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A circular economy approach for lifecycles of products and services

Report on Technical Implementation of ecoPoints Management, LCA & EPCIS Systems Interoperability

Deliverable 4.3

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Executive Summary

This document describes an approach for circular economy information interoperability – one of the major challenges when managing data and information in the context of circular economy. Not only is the context of information and data management in circular economy a gigantic challenge in view of pure volume of information and data but also in the context of current and future information / data / process complexity.

In this deliverable the following actions has been conducted:

- Design of a development approach for the interoperability layer adapter system – result based on REST services and JSON format combined with extended data types in the first version for CIRC4Life
- Evaluation of current and potential future demands on information and data interoperability in the context of circular economy which will pose demands on additional adapters and system interaction points
- Clarification of priorities of what will be achievable during the task in CIRC4Life
- Coordination of the development effort allowing the resulting structures to fulfil several roles & process solutions in the CIRC4Life effort
    - As a data entry system for demonstrator base data
    - Integration of concepts and development that supports escrow database functionalities in coordination with T4.6.
- Investigation of future upgrades to the resulting solution – future development, research & implementations
    - One such future development can be eventual coordinated efforts with EU sustainability efforts in the context of G7/G20 – strong support from EU representation Circular Economy G7/G20.

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Acronyms and abbreviations

Abbreviation	Description
CE	Circular Economy
CEBM	Circular Economy Business Models
EC	European Commission
ICT	Information Communication Technology
JSON	JavaScript Object Notation
LCA	Life Cycle Assessment
P2P	Peer-To-Peer
PEF	Product Environmental Footprint
REST	Representational State Transfer
SOAP	Simple Object Access Protocol

Introduction

Current and future needs for effective and efficient data and information transfer in a circular economy context will demand high levels of flexibility, adaptability and performance of the information logistical solutions. To effectively support closing of resource loops, use phase support and support market mechanisms that also include environmental and social impact aspects, the solutions must support information and data beyond the current contexts of LCA, LCA(S) and current product supply chain data. In order to manage efficiently closed resource loops the data and information connected to the product, service or resource must also contain detailed information on resource amounts, recyclability, hazards and in the case of refurbish able product also the products service and use history. Also connected to products and resources, it is vital to add instructions, skills and other knowledge resources to effectively plan and execute the recycling / refurbishing stages. To handle these complex contexts of information and use context a neutral interoperability layer needs to be developed.

An interoperability layer supporting not only current data and information demands but also future demands represents major challenges since the future data and information types can contain data not fully utilized today. Examples of such potential future information types are standardised modules for connectivity information for computational services for maintenance and impact analysis etc. and infrastructures to handle meta-data to support efficient market mechanisms. These information types are characteristic of escrow system approaches which will have to support future products over extensive lifecycles and complex use phases.

The functionalities of adapters is currently managed within the CIRC4Life interoperability layers by the use of REST-based webservices using JSON as a neutral transmission format. Future versions planned for further development will add more complex supporting data types and logic to handle complex data and information contexts that cannot fully be managed by REST/JSON. The development of this additional support is planned for future projects / exploitation.

An additional role of the interoperability layer in the CIRC4Life project is to act as a data entry system for the ICT platform and to deliver a vendor-neutral and flexible platform for storing and managing base data for different scenarios in the project itself.

The current implementation can with some minor changes directly be used as a foundation for sector specific solutions. Future versions will be significantly more powerful in the ability to handle specialised data formats and processes – especially when optimized for Peer-To-Peer (P2P). Currently there are discussions to prepare proposals / projects aiming at developing information logistical solutions for circular economy able to handle not only data and information types but also support management of advanced services and resource / services markets. These future plans include proposals and efforts involving collaborative development involving circular economy actors within G7/G20 organisations. Discussions have started with representatives covering circular economy information logistics and standardisation based on the interoperability layer concepts in the context of G7/G20.

Analysis

During the analysis phase the different demands on the interoperability system is defined forming the basis for the development of the different components in the system. During this phase it was clarified that the interoperability layer also should be able to handle support functions for different systems in the CIRC4Life effort – base data entry for LCA calculations, eventual support for impact assessment systems and approaches etc. Additional services potentially offered by this system are base data entry for demonstration processes and information flows. These additional demands placed additional demands on work efforts and planning.

A general conclusion of the analysis phase was that the system must be able to support data and connectivity information allowing the end-user systems developers to interact with a large number of different systems and processes – example of coordinated development work in coordination with T4.6 - escrow. Examples of this are database systems from different DB vendors, REST and SOAP-based web services, access to media resources of different kinds etc. In short – the interoperability layer must be able to function as a functional directory / storage service for a multitude of resources and connections to any product or element managed in the system. More extreme examples of such connectivity are access to systems for data analysis during a products use-phase (maintenance support) and access to knowledge / skill resources internally managed inside producers' knowledge systems or public forums.

The most important scenario to cover during the project is the ability for the interoperability system to handle static base data of different types connected to a product class – not dynamic data and resources linked to a specific instance of a product. The underlying system should be able to handle customised setups of dynamic data to a specific product in future versions – examples of this can be a products service records, traceability of events, storage or linkage of measurement data for analysis, contracts etc.

A final result of the analysis phase is that the resulting system and its future development should support applications that supports large-scale Peer-To-Peer approaches. This in preparations for future developments that must be optimised for maximal distributed deployments.

1.1 Support for multiple languages

The overall interoperability system must be able to handle multiple languages – also including languages outside of the EU – during the project the languages English, Spanish and Basque is supported, experiments made with Chinese, Russian and Finnish as examples.

1.2 Information & Data security

A general and important aspect is information and data security – the ability of actors to extract the information should be minimized as much as possible. The management of data in the database and connectivity between database server and applications can be secured – the weak spot in most systems is the web browser systems at the end-user's computers since the source code for the web pages are accessible by the web browsers developer tools.

The client GUI system for the interoperability layer must be designed to prevent location, navigation and uncontrolled access to data via the web browser. The user should not be able to evaluate data locations and access routes by evaluating contents of web pages, nor should they be able to use SQL injection attacks to attack the systems.

The current simplified version is not fully protected from resource location extraction effort due to workload but have a basic protection from SQL injection attacks.

The implemented base data tools and information types do not manage personal data – only product information and the site access is centrally managed.

1.3 LCA / ecoPoints / ecoCredits Management

The main functionality to support LCA computations are interfaces and logic to support base data entry / results for LCA calculations and interfaces to support storage of CIRC4Life specific results such as ecoPoints and ecoCredits connected to the given product. To support ecoPoint / ecoCredits calculations parameters for products estimated lifetime and categorization must be stored and managed. Additional future functionalities in regard to LCA, LCA(S) and PEF interactions should be possible to add – a product can contain sections covering all these and future resource and impact computational models in parallel.

The base data entry and management structures for PEF follows more or less identically the same approaches in the management of LCA base data. Since the overall system is optimized for modular and continuous addition of new information and data types, specific versions of PEF base data entry could be created based on sectorial specializations and approaches.

The ecoPoints / ecoCredits must be stored connected to the product. The GUI system for the interoperability layer should be prepared to also function as a platform for scenario management / impact analysis / decision support when the resulting impact datasets from the LCA / PEF / LCA(S) calculations is stored. The scenario management can allow for extended uses such as simplified or specialised tools for impact assessments, product resource offerings involving complex and variating product contents setups over time etc.

1.4 Product Data Management

The interoperability system must be able to handle and interoperate with existing standards for product base data, mainly represented by systems from GS1 and 1WorldSync. The core routines must be able to support customised interactions with these standard systems taking into account the very high level of complexity of many product types and categories. Product information for a tablet is widely different from product information for an electric car as an example. Currently support for GS1 product base data is implemented, support for 1WorldSync product data can be developed using the same core data management functions as for GS1 product base data.

1.5 GS1 Repository Information Sources

The exchange of correct product information with business partners is the key to trusting and efficient cooperation. However, many manual and bilateral steps for exchanging product information make the process inefficient and confusing. This is where Verified by GS1 comes in. Due to its use in global markets it has to be represented as an information type in the overall system.

Verified by GS1 is a global solution that offers a centralised way to assign unique product identification and basic product information for every product that we create. Brand owners can record their products and provide seven product attributes each to business partners. Verified by GS1 is designed to ensure every product has a unique GTIN assigned to it that has been allocated per GS1's rules and guidelines (as outlined in the GTIN Management Standard) and can be confirmed by trading partners. By registering legacy GTINs and new GTINs with a limited set of attributes that identify the products, Verified by GS1 enables brand owners to confirm the availability of the products' GTINs. Dealers can access this data at any time via the Verified by GS1 service. This enables them to synchronize and update their own stored product information with the manufacturer's data in the GS1 Registry. This saves time and money for industry and trade.

GS1 Repository Information Sources

Minimum set of attributes needed to uniquely identify an item.

Attribute		Description
1)	Global Trade Item Number (GTIN)	The GTIN uniquely identifies a product and can be machine-readably integrated into the barcode.
2)	Brand name	Under the brand name, consumers find a product in the trade.

3)	Product description	Characteristics and scope of the product, such as net content, function or variant.
4)	Product image URL	Link to product image.
5)	Global Product Classification (GPC)	The GS1's Global Product Classification (GPC) helps you find the right category.
6)	Net content & unit of measure	Packaging size and net content of a product.
7)	Target market (Country of sale)	Information on the countries in which a product can be purchased.

Products core attributes in GS1 Cloud

By sharing GTINs and core attribute information through Verified by GS1, brand owners will now have a single place for retailers, marketplaces and others to verify the presence of attributes for product listings. Verified by GS1 ensures that a GTIN has been properly constructed and is not duplicated in the system. Additionally, Verified by GS1 checks that the GTIN is licensed to the brand owner providing the information. Provided the data entered into Data Hub is accurate, this can help aid integrity and security in the listing process and helps to prevent a seller from inadvertently “borrowing” a GTIN from another item for its listing. In addition, Verified by GS1 will help increase data transparency, operational efficiencies and the overall consumer experience.

1.6 How GS1 Registry for Trademark Owners Works

Trademark owners and GS1 Complete customers can use the GTIN Manager to transfer their product information to the GS1 Registry. Once all necessary fields in the online tool have been filled in, a product can be "activated". The seven product attributes are automatically transferred to the GS1 Registry.

1.7 How Verified by GS1 Works for retailer

Retailer and GS1 participants can query the product data provided by the trademark owner through the service Verified by GS1. The inquiry can be accomplished at any time and everywhere.

The GS1 Cloud information is in the interoperability layer handed by a specific information type present in both the user interface and in the web services provision.

1.8 How GDSN works

The GS1 Global Data Synchronisation Network® (GDSN®) is a network of interoperable data pools enabling collaborating users to securely synchronise master data based on GS1 standards. GDSN supports accurate, real-time data sharing and trade item updates among subscribed trading partners. Product master data can be exchanged globally between manufacturers and dealers via the GDSN®. The data only has to be entered into a single data pool. The GDSN® connects 30 certified data pools worldwide, to which almost 25,000 companies are connected.

This means organisations can have confidence that when one of their suppliers or retailers updates their database, their own database is similarly updated as a result. Everyone has access to the same continuously refreshed data. This automatic and efficient exchange helps in meeting the demand of today's data-hungry consumers.

For this to happen, each organisation needs to join a data pool certified and tested by GS1, who connect to the GS1 Global Registry®, a central directory which keeps track of connections, guarantees the uniqueness of data and ensures compliance with shared GS1 standards.
This makes it possible to localize article and company data worldwide in data pools. The GS1 Data Quality Framework defines the quality of the data and the GS1 Global Product Classification ensures that the product master data is all classified according to the same scheme. There are many data pools spread across the world.

1.9 Master Data Pool for Germany

With customers from more than 50 countries, Atrify (formerly 1WorldSync), a wholly owned subsidiary of GS1 Germany, is the leading provider of global product data management and data pool solutions certified for Global Data Synchronization Network™ (GDSN®).

Integration of GDSN data and information into the interoperability system where evaluated to be possible with additional planning and development time. The GDSN data for complex products can be supported by advanced and complex information types – the development of these structured information types demands more resources than was available during the project.

1.10 Interoperability Layer as a Product Data Escrow System

The core infrastructure of the interoperability layer has by coordination with T4.6 been developed to function as an escrow repository for product data and resources. By placing a products data in escrow, important product resources can be stored protected from consequences such as bankruptcies and server crashes and thus be available for future users of the products. This is important since data and information vital for the use, maintenance and recycling/refurbishment processes must be secured over long time for the product.

The properties of the interoperability layer to dynamically add and handle new information over time comes in handily in the context of T4.6 since the information / resource pool for a product might drastically grow over time – platforms for maintenance/repair/recycling practices are some examples of future resource types, user forum access and external suppliers of spare parts are other resources which must be supported.

For this purpose the interoperability layer can form the foundation for a centralized escrow system for data vital for future support and management of products / resources over time. Especially when routines for handling relationships between elements are implemented the development of knowledge-based markets for product and recycling support can be created.

1.11 EPCIS / Event Tracking Systems Interoperability

EPCIS is an important standard for capturing, storing, and sharing traceability data of a product or resource through the supply chain. Within CIRC4Life, EECC extended the traceability to also cover the usage/maintenance and recycling phases, which are not typically in scope of traceability as of today.

The interoperability system must be able to support the presentation and loading of EPCIS data for the product – preferably through both web service access and web page access. Future functionalities in traceability such as geographical tracking etc. can be supported. It must also be noted that other types of event tracking solutions should be supported if need arises in the future – circular economy involves as a context wider than supply chains for products and / or interaction with recycling processes – knowledge management / planning / strategies development processes and public services interactions that are not based on existing traceability standards.

In the CIRC4Life effort the interoperability network will be centring on product static data – not dynamic data for individual product entities. Thus, it is not planned to implement a direct interaction with the Traceability Module developed by EECC. Nevertheless, access routines and approaches for exchanging data via REST instead of EPCIS standard SOAP has been tested. Examples of EPCIS data for an individual product entity can be represented in the interoperability layer if requested – will have to change scope from product class to individual product example.

1.12 Connectivity to external databases

Many aspects of a products / service are covered in different databases with different levels of accessibility to contents. The interoperability layer as an escrow system should be able to handle connectivity data for external databases but also include documentation regarding the resources use,

limitations of access and information concerning quality control in parallel to present the accessed data. An example of this type of external resource is the access to services for analysis of measurement data and ability to connect datasets to the connected services.

The applications / application servers accessing and using the external database connectivity information types must be able to connect and interact with a number of different database systems – especially over time.

1.13 Website & Media Resources Support

Also, as a part of the escrow function support the product record in the system should be able to connect to a large number of different resources of different types and with different abilities. Below are some of these resource types that should be supported by the system.

Integrated access to websites
The GUI system must be able to integrate websites without unnecessarily revealing URLs for the resources to non-authorised users – presenting the contents in a controlled manner. For sites that do not allow to be integrated, the option should exist for the site to be presented in an external web browser window (less secure option).

This functionality should allow a trusted channel for integrating internal product support sites into the information flows with external actors. It also should allow integration of external resources such as product surveys and their results, linkages to external support forums etc. into the products "information package".

Access to multimedia resources
All multimedia resources that can be handled by web browsers must be supported – videos and pictures, standard document types such as PDF, RTF etc. These types of resources are vital for learning and maintenance of the product but also to instruct on efficient disassembly of the product for effective recycling / refurbishment etc.

Alternately, multimedia resources and files should also be able to be stored as binaries in the database system for future solutions.

Both the support for web based and multimedia resources will support the development of knowledge and learning asset repositories for the product's different life-stages and usage. This is especially important for the escrow database functionality for complex and advanced products containing valuable subcomponents and/or materials – being able to maintain a long service life and also support effective refurbishment, recycling, repairs will be increasingly important over time.

1.14 Potential Future Demands

Information logistical solutions for circular economy must handle a large number of complex challenges – not only management of product information and supply chain traceability and management but ultimately also support eventual transformation to a system that in parallel handle finance, resources, impacts and complex market signals / processes. A very important point is that LCA- and PEF-based indicators have a role up to the customer evaluation before use and start of

recycling / waste management processes but from that point forward the important parameters are access to information on real resources contents and quality, access to supporting data and information on hazards, decomposition, disassembly and or refurbishing approaches. This places heavy demands on the ability of the system to adapt to new types of information and data types over time and also support massive distributed approaches.

The interoperability system must be scalable to support a large number of nodes due to the large size of data and complexities in a real-world implementation. Due to this the system must also be flexible enough to handle new information types without the need to update thousands of nodes with additions to their database models which risks creating challenges for the end-user's systems. This is the motivation for minimizing the database model structures complexity.

A strong argument for a heavily decentralised system supported mainly by P2P protocols is the need for the involved actors to have local control of both vital data and intellectual property rights. One can clearly state that no company is interested in placing vital and secret detailed product composition data on centralised datacentres where they do not have control of the access to the data. Another strong argument is the increased vulnerability deriving from storing vital data in external datacentres that might become inaccessible as a result from solar storms, electrical grid malfunction or even political decisions to prevent access.

1.15 Overall Data Management System Demands

A vital part of the analysis centred on the choice of database system for the interoperability layer. The demands on the interoperability / escrow functionality was evaluated to be different from the core ICT system due to the need to support a wider spectrum of data types. At large two options where evaluated.

Document / NoSQL databases where evaluated because of their relative freedom due to their independence from strictly structured schemas / structures otherwise existing in regular SQL databases. Performance in context of the CIRC4Life effort where also regarded as sufficient and some aspects of programming could be simplified. The disadvantages of the document database / NoSQL approach are their limited management of data types (especially advanced ones) and performance challenges when performing large-scale analysis and decision support. Also lack of management routines for advanced data validation structures are also missing in document databases.

The option selected for the interoperability layer is PostgreSQL – a object-relational database system that also has functionalities to allow it to function as a document / object / graph database (with added modules). In the current implementation of the interoperability layer / escrow system for the CIRC4Life effort the data will be mainly managed using REST and JSON but with the added ability to use qualified data types for more advanced searches, analysis and presentation (geotagging etc.). A vital part of the PostgreSQL solution is its ability to integrate different languages and use them for processing of data – Python, Java and JavaScript are the main examples. This will allow future solutions to include powerful processing of services and contracts.

The database model created for CIRC4Life is a simplified version of larger scale implementation model planned for future projects and can be described as a hybrid between a relational/object database and a document database optimised for use in P2P contexts. This maximizes flexibility both for

CIRC4Life but also for future further development. The larger future implementations will add support for advanced datatypes in parallel to the JSON datatype used in the current implementation.

Clarification LCA data interoperability, ecoPoint & ecoCredits calculations

The implementation of the product / escrow / interoperability system developed in CIRC4Life shall be seen as a neutral storage format allowing external systems to store and exchange differently formatted data between them. The advantage with the neutral interoperability layer is the ability to combine different data and information from many sources into a common repository with unified rules and processes for accessing and store data regardless their origin or original formats.

The data management is based on the concept of *information types* combining storage format definitions and routines for storing and accessing the data. In the first simpler version developed in CIRC4Life the data is stored in JSON format and the access and storage routines are based on REST services. Future implementations will support management of more complex data in combination with the JSON stored data – why PostgreSQL database where chosen.

The information types can be directly mapped during development to existing data storage and transmission formats – an option evaluated during CIRC4Life was JSON-LD formats, other standards for exchanging data can also be directly mapped and used in the interoperability layer. To support a given data management format the format has to be mapped into a JSON structure, routines for accessing (GET) and storing (PUT) must be developed and in the context of the tool also the user interface has to be developed for the information type to allow manual management and entry of the data.

This approach allows for inclusion of different data sets from different sources using different formats and connecting them to a product, process, methodology or knowledge resource.

In the case of LCA(S) / PEF both the input data for the calculations can be entered and stored for a product (version), the resulting aggregation lists for resources and impacts can be stored for later complementary analysis and the resulting meta-indicators can be stored as individual information items connected to the product. The approach also allows for storage of other evaluation approaches for environmental impacts, KPIs and sustainability parameters combined with data covering models' specifications, versions, documentation and logging if needed. This in combination with other resources connected to the product.

1.16 Use of existing LCA databases and solutions

Existing LCA databases and solutions are not by themselves used by the interoperability layer since the interoperability layer is a neutral storage and management mechanism for data used and resulting from LCA calculations. The LCA and other systems can be adapted to interact with the interoperability layer using REST services for access and storage of data and results. A condition for this functionality is standardisation of the exchange formats. During the CIRC4Life project an approach based on JSON-LD where evaluated but a simpler generic LCA data entry approach where selected due to lack of standardisation – the JSON-LD approach where optimised for OpenLCA but CIRC4Life is using SimaPro as LCA computational engine. Complete support of the JSON-LD format would also demand development of fairly complex user interfaces which would demand significant development efforts. This is an example of the importance of standardisation.

1.17 Product / escrow / interoperability system used in ecoPoint calculations

The ecoPoints calculations can utilise the interoperability layer as a storage facility both for input data to the calculations and for the ecoPoint calculation results – ecoPoints, ecoCredits etc. It is important to note that the interoperability layer also can support versions for products – each with their own setup of input data, intermediary result aggregates and resulting indicators allowing for trends analysis etc. of the products sustainability trends.

1.18 Linkage with databases to estimate ecoCredits

As stated earlier the interoperability layer is a storage mechanism for vastly differentiating information types for products. The interoperability layer can support information types that support connectivity to external databases and data sets to be used in ecoPoints and other calculations – examples of external data sources can be vendors own databases for managing ecoCredits for their products if not stored in centrally managed escrow systems. Use of these external data source demands development of user interfaces and / or development of REST services to work.

1.19 Potential to include background LCA systems

Local nodes of the interoperability layer can be integrated into solutions for LCA(S) computation for storage and management of LCA(S) and PEF data combined with supporting documentation – a form of extended computation context support. Another scenario can be to use the interoperability system in combination with adapted information types for controlled access to external LCA(S) / PEF toolsets for data entry, computation control and controlled download / access to the computation results. This approach will demand web access to the background LCA system or interaction through web services.

Scenarios

At large the two scenarios covered during the project are:

- Entry of base data for LCA / PEF / ecoPoint / ecoCredit calculations
- Entry and viewing connected static data and information for the product

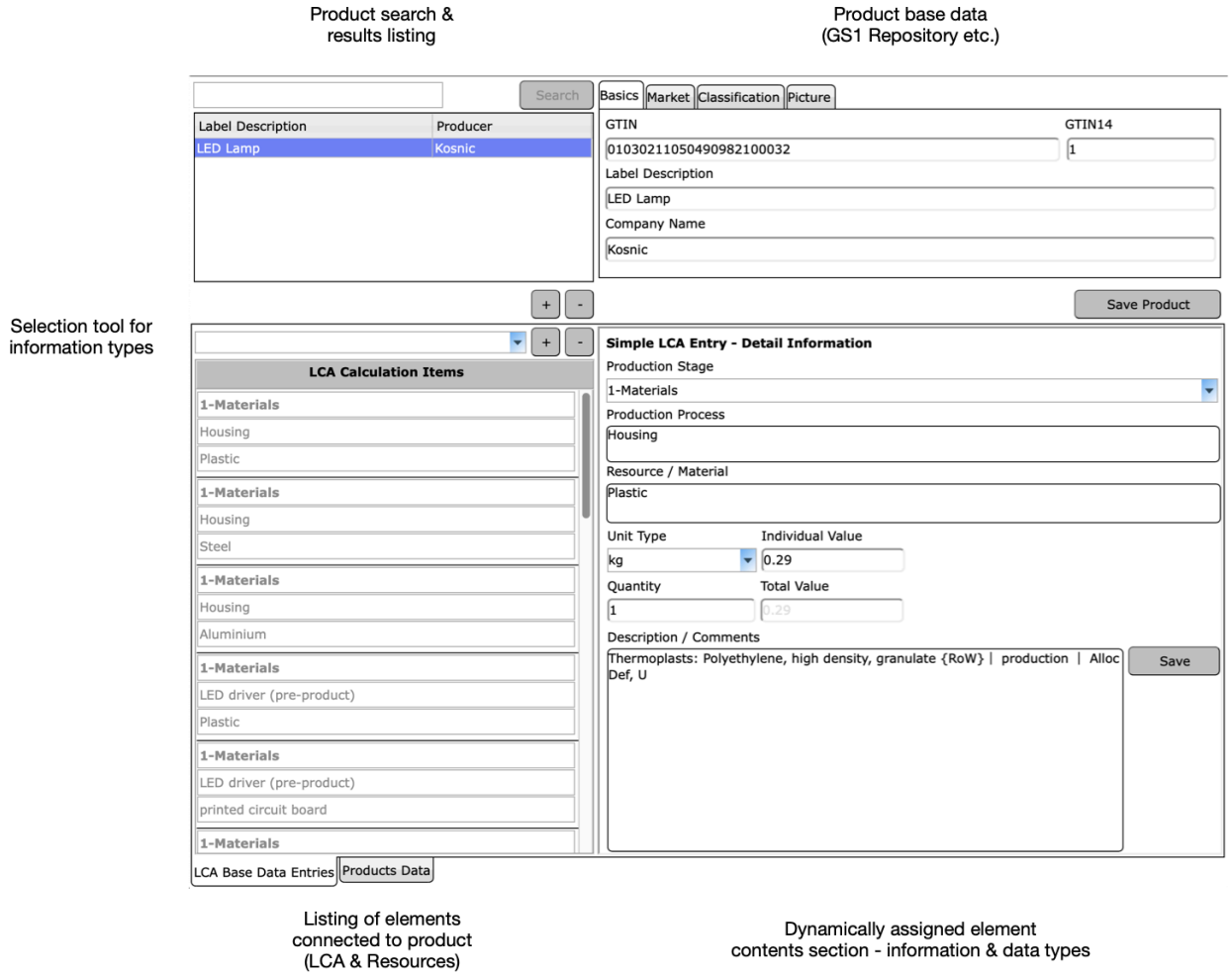
Management of dynamic product data/information and data centring on processes, knowledge resources, advanced meta-data management for searches etc. are not covered in this setup of the interoperability layer. These are possible to implement but do not have budget or time assigned for them in CIRC4Life. These functionalities can be added and integrated into the modular system for future, more comprehensive solutions.

The information entry flow is the same for both LCA / PEF / ecoPoints etc. input into the interoperability layer. The user first selects the information type to be entered and then enter the data. The system offers navigational aids to present to the user the available information types that can be utilized. The main rule is that LCA and static data cannot be entered until the product to link to has been entered or selected.

1.20 Entry of base data for LCA / PEF / ecoPoint / ecoCredit calculations

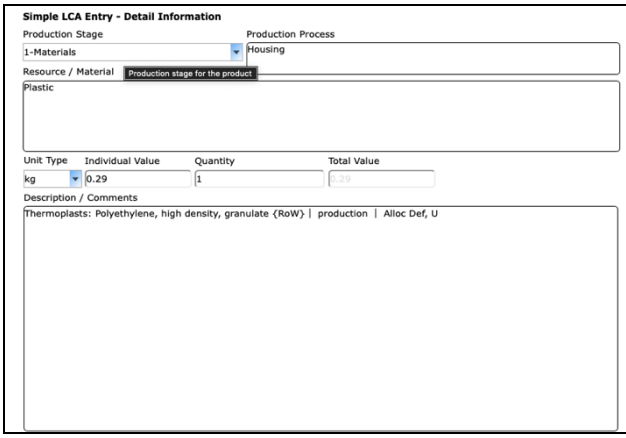
As a part of the computation of a products ecoPoints / ecoCredits an LCA calculation has to be performed using basic data entered by in this case the producer of a product. This base data is then transferred to the ICT platform. The ICT platform uses web service calls to the interoperability layer to retrieve this base data and then interact with the actors responsible for the LCA computation.

The LCA calculations can be performed using the base data retrieved from the interoperability system by the ICT platform, the results is used to compute the ecoPoints for the product and then the actor responsible for the ecoPoints / ecoCredits calculations enters this information into the products static data in the interoperability system if needed in addition to storing these values in the ICT platform. This scenario is today not fully supported but is possible to implement.



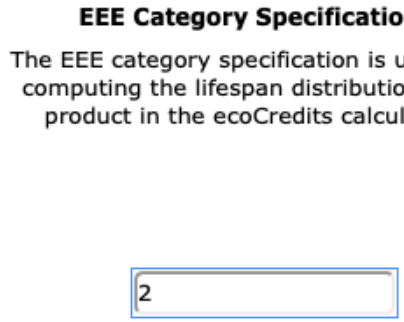
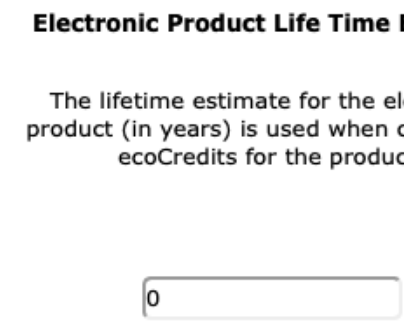
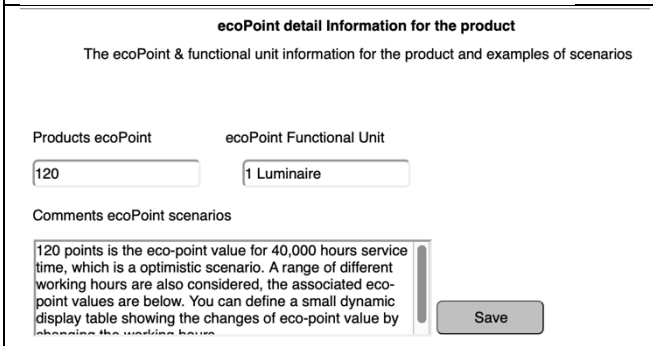
Integrated user interface for management of a products information elements

1.21 Examples of information types – LCA & ecoPoint calculation parameter data



The information type for covers the entry of an individual LCA calculation element with corresponding comment section for the LCA specialist to enter the selected value in the LCA toolset.

The LCA calculation entries are the same between LCA and PEF computations.

	The EEE category specification is used in the ecoCredits calculation.
	The electronic product life time estimate is used in the ecoCredits calculation.
	The ecoPoint result is entered with including information on the functional unit and a comment section describing usage scenarios.

Since many of the computational processes are similar between LCA and PEF then PEF can relatively easily be added into this flow – except for adaptations of the ecoPoint calculation methodology. Information types specific for PEF calculations and results presentation can be created, managed and presented in this system for a product and both LCA and PEF can be managed in parallel.

It must be emphasised that the interoperability layer can after modification support multiple calculated scenarios of LCA / ecoPoints / PEF results – to support versions of products or support future approaches for qualified impact scenarios. The interoperability layer can act as a repository system for multiple scenarios / versions of analysis results. This has been a subject for discussion and initial concept designs between ENV and JS – evaluation of approaches to use the interoperability system as a user interface / data management platform for impact assessment scenarios management and results logistics.

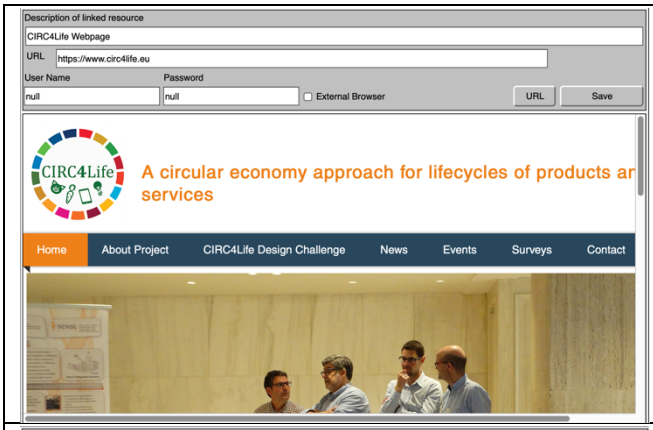
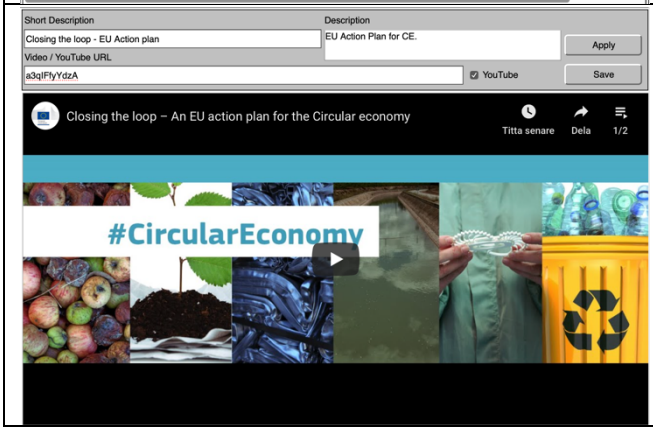
1.22 Entry and viewing connected static data and information for the product

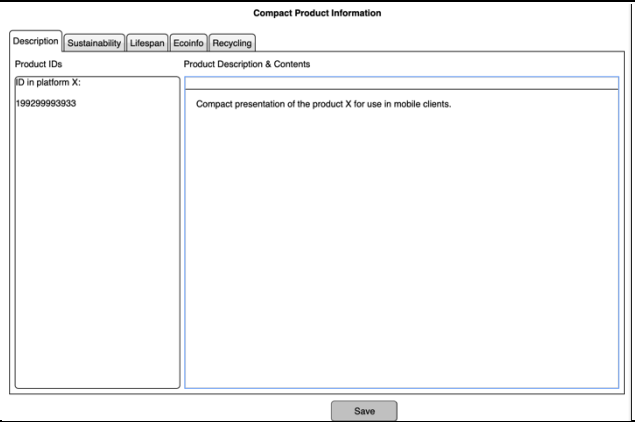
The user can at any time enter additional information and data types to the product – often multiple instances of the same information type. An example of this is the entry of different web sites for different functions covering the product – sales brochures, documentation, instruction manuals, repair resources and forums etc. There are no limitations on the number of information / data entries connected to the product or any other relevant main entity of different types.

The number of information types and entries for a product can over time be quite large and thus it is needed to allow grouping, access control and ability for the end-user to create custom selections for their own use-scenarios. In the CIRC4Life base data interface a simple grouping of information types is used.

Examples of static information connected to a product can be links to product detail information, presentation of different indicators and labels, documentation for chemical contents, use and maintenance instructions as some examples. To this category can also be mentioned labelling information and ready-made graphics for shelves. Over time a product labels for repairability, energy consumption or circularity can be added.

The static information types for a product currently developed are presented below.

	Web resources is handled by an information type allowing access to web sites, PDF files and pictures that are accessible by web browsers (video is handled by a specific information type). The information covering the access to web-based resources also include access control information. The web-based resource is not even shown if the user has not fulfilled access control demands by the platform itself and the database access control routines.
	The video information type manages videos from YouTube and from websites using the most common video formats.

	Compact product information is an information type tailormade to handle the product information specifically for mobile devices during the project's demonstration phase. This information type also represents more complex approaches for managing information that covers several hierarchical levels and combinations of data.

1.23 Meta-data management approaches – brokerage systems

During the work developing the interoperability system initial concepts and approaches for meta-data information types where evaluated for future use in collaboration with T4.7 (Brokerage System). The meta-data information types can allow for product category / services specific meta-data to be effectively stored and managed and search routines can then directly use the very specific meta data to perform very accurate and relevant searches on complex products. As an example, search terms for recycled steel is different than search terms for specialized plastics for food storage or plastics used in products with high demands on structural strength. This can allow for very accurate and efficient search approaches adapted to very specific use cases for products and materials – especially valuable in specific market solutions for recycled materials. This functionality is directly dependent on the strong support for JSON data structures in the most modern PostgreSQL database systems.

Another area where the interoperability systems approach can be useful is for storage of a company results from an N-dimensional maturity model evaluation – not only the results but also the underlying responses.

1.24 LCA / PEF scenario management

In collaboration with JS concepts where evaluated to allow the interoperability layer structures to be used for LCA / PEF scenarios management, allowing enhanced support for future more advanced impact assessment approaches and improved transfer for LCA / PEF actors along the supply chain. Since the interoperability layer is developed to support structured management of disparate information types for both storage and distribution, the ability to "package" LCA / PEF analysis input data together with results for storage as scenarios is improved. The packaging allows for the end-user to open an existing solution, change parameters and perform analysis of delta values between new and old versions. An example is evaluation of the impacts by changing diesel to biodiesel in combination with other changes. Part of this concept can also be the delivery (after non-disclosure) of the complete LCA / PEF / other computation results to partners further ahead in the supply chain.

Time limitations prevented this concept and design to be implemented but is in the plans for future expansion.

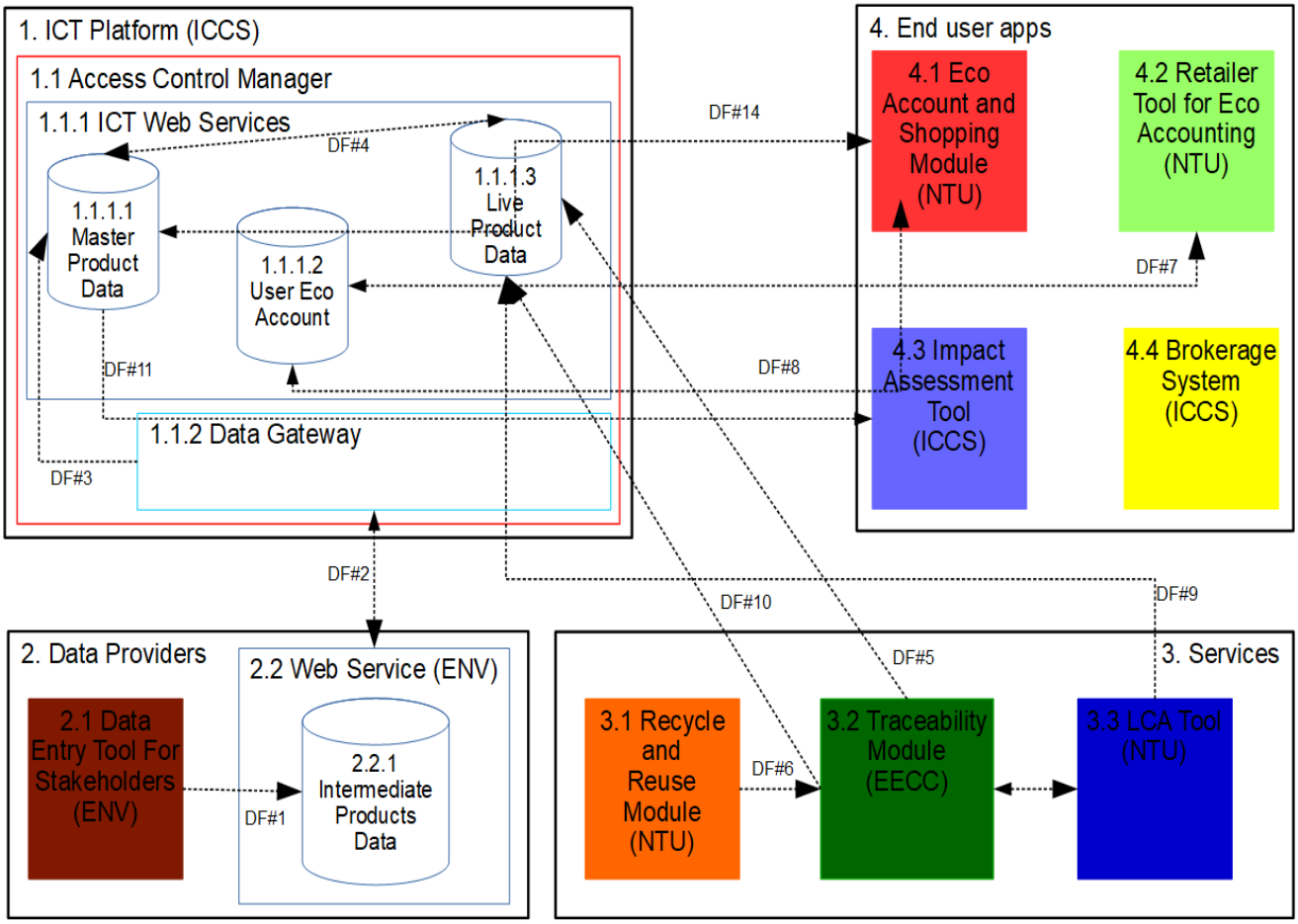
1.25 Dynamic data management

Close to all of the approaches described above can be used for data and information management for an individual product instead of a product class. The difference mainly lies in the selection of information types and their use. One example is the access to traceability information for an individual product that can contain the events for the product along the supply chain and eventual geographical mapping of transport routes etc. Information types allowing access to databases for timeseries management of vibration data, service / refurbishing work done to the product are other examples of information types / data that can be created and integrated specifically to support individual products / components. Information types supporting maintenance and optimized use phases will become more important over time for vital and complex subcomponents – interaction points with AI-based systems for prognosis (Remaining Useful Life – RUL) and experience / practices management systems will become vital.

Design Elements of the Solution

In this section the overall system architecture for the interoperability layer is described and its role in the overall system. It also covers the main design principles that formed the foundation for the development work. Due to the unique needs and functions the systems in the interoperability layer and the user interfaces are designed and developed from the ground up – no use of existing templates or frameworks except those needed for optimised database and services access.

1.26 Role in ICT Platform



CIRC4Life System Architecture and Data Flow

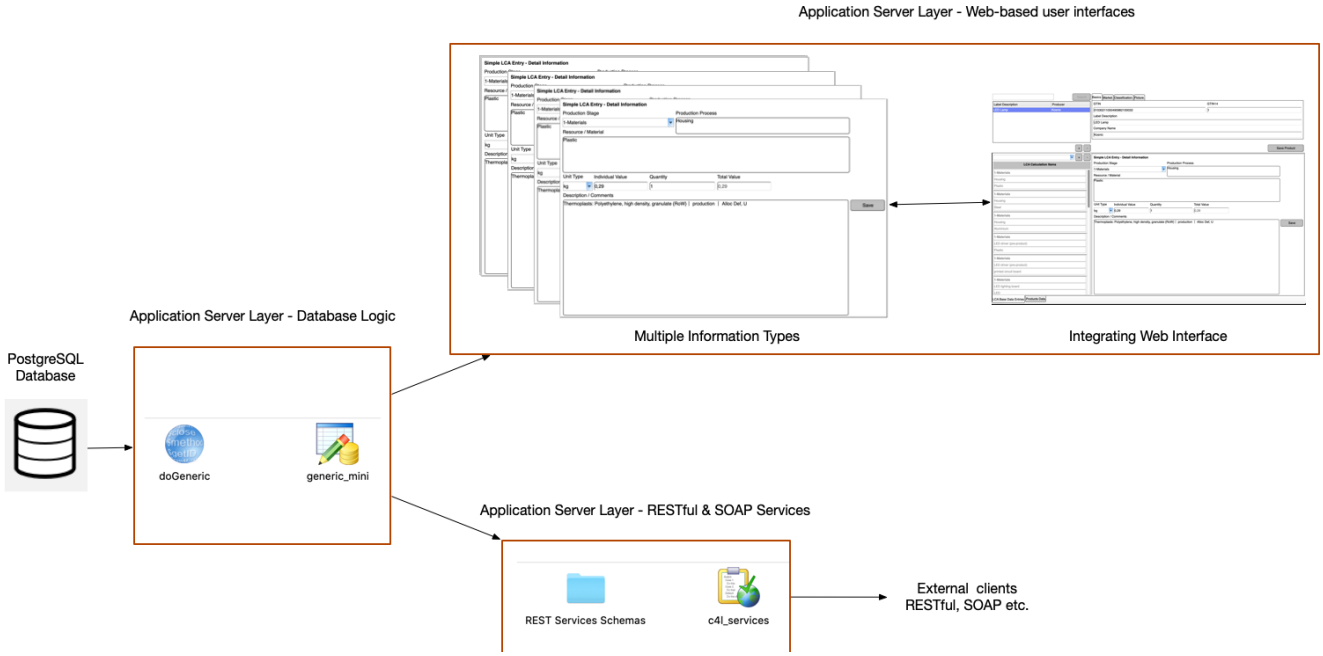
The interoperability system manages in the CIRC4Life platform the entry of basic product properties data, base data for LCA calculations and also acts as an entry tool / storage mechanism for other types of information, data and resources not planned for inclusion into the ICT platform. The interoperability system is also a good candidate to handle the escrow services for long-term data storage of products.

The various product data and information is accessible to the CIRC4Life system by RESTful web services and can also after further development allow access by SOAP services. Beyond manual input through end-user interfaces the external data can also be accessed by direct database access, RESTful- and SOAP-based web services. All these access methods allow multiple access points in parallel to different

servers and services if needed – also different database servers from different vendors and in different contexts.

1.27 Overall Interoperability Layer Architecture

The current overall design of the interoperability system is separated into three main components – the database environment for storing the data, the application server managing the systems logic / service provisioning and management of end-user systems and the end-user systems utilizing web browsers or external systems for user interfaces.



Interoperability Layer Components and Relationships

In a real-world deployable system optimised for P2P approaches the database layer would be responsible for close to all logical management of the information and data types managed in the system - many of those responsibilities are now in CIRC4Life placed in the application server layer of the interoperability system. The planned continuation development will use this more extensive P2P approach.

For the CIRC4Life effort the main interface for external systems is based on REST and JSON – basic web-based interaction is supported.

1.28 Application Server Layer

The application layer for the CIRC4Life task is responsible for a number of vital functions.

- Management of the individual data models for respective information type to be handled using JSON objects.
- Displaying and managing the end-user interface responsible for handling the information type.
- Management of database logic integration with the end-user interfaces and the interoperability layer database.
- Handling database management for both the web pages, mobile clients and REST services in the system utilizing the same data management logic.
- Serving the web / mobile application to the web-based end-users and the REST services for external systems.

In future versions for future projects and further development the data models management, database logic and services will be integrated into the PostgreSQL database environment itself to create an autonomous approach for data and information management.

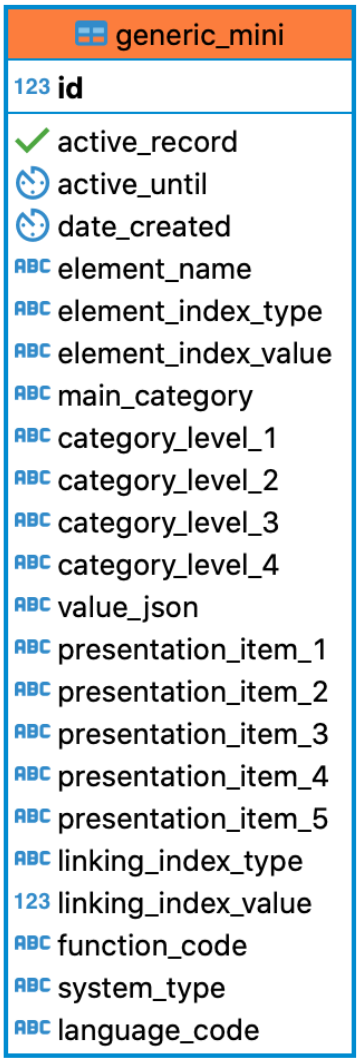
1.29 Database Platform & Data Model

During the development work in T4.2, T4.4 and T4.6 it became clear that the work done in these different tasks should be coordinated – allowing for development of common core elements such as database structures / access, service provisioning and user interfaces for management of data.

The database environment of choice for the interoperability layer / escrow functionality is PostgreSQL, a true open source database system that more should be regarded as an information / data management operating system. Postgres allows approaches of database management that covers both relational, document, object and graph database approaches and have powerful functionalities for data typing, validation, integration of powerful programming languages such as Python, Java, JavaScript and allows integration management of geocoded data. The PostgreSQL environment allows scalability from individual PCs up to massive clusters / distributed database systems with very large databases.

The database model for the CIRC4Life interoperability layer is optimized for simple maintenance in very large-scale Peer-To-Peer installations – mainly consisting of one singular table in this version of the system. Future versions will add and integrate more advanced functionalities such as relationships, simpler events management, tagging and interaction with distributed ledgers etc.

It is important to note that the individual item in the interoperability layer can be managed and stored both as a JSON object and / or as a record components / node in an object / graph / relational database. Beyond storing the data for an information item as a JSON the system can also add additional operators and complementary data structures to strengthen the use of the data stored as a JSON – geotagging, management of property lists, advanced binary management and handling of large hashes are such examples.



Kindly note that this DB model is the simplest variant (mini) – the more advanced database models will contain additional functionalities in the future.

At large the database model contains several sections.

The active properties controls if the record is active or not – vital when the data is placed in escrow.

The element name and indexation are the name of the resource and the indexing type and the category section allows for granular categorisation of the individual element.

The value section in this database model represents one data type – JSON data that contains the data contents of the complete record – dynamically adapted according to the information type stored. In more extensive database models additional advanced datatypes will be introduced.

The presentation section represents the data items to be shown in user interfaces presenting the main properties of the element.

The linking index type informs which master record the element is connected to and the relevant indexed link value.

The function code informs what information type the element record has which is used by either the application server or DB programming to select proper logical processing routines for management of the element record.

The system type is for this project used to group function codes / end-user interface structures for hierarchical presentation of information types.

1.30 Main principles of for end-user tools

Modularity

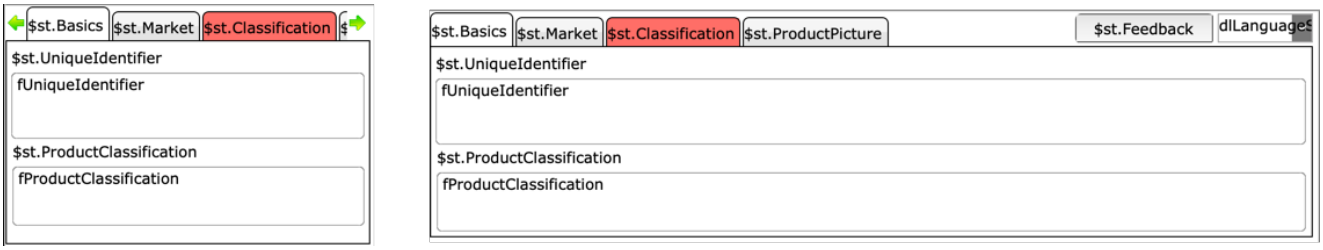
The overall approach of the system is to store the information and data as much as possible as modules to be combined and managed separately as much as possible. This to allow massive flexibility in adding and managing current and future information storage and processing. Due to this the end-user environment must be able to dynamically handle modular data / information access and presentation, preferably in end-user customizable interfaces.

More advanced approaches of modularity also allow the data and information components to be dynamically matched with others in new usage and presentation contexts depending on need and demands.

A module managing a specific information type in the C4L interoperability layer consists of three main parts – the data access management, the structure definition of the information type itself and the user interface for interacting with the end-user. In future development the module will handle advanced access control / data quality logic for the information "package" – down to individual terms / fields of information.

Multiple use of modules

The modular approach also allows for parallel deployment between different usage modes – standard web pages and / or mobile systems is one example of this. This major challenge can be mitigated by the modular management of information since it simplifies the development of dynamic systems also in the context of mobile devices such as phones and tablets etc. In addition, the modular approach also increases the support for dashboards – user interfaces that collects and presents data and information from a number of different sources in a common interface.



Different Presentation Modes – Product Core Data

Service provisioning

The interoperability layer in the current simpler version supports service provisioning in the form of JSON / RESTful services and can also if need arises support SOAP-based services. Examples of processing of a REST service data access process and delivered results are presented below. The services can be exposed to external users by Swagger API definition files.

Both the service programming and resulting JSON object presentation is presented in Annex B

EPCIS Service access

The demonstration scenarios for the Data Entry tool and the interoperability system do not involve product information and traceability functionalities for individual product items, it covers individual product classes – for which traceability by EPCIS is not a viable approach. The interoperability layer data structures and end-user tools allow though for addition of information types that include service access to the traceability services of EECC or any other service provider by using direct database access or using web services like RESTful and/or SOAP. The information types to support these functions must contain relevant connectivity and access control information and optimally also linkages to documentation and feedback structures when using the traceability services.

Future developments and exploitation

The current implementation of the interoperability layer (base data entry / escrow support) in CIRC4Life should be regarded as a foundation for more extensive development efforts aiming at delivering interoperability systems based on P2P approaches and for very large-scale deployments. This more extensive development work will be based on system designs and development work aiming at creating a large-scale, P2P-based system for large scale (global) deployments. The conceptual descriptions for this development work have been shared with actors in European Commission and the EU efforts covering Circular Economy in the G7/G20 efforts, resulting in strong interest for further evaluation and potentially development.

The current state of implementation can with smaller further developments be offered as a solution for individual organisations and supply chains as an information hub to better manage fragmented data and information flows and integration of data to close the resource flows. But the most useful implementation should be a wider and more extensive approach centring on resource and information flows and supporting large-scale functional market approaches for a circular economy.

As stated in other parts of this deliverable, the underlying system and approaches are not only viable for products in a supply chain but also in context of services provisioning, management of other types of resources such as services, knowledge, experiences, policy implementation and reporting etc. due to the ability to handle and store a multitude of different, often complex types of data and information.

At large the future planned developments (if funding is secured) will concentrate on managing complex data relationship management, simpler internal approaches to events management, more qualified interaction with traceability solutions and interoperability with specialized solutions for distributed ledgers for data quality control and later smart contracts management.

Annex A – Connection information

Access information Base Data Entry / Interoperability Layer UI tool

http://envirodata.se/c4l_data_entry/

Access to RESTful services (use webservice access tools)

Access to all entries for a product:
http://envirodata.se:5012/api/C4L_DB/c4l_services/ProductAllEntries?pgtin=01030211050490982100032

Access to LCA entries for a product:
http://envirodata.se:5012/api/C4L_DB/c4l_services/ProductLCAEntries?pgtin=01030211050490982100032

More service calls available at request.

Annex B Code example of RESTful service call and result

_____

Example of service programming and resulting JSON object – Kosnic lamp.

RESTful Server Routine - get all entries for a product with a given GTIN

Connect to DB and get a DB session

```
Do $clib.$objects.doDBStandardOps.$newref() Returns lrefDBStdOps
Do lrefDBStdOps.$GetSession('C4L_DB_RO') Returns loSession
Do loSession.$newstatement() Returns loStatement
```

First get the ID for the record... Add the language parameter later and insert it into the search terms.

```
Begin text block
Text:SELECT id FROM generic_mini WHERE element_name = 'product_masterdata_entry' AND element_index_type = 'GTIN' AND element_index_value = '[pgtin]';
End text block
Get text block lchSQL

Do loStatement.$execdirect(lchSQL)
Do loStatement.$fetchinto(lnID)
```

Get the product base data and enter it into the result list...

```
Begin text block
Text:SELECT value_json from generic_mini
Text:WHERE system_type = 'Product_Master_Data' AND
Text:id = [lnID];
End text block
Get text block lchSQL

Do loStatement.$execdirect(lchSQL)
Do loStatement.$fetch(llTempList,99999,kTrue)

Do lrwProduct_All_Entries.Product_Base_Data.$merge(llTempList) Returns lbStatus

Do llTempList.$clear()
```

Get the parameter data not LCA base data

```
Begin text block
Text:SELECT value_json from generic_mini
Text:WHERE system_type = 'LCA / ecoPoint / ecoCredit' AND
Text:function_code <> 'rfSimple_LCA_Item_Entry' AND linking_index_value = [lnID];
End text block
Get text block lchSQL
```

```
Do loStatement.$execdirect(lchSQL)
Do loStatement.$fetch(llTempList,999999,kTrue)

Do lrwProduct_All_Entries.Product_Parameters.$merge(llTempList)

Do llTempList.$clear()

# Get the base data for LCA calculation

Begin text block
Text:SELECT value_json from generic_mini
Text:WHERE system_type = 'LCA / ecoPoint / ecoCredit' AND
Text:function_code = 'rfSimple_LCA_Item_Entry' AND linking_index_value = [lnID];
End text block
Get text block lchSQL

Do loStatement.$execdirect(lchSQL)
Do loStatement.$fetch(llTempList,999999,kTrue)

Do lrwProduct_All_Entries.Product_LCA_Data_Entries.$merge(llTempList)

Do llTempList.$clear()

# Get entries for EPCIS connectors

Begin text block
Text:SELECT value_json from generic_mini
Text:WHERE
Text:function_code = 'rfEPCIS_Access' AND linking_index_value = [lnID];
End text block
Get text block lchSQL

Do loStatement.$execdirect(lchSQL)
Do loStatement.$fetch(llTempList,999999,kTrue)

Do lrwProduct_All_Entries.Product_EPCIS_Entries.$merge(llTempList)

Do llTempList.$clear()

# Get entries for support resources

Begin text block
Text:SELECT value_json from generic_mini
Text:WHERE
Text:function_code <>'rfProd_Base' AND function_code <>'rfEPCIS_Access' AND function_code
<>'rfSimple_LCA_Item_Entry'
Text:AND function_code <>'rfEcoPoints_EcoCredits' AND function_code <>'rfEEE_Category' AND
function_code <>'rfLifetime_Estimate'
Text:AND linking_index_value = [lnID];
End text block
Get text block lchSQL
```

```
Do loStatement.$execdirect(lchSQL)
Do loStatement.$fetch(llTempList,999999,kTrue)

Do lrwProduct_All_Entries.Product_Support_Resources.$merge(llTempList)

# Create the JSON text and parse away control chars...

Do OJSON.$listorrowtojson(lrwProduct_All_Entries,kUniTypeCharacter) Returns lbinJSON
Do OJSON.$formatjson(lbinJSON) Returns lchJSONFormatted

Do method $RemoveControlCharacters (lchJSONFormatted) Returns lchJSONFormatted

Do $cinst.$sethttpstatus(200,'OK')
Do $cinst.$addhttpresponseheader('content-type','application/json')

Quit method lchJSONFormatted
```

Resulting JSON object from the RESTful service

Call:

http://envirodata.se:5012/api/C4L_DB/c4l_services/ProductAllEntries?pgtin=01030211050490982100032

Result:


```
{
  "Product_Base_Data": [
    {
      "element_type": "product_masterdata_entry",
      "gtin": "01030211050490982100032",
      "gtin14": "1",
      "brand": "",
      "label_description": "LED Lamp",
      "image": null,
      "target_market": "",
      "company_name": "Kosnic",
      "classification": "",
      "unique_identifier": "",
      "language_code": ""
    }
  ],
  "Product_Parameters": [
    {
      "element_type": "ecoPoint_entry",
      "ecoPointValue": 120.0,
      "ecoPointFunctionalUnit": "1 Luminaire",
      "ecoPointComments": "120 points is the eco-point value for 40,000 hours service time, which is a optimistic scenario. A range of different working hours are also considered, the associated eco-point values are
```

below. You can define a small dynamic display table showing the changes of eco-point value by changing the working hours. ",


```
        "ecoPointScenarios": [

        ],
        "language_code": ""
      }
    ],
    "Product_LCA_Data_Entries": [
      {
        "element_type": "simple_lca__individual_entry",
        "stage": "1-Materials",
        "process": "Housing",
        "resource": "Aluminium",
        "unit_type": "kg",
        "quantity": 1.0,
        "individual_value": 1.1,
        "total_value": 1.1,
        "description": "Alloys:Aluminium alloy, AlLi {RoW}｜ production ｜ Alloc Def, U",
        "language_code": ""
      },
      {
        "element_type": "simple_lca__individual_entry",
        "stage": "1-Materials",
        "process": "Housing",
        "resource": "Steel",
        "unit_type": "kg",
        "quantity": 1.0,
        "individual_value": 2.199,
        "total_value": 2.199,
        "description": "Ferro:Steel, low-alloyed, hot rolled {RoW}｜ production ｜ Alloc Def, U",
        "language_code": ""
      },
      {
        "element_type": "simple_lca__individual_entry",
        "stage": "1-Materials",
        "process": "Housing",
        "resource": "Plastic",
        "unit_type": "kg",
        "quantity": 1.0,
        "individual_value": 0.29,
        "total_value": 0.29,
        "description": "Thermoplasts: Polyethylene, high density, granulate {RoW}｜ production ｜ Alloc Def,
U",
        "language_code": ""
      },
      {
        "element_type": "simple_lca__individual_entry",
        "stage": "1-Materials",
        "process": "LED driver (pre-product)",
        "resource": "Plastic",
        "unit_type": "kg",
```

"quantity": 1.0,
"individual_value": 0.252,
"total_value": 0.252,
"description": "Thermoplasts:Polyethylene, high density, granulate {RoW}｜ production ｜ Alloc Def, U",
"language_code": ""
},
{
"element_type": "simple_lca__individual_entry",
"stage": "1-Materials",
"process": "LED driver (pre-product)",
"resource": "printed circuit board",
"unit_type": "kg",
"quantity": 1.0,
"individual_value": 0.688,
"total_value": 0.688,
"description": "Printed wiring board:Printed wiring board, surface mounted, unspecified, Pb containing {GLO}｜ production ｜ Alloc Def, U",
"language_code": ""
},
{
"element_type": "simple_lca__individual_entry",
"stage": "1-Materials",
"process": "LED lighting board",
"resource": "LED",
"unit_type": "kg",
"quantity": 1.0,
"individual_value": 0.32,
"total_value": 0.32,
"description": "Component:Light emitting diode {GLO}｜ production ｜ Alloc Def, U",
"language_code": ""
},
{
"element_type": "simple_lca__individual_entry",
"stage": "1-Materials",
"process": "LED lighting board",
"resource": "Aluminum",
"unit_type": "kg",
"quantity": 0.0,
"individual_value": 0.012,
"total_value": 0.0,
"description": "Alloys:Aluminium alloy, metal matrix composite {RoW}｜ aluminium alloy production, Metallic Matrix Composite ｜ Alloc Def, U",
"language_code": ""
},
{
"element_type": "simple_lca__individual_entry",
"stage": "1-Materials",
"process": "Other plastic members",
"resource": "Plastic",
"unit_type": "kg",
"quantity": 1.0,
"individual_value": 0.027,

"total_value": 0.027,
"description": "Thermoplasts:Polyethylene, high density, granulate {RER}｜ production ｜ Alloc Def, U",
"language_code": ""
},
{
"element_type": "simple_lca__individual_entry",
"stage": "1-Materials",
"process": "Fasten members",
"resource": "Steel",
"unit_type": "kg",
"quantity": 1.0,
"individual_value": 0.07838,
"total_value": 0.07838,
"description": "deep drawing, steel, 650 kN press, automode | deep drawing, steel, 650 kN press, automode | APOS, S - RoW",
"language_code": ""
},
{
"element_type": "simple_lca__individual_entry",
"stage": "1-Materials",
"process": "Fasten members",
"resource": "Plastic",
"unit_type": "kg",
"quantity": 1.0,
"individual_value": 0.0016,
"total_value": 0.0016,
"description": "extrusion, plastic pipes | extrusion, plastic pipes | APOS, S - RoW",
"language_code": ""
},
{
"element_type": "simple_lca__individual_entry",
"stage": "3-Packaging",
"process": "Board box",
"resource": "Corrugated board box",
"unit_type": "kg",
"quantity": 1.0,
"individual_value": 1.17,
"total_value": 1.17,
"description": "Corrugated board:Corrugated board box {RoW}｜ production ｜ Alloc Def, U",
"language_code": ""
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"process": "Energy input",
"resource": "Electricity",
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"quantity": 1.0,
"individual_value": 4000.0,
"total_value": 4000.0,
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      "unit_type": "kg",
      "quantity": 1.0,
      "individual_value": 0.0003,
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U",
      "language_code": ""
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      "stage": "3-Packaging",
      "process": "Packaging paper",
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      "unit_type": "kg",
      "quantity": 1.0,
      "individual_value": 0.0004,
      "total_value": 0.0004,
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Def, U",
      "language_code": ""
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      "resource": "Plastic form",
      "unit_type": "kg",
      "quantity": 1.0,
      "individual_value": 0.066,
      "total_value": 0.066,
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      "language_code": ""
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      "stage": "4-Transport",
      "process": "Shipping",
      "resource": "Shipping",
      "unit_type": "kg*km",
      "quantity": 1.0,
      "individual_value": 56451.96,
      "total_value": 56451.96,
      "description": "Water:Transport, freight, sea, transoceanic ship {GLO}｜ market for ｜ Alloc Def, S",
      "language_code": ""
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      "process": "Use phase",
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      "quantity": 1.0,
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      "language_code": ""
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      "stage": "6-End of Life",
      "process": "Disposal",
      "resource": "Disposal - incineration",
      "unit_type": "kg",
      "quantity": 1.0,
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      "total_value": 7.1744,
      "description": "Municipal solid waste {RoW}｜ treatment of, incineration ｜ Alloc Def, U",
      "language_code": ""
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  "Product_Support_Resources": [
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      "ecoPointFunctionalUnit": "1 Luminaire",
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      "ecoPointScenarios": [

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