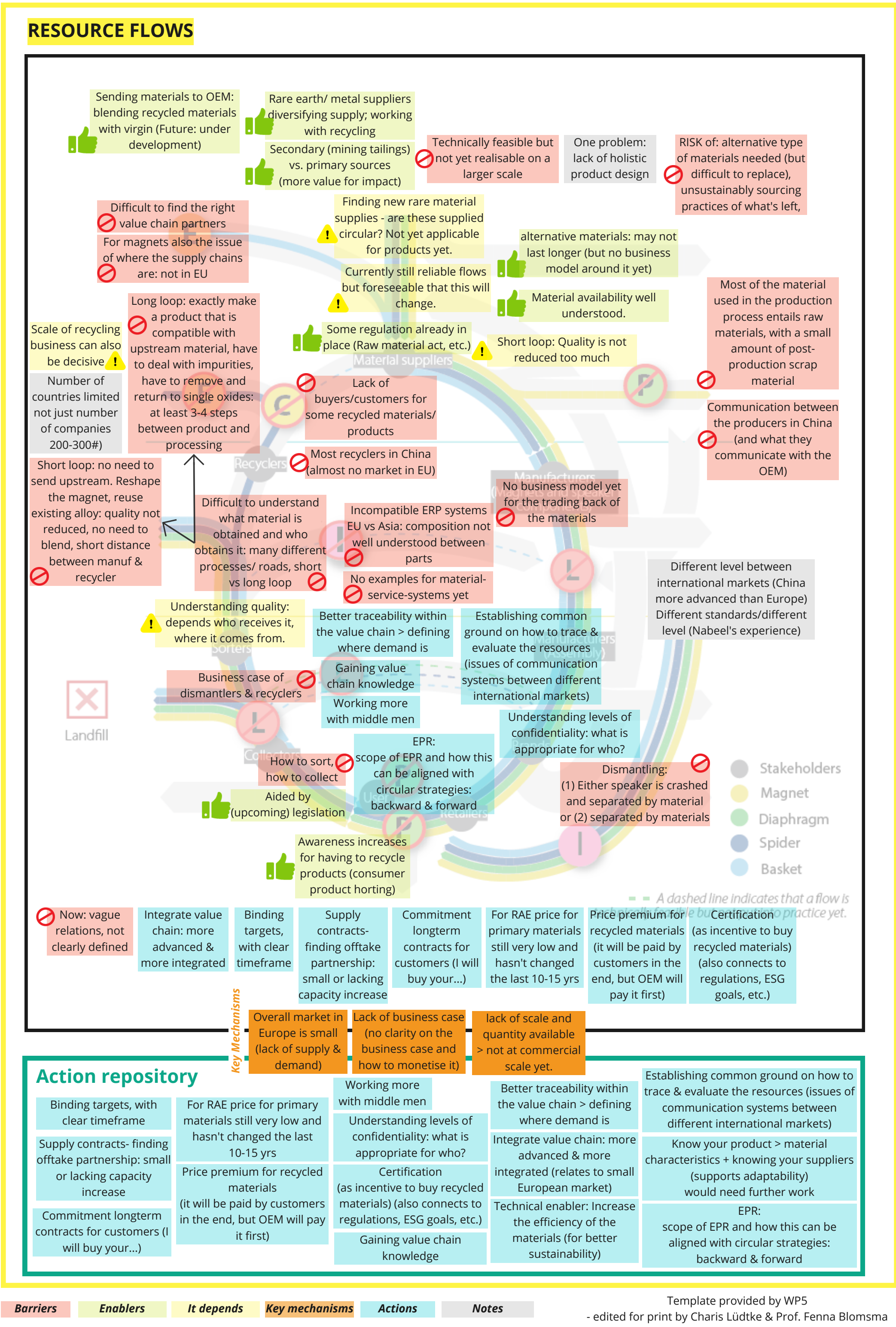


Figure 20 Electronics Use Case – Resource Flows

Mapping of barriers & analysis for resource flows

In the context of the circular economy, we can talk about a primary and secondary value chain. The Primary Value Chain is the traditional value chain and involves the extraction of virgin materials, their transformation into products, and the eventual distribution and consumption of those products. On the other hand, the Secondary Value Chain focuses on recovering value from products at the end of their life cycle. The landscape for rare earth metals and thus for the manufacturing of speakers is that the secondary value chain is very nascent and there is still a dependency on the primary value chain. This results in a big focus on the linear economy for the European manufacturers.

With the recent regulations and the sustainability goals set worldwide, there are increasing efforts towards improving the EoL processes of value chains, as well as connecting the downstream with the upstream, achieving full circularity. In the rare earth sector, the CRMA sets a goal of increasing the overall recycling rate of critical raw materials within the EU to at least 15% of annual consumption by 2030. Consequently, in the particular case of the speakers' value chain, there have been a lot of efforts devoted to improving and increasing the recycling of rare earths within the magnet. The results so far present raw materials that do not have the same quality as the virgin ones, which disincentivises its use. Additionally, to meet quality, as well as the demand required, these products still need to be mixed with virgin materials. Alternatively, the quality can be improved through different processes. An example is the purification of mined oxides. This is a critical stage that is yet concentrated in the hands of relatively few companies, as most of the industry is centralized in China. In the end, this leads to a bottleneck.

Moreover, virgin materials are still less expensive and easier to obtain, given the large-scale production, in comparison with recycled materials, as well as the already existing and established routes and mechanisms for these processes. Furthermore, sourcing primary materials is highly automated, while secondary materials are often obtained through manual assembly. This disincentivises even further the use of the secondary value chain and thus the possibility of creating viable business cases for recycling routes. This is further supported by the fact that there are few "early-stage" manufacturers in Europe. Some years ago, mining activities, as well as mining-related activities (such as magnet ore processing and refining) were outsourced and stopped within Europe. Consequently, there are not many magnet manufacturers that could use the currently existing resources produced from the EoL processing. Consequently, even though there is a high potential for developing EoL processing facilities with viable prices, there is still no demand to meet such an offer, in other words, no clear business case for Europe. It is worth mentioning that the recycling processes and other EoL processing are currently in a very early stage, not yet commercially viable, meaning a lack of scale and quantity available to meet the demands of the market.

With the recent finding of rare earth deposits within Europe (Norway and Sweden) and the investment in projects for the development of mining and further exploitation facilities, there is a tendency towards building a primary value chain within Europe. This will facilitate the flow of resources, and help build a more resilient value chain, with a more diverse sourcing of rare earths, as well as the increase of demand for the secondary value chain. This is identified to be in early stages, however, supported by multiple governmental initiatives. Experts are however not sure whether Europe is able to catch up with the technical developments of China, given its knowledge gap of not operating in this market for decades.

Generate actions for improving resource flows

As mentioned before, the main issue regarding the resources' flow is the lack of such within Europe, which in turn results in unviable business cases for circular strategies such as recycling EoL products. One of the main actions identified is the support from public and governmental entities on the use of recycled products (through regulations, creation of certifications, etc.), as well as incentives for the use of such resources (e.g. price premium, long-term contracts, etc.). This will increase its use and end up in more suitable business models.

Also, the traceability of resources for manufacturers can ensure sourcing from various countries, to achieve a more resilient value chain. Additionally, with traceability, data regarding the composition of products will be available, which will in turn improve recycling, as well as the creation of more business cases. For example, by knowing how many magnets are in a speaker, a recycler can determine better prices, or if they know if any coating or glues were used they can process the components accordingly and reduce contamination of the end product, improving quality, and having more possible clients. Furthermore, through traceability, it will be possible to know the use of recycled content and make validated claims. This will promote the creation of certifications on recycled content, and companies willing to position themselves as sustainable and having a better conception from the public will seek to achieve such certifications through the use of recycled content, building up on circular economy strategies.

4.4.2 Information flows

Mapping of barriers & analysis for information flows

Key to the management of resources within speaker manufacturing is the need to meticulously label the different types of magnets used, considering they can contain elements of varying degrees of criticality and market value, such as dysprosium and terbium. Recyclers have expressed an interest in identifying these materials, yet manufacturers can be resistant to sharing such intricate details due to proprietary concerns. The chemical compositions are often closely guarded secrets, as this knowledge is fundamentally linked to the core business and intellectual property (IP) of any stakeholder along the supply chain.

The efficiency of recycling processes is significantly impacted by the coatings applied to magnets. These coatings, glues, and other substances can introduce impurities into the recycling process. Fully understanding these materials is critical, yet knowledge gaps persist as such information is unavailable to multiple stakeholders downstream such as EoL operators. Over time, the recycler might find that the immediate supplier or dismantler, who initially doesn't know the composition, might have processed the product further, complicating information retrieval and allowing only for a low material quality recycling process and secondary use option.

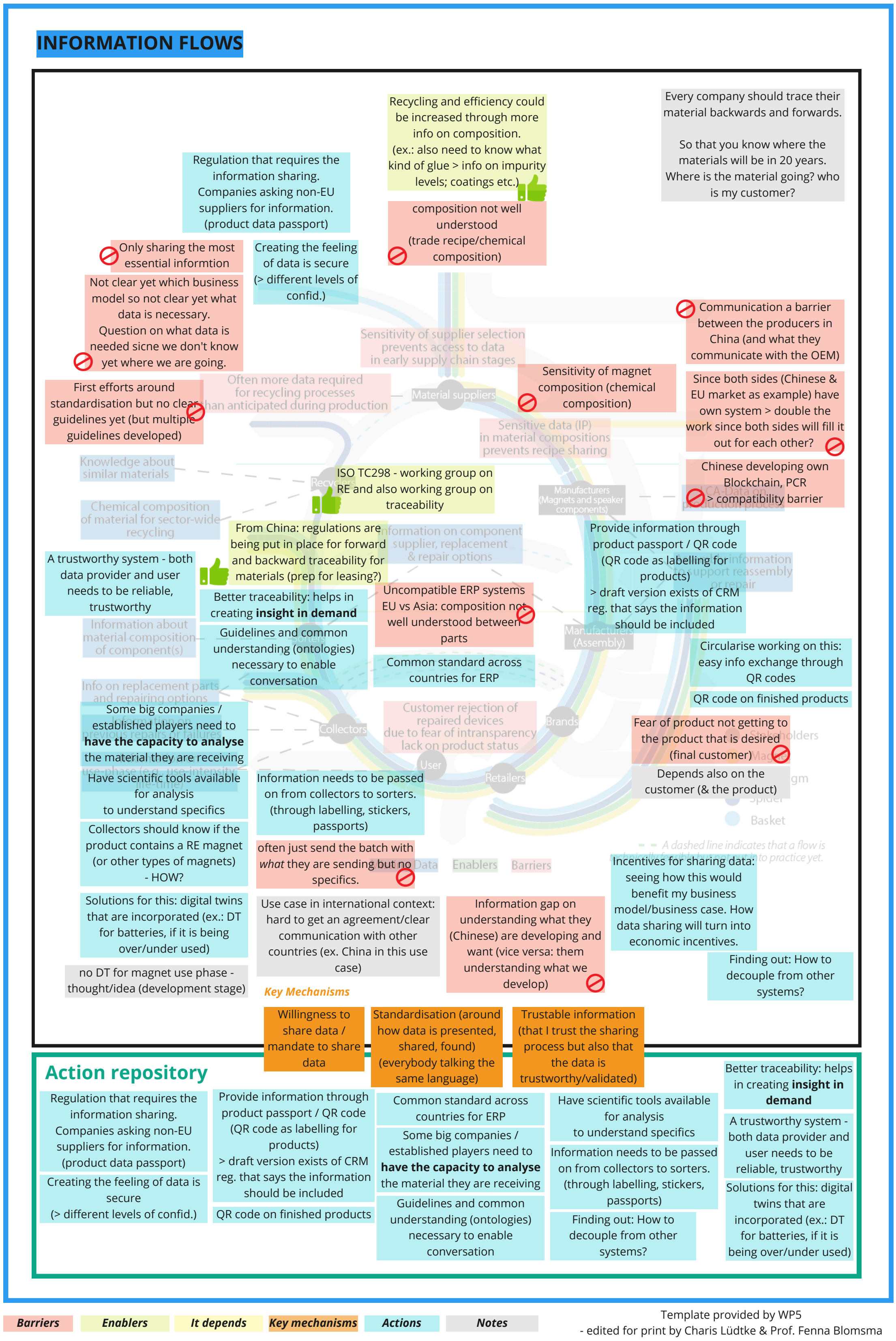


Figure 21 Electronics Use Case – Information Flows

Generate actions for improving information flows

As mentioned before in the resources flow, improving traceability is a key action to take for achieving a circular economy. In this case, information availability will enable better resource allocation. By knowing where components are sourced, possible risks can be mitigated, for example, from geopolitical issues or circumstances in which a value chain may be harmed. For traceability to be achieved steps towards standardisation of systems, as well as means for sharing data, should be defined. Given the international context of the value chain for the speakers' manufacturing, it is important to set some rules and guidelines on what data should be shared, how should this data be captured, what level of detail is required, as well as how this should be shared and with whom. The creation of standards (e.g. ISO 14040 for calculating Life Cycle Assessment), is a strategy to achieve this. Nevertheless, not all stakeholders agree on which standard to use and sometimes this leads to differences at a regulatory level (national politics and rules might lead to requirements differing among countries). Consequently, initiatives should come from governments and international organisations regarding the alignment of strategies and actions for traceability solutions. These agreements should start by considering the scenarios in the different countries to respond to local needs and at the same time establish a common language that all stakeholders adhere to.

Some initiatives like the Digital Product Passports (Circular Economy Action Plan of the EU) respond to these challenges, by introducing components QR codes with the required information. For example, on toys to indicate the presence of batteries, or speaker systems with labels about the presence, type, and treatment of magnets and glues used.

The intricacies of international political dynamics, where numerous nations deem only internally made decisions as "acceptable" and reject requirements resulting from legislation passed in countries they export, add layers of complexity to establishing a "common language" for traceability. Political frictions among countries often create doubt on the reliability of information, complicating the acceptance of data across borders and inhibiting effective global traceability standards. This is already seen with one of the standardization efforts - ISO Technical Committee 298 (ISO TC298), home to multiple working groups dedicated to recycling and traceability. Scepticism exists in certain nations, potentially influencing a wave of mistrust among others. Concerns arise from the perception that not all standards benefit the global community fairly and that strong links with specific international systems might undermine neutrality. Despite these concerns, it is becoming increasingly clear that stepping back from such established and interconnected systems would cause significant disruption. Finding institutions that are globally trusted is paramount since trust facilitates smoother transactions and collaboration across international borders.

Tackling data-sharing resistance requires a shift in perception - from obligation to cooperation. Companies often face mandates to share information but meet them with reluctance, leading to repeated reconsideration and delay of legislative adoption. Changing the mindset from one of mere compliance to one of active willingness can unlock mutual benefits across the value chain. Transparent data sharing facilitates efficient resource allocation, not just downstream but also at the end-of-life stage, creating a renewable resource flow for earlier value chain participants.

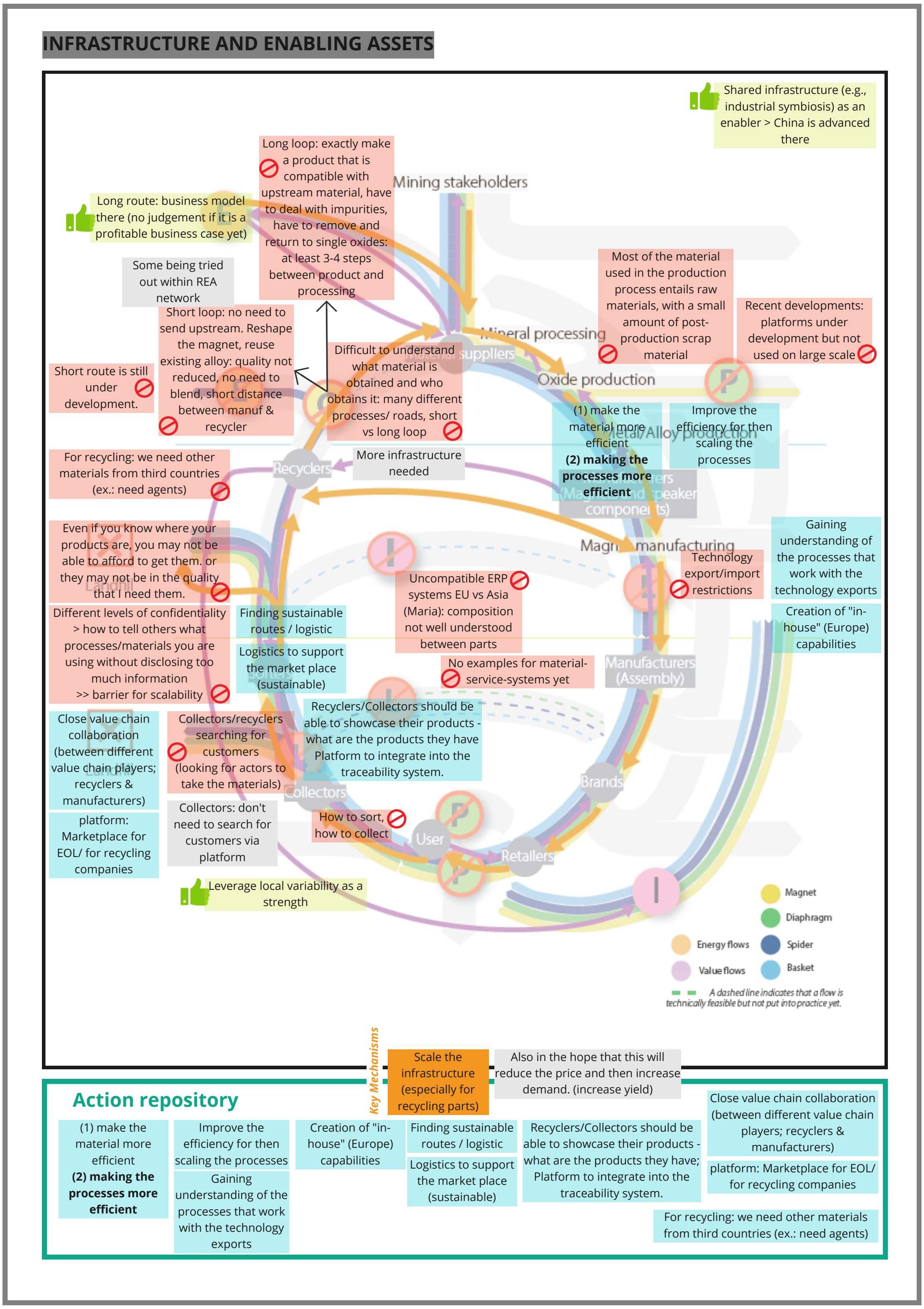
Furthermore, open data can pave the way for innovative business models that enhance financial performance and bolster market position by substantiating environmental claims.

The systems created to support this traceability should be based on two principles:

- Stakeholders can be assured of the secure exchange of their data, with stringent measures in place to ensure that only selected information reaches the intended parties within the value chain. This selective sharing mitigates the risk of sensitive data getting to undesired parties, such as competitors. This is also supported by encryption developments. For instance, a mining operator might divulge only the composition percentages to smelters (ore processing companies), while confirming the presence of any hazardous materials exclusively to magnet producers.
- Furthermore, the data must not only be secure but also credible. The information logged into these systems must be accurate and subject to verification through various checks, curtailing the chances of fraudulent claims. This guarantees that the recorded data aligns with actual operations and activities.

In general, establishing a robust, transparent, and efficient information flow is essential in the speaker manufacturing industry to meet the growing demands for sustainability and circular economy principles. Circularise, leading the electronics use case has already proven across several sectors that the provision of data about the products at EoL enhances the possibilities of reuse of products, components and materials and thereby has positive effects on the circularity in supply chains. This and the possibility to do so without sharing the sensitive data of suppliers while doing so is the unique selling point of Circularise. Within Onto-DESIDE Circularise has tested its software fulfilling these principles in a real-life speaker value chain, proving the importance and value of such technologies (for more information see D6.8).

4.4.3 Infrastructure & other enabling assets



Barriers | Enablers | It depends | Key mechanisms | Actions | Notes

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Figure 22 Electronics Use Case – Infrastructure & Enabling Assets

Mapping of barriers & analysis for infrastructure & enabling assets

Current value chain logistics for the speakers' manufacturing focus on upstream and the primary value chain. At the moment, stakeholders in the early stage of the value chain don't look for suppliers for their facilities (e.g. to make components that are composed of both virgin and recycled materials), but rather recyclers need to look out for potential buyers. Given the lack of clear business models and attractive fees for the use of recycled materials, recycling facilities are not very developed or established, which adds another layer of difficulty to the success of a circular value chain.

Another aspect, as mentioned before, there is a gap in terms of information infrastructure. There are not many known or used platforms/systems that support data sharing for such international and complex scenarios. Each country has its own systems which are not necessarily compatible with each other. This makes it difficult for information to be available for a company if its suppliers are from a different part of the world. This could be because such data collection is not available (for example, for mechanical properties, this could be that they are measured differently, through other standards, or that the units are not the same, or that different parameters need to be captured to follow regulation) or because the suppliers do not trust the software to share the data (can't rely that data will not be leaked, and thus harm their IP), or even because of local policies that don't allow certain data or component sharing.

Generate actions for improving infrastructure & enabling assets

Infrastructure regarding recycling processes should be scaled up to support circularity. For scaling such infrastructure multiple things should be considered:

- Make the material more efficient. Currently, recycled products lack the quality of virgin products, which makes these materials less attractive and reduces its demand.
- But also making the processes more efficient. To be able to recycle components independently of their composition or state (can include multiple batches from different suppliers under the same process without sacrificing the quality of the outcome).
- Developing new recycling centres as well as getting more clients for recycled products (increase local demand). Currently, the demand from recycling processes does not match the offer (most activities are outsourced). By increasing the existence of early-stage value chain stakeholders within the European ecosystem, the products from recycling processing can be further used. This will entail further "In-house" knowledge development, which can be achieved by governmental and public financing of initiatives around recycling processes as well as primary value chain activities.
- The previous point should be linked with finding sustainable routes/logistics. In the creation of these facilities, it should be considered that these new routes should still be sustainable and feasible, as they should be able to compete with the already existing flows from the primary value chain
- Close value chain collaboration and traceability on resource availability. By having a clear idea of how many resources are being produced, how many are needed, and how many are still left, better planning and allocation can be done. For example, through the creation of a "marketplace" companies can make use of those resources which are more suitable for their activities to maximise their efficiency without compromising sustainability.

- “Cross-border” information systems. Platforms where data can be safely and effectively shared among stakeholders in the value chain should be developed and implemented across different countries. These platforms should respond to national, as well as international demands, to ensure companies adopt them by complying with their local guidelines but are also interoperable with “external” software/needs.

4.4.4 System environment

Mapping of barriers & analysis for system environment

The speaker manufacturing sector is significantly affected by export restrictions across different regions. For instance, China's national regulation prohibits the export of magnets, which can disrupt the supply chain for companies needing these materials for production. Similarly, proposals in the EU around the restriction of export of EoL products, to ensure they are reused or recycled within the region, might harm circular strategies. Countries like the Philippines and Vietnam often serve as destinations for electronics recycling because of cost efficiencies. Yet, the adoption of such a proposal could lead to tension for companies registered in the EU that rely on business models centred around exporting to these countries.

Such strong policymakers indicate a shift toward cultivating local developments within Europe with a pressing need to establish an independent, EU-centric primary value chain. Currently, Europe is heavily reliant on materials from China and other Asian countries. Additionally, the business model around building a circular value chain within Europe is challenging because there is no demand to meet the offer from the material produced by recycling (no know-how or facilities of early-stage value chain actors). Consequently, there is a need for a primary value chain that can offer quality materials, which can then be mixed with recycled material without compromising performance.

The addition of this new primary value chain should be carefully studied. The economic models must consider sustainable extraction quantities that align with principles of circularity. For example, extracting only what is necessary to maintain quality and purity for recycling. In turn, viable value chains can be developed and maintained within Europe.

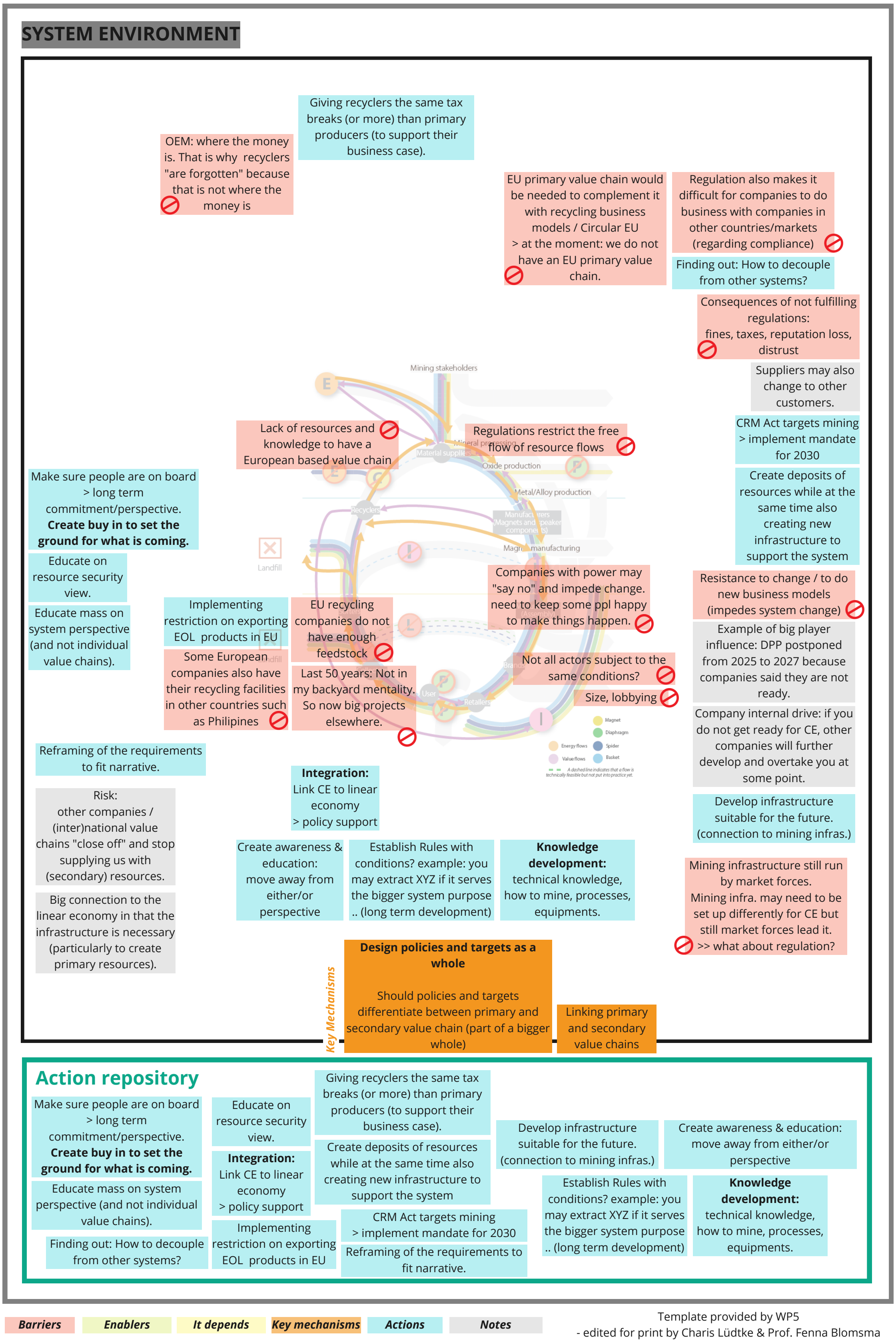


Figure 23 Electronics Use Case – System Environment

Generate actions for improving system environment

Regulations and certifications can help increase the value of companies by the mechanisms mentioned before. However, these can also harm value chains when they for example prohibit or limit exporting or importing activities. It is important when creating these policies to balance the need for establishing local, independent value chains, that do not harm international or already existing resources flow. This way an international circular flow can be maintained and support sustainable practices.

The CRMA, along with targets set by the EU regarding mining and processing percentages, pushes toward creating more local material sources. New mineral deposits in Europe and the creation of infrastructure that synergises with the recycling or secondary value chain are seen as key elements to reducing dependency on non-EU sources. Activating mining activities again in Europe doesn't compromise the potential transfer towards a circular economy but rather supports such activities, by providing resources and business models viable through the secondary value chain. Nevertheless, priority should be given to recycled content and have virgin material as a complement to achieve quality and the required amount for viable activities.

It is important to highlight that it was stringent environmental regulations that resulted in the outsourcing of processing and manufacturing. Consequently, creating awareness within society about the importance of bringing these activities back within the EU is crucial to have the general public approval and support. This should be accompanied by showing that these initiatives do not necessarily bring an increase in negative environmental impacts, as in the future, they will provide a more sustainable, circular, local and resilient value chain.

Additionally, these regulations can also be around providing financial support to the development of the industry. Several extractive industries in Europe already benefit from tax incentives; the same advantages could extend to recycling operations to foster a fair equilibrium between primary production and recycling efforts.

In conclusion, there's an evident need to integrate linear economy infrastructure with circular economy principles. New mining activities are not solely about extraction but also about contributing to a cycle that includes end-of-life strategies. Regulations can support building this system, however, they should be "future-proof" and balance support for primary and secondary value chains, as well as for "local"/"national" and international rules/initiatives.

4.4.5 Value flows

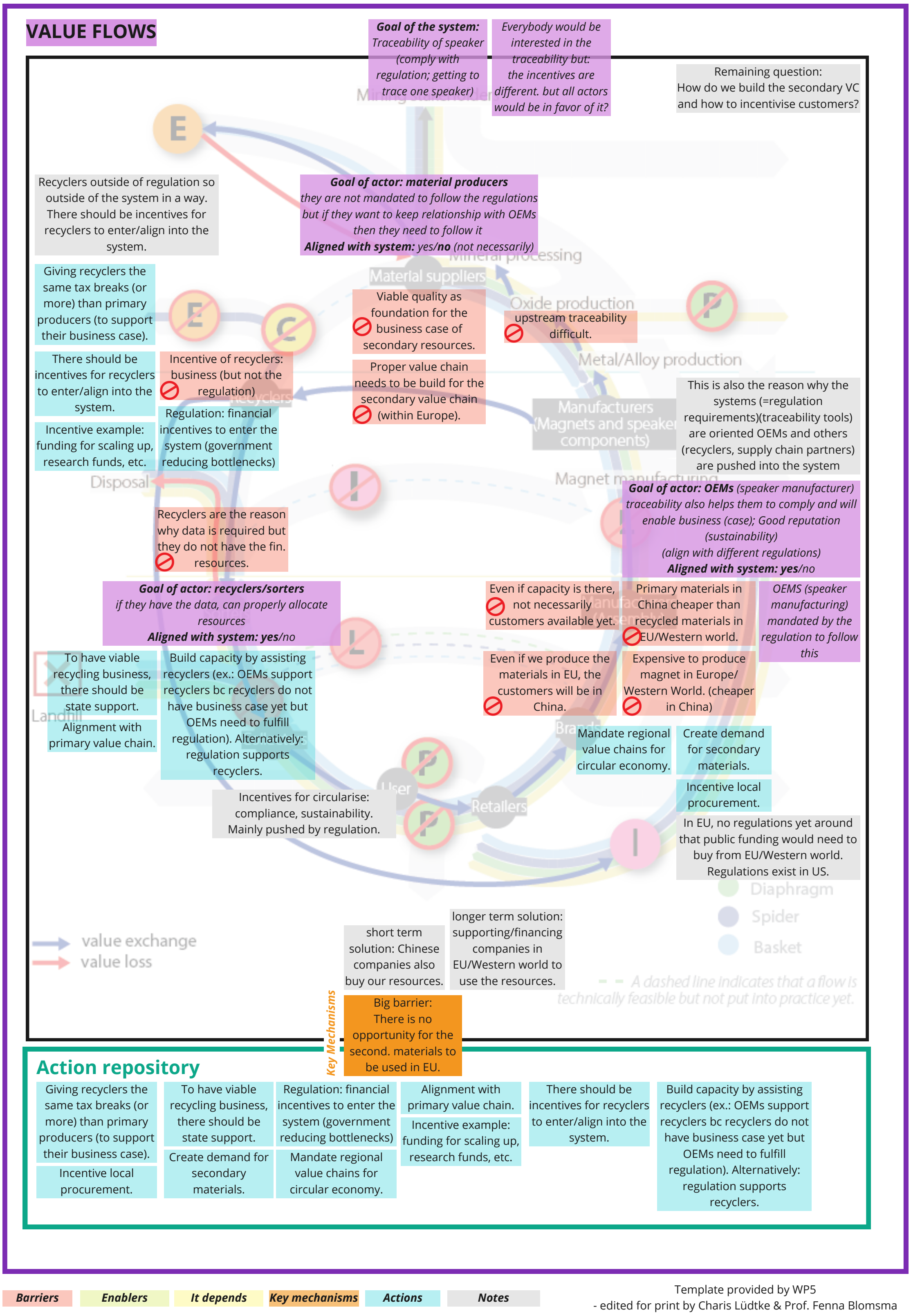


Figure 24 Electronics Use Case – Value Flows

Mapping of barriers & analysis for value flows

Certifications enable companies to improve their positioning within the market and increase their value. By having a robust traceability system, companies can know more about their products' characteristics, such as composition, and sourcing, among others, that in turn support their compliance with certain standards. For example, by knowing where their products come from, where they are sourced and how much recycled content they have, it is possible to get certifications that their activities are not within areas of conflict or make sustainability claims which in turn gives them a competitive positioning in the market and allow them to for example increase prices, get more visibility or be better perceived by consumers.

However, the current speakers' value chain is not based on certifications, or traceability at all, given the nature of the lack of transparency from upstream operations. During the mining of oxides, tracing the origins of materials can become complex because suppliers, serving a diverse clientele, may withhold detailed information, particularly in niche markets such as rare earths and magnets. Companies in certain regions, where regulations may permit, often retain information, creating hurdles for comprehensive traceability efforts.

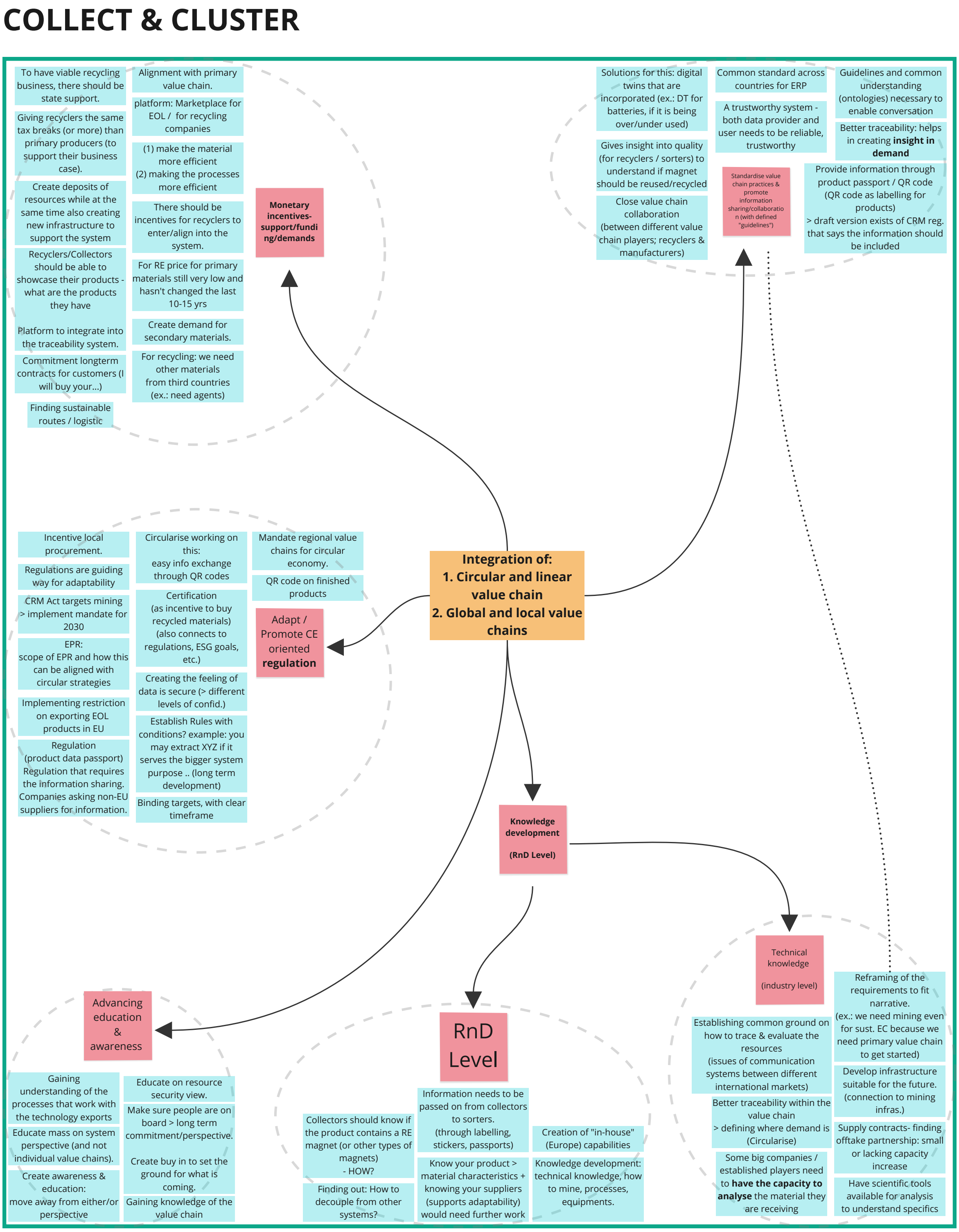
Generate actions for improving value flows

To address the complexities mentioned above and unlock the potential of the value flow for speaker manufacturing:

- Certification systems should be expanded and perhaps mandated, setting an internationally agreed-upon standard that balances market dynamics with compliance. It is important to consider that these certification systems should consider current logistics, as well as the desired future scenario of a more circular economy and that these should avoid the creation of new silos or that might hinder resiliency from existing resource flows.
- Efforts to enhance supply-chain transparency, especially for critical materials, should be a priority. This could include improved traceability from the mining to the recycling stages.
- Targeted investments and the support from governmental/public or other entities to find viable markets should be increased. This will help develop the process to answer to the needs from the circular strategies, for example, to improve secondary value chains and their use.
- Comparative analyses of initiatives from areas with more reserved approaches and those with stronger, more active ones in handling value chain rules may highlight strategies that could be applied effectively. These strategies would be designed to strengthen oversight and still remain within the boundaries of international trading standards, recognizing that some regions enforce more rigorous policies.

Solving the challenges within the value flow depends on building an environment that combines meeting regulations with incentives driven by the market itself. This approach will support a self-reliant and competitive manufacturing process for speakers, which is crucial in a global market that is becoming more focused on environmental awareness. Such standards and regulations include the CRMA, the Green Deal and further initiatives that support circular economy strategies

4.4.6 Generating actions



Template provided by WP5
- edited for print by Charis Lüdtke & Prof. Fenna Blomsma

Figure 25 Electronics Use Case – Collect & Cluster+

For the electronics use case, there was a main trend identified for the actions from the different mappings. This is around the need for an integration of:

- Circular and linear value chain - to join efforts for having the use of virgin materials (primary value chain) and their complement with recycled/reused/repaired/... resources (secondary value chain).
- Global and local value chains - to consider the different guidelines and regulations set at a national and international level.

Taking this as the starting point and goal to achieve, multiple sub-actions were defined:

- Standardise value chain practices and promote information sharing/collaboration: for circular economy to be incorporated in the electronics sector particularly in speakers manufacturing (involving rare earths and metals), data needs to be shared among stakeholders. This is to have a better understanding of components, and thus improve recycling practices and its efficiency, as well as support compliance with regulations and create new business opportunities. For this to happen, there needs to be a definition of guidelines that respond to the requirements of the different stakeholders in the value chain, considering the national and international laws, as well as existing and future systems/standards.
- Adapt and promote circular economy-oriented regulations: as mentioned before, regulations can help in the transition towards a more connected and sustainable economy, by, for example, setting targets on the amount of recycled content on products, thresholds for environmental impact measures, diversification of sourcing, data availability, among others. However, when setting these regulations, the current status, capabilities and the envisioned state must be considered, to avoid creating silos or “unrealistic” measures that could harm the adoption of such initiatives.
- Monetary incentives: including support or funding opportunities from governmental, public and private institutions, as well as increasing the demands for recycled materials. This will help break the initial barrier to achieving viable business models and support the changes required for the adoption of recycled content and new processing routes. This could also be linked with the point above, for the establishment of laws/rules that reward the use of recycled material, local suppliers, and other sustainable and secondary value chain initiatives.
- Advancing education & awareness: in order for the measures implemented to be welcomed by the public, it is necessary to promote an awareness about the importance of circular economy initiatives, and the steps towards achieving it. This involves educating people on what such an economy entails, and how certain actions, for example re-building a primary value chain within Europe, can contribute to improving sustainability impacts, contrary to the usual belief. Additionally, there should be a shift of mindset to move away from the “either/or” perspective, where there is a conception that a sector can rely only on a primary or a secondary value chain. Instead, there should be constant interaction and a clear integration between these two, to be able to maximise the use of recycled materials and reduce the virgin ones, to a level where it is still sustainable and financially viable.
- Knowledge development: for the current system to be able to support a circular value chain, it is crucial that there is an advancement in knowledge. This includes from a research and development perspective (development of new recycling methodologies, material

characterisation systems, more sustainable mining and mining-processing operations), as well as from an industrial perspective (scaling up of current manufacturing and recycling facilities, a more connected infrastructure, systems that support data tracing from multiple and global actors).

These actions were later prioritised based on two main decision criteria. First, the "Know-how", which is around the knowledge available for implementing such actions, ranging from "beginning/lack of development", to "mature knowledge". Second, the capability to implement change, which is related to the power to make the change come true. This considers the time, the money, the resources, both human and physical or material. The scale goes from having no resources up to the resources being used to their maximum.

For the actions mentioned above, none of them have mature knowledge, but they still require some development and work to have a more structured and stable basis to build upon. On the other hand, there is still room for improvement regarding the resource allocation, as they are mostly being misused or inexistent.

For each of the actions mentioned, a list of stakeholders was suggested to see who is responsible and what would be the timeframe for these to happen. Seven main actors were identified, which is more than the actions found, however, for some actions, more than one actor is required for it to be effective.

- Governmental institutions (globally): This should support the transition towards a circular economy by providing monetary incentives-support or funding opportunities so solutions can be developed and incorporated into a viable business model. They should also start now with the development of Circular economy-oriented regulations and measures that will push companies to adopt circular models, as well as provide mechanisms to facilitate such change. The final adoption and commencement of these regulations can take some time, however, their creation and announcement, as well as promotion, should start now. These regulations are about the promotion of circular practices, a common language and systems for data traceability, as well as commitments to these. This goes in hand with the education & awareness of people around the need for this transition, to avoid the rejection of upcoming measures, and prepare for behavioural and mindset change needed for the new structures
- OEMs: speakers (and their components) manufacturers should receive, as well as provide funding (depending on their size and influence within the industry) for the transition towards a circular economy. With this funding they would need to work on the improvement of facilities and general knowledge development, to fulfil the needs for the new demands. In the upcoming future, once the guidelines and requirements for traceability have been established, they should start using them and promoting them in their value chain, so all stakeholders adhere to one, universal and effective framework. Finally, this is also true for upcoming regulations, which in the future they will need to comply with, and thus, should start with time preparing themselves to avoid any delays and possible issues with their activities.
- Industry associations and international organisations (ex. REIA, ISO, ...): as the governments, these can provide monetary incentives-support/funding. Additionally, they can provide

feedback for the development of a standardised information-sharing system and for regulations, as well as facilitate the space for discussions with multiple value chain partners and experts. In the future, they should support and promote the use of such initiatives. Additionally, they can support the education and awareness of the public and of companies, to prepare them for the upcoming changes and set the ground for a better and more circular economy.

- Traceability providers (e.g. Circularise): these actors should lead or support the definition of a standardised system and value chain practices to promote information sharing/collaboration. They should be aware of the needs to be covered and fulfilled for partners, as well as for regulatory affairs. In the future, they should be aware of possible changes and updates in regulations, to keep their systems up to date and compliant with any possible advancements.
- Other value chain stakeholders: this involves for example suppliers from early-stage and recyclers, who need to start developing knowledge on new processes that are aligned with the circular practices. This can be through the monetary incentives from governmental entities, or associations, to research improved processes, as well as how to scale their current systems to meet the new demands. In the future, they should start using the systems for data tracing, as well as comply with regulations.
- Public: for regulations to be accepted and adopted, awareness and education of the public is needed. This would avoid rejection of certain practices that might endanger the future of a circular value chain (e.g. in the past mining activities were eliminated from Europe given the push from the public for more environmentally friendly practices, which is one of the reasons for the current issues in the electronics value chain).

4.4.7 Use case conclusion

For value chain design and development

To secure the future growth of this dynamic industry, stakeholders need to advocate for stronger, more cohesive value chains, establish clear objectives, and build enduring commitments. Such cohesion can be achieved by enabling data sharing, for example through platforms such as Circularise and the open platform developed within Onto-DESIDE, as well as the connection between EoL and downstream stakeholders with upstream ones. Additionally, the viability of using recycled materials relies on striking the right balance between affordability and environmental sustainability. This balance is critical in shaping the future of speaker production and the wider electronics sector. Consequently, there is a need for having “local” primary value chains that can be complemented with secondary value chains, ensuring a circular flow of resources that doesn’t compromise the quality, is affordable and sustainable in the long term.

Primary production often operates with a different outlook compared to recycling entities: while recyclers typically market their materials to buyers based on demand, without specific end uses in mind, producers of primary materials adhere to stricter standards aimed at creating materials that match the quality of new, or 'virgin', substances. New supply chain practices must consider this to guarantee that the quality of materials provided meets these exacting criteria.

The speaker manufacturing sector must foster a resilient, clear, and effective exchange of information to rise to the increasing expectations for sustainable practices and circular economic models. Advancements in the ontology, like the ones achieved in Onto-DESIDE represent a first approach towards data standardisation and facilitation of value chain communication for complex value chains where multiple stakeholders from different locations, cultures and industries need to share data.

Implications for ontology development and information support

When analysing the electronics use cases, a primary issue identified was the required unified understanding across all stakeholders. The electronics industry, characterised by its global reach and intricate value chains, necessitates a standardised foundation for data exchange and value chain traceability. Achieving this involves establishing a "linguistic uniformity" whereby a shared definition of parameters is maintained, ensuring consistency in both measurement and interpretation. Furthermore, it requires an ontology - a structured framework dictating data traceability, exchange protocols, retention periods, and other vital components - to streamline communication and promote efficiency.

The creation of such an ontology demands a thorough consideration of the diverse needs across the value chain, including OEMs, recyclers, early-stage participants, and all others involved. Analysing their data-sharing capabilities and willingness (what can they share that will not harm their IP or their business) not only supports inclusive development but also addresses critical concerns. Stakeholders need to examine the motivation behind data requests - are they regulatory in nature, process-oriented, or driven by marketing? They must also assess the reluctance to share data, evaluating whether it truly jeopardizes IP, stems from distrust, or conceals illegal practices. An understanding of these complexities is essential to developing a universally applicable solution that facilitates data sharing while underpinning a sustainable, circular value chain.

Furthermore, the ontology must be forward-looking, accounting for the industry's anticipated expansion and increased globalisation. It should foresee the growth of global exchanges, enable conducting business with an ever-broadening network of partners, and comply with stricter transparency demands, as well as the increase in EU-based value chains. Having a balance between these two trends and ensuring that resources follow a circular economy is something to be considered within the ontology. It should seek an alignment with other multiple ontologies, given the international nature (China, Australia, and Brasil, among some EU countries, are expected to be sources for the supply of rare earth). As mentioned before, the ontology should integrate the needs of recyclers and of producers in the primary value chain to ensure that the resources delivered meet the requirements for both (e.g. include metrics and definitions around how much recyclate, how much virgin, quality required, etc.). This also entails the definition of what are quality criteria, and what are the values and permitted thresholds for the different stakeholders. Additionally, what are the methods and units used and how to standardise such activities for a common understanding and effective use of resources. Finally, nvisioning the integration and interoperability with existing and forthcoming resource management systems - for instance, advanced Enterprise Resource Planning

(ERP) systems – and others used by companies for product tracing, is also vital to ensure future relevance and functionality.

5. Textile Use Case

5.1 Objectives of use case

As per the product description below, this case focuses on fibres and filling materials. With different materials to consider and different recycling technologies available, this case explores that is possible and desirable to take the recycling of textiles and fibres to the next level. Fibre-to-fibre recycling was explored, as well as other forms of recycling, ranging from mechanical to chemical recycling and the connections that exist with other sectors to reuse materials (e.g. such as paper and automotive).

5.2 Involved partners and contributions

Three organizations contribute to the Textile Use Case:

- **+ImpaKT Luxembourg** (http://positiveimpakt.eu/en/pcds/), 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[5].
- **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
- **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.

Together these partners provide insight into the following domains: supply chains, product information, and criteria for sustainability, circularity and recyclability claims as well as their evaluation.

[5] 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

5.3 Use case description

Introduction to textile sector

Textiles are essential to daily life, providing clothing, shoes, and home furnishings. However, the industry has significant environmental and social impacts. According to the European Environment Agency (EEA), textiles are the fourth largest user of raw materials and water in the EU, and they contribute significantly to land use and greenhouse gas emissions[6]. The global textile value chain also faces issues like child labour, driven by the need for cheap production. Additionally, textile production involves many chemicals, some of which are hazardous, and synthetic textiles contribute to microplastic pollution.

The industry's linear model, which prioritizes low-cost production over sustainability, exacerbates these issues. For instance, while EU consumers buy 26 kg of textiles per person annually, they discard 11 kg year[7]. Globally, less than 1% of textile fibres are recycled into new fibres. To address these problems, initiatives are emerging to improve traceability and transparency in the supply chain. These include the UNECE's Traceability for Sustainable Garment and Footwear[8], Trustrace[9], the EU's Digital Product Passport (DPP) under the European Green Deal, EonGroup's Circular ID protocol[10] and circularity.ID® Open Data Standard[11] developed by circular.fashion, and various other projects focused on increasing recycling quality and data transparency.

However, challenges remain in accessing and sharing reliable data across the supply chain, with issues such as limited visibility, confidentiality concerns, and maintaining the link between physical and digital products. Addressing these challenges will require systemic solutions to standardize data sharing, which is crucial for creating a more sustainable and circular textile industry. The project's Ontology Network and Open Data Sharing platform aims to enhance traceability and transparency, contributing to this goal.

Scenario for use case

For this use case, the discussions were conducted through flow mapping analysis using the Circularity Compass. They primarily revolved around identifying barriers and enablers for promoting the recycling of industrial and post-consumer textile waste. These discussions considered various flows between supply chain stakeholders, involving material suppliers, manufacturers, brands, users, collectors, sorters, and recyclers. The analysed flows concerned interdependent themes such as resources, information or infrastructure, extending beyond supply chain boundaries to include other domains like the paper industry. Much of these discussions focused on the obstacles (technological, logistical, supply, regulatory etc.) faced by the sorters and recyclers in processing these types of

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[6] 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

[7] 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

[8] https://unece.org/trade/traceability-sustainable-garment-and-footwear

[9] https://trustrace.com

[10] https://www.eon.xyz

[11] https://circularity.id

waste. This also involves investigating the criteria for improving recycling efficiency, which depend on different aspects of waste supply to be processed, such as quality and availability, as well as exploring potential solutions to break down the identified impediments.

Product information

The product considered in this use case is a shoe, specifically a sneaker, the components of which are manufactured by Texon. The shoe is composed of several parts, each with its own characteristics and expected performances, as depicted in Figure 26. These parts are made from simple or composite materials, which can be fabricated from polymer-based fibres, such as polyester, or bio-sourced fibres, such as cellulose. Additionally, these fibres may come from either virgin or recycled sources. Each part of the sneaker is assembled using techniques, typically chosen by the brand. Technical specifications including a list of components and materials to the assembly manufacturer are also provided by the brand.

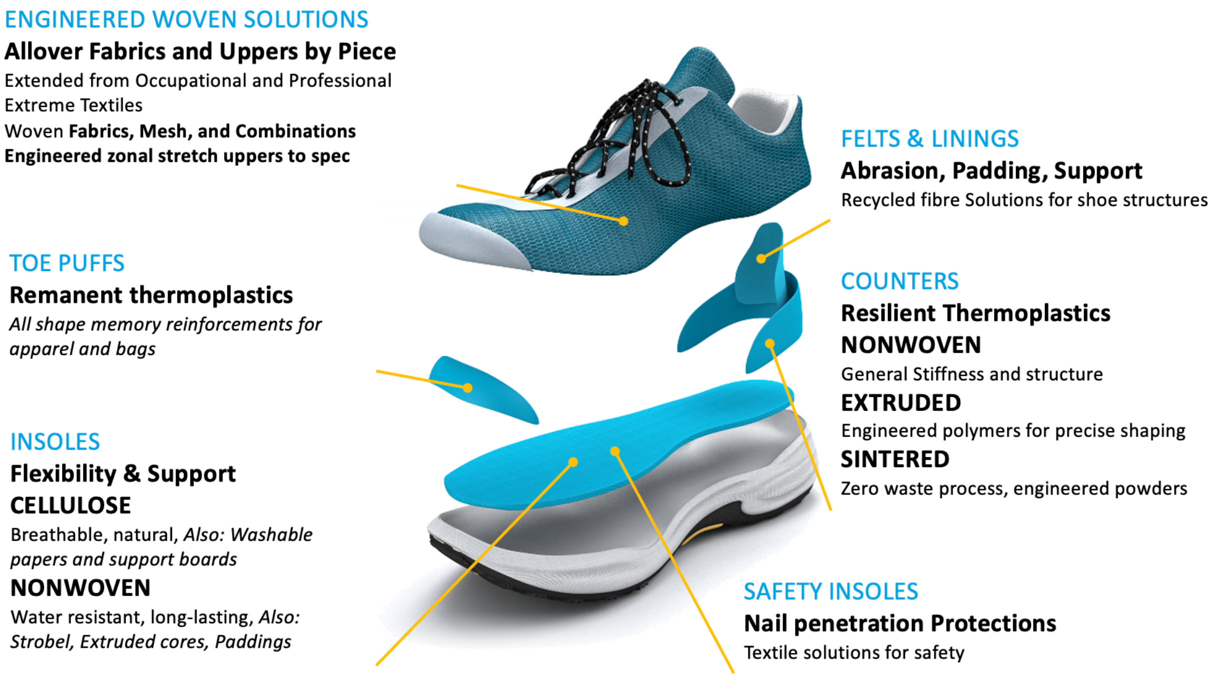


Figure 26. Example of shoe components assembled by Texon

5.4 Investigating value chain improvement opportunities

For the Textile use case, a summary and the highlights of the discussions is provided for the following mapping tasks: resource flows, energy flows, value flows, information flows, infrastructure & enabling assets, and systems environment. This section closes with a reflection and considerations for further ontology development.

5.4.1 Resource flows

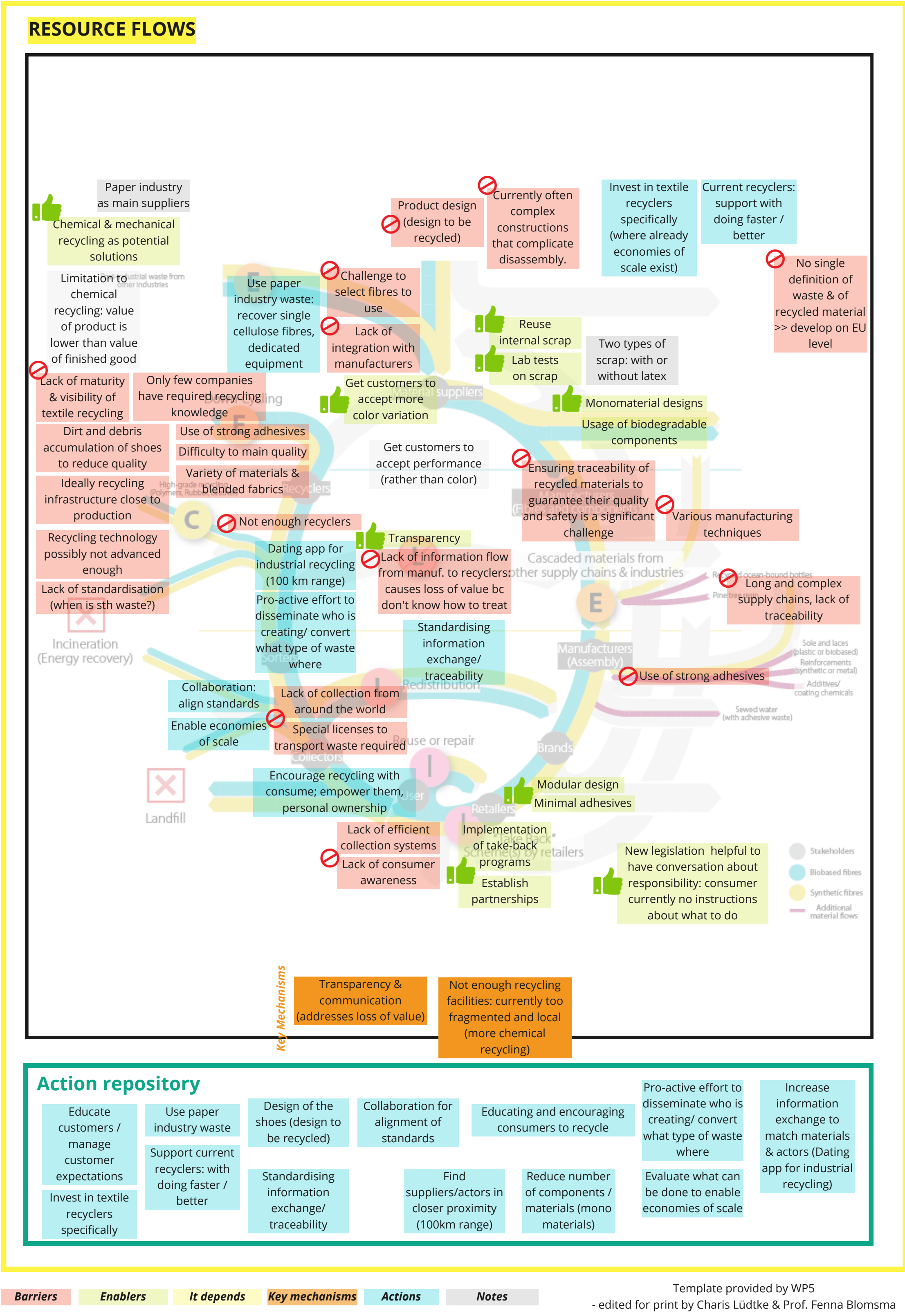


Figure 27 Textile Use Case - Resource Flows

Updates on the resource flows since D6.2

Three additional flows were incorporated into the mappings based on the discussions during the mapping process. The first flow connects material suppliers with recyclers. It was noted that recycling facilities should ideally be located near production sites; however, they are generally concentrated closer to the end consumers, resulting in a disconnection in the supply chain flow. Furthermore, the limited number of recyclers leads to significant delays when one is unavailable, rendering the entire process fragile.

The second flow is between manufacturers and recyclers. It addresses the lack of information flow from manufacturers to recyclers, leading to significant value loss. Recyclers often lack awareness of how to effectively treat recycled materials, which hinders the recycling process.

on directing paper industry waste to recyclers for the recovery of single cellulose fibres, integrating the paper industry more effectively into the recycling loop.

Mapping of barriers & analysis for resource flows

The **wide range of materials used in shoes** is the most significant challenge. Recycling processes are often material-specific, and shoes typically contain combinations of leather, rubber, plastics, textiles, and metals. Each material has its own recycling process, making it challenging to recycle the shoe as a whole. Additionally, many shoes use blended fabrics (e.g. cotton-polyester blends), which are harder to separate and recycle into high-quality fibres. Some fibres are blended with latex which leads to the mix of paper and plastic being created.

Shoes often have intricate designs and multiple layers, often involving glued, stitched, or welded components, complicating the process of disassembly and separation of recyclable components. Materials cannot be separated in a clean way (with mechanical recycling), there are always impurities and residuals of other materials. Also, construction techniques are too diverse to automate the disassembly process. Furthermore, many shoes are treated with chemicals for waterproofing, fire resistance, or durability. Those strong adhesives make it difficult to separate and recycle the different materials without degrading the quality of the recycled fibres or completely damaging them.

Shoes need to be designed with recycling in mind from the outset, which requires changes in design practices. To this end, the entire life cycle of footwear must be taken into account, including the selection of materials, so that these products can be recovered and reused after use, rather than ending up in a landfill. Unfortunately, **sustainable materials**, which **are often more expensive**, and the **additional design time to ensure recyclability can increase production costs**. Also, manufacturers want to use a bigger range of inputs to reduce time for processing. While this can improve efficiency and responsiveness, unfortunately it can also complicate recycling efforts.

Generate actions for improving resource flows

The first action for improving resource flows is to **choose biodegradable components** for manufacturing textile products. In fact, these types of material allow reducing the amount of waste that ends up in landfills as they break down naturally over time. Furthermore, they do not release harmful substances as they break down, and generally decompose into non-toxic substances.

Using a single type of fibre, monomaterial or easily separable materials simplifies the recycling process. Shoes shall be designed in a way that components can be easily separated. For instance, by using fewer adhesives and more mechanical fastenings that allows easier material separation. Besides, the utilisation of fibres that are already known to be recyclable, such as certain types of polyester or natural fibres, also helps facilitate the recycling process.

Manufacturers must **balance the need for performance with the sustainability** of the materials used. For instance, some high-performance materials may be difficult to recycle, while more recyclable materials might not offer the same level of durability or comfort. There are services (like circular.fashion workshops) that help brands to design with a circularity in mind. Products should be designed with repairability in mind. This means using modular components that can be easily replaced or upgraded and providing clear instructions for disassembly. Additionally, offering repair services can build strong customer relationships. When a brand offers reliable repair services, it demonstrates a commitment to customer satisfaction beyond the initial sale. This can lead to increased brand loyalty and repeat business.

Lastly, it is essential to **support and invest in recyclers** by providing funding for upgrading existing infrastructure and developing new facilities capable of handling various types of textile fibres. Additionally, **offering technical support and expertise** is crucial to help recyclers implement advanced recycling techniques and address operational challenges; this support can include training programs, facilitating knowledge exchange, and fostering innovation in recycling technologies. Further investment in recycling infrastructure can be encouraged through **incentives such as tax breaks, subsidies, or grants**. Moreover, **developing a network of local suppliers** to provide shoe waste or scrap materials for recycling is vital for reducing transportation costs and preventing supply disruptions.

5.4.2 Information flows

Any updates on the information flows since D6.2

A new information flow has been introduced in the revised mapping diagram since the second. This newly identified flow pertains to Post-Industrial Recycled (PIR) materials, which goes backwards in the supply chain, more precisely from "manufacturers of fibres and components" to "material suppliers". This flow represents a critical pathway for the redistribution of PIR scrap materials, which are technically the easiest to recycle within the supply chain, since they are often clean, homogenous and unmixed.

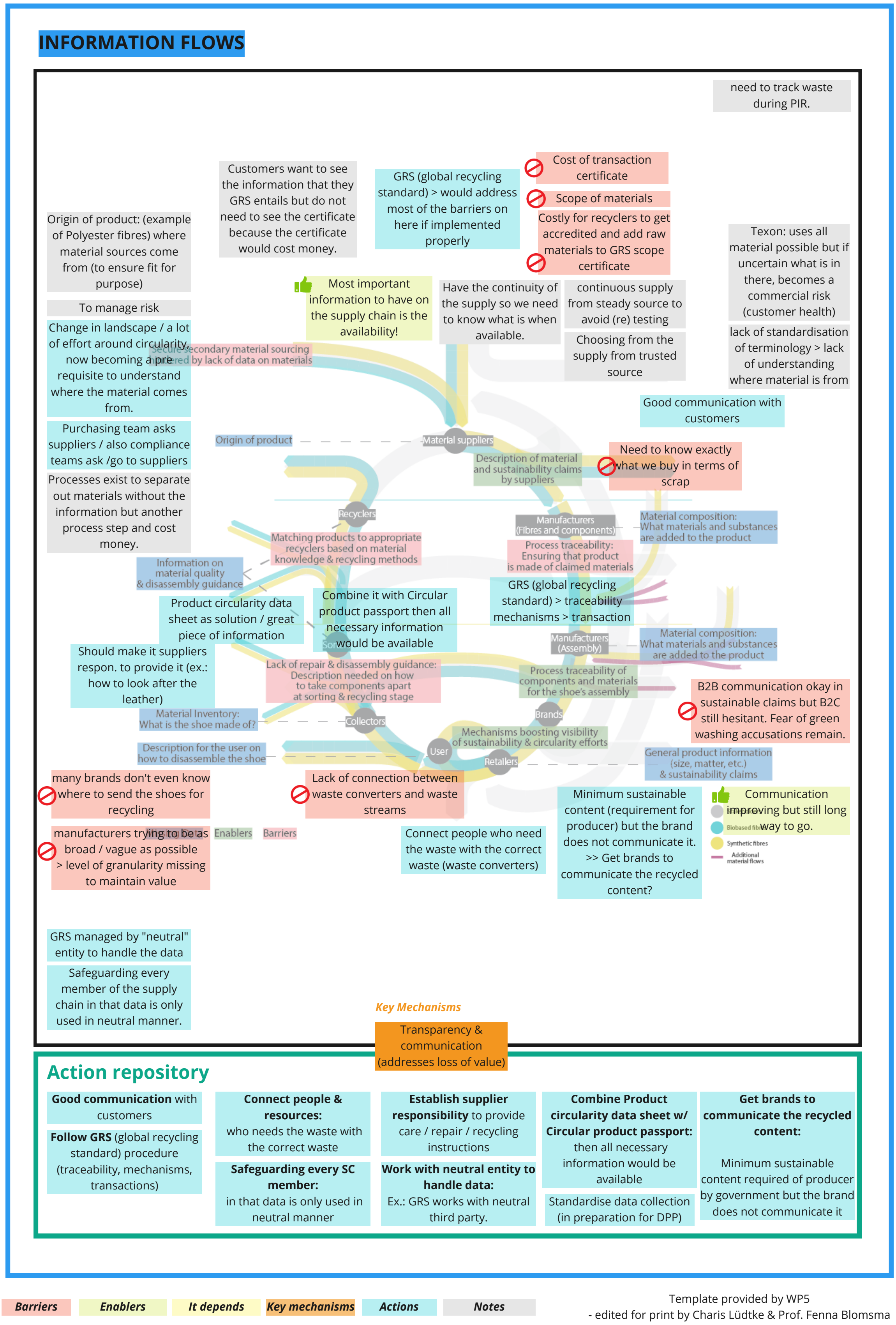


Figure 28 Textile Use Case - Information Flows

Mapping of barriers & analysis for information flows

Barriers to the effective transmission of information were identified from the mappings and those that were deemed the most restrictive are cited below.

The **availability** and **continuity of supply** are crucial information to know for the actors of the supply to ensure consistent production, cost efficiency, quality control and operational stability chain. However, some scrap material suppliers are not able to provide this information to the recyclers to the extent that they are classified as untrusted source and can be potentially discarded from the supply chain.

Many brands **lack the necessary information to properly direct end-of-life shoes to appropriate recycling facilities**. While recycling pathways do exist, they are rare, and it is sometimes unclear how to access them, such as accepted waste type requirements or criteria for waste suppliers. Consequently, a significant proportion of these scrap materials are ultimately disposed of or ends up in landfills.

Being accredited with reference standards such as the Global Recycled Standard (GRS) offers several significant advantages to recyclers, including enhanced credibility and trust, improved supply chain transparency, market differentiation. However, **obtaining such accreditation can be prohibitively expensive**, especially when adding raw materials to materials' scope in GRS.

Generate actions for improving information flows

To enhance the effectiveness of information flows, the following actions have been suggested:
Enhance information exchange to improve connectivity between stakeholders and resources, specifically by increasing visibility to align waste generation with the needs of collectors and recyclers. This can be achieved by **developing and promoting comprehensive IT solutions, such as specialized matchmaking platforms** for industrial recyclers, on a broad scale. In this context, it is imperative for supply chain participants responsible for waste generation to actively disseminate detailed information about characteristics and quantities of waste they produce or process.

Set up a standardised document that each actor in the supply chain can use to minimise the burden of collecting and sharing data in multiple formats, to overcome the lack of harmonisation. This document should encompass all essential data pertaining to product circularity and could combine the data attributes in the Product Circularity Data Sheet (PCDS) and the circularity.ID®, for instance.

Adhere to the Global Recycled Standard (GRS) procedures to effectively address a broad spectrum of challenges associated with traceability, operational mechanisms, and transactional processes within the recycling and supply chain management sectors. The protection of all actors within the supply chain will also be ensured, by implementing robust data governance practices that guarantee the secure use of data, as outlined by the GRS.

5.4.3 Infrastructure & other enabling assets

As for the information flows, a new flow has come up for infrastructure and enabling assets since the first iteration, which is from “manufacturers of fibres and components” to “material suppliers”.

Mapping of barriers & analysis for infrastructure & enabling assets

Barriers to infrastructure and enabling assets were identified, and they are as follows:
Cellulose fibres can derive from multiple sources, namely wood pulp, bamboo, hemp and more. However, wood fibre is currently the most common and viable option for producing cellulose fibres. Mixing scrap materials made from different fibre sources during the recycling process is generally not recommended, as it can compromise the quality and consistency of the recycled fibres. This presents significant challenges for material suppliers, who **must navigate specialised processes and dedicated equipment** for selecting and processing these fibres.

For fibre and component manufacturers, utilizing a **broader range of inputs** can reduce processing time. However, this advantage is offset by the increased **need for tracking, sorting, and cleaning of scrap materials**, which impedes the full automation of processes. On top of that, recyclers are observed to be in a significant minority compared to other actors in the supply chain, and there are not enough of them.

Generate actions for improving infrastructure & enabling assets

Some of the actions for improving infrastructure and enabling assets resulting from the brainstorming are the following:
Invest in textile recycling operations, particularly in areas where economies of scale have already been achieved. By channelling resources into established recyclers that are already operating at scale, we can maximize the impact of investments, fostering greater efficiency and reducing costs per unit of recycled material. To note that upgrading equipment may become necessary in the future but is not an immediate requirement.

Construct dedicated warehouses to ensure that waste and secondary resources are protected from external environmental conditions such as sunlight and rain. Additionally, the development and expansion of recycling infrastructure are critical steps toward advancing a circular supply chain.

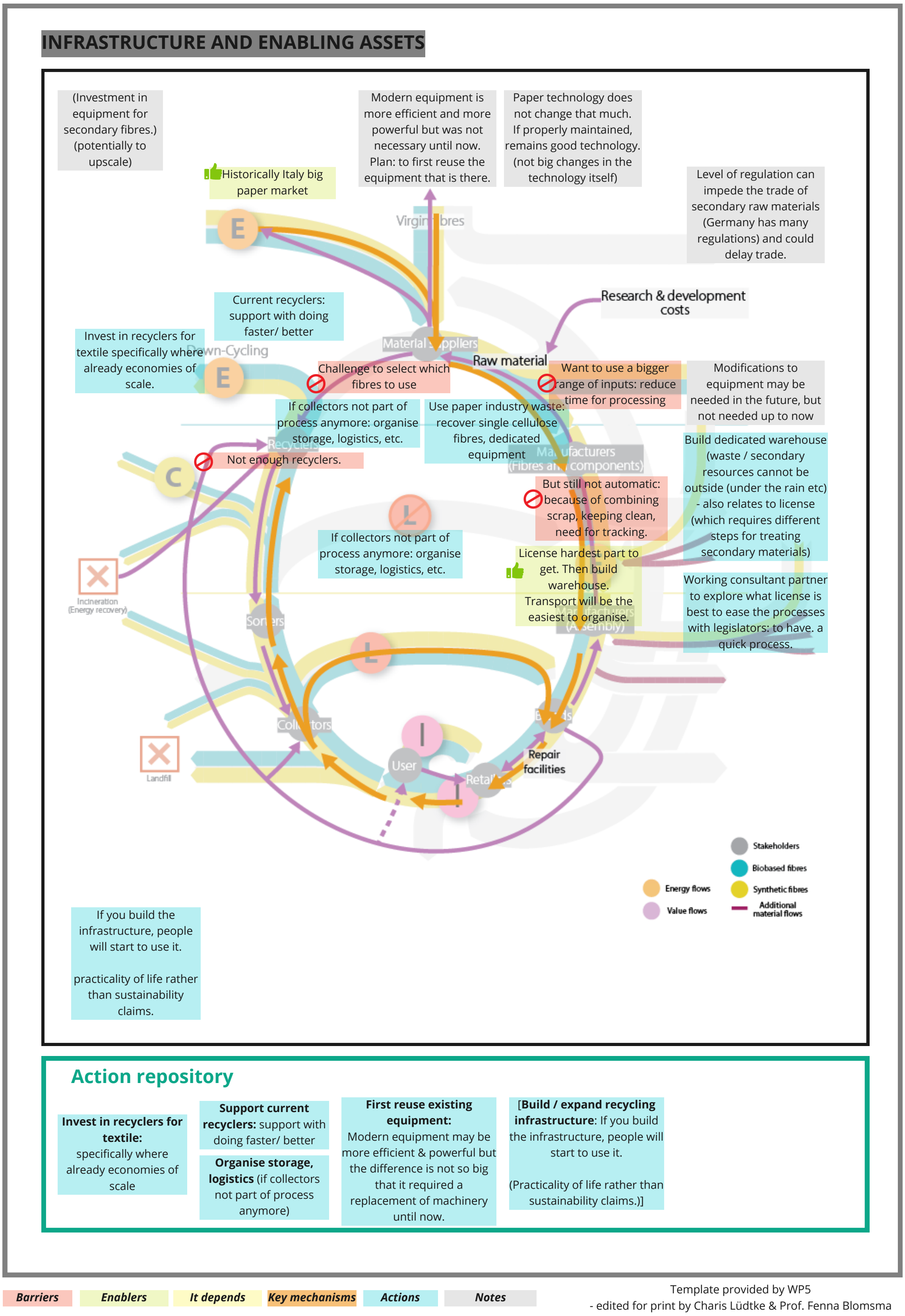


Figure 29 Textile Use Case - Infrastructure & Enabling Assets

5.4.4 System environment

Considering that the value chain is embedded in a larger environment such as a sector with cross-sectoral linkages, and a larger legislative and cultural environment (at a national or international level), a new mapping task related to the system environment was added since the second iteration.

Mapping of barriers & analysis for system environment

One of the biggest impediments related to the system environment that has been mentioned during the mapping sessions is the **variation in legislation regarding the use of secondary materials across different countries**, which make their trade difficult. These discrepancies include definitions of key terms, as well as threshold values for what qualifies as secondary materials. In some countries, special licenses are required for transport, and this restriction can lead to potential disruptions in supply chains. Certain regulations also impact the quality of the supply chain. For instance, recent regulatory changes have impacted Texon's method of sourcing scrap materials, which were previously obtained directly from producers or customers. The involvement of middlemen, such as collectors, has resulted in a decrease in batch quality, as these intermediaries are less attentive to Texon's specific requirements.

On the other hand, **recycling requirements**, such as those enforced by the EU regulations for the minimum required percentage of recycled content, act as powerful enablers for the transition to a circular economy in the textile industry. In fact, these regulations allow creating a guaranteed market for recycled materials and pushing companies to innovate in recycling technologies and material sourcing.

Generate actions for improving system environment

To minimize disruptions in the supply of secondary materials, **fostering a diverse industry or economy profile** is crucial. By engaging a wide range of industry stakeholders, such as manufacturers, recyclers, and suppliers from various sectors, resilience in the supply chain can be enhanced. A more diverse economy, characterized by strong yet non-dominant positions across various sectors, creates greater opportunities for the acceptance and integration of waste materials.

Obtaining license also serves as a crucial enabler for improving system environment. Indeed, license allows recyclers to process materials directly sourced from customers. By streamlining the supply chain, recyclers can maintain better control over the material's origin and condition, thereby enhancing the efficiency and quality of the recycling process. Furthermore, the license can facilitate compliance with regulatory standards, attract potential partnerships.

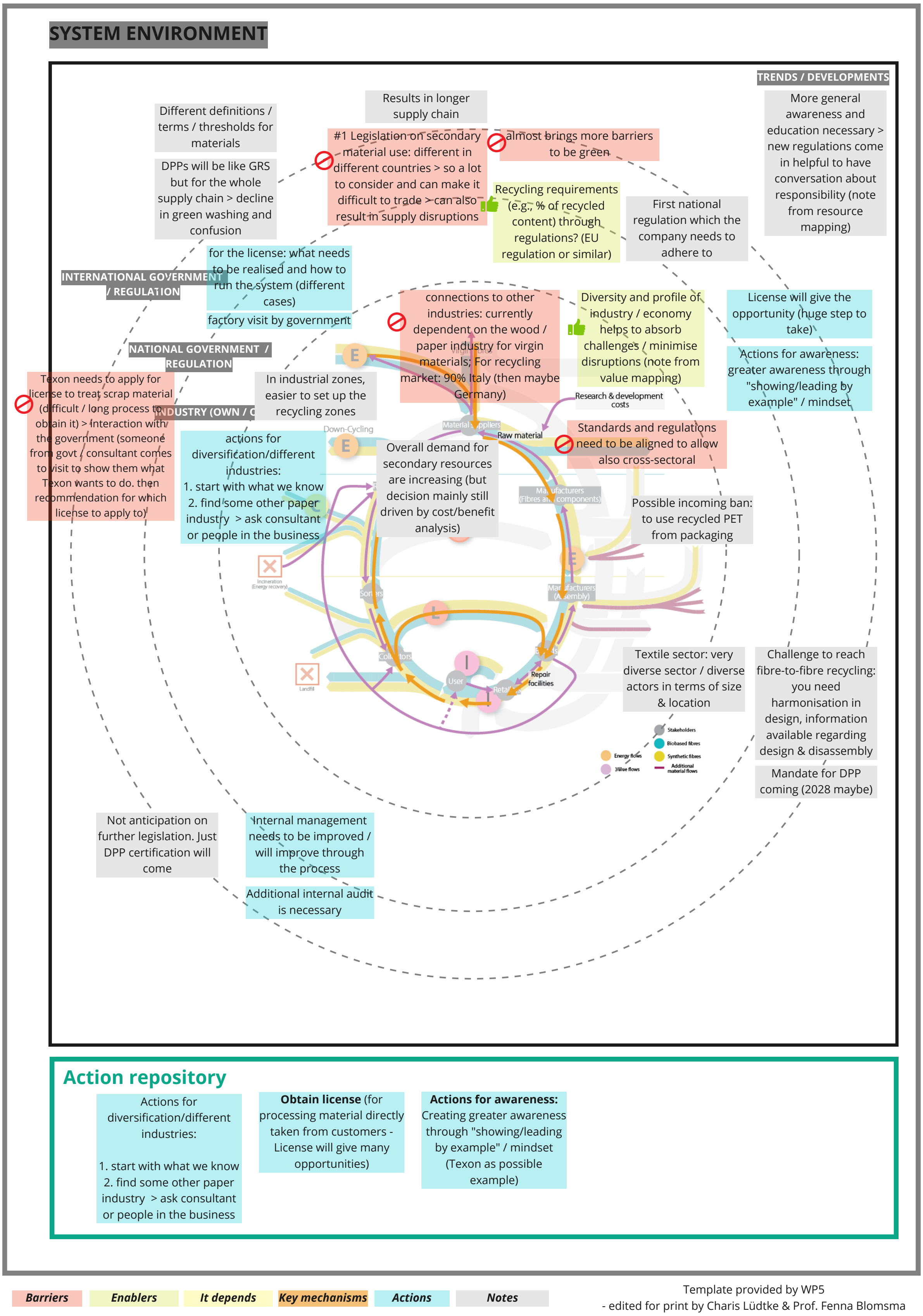


Figure 30 Textile Use Case - System Environment

5.4.5 Value flows

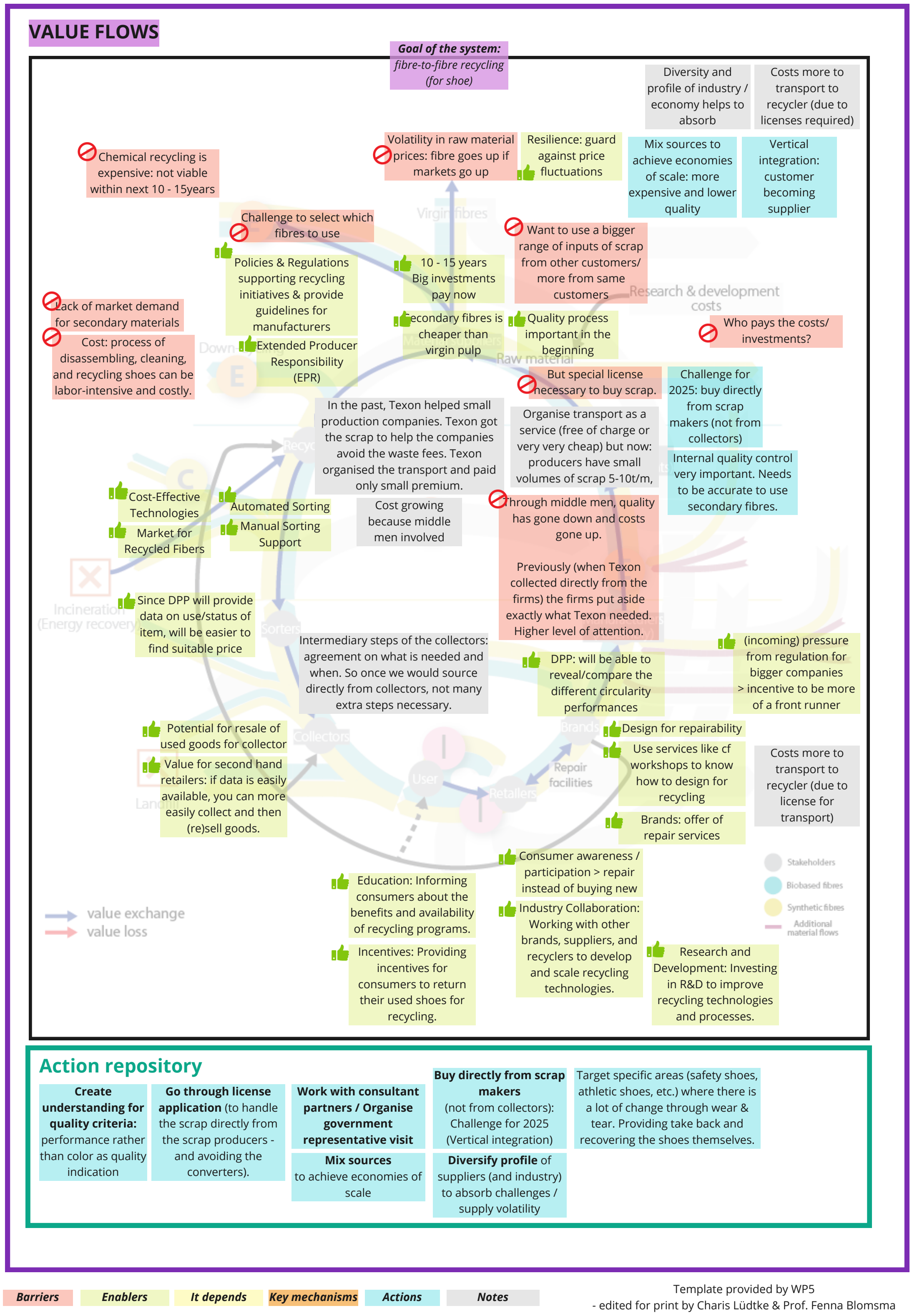


Figure 31 Textile Use Case - Value Flows

Any updates on the value flows since D6.2

The desired change in the flow would be to increase the range of scrap inputs, by sourcing from a broader array of customers, or obtaining more scrap from existing customers. This suggests introducing an additional flow of input, besides virgin and recycled materials, and specifically scrap materials.

Mapping of barriers & analysis for value flows

Economic viability remains the most significant barrier to the widespread recycling of shoes. The process of disassembling, cleaning, and recycling shoes is labour-intensive and expensive. Currently, chemical recycling methods are prohibitively costly and are not expected to become viable for another 10 to 15 years. While secondary fibres can be cheaper than virgin pulp, they present challenges in terms of usability. Virgin pulp is generally easier to process, and the use of secondary fibres requires highly accurate internal quality control, which adds another layer of complexity and cost.

Moreover, the **limited market demand for recycled shoe materials** further diminishes the economic incentive for manufacturers to invest in these recycling processes. The absence of off-take agreements for recycled materials exacerbates this issue, leading to a scarcity of collectors and recyclers globally. Recycling markets remain small and localized, resulting in significant delays if a single recycler becomes unavailable. The lack of vertical integration within the industry contributes to the fragility of the recycling process, with no safety margins in place to handle disruptions.

Using scraps of materials seems like a strong enabler, as it reduces the amount of scrap that ends up as waste. Previously, it was possible to purchase scrap directly from small production companies. This arrangement was mutually beneficial: companies avoided waste disposal fees, and buyers enjoyed lower prices. However, recent **regulations** now require a special license to buy scrap, which has introduced middlemen into the process. Unfortunately, this has led to a decline in quality and an increase in costs. Another advantage of **buying directly from production companies** was the personalized service. They would set aside exactly what the buyer needed, ensuring a higher level of satisfaction.

Generate actions for improving value flows

To improve value flows, we firstly need to **develop recycling processes that are economically viable**. This involves creating methods that not only reduce waste but also operate efficiently within the constraints of cost and resource availability.

Secondly, we need to ensure **the existence of a robust market for recycled fibres** to guarantee the sustainability of the recycling process. This implicates fostering demand among manufacturers and consumers, which in turn drives the economic viability of recycling initiatives.

By implementing **take-back schemes** that enable consumers to return used shoes to retailers for recycling, recycling viability can be enhanced. This approach not only ensures a consistent supply of recyclable materials but also engages consumers directly in the recycling process.

Government policies that promote recycling initiatives and provide guidelines for manufacturers need to be developed. Furthermore, **regulations** that hold producers accountable for the end-of-life disposal of their products shall be implemented. Additionally, we can organize **transport services** for scrap collection, ensuring they are either free of charge or offered at minimal cost.

5.4.6 Generating actions

Around 70 actions were discussed during the different mappings mentioned previously. After consolidating those that align around similar themes, seven distinct action groups have been drawn out, which are presented below in size order, based on the number of actions they contain.

In the first group, the actions gravitate around **improving or standardising information flow**. They involve aligning standards through collaboration, establishing supplier accountability for lifecycle management, and working with neutral entities for data management. Additionally, there is an emphasis on improving information exchange by integrating tools like the PCDS and circularity.ID® and building obligatory networks for better resource visibility. Brands are also encouraged to transparently communicate recycled content, while supply chain actors should proactively share waste information to facilitate effective recycling processes.

The second one regards the **development of new relations** and encompasses actions on strengthening and diversifying supply chain networks with cross-sector actors to enhance resilience. These actions revolve around building new relationships, creating clusters of manufacturers and recyclers, diversifying supplier profiles, and optimizing logistics to lower costs and improve operational efficiency. By finding suppliers closer to production sites and increasing the visibility of local resources, one can create a more robust and flexible supply chain, which is capable of absorbing market challenges and volatility.

The third one entails actions focusing on optimizing existing resources and processes, whether by reusing current equipment, organizing logistics, supporting recyclers, or investing in advanced technologies like automated sorting assisted by artificial intelligence (AI). The overall goal is to **improve recycling operations**, making them faster, more efficient, and better suited to handle current and future demands.

The fourth one emphasis on the importance of **obtaining necessary licenses** to enable the direct processing of materials sourced from customers. This can be done by collaborating with consultant partners, for example to organize visits from government representatives, who will assess the proposed activities and provide guidance on the required licenses and the application process.

And the **creation of education** is the central core of the fifth group. Indeed, to promote the use of recycled materials and enhance recycling efforts, it is important to educate customers about the relationship between product colour, quality, and performance. Additionally, by encouraging consumers to participate in recycling programs, such as returning waste to post-consumer scrap (POS) for vouchers. By doing so, they can be empowered and given a sense of ownership in the recycling process.

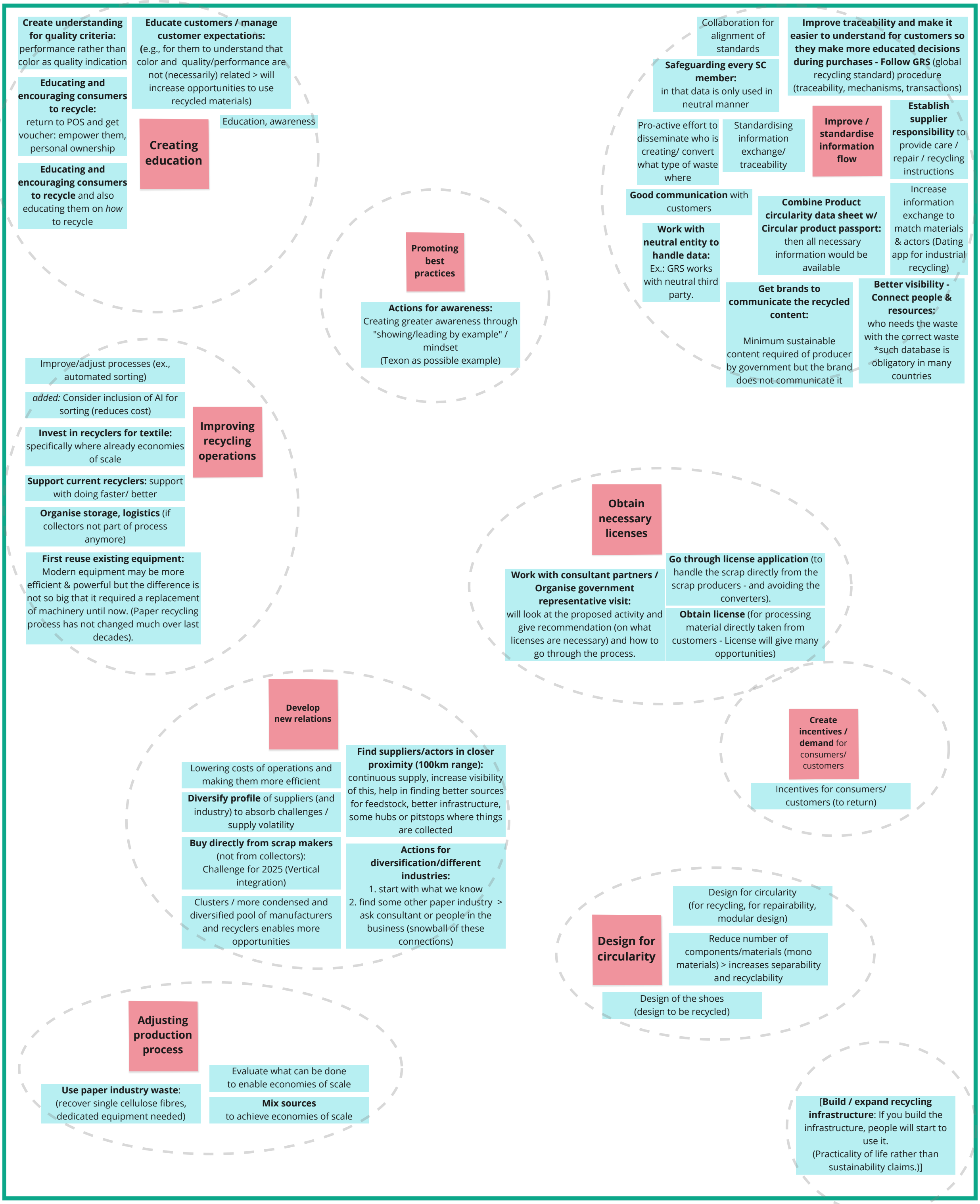
The sixth group cover actions linked to **design for circularity**, which focus on creating products that are easier to recycle and repair, such as through modular design. The simplification of product composition is also essential to reduce the number of components and materials used in products, even considering mono-material designs. This approach increases the ease of separation, recycling, and recovery processes, ultimately improving sustainability in manufacturing.

Finally, the overall goal of the seventh action group is to **adjust production process**. One of the alternatives for doing this is the utilisation of paper industry waste by recovering cellulose fibres, even if specialised equipment is required. Another option is to explore economies of scale in recycling, including the potential to mix different sources during the recycling process.

Two other actions have not been clustered although they are less important than the others. These are as follows:

- **Promote best practices** by creating greater awareness through showing or leading (example of Texon).
- **Create incentives or demand** for consumers/customers to return their waste.

COLLECT & CLUSTER



Template provided by WP5
- edited for print by Charis Lüdtke & Prof. Fenna Blomsma

Figure 32Textile Use Case - Collect & Cluster

The following step consisted of finding criteria allowing to prioritise the action groups. To this end, the approach using two-dimensional axis was proposed. A number of proposals were put forwards during the work session, although their common point is the consideration of “effort to implement” (e.g. human or cost effort) on the vertical axis. The different criteria suggested for the horizontal axis were:

- Timescale for implementation
- Time for the expected impact
- Scale of the expected impact (local or global)
- Information standardization or availability
- Eliminate game stoppers
- Improve process
- Educate and cement changes i.e. make sure that change is long lasting
- Number of issues around topics
- Size of bottleneck

Figure 33 illustrates the priority of each action group based on effort to implement and timescale for implementation.

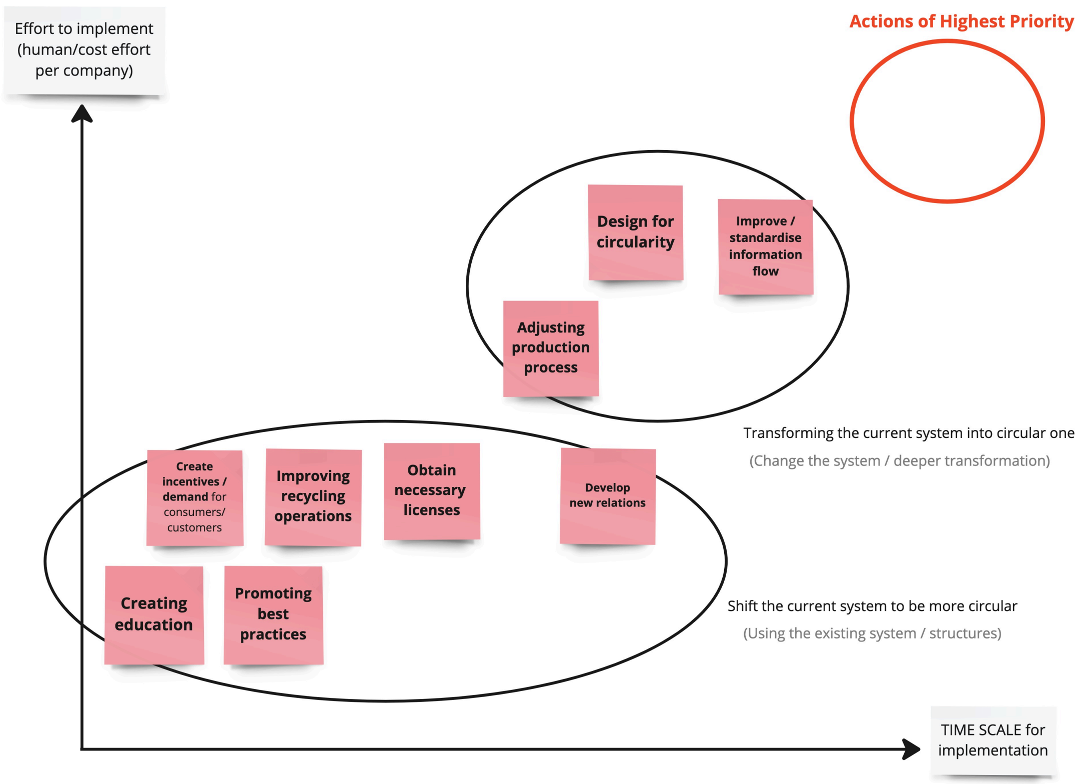


Figure 33 Priority of each action group based on effort to implement and timescale for implementation

Another suggestion on having “complexity” vs “business value” on the two-dimensional axis (see Figure 34) arose, but due to the lack of time, we could not complete the diagram given that we consume more time on the previous steps.

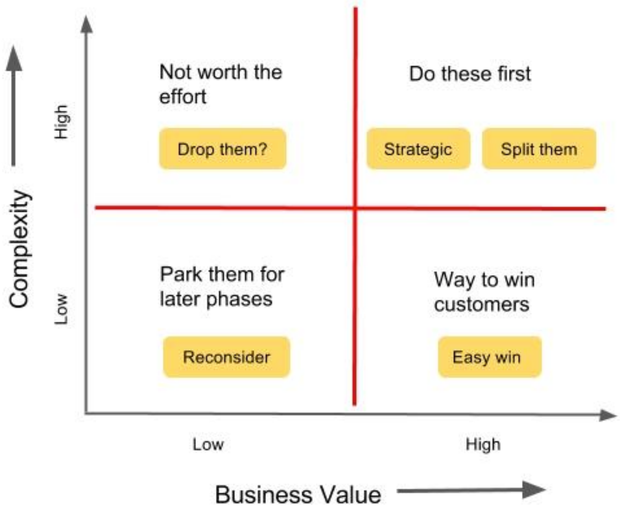


Figure 34 “Complexity” vs “business value” diagram for prioritising actions. Source: https://university.hygger.io/en/articles/1635183-value-vs-cost-and-value-vs-complexity

Likewise, the attribution of actors or stakeholders to each action group was not done during the work sessions.

5.4.7 Use case conclusion

5.4.7.1 For value chain design and development

This analysis reveals critical insights across several domains, including resource flows, information flows, infrastructure, and the broader systems environment. Each of these areas presents both challenges and possibilities for enhancing the circularity of the value chain.

In the context of resource flows, the integration of new flows, particularly those connecting material suppliers with recyclers and incorporating the paper industry, highlights the importance of proximity and communication within the supply chain but also across domains. However, the complexity of materials, especially in products like shoes, poses significant barriers to efficient recycling. Addressing these challenges requires a design-for-recycling approach, coupled with the use of biodegradable and easily separable materials.

Information flows play an essential role in ensuring that all actors within the value chain are aligned. Setting up a standardised document is crucial for an efficient and confidential data exchange between supply chain actors. Barriers such as inconsistent supply information and the high cost of accreditation like the GRS hinder the efficiency of these flows.

The infrastructure and enabling assets analysis points to the challenges posed by material diversity and the need for specialized processes. Investing in recycling infrastructure and ensuring that waste is protected from environmental conditions are critical actions for improving these flows.

Finally, the system environment analysis highlights the impact of regulatory variations and the importance of fostering a diverse industry to minimize disruptions in recycling materials. The role of government policies and licenses in shaping the system environment is crucial for supporting circular economy initiatives.

To conclude, the methodology used in this work allowed us to identify, cluster, and prioritize actions to enhance the value chain in the textile industry, particularly for promoting fibre-to-fibre recycling. Grouping these actions into distinct categories highlights the interconnectivity of the issues and underscores the need for a holistic approach to value chain improvement.

5.4.7.2 Implications for ontology development and information support

Following mapping sessions, a multitude of interdependent actions in different domains were proposed to support circular value chains in textile industry. To manage this complexity, several key points need to be addressed in developing the ontology.

- First, considering the wide variety of data and information flows between the different actors in the supply chain, the ontology must be compatible with existing standards and information systems across various stages and sectors of the value chain. To this end, it shall employ language and data organisation that all stakeholders can easily understand and access. This will facilitate collaboration and resource sharing among different groups, such as manufacturers, collectors, recyclers, brands, consumers, and regulators.
- Then, the ontology should be able to track materials, products, and components throughout their entire lifecycle and must be flexible enough to adapt to new technologies, processes, and business models as they emerge in the circular economy. Additionally, the system should include geospatial and temporal information to assist in planning and identifying local resources such as scrap materials or used shoes.
- An essential feature is the capability to record and share circularity-related data attributes of materials and products like those included in the standard Product Circularity Data Sheet (PCDS). Besides, it needs to include detailed information about product design, composition, and manufacturing processes to support design for circularity and process optimization, ultimately aiding in the creation of products that are easier to recycle or reuse.
- The ontology should encompass information about licenses, certifications, and regulatory requirements to ensure legal compliance. It should assist in the process of acquiring licenses and aid policymakers in gathering necessary data, such as proof of the benefits of allowing certain types of activity. Additionally, since policymakers have climate, employment and regional development objectives, the ontology should provide the 'evidence' or 'political business case' to support specific activities.
- Finally, the ontology should address traceability, data privacy, and security considerations allowing to protect sensitive information while still enabling necessary data sharing and transparency. Striking this balance is crucial for the system' effectiveness and for maintaining trust among all users.

6. Conclusion

Three demonstrator cases involving supply chains of varying lengths and regulatory contexts were identified for testing and validation of both the technology and ontology developed in the Onto-DESIDE project. The selected example products from each use case effectively cover an extensive range of materials, aiming to reflect circularity and data communication across diverse sectors. The new parts of the Circularity Thinking method introduced during this phase of the project provided an analytic framework, enabling a comparison of use cases regarding circularity and information flow, and offering a methodology to examine the processes observed in the demonstrations following this initial status quo assessment. Despite the different backgrounds of the use cases, the analysis showed some interesting similarities which are discussed in the following paragraphs.

The methodology developed within this project has proven effective across various use cases and sectors. It presents a comprehensive means to analyse the current logistics of value chains and pinpoint opportunities and obstacles that are critical for the shift towards a circular economy model. Through its multifaceted approach to evaluating resources, information, and value exchanges, among others, the tool encompasses a wide array of factors, ensuring a truly holistic analysis. This establishes a solid foundation to devise strategic plans for adopting circular practices, outlining the roles of particular stakeholders, defining actionable steps, and setting a clear timeline for execution. In addition, by focusing on actionable insights and overarching challenges and solutions, the methodology encourages practical discussions on concrete activities that stakeholders can take up or on devising plans to make them a reality.

This initial deliverable lays the groundwork for what might become a detailed roadmap for governments and public agencies to adopt and advocate for, promoting a shift to a more circular and resilient economy. It inspires collective action and accountability across a broad spectrum of stakeholders, including public organizations, manufacturers, and suppliers. By involving a range of actors in the initiative, it fosters a collaborative approach in task sharing and resource allocation, accelerating progress towards a mutually beneficial, sustainable transformation.

After the individual reflection of the use cases, there were some commonalities found. One of the main issues highlighted by the construction, electronics and textile use cases is the lack of data and the need to incentivise partners along the value chain to provide the required information, that is of quality and trustworthy. The definition of such data should be supported by the ontology, which, depending on the relevance and requirements per industry and actors, would determine key data points for regulation compliance, value chain processes and overall circularity. Additionally, the OCP developed within the project also contributes to information availability, given the connection it brings to stakeholders in the value chain in terms of data sharing, as well as the privacy and data protection it is built upon, following the practices and requirements mentioned by the multiple use case partners.

Second, related to the aspect above, is the specific need for composition and material information. As indicated multiple times in the use cases, companies need to know what are products made of, whether they contain certain substances or not, to be able to perform certain processes and allocate them to the most suitable routes. For example, certain substances can’t be present in the product for some recycling processes, given their release and thus harmful consequences for the environment and health. Just as before, the definition of the ontology should consider these aspects, around what do stakeholders in the value chain need to know to perform their activities, and what is needed in terms of compliance with regulations and for safe and effective handling of products. Online tools such as the OCP, and systems like Circularise, Concular and Circular Fashion address such problems. The use case partners have already demonstrated their potential and how these systems can maintain data confidential and accessible only to relevant stakeholders, without compromising its quality and enabling actors to comply with regulations, validate their claims, and achieve circular economy practices.

Finally, there is the need to consider policymakers as a key stakeholder. As seen in all use cases, there is a lack of recycling facilities and overall EoL operators and management, given the reduced investment in such initiatives, as well as no clear business models for them. Here policymakers play an important role, as they can have the power to promote such initiatives by incentivising projects, financing, standards, and new regulations that mandate and support circular strategies. Given policymakers make decisions based on data, each industry needs to determine what data is required to prove the potential of recycling cases, for example, life cycle and other sustainability assessments comparing the material flows with and without the new circular initiatives. Again, the ontology can support such goals by defining such measures and making sure they are relevant throughout the value chain, and applicable to each industry and product.

The discussions with the use cases also generated general insights on circular value chain development across the cases. These learnings are summarised as critical cross-use-case issues in Table 3. Note: since not all use cases completed every mapping task within the method, these findings may feature in either 2 or 3 of the cases and should be considered preliminary.

Table 3 - Circular Value Chain Themes and the Ontology Core Topics

Circular Value Chain Theme – critical cross-use case issues	**(Possible) Connection to WP3 core topics of ontology network & WP4 Open Circularity Platform – possibility to further explore and assess if and how this impact ontology development in WP2**
Market demand and awareness A notable lack of demand and difficulties in creating markets for secondary materials exist. One of the reasons proposed for this is insufficient customer interest and a general lack of awareness and education about circular practices, as well as a lack of incentives to encourage uptake.	• Value • Material and Product/Component

Regulatory Alignment Aligning regulations with objectives and incentives is crucial. Current contradictory regulations, coupled with ineffective business models, hinder the transition to circular systems. For example, while there is a desire for increased recycling, economic incentives, such as tax breaks for recyclers, are not adequately driving this change.	• Objectives (Tbd more specifically)
Circular Design Considerations The principles of circularity are not yet adequately incorporated into design practices. It is important to explicitly consider trade-offs. For instance, while exploring alternative materials is important, it is also crucial to evaluate how replacing one material affects the critical mass needed for the recycling of a material.	• Process • Product/Component
Collaboration for Shared Goals There tends to be a lack of collaboration focused on shared goals; often, collaboration is still primarily driven by self-interest. For example, support for recyclers is necessary to enable more circularity overall by increasing recycling capabilities.	• Value • Process • (Actors)
Scaling Solutions Even where technological solutions for circular practices exist, a significant challenge is scaling these solutions. Moreover, some processes need refinement or reorganisation, particularly in logistics, storage, and recycling operations.	• Process
Integration Challenges There is a need to better integrate circular systems and primary systems while also managing the balance between decoupling from other systems (such as dependencies on other nations) and coupling within our own systems, particularly in Europe. It is essential to adapt primary value chains to facilitate circular practices instead of merely creating new ones, ensuring that existing conditions align better with circular principles.	• Process
Standardisation of Data The standardisation and harmonisation of data are necessary. Another aspect complicating predictions regarding what data will be necessary in the future is the uncertainty surrounding future business models. Additionally, ensuring transparency and traceability throughout the circular value chain is essential for building trust and accountability.	• (implicitly included in the ontology)
Education and Skill Development There is a need for education and skills development to enhance awareness and skills among both customers and consumers about circular practices.	• Actors (Capabilities) • Tbd • – how or whether theme on consumer education is to be included in the ontology development

Trade-offs and Flexibility Adopting circular value chains may necessitate trade-offs in terms of flexibility and time, which could require adjustments to operational processes.	• Process
Different Pricing/Value strategies A need exists for differentiated (and more flexible) pricing structures. Currently, prices are determined based on an individualistic focus rather than including systemic value and externalities for the system. For example, the true cost should be integrated more commonly as done through CO_2 prices, which helps to increase demand for secondary materials. Additionally, as the quality of secondary materials can vary, more flexible pricing structures are necessary.	• Value
Recycling Capacity and Return Schemes To increase recycling capacity, it is essential to support recyclers, provide necessary information, alter regulations, and enhance economic incentives. Return schemes also remain underdeveloped across various cases and require further attention to enhance circularity.	• Process

These themes deserve further attention in WP2 (and the collaboration of the other relevant WPs) to determine how to integrate these findings into the circularity requirements being developed here and from which ontology requirements are derived, that feed into the development of the project's ontology – and whether this fits within the scope of Onto-DESIDE or constitutes further work. That is: for these themes it needs to determine how data can support or influence it, what data is needed, why the data is not there at the moment, what the solution could be and what steps should be taken to shape it (e.g. does it influence the development process (who should be involved & in what way) or whether technical requirements can already be derived). This way, the ontology can serve both the immediate concerns for sharing and exchanging data between and across value chain partners, but also – in the future – address larger questions relevant for understanding the behaviour and further development of circular value chains.

That is, to give an example, under the theme Collaboration for Shared goals, it should be further explored how the availability of data can be improved even when this data is more important for one actor or stakeholder than another. That is: can putting in data somehow be rewarded, through micro-payments or profit sharing for example, and how can an ontology support this – such as through enabling keeping track of who adds which data, and the quantity and quality of it.

Likewise, it can be explored, as part of the theme Regulatory Alignment, how data can support policy makers making decisions in favour of developing consistent regulation, but also offer decision support for issues such as developing circular infrastructure – whether this is in the form of new recycling facilities, logistical hubs or other tangible and intangible assets. And: what companies can provide or give regulators so that issues previously perceived as outside of their sphere of influence, they (re)gain a measure of control over. This requires framing policy makers as customers who input and use data also – and what their needs are.

Or: as part of Market Demand, it can be explored how potential customers can be better supported with aggregating data on resources, so that they can aggregate flows better and in more predictable ways. That is: that the ontology, if needed, can support providing insight into the different ways in which material composition is assessed (what's in it (what should be there), what's not in it (e.g. contaminants, toxins), and what resolution (e.g. parts-per-million or other) - and therefore what the potential risks or unknowns about a flow or stream are.

In short: a closer look at what data, exactly, is missing, what function it should serve and how it can be generated – and how the design of the ontology can support this can now be done based on the identified themes.

7. Appendix

7.1 Appendix 1 – Circularity Thinking - Continued

Circularity Thinking in Onto-DESIDE

To support the use of the Circularity Thinking tools within 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):

o Resources, waste and a systemic approach to CE - *Blomsma and Brennan*

o Making sense of circular economy - understanding the progression from idea to action - *Blomsma, Tennant and Ozaki*

· Explanation videos

o **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 #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[12], see Figure below (Figure 35) for how this applies to the three resource states, and which circular strategies can be used to address the waste.

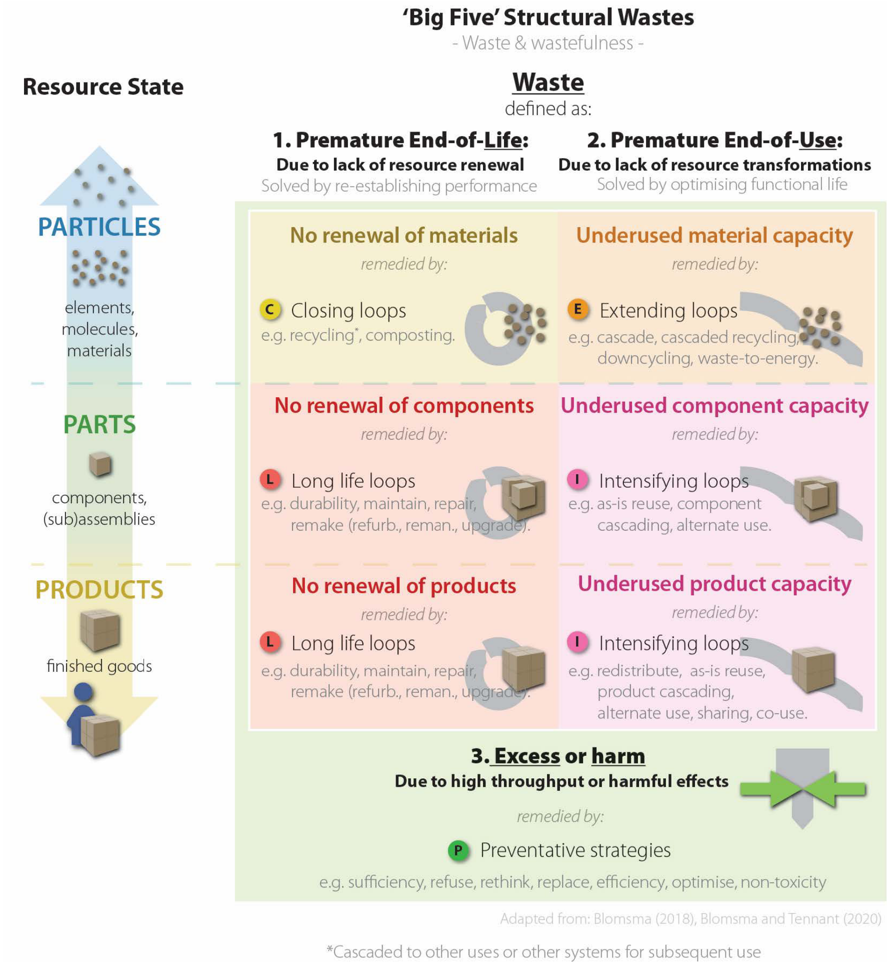


Figure 35 - Example mapping of problem situation (identifying structural wastes) and a proposed solution (identifying circular strategies solving the earlier identified problems, offering opportunities for value creation).

Circularity Thinking tool #03 - Multi-Flow Metabolism

12 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

We also know, from previous research [13], 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.[14] or Pieroni et al.[15]; for information flows see the work by Kristoffersen and colleagues[16], the call for a European Dataspace for Smart Circular Applications; and see for energy flows the work by Allwood and colleagues[17], Cullen or Bakker and colleagues[18].

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 [19] 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 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

13 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

14 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

15 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

16 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

17 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

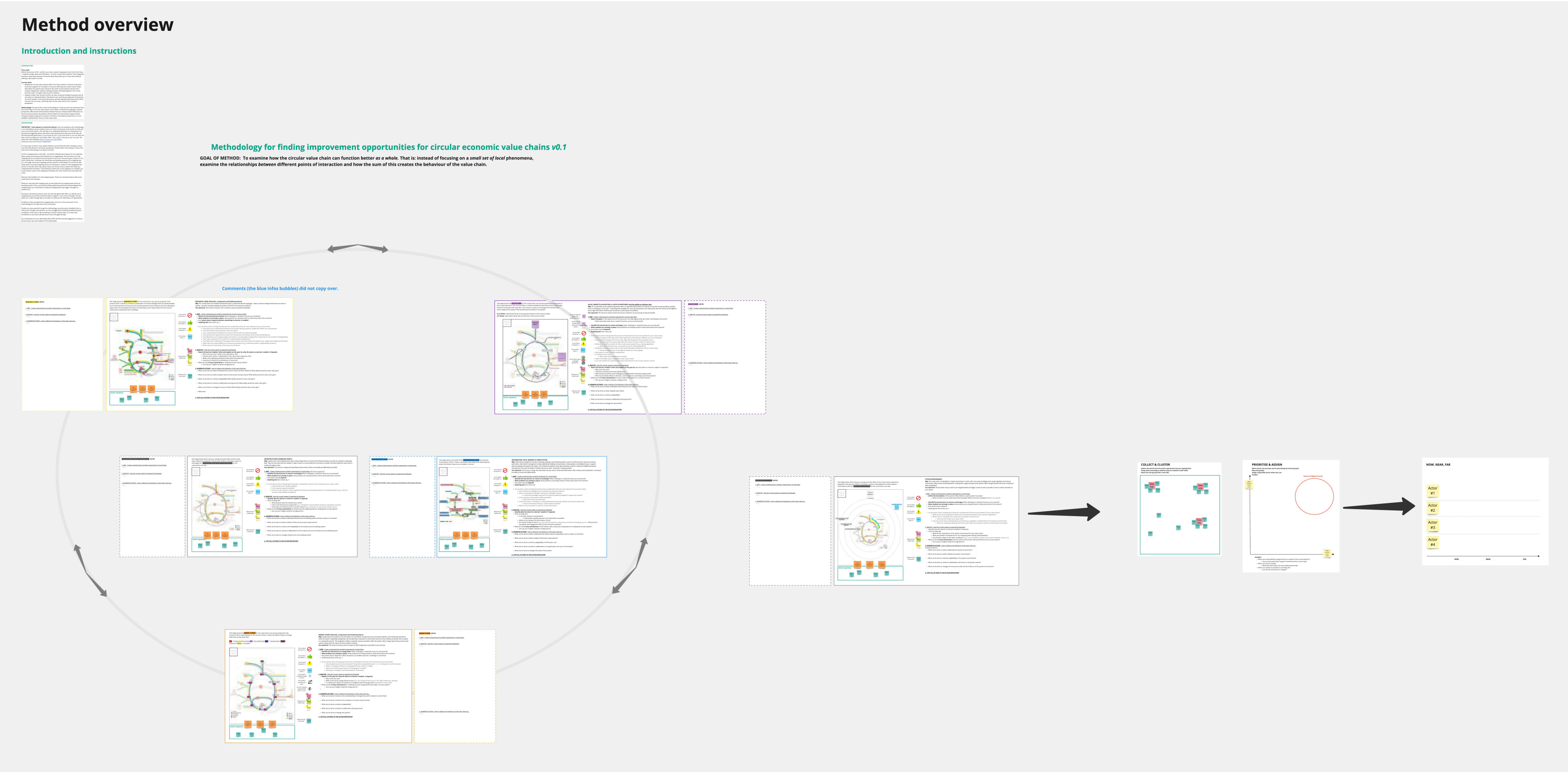
18 Bakker, C., Wang, F., Huisman, J., & den Hollander, M. (2014). Products that go round: Exploring product life extension through design. *Journal of Cleaner Production*, *69*, 10–16. https://doi.org/10.1016/j.jclepro.2014.01.028

19 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

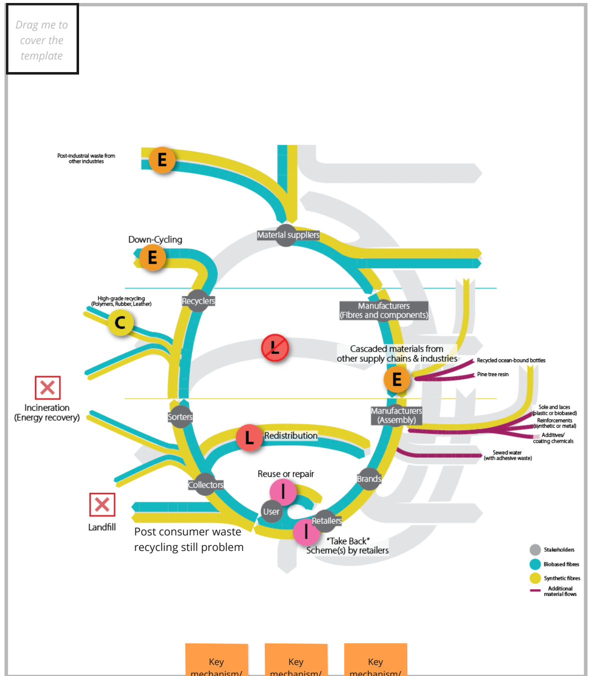
needs and with that for the ontology to be designed in Onto-DESIDE. This then also formed an important foundation for WP05 that further conceptualises, develops, validates and implements tools and approaches that transform the Multi-Flow Metabolism (MFM) model into a method for the accelerated development 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.).

7.2 Appendix 2 – Multi Flow Method (full version)



This image shows the **RESOURCE FLOWS** for the construction use case (as prepared in the process of D6.1 and D6.2). It shows a combination of circular strategies that are already feasible from a technical point of view, yet some of the proposed circular solutions cannot be operated a larger scale, thus standing in the way of a functioning circular value network for the reuse of construction components from a building.



Action repository

Action A | Action B | Action C | Action D

Put me where the barrier is >

Put me where the enabler is >

Put me where 'it depends' is >

Put me where 'other' is: (other)

Add post-its to explain why: Why? Why? Why?

Add post-its for each action In what way?

RESOURCE FLOWS: Materials, components and finished products
Why: *For circular flows to be realised and function well it is important that the exchanges - when a resource changes hands from one actor to another - function smoothly enabling the system's OUTPUTS to also become its INPUTS.*
You represent: *the resources and your aim is to flow as long as possible and feasible.*

***1. MAP** - Create a shared picture of what's important for circular resource flows*

- **Where are the key barriers located:** what challenges or obstacles have you encountered?
- **What enablers are already in place:** what problems are already solved or what works well at the moment?
- And, **where does it depend whether something is a barrier or enabler**?
- **Anything else** that comes up...?

- For the above, think of things like (Choose the considerations that are most relevant for your value chain):
  - How well do you understand the flows at the moment (timing, quantity, quality etc)? Where are uncertainties?
  - How well are flows synchronised in time and space?
  - How consistently and reliable do the resources flow within the system? [Supply]
  - How well does the system bounce back from disruptions and maintain flow continuity? [Resilience]
  - How effectively can the system adjust and evolve to accommodate changing flow requirements and conditions? [Adaptability]
  - How ready / prepared is the solution for implementation? [Readiness]
  - How high is the complexity of the supply chain and how does that impact the system? (e.g., supply chain length and diversity)
  - Where does the responsibility for the resources transition? (e.g., Extended producer responsibility schemes)
  - Where does the ownership of the resources transition?

***2. ANALYSE** - How the circular system (is expected to) behave(s)*

- **Name the barrier/ enabler/ other and explain on the post its: why the above is a barrier/ enabler/ it depends**
  - Why is this the case? / What is the rationale for this?
  - How do other actors or stakeholders in the value chain respond to this?
  - What's the underlying mechanism that drives the behaviour?
  - How does it influence the distribution of resources?
- What are the **2-3 key mechanisms** for enabling circular resource flows?
  - Sum up your insights using the orange post-its.

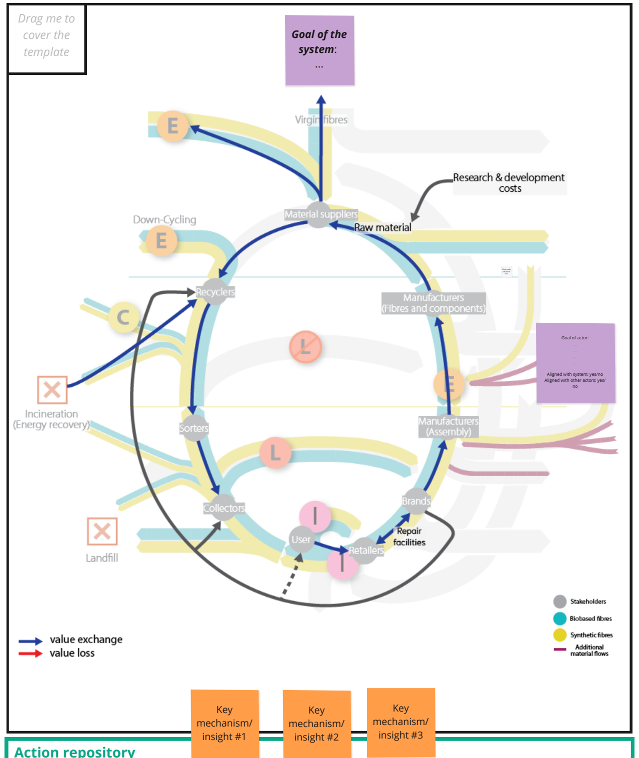
***3. GENERATE ACTIONS** - How to influence the behaviour of the value chain by...*

- What can be done to better *understand* the resource flows and their relations? What ability would the value chain gain?
- What can be done to better *evaluate* resource flow actions and processes? What ability would the value chain gain?
- What can be done to enhance *adaptability*? What ability would the value chain gain?
- What can be done to enhance *collaboration* (among actors)? What ability would the value chain gain?
- What can be done to *manage* the resource flows? What ability would the value chain gain?
- What else?

4. COPY ALL ACTIONS TO THE ACTION REPOSITORY

This image shows the **VALUE FLOWS** for the construction use case (as prepared in the process of D6.2) superimposed on the resource flows. It shows the *financial* value flows of the circular value network and presents *who* pays *who*. This canvas is a space to interrogate the financial flows more closely and to explore other benefits and incentives in the system.

BLUE flows: value flows that go in the opposite direction of the resource flows
RED flows: value flows that go with the direction of the resource flows



Action repository

Action A | Action B | Action C | Action D

Use me to name the goals of the system/key actors >

Use the icons to indicate what value each aim creates > **Env. Fin. Soc.**

Put me where the barrier is >

Put me where the enabler is >

Put me where 'it depends' is >

Put me where 'other' is: (other)

Put me where value is exchanged/ gained/lost >

Add post-its to explain why: Why? Why? Why?

Add post-its for each action In what way?

VALUE, BENEFITS & INCENTIVES vs COSTS & INVESTMENT **<u>and the ability to influence this</u>**

Why: *For circular flows to be realised and function well it is important that all actors not only act in line with circular principles, but that there is something 'in it' for them - something that outweighs the costs and investments. And, importantly, that the interests of the different actors align WITH EACH OTHER as well as with the circular system AS A WHOLE.*

You represent: *The resources and you want to be of use to everyone on your journey as long as possible.*

***1. MAP** - Create a shared picture of what's important for circular value flows*

- **Name the goals**: of the system and of the key actors. Are they aligned with each other? And between the actors?
  - What value does each aim to create? Economic, social, environmental?
- **Identify the key barriers to value exchanges:** what challenges or obstacles have you encountered?
- **What enablers are already in place:** what problems are already solved or what works well at the moment?
- And, where does **it depend?**
- **Anything else** that comes up?
- For the above, think of things like (Choose the considerations that are most relevant for your value chain):
  - What is the goal of the value chain? (Does agreement exist between different actors on that goal?)
  - How well does the goal of the value chain align with the goals of the individual actors?
    - Do the goals of the actors align with each other? Or does conflict of interest exist?
  - What other benefits are there for the circular value network? (e.g., meeting legislation)
    - What risks are there? (e.g., consequences of not meeting legislation)
  - Who/what creates or adds to the circular value? Who/what subtracts from the circular value?
    - *Use the exchange / plus / minus signs to indicate it on the mapping.*
  - Who pays the costs or makes investments?
  - Incentives versus value
    - What costs are imposed (from outside)?
  - What's the added value compared to linear value chains?
  - Can new markets be created for the value chain (based on the circular solutions chosen

***2. ANALYSE** - How the circular system (is expected to) behave(s)*

- **Name the barrier/ enabler/ other and explain on the post its:** why the above is a barrier/ enabler/ it depends?
  - Why is this the case?
  - How does it influence the value distribution?
  - What outcomes will the actors willingly pursue? And which will they actively avoid?
  - Who has the ability influence decisions, control resources, and shape outcomes? [power]
- What are the **2-3 key mechanisms** for value creation and capture in a circular manner?
  - Sum up your insights using the orange post-its.

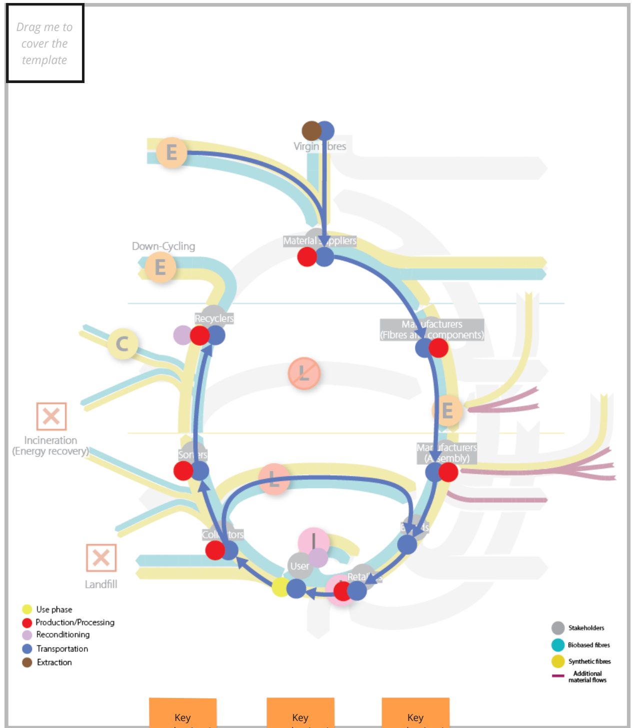
***3. GENERATE ACTIONS** - How to influence the behaviour of the value chain by...*

- What can be done to better *understand* value flows (and its relation to other flows)?
- What can be done to better *evaluate* value flows?
- What can be done to enhance *adaptability*?
- What can be done to enhance *collaboration* (among actors)?
- What can be done to *manage* the value flows?

4. COPY ALL ACTIONS TO THE ACTION REPOSITORY

This image shows the **ENERGY FLOWS** for the construction use case (as prepared in the process of D6.2) superimposed on the resource flows. It shows the different types of energy within the circular value flow.

Red = Production/Processing. Pink = Reconditioning; Blue = Transportation; Brown = Extraction; Yellow = Use phase.



Key mechanism/ insight #1 | Key mechanism/ insight #2 | Key mechanism/ insight #3

Action repository

Action A | Action B | Action C | Action D

Put me where the barrier is >

Put me where the enabler is >

Put me where 'it depends' is >

Put me where 'other' is: (other)

Put me where renewable energies are used >

Put me where fossil fuels are used >

Use me to indicate energy intensity (use 1, 2 or 3) >

Add post-its to explain why: Why? Why? Why?

Add post-its for each action In what way?

ENERGY FLOWS: Materials, components and finished products

Why: *Energy inputs and outputs across the system are essential for moving resources, processing materials, and maintaining operations within the system. Integrating energy flows into the planning is important to ensure that resources can be utilised, processed, and circulated in a sustainable manner. This integration enables a seamless resource transition within the system, where energy inputs drive processes that convert outputs back into inputs, and thus enable circularity.*

You represent: *The resources and you want to require as little energy input as possible on your journey.*

***1. MAP** - Create a shared picture of what's important for circular flows*

- **Identify the key barriers to energy flows:** What challenges or obstacles have you encountered?
- **What enablers are already in place:** what problems are already solved or what works well at the moment?
- And, where does it depend? in which situations can enablers become a challenge or vice-versa?
- Anything else that comes up...?

- For the above, think of things like (choose the considerations that are most relevant for your value chain):
  - How energy intense are the processes? (For general comparability, place 1, 2 or 3 energy icons on the process)
  - Where is energy lost? Where is energy gained? (e.g., waste to energy)
  - Where are missed opportunities for energy gains / savings?
  - What type of energy is used? (renewable vs. fossil fuels)

***2. ANALYSE** - How the circular system (is expected to) behave(s)*

- **Explain on the post its: why the above is a barrier/ enabler/ it depends**
  - Why is this the case?
  - What is the macro energy infrastructure? (e.g., the energy infrastructure in the region where you operate)
  - Is it within your sphere of influence to change the kind of energy used? (renewable vs fossil fuels)
- What are the **2-3 key mechanisms** for enabling (circular) energy flows that enable a circular system?
  - Sum up your insights using the orange post-its.

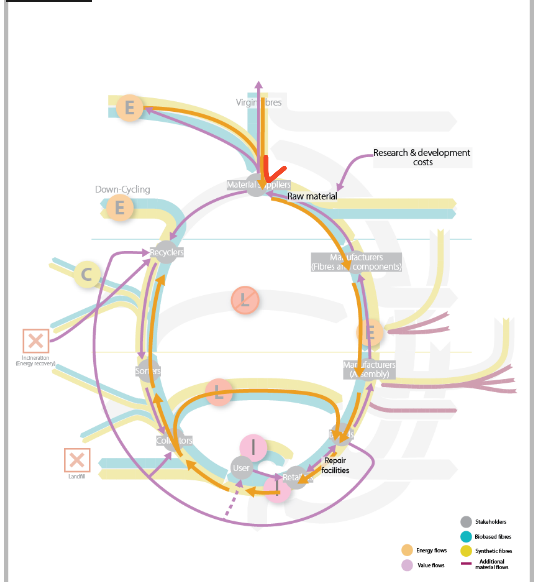
***3. GENERATE ACTIONS** - How to influence the behaviour of the value chain by...*

- What can be done to enhance the understanding of energy flows and its relation to other flows?
- What can be done to enhance the evaluation of actions and processes?
- What can be done to enhance adaptability?
- What can be done to enhance collaboration (among actors)?
- What can be done to manage the system?

4. COPY ALL ACTIONS TO THE ACTION REPOSITORY

This image shows all the resource, energy and value flows of the circular value network (as prepared in the process of D6.2). It provides a space to interrogate the **INFRASTRUCTURE AND ENABLING ASSETS** for the construction use case.

Drag me to cover the template



Key mechanism/ insight #1

Key mechanism/ insight #2

Key mechanism/ insight #3

Action repository

Action A

Action B

Action C

Action D

Put me where the barrier is >

Put me where the enabler is >

Put me where 'it depends' is >

Put me where 'other' is: (other)

Add post-its to explain why: Why? Why? Why?

Add post-its for each action In what way?

INFRASTRUCTURE & ENABLING ASSETS:

Why: *Infrastructure and enabling assets refer to those things that are not part of the flows themselves, but that are needed to make flows flow. These are the assets that are needed or make it easier to connect flows from one point to another and that enable the value chain to create and capture value.*

You represent: *The resource, energy and value flows and you want to flow as smoothly and efficiently as possible .*

***1. MAP** - Create a shared picture of what's important for circular flows [add timing suggestion]*

- **Identify the key barriers to resource exchanges:** What challenges or obstacles have you encountered?
- **What enablers are already in place:** what problems are already solved or what works well at the moment?
- And, where does **it depend**?
- **Anything else** that comes up…?

- For the above, think of things like (choose the considerations that are most relevant for your value chain):
  - Is the infrastructure readily available?
  - Is the required capacity available?
  - Do the circular solutions require additional infrastructure/enabling assets for its implementation? (e.g., does the customer need additional support?)

***2. ANALYSE** - How the circular system (is expected to) behave(s)*

- **Identify why the above is a barrier/ enabler/ it depends**
- Think of things like:
  - What purpose does the infrastructure serve?
  - How is the infrastructure organised? (e.g., centralised vs decentralised; shared vs ownership vs public)
  - How long is the infrastructure to remain in place? (e.g., temporary vs. permanent infrastructure)
- What are the **2-3 key mechanisms** of infrastructure & enabling assets for enabling the circular system?
  - Sum up your insights using the orange post-its.

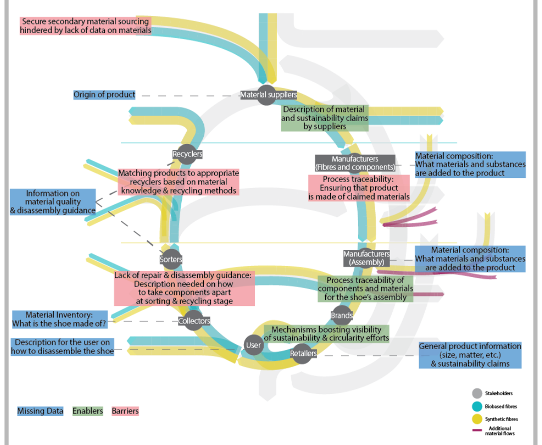
***3. GENERATE ACTIONS** - How to influence the behaviour of the value chain by…*

- What can be done to better *understand* infrastructure & enabling assets and their relation to the flows?
- What can be done to better *evaluate* infrastructure & asset requirements?
- What can be done to enhance the *adaptability* of the infrastructure & enabling assets?
- What can be done to enhance *collaboration* for the creation and use of infrastructure & enabling assets?
- What can be done to *manage* infrastructure and enabling assets?

4. COPY ALL ACTIONS TO THE ACTION REPOSITORY

This image shows a first draft of the **INFORMATION FLOWS** (as prepared in the process of D6.1). That is, it provides a first draft of the data required, where information may act as an enabler or barrier.

Drag me to cover the template



Key mechanism/ insight #1 | Key mechanism/ insight #2 | Key mechanism/ insight #3

Action repository

Action A | Action B | Action C | Action D

Put me where the barrier is >

Put me where the enabler is >

Put me where 'it depends' is >

Put me where 'other' is: (other)

Add post-its to explain why: Why? Why? Why?

Add post-its for each action In what way?

INFORMATION, DATA, MEMORY & COMPUTATION

Why: *Information management involves collecting, analysing, and distributing data to ensure all relevant actors have the necessary information. Information management includes effectively handling communication, timely updates, and feedback loops to support decision-making and maintain the system. This includes the ability to store data (memory) as well as compute for different purposes, meaning that one needs the ability to handle and process data - sometimes in large quantities.*

You represent: *The resource, energy and value flows and you want to know what information, data, memory and computation is necessary to enable a smooth and efficient flow.*

***1. MAP** - Create a shared picture of what's important for circular flows*

- **Identify the key barriers to resource exchanges:** What challenges or obstacles have you encountered?
- **What enablers are already in place:** what problems are already solved or what works well at the moment?
- And, where does **it depend?**
- **Anything else** that comes up?

- For the above, think of things like (choose the considerations that are most relevant for your value chain):
  - Does sufficient knowledge exist to facilitate the proposed solution?
  - Where is speciality knowledge / particular knowledge required?
    - Is external knowledge required? Are external (experts) available to support the system?
  - Is the necessary information readily accessible?
    - What forms does the data have?
  - If the information is available, is it being effectively shared with relevant actors (who requires it)?
    - How is information sharing / communication handled?
  - What are the incentives for actors to share information?

***2. ANALYSE** - How the circular system (is expected to) behave(s)*

- **Identify why the above is a barrier/ enabler/ it depends**
- Think of things like:
  - Is the data collection standardised?
    - Is information quality assured? Is the information traceable?
  - Where is the timing of the information critical?
  - Do mental models of actors (e.g., personal assumptions, experiences, professional background, etc.) influence their perception and engagement with circular economic practices?
- What are the **2-3 key mechanisms** of information, data, memory & computation for enabling the circular system?
  - Sum up your insights using the orange post-its.

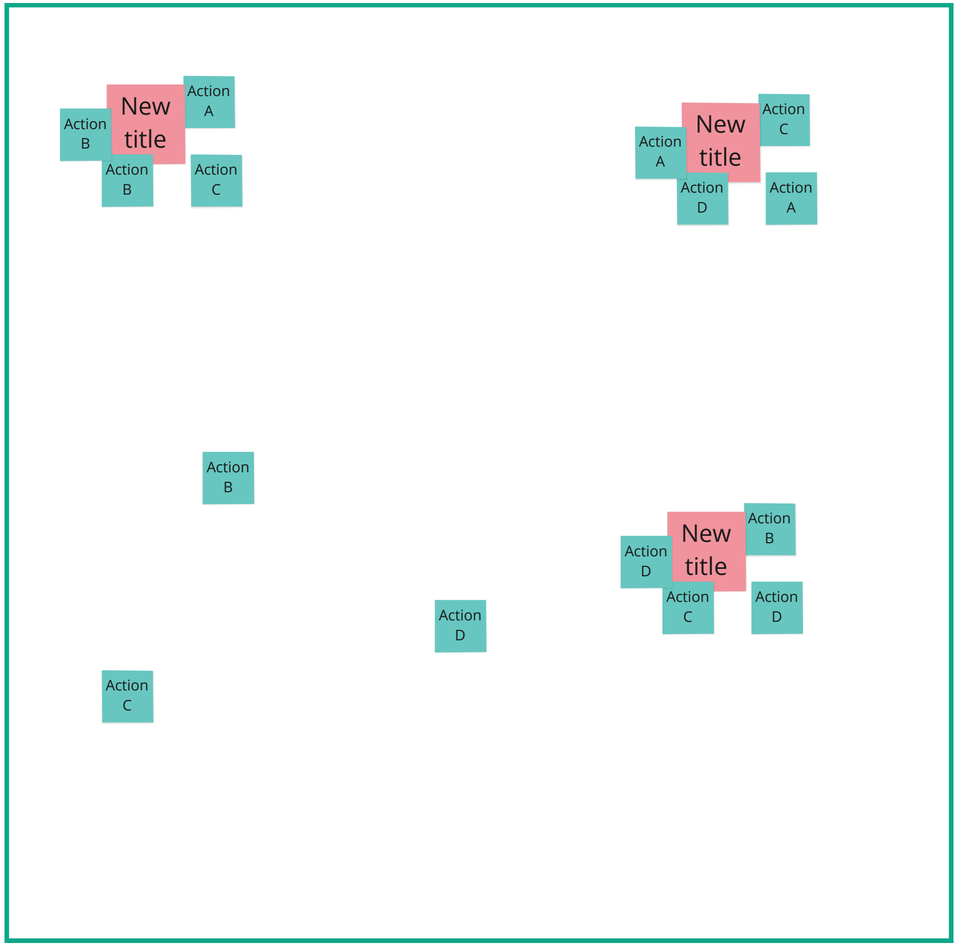
***3. GENERATE ACTIONS** - How to influence the behaviour of the value chain by...*

- What can be done to better *understand* information, data & computation and its relation to the flows?
- What can be done to better *evaluate* information requirements?
- What can be done to enhance *adaptability* of information use?
- What can be done to enhance *collaboration* on the generation and use of information?
- What can be done to *manage* information flows better?

4. COPY ALL ACTIONS TO THE ACTION REPOSITORY

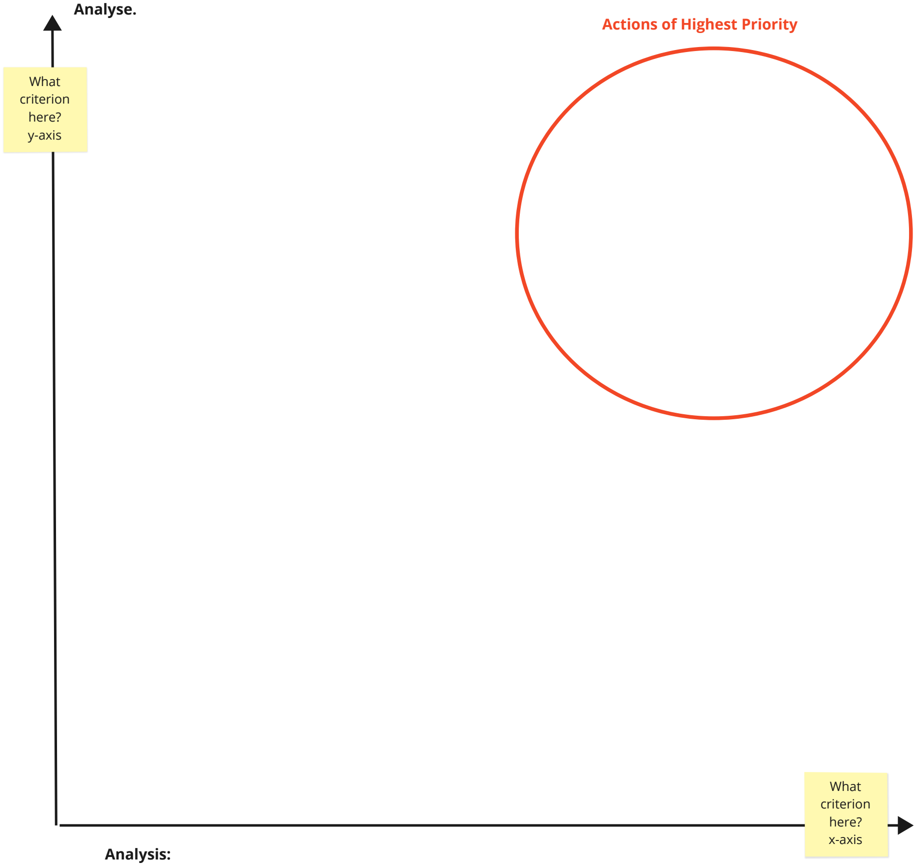
COLLECT & CLUSTER

Gather all actions from the Action repositories here by copying them.
Group them according to whether they are related to each other.
Name the new groups with a new title.



PRIORITISE & ASSIGN

What criteria can you best use for prioritising the Action groups?
Place the groups.
Assign responsible actors where you can.
Analyse.



Analysis:

- Where are responsibilities assigned that are outside of the current partners?
  - Can you work with them/ support/ incentivise them in some way?
- Where are actors missing?
  - What does that mean? Can new collaborations help?
- Where is it simply not possible to do things yet?
  - Can this be monitored for changes?

NOW, NEAR, FAR