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CIRCULAR FOAM

MVP Material Certification tool

Deliverable 2.5

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Technical References

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[1]PU-public, CO-confidential, only for members of the consortium (including the Commission Services), EU-SEC-classified information: SECRET UE (Commission Decision 200/444/EC)

History of changes

Version	Date	Short description of changes
V0.1	2 June 2023	First Draft
V1.0	26 September 2023	Submitted deliverable with integrated feedback from Kingspan, Covestro, Electrolux, Unilin

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Executive Summary

This deliverable presents the design and development processes and outcomes regarding the online tools created as part of Work Package 2 of the Circular Foam project. In the course of Circular Foam, ICT tools are built to enable safe and efficient communication between the stakeholders within the supply chain.

The design of the tools was mainly based on an iterative co-creation process with the industry partners of the Circular Foam project, specifically from work package 2. This helped understand the needs and expectations of the partners, along with previous work in the context of Circular Foam, to determine the opportunities for the use of these tools for each partner. Additionally, Circularise developed extensive research on software requirements, safety standards, current developments in software architecture, and data security.

The result was a list of tools and data points to be traced across the stakeholders within the supply chain, that will support partners' needs. This list was further analyzed based on priority and feasibility, to assess its complexity, available time, and the scope of the project to incorporate them into Circularise's platform. With this in mind.

In general, partners showed their interest in circular economy and sustainability practices, however, they also expressed their concerns with regulations, and the need for data sharing and availability, given the threat it could present to their confidential information. They also highlighted the need for regulations and standardisations regarding circular practices. Circularise provides a solution to these points by means of its communication platform, which enables data sharing, without compromising confidentiality. Moreover, partners expressed the need to onboard more stakeholders into the tool, given the value and potential of the platform when more steps of the value chain are included. Finally, the benefit for partners in their day-to-day business from a circular economy, and thus from the ICT tools, is linked to the concern whether the presence of re-use, refurbished, or recycled products will negatively affect their market share in the sector.

The data needs to address were mainly focused on four main categories.

- First, the composition, to determine the presence of harmful or other specific substances that might change the outcome or procedure of processes further in the value chain (chemical composition), as well as the origin of the materials (sourcing composition)
- Second, the characteristics of the foam, which will help in the recycling process, to better allocate the components and determine the process to recover the foam
- Third, the dismantling (and installation of products for the case of construction) of components, to facilitate the collection and sorting and increase the recovery
- Finally, the environmental impact, given all the increasing needs for sustainable behaviour.

These and the remaining categories will be further detailed in this document.

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1 Acronyms and abbreviations

MVP	Minimum Viable Product
OEM	Original Equipment Manufacturer
PUR	Polyurethane
PIR	Polyisocyanurate
EoL	End of Life
EPD	Environmental Product Declaration
LCA	Life Cycle Assessment
CMR	Carcinogenic, mutagenic, and reprotoxic chemicals
SVHC	Substances of Very High Concern
HCFC	Hydrochlorofluorocarbon
CFC	Chlorofluorocarbon
HFO	Hydrofluoroolefins
HCFO	Hydrochlorofluoroolefins
PFAS	Per-and polyfluoroalkyl substances
TDS	Technical Data Sheet
MSDS	Material Safety Data Sheet

The words “Online tools”, “Platform” and “Certification system” will be used indistinguishably to refer to the “certification system” developed by Circularise as the outcome of the Circular Foam project.

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2 Introduction

Work Package 2 within the Circular Foam project seeks to improve the design of materials and products of interest to facilitate dismantling and recycling processes to promote circular economy practices within the pertaining industries. This improvement is supported by the development of online tools that enhance data communication along the supply chain to provide transparency and traceability that facilitates product processing and the transformation from current practices to more sustainable ones.

These ICT tools were developed based on the needs and input of the partners involved in the work package, who are also the main users of the platform. This involved various rounds of guided interviews, roundtable talks, and co-creation workshops where the current and desired states of the industries, along with the data to be traced with the platform were defined. The data was selected based on the needs of the stakeholders previously mentioned, which included the information these entities require to perform the activities associated with their steps on the supply chain. Moreover, given the emphasis of the project on recycling, recyclers were involved, to identify their needs and the requirements for their processes. Where available, insights from business contacts and conference participants were taken into account to validate the insights from the limited number of project partners.

This deliverable presents a description of the online tools developed. This process entails the definition of design guidelines, which comprise the software tools and specifications (e.g. functionalities and data) needed to incorporate into Circularise's certification system to support stakeholders' needs. These specifications are derived from research and interviews conducted.

Here the reader can also find the explanation and thought process used during these guidelines. This includes the outcomes of the interaction with the abovementioned stakeholders, along with the analysis and general process for the selection of data to be included in the platform. Given the iterative nature of the process, this document goes through the different steps so that readers can have details on the decision-making process, the prioritisation, and selection of the requirements, and the reasoning behind them. In general, the final information chosen addresses the needs of most stakeholders and responds to the goal of the Circular Foam project as well as the technical requirements of the Circularise technology.

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3 The problem and partners' needs

The Circular Foam project seeks to *"demonstrate a territorial cross-sectorial systemic solution for the circularity of high-performance plastics from diverse applications"*, mainly of rigid polyurethane foams used for insulation, on white goods, such as refrigerators, and on the construction sector. Consequently, there is a need for improving material and product design for easy dismantling and increased recyclability. Here, the creation of ICT tools aims to support the circularity of plastics throughout the value chain. Circularise's certification system facilitates data communication and certification, given the availability of information necessary for compliance, for example on recycled content, origin, and quantities of components. In order to develop tools that address the industry's needs, the context, usability and design need to be studied and assessed by the stakeholders involved. These include a wide range of actors, with different needs and interests as they respond to different steps within the value chain and industries.

3.1 Circular economy

The partners involved in the project are very interested in circular practices given the increasing need for recycling and in general more sustainable behaviours. Legislation is going towards "zero policies", for example, eliminating waste and gaining alternative feedstock, reducing carbon footprint, and going towards CO2-neutral circular logistics systems, among other initiatives. During the interviews and workshops, Circularise explored the current context of sustainability practices to understand the starting and "end-desired" points and determine what is still lacking for each of the partners.

Current sustainability practices
Most of the stakeholders expressed their interest in sustainability and reducing the environmental impact, as well as being able to prove such claims. This interest is supported by industry regulations, which aim to promote sustainable behaviors. For example, for the appliance sector, the directive of Repair of Goods aims to increase the repair and reuse of viable defective goods purchased by consumers within and beyond the legal guarantee. This entails changes on the supply side, setting frameworks for product reparability, and on the demand side, by leading consumers into more sustainable practices with the provision of data related to best practices on usability and reparability.

Despite a general awareness of the importance of circular economy and its clear interlinkages with the achievement of several internal sustainability goals, the amount of implemented measures was fairly low due to its complexity. Some of them even expressed that the industry was not prepared for these changes, as they involve not only a change in the processes and thus in the requirements but also in the mindset and the way the industry is perceived. For companies such as Electrolux, changes in their production that lead towards circular behaviours, are dependent on customers' thoughts: are customers willing to buy refrigerators built with recycled materials? What do customers want (and need) to know about these refrigerators?

To establish circularity practices companies need to transform their processes from the use of virgin components to recycled ones. This can be very complex as companies might need to separate current from new practices to have an overview of the recycled content. There have been approaches to reduce the complexity of bookkeeping and be able to allocate sustainability claims, among others, to products with Circularise software. Most of the stakeholders were aware of these approaches and some have even ongoing research on their compliance with these practices. However, moving towards sustainability certifications was not the main immediate goal or priority for all, as it still

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involves changes companies were not ready to face, or the existing tools do not fit their needs. This is forecasted to change within the next years given the increasing efforts from governmental and public entities and the reinforcement in policies towards recycling, which will force companies to certify their products. Consequently, there is still a gap to fill regarding knowledge about these strategies, their impact, benefits, and importance in the transition toward a circular economy.

Recycling of components

Integration with recycling practices is still very new for some industries. Electrolux, as part of the APPLiA (association for the home appliance industry in Europe), has previously worked with recyclers to develop a *Code of Conduct for Vacuum Insulation Panels* that help in the proper sorting of large appliances so that they can be adequately treated, along with guidelines for recycling technologies and the appropriate safety and security of the recycling plants and workers. Recycling refrigerators is possible, where many of the components can be broken down into their basic units, so these materials can be reused. With the Circular Foam project, Electrolux is investing in optimizing these practices, by recycling the Polyurethane Foam.

The definition of recycling processes is accompanied by the establishment of rules and requirements to assess the quality and impact that these new processes have. For example, regulation around the use of ozone-depleting substances (ODS), such as blowing agents, and their capture during recycling processes, given its classification as hazardous components. Consequently, there have been increasing efforts in making composition and other general material properties available in refrigerators for its adequate disassembly and further component identification and sorting. Current recycling practices focus on the retrieval of metals (ferrous and non-ferrous) and plastics.

On the other hand, for the construction sector, there are no guidelines yet regarding the recycling of insulation panels, or metal boards. Consequently, companies such as Kingspan and Unilin are looking for ways to set up circularity among their value chains. They are looking to establish processes around waste collection, dismantling, sorting, and general handling so that components can be easily recycled and reused. For construction products that include foam components, the regulation around ozone-depleting substances, previously mentioned, also applies. Moreover, there are other legislations relating to the disposal at end-of-life of metal-faced panel systems, among them Landfill Regulations 2002 (applicable in England and Wales), as well as the Landfill Directive (Council Directive 1999/31/EC), the Hazardous Waste Directive (91/689/EC) and the waste Incineration Directive (WID) (2000/76/EC). In 2004, there were some initial efforts towards traceability for the construction sector, where panels should have clear markings (on the tape at the panel/panel joint and/or UV marking on the face) with information about the manufacturer, the date and the type of core (Blowing agents, PUR/PIR/Mineral wood/PS/…). Furthermore, standard EN 14509 is required with minimum guaranteed performance values for the principal characteristics of the panels. Among the information is:

- Identification and the intended use of the product (e.g roof/wall, internal/external, ceiling,...)
- Description of the main components such as facings, core insulation, mass etc.
- Declaration of the main mechanical characteristics such as tensile, shear and compressive strength, bending resistance, among others, for determining its fit in certain applications.
- Regulated characteristics in the country of use.
- Other information where there is a regulatory requirement e.g. sound absorption, air and water permeability, Thermal Performance, Fire Performance, and others.

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Even though there are multiple regulations already available for the production of components in the construction sector, there are no clear guidelines for its processes at the EoL, making the outcomes of the Circular Foam project very relevant for the definition of standard procedures and rules for dismantling, collection, sorting and other relevant EoL activities.

3.2 Partners' perspectives

The methodology followed in the project involved multiple rounds of guided interviews and co-creation workshops. They were used to determine the needs of the industry regarding data to be traced to ensure the circularity of PUR within the industries of interest. The interviews' main goals were first to give an introduction to Circularise, its platform, and its role and expectations within the project, so partners can understand the support the systems can provide and clearly identify the needs that can be addressed. Second, to get an overview of the context regarding PUR foams for both the construction and home appliances (refrigerators) industries.

The different stakeholders, from manufacturers and producers to collectors and recyclers, support the circular initiatives proposed in the framework of the project. As mentioned above, most of the partners have pre-knowledge when it comes to circular economic practices, however, there are still some learnings to be made. Most of the partners have faced difficulties when implementing circular practices. Contrary to "public belief", recycled products and processes do not always contribute to a reduction in a company's expenses or in the final costs for the customers. This makes companies carefully consider whether to adopt such practices, as not always consumers prefer sustainability over costs. Moreover, to properly certify their products, there is a need for recycled content tracing, which is not always feasible to obtain given confidentiality constraints in data sharing, making it difficult to know if the components received comply with certain standards. Consequently, even though companies want to work towards more sustainable behaviours, not all industries are ready for this change and further measures and strategies need to be developed. The Circular Foam project provides support to this change, where stakeholders from different steps of the value chain come together to become pioneers in their industries.

Manufacturers, producers, collectors, recyclers, and all the stakeholders involved in the project are interested in exploring the opportunities of ICT tools further and in the demonstrations or simulations of this technology in their operative environment. Partners consider these tools as valuable input in their processes. First, they are interested in getting the information they did not have before regarding the components to be processed, or that was not correct (outdated information available in centralized databases), or that took a long time and effort to obtain. Second, the speed, accessibility, and availability of this information are valuable for them, as they can now, when receiving the physical component, immediately have access to the data needed. Third, the support in certification, monitoring, and reporting activities is beneficial to them, as they can easily assess if a component is suitable and comply with their requirements or with certain regulations. Finally, the possibility of having information pertaining to one product, which usually entails different sources as a product is made from various parts and can have different suppliers, in one place.

This round of interviews included more than one session, when needed, as the invite was extended to colleagues from different departments, and not only the person responsible for the work package. This entailed people outside the circular foam project, which brought a new and fresh perspective on the needs of the platform. Consequently, further introductions and onboarding to the Circularise

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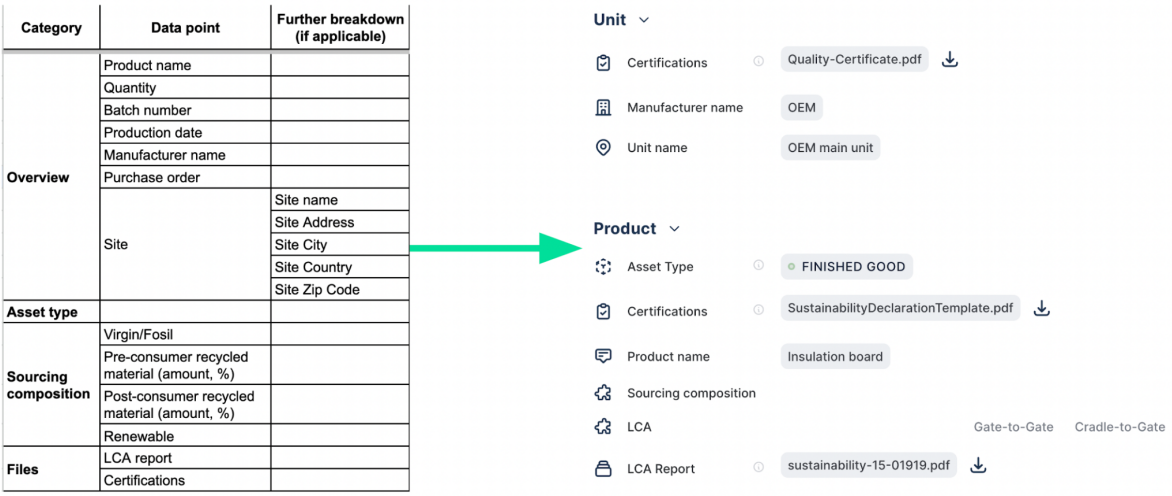
system were needed for these external stakeholders. Some of the actors involved were part of the purchasing, and technical, among other departments.

Moreover, not only the partners part of Work Package 2 were involved but also partners from Work Package 3. We included the recycling companies, who were also responsible for the definition of the collection and sorting of the EoL components. This interaction allowed us to incorporate the results from task 3.3 of the circular foam project, which entails the "development of a fine-sorting method and device for PU rigid foams". In this case, for the sorting, and thus for determining the recycling route of the part, some categories were defined, for example, characteristics of the foam such as the index (PUR, or PIR), if there were any blowing agents used and the type, among others. By including this information the platform could support the decision process for the sorting categories, as it could contain the information needed.

3.3 List of requirements

After the first round of interviews, an Excel was created with the draft of the proposal of data points to be included in the platform (Figure 1). This draft included the points mentioned by the stakeholders and some data requirements resulting from desk research of sector needs and technical requirements of supply chain communication technology. Some of these resources included documentation about the material passport best practices in the construction sector ([1]), current regulations, such as the Ecodesign for Sustainable Products Regulation and others mentioned in the previous chapters, as well as other initiatives, such as the EU project CIRPASS, with its goal of standardizing a legal framework for DPP. With this in mind, further details could be achieved regarding the exact information that stakeholders wanted to trace within the value chain. When presenting the outcomes to the stakeholders, there were many concerns raised regarding the "shareability" of the data, as some of the points included information that could risk their competitive advantage, for example, disclosing the names of some materials that are part of their IP-protected recipe to the rest of the stakeholders within the value chain. Moreover, the presence of competitors within the project (e.g Unilin and Kingspan) also presented a challenge to data sharing.



Category	Data point	Further breakdown (if applicable)
Overview	Product name	
	Quantity	
	Batch number	
	Production date	
	Manufacturer name	
	Purchase order	
	Site	Site name
		Site Address
		Site City
		Site Country
		Site Zip Code
Asset type		
Sourcing composition	Virgin/Fosil	
	Pre-consumer recycled material (amount, %)	
	Post-consumer recycled material (amount, %)	
	Renewable	
Files	LCA report	
	Certifications	

Figure 1. Translation of outcomes from the consultations with stakeholders, into data points within the Circularise's platform.

The first data point proposal was further assessed by partners, where they could indicate the level of relevance of the data (whether partners required certain information for certifications or internal

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processes, or whether the availability or not of information did not affect any of their operations) and its level of disclosure (if this information could be shared with any stakeholder, or only to some on the value chain or if it is private information that can not be disclosed). This step also helped Circularise understand the challenges for the demonstration of the technology, as well as for the platform to be fully incorporated into the value chain in a real setting. The strategy for the demonstrations was adjusted accordingly with the use of data that could be shared without endangering IP. This would help demonstrate the potential and benefits of the platform to the stakeholders, even for data points that industry partners don't feel ready to share during a demonstration setting of an EU project.

The next step was to conduct workshops with the partners, where co-creation sessions could be hosted, for an interactive definition of the data points. The main goal of the workshops was to discuss with partners their decisions (outcomes from the previous step) on the data to incorporate into the platform (which data points, why would they be of interest and how will they improve the process within the value chain). In these sessions, partners included stakeholders from different areas and departments, to ensure the presence of experts in different areas, such as supply chain management and procurement, legal and compliance, sustainability, and technical, among others. During these workshops, issues around data privacy and the possibility for data sharing presented a challenge when determining the relevance of the information, as partners sometimes classified a data point as not relevant, not because it was not important to trace, but because it was not possible to disclose. Nevertheless, proposing the use of "dummy" data and ranges, instead of exact numbers, helped partners change their perspectives and answers. Additionally, during these workshops partners were encouraged to think in terms of:

1. General ecosystem data needs: based on the industry and product type, partners need to comply with certain regulations. Moreover, information about specific materials and properties might be relevant to trace for competitive advantage in the sector. For example, in the case of the appliance, ensuring food compliance is key.
2. Component-specific data needs: Each product is comprised of different parts, which are also made of multiple materials. This turns into other data points that are not specifically revealed when thinking in terms of the industry. For example, as mentioned before, for the appliance sector, it might be interesting to determine food compliance, however, when looking at the components of a refrigerator, steel is a key material, which in turn makes information about green steel relevant.

Once the workshop was over, each partner checked the responses internally, to verify the possibility of data sharing or whether there were some unmet needs from other departments. After this internal check, they shared the end results with Circularise to create the final proposal to incorporate into the platform.

With the results from partners, data were classified based on the results of the categories assessed by partners (relevance and availability):

- Relevant and shareable data
- Relevant and private data
- Nice to have and shareable data
- Not relevant data

In general, most of the private data, as mentioned before, was regarding **chemical composition**. Companies are very reluctant to disclose this information given its importance for their internal processes and the competitive advantage, however, they do see the importance of accessing this

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information from their suppliers and the effect it can have on recycling processes. They are mostly interested in knowing the presence of **hazardous substances**, **blowing agents**, and **flame retardants**, among others, that, as previously mentioned, could affect their processes or be harmful to the environment. On the other hand, information about the **chemical properties**, and **technical specifications**, was not considered relevant for most of the partners. Partners indicated that by knowing the composition, many of the properties and behaviours could be determined, as these are linked and "expected" from the substances. Moreover, given the expertise and "knowledge" within the industry, these data were clear to the people handling the components and thus, could be omitted.

Besides the chemical composition, partners were also interested in tracing the **recycled content**. They want to know the origin of the materials, whether virgin or recycled, to certify sustainability claims and ensure circularity. Moreover, they are interested in the index or the type of **filler** used, as the Circular Foam project focuses on PUR, rather than PIR, or other types of fillings; and the recycling possibilities, processes, and outcomes vary according to this input. Moreover, data regarding the **environmental impact**, as well as other sustainability behaviours were of interest to the partners given the increasing regulations towards green and more sustainable initiatives. During internal conversations, the different departments were attracted to know more about the platform given the possibilities it brought around **LCA** and different sustainability certifications.

Another interesting category is regarding the **dismantling** and **installation** of the foam, especially in the case of the construction sector, where this information is not currently available and should be developed as it will ease the mounting and disassembly of metal panels and insulation boards. Partners mentioned how the use of videos could support companies in charge of installing the panels and boards and those in charge of the collection and dismantling for more efficient results. In the case of Unilin, they already work with videos for assembly, which could be linked to the QR code for the Circularise platform, and these could be extended for disassembly. In the case of Electrolux, as mentioned in section 3.1, they have developed guidelines around the recycling of vacuum-insulated panels. The results of the research inform recyclers on the main aspects to consider when handling this type of refrigerator, the main issues that could appear when trying to recycle, among other aspects. This could be used as a starting point for developing these guidelines for other types of products, for example, refrigerators containing PUR foams. Here the platform would serve as a support for disclosing the information and for manufacturers to directly share relevant data with recyclers to improve these processes.

The categories finally implemented are described in section 4.1.

4 Circularise's value proposition

The Circularise System is a blockchain-based open-source distributed communication protocol, which facilitates knowledge transfer between stakeholders along the value chain, despite these chains being secret, intransparent, and fragmented. It consists of a decentralised information storage and communication platform built using a combination of blockchain, peer-to-peer technology, and cryptography such as Zero-Knowledge Proofs (ZKPs). The system applies a method called "smart questioning" that enables stakeholders to ask questions about a product and receive trusted answers, based on data provided directly by the responsible entity. The Circularise System allows every stakeholder to keep their competitive advantage while contributing to a circular economy. It enables trusted information exchange between participants in value chains while allowing them to (1) remain anonymous, (2) easily fine-tune and update the amount of disclosed information, (3) determine

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access rights, and (4) validate the information easily, and efficiently. This is critical for a circular economy.

One of the main challenges that stakeholders face when sharing information is connectedness, it is sometimes hard to disentangle and share only pieces of information that do not compromise the company's intellectual property (IP) or competitive advantage. For example, to prove someone's age, we might need a document such as a birth certificate, however, this document contains more information, such as the place of birth, and the picture, among others. This is also the case in the supply chain when certain information is needed and companies need to share their contracts, bills, orders, certifications, bills of materials, lab reports, audit reports, etcetera. With Circularise's technology, by means of cryptography, it is possible to share parts of data, without compromising its trustworthiness. By being "flexibly transparent", stakeholders can request and share specific bits of information, without all the information connected to it. Consequently, information exchange is facilitated, and the processes dependent on this information also are.

As mentioned above, another challenge is the reliability and trustworthiness of data. To disincentivize the spreading of untruthful information, Circularise's platform keeps all participants accountable for the data shared, even after the products are sold, and manufacturing is discontinued. This facilitates the recycling of components, even for those that have a long lifetime, for which files might be nonexistent once they reach the recycling facilities (as their manufacturing was discontinued or changed). It also promotes thinking in advance on the needs of stakeholders further in the value chain, supporting circular behaviours. As mentioned before, manufacturers will now be connected with recyclers and thus can think, when improving or developing new products and processes, about ways that can facilitate recyclers' tasks and improve overall circularity. It is important to clarify, that all this information can be shared without compromising stakeholders' anonymity, or risking competitive advantage, as explained before. In general, the platform will provide material certificate data to support sustainability efforts and compliance with different standards.

In the Circular foam context, the platform can:

- Provide information to easily collect and dismantle. Knowing the composition and certain properties of the components to recycle, it is easier to determine the most appropriate approach for more efficient results. For example, knowing a metal panel can be detached by a glue-dissolving process or by simply unscrewing the parts can help distribute parts and allocate resources. Here, Circularise can communicate specific data related to the process of dismantling.
- Inform recyclers to recycle better. It is crucial to know the chemical composition of the products, for example, the presence or absence of specific chemicals such as chlorofluorocarbon (CFC) in refrigerators, as these substances can not be released into the environment, but they need to be recovered. With Circularise, companies can know if a product contains certain substances, without knowing the specific content, to maintain confidentiality.
- Support reusing recycled content. The recycling process used to recover the material from the EoL parts can change the final product and its properties. Manufacturers need to be aware of these changes so they can adjust their processes and maintain the quality of their products. With the circularise tools, manufacturers can see the previous steps in the supply chain and know the origin of the components.
- Certificate recycled content. By tracing the components, it will be possible to know which parts were recycled, the final material and quantity produced, that will be reused and sent

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from recyclers to manufacturers as input for new parts. With the Circularise's certification platform manufacturers such as Covestro can prove to original equipment manufacturers (OEM) such as Electrolux that the 2kg of PUR foam delivered, is made with recycled PUR, or how much of the content delivered comes from this content and how much is virgin.

- Improve communication throughout the supply chain's stakeholders. Many products have long and complex supply chains. In these cases, no single party is responsible for a specific product from raw resources to market distribution, and the information concerning the whole supply chain is "fragmented" and is unclear who, in the supply chain, owns specific data. Circularise enables information sharing all in one platform, without giving the responsibility to one actor, as each partner is still in charge of the information of their processes, making it easier to track information ownership in supply chains.
- Provide reliable and up-to-date information. Currently, there are centralized databases, managed by third parties, where companies can keep their information available to regulatory entities and others. However, this could be outdated. With the Circularise platform, each partner discloses information about each batch they create, which allows them to fine-tune details every time they create a new batch and share this "real-time" with their customers. Moreover, as the information is created in the blockchain system, once it is uploaded, it can not be deleted or adjusted without these changes being made public. This ensures that data can not be manipulated or compromised.
- Promote information sharing within supply chains. Companies are not always willing to share data publicly as it can be a threat to their business if their "recipes" or "Know-how" is known by their competitors or clients. Circularise tackles issues around secrecy among supply chains, by making it possible to share and obtain information without compromising personal identities. This happens encrypted, given the use of blockchain technology, in the form of simple answers to the questions of the recycler or manufacturer or just by disclosing a full list of material publicly. The level of disclosure (who is the data shared with and to what extent) is defined by each actor based on their needs and interests.
- Easily access (and provide) information about components from suppliers (and to customers). With Circularise, manufacturers and recyclers can retrieve information about all product's properties and materials only by scanning the QR-Code on the products. Products such as insulation boards and metal panels can include QR codes that dismantlers can scan on the site and get information about how to disassemble the component and how it should be handled at its EoL. Moreover, refrigerators can also include these codes so consumers can know about its proceedings, recycled content and overall environmental and social impacts, which in turn promote their sustainable behaviours and support decision-making.

4.1 Data points

Based on the interviews and co-creation workshops done with partners, and the list of requirements and needs, the functionalities to be supported and the data points to be included in the platform were defined. The selection was based on the partners' needs, the alignment with the goal of the Circular Foam project (to support *"circularity of polyurethane foams used as insulation in refrigerators and construction"*), and the scope of Circularise within the project (technology state and forecast, and manpower). Given the differences in the partners' needs and the goals of each sector, two lists of requirements were proposed, one for the construction sector, and another for appliances, specifically for refrigerators.

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4.1.1 Data Points for the construction sector

To develop the categories, the current platform was used as a starting point. In this case, the main categories identified are listed below:

1. Overview

This category provides some basic information on the components delivered throughout the value chain. Here companies will get information about the:

a. Product name. So that stakeholders on the value chain can know what the tokens they are receiving are from. Whether is a screw, a panel, a motor, or any other component.
b. Quantity. This will help in assuring that companies do send the amount produced, thus they can not send more tokens than the available quantity.
c. Production date. It will support informing the lifetime of components and recycling better. Also, to allocate components to specific batches and thus production processes.
d. Manufacturer name. To enable stakeholders on the next steps of the value chain allocate a specific component and process to a company and contact them in case of missing information or further details.
e. Site. This is of interest as can help companies for certification purposes, for example, on recycled content. Specific data on the site name, site address, site city, and site zip code will be collected with the platform.

2. Sourcing composition

Given the goal of the circular foam project in recycling components, companies are interested in tracing this quantity. This would enable sustainability claims and certify recycled content, thus complying with regulations such as ISCC, among others. In this case, partners can declare whether the origin of the materials they use is virgin, renewable, or recycled (either pre-consumer or post-consumer). By declaring this information, it is possible to trace throughout the value chain how the different stakeholders allocate this quantity and to know in the end product, how much recycled or virgin content is present.

3. Chemicals of special interest

In the chemical industry, there are specific elements that can't be used, or which use is regulated. Consequently, it is important to know the presence of certain substances, to certify that the end products are free from them, or comply with the specified amount. According to the construction sector, partners indicated the need to check for substances that represent a threat to humans, for example, CMRs (Carcinogenic, mutagenic, and reprotoxic chemicals), SVHC (Substances of very high concern), candidates for these substances, halogenated compounds (among which fluorinated, brominated, chlorinated). The importance of this information lies in the need to know the presence of substances that can't be released into the environment, given the harmful effects, such as HCFC, CFC, HFO, and HFCO; or that require special attention. Other substances that need to be traced are those that might lead to accidents, such as explosions, in which pentane was highlighted, given its flammable behaviour.

4. Installation

Kingspan and Unilin expressed their interest in implementing a category that could support stakeholders who will handle panels, as this could ease the mounting and overall use. This category involved basic information on:

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a. Main processes to install. To support manufacturers' clients.
b. Uses. This will give an idea of the portfolio and possible applications for their customers.

5. Technical specifications

The information included in this category would be a support for the OEM's customers and a way to quickly access data that could be otherwise found on files such as TDS. The highlighted data were thickness, density, and thermal conductivity, which all help customers commercialize and install their products.

6. Chemical composition

This category portrays information related to the substances used in the foam's production. The data points included here are mainly a result of the tasks performed in WP3, where stakeholders defined what was needed to adequately allocate the EoL products' parts on the possible recycling routes. This entails the information of composition, as some substances might harm or compromise certain processes.

a. Material core and index. Determine whether the foam is PUR/PIR based and the index.
b. Polyether content. In the case of the presence of polyethers, it is also important to know the type (e.g. whether they are Aromatic amine-, sugar-, sorbitol-, initiated polyols, brominated polyols, or which other).
c. Polyester content
d. Filler.
e. Blowing agent. As mentioned for the category of "chemicals of special interest" it is important to determine if there are any HF(C)O, pentanes, or other particular substances that might interfere with the recycling process.
f. Flame retardant. Similar to the previous point, is important to identify if flame retardants are halogenated or not if they are non-phosphorous-containing, a combination, or what type of flame retardant was used.

7. Dismantling

To support the collection process and make it more efficient, through information on best practices or guidelines on how to handle the products at their EoL. The goal of this category is to better allocate resources, reduce efforts and improve logistics around EoL processes. In this case, partners propose the incorporation of videos where they could include the most effective way for disassembling their products to maximise recovery rates.

8. Regulations and other compliances

The main regulations to consider for the construction sector are around chemical composition, where REACH and RoHS were the main ones. Moreover, child labour is mentioned, for claims around human resources and fair working conditions requirements.

9. Environmental impact

This is a very relevant category for partners, as companies have increased their efforts and interest towards sustainable behaviours. This is further incentivized by the need of stakeholders to make sustainability claims, for regulation compliance, competitive advantage or as a positioning strategy within the market. Given the potential of Circularise's platform to trace components since its origins (early steps within the value chain), it is possible to have an accurate trace of the impact derivated

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from the materials and activities on each step. Circularise's platform enables to follow LCA data from early suppliers, going through the OEMs, and continuing with further downstream actors. Information about, but not limited to resource use (e.g. land, minerals, metals), ecotoxicity, human toxicity, and climate change, can be reported.

10. Files

The last category is relevant files that companies normally share with the products, either per mandate or voluntary initiatives. These could include the TDS, MSDS, or more publicly available files such as EPD.

4.1.2 Data points for the refrigerators

In the case of refrigerators, most of the data points proposed for the construction sector, also apply here. The main difference is for the category "Installation", which is not needed, as the refrigerators already come assembled and there is no need for further work. Moreover, the "Technical specifications" are focused on the fire and thermal performance, which are relevant to know, to determine the overall performance of the products and comply with the regulations specified for home appliances. Regarding the "Chemical composition", Electrolux is interested in knowing the surfactants and adhesives used in the production of the foam, as these have an impact during the recycling process. For example, a sealant based on silicon can compromise compatibility between the foam and some solvents used in chemical recycling processes (such as chemoslisis). In this sector, different regulations apply, and the need for complying with food contact is key. Moreover, the interest in food-related regulations is extended to compliance with Hallal and Kosher standards, which consider guidelines for refrigerators, being these "food containers".

It is important to mention that all this information does not have to be filled in by one actor, but each actor is accountable for sharing the data related to the processes they are in charge of. For example, the OEM will not input the information from their raw materials received, but their suppliers will provide this data. This way, Circularise ensures that data is reliable and up-to-date, as it comes directly from its source. This also encourages actors to have an active role in gathering the correct information, as each stakeholder is accountable for the data they include on the platform. Moreover, as the platform is based on blockchain, changes are also traced, which means that if at any point, stakeholders change their processes/materials and update the information on the platform, this will be seen in the history of changes and stakeholder further on the value chain will see this. In the end, this is a mechanism to avoid greenwashing and other corruptive strategies, where they can not change claims made in the past, as transparency is a core value for Circularise.

Moreover, without compromising transparency, Circularise considers the need for maintaining sensible data private. In this case, each stakeholder can determine who to share the information with, as well as how much will be shared (whether the exact answer or a range will be provided). This makes it possible for suppliers to prove to their customers that they comply with, for example, certain ranges of composition of substances, without revealing the actual percentage or value. This is mostly used for composition data, where for the recycling processes it is not needed to know the specific value of substances within the components, but the presence or absence of these.

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4.2 User flow

Based on each use case, the information flow needed to be defined, to determine the stakeholders that will be involved and if there are any more data that should be traced to ensure compliance. As mentioned before, the main goals of the platform are first, for downstream partners, to provide EoL operators (such as dismantlers and recyclers) with the necessary information for correctly handling the EoL products. Second, for partners along the value chain to comply with different legislations, by having the required data from the partners upstream. Third, to enable partners to make claims around the recycled content of products, by tracing the components along the value chain and seeing how much of the initial product is left at the end of the process, and thus enters as an input (recycled content) into a new lifecycle.

In this case, the actors to be involved in the traceability solutions are the partners within WP2, which represent the OEMs in the construction and appliance sector, as well as their suppliers. For PU Foam specifically, Covestro can take this role, however, any other components, outside of the scope of the project will be defined by partners, based on their needs. The information will be first uploaded in the platform by the earliest suppliers in the value chain, who will create components and share them with the following stakeholders until the OEMs receive the information, so they can adequately create the components. In real-life applications, this data would then be shared with recyclers, who can then the right decisions to ensure a more efficient recycling process and better resource allocation based on the composition and origin of products. This will be further clarified during the demonstrations in Work Package 6.

4.3 ICT Tools developments

Besides the inclusion of data points to fit the needs of the appliance and construction sectors, Circularise also worked on the extension of its platform's functionalities, so it enables the integration with companies' own internal systems. Through further development of Application Programming Interface (API) technology, it is possible to integrate with stakeholders' Enterprise resource planning (ERP) systems. This facilitates multiple operations by updating the information from materials received and sent on the ERP, into the Circularise's platform. The CircularFoam project work particularly focused on the development of the relevant customer documentation for the use of API.

To make the API of Circularise respond to the growing need of technologies and the implementation of new features, improvements in the areas of maintainability, performance and extensibility, need to be done. The work done in circular foam pertains to the improvement of the maintainability and extensibility of the APIs, for example, by implementing SOLID programming principles and improving the design pattern usage. As a result, API integrations will run smoothly, increasing development efficiency while enhancing the ability to expand the API and supporting ERP integrations with new functionality.

Moreover, to ensure the correct functionality of the platform, a security audit was conducted in November 2022. During this audit, Circularise's security was assessed, with a positive result, confirming the fit of the current resources with its objective of communicating highly sensitive customer data via a decentralised storage system, which enables companies to select the data storage they trust. The assessment was successful and improvements proposed are currently being internally assessed and integrated.

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Needs assessments via the industry partner consultations revealed a need for a high level of usability and understandability of the user interface, including the way data is displayed, collected and edited.

Circularise made front-end technology improvements meeting these needs. This included the industry-specific data dashboard for the sector. This entails the adjustment of the digital product passport provided by the system to the needs of the sector. Industry partner conversations specifically highlighted the focus on recycled material traceability. In line with the interest of the users to use the system for traceability of certified recycled material and its quantity, Circularise added functionalities to add information at later stages of the digital product passport lifecycle. Furthermore, WP2 entailed the need to improve reporting opportunities of material data. In combination with the need for recycled material tracing, this user story was translated into software improvements on renewable material certification, namely ISCC compliance verification and certification including the facilitation of the auditing process.

The need for material certifications also entailed the adjustment of the supply chain transparency software to support recycled material certification management at a scale that fits the company size and process maturity of big corporate partners with high amounts of materials and different facilities. Circularise therefore added specific software that supports a growing number of material characteristics especially in compliance tracing and recycled material content monitoring.

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5 Conclusion

This deliverable presents a first approach and proposal for the incorporation of the DPPs Initiative into the construction and appliance sector. These initiatives are expected to come into force by 2026 starting with the battery sector, followed by other prioritized industries from the Circular Economy action plan (electronics and ICT, textiles, plastics, construction and buildings) [2,3]. Given the early application of these initiatives, there are no guidelines on the content and requirements for DPPs. Consequently, Circularise conducted various iterations in the process of definition of the data points, as with further use and more clarity on the purpose and possibilities the platform brought, partners saw the potential of new information to trace. Future use of the platform will enable partners to propose additional data points, resulting in better component tracing and more informed decision-making.

Introducing the platform to stakeholders and explaining its potential took considerable effort and dedication given the newness of digital tools and supply chain transparency solutions. The need for security validations, internal IT analyses, and stakeholder involvement was evident as the technology is still unexplored territory for many companies. In general, these validations supported assessing the viability and feasibility (possible to use in terms of technology and internal policy concerns), as well as the desirability (what were the benefits and possible use cases for the company's logistics) of the platform. It is essential to increase visibility and provide training for digital tools and technologies, even if they are not subject to regulation in the foreseeable future, as they can assist in overall bookkeeping and activity tracking. This ensures their adoption and maximizes their use when stakeholders fully understand their functionalities.

This deliverable's outcomes inform task 6.3, where the technology demonstration will occur. The platform will be used to create a digital twin or DPP of physical components throughout the value chain, sharing defined data points within the system. Stakeholders will have the required information for sustainability and recycled content claims, among others. Visibility of data from the source will support certification and audits. The platform will also aid dismantling and recycling processes by providing data to assess EoL parts' status and the best disassembly procedures and logistics to maximize resource recovery. Finally, the most suitable recycling route can also be determined.

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References

[1] Heinrich, M. and Lang, W., Materials Passports-Best Practice; Technische Universität München, Fakultät für Architektur: Munich, Germany, 2019.
[2] Battery Pass consortium. Battery Passport Content Guidance -Executive Summary - Achieving Compliance with the EU Battery Regulation and Increasing Sustainability and Circularity Version 1.0. 2023. Retrieved from https://thebatterypass.eu/assets/images/content-guidance/pdf/2023_Battery_Passport_Content_Guidance_Executive_Summary.pdf
[3] WBCSD, and BCG. Enabling Circularity through Transparency: Introducing the EU Digital Product Passport. 2023. Retrieved from https://www.wbcsd.org/contentwbc/download/15585/226483/1

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 10103685