ONTO-DESIDE

DELIVERABLE

Project requirements specification and research methodology – v3

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Project summary

Circular economy aims at reducing value loss and avoiding waste, by circulating materials or product parts before they become 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 that enables collaboration in a secure and privacy-preserving manner.

The project addresses several 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 by considering resource, information, value and energy flows as an integral part of the same complex system. Three industry use cases, from radically different industry domains, act as drivers for the research and development activities, as well as test beds and demonstrators for the cross-industry applicability of the results. The developed solutions will allow for automation of planning, management, and execution of circular value networks, at a European scale, and beyond. The project thereby supports acceleration of the digital and green transitions, automating the discovery and formation of new collaborations in the circular economy.

Project start date and duration

1st of June 2022, 36 months

Project consortium

No	Partner	Abbreviation	Country
1	Linköping University	LIU	Sweden
2	Interuniversitair Micro-Electronica Centrum	IMEC	Belgium
3	Concular Ug Haftungsbeschrankt	CON	Germany
4	+Impakt Luxembourg Sarl	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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Table of Content

Abbreviations

Abbreviation	Explanation
GDPR	General Data Protection Regulation
PCDS	Product Circularity Data Sheet
FAIR	Findability, Accessibility, Interoperability, and Reuse of digital assets

1 Introduction

The Onto-DESIDE project applies an iterative methodology, 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, it constitutes 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 technical Work Package (WP) contributes to all the iterations. The WP dependencies are illustrated in **Error! Reference source not found.** where the details of the first project iteration are shown. 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).

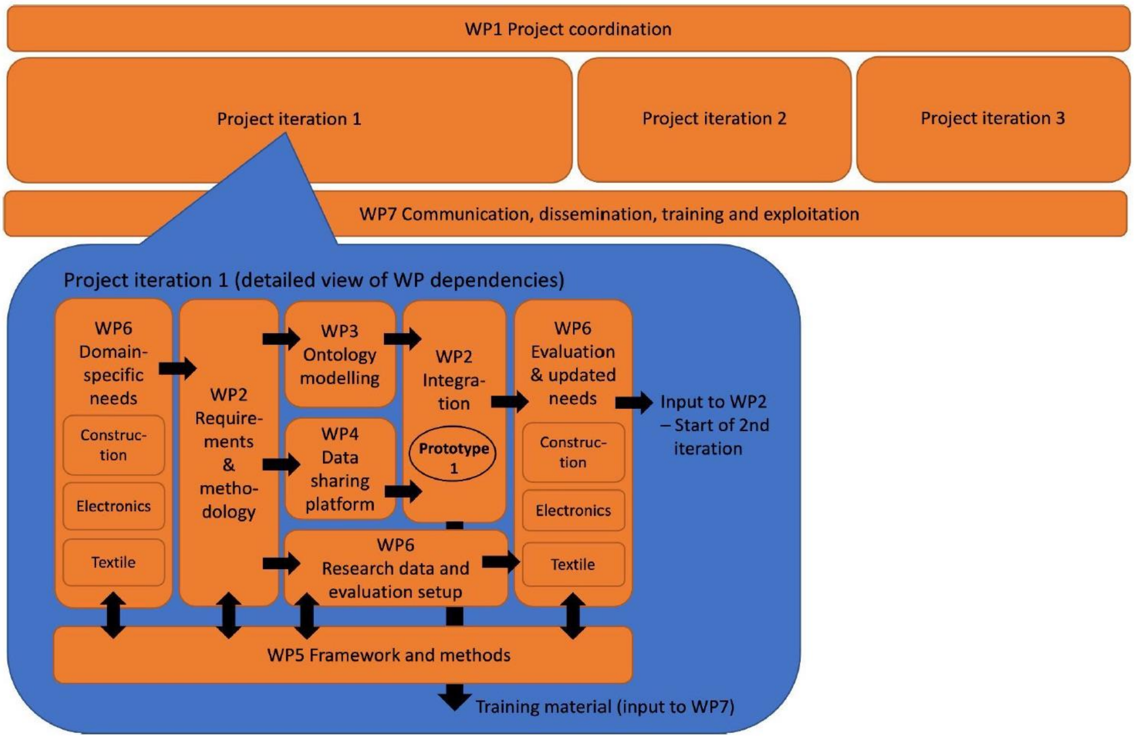

Figure 1: Project outline and dependencies between work packages.

1.1 Objectives and research methodology

1.1.1 Objectives

Work package 2 (WP2) will ensure the generalization over the three use case domains as described in industry use cases in WP6 ensuring that the project treats a set of requirements that covers the needs of all the three use cases, but that are general enough to also apply in other industry domains.

The WP2 will also be responsible for setting up the overall research and development methodology applied in the project, as well as performing the technical integration of software components, and protocols for data sharing, to ensure that a coherent technology stack for ontology-based data documentation is delivered at the end of the project.

Further, the WP2 is responsible for preparing a standardization plan for the results produced in the project and initiating standardization efforts according to that plan.

1.1.2 Research methodology

The concrete research process of the Onto-DESIDE project has been divided into three iterations, each divided in 3 steps (cf. Figure 2):

- Step 1: analysis of needs and elicitation of requirements
- 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 and requirements to start off the next iteration.

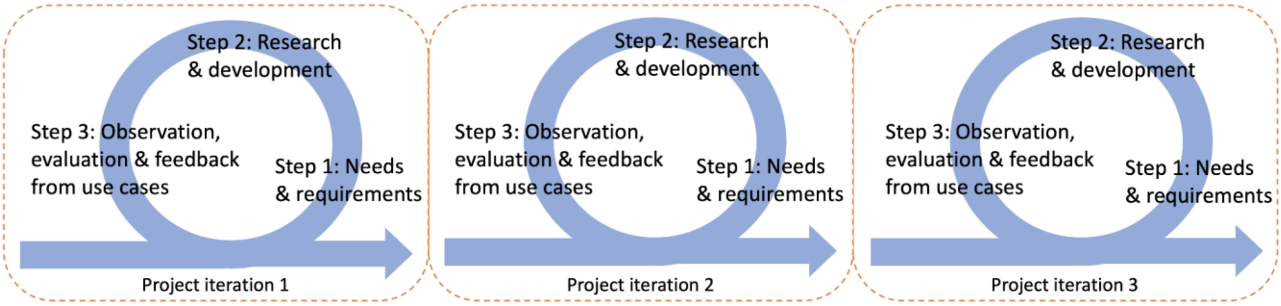

Figure 2: The Onto-DESIDE research process, divided into 3 iterations, each consists of three steps.

Specifically, for WP2, the focus is on transforming the use case definitions of WP6 into technical requirements that will be the base for further work in WP3 and WP4. For this, practices from the software engineering domain will be used to capture and detail functional requirements in the form of user stories, (Figure 3).

Additionally, non-functional requirements, such as performance and security that are not directly linked to specific functionality that users need to fulfil their tasks, will be derived from the project specification and included as a list in this deliverable.

FIGURE 3 DIAGRAM VISUALIZING THE WORKFLOW OF WP2 AND THE RELATED ARTIFACTS

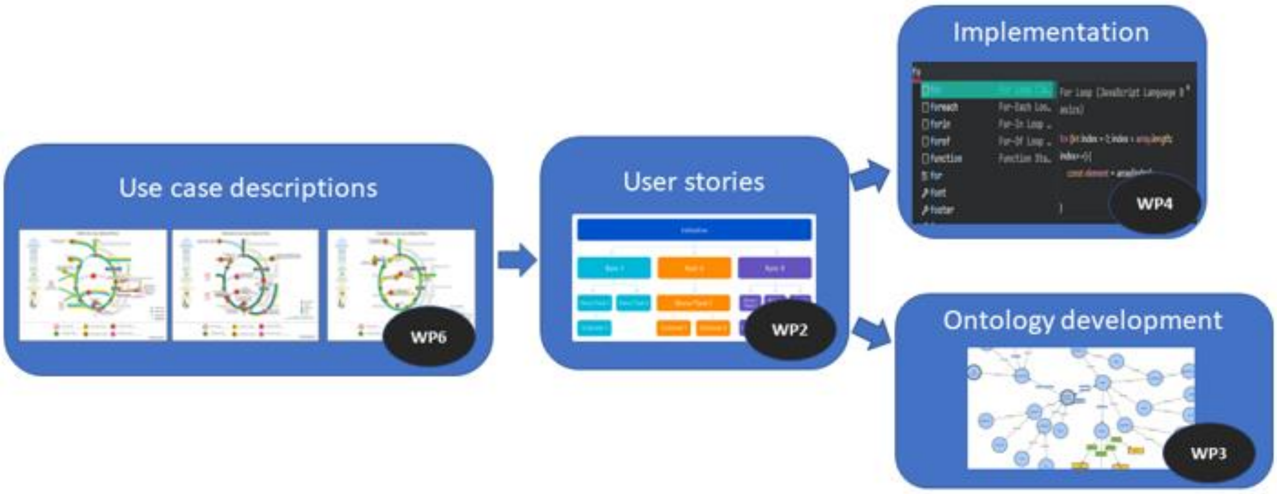

Figure 3: Overview of the workflow between work packages.

User stories for capturing functional and circularity requirements

A user story is an informal, general explanation of an action that needs to be taken to achieve a certain result. User stories are written from the perspective of the end user. Its purpose is to articulate how the user plans achieving a certain goal or task.

For the purpose of this project, user stories will be defined and based on the detailed use cases produced in WP6. The same approach will be used to also capture circularity requirements coming from the methodology development in WP5.

For use-case and circularity requirements, the numbering system used will reference the use case or CE (abbreviated in two letters), then the number of the user story, lastly the textual name of the story heading. The layout of a user story would be text represented in a document as illustrated in Figure 4.

TUS1: Access to production data
As a: Fiber Supplier **I want:** To access data about processes in which the waste I use in combination with my raw material have been produced **So that:** I can assure the quality and the sustainability of the material (traceability) **Additional context information** I introduce recycled fibers (from post-industrial or pre-consumer uses) to my raw material to improve the sustainability of my textile fibers (% of recycled content) **Data needs:** - Process generating waste - Recycling process used - Product characteristics

Figure 4: Example of a user story layout

As a guidance for writing a user story the following template is used:

- As a (**who** wants to accomplish something)
- I want to (**what** they want to accomplish)
- So that (**why** they want to accomplish that action, item, etc.)

Additionally, each user story will follow a use case specific numbering scheme where the first letter is the use case, followed by the number of the specific user story. As an example, the first user story in the construction use case would be CUS1, followed by CUS2, etc. Also, where possible, a short extra context description will be given as well as generic pointers to what type of data are required (see example template above).

Generalisation into cross-domain requirements
Throughout the tree iterations of the project, we also consider generalizations in the sense of user stories that prove to have relevance for all the use cases. These user stories are then rephrased as cross-domain requirements, as to point out that they support more than one use case. Further detailing of the use-case requirements into ontology requirements in WP3 and the evaluations of the platform in WP4 will be used as input into compiling the cross-domain requirements. This process are repeated over the three iterations of the project. These cross-domain requirements will be represented in the same way as the functional and circularity requirements, but with the addition of references to the respective use-case and circularity requirement that underpin them.

Circularity requirements
The development of methods to find, analyse, and assess new value chain configurations is done within WP5. WP5 is using and extending tools from Circularity Thinking (developed by Blomsma and colleagues) for the accelerated development of systemic circular solutions. To evaluate the circularity methodology throughout the project, requirements pertaining to circularity are listed as part of this deliverable. See chapter 3, circularity requirements for further detail.

1.2 Tasks and deliverables

WP2 is led by RS and is divided into four tasks, each related to the objectives of the work package. These tasks are outlined below:

- T2.1 - Requirements - lead: RS - participants: all project partners
- T2.2 - Integrated methodology framework - lead: UHAM - participants: LIU, IMEC, RS
- T2.3 - Technical integration - lead: RS - participants: LIU, IMEC, CIRC
- T2.4 - Standardisation - lead: POS - participants: LIU, IMEC, RS

Eight deliverables are to be produced for WP2 during the project:

- D2.1 Project requirements specification and research methodology (v1 M6, v2 M20, v3 M29)
- D2.4 Software and protocol releases (v1 M12, v2 M24, v3 M33)
- D2.7 Standardization plan (v1 M18, v2 M30)

This document constitutes the report for deliverable D2.3 and aims to collect and describe industry needs from the three use cases in the project and based on these provided generalisations on cross domain needs. It also includes collecting legal, ethical, security and privacy requirements and generalising from all three use cases as they are documented in WP6.

2 Data needs analysis

The deliverable D6.3, Use Case Needs Analysis and Circular Value Flow Mapping – Report v3, produced in WP6 constitutes the most recent update of the use case mapping, providing a detailed overview of their respective flows. That deliverable also presents general insights on circular value chain development that were generated across the cases. Table 3 (Circular Value Chain Themes and the Ontology Core Topics) of D6.3 summarised these learnings as critical cross-use-case issues. This summary table includes different dimensions of what are considered important issues, some relate to market and regulations while others relate to education and skills. There is also the dimension of data, more explicitly, the availability or lack of it.

In the current chapter we aim to provide an overview of where the collective partners of the Onto-DESIDE project identify data gaps; that is: first, from the perspective of realizing the goals set out for the project and thus meeting the requirements, and second, where we see that additional data would open up other possibilities – possibilities that might have been obscured before the project and that would play a positive role in enabling the objectives set out for the project.

Based on table 3 in D6.3 we have grouped the themes presented there into a list of areas and corresponding data needs that are deemed important in this stage of the project.

2.1 Market demand and awareness

In the analysis of the use cases, and discussions with use case partners, a notable lack of demand and difficulties in creating markets for secondary materials have been noted to 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.

Data needs:
In order to improve such a situation, e.g. to increase the demand by increasing awareness and education on circular practices, and potentially inspire future initiatives and new incentives for uptake, there are certain data needs that have to be met. To enable awareness of actual demand and availability, data about the availability (current and future potential availability) of materials, components and products need to be shared. This could on one hand mean data about actual materials, components and products, such as through marketplaces for offers or match-making services. However, it could also mean data of potential, e.g. potential availability, such as the capacity of an actor to provide a certain material, component, or product. Or even the potential of replacing materials, components and products in current flows, based on new research and innovations.

Current state and how realistic it is to fulfil the need:
Currently, CE actors might share their needs with close collaborators, but rarely publicly, except for posting calls for offers on public marketplaces or in industry networks. Hence, it is currently not possible to assess the overall demand and interest in a certain material, component or product. While the proposed technologies of this project can technically support the sharing of such data, in a comparable and semantically compatible way, they do not necessarily increase the incentives or willingness to share such information. Hence, at the moment it does not seem realistic to scale such sharing to the full CE, but it will likely remain within closed collaboration networks. However, the outlook for raising awareness of CE practices and opportunities in general is much better, since this data is not company-specific and often not confidential. Instead such data can be extracted from scientific publications, and white papers, etc. However, this still requires some elaborate technologies, not covered by this project, in scaling the extraction of such data from natural language text.

2.2 Regulatory Alignment

A second aspect arising from the discussion with the use case partners is that the alignment of 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.

To support circular economy practices, the availability of information regarding products (e.g. chemical and sourcing composition, mechanical and physical properties, etc.) is key. End-of-life (EoL) operators need to know the presence or absence of certain substances on the components they process for better and more efficient handling. However, companies are very concerned about their sensible data being leaked, harming their IP. Establishing regulations around data sharing and transparency among value chains would help achieve such goals and facilitate traceability for better practices. Additionally, regulation enforcing the use of recycled content would make companies prioritise circularity practices for using EoL components as raw materials.

Along these lines, product-specific Delegated Acts (under ESPR) define mandatory performance and information requirements. All three use cases in the project are affected by the ESPR working plan; Iron and Steel (which are construction products), textiles (in particular garments and footwear), energy related products, Information & communication technology products and other electronics (presented during ESPR webinar, 22.05.2024). The European Commission is expected to implement ESPR and adopt Delegated Acts around 2026, but some requirements have already been communicated in preliminary ESPR studies. This kind of regulation drives the sharing of data, which in many cases can support and drive change, while other incentives may still be lacking.

Data needs:
In order to assess the effectiveness of existing and emerging legislation, and the alignment between objectives and current regulation, data on the actual operation of the CE, beyond mere product data, will be needed. For instance, the amounts of materials, components and products in circulation, at an aggregated level (e.g. at a macro level) is an important aspect to assess for analysing the extent to which materials and components are circulated, rather than becoming waste.

Current state and how realistic it is to fulfil the need:
Emerging legislation will drive the sharing and availability of detailed information regarding products (e.g. chemical and sourcing composition, mechanical and physical properties, etc.), including the presence or absence of certain substances in materials, components and products which will ensure more efficient handling and enables implementation of more circular practices. From an EU perspective, the work being done as part of implementing the ESPR will mandate that more CE relevant data will have to be shared. Working closely to the implementation of the legislation will uncover what data become available and for what applications that data could be used. This is also not a constant state that will either be implemented and concluded. Rather it will be a process, that going forward will uncover additional areas where new/additional data will have to be shared.

However, in order to ensure better regulatory alignment, data on the overall operation of the CE must become available to researchers and policy makers, to assess the actual effects of existing and emerging regulations. This implies scalable data integration and aggregation over the CE as a whole, not only in the traceability of individual products and materials. While this project lays the foundation for semantic interoperability and web-scale data sharing, actual scalability assessments and issues around data aggregation and access by policy makers is still open challenges.

2.3 Circular Design Considerations

Another observation made in the use case analysis was that 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.

Products should be designed with a circular mindset ensuring that when they reach their End-of-Life (EoL), it is easy for EoL operators to allocate them to the appropriate "next stage" (e.g., reuse, repair, re-manufacture, or recycling). To achieve this, circularity must already be considered in the design phase. For example, material composition and component modularity should be accounted for during design, making disassembly or repurposing more efficient. Additionally, circular design should consider trade-offs, such as how the choice of alternative materials affects the recyclability, and the critical mass needed for economically viable recycling processes.

To ensure products are effectively cycled back into reuse, repair, re-manufacturing, or recycling stages, stakeholders across the value chain need to align their processes and requirements. Upstream actors (designers and manufacturers) should engage with downstream stakeholders (EoL operators, recyclers, re-manufacturers) early in the design process. This helps ensure that products meet the specific material, process, and compliance needs of downstream companies. Additionally, upstream actors should consider how design choices, such as material selection and product assembly methods, impact not only initial use but also future disassembly, repairability, and recyclability. Continuous collaboration and feedback loops between these actors will make it easier for products to re-enter the cycle in an efficient manner.

Data needs:

Data needs of the design phase, partially overlaps with what was expressed in Section 2.1, on market demand and awareness – product designers need increased awareness of both opportunities and demand of certain solutions, and this needs to be aligned with incentives. Hence data needed is both concerning the actual demand, as well as potential and innovations, based on research and other sources. However, to design for circularity also implies the need for data on actual, or potential effects, of certain choices, and the trade-offs involved. In a general sense, this can be described as data about the value of a certain solution, i.e. both monetary value (demand), but also value in terms of environmental impact, utility etc. of the material, component or product being designed.

To enable the assessment of EoL scenariosachieve this alignment, data on material composition and disassembly processes must also be shared between stakeholders. For example, EoL operators need to provide data on which materials and components can be easily recycled or repaired, while manufacturers should incorporate this feedback into their design choices. Standardized labelling of components and materials based on recyclability and repairability could further improve communication.

Current state and how realistic it is to fulfil the need:

As mentioned in section 2.1, much of the data on needs and demand are currently considered confidential, or only shared with a set of close collaborators. While the platform proposed in this project provides the means for sharing such data in a secure manner, under granular access control, it does not provide any incentives to do so. Hence, without further incentives for data sharing, this situation will most likely continue, and very little information on the overall market demands and opportunities will be available at a larger scale. This also makes it hard to assess different dimensions of the value of a certain solution, particularly the potential monetary value. While regarding other aspects, such as the needs of EoL actors, e.g. recyclers, there are more clear incentives to share this data. Even though the recycling processes are the business of the recycler, in order to receive enough material input and material of sufficient quality, there is a clear incentive to collaborate with actors earlier in the value chain, e.g. even designers, to ensure that such an input flow becomes possible.

2.4 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.

For a circular economy to work, recycling practices need to improve to match the demand for such product components and secondary materials. Currently, recycling practices lack the development and technologies needed to match the scale of the existing "virgin" materials production. Consequently, the recycling industry needs to increase its knowledge of new techniques and improve existing processes to make them more efficient and faster.

Beyond the recyclers and producers, consumers also need greater awareness of how they can extend the life of products and materials. Educating both industry and consumers on ways to maintain products in the loop, through better use, maintenance, and repair, is critical for enabling more effective circularity.

Data needs:
Similar to what was discussed in Section 2.1, to improve this situation knowledge needs to be extracted from research and innovation literature, and shared with different types of actors in the CE. In addition, more detailed data on the needs of different actors in the circular flows need to be shared, at scale.

Current state and how realistic it is to fulfil the need:
Support from governmental and public entities (such as associations) for research on such topics would incentivise companies to increase their knowledge of alternative and better techniques. Additional investment from big manufacturers on new processes for EoL products would also improve such technologies that would turn into new commercial opportunities and business models. However, technical support to gather, manage, share and present such knowledge is still needed. Such technologies exist, and for instance the semantic interoperability and integration of such knowledge can be supported by the technologies offered by this project. Nevertheless, retrieval and presentation of the data in a target-focused manner is not a topic of the project.

To close the loop effectively, consumer education also needs to be improved. Awareness campaigns on circular practices, such as repair, maintenance, and reuse, would help consumers contribute to keeping products in circulation longer. Additionally, educational programs targeting future engineers and business professionals should emphasize circular economy principles and ensure that the next generation has the technical and system-thinking skills to advance these processes. Educating all stakeholders – from recyclers to consumers – may contribute to the demand for and efficiency of circular systems in the future.

2.5 Value

What is value in the context of the circular economy? Certification and standard compliance is important parts of this equation in supporting transparency, trust, credibility and compliance across supply chains. Market demands and awareness of circular solutions are also important drivers for building up value. Additionally, the quality and/or performance of recycled materials are important factors that drive value of materials and products. Then there are additional aspects of value that relate more to process and handling along the value-chain, such as energy and information. Value as a concept is complex and how it is defined, calculated and perceived will depend a lot on context.

Data needs:

To be able to assess or calculate value based on a certain perspective data from different domains will need to be available. As brought up in section 2.1, data on materials, components and products would also be needed in the context of value. Additionally so, data on energy, logistics or demand would be relevant. It is hard to single out specific data needs but rather conclude that our ability to define and work with value in a CE context today are insufficient.

Current state and how realistic it is to fulfil the need:
Although value is a very central concept in the Circular Economy (CE), and closely related to the circular value network through its value proposition, value is also a very hard concept to define. Following the discussions on the value concept that is currently ongoing in other forums, e.g. including standardisation bodies. It is our view that no “one” agreement on what value is will ever be defined, rather there will be a number of concepts that include pieces of definitions related to values. The end value of some particular circular collaboration will then be based on these concepts and pieces. It is also our view that over time, these concepts will be extended/adapted and transformed as to fit new configurations.

2.6 Circular practices

For the implementation of circular value networks, value chain processes must adapt to the shift from linear to circular practices. A key challenge is to integrate developing circular systems into existing infrastructure, ensuring compatibility and avoiding the creation of parallel systems. In particular, balancing the decoupling from external dependencies (such as reliance on other nations) with strengthening internal system integration (particularly in Europe) is essential. Rather than building entirely new value chains, adapting current ones to better align with circular principles is critical.

Collaboration between stakeholders must also shift towards shared and circular goals rather than being driven by self-interest. Many processes and standards require adaptation to support the transformation towards circular systems. For example, scaling existing technological solutions for circularity presents a significant challenge, as does the need for refining logistics, storage, and recycling operations. Furthermore, adopting circular value chains may require trade-offs in flexibility and time, which could necessitate adjustments to operational processes.

Data needs
Similar to what is discussed in section 2.1, 2.3 and 2.4 more detailed data on materials, products and practices of different actors need to be made available to enable circular value networks. Additionally, to create new collaborations between actors, or to transform existing linear value chains to circular ones there is a need to be able to share circular practices that are proven to be be of value. To be able to do this, actors need to share data on how these practices work and perform, i.e. a return-scheme or how a certain type of product reuse could be achieved.

Current state and how realistic it is to fulfil the need:
Circular economy is still a relatively new concept but there are currently an increasing amount of work being put into structuring, standardizing and scaling this system of producing and consuming value and resources. There are examples of good practices being shared but these are today largely unique and not easily reproducible and thus inefficient to scale. Even though different schemes could have a similar label, I.e. reuse of construction material, how these are defined in structure, data and operation, could be largely different. As standardisation efforts related to the circular economy mature and increase in adoption we expect that there will be more of a common language in how circular practices are defined. Additionally, there are a current regulatory push in the European Union for sustainable practices in many areas of society as part of the green deal. Some of the legislation put into place by EU relate to technical infrastructure that would support scaling circular practices. Collectively, these ongoing efforts are moving in the right direction when it comes to establishing a way of describing, sharing and scaling circular practices but there are immidiate effort needed to be put into making sure uptake of these efforts.

3 Circularity requirements – Top-down perspective

In the preceding version of this report (D2.2), we have already presented a set of circularity requirements. The circularity requirements are based on the Circularity Design Framework conceptualized in D5.1, the state of knowledge review around resource-, energy-, information-, and value-flows in the context of value chain design. These circularity requirements serve as input for the method developed within WP5 for systemic circular solutions, as well as provides a top-down perspective from which to elicit further detailed requirements in WPs 3 and 4. They guide the conceptual development of the method and serve as a means to evaluate it.

The Circularity Design Framework consists of three levels:

The conceptual levels of the Circularity Design Framework	Explanation of each level
Circular Metabolism Factor (First order principles)	Circular factors propose superordinate design considerations for the development of circular value networks.
Circular Enablers (Second order principles)	Circular enablers provide more specific requirements for the realisation of each factor.
Implementation actions (Third order principles)	Implementation actions deliver specific suggestions how an enabler can be implemented for material, energy, and value flows.

Table1: Overview of the Circularity Design Framework developed in D5.1

As the circular enablers provide more specific requirements for the realization of each factor, we used these factors as circularity requirements within D2.2. The circular metabolism factors were used to group the requirements due to their subordinate character, resulting in the definition of 13 circularity requirements. The implementation actions listed for each requirement were included with each respective enabler, to further detail and explain them. A full overview of all circularity requirements is included in Appendix 2.

One objective of this deliverable is to consolidate the separate sets of requirements into a single, unified set. Specifically, it involves combining the requirements from the Construction, Electronics, and Textile Use Cases into one cross-domain set. During this process, we will also compare these cross-domain requirements with the circularity requirements and integrate the latter, resulting in one cohesive and connected set of requirements. The circularity requirements are thus directly integrated into the cross domain requirements presented in Chapter 4.

4 Cross-domain requirements – Integrating the bottom-up and top-down Perspectives

While requirements should be firmly grounded in observation or other empirical investigations, in order to develop ontologies and a data sharing platform that is generic and independent of industry domains, they also need to be sufficiently generic. In this chapter we present an analysis that is based on the top-down perspectives from the CE requirements discussed in Section 3, but grounded in the data needs of Section 2, as well as the industry domain-specific from each use case analysis in D6.1-3.

More concretely, based on the initial set of needs (D6.1-2) and requirements identified in dialog with the use cases in D2.1-2, further analysis and detailing in WP3, WP4 and WP5 during the first and second project iteration uncovered common themes that are present for all the use case domains. The resulting implementation in the Circular Economy Ontology Network (CEON) and the Open Circularity Platform (OCP) represent a generalization over the use cases in terms of common functionalities that are needed by all of them to operate in a circular context, and they all relate to the CE needs as outlined in the CE requirements.

Further, the chapter is divided into functional and non-functional requirements. For traceability throughout the project deliverables, all the functional requirements are using a numbering that is also used in deliverables from WP3 and WP4 to provide provenance to the implementation.

4.1 Cross-domain functional requirements

For the D2.3 deliverable a total of 9 cross-domain requirements have been identified. Following is a short description of each requirement together with one or more corresponding use-case requirement that express the core needs of the cross-domain requirement, set in a specific industry context. Please see Appendix 1 for a full textual description of each use-case requirement.

4.1.1 Circular Value Network

The circular value network represents a structure for setting up roles, actors and process that work together to produce value according to circular principles.

Cross-domain requirement 1: *Circular Value Network*
The value network is a specific configuration of a circular collaboration, which could be abstracted into a pattern (or plan) describing either a typical or a required setup, with needed functions in the network possible to fill by certain actor types, types of circular strategies targeted (e.g. refurbishment of a product), and relations to typical value propositions and goals. **Cross-domain circular value network related requirements:** **CDR1** As a value chain actor, policy maker, or other organisation I need to be able to access information about the (concrete or needed) setup and configuration of a network, and how it operates as a system **CDR2** As a value chain actor, policy maker, or other organisation I need to access information about the operations and characteristics of the networks **CDR3** As a value chain actor I need to be able to share information with and consume information from other actors in the value chain. **CDR4** As a value chain actor I need to be able to understand what actions I am able to take in the value chain at any given time. **Specific use-case and circularity requirements underpinning this cross-domain requirement:** **Circularity** • CE1: The capacity to understand interrelations between processes and actors in the system • CE2: The capacity to identify and consider all (relevant) system actors • CE3: The capacity to consider processes throughout entire life cycle

- CE4: The capacity to understand interrelations with other systems (at different levels)

Construction use-case

- CUS1: End of life scenarios
- CUS5: Cost
- CUS13: Planning

Electronics & Appliances use-case

- EUS1: Provenance/quality and sustainability of raw materials
- EUS2: Production process
- EUS3: Quality and compliance
- EUS4: Product usage
- EUS5: Product composition

Textiles use-case

- TUS2: Access to editable and updatable content
- TUS3: Integrated product data
- TUS6: Sustainability score
- TUS7: Circular materials catalogue
- TUS11: Authentication of data
- TUS12: Visibility
- TUS14: Brand's take back schemes information
- TUS16: Sustainability product data
- TUS17: Verified claims
- TUS20: Take-back data
- TUS21: Resale product information
- TUS22: Material inventory
- TUS23: Disassembly

4.1.2 Value

Value is a central concept to any economy. Being able to express value is central to any circular collaboration and as a consequence it is expressed by requirements in all the use cases.

Cross-domain requirement 2: *Value*

Value as a concept is complex and how it is defined, calculated and perceived will depend a lot on context. Certification and standard compliance is important parts of this equation in supporting transparency, trust, credibility and compliance across supply chains. Market demands and awareness of circular solutions are also important drivers for building up value. Additionally, the quality and/or performance of recycled materials are important factors that drive value of materials and products. Then there are additional aspects of value that relate more to process and handling along the value-chain, such as energy and information.

Cross-domain value related requirements:

CDR5
As a value chain actor I need data to be able to assess the value of a certain material, process or action in a specific context.

CDR6
As a value chain actor I need data to be able to compare the value of different actions I could take.

Specific use-case and circularity requirements underpinning this cross-domain requirement:

Circularity

- CE5: The capacity to scope (new) combinations of processes.
- CE10: The capacity to work together for a shared goal
- CE12: The capacity to coordinate processes and actors for the benefit of the system

Construction use-case

- CUS1: End of life scenarios
- CUS2: Material business case
- CUS5: Cost
- CUS6: Market demand
- CUS8: Tender
- CUS11: Marketplace

Electronics & Appliances use-case

- EUS1: Provenance/quality and sustainability of raw materials
- EUS4: Product usage

Textiles use-case

- TUS17: Verified claims
- TUS20: Take-back data
- TUS21: Resale product information

4.1.3 Actor

A circular collaboration consists of a set of actors with different roles, participating in different phases of the collaboration. Actors are the ones that perform work and realise value in the collaboration.

Cross-domain requirement 3: *Actor*
Actors belong to organizations that are part of the value network and are the ones that actually perform work in a circular value network. Actors work to transform materials, components, and products in the various steps in the value network phases. There are different actor types, each fulfilling a certain role in a network, such as a "recycler" or "manufacturer". The roles an actor are able to fulfil in the network are related to the capabilities and competencies these actors hold.

Cross-domain actor related requirements:

CDR7
As a value chain actor I want to be able to discover, access and retrieve data from other actors

CDR8
As a value chain actor I want to be able to share data with other specific actors, or groups of actors

CDR9
As a customer, end-user, or other value chain actor I want to be able to access and retrieve data from other actors

CDR10
As a value chain actor I want to be able to control access and assure the accurate, verifiable, and secure sharing of data with other actors, groups of actors, or individuals

Specific use-case and circularity requirements underpinning this cross-domain requirement:

Circularity

- CE1: The capacity to understand interrelations between processes and actors in the system
- CE2: The capacity to identify and consider all (relevant) system actors
- CE11: The capacity to integrate (relevant) actors throughout entire process
- CE12: The capacity to coordinate processes and actors for the benefit of the system

Construction use-case

- CUS7: Dismantling
- CUS8: Tender
- CUS9: Recycling
- CUS10: Deconstruction
- CUS13: Planning

Electronics & Appliances use-case

- EUS1: Provenance/quality and sustainability of raw materials
- EUS2: Production process
- EUS3: Quality and compliance
- EUS4: Product usage

Textiles use-case

- TUS1: Access to production data
- TUS2: Access to editable and updatable content
- TUS3: Integrated product data
- TUS4: Access to trustful data

- TUS11: Authentication of data
- TUS12: Visibility

4.1.4 Process

Each circular collaboration consists of one or more value-adding tasks that are performed in sequence. This is in essence a process where actors collaborate in acting on some type of resource.

Cross-domain requirement 4: *Process*

Each circular value network realises one or more circular value flows, which can be seen as a process of transforming some resource, e.g. from materials, to components, into products, and then potentially back again. Such processes have different phases, e.g. the phase that takes something from materials to components, or the phase of deconstructing a product into its material composition, and each phase can further be subdivided into smaller steps, which can be performed by different actors. Each step may then also have inputs and outputs, both in terms of resources, but also work, energy, and information. Steps can be performed by actors, i.e. participants in the value network, with the right capabilities.

Cross-domain process related requirements:

CDR11
As a value chain actor I need to be able to define my work as part of the value chain

CDR12
As a value chain actor I need to be able to understand and act on different process steps in the value chain.

Specific use-case and circularity requirements underpinning this cross-domain requirement:

Circularity

- CE1: The capacity to understand interrelations between processes and actors in the system
- CE3: The capacity to consider processes throughout entire life cycle
- CE4: The capacity to understand interrelations with other systems (at different levels)
- CE5: The capacity to scope (new) combinations of processes
- CE6: The capacity to understand system barriers and external factors
- CE7: The capacity to understand the effect of (a set of) actions (on the system)
- CE12: The capacity to coordinate processes and actors for the benefit of the system

Construction use-case

- CUS1: End of life scenarios
- CUS2: Material business case
- CUS3: Inventory
- CUS4: Rest material from production

- CUS7: Dismantling
- CUS10: Deconstruction
- CUS12: Reuse
- CUS13: Planning

Electronics & Appliances use-case

- EUS1: Provenance/quality and sustainability of raw materials
- EUS2: Production process
- EUS3: Quality and compliance
- EUS4: Product usage
- EUS5: Product composition
- EUS6: Safety

Textiles use-case

- TUS3: Integrated product data
- TUS8: Component data
- TUS14: Brand's take back schemes information
- TUS15: Repair and reuse guidance
- TUS17: Verified claims
- TUS18: Care guidance
- TUS19: User guidance
- TUS23: Disassembly

4.1.5 Material

A material is a specific kind of resource in a circular collaboration and are used as inputs and outputs in different steps. Resources and materials are central to the circular economy which is also reflected in the requirements from each of the use-cases.

Cross-domain requirement 5: *Material*

Materials are the most basic physical object that are being managed as part of a circular value network. Materials are used to produce products or to achieve a certain result by its consumption. Materials could be either virgin, i.e. dug up from the earth, or extracted by the means of a circular strategy, i.e. recycling. Materials are managed at different levels of granularity, either individually or in some form of batch. As materials are able to move between actors, their physical location might change over time. Different materials have different characteristics and applications.

Cross-domain material related requirements:

CDR13
As a value chain actor I want to access the material breakdown of a product, component or material

CDR14
As a value chain actor I want to access data about the production processes of materials

CDR15
As a value chain actor I want to access data about the processes of a material

CDR16
As a value chain actor I want to understand the origin of a materials

CDR17
As a value chain actor I want to understand the end-of life options of a materials

CDR18
As a value chain actor I want to know the availability of material options

CDR19
As a value chain actor I want to assess and ensure the accuracy, recency/validity, and trustworthiness of material data

Specific use-case requirements underpinning this cross-domain requirement:

Circularity

- CE3: The capacity to consider processes throughout entire life cycle
- CE5: The capacity to scope (new) combinations of processes

Construction use-case

- CUS1: End of life scenarios
- CUS2: Material business case
- CUS4: Rest material from production
- CUS7: Dismantling
- CUS9: Recycling

Electronics & Appliances use-case

- EUS1: Provenance/quality and sustainability of raw materials
- EUS2: Production process
- EUS5: Product composition
- EUS6: Safety

Textiles use-case

- TUS1: Access to production data
- TUS2: Access to editable and updatable content
- TUS3: Integrated product data
- TUS4: Access to trustful data
- TUS5: Generate material inventory
- TUS7: Circular materials catalogue
- TUS8: Component data
- TUS9: Certificates
- TUS10: Materials composition
- TUS13: Product availability data
- TUS16: Sustainability product data
- TUS22: Material inventory

- TUS23: Disassembly

4.1.6 Product

Products are a common concept shared by all three use-cases. Apart from the concept of a product, also parts of products, or components are a central concept to the cross-industry collaborations in the different use-cases.

Cross-domain requirement 6: *Product*

In itself, a product are made up by parts, i.e. components, these components might then in themselves also be a product. Products produced using different types of resources i.e. materials, energy, or knowledge. Further, products have a lifecycle whereas they are produced, used and disposed (or transformed). Throughout its lifecycle, different resources could be used to either use the product or maintain it.

Cross-domain product related requirements:

CDR20
As a value chain actor I need to provide and consume product data

CDR21
As a value chain actor I need to be able to asses products and their components given different actions I need to undertake

CDR22
As a value chain actor I need to be able to understand the usage and performance of a product and its components

Specific use-case and circularity requirements underpinning this cross-domain requirement:

Circularity

- CE3: The capacity to consider processes throughout entire life cycle
- CE5: The capacity to scope (new) combinations of processes
- CE9: The capacity to develop new configurations

Construction use-case

* All construction use case requirements bring up the concept of a product

Electronics & Appliances use-case

- EUS2: Production process
- EUS3: Quality and compliance
- EUS4: Product usage
- EUS5: Product composition
- EUS6: Safety

Textiles use-case

- TUS2: Access to editable and updatable content
- TUS3: Integrated product data
- TUS6: Sustainability score
- TUS7: Circular materials catalogue
- TUS8: Component data
- TUS10: Materials composition
- TUS12: Visibility
- TUS13: Product availability data
- TUS14: Brand's take back schemes information
- TUS15: Repair and reuse guidance
- TUS16: Sustainability product data
- TUS17: Verified claims
- TUS23: Disassembly

4.1.7 Location

Location appears in many places in the list of use case requirements in appendix 1. Location is used in the context of tracking specific resources over time or for establishing its origin. Location are also relevant in the context of actors and to describe a physical location of something, for example within a building.

Cross-domain requirement 7: *Location*

As actions are taken, materials are transformed, and resources are moved, there are the need for keeping track of when and where this occurred in the physical world. Further, location could be rather specific, as in that something is located in a particular room, on a particular floor, in a particular building, in a particular city. Or it could simply be denoted as a point of origin.

Cross-domain location related requirements:

CDR23
As a value chain actor I need to be able understand the location of different resources

Specific use-case and circularity requirements underpinning this cross-domain requirement:

Circularity

- CE3: The capacity to consider processes throughout entire life cycle.
- CE4: The capacity to understand interrelations with other systems (at different levels

Construction use-case

- CUS7: Dismantling
- CUS9: Recycling
- CUS10: Deconstruction
- CUS13: Planning

Electronics & Appliances use-case

- EUS1: Provenance/quality and sustainability of raw materials
- EUS2: Production process
- EUS3: Quality and compliance

Textiles use-case

- TUS1: Access to production data
- TUS2: Access to editable and updatable content

4.1.8 Quantities and Units

When specifying concrete data about products, components and materials, for instance, there is a need to specify the type of quantity a value represents and the units of measure of the concrete values.

Cross-domain requirement 8: *Quantities and Units*

In a circular value network, working with products, components and materials, there is a need to specify the type of quantity a value represents and the units of measure of the concrete values.

Cross-domain quantities and units related requirements:

CDR24
As a value chain actor I need to be able to specify and understand the quantity of different resources

CDR25
As a value chain actor I need to be able to specify and understand the units of measure of different resources

Specific use-case and circularity requirements underpinning this cross-domain requirement:

Circularity

- CE5: The capacity to scope (new) combinations of processes
- CE6: The capacity to understand system barriers and external factors
- CE7: The capacity to understand the effect of (a set of) actions (on the system)

Construction use-case

- CUS1: End of life scenarios
- CUS2: Material business case
- CUS3: Inventory
- CUS4: Rest material from production
- CUS5: Cost
- CUS11: Marketplace
- CUS12: Reuse
- CUS13: Planning

Electronics & Appliances use-case

- EUS1: Provenance/quality and sustainability of raw materials
- EUS2: Production process
- EUS3: Quality and compliance
- EUS4: Product usage
- EUS5: Product composition

Textiles use-case

- TUS2: Access to editable and updatable content
- TUS22: Material inventory

4.1.9 Provenance

In order to support traceability and support transparency, provenance metadata is an important part. Provenance can be tracked at the level of single statements about products and materials, e.g., the time of measurement of a specific quantity value, or the actor responsible for the statement.

Cross-domain requirement 9: *Provenance*

In order to support traceability and transparency, provenance metadata is an important part. Provenance can be tracked at the level of single statements about products and materials, e.g., the time of measurement of a specific quantity value, or the actor responsible for the statement. I can also be tracked at the level of data sets, e.g. a product data sheet.

Cross-domain provenance related requirements:

CDR26
As a value chain actor I need to be able to provide and understand the provenance of resources and actions

Specific use-case and circularity requirements underpinning this cross-domain requirement:

Circularity

- CE8: The capacity to acquire and share (new) knowledge
- CE12: The capacity to coordinate processes and actors for the benefit of the system.
- CE13: The capacity to interact and share information with actors in an effective and trustful way

Construction use-case

- CUS1: End of life scenarios
- CUS2: Material business case

Electronics & Appliances use-case

- EUS1: Provenance/quality and sustainability of raw materials
- EUS2: Production process
- EUS3: Quality and compliance
- EUS6: Safety

Textiles use-case

- TUS1: Access to production data
- TUS2: Access to editable and updatable content
- TUS3: Integrated product data

4.2 Non functional requirements

The following chapter outline non-functional requirements as derived from the project specification. Non-functional requirements are listed per sub-section to denote what part of the developed solutions they affect. These requirements are to be seen as applicable for the project as a whole and is not considered as related to a specific use case only.

4.2.1 Interoperability

- Interoperability of data needs to be done using shared vocabularies and languages for knowledge representation.

- Vocabularies and languages for knowledge representation needs to adhere to the FAIR principles for scientific data.

4.2.2 Security

- It should not be possible to manipulate source data by an unauthorized actor.

- It should not be possible to manipulate data in transit by an unauthorized actor.

- The source code of the circularity platform can be uploaded to a publicly accessible online software repository (e.g., GitHub, Bitbucket), under an open source license.

4.2.3 Privacy

- Storage and handling of data related to individuals and organizations need to adhere to the standards of the European General Data Protection Regulation (GDPR).

- Interoperable data needs to be managed in a privacy preserving manner.

4.2.4 Usability

- Clear guidance and instructions on how to use the solutions developed needs to be provided.

- Code should be clearly documented.

4.2.5 Scalability and performance

- All solutions developed needs to scale with performance given an increase of utilization.
- For users who will use the solutions developed, they should not get the perception that the solutions have poor performance.
- The specific roles of tenderer and planner that are specified in the requirement are not part of the validations.

4.2.6 Availability

- Data needs to be recoverable from accidental and malicious deletion.
- Operations needs to be recoverable from disasters as well as malicious attacks.

4.3 Domain specific considerations

Looking at the initial use case list of requirements presented in appendix 1, all the initial requirements have contributed to the core cross-domain requirements that represent the current state of what is the focus of implementation in the project. But, this does not imply that the full extension of specific requirements have been taken into account. As the focus for implementation have been in the common parts, there are a number of more domain specific considerations that have not been taken into account. The following is an attempt at highlighting and acknowledging the key areas where domain specific requirements have not been fully addressed.

4.3.1 Construction use case

Requirement	Comment
CUS8, Tender	The specific role of tenderer that are specified in the requirement are not part of the validations.
CUS13, Planning	There is no concept of “planning” as implemented in the ontology or platform. Additionally the specific roles of tenderer and planner that are specified in the requirement are not part of the validations.

4.3.2 Electronics and appliances use case

Requirement	Comment
EUS2, Production Process	There are support for describing data related to the production process but it is not validated in the Electronics and appliances use case in terms of a production process.
EUS4, Product Usage	Product usage scenarios are not evaluated in relation to the Electronics and appliances use case.

4.3.3 Textiles use case

Requirement	Comment
TUS9, Certificates	On a basic level, there are support for adding references to certificates in the product information in the ontology but this is not specifically verified in the platform evaluation.
TUS13, Product Availability data	Partly taken into account but not to the extent of linking different manufacturers and suppliers to this representation.
TUS14, Brand's take back schemes information	Take back schemes are not taken into account. There are support for describing this in the CEON ontology but it is not verified in the platform.
TUS15, Repair and reuse guidance	Repair and reuse guides are not explicitly addressed in the ontology or platform validation. I could though be argued that it could be part of product data as produced in a product overview.
TUS17, Verified claims	On a generic level, data related to claims could be made available on the platform. But, how these claims would be verified in the context of the textile ontology are not taken into account.
TUS18, Care guidance	Care guides are not explicitly addressed in the ontology or platform validation. I could though be argued that it could be part of product data as produced in a product overview.
TUS19, User guidance	User guides are not explicitly addressed in the ontology or platform validation. I could though be argued that it could be part of product data as produced in a product overview.

5 Discussion

In this deliverable we describe the work done through the first two iterations of the project, up until this final update of the requirements specification. This version of the deliverable contains four main parts, covering; data needs, circularity requirements as described by WP5, cross-domain requirements based on generalizations over the use-case specific requirements, domain specific considerations. In this third and final version of the deliverable we have made an effort of adapting and adjusting to what we have learned in the two previous iterations of the project in providing an as coherent as possible baseline for the last iteration of the project. We acknowledge that there are areas where additional data had been of value, or where data have not been available. In response to this we have included an analysis of the data needs as perceived by the project stakeholders at this point in the project. Some of these needs have been there from the start, some have emerged during project execution.

6 Conclusions

This final version of the requirements deliverable represents a major restructuring of the previous version. This is due to the fact that additional knowledge has been acuminated over the two project iterations so far, as well as additional feedback provided by project partners. In the initial version of this deliverable, requirements strongly tied to the respective use-case domains. As work have transpired, additional understanding of domain specifics as well as of the cross-domain needs have become more visible and thus possible to document in a structured and understandable way.

For the initial two versions of this deliverable in working with this deliverable, we have used the use-case descriptions produced in WP6 as input for defining more detailed requirements. Most of the effort was spent on working out actor's and the respective actions they take and describing this in text as user stories. The number of user stories produced by each use case vary, as do the detail of those stories. In this final version of the deliverable, we also have the experience of having done two iterations of the project as input in producing a coherent representation of the requirements landscape addressed by the project. Through the two iterations of the project, initial version of the ontology network and platform has been built, evaluated, and extended. The circularity compass methodology used in the project has also been applied, evaluated, and extended. The core use-case requirements have not changed much over the iterations but the further detailing of them in terms of ontology requirements and evaluation acquirements for the circularity platform have highlighted areas of commonalty cross the use-case domains. This is reflected in chapter 4 where we list the cross-domain requirements identified and what original use-case requirements relate to those.

Working through the first iteration of the project it became clear to us the circularity requirements were not visible enough. These requirements are implicit to the whole project as they are part of the underlying methodological framework used. Also, they are continuously worked on as part of WP5. For the second version of the deliverable, the circularity requirements were included in an own chapter as requirements, visible and possible to reference in the other WP:s in the project. For this final version of the deliverable, this representation has not changed. These requirements have now been taken into account on the ontology design and platform in one iteration of the project and will be further integrated in the last iteration of the project.

Working with the requirements as represented in this document have proven to be a good basis for further development tasks in the project. Later WP:s have been able to make use of these requirements and further detail, enrich and transform them for their respective use. Furthermore, connecting back to these requirements in the evaluation done in WP6 is a good way to keep consistency and traceability in what is developed. But, what has been a bit of a struggle throughout the project have is to keep this consistency. As knowledge and understanding increase as we learn by working in the project, the demands and needs might evolve, this needs to be taken into account in the evolution of this deliverable. Transparency into what is a requirement and how that has been detailed and implemented needs to be possible to follow. In this final version of the deliverable our ambition have been to provide a structure on which other WP:s are able to converge in terms of telling a coherent story on project requirements.

7 Appendix 1 – Original use case requirements

This appendix lists all the requirement user stories collected from the use-cases throughout the project. These are the original requirements from which generalisations has been done in later phases of the D2.x deliverable.

To better prioritize development of the ontology and the open circularity platform some user stories will be marked as prioritized or, on the other end of the scale, less important. In dialog with the respective use case leads, these stories represent functionality in the envisioned platform that are more important than other features. This prioritization is intended to be used as guidance for WP3 and WP4 but not to be the sole truth, given the holistic picture of implementing certain user stories, WP3 and WP4 are free to do their own prioritization that makes the most sense from an implementation perspective.

User stories that are important will be denoted with a green arrow:

User stories that are less important will be denoted with a grey arrow:

7.1 Construction use-case

Based on the work done using the Circularity Compass in D6.1, several shortcomings have been identified across all phases of the product life cycle of the selected construction component, where information and understanding on handling of the component are lacking. Based on these shortcomings, needs have been identified corresponding to the product lifecycle. Additionally, a set of initial stakeholder types have been identified. These stakeholder types will be used as the subject actors of the defined user stories for this use case.

Actors:

- **Building owner**
- **Manufacturers**
- **Dismantler**
- **Tenderer**
- **Recycler**
- **Deconstruction company**
- **Planner**
- **Marketplace**

7.1.1 CUS1: End of life scenarios

As a: Building owner

I want:
I want to know which are the different end-of-life scenarios for building materials.

So that:
I can decide on how the material should be handled.

Additional context information

To be detailed in later versions of the deliverable. Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
Detailed product information and information on the state of the product.

7.1.2 CUS2: Material business case

As a: Building owner

I want:
I want to obtain economic and environmental costs of different end-of-life scenarios for building material.

So that:
I can make financially and environmentally sound decisions on how the material should be handled.

Additional context information
Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
Detailed product information and information on the state of the product. Additionally, data related to environmental impact and lifecycle of the product.

7.1.3 CUS3: Inventory

As a: Manufacturer

I want:
I want to obtain information on quantities and locations of my products that will be dismantled.

So that:
I can organize take-back-systems, refurbishment or reselling for these products.

Additional context information
Timings are relevant in this context, as to be able to plan for taking back at the right time and with optimal logistics. Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
Location and quantity.

7.1.4 CUS4: Rest material from production

As a: Manufacturer

I want:
I want to find out if the rest material from my production could be used in other production processes.

So that:

I can find other financial and environmentally sound ways to offset the material.

Additional context information
For this to be practical, some type of matching functionality would be needed where one could enter criteria and do a search on matching offset paths. Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
Data to correlate with material data of the rest materials produced in production.

7.1.5 CUS5: Cost

As a: Manufacturer

I want:
I want to know the costs of dismantling and refurbishing my products.

So that:
I can be able to make financially sound decisions on how to design a take-back system.

Additional context information
Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
Product data. Tender cost for the dismantling and/or refurbishment.

7.1.6 CUS6: Market demand

As a: Manufacturer

I want:
I want to know the market demand for a refurbished product.

So that:
I can be able to make financially sound decisions on how to design a take-back system.

Additional context information
Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
To be detailed in later versions of the deliverable.

7.1.7 CUS7: Dismantling

As a: Dismantler

I want:
I want to find out where there are needs of dismantling of products for a certain building and what these products are.

So that:
I can go to the building and dismantle the products in the correct way.

Additional context information
The actions taken and the information needs are to be seen from the perspective of a dismantler. Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
Product and location data, as well as information on dismantling and handling of the product.

7.1.8 CUS8: Tender

As a: Tenderer

I want:
I want to retrieve product information from the manufacturer.

So that:
I can integrate a dismantling method description in the deconstruction tender.

Additional context information
Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
Detailed product information.

7.1.9 CUS9: Recycling

As a: Recycler

I want:
I want to be informed on buildings where deconstruction and retrieval of certain secondary raw materials is planned and for what products it is planned.

So that:
I can go to the building and handle the products and materials in the correct way.

Additional context information
Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
Product data as well as location data.

7.1.10 CUS10: Deconstruction

As a: Deconstruction company

I want:
I want to be informed on buildings where the deconstruction is planned and for what products.

So that:
I can go to the building and perform the deconstruction in the correct way.

Additional context information

Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
To be detailed in later versions of the deliverable.

7.1.11 CUS11: Marketplace

As a: Marketplace

I want:
I want to retrieve product information such as composition, dimensions, quantities, and pricing.

So that:
I can market and sell these products.

Additional context information
Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
Detailed product information as well as quantities, location, and pricing.

7.1.12 CUS12: Reuse

As a: Planner

I want:
I want to retrieve product information such as measurements, qualities, and quantities.

So that:
I can propose the building material when planning for a new building.

Additional context information
Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
Detailed product information as well as quantities, location.

7.1.13 CUS13: Planning

As a: Manufacturer, Dismantler, Tenderer, Recycler, Deconstruction company, Planner, Marketplace

I want:
I want to retrieve product information such as measurements, composition, qualities, quantities, and location. I also need to be able to access the process and handling information that are related to these products.

So that:
I can offer the correct services and handling at the correct cost and at the correct time and location.

Additional context information
Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
TBD.

7.2 Electronics and appliances use-case user stories

Based on the work done using the Circularity Compass in D6.1, several shortcomings have been identified across all phases of the product life cycle where information and understanding on handling are lacking. Based on these shortcomings, a set of initial stakeholder types have been identified. These stakeholder types will be used as the subject actors of the defined user stories for this use case.

Actors:

- **Suppliers** (material suppliers)
- **Manufacturers** (part, component, and product)
- **Brand** (can be active in the production phase i.e., direct manufacturing; can be also active in the retailing phase i.e., direct selling)
- **Users**
- **Recycler**
- **Sorter**

7.2.1 EUS1: Provenance/ quality and sustainability of raw materials

As a: Supplier

I want:
To be able to proof the quality characteristics of the material I supply to the Brand, End-user, and Legislator

So that:
I can assure the quality and the sustainability of the material (traceability) and a) unlock a higher price category for my certified high-quality material and b) secure my continuous contract with the customer.

Additional context information
As a material supplier, it is often almost impossible to know which final product my material ends up in, let alone proof it. This is, among others since supplier's identity is secret as intermediaries fear that their suppliers and customers cut them out of the deal by interacting directly. With a traceability system I want to be able to proof the quality characteristics assessed at my stage of the supply chain to the brand and end user, several steps later. This also includes the compliance with legislation and the sustainability of the material and its contribution to circularity. Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:

- Recycled material content
- Product Carbon Footprint data of material provided and production process
- Regulatory frameworks

7.2.2 EUS2: Production process

As a: Manufacturer

I want:
To understand the origin of the materials and the production processes

So that:
I can understand what kind of materials and components my product contains to a) mitigate supply risks, b) improve my supply chain, c) fulfilling regulations on e.g., digital product passport and the supply chain act in the future.

Additional context information
Supply chain stakeholders are currently unknown to the OEM. However, the increasing need for material data also requires being able to retrieve the data from the supply chain step where the data originates, the supplier who can proof validity of data. Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
- Provenance
- Material composition
- Stakeholder types in the supply chain,
- Location of production

7.2.3 EUS3: Quality and compliance

As a: Manufacturer/ Brand

I want:
To assess the sustainability performance of my production.

So that:
I can assure a) the quality of my product b) the compliance of my product with legislation and standards. I can assure that my product is sustainable, entails sustainable materials. I can calculate my life cycle assessment and product carbon footprint.

Additional context information
Manufacturers are under increase pressure to meet sustainability targets and regulation. They require a system that allows them to proof that they are sourcing sustainability and meeting quality standards (e.g., the Made in XXXX, critical raw materials sourced sustainably). Furthermore, many manufacturers have made big claims to move towards carbon neutrality. To achieve that, they need to a) understand what their current sustainability parameters are, b) how to improve them and c) how to proof the sustainability to their customers. Most big companies cannot assess the sustainability of their product and supply chain, right now, without employing an external consultancy to conduct expensive research. What is required is a system that provides access to the knowledge and data that is available dispersed across different stakeholders of the supply chain. Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
- Compliance schemes (e.g., REACH)
- Monitored materials (e.g. mercury, flame retardants, CFCs…)
- Recycled material content

- LCA data of each supply chain stakeholder (where available)
- Sustainability of production processes
- Carbon accounting data

7.2.4 EUS4: Product usage

As a: User

I want:
To find information on how sustainable my product is and how to recycle or refurbish my product.

So that:
I can ensure that I get the most optimal performance in all phases of the products lifecycle. I can reduce my carbon footprint. I know that the quality I paid for (more sustainable product) is there.

Additional context information
To avoid greenwashing and encourage users to buy more sustainable and circular products, the communication of sustainability parameters is crucial. Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
- Dismantling/ repair information
- Material composition
- Certifications of sustainability (e.g., recycled material certificate).
- Quality criteria e.g., made in EU, sustainably sourced critical materials.

7.2.5 EUS5: Product composition

As a: Recycler

I want:
To understand the composition of the product.

So that:
I can recycle it efficiently and securely.

Additional context information
Information on hazardous substances and safe handling are important in this context but they are not always easy to get hold of. Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
- Dismantling information
- Chemical composition
- Hazardous substances contained
- Degradation level of materials

7.2.6 EUS6: Safety

As a: Recycler

I want:
To find out if a product contains hazardous materials.

So that:
I can recycle it in a safe and efficient way.

Additional context information
This pertains to more to handling of the product so that it does not cause human harm and to what extent known effects on the environment there are. Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:

- Dismantling guidelines
- Compliance schemes
- Hazardous substances

7.3 Electronics and appliances use-case

7.4 Textiles use-case

Based on the work done using the Circularity Compass in D6.1, several shortcomings have been identified across all phases of the product life cycle where information and understanding on handling are lacking. Based on these shortcomings, needs have been identified that correspond to the product lifecycle. Additionally, a set of initial stakeholder types have been identified. These stakeholder types will be used as the subject actors of the defined user stories for this use case.

Actors:

- **Suppliers** (fibre suppliers, other components suppliers)
- **Manufacturers** (fibre manufacturers, shoe manufacturers, product assembly)
- **Brand** (can be active in the production phase i.e., direct manufacturing, can be also active in the retailing phase i.e., direct selling)
- **Retailer**
- **Users**
- **Collectors/Sorters**
- **Recycler**

7.4.1 TUS1: Access to production data

As a: Fiber Supplier

I want:
a possibility to display the material content of my fibers requested by my customers.

So that:
I can assure all information on my fibers can be easily accessed by my customers.

Additional context information
I receive frequent requests from my customers to provide information on the type of fibers, their origin, the recycled content as well as proof related to this information. Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:

- Category of fiber (fabric, yarn, trim, etc.)
- Type of material (Specific type of a material depending on the chosen category of a fiber)
- Country of origin of raw material
- Certificates
- Colors
- Any recycling recommendation
- (Biodegradability certificate:
  - REACH compliant = Does the product comply with REACH? Compliance with chemical regulations or standards can determine recycling cycle.
  - AFIRM compliant = Does the product comply with AFIRM? Compliance with chemical regulations or standards can determine.

Functional requirements:

- A form where I can fill in all data clustered by product, variation, material, assembly e.g., as dropdowns to select or free text fields.
- Save functionality.
- Upload functionality for certificates
- Input for certificate numbers
- Upload functionality for images of fiber

7.4.2 TUS2: Access to editable and updatable content

As a: Fiber Supplier and Transformation actor

I want:
A possibility to edit and update the material content of my fibers/properties of my product displayed on the platform.

So that:
The information that my customers accessed is always up to date.

Additional context information
The input materials to my production process may vary due to e.g., change of suppliers. This has an impact on the chemical composition of the fibers, without impacting the overall performance of the fibers or of my product.

Data needs:

Functional requirements:

- Edit possibility to e.g., upload newly required certificates or new colors

7.4.3 TUS3: Integrated product data

As a: Fiber Manufacturer and Transformation actor

I want:
An overview when I log into the platform to see all my materials including which materials have been viewed or where I have been contacted.

So that:
I can check and verify what materials have been uploaded and who is trying to get in contact with me.

Additional context information
As a manufacturer/ material supplier I want to see my material library to check materials that have been uploaded, edited e.g., history. Also, see appendix B of deliverable 3.1, ontological requirements.

Functional requirements:
- Easy navigation
- Dashboard overview with all my products and information I am sharing
- Function to add/edit product information e.g., a newly received certificate

7.4.4 TUS4: Access to trustful data

As a: Transformation actor

I want:
Access trustful data of the fibers and other materials I used in my transformation process (properties, origin of materials/fibers and the conditions in which they have been produced/ cultivated)

So that:
I can remove expired or old data.

Additional context information:
Textile product labels often (or even only) show the countries where the fibers are processed. However, my customers and the brands are requesting information on the recycled content, country of origin of the fibers and the conditions in which they were produced or grown (pesticide or not, good working conditions or not, etc.). Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
- Production conditions:
  - The Fairtrade Textile Standard
  - GOTS
  - C2C
- Fiber properties:
  - Product Type
  - Facility Name & Country
  - Material Name
  - Lot No.
- Restricted Substances List (RSL) self-declaration
- REACH compliance
- RoHS compliance
- Hazardous (MSDS)
- Transaction certificate for recycled content (GRS, etc.)
- For Biomaterials:
  - LCA to confirm the mass balance)
  - ISCC certification
  - Carbon footprint (production scope)

- Water/Energy Consumption* (see Higg Index)

7.4.5 TUS5: Generate material inventory

As a: Fiber supplier and Transformation actor

I want:
A platform that can generate material inventories (based on imported data from my ERP system or from digital document such as excel, json, etc.) and upload certificate.

So that:
I can facilitate my administrative work and decrease manual workload.

Additional context information:
Because it exists no standardized/automized Product Data exchange, I still have significant manual processes to do & poor data quality. Also, see appendix B of deliverable 3.1, ontological requirements.

Functional requirements:

- Auto-fillable fields based, e.g., on certificates that have been checked e.g. by machine readable pdfs or certificate numbers (e.g. GOTS number) OR imported data.
- Upload system

7.4.6 TUS6: Sustainability score

As a: Transformation actor

I want:
A visible and transparent score on my product sustainability/circularity performance

So that:
I can show my sustainability efforts.

Additional context information
I want to show my sustainability efforts to my customers so they can be rewarded. Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:

- Circularity score of the product based on a list of criteria (to be detailed in iteration 2) e.g.
  - Non-virgin content (Recycled content and renewable content)
  - Longevity
  - Recyclability
  - Biodegradability

7.4.7 TUS7: Circular materials catalogue

As a: Brand

I want:
To have access and explore freely a catalogue of available circular materials.

To improve the design phase of my products (eco-design).

So that:
I can improve the circularity of my products.

Additional context information
I am looking for more sustainable components than my current ones to create circular products: where and how can I find this information? Does it exist? Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
- Catalogue of sustainable/ circular Materials e.g., material library
- Materials record (sheet)
- Search engine by characteristic/ alternative to/name/
- Possibility to filter for materials e.g., by categories, composition, properties

Functional requirements:
- Search functionality
- Filter functionality

7.4.8 TUS8: Component data

As a: Brand

I want:
To have access to data on properties, assembly methods and composition of components

So that:
I can assure the quality and the sustainability of the material

Additional context information
To ensure the quality of final products and communicate objectively about them, I need information: how can I be sure that I have the right content of the materials used? Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
- Fiber properties (see list of data for fiber supplier)
- Assembly methods (e.g., gluing, stitching, etc.)
- Added substances or product in the composition
- Long-term access to the data of materials I bought

7.4.9 TUS9: Certificates

As a: Brand

I want:
Recognition of recycled material though certificates, labels, etc.

So that:
I can avoid greenwashing and avoid bad press and I can obtain trustworthy data.

Additional context information
To achieve my sustainability goals, I want to use recycled materials: how can I be sure I do it the right way? Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:

- Mechanism to ensure trustworthiness of data e.g., by checking claims through certificates, certificate numbers

7.4.10 TUS10: Materials composition

As a: Brand

I want:

- To access data on manufacturing process on how fibers have been assembled AND/OR the quantity of resources used in the process.
- To create waste minimization strategies
- To find eco-friendly alternatives.

So that:
I can know the composition of the material I use to make my products.

Additional context information
For example, natural rubber used for shoe soles, and leather used in upper shoe materials are naturally occurring biodegradable biopolymers, However, to provide stability and good properties in service, these materials have been chemically modified to produce cross-linked stable structures. It's the same story for dyeing/printing and finishing treatment phases. Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:

- Quantity of resources used in a process.
- Nature and quantity of substance or material added to the fiber in the assembly process.
- (Semi-finished components) Materials properties (e.g., water repellent, fire resistance, washable, etc.)

7.4.11 TUS11: Authentication of data

As a: Brand

I want:
To access to secure and validated data (i.e., composition of material) through the platform.

So that:
I can trust and rely on it.

Additional context information
Can I trust the data listed on the platform? What mechanisms are in place to ensure the reliability and security of the data? Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:

- Validated data.

Functional requirements:

- Authentication process of the accessed data

7.4.12 TUS12: Visibility

As a: Brand

I want:
Mechanisms boosting visibility of sustainability & circularity efforts.

So that:
I can improve/proof my communication on sustainability actions to avoid greenwashing.

Additional context information:
If I provide sustainable and circular products, I want to have a safe and trusted way of communicating this to my customers and stand out from greenwashing. Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:

- Objective(-able) arguments on product sustainability

Functional requirements:

- Dashboard to download a summary sheet of my product's sustainable properties.

7.4.13 TUS13: Product availability data

As a: Brand

I want:
Display my circular and sustainable products in the platform including all product details.

So that:
I can make products available and even cross-link to materials uploaded by manufacturers, fiber suppliers.

Additional context information
To be detailed in later versions of the deliverable. Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:

- Product data such as name, brand name, variation, prices, sizes, colors, material category, material type, reverse supply chain information

Functional requirements:

- Space to fill in all product related data including save button
- Image upload for the product
- Delete button if product is not available anymore

7.4.14 TUS14: Brand's take back schemes information

As a: Retailer

I want:
To access information on brands that offer product that can be remanufactured AND ways to sell them the products back.

So that:
They can remanufacture products or reuse parts.

Additional context information
I want to set up a “take back” program to be more involved in circularity at my level: which shoes can I take back and why? (In general, it makes more sense to reduce or even minimize waste than to develop extensive treatment schemes and techniques to ensure that waste poses no threat to the environment). Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
- Information on Brand’s potential take back scheme or programs

Functional requirements:
- Contact button

7.4.15 TUS15: Repair and reuse guidance

As a: Retailer

I want:
To access guidance on how to repair or reuse product.

So that:
I can reintroduce them on the market.

Additional context information
I want to reuse old shoes and sell them through second-hand markets. Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
- Repair guide
- Reuse guide

7.4.16 TUS16: Sustainability product data

As a: Retailer

I want:
To access sustainable data on the product from the brands
So that:
I can support sustainable purchase.

Additional context information:
Sustainability aspect is increasingly becoming important for my customers. Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:CS demands that are not accounted for now
- General product information
- Material composition (high level)
- Sustainability claims
- Information and guidance to correctly dispose of shoes

7.4.17 TUS17: Verified claims

As a: User

I want:
To access trustful and understandable data on circularity and sustainability aspects of the shoes

So that:
I can make informed choices and choose more sustainable and circular products.

Additional context information:
Sustainability criteria are important for choosing the shoes. But I have difficulty to get meaningful information and verified claims. Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
- General product information
- Material composition (high level)
- Sustainability claims
- Information and guidance to correctly dispose of shoes.

Functional requirements:
- Permanent link (QR code or others) between the physical product and the digital information

7.4.18 TUS18: Care guidance

As a: User

I want:
To access information on the appropriate treatment to my shoes (e.g., wash, care for)

So that:
I can maintain my shoes in good condition.

Additional context information:
I face the difficulty to know what care treatment to apply to my shoes. Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:

- Care guide information

7.4.19 TUS19: User guidance

As a: User

I want:
To access guidance on how to replace shoes elements (i.e., inner sole, outer sole, laces)

So that:
I can extend the life of my shoes.

Additional context information
I face the difficulty to know on how I can repair my shoes. Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
- Repair guide
- List of critical spare parts which are expected to be repaired/replaced during the lifetime of the shoe

7.4.20 TUS20: Take-back data

As a: User

I want:
To access guidance on how to dispose my shoes after I don't want them anymore.

So that:
They can be properly valorized.

Additional context information:
To make sure the footwear product is just not thrown into the bin the user requires more information. Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:
- Information on take-back channels if available and collection points

7.4.21 TUS21: Resale product information

As a: Collector and sorter

I want:
To access product information

So that:
I can make informed decisions about whether and how to resell a certain product.

Additional context information
Business model of sorters and collectors is mainly based on the resale potential of textile products. Therefore, I am looking to maximize the resale potential of used shoes. Also, see appendix B of deliverable 3.1, ontological requirements.

Data needs:

- Product information
- Product name,
- Brand name
- Description,
- Color,
- Size,
- Category of fiber (fabric, yarn, trim, etc.)
- Type of material (Specific type of a material depending on the chosen category of a fiber)
- Original price
- Time of market entry
- Resale demand

7.4.22 TUS22: Material inventory

As a: Collector and sorter

I want:

- To access to material inventory
- To build knowledge about mechanical and chemical recycling destinations

So that:
I can valorize it in the best way possible (best available technologies).

Additional context information:
Materials significantly influence, not only the life of the footwear but also the end-of-life treatment of the product. Approximately 40 different materials can be used in the manufacturing of a shoe.

Data needs:

- Valorization methods and actors
- Information on legal restrictions regarding resale, repair, sorting and recycling of already used footwear products.
- Material composition with data such as
- Product with name, type, category & country code (ISO country list)
- Brand name
- Variation with name, description (consumer facing description provided by brand), year of sale, price, images, color, size, country of origin.
- Material with name and composition, content, percentage, is recycled.
- Material component steps with step type (Origin of raw material e.g. Production, Spinning
- Tanning, Pre-Tanning, Dyeing, Finishing, Printing), country, color, category (trim, yarn, fabric, leather etc.) and country

7.4.23 TUS23: Disassembly

As a: Recycler

I want:
To access guidance on how to disassemble the components.
To access material inventory

So that:
I can valorize it in the best way possible (best available technologies).
I can cleanly separate the components and get high quality recycling materials.

Additional context information
Materials significantly influence, not only the life of the footwear but also the end-of-life treatment of the product. Approximately 40 different materials can be used in the manufacturing of a shoe.

Data needs:
- Disassembly methods and guidance
- Material properties- see properties for sorters

8 Appendix 2 – Circularity requirements

8.1 The capacity to understand the system and its relations.

For detailed explanations of each capacity group of circularity requirements, see chapter 3.3.1, design principles for circular metabolisms in the deliverable 5.1 (state of knowledge review).

8.1.1 CE1: The capacity to understand interrelations between processes and actors in the system.

Energy implementation actions:

- The ability to understand all parts of energy (i.e., exergy and anergy).

Value implementation actions:

- The ability to consider a diverse variety of value forms (incl. economic, environmental, and social)

8.1.2 CE2: The capacity to identify and consider all (relevant) system actors.

Material implementation actions:

- The ability to identify connections by analysing (large amounts of) supply chain data.

8.1.3 CE3: The capacity to consider processes throughout entire life cycle.

Material implementation actions:

- The ability to collect data along entire supply chain.
- The ability to observe and track materials (in real time) throughout all life cycle phases.

Energy implementation actions:

- The ability to collect and analyse large amount of data fast.
- The ability to visualise and simulate all processes.

8.1.4 CE4: The capacity to understand interrelations with other systems (at different levels).

Material implementation actions:

- The ability to identify connections by analysing (large amounts of) supply chain data.

Energy implementation actions:

- The ability to understand carbon intensity and sustainability of energy sources.
- The ability to visualise and simulate all processes.

8.2 The capacity to evaluate actions & processes.

For detailed explanations of each capacity group of circularity requirements, see chapter 3.3.1, design principles for circular metabolisms in the deliverable 5.1 (state of knowledge review).

8.2.1 CE5: The capacity to scope (new) combinations of processes.

Material implementation actions:

- The ability to analyse the feasibility of resource exchange.
- The ability to record material specifications and activities in central and standardised unit.
- The ability to understand the connection of the quality and quantity of flows.
- The ability to incorporate data from various sources.
- The ability to visually capture processes.

Energy implementation actions:

- The ability to trace materials back to their origin to evaluate energy consumption.
- The ability to identify energy requirements of rebound effects from material flows.
- The ability to consider alternatives for achieving efficiency.
- The ability to forecast energy demand and supply.
- The ability to assess technical feasibility.

Value implementation actions:

- The ability to evaluate the economic feasibility of material and energy strategies.
- The ability to account for social and environmental externalities.
- The ability to develop holistic value proposition.
- The ability to identify activities for value creation, capture, and delivery.
- The ability to develop core objectives.
- The ability to understand value created, value destroyed, value missed.

8.2.2 CE6: The capacity to understand system barriers and external factors.

Energy implementation actions:

- The ability to consider macro level energy infrastructure and legislature.

8.2.3 CE7: The capacity to understand the effect of (a set of) actions (on the system).

Material implementation actions:

- The ability to understand success factors of exchanges.
- The ability to measure and compare material flows.
- The ability to evaluate direct and indirect effects.

Energy implementation actions:

- The ability to evaluate energy consumption and carbon emissions.
- The ability to analyse large amount of data fast.
- The ability to manage the dynamic and complexity of energy data.
- The ability to measure rebound effects.
- The ability to establish (prompt) feedback structures.

Value implementation actions:

- The ability to measure economic, environmental and social value each.
- The ability to combine all dimensions of value for a comprehensive evaluation.
- The ability to assess value created, missed, destroyed.

8.3 The capacity to adapt.

For detailed explanations of each capacity group of circularity requirements, see chapter 3.3.1, design principles for circular metabolisms in the deliverable 5.1 (state of knowledge review).

8.3.1 CE8: The capacity to acquire and share (new) knowledge.

Material implementation actions:

- The ability to track actions and decisions made by system actors.

Energy implementation actions:

- The ability to collect data during all life cycle phases.
- The ability to incentivize the sharing of data.

8.3.2 CE9: The capacity to develop new configurations.

Material implementation actions:

- The ability to understand the qualities and characteristics of a material.

Energy implementation actions:

- The ability to collect and process dynamic and complex energy data quickly.

- The ability to simulate processes to identify efficiency potential.

Value implementation actions:

- The ability to define different types of value.
- The ability to understand underlying needs and wants.

8.4 The capacity of actors to collaborate.

For detailed explanations of each capacity group of circularity requirements, see chapter 3.3.1, design principles for circular metabolisms in the deliverable 5.1 (state of knowledge review).

8.4.1 CE10: The capacity to work together for a shared goal.

Material implementation actions:

- The ability to share infrastructure (Hardware and software).
- The ability to align processes.

Energy implementation actions:

- The ability to share infrastructure (Hardware and software).
- The ability to collaborate for energy recovery.
- The ability to bring together all energy sector stakeholders.
- The ability to share information on energy demand and surplus.

Value implementation actions:

- The ability to collaborate for value (co)creation, value transfer and value capture.

8.4.2 CE11: The capacity to integrate (relevant) actors throughout entire process.

Material implementation actions:

- The ability to incentivize cooperation.
- The ability to establish reciprocal information exchange.

Energy implementation actions:

- The ability to allow and encourage active engagement by users (i.e., prosumers).
- The ability to collect and provide consumption data during use phase.

Value implementation actions:

- The ability to include stakeholders during identification of value.
- The ability to integrate stakeholders in evaluation processes.

8.5 The capacity to manage the system.

For detailed explanations of each capacity group of circularity requirements, see chapter 3.3.1, design principles for circular metabolisms in the deliverable 5.1 (state of knowledge review).

8.5.1 CE12: The capacity to coordinate processes and actors for the benefit of the system.

Material implementation actions:

- The ability to manage risk in case of exchange failure.

Energy implementation actions:

- The ability to manage energy exchanges decentralised.
- The ability to make decisions automatically.

Value implementation actions:

- The ability to establish shared vision and align objectives.
- The ability to ensure that responsibilities and obligations are met.

8.5.2 CE13: The capacity to interact and share information with actors in an effective and trustful way.

Material implementation actions:

- The ability to share information transparently and traceable.
- The ability to standardise material information.

Energy implementation actions:

- The ability to share information transparently and traceable.

Value implementation actions:

- The ability to verify value creation.