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ONTO-DESIDE

DELIVERABLE

Digital twin concept design, including ontology-based data sharing platform architecture and methodology – Report v2

Deliverable number	D4.2
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Lead partner	IMEC
Contributing partners	LIU, CIRC, FAS
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PROJECT INFORMATION

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 decentralised 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 decentralised 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, analyse, 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

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2.0	31.5.2024	Mikael Lindecrantz	Internal reviewer	RS
2.0	31.5.2024	Eva Blomqvist	PC	LIU

Table of Content

1 Abbreviations

Abbreviation	Explanation
ACP	Access Control Policy
API	Application Programming Interface
CSS	Community Solid Server
FAIR	Findable, Accessible, Interoperable, Reusable
LDP	Linked Data Platform
OIDC	OpenID-Connect
R2RML	Relational to RDF Mapping Language
RDF	Resource Description Framework
RML	RDF Mapping Language
TRL	Technology Readiness Level
WP	Work Package
YAML	Yet Another Markup Language
YARRRML	Yet Another R2RML/RML Mapping Language

2 Introduction

Semantic interoperability of data is one of the biggest barriers towards data sharing in the Circular Economy. Onto-DESIDE aims to provide the technical foundations for information flows that will transform European Industry towards a Circular Economy, by means of digitalisation and data sharing. The project leverages a decentralised digital platform that enables collaboration in a secure manner. This allows for automation of discovery, planning, management, and execution of cross-industry circular value networks, at a European scale and beyond. Combined with access control policies for data privacy and confidentiality, flexible data sharing is enabled whilst protecting company-internal data, at the right level of granularity.

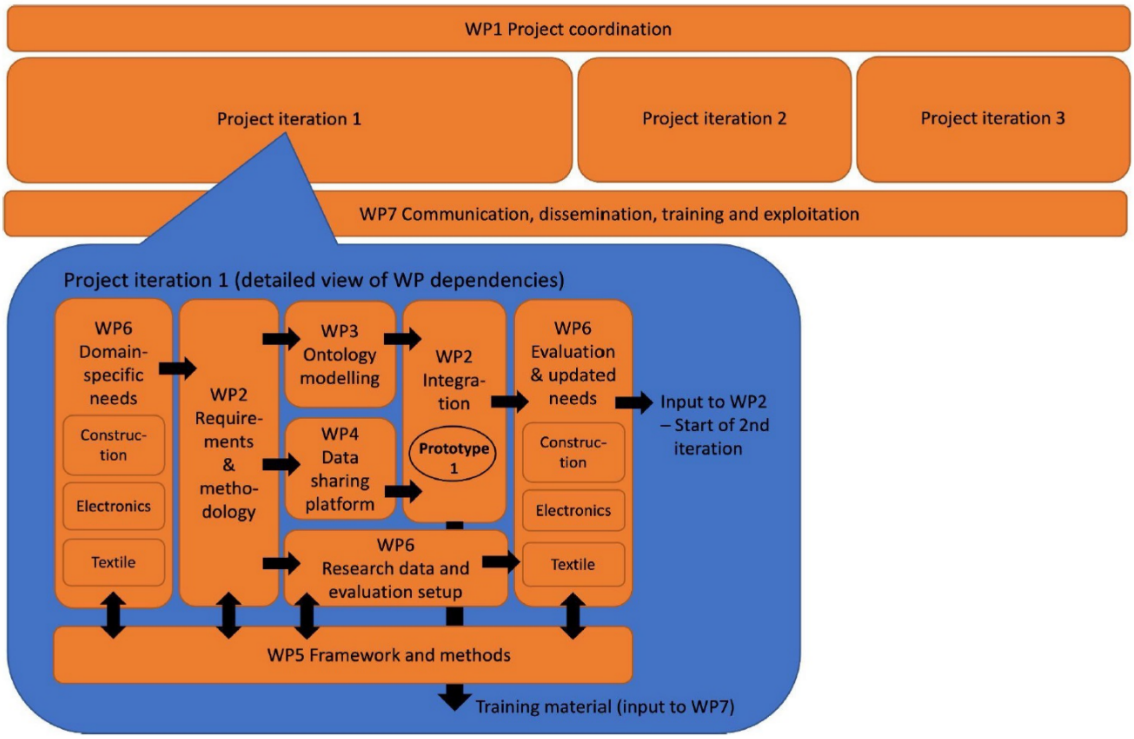
This project will develop a technology for sharing data about materials and products at a global scale. Since access to verifiable information is primordial, the project will use well-established open standards for secure data and information sharing. As ownership and storage of data should remain with the actor that produces the data, a decentralised approach is necessary. Metadata and structures for transforming data into information (semantic descriptions and vocabularies) will be open, and comply with FAIR principles, to enable the highest possible degree of semantic interoperability and automation in data sharing.

Further, this interdisciplinary project will also develop integrated tools and methods for further enhancing a Circular Economy. Although the importance of various 'flows' – i.e. resource flows (the various forms resources can take along their journey, e.g. material, component, product), information flows, energy flows, and value flows – has been widely acknowledged within the transformation to a Circular Economy, they have not been integrated or linked into a single framework or approach. Without such integration or linking it is not possible to make robust designs of circular value networks and to implement and operate value network coordination within industry.

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, electronics and appliances, and textile – 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. This way, the project aims to show that the Open Circularity Platform is concrete enough to solve specific problems (i.e., the three specific use cases) but also has potential to be widely applied.

The project consists of three iterations, where each technical Work Package (WP) contributes to all the iterations. The WP dependencies are illustrated in Figure 1 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 (M19-27 and M28-36 respectively). Each iteration ends with a collection of feedback from the industry use cases, analysed and reported in a WP6 evaluation report.

FIGURE 1- PROJECT OUTLINE AND DETAILED DEPENDENCIES BETWEEN WORK PACKAGES EXEMPLIFIED BY THE FIRST ITERATION



2.1 Objectives and Research Methodology

2.1.1 Objectives

Today, access to data in a secure, quality-assured, and automated way is one of the main obstacles that industry actors point to when attempting to create new circular value chains.

Work package 4 (WP4) will contribute to an open decentralised digital platform that enables secure collaboration. This includes supporting the correct enforcement of access control policies, as well as using Verifiable Credentials to verify sensitive data. The outcome of the WP will be an Open Circularity Platform, i.e. an open framework for secure, verifiable, traceable, and decentralised data sharing within and across industry domains, expressed and documented using the ontologies from WP3.

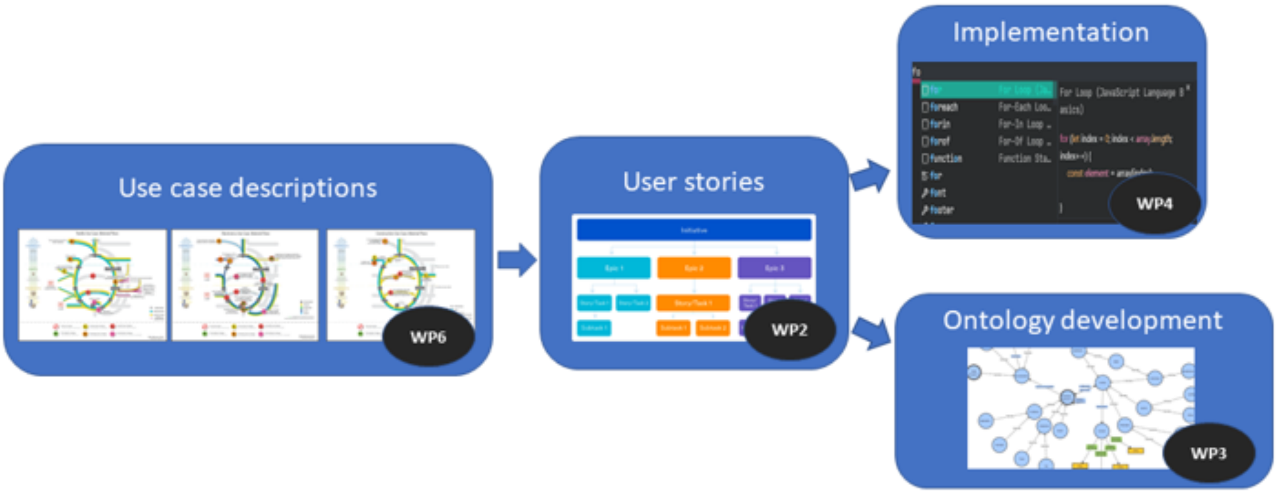
2.1.2 Research Methodology

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; and
- 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.

Specifically, for WP4, the focus is the technical development of the Open Circularity Platform, adhering to the technical requirements as put forward in WP2. For this, a new method will be devised to set-up decentralised networks of data vaults and actors.

Figure 2 Diagram visualising the workflow of WP4 and the related artefacts



2.2 Tasks and Deliverables

WP4 is led by IMEC and is divided into five tasks, each related to the objectives of the work package. These tasks are outlined below:

- T4.1 - Data transformation - lead: IMEC, participants: CIRC
- T4.2 - Retrieving public and private data - lead: IMEC, participants: LIU
- T4.3 - Verifiable statements and credentials - lead: IMEC, participants: LIU, CIRC
- T4.4 - Blockchain-based implementation - lead: CIRC, participants: IMEC
- T4.5 - Querying data - lead: IMEC, participants: LIU, FAS

Two sets of deliverables are to be produced for WP4 during the project:

- D4.1-3 Digital twin concept design, including ontology-based data sharing platform architecture and methodology (4.1 M9, 4.2 M24, 4.3 M33) - report
- D4.4-6 Open circularity platform (4.4 M10, 4.5 M22,4.6 M31, v4 M33) - software

This document constitutes the report for deliverable D4.2 and aims to describe the ontology-based data sharing platform architecture and methodology.

3 Concept (was: Digital Twin Concept Design)

While semantic interoperability and ontology-based data documentation are essential enablers for large scale digital Circular Economy, it is not enough in itself. Semantically described data also needs to be put into use. Today, there is limited data collaboration within industry domains and even less across domains, and as a result, new circular value networks are only created between known actors that have a certain degree of comfort working together (Bressanelli2018) – limiting the possibilities of more and more high value circulation scenarios.

However, instead of having each industry domain create their own circular interconnections over time, the core logic of circularity should be common and manifested in a digital entity that translates between industry domains. By building upon a shared vocabulary – i.e. defined in an ontology network – we create reusable templates for a certain type of circular value network, and could at minimal effort be shared with a different set of actors or used within a different industry domain to instantiate new value networks. By translating between domains, there is no need for a central information repository: every organisation will keep and manage their own data. By building on well-established standards for semantically describing, interlinking, and sharing data, collaboration is made secure and scalable.

Increasing the potential of such networks requires information flowing between actors, regardless of the domain they operate in, the systems they use, and the data models they adhere to. However, a network's potential is hindered due to lack of data interoperability (Blomqvist2022), both semantically (i.e. actors adhere to different data models) and technically (i.e. actors share in various formats using various protocols).

Knowledge graphs based on Semantic Web technologies is an established method to increase semantic interoperability. A centralized platform can increase technical interoperability by providing infrastructure and services tailored to a common data model and format. However, such centralization shifts control to the authority that governs the platform. Companies are typically reluctant to put their sensitive data on servers beyond their control. Instead, a decentralized approach where each actor is in control of its own data is desirable.

Technically, we will implement the Open Circularity Platform: a decentralized data sharing platform, built on semantic and technical interoperability standards, to facilitate the establishment of circular value networks.

To provide for an interoperable, transparent, and secure solution, we rely on open Web standards. We map existing data to the interoperable Resource Description Framework (RDF) using the RDF Mapping Language (RML) for semantically annotating heterogeneous data sources (Dimou2014), allowing actors to complement their existing infrastructure with a component that maps their existing data to an RDF representation that can subsequently be shared through the platform. We leverage Solid – a set of open Web specifications[1] – to establish a decentralized data sharing platform. Specifically, we store each actor's mapped RDF data on their respective Solid pod. We further leverage Solid's authentication and authorization specifications to enable secure and controlled

[1] https://solidproject.org/TR

sharing of resources stored on the pod. We employ the W3C Recommendation for Verifiable Credentials to allow users to verify the authenticity and integrity of the information shared on the platform by incorporating validation and verification methods that provide proofs of data authenticity (Sporny2022). We provide a Web application that allows users to query and verify the information shared on the proposed platform[2]. We combine these technologies to tackle following three challenges to provide the novel decentralised solution:

- semantic interpretation of existing data, so that actors can rely on existing infrastructure;
- a decentralised network to publish and retrieve semantically annotated data, behind a layer of authentication and authorization, so that actors can share their data with only those partners they are comfortable with; and
- a verification method so that collaborating actors can trust the data they are using.

Our objective is to demonstrate (at TRL6) an ontology-based decentralised data sharing platform that maximally takes advantage of existing IT infrastructures and standards, without compromising on access control and trust.

4 Methodology

We will set up an ontology-based decentralised data sharing platform using the Solid protocols. As no best-practice methodology for designing such a data sharing platform is in place, part of our research is to devise such a methodology.

4.1 Proposed Methodology

We present following methodology:

1. Extract use cases by means of user stories. A user story is an informal, general explanation of a software feature written from the perspective of the end user. Its purpose is to articulate how a software feature will provide value to the customer. *This allows us to form the (high-level) requirements.*
2. Create a list of data sources per use case: what is their content, how do you access it, and who owns them. Use cases can involve different types of data, and different ways of governance. As such, multiple data sources can provide essential or context information concerning a single use case. Whether – and how – this data must be interpreted semantically, depends on the use case requirements. *This allows us to identify what existing or sample data is available.*
3. Prioritise the use case based on data availability, stakeholder importance, and complexity. *Based on this prioritisation, we can select the first use case to work on and continue iteratively.*
4. Create a list of technical scenarios within the use case. A technical scenario is a list of steps, written in plain text, where detailed data flows are elaborated on specific use cases. E.g., when a use case specifies "I want to retrieve product information from the manufacturer.", a technical scenario specifies which specific product information is retrieved from the manufacturer, in which required format. *This allows us to further detail the technical data requirements.*

[2] https://viewer.onto-deside.ilabt.imec.be/

5. Per scenario, create a list of actors and existing systems (databases, APIs, user interfaces, and so on), and how the data flows between them. This could be via a data flow diagram, or a (more detailed) sequence diagram. These diagrams provide details about the calls that happen between the different actors and components.
6. Devise (alternative) Solid-based set-ups that adhere to the requirements and data flows.

4.2 Discussion

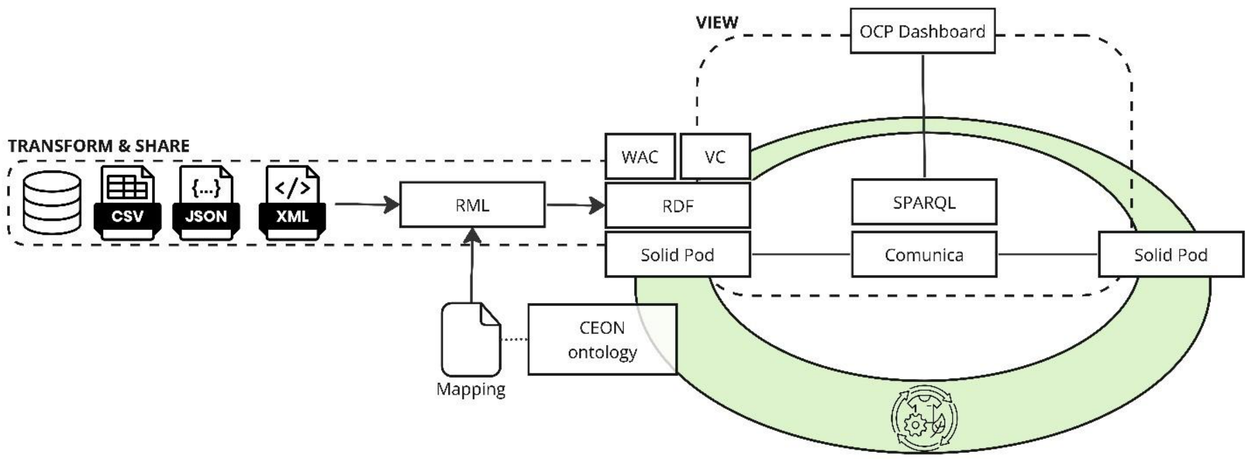
Within Onto-DESIDE, the first step is achieved via a combination of defining example cases (WP6) and technical requirements (WP2). A first series of validation was executed during the first iteration of the project, resulting in the evaluation results as described in Deliverable 6.7. The previous version of the Open Circularity Platform was validated against these requirements, and new features were re-prioritized in the next version of D6.7, namely, D6.8.

5 Open Circularity Platform Architecture

A large part of this deliverable is also being published as a paper:
G. De Mulder, E. de Vleeschauwer, B. De Meester, P. Colpaert, and O. Hartig, "The Open Circularity Platform: a Decentralized Data Sharing Platform for Circular Value Networks," in Proceedings of the 2nd International Workshop on Knowledge Graphs for Sustainability (KG4S), Hersonissos, Greece, May 2024.

The Open Circularity Platform is completely built on open Web standards and provides four steps for enabling companies to participate and collaborate on the platform (Figure 3). Specifically, a company's source data needs to be mapped to an interoperable representation (*Transform*, T4.1), which can subsequently be shared with others (*Share*, T4.2) through interoperable interfaces. Then, the interoperable data, spread across the platform's actors, needs to be retrieved (*Query*, T4.5) and presented to other actors in an accessible and convenient manner (*View*, T4.5). To establish (cryptographic) trust (T4.3), additional operations to make the information verifiable are orthogonally integrated in each step.

FIGURE 3 THE OPEN CIRCULARITY PLATFORM TRANSFORMS HETEROGENEOUS SOURCE DATA TO VERIFIABLE RDF ACCORDING TO AN ONTOLOGY, THROUGH A MAPPING DEFINED IN RML. THIS DATA IS SHARED SECURELY USING SOLID SPECIFICATIONS AND QUERIED USING SPARQL IN A FEDERATED MANNER. A PROOF-OF-CONCEPT DEMONSTRATOR PROVIDES AN END-USER VIEW.



5.1 Transform (T4.1, T4.3)

To unambiguously convey information between diverse systems that incorporate heterogeneously structured data sources (databases, CSV, JSON, XML, etc.), the Open Circularity Platform provides a mapping component that transforms a company's source data to RDF according to an ontology that is commonly understood by all actors of the platform. A mapping language describes different types of mappings between a source schema and a target schema and provides a means for linking a particular data source to its specific mapping policy. Various mapping languages, exhibiting different characteristics and features, exist (VanAssche2022). We leverage the RDF Mapping Language (RML), an extension of W3C's recommended R2RML (Das2012), supporting heterogeneous data sources, hence, allowing actors to maximally rely on existing systems. We can then use RML to map each company's source data according to the Circular Economy Ontology Network (CEON, Blomqvist2023)[3].

To allow consuming actors to verify the integrity and authenticity of an actor's data, the resulting RDF data is complemented with verifiable claims. We leverage Verifiable Credentials (VCs, Sporny2022) to complement the transformed RDF data with verifiable claims.

5.2 Share (T4.2, T4.3)

Across companies, a network of decentralised data stores that allow fine-grained access control is needed. Traditional, centralised platforms require centralised systems for identification, authentication, authorization, and data storage. This requires actors to use the systems that have been put forward by the platform itself. For example, actors are required to store their data on the centralised platform servers, thereby giving up control of their data to the platform. In contrast, decentralising every part of a platform enables actors to choose which solutions to use for identification, authentication, authorization, and data storage.

Solid is a novel concept that aims to change the way Web applications work today. The Solid ecosystem encapsulates a set of W3C standards and tools, based upon the Linked Data principles, taking authentication and authorization into account, and aiming towards a sustainable Web and decentralised data-ecosystem (Verborgh2017). Users (within the context of this project also referred to as actors) can store their data in one or more data stores (called pods) that are fully controlled by their respective user.

By separating data from logic, services and applications become federated views on top of a set of distributed data pods, and service providers no longer need to centralise all data themselves. In Solid, decentralisation does not only pertain to where data is stored, but also to every other component within the Solid ecosystem. As such, Solid constitutes of separate interoperable standards covering identification, authentication, authorization and managing resources. To provision the (verifiable) RDF data through an infrastructure that enables technical interoperability between diverse systems and allows actors to be in control of their data, the platform leverages several components of the Solid ecosystem (for simplicitly, these components are not individually presented in Figure 3, but can be seen as sub-components of the Solid Pod component).

[3] https://liusemweb.github.io/CEON/

Identity in Solid: WebID. Users, organisations, services, and applications of the decentralised data-sharing platform need to be unambiguously identifiable. Such *identity resources* are the cornerstone to enabling trust between actors (authentication), defining access control (authorization), and determining each actor's associated decentralised data store(s) to enable data collaboration. The WebID specification allows – through a Web resource – to describe the identities of users, organisations, services, and applications (Sambra2014).

Authentication in Solid: Solid-OIDC. To establish trust between actors, authentication is required to verify the identity of each party. The current Solid ecosystem recommendation for authentication relies on Solid-OIDC: an OpenID-Connect extension to authenticate users without hard-coding the connection between the Identity Provider and the Data Store (Coburn2022).

Authorization in Solid: WAC. Access Control defines which data can be accessed by what or whom. The Web Access Control (WAC) specification describes how authorised access can be defined by associating access permissions with identities.

Resource management in Solid: LDP. When separating data from applications, strict protocols need to be in place to manage resources. Basic data manipulation is described by the Linked Data Platform (LDP) specification, where actors can manage and operate on both binary data (e.g., PDF files) and semantically annotated linked data (e.g., RDF graphs).

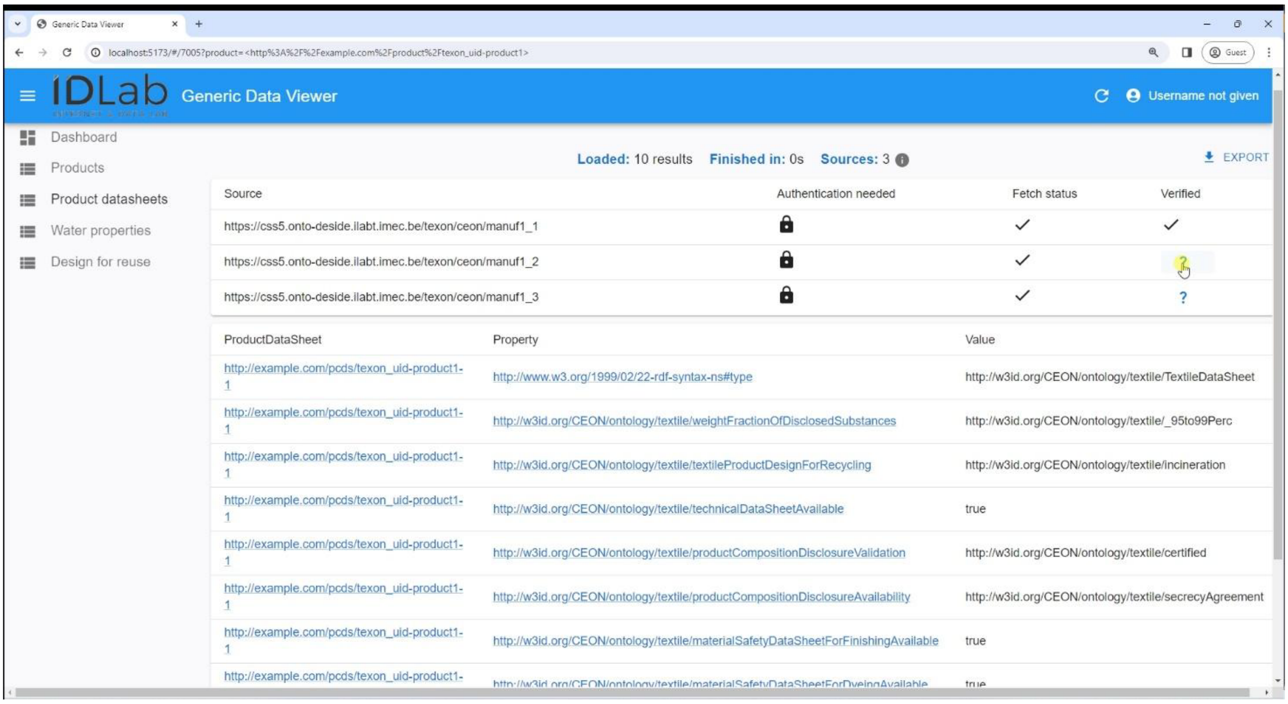
5.3 Query (T4.5)

As the data is stored decentralized across different Solid pods that belong to different actors, we employ a uniform access abstraction layer in which SPARQL queries (Harris2013) are executed in a federated manner. This allows to query data that is distributed across multiple sources, as if it was a single source. Hence, we leverage SPARQL to express which subsets of information to retrieve and/or aggregate (e.g., by computing statistics such as sums or averages) from the platform. When the functionalities of the network will change (e.g., support for Verifiable Credentials by M24), this uniform access method will not need to change.

5.4 View (T4.3, T4.5)

A Web-based dashboard application (Figure 4) allows users to select different views (i.e., different SPARQL query results) over the data they have access to, while being able to check whether data originates from verified sources. For example, a manufacturer should be able to execute views including all details about its materials, components, and products. However, supposing that the manufacturer shared only a subset of its data (e.g., only products) with a reseller, the views executed by that reseller should only include subsets of the data to which the reseller was granted access. The dashboard hides away potential complexities inherent to the decentralized infrastructure (i.e., data being stored across multiple data sources and heterogeneous data structures) by providing the users with a unified, simple, and tabular representation of the query results produced by each data view.

FIGURE 4 SCREENSHOT DEMONSTRATING HOW THE OPEN CIRCULARITY PLATFORM ALLOWS TO SECURELY QUERY AND VERIFY DECENTRALIZED DATA SOURCES.



5.5 Technical considerations

To transform company data into a semantically and technically interoperable model and format, we map each actor's source data to RDF annotated with the Circular Economy Ontology Network (CEON) using RML mapping rules executed by RMLMapper[4], a JAVA processor. The result is technically (RDF) and semantically (CEON) interoperable data for each actor. By generating each resource conform to the Verifiable Credential standard, we allow that each resource is cryptographically verifiable (i.e. it can be shown that the resource is untampered and published by a verified source)..

The resulting RDF is then stored on the actor's Solid Pod, hosted on a Community Solid Server[5]: the reference open-source implementation. By default, all data (except for the public profile) is private to the actor that owns it. The use case's read permissions are configured using WAC rules, so that every actor controls which data to share with whom.

To better align the Transform and Share steps, we directly configured how to organize the data in a Solid pod within the RML mapping rules. For this, we make use of RML's *Logical Targets*. In RML *Logical Targets*[6] describe how RDF data – resulting from the execution of RML mapping rules – must be exported after generation. Such *Logical Target* includes a *Target* that describes how a target must be accessed when exporting the RDF data. To export the RDF data to a Solid Pod we have defined two Solid related Targets: a *Solid Resource Target* to store RDF data as a resource to a Solid Pod, and a *Solid ACL Target* to add access rules (via the WAC standard) to a resource on a Solid Pod. We implemented both targets in RMLMapper, and included them in the RML mapping rules. As a

[4] https://github.com/RMLio/rmlmapper-java

[5] https://github.com/CommunitySolidServer/CommunitySolidServer

[6] https://kg-construct.github.io/rml-io/spec/docs/#target-vocabulary

result we can now configure the transformation of the company data and the storage of the resulting RDF data with WAC rules in one RML mapping document, executable with one command.

The SPARQL queries are executed by the state-of-the-art federation engine Comunica[7]: a meta-query engine designed in a highly modular and configurable manner to deal with the heterogeneous and federated nature of Linked Data on the Web. Comunica can take Solid's authorization mechanisms into account[8], so that the query results only include the (subsets of) data for which the consuming actor has been granted access.

We allow data, queried across different sources, to be cryptographically verified by validating the digital signatures bound to each published resource. Each data resource is published together with a Verifiable Credential, signed by the owner of that credential. For this, we first set up each actor with a cryptographic key pair, of which the public key is added to the actor's public profile. Then, we apply the BBS+/BLS12381 cryptographic suite (Bernstein2023) to sign each published resource using the actor's private key. As such, other actors in the network can verify the authenticity and integrity of a claim by verifying the claim's digital signatures against the public key published by the issuing actor of the claim.

Our demonstration dashboard application allows actors to explore data across the entire network, i.e. across domains, via a predefined set of configurable views (Figure 4). Selecting a view triggers the execution of a particular SPARQL query in the background and provides the user with a tabular representation of the results.

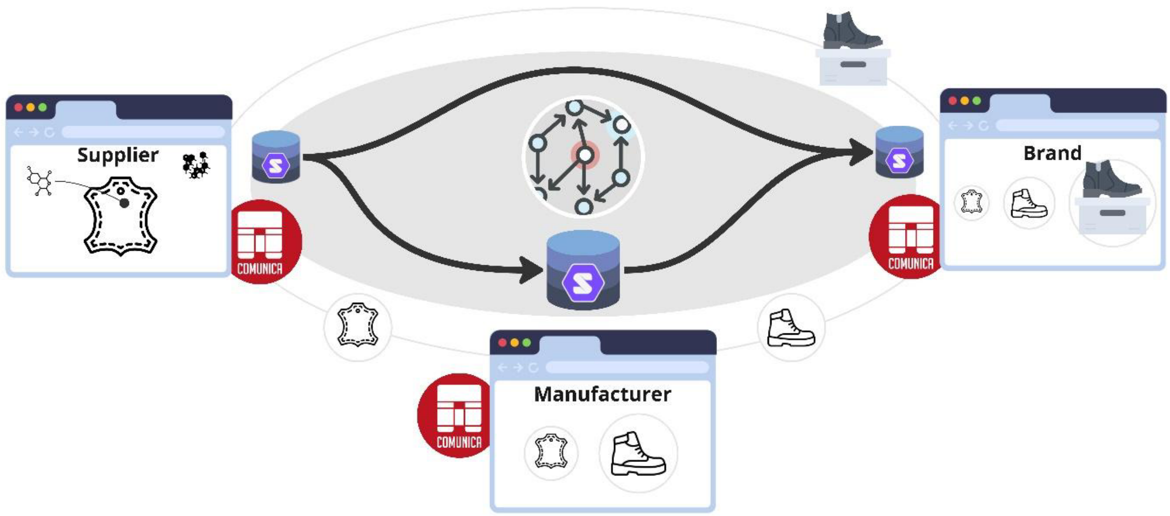
6 Textile Use Case: A Visible and Transparent Sustainability Score

We extracted multiple scenarios from the textile, construction, and electronics domain, validated by use case partners. Our example scenario within the textile domain involves three actors: i) a supplier of materials for footwear; ii) a shoe manufacturer that combines different materials that make up the final product (i.e., a shoe); and iii) a brand that sells the shoe. For information to flow across these actors, data about materials and assembled shoes needs to be made available from supplier, to manufacturer, to brand, which we can demonstrate using (the viewer of) the Open Circularity Platform (Figure 5).

FIGURE 5: AN OPEN CIRCULARITY PLATFORM TEXTILE USER STORY: A SUPPLIER DELIVERS MATERIALS TO A SHOE MANUFACTURER, WHICH ASSEMBLES VARIOUS COMPONENTS TO CREATE SHOES. FINISHED SHOES ARE THEN SOLD BY A BRAND.

[7] https://comunica.dev/

[8] https://comunica.dev/docs/query/advanced/solid/



The concrete user story (TUS06) is as follows:

> As a brand, I want to show my sustainability efforts via a visible and transparent score on my product circularity performance.

The user story requires the brand to compute a circularity performance score of the shoes it resells. More specifically, we focus on the average recycled content of each shoe, as brought forward within Onto-DESIDE as a commonly used scenario. By means of weight percentage, we can calculate the average recycled content of each product based on which of its components are recycled.

Calculating the average recycled content percentage involves data about products, components, and materials, from different actors in the network. The brand requires read access to the manufacturer's product and component composition data. The component composition data in turn is derived from the supplier's material data.

Transform Each actor in the network (supplier, manufacturer, brand) has data about the materials and components it supplies/manufactures/sells. For example, the manufacturer's data consists of products and their corresponding composition of materials (i.e., their bill of materials (BOMs)). RML Mapping rules to map this data to CEON must be provided for each actor.

Share The user story requires the brand to query material, component, and product data from the supplier's and the manufacturer's data stores to compute the average recycled content of a product. Hence, the brand requires read access to the manufacturer's BOM data.

Query & View The brand needs to query data about materials, components, and products from the supplier and the manufacturer's data stores to calculate the average recycled content. Within the application, the brand can verify the credential to make sure that the data is in fact genuine.

7 Alignment with Distributed Ledger Technology

Task 4.4 aims at the implementation of ontology-based data sharing on the Circularise blockchain system. With this technical use case, the project aims to identify similarities between the OCP and blockchain-platforms and identify the opportunities and challenges of integrating the project ontology and OCP with blockchain-platforms.

Based on the ontology provided by WP3 and the functional requirements shared by the use case partner Rare Earth Industry Association in WP6, Circularise has added a project specific dashboard with the ontology resulting from the research (WP3) and its testing in an operational environment (WP6). Through several consultations with the use case company, the ontology developed in collaboration between WP3 and WP5 of the project was validated for the blockchain system and the electronics use case with the specific data of the speaker producer.

Through reviewing Deliverable 4.1 and aligning with UGhent, Circularise assessed the needs of both parties when it comes to software integration. Given the open nature of the OCP, both parties identified an integration with a big share of publicly available information as a joint priority. The Circularise software system is a B2B system that until today only catered to companies using the system but not to end-users or to any data consumers outside the platform. In line with this assessment Circularise built a specific API integration that displays and shares the publicly available data on the system with a focus on endusers. The so-called pDPP enables fine-tuning the CEON ontology to match the needs of the project. Through this functionality the adjusted ontology can be directly used via the API of the Circularise system on the OCP. Furthermore, Circularise also developed a dashboard that displays this data and any changes made to the data on the Circularise system publicly (see

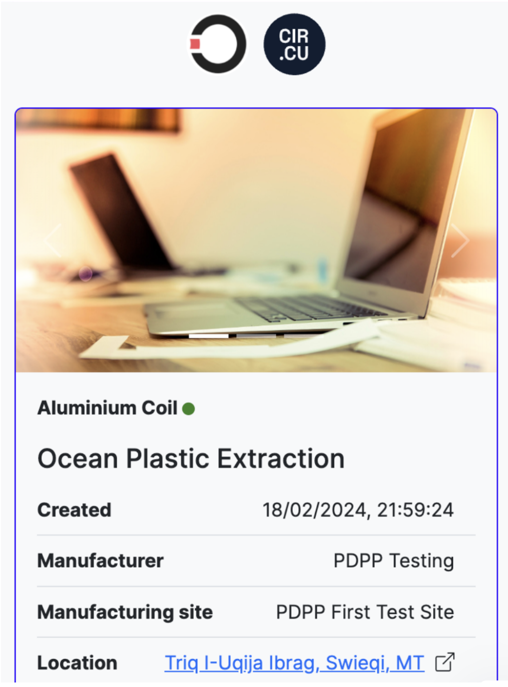
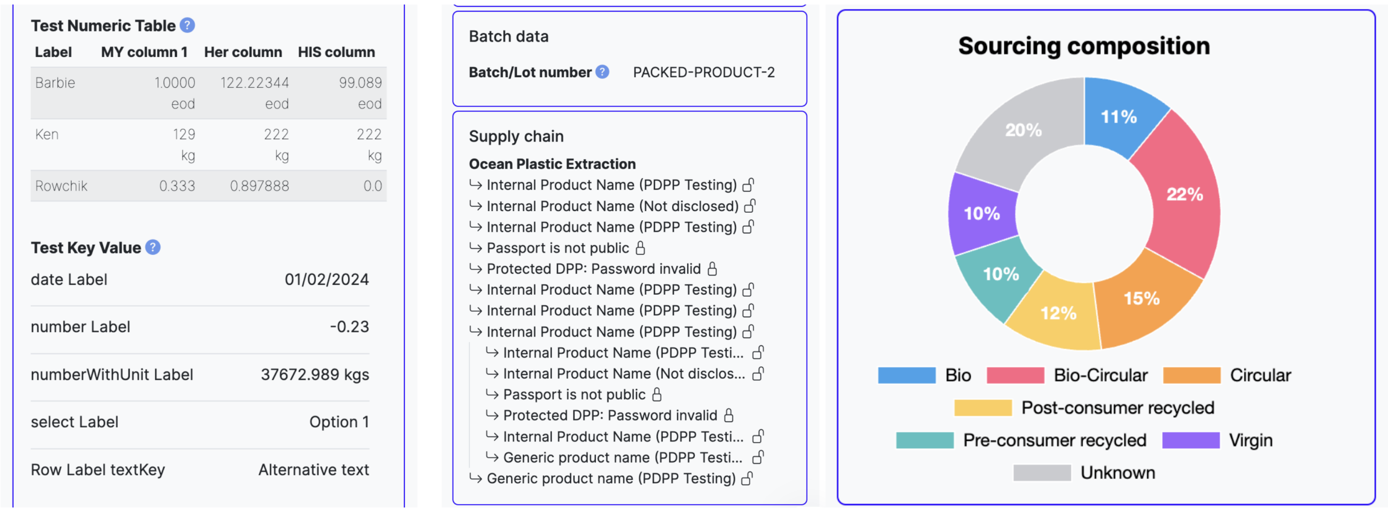


figure).This new setup enables sharing data about a specific use case in a custom ontology (e.g. for a digital product passport) as well as using this data in the OCP.



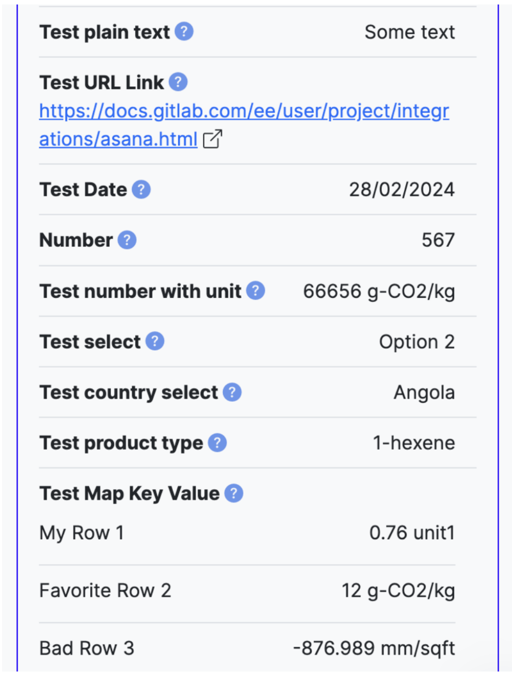


Fig: Directly generated Public data output from Circularise system as accessible via API integration. Sample data.

Furthermore Task 4.4 focuses on adjusting the Circularise system backend technology to accommodate open communication protocols or standards.

- Relevant standards

Circularise has investigated relevant standards for open data sharing in electronics and is preparing further development of system components to accommodate this.

Standardisation and open software infrastructures has increased in relevance over the past years. The European Commission has since pushed for more standardisation of a previously very diverse landscape of digital product passport initiatives in their funding portfolio. With the CIRPASS project and several open calls for integrated dataspaces, rather than single software solutions, a trend towards interlinked software ecosystems is emerging. Given the increasing need for data sharing, governments and industry associations have been setting up projects towards the standardisation of data and software infrastructures. Circularise has looked at the most important standardisation projects in the electronics industry in order to determine general trends in technical infrastructure, standards and protocols that focus on data interoperability. Given the diversity of materials in the electronics industry, Circularise focuses in its assessment mostly on rare earth materials as it a) constitutes the use case of the Onto-DESIDE project and b) is by far the most standardised sector, given the latest battery passport legislation[9].

The most important standards shaping electronics and looked at during the assessment period were:

MOBI - This global non-profit organisation that specifically focuses on Web3 digital infrastructure for the mobility sector. While mobility is not the focus of Onto-DESIDE, MOBI is still a trendsetter for the industry Onto-DESIDE does focus on: the rare earth industry. Spearheading one of the first initiatives towards a battery passport and a related infrastructure, this standardisation initiative is crucial for the development of open standards and software ecosystems across all rare earth and metal processing industries of the mobility sector. This standard was issued by MOBI and its members[10].

Catena-X - Catena-X is a non-profit organisation aiming to standardise data communication in the automotive sector[11]. All standards, protocols and dataspace components of Catena-X are available for integration. Catena-X is the first dataspace for a specific industry reaching this majority level of having more than 20 established standards and open software available. It thereby marks the starting point of industrial dataspaces, with successors like Manufacturing-X already having started in the same spirit.

CIRPASS - In line with collaboration of several Directorate Generals joining forces towards a unified approach to data sharing, the CIRPASS project was set up. The project standardised data sharing by standardising data formats, unique identifiers, data carriers and data repositories. In the followup project CIRPASS-2 the project then started more concrete work on joint infrastructure with a specific focus on the battery sector[12].

Battery Pass - The Battery Pass consortium constitutes the first and biggest association towards the standardisation of a digital product passport initiated from a European member state. The availability of standardisation recommendations well ahead of most international consortia has led to the Battery Pass policy recommendations influencing many other initiatives around standardisation across not just the mobility sector[13].

- ### 7.1 Items identified as required standards and developed to date

  - *User-verifiable transaction receipts*

One of the main standards of traceability in electronics and electronic applications in the automotive sector is the verifiability of transactions via blockchain. It should be possible for users of the system to verify the transactions they see in their dashboard is part of our ledger committed to a public blockchain for the future. With the changes made, users can now click on an activity and see a transaction receipt. A transaction receipt can be compared to the padlock you see in the url bar of

[9] https://data.consilium.europa.eu/doc/document/ST-5469-2023-INIT/en/pdf
[10] https://dlt.mobi/wp-content/uploads/2023/06/MOBI-BP0001TG2023-Version-1.0.pdf
[11] https://catena-x.net/fileadmin/_online_media_/CX_Operating_Modelv2.1_final.pdf
[12] https://cirpassproject.eu/dpp-related-standards-dataset/
[13] https://thebatterypass.eu/assets/images/content-guidance/pdf/2023_Battery_Passport_Content_Guidance_Executive_Summary.pdf

your browser, which you can click on to see the certificate of the website you are visiting and either trust that it has been verified by the browser, or use an external tool to verify the certificate yourself. Similarly, a transaction receipt contains a human-readable explanation (and metadata) of the receipt and machine-readable proof that can be verified either offline or in the browser with a provided verifier program.

- *Transaction management*

Data transactions are often simplified within the newly created data spaces. Given the technical fit with data infrastructures companies currently already use and the eased way of onboarding new companies, the architecture is simplified in its backend technology for transaction management. This enables following data standards around data sharing and traceability across key dataspaces and aligns with the requirements regarding APIs, protocols, and commonly used data connectors..

7.2 Next steps

Over the remaining months of the Onto-DESIDE project, Circularise will implement technology to facilitate the integration with further standards and/or protocols relevant to the electronics sector. The integration of Circularise with OCP for the specific electronics use case is to validate the specific Onto-DESIDE example of data interoperability and collaboration of software platforms.

8 Conclusion

This deliverable is the second iteration to the Open Circularity Platform design. The main design was retained, most focus was put in adding authentication and verifiability in the design (T4.3) and providing an end-user viewing application to better demonstrate the platform's functionalities. The first evaluation already showed a good requirements conformance (D6.7), which is being updated for D6.8.

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