A circular economy approach for lifecycles of products and services

Report on the Implementation of Traceability Solutions in the three CEBMs and on ICT Integration

Deliverable 5.3

PROJECT INFORMATION	
Type of Project	European Commission Horizon 2020
Topic	CIRC-01-2016-2017 Systemic, eco-innovative approaches for the circular economy: large-scale demonstration projects
Grant Agreement No.	776503
Project Duration	01/05/2018 – 30/04/2021 (36 months)
Project Coordinator	Nottingham Trent University (NTU)
Project Partners	Enviro Data (ENV), Jonathan Michael Smith (JS), Kosnic Lighting Limited (KOS), Centre of Research for Energy Resources and Consumption (CIR), European EPC Competence Center GmbH (EECC), The Institute for Ecology of Industrial Areas (IETU), SWEREA IVF AB (SWE), Make Mothers Matter (MMM), ONA PRODUCT (ONA), INDUMETAL Recycling (IND), GS1 Germany GMBH (GS1G), Laurea University of Applied Science (LAU), Center for European Policy Studies (CEPS), Institute of Communication and Computer Systems (ICCS), Recyclia (REC), S.A.T. Alia (ALIA)

DOCUMENT INFORMATION	
Title	Report on the Implementation of Traceability Solutions in the three CEBMs and on ICT Integration
Version	1.1
Release Date	12.12.2019
Work Package	WP5
Dissemination Level	PU

DOCUMENT AUTHORS AND AUTHORISATION	
Document Responsible	Dr. Sebastian Schmittner, EECC
Contributors	GS1 G, ALIA, KOS, NTU, ONA
Reviewed by	ICCS, KOS
Approved by	Prof. Daizhong Su, NTU

DOCUMENT HISTORY			
Version	Date (dd/mm/yy)	Description	Implemented by
0.1	1/11/19	First draft	EECC
0.2.1	11/11/19	Contributions form ALIA	ALIA
0.2.2	13/11/19	Contributions from GS1G	GS1G
0.2.3	13/11/19	Contributions from IND	IND
0.2.4	14/11/19	Contributions from ONA	ONA

0.2.5	15/11/19	Contributions from KOS	KOS
0.2.6	17/11/19	Contributions from NTU	NTU
0.3	27/11/19	Editorial: All Contributions Reviewed and Consolidated by EECC	EECC
0.4	28/11/19	Second Draft for Reviewed by all Contributing Partners. Outcome: Changes Requested	EECC
0.5	03/12/19	ICCS Review and Contributions	ICCS
1.0	5/12/19	All Requested Changes Implemented. Final Draft for Review by the Board	EECC
1.1	12/12/19	Final Version for Submission	EECC

Summary

This deliverable reports on the implementation of the traceability tools into the three Circular Economy Business Models (CEBMs) developed within CIRC4Life and the technical integration with the other ICT Tools, as a prerequisite for this. The Traceability Module supports all three CEBMs by providing its core functionality of tracking items and all associated impacts throughout their value chain. This impact tracking is a major development of WP5 and an addition to the EPCIS standard that is described in detail in Deliverable (D) 5.2. Furthermore, tailor-made traceability tools have been implemented in order to enable the business cases and demonstrations. “Traceability Tools” here and throughout refer to concrete RESTful web services which have been developed and implemented in Java by EECC and are provided as Software as a Service (SaaS) running on servers in Germany.

Needs and opportunities to use traceability in the CEBMs have been identified and developed within WP5 and also in close collaboration with the other work packages. The Traceability Tools have been developed such as to fully support all use cases that passed critical discussion and review from the business model owners as well as from the ICT team. Concretely, Sustainable Production is an important data source, but it also benefits from traceability data in deriving KPIs for a sustainable production based on empirical evidence from the product’s whole life cycle. Traceability data is crucial for the Sustainable Consumption CEBMs which involve leasing, but also take-back and repair systems. Sustainability labels based on primary dynamic data have been developed which make a product’s impacts transparent and are hence encouraging more sustainable buying behaviour of customers. Such labels can serve as a blue print for novel certificates which can be given out for individual products or badges. They contain a fine grained and yet comprehensible rating and are much easier to audit than existing labels. The Recycling and Reuse CEBM has developed very concrete applications of their business model in the demonstrations and consequently provided concrete requirements for the Traceability and the other ICT Tools. Tracking a product through its usage phase yields its accurate lifetime which, combined with the end of life (EOL) assessment data collected through a specifically developed capturing application, constitutes the dynamic input for the eco-credit calculation. Eco-credits in turn can be converted into incentives which encourage recycling of used electronics or return of bio-waste for recycling.

Furthermore, general purpose capturing and accessing applications are provided as RESTful web services in order to enable the use of the Traceability Tools in a more flexible way also in yet unforeseen use cases.

The integration of the Traceability Module with the ICT Platform is successfully accomplished and the functionality provided by their interplay is ready to be used in living labs and demonstrations. All mutually facing end-points have been integrated and tested and found to be working as expected at the technical meeting in Cologne in October 2019. All connections are made by means of RESTful webservice which publish open API specification (OAS, formerly known as Swagger) in order to provide a human as well as machine readable description and means of test and verification. ICCS (ICCS, 2019) and EECC (EECC, 2019) publish those specifications’ latest versions as part of their SaaS deployment. The End User Mobile Applications developed by NTU are integrating with the Traceability Module and so is the Interoperability Layer developed by ENV.

Table of Content

List of Tables

List of Figures:

Acronyms and Abbreviations

Abbreviation	Description
ASN	Advanced Shipping Notice
CBV	Core Business Vocabulary for EPCIS
CEBM	Circular Economy Business Model
D	Deliverable
EPC	Electronic Product Code
EPCAT	Product Name of EPCIS Implementation by EECC
EPCIS	Electronic Product Code Information System
EOL	End of Life
FMCG	Fast Moving Consumer Goods
GCP	GS1 Global Company Prefix
GEPIR	GS1 Global Electronic Party Information Registry
GIAI	GS1 Global Individual Asset Identifier

SaaS	Software as a Service
(S)GLN	GS1 Global Location Number (with Extension)
GRAI	GS1 Global Returnable Asset Identifier
GTIN	GS1 Global Trade Item Number
IoT	Internet of Things
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
OAS	Open API Specifications (formerly known as Swagger)
POS	Point of Sale
PU	Public, fully open, e.g. web
RFID	Radio-Frequency Identification
RTI	Returnable Transport Items
SSCC	GS1 Serial Shipping Container Code
SGTIN	GS1 Serialised GTIN
T	Task
WP	Work Package

Table 1: Acronyms and Abbreviations

1 Introduction

Tracking an item refers to giving individual items a unique identifier, such as a serial number, and then to record events (specific points in space and time) at which important (from the business perspective) things happen to the item. This can be processes in production, transportation related events such as shipping and receiving, or also events such as assembling parts or packing products together into containers which create permanent or temporal conglomerates of individual parts. By recording all events in the history of a product, it is possible to trace e.g. the exact material composition of a complex product, the lifetime of each component of a leased product, date of the last exchange/repair, and many other KPIs which are relevant to Circular Economy Business Models (CEBMs) developed in CIRC4Life.

Beyond these conventional features of traceability, a major development of Work Package (WP) 5 was the tracking of ecological and social impacts along with potentially any event. To this end, the Electronic Product Code (EPC) Information Services (EPCIS), a global standard by GS1, has been extended in order to include such impacts. The Traceability Module has been developed by WP5 in order to make all of these features available to CIRC4Life. The general concepts are adapted to the concrete needs of the CEBMs and demonstrations developed in the project to create technical solutions together with the other ICT developing partners. These solutions can serve as the back bone of the newly developed CEBMs.

The relevant developments have largely been described in deliverables D5.1 and D5.2 for the Traceability Module and 4.1 and 4.2 for the ICT Platform. Another important component to mention is the online LCA Tool which has been covered in the afore mentioned deliverables but more dedicatedly in D1.2 section 2.3.

The Traceability Module is deployed by EECC as a Service with interface specifications available in human as well as machine readable form (EECC, 2019). It is constantly being improved through agile development and continuous deployments. The main components are Capturing Applications, which are developed in order to facilitate the traceability data gathering from all involved partners, Accessing Applications, which aggregate and transform data in order to make the relevant information easily accessible through RESTful web services, and the Traceability Core which contains the business event models, and an EPCIS conformal repository that stores the data and provides the EPCIS standard service (SOAP) interfaces. D5.2 contains all the details of the development at the time of writing. As expected, the project makes progress and new concepts are being developed in all WPs, hence it pays out that the Traceability Module was developed in a flexible and generic way such that it can be constantly adapted to the volatile requirements. In particular, it has turned out that the integration of data from ALIA and KOS will require more specific interfaces in order to connect to their local ICT systems and also specific GUIs will be needed. Those capturing applications are currently being added to the Traceability Module. EECC expects more changes of this kind and is prepared to make the necessary additions also during the second reporting period. This deliverable describes the state of the implementation of the Traceability Tools at the time of writing, while hinting to current developments of new ideas and processes in the CEBMs with further opportunities to support them with traceability data, where applicable.

This document is structured by covering the three CEBMs one by one and then summarising the state of the integration of the Traceability Module with the other ICT tools developed in the project. This is most notably the ICT Platform by ICCS which is well developed and mutually well integrated with the Traceability Module, but also the integrations with other tools that directly interact with the Traceability Module are discussed in Section 5.

2 Implementation of the Traceability Solutions in Sustainable Production

Traceability in sustainable production has the goal to empower the producers and suppliers along the supply chains to react to the economic incentives for more sustainable production created through the other CEBMs. The Producers role is to improving their products and production processes. If the Sustainable Consumption CEBM successfully creates demand for transparency of ecological impacts and a reduction of those, producers need the tools to understand the impacts of their products themselves in the first place. From here they can iteratively improve processes and re-measure impacts, as well as share the data to create transparency. If the Collaborative Recycling CEBM successfully creates demand for more recyclable products, the producers need to keep closer track on what materials and components go into which product in order to provide accurate information about the composition of products to the recycler. Traceability is implemented in the production phase in order to enable these overarching goals.

To understand the ecological impact of a specific product, it is important to be able to gather detailed product and process specific information about individual impacts from the production stage. This involves information on used materials, energy and water consumption, and of course the waste and pollution that was created in production. For this reason, the Traceability Tools include capturing interfaces which are tailor made for the industrial partners' production processes in CIRC4Life. Additionally, we also provide general purpose interfaces to demonstrate how the tools and methods developed in CIRC4Life can be carried over to other sectors as well.

Traceability data can help to make production more sustainable in two ways. By providing digitalization and transparency of the processes and goods flows, efficiency can be increased throughout the supply chain which by itself can reduce resource consumption. Depending on the digitalization and automatization level to start from, this effect can be very pronounced and is typically the driver to introduce traceability tools in the first place. In CIRC4Life, the Traceability Tools additionally offer interfaces to gather all these product's sustainability information from suppliers, designers, and producers in order to provide the required information for the online LCA and eco-point calculation. This enables real-time process and resource consumption analysis and optimisation with a dedicated focus on reducing impacts. The later aspect enables novel business models.

Provided that the Sustainable Consumption Business Model creates customer demand in highly sustainable products, the value of such products increases and it becomes economically worthwhile to gather primary data on impacts and sell a product together with such highly reliable data at a higher price. In fact, the price can further be raised the lower the impacts. This creates economic incentives for producers to be more transparent and to cause lower impacts. The Traceability Module provides the ICT infrastructure for gathering, storing, and sharing the relevant data in a standardized way as well as through convenient interfaces. Of course, as with all similar labels/certification, audits, random sampling, or similar processes have to be established in the analogue world in order to ensure that the digitalized data is accurate. Real world auditing is beyond the scope of WP5, but the idea of a certified eco label for individual products based on primary data is put forward to the policy alignment task 8.4.

2.1 Tracking Impacts from the Production Phase

As mentioned throughout (see above, D5.1 Section 2.1.2, and D5.3 Section "Dynamic Data Sources"), an important feature of the Traceability Module is the ability to track ecological and social impacts throughout the life cycle of the tracked products, but a great deal of the impacts is typically related to the production phase. Consequently, the Traceability Tools are focussed on collecting data from this phase in particular.

2.1.1 Tracking Impacts of Meat Products Production

ALIA, the demonstrator of the meat sector in the CIRC4Life project, participates in most of the stages of the meat supply chain, including animal feeding production, livestock farming, the slaughterhouse and the meat elaborates plant. ALIA is not present in the primary production stage and in the selling point. ALIA does have a local shop in the animal feeding factory, but just a small amount of their total production is sold there.

Due to that, ALIA can have access to relevant and reliable information about almost the whole process of the production of their meat products, as they are made in their own facilities (the meat elaborates plant), using fresh meat provided by the slaughterhouse, which uses the animals grown in their farm, which, in addition, have been fed with the animal feeding produced in their own facilities. In summary, ALIA has the control of the main stages of the meat sector supply chain, so it has the possibility to track all the steps and gather reliable data, independently from external suppliers.

In addition, ALIA has is already tracking information at every stage of the supply chain. In their system, lots of aspects regarding quality and trade information are registered. However, this system is not focused on the sustainability aspects of the process and does not include much information about it. Still, some of the data registered, although is not focused on that, can be directly translated to sustainability aspects. The origin of raw materials, the destiny of the final products, the medicines used in the process, and the ingredients used for the production of the nutritional formula which feeds a specific batch of animals all have an environmental impact. These have already been studied in a manual LCA conducted in CIRC4Life project, hence also the relevant LCA models are available. By interpreting the data that is already tracked, it is possible to replace some of the average values used in the manual LCA by dynamic values, i.e. primary data for concrete batches of meat products. ALIA is working with EECC on the automated transformation and interpretation of the data for this purpose.

Furthermore, ALIA has direct access to data about relevant impacts such as energy, water, gas or biomass consumption or the wastes generated (also differentiating the kind of wastes produced) from all main stages of the whole production process. This data is not included in ALIA's own traceability system at this moment, but EECC develops graphical web-based user interfaces for ALIA to input this kind of data. This data is collected on a monthly basis. In the demonstration stage of the project, more accurate data, i.e. with a higher time resolution, will be collected using measurement instruments. This data will be carefully analysed for sustainability KPIs.
The Traceability Tools have been developed to cover this use case (see e.g. D 5.1 Section 2.1 and D 5.2 Section "Meat Production") and it is one of the main objectives of ALIA and EECC to demonstrate the real life data collection and usage of this data for dynamic eco point calculation in the second half of the project. Owning the main stages of the meat supply chain is a guarantee of reliability and accuracy on the information obtained.

Obviously, there are some important parts of the process which depend on external agents. In that case, ALIA will include as much information as possible from all the events needed. ALIA already tracks aspects as origin of the products, which gives information about the sustainability of the products. This information can be incorporated in the traceability tool as well.

ALIA has also conducted a Social-LCA about the whole production process. However, this information is not included in the eco-points calculation method due to lacking capabilities of the LCA tool. Furthermore, the social data is quite static and no changes are expected in the relevant figures during the next year. For this reason, ALIA decided to implement the Traceability Tools developed in WP 5 into sustainable production for tracking ecological impacts, but not for social impacts.

2.1.2 Tracking Impacts of Growing Vegetables

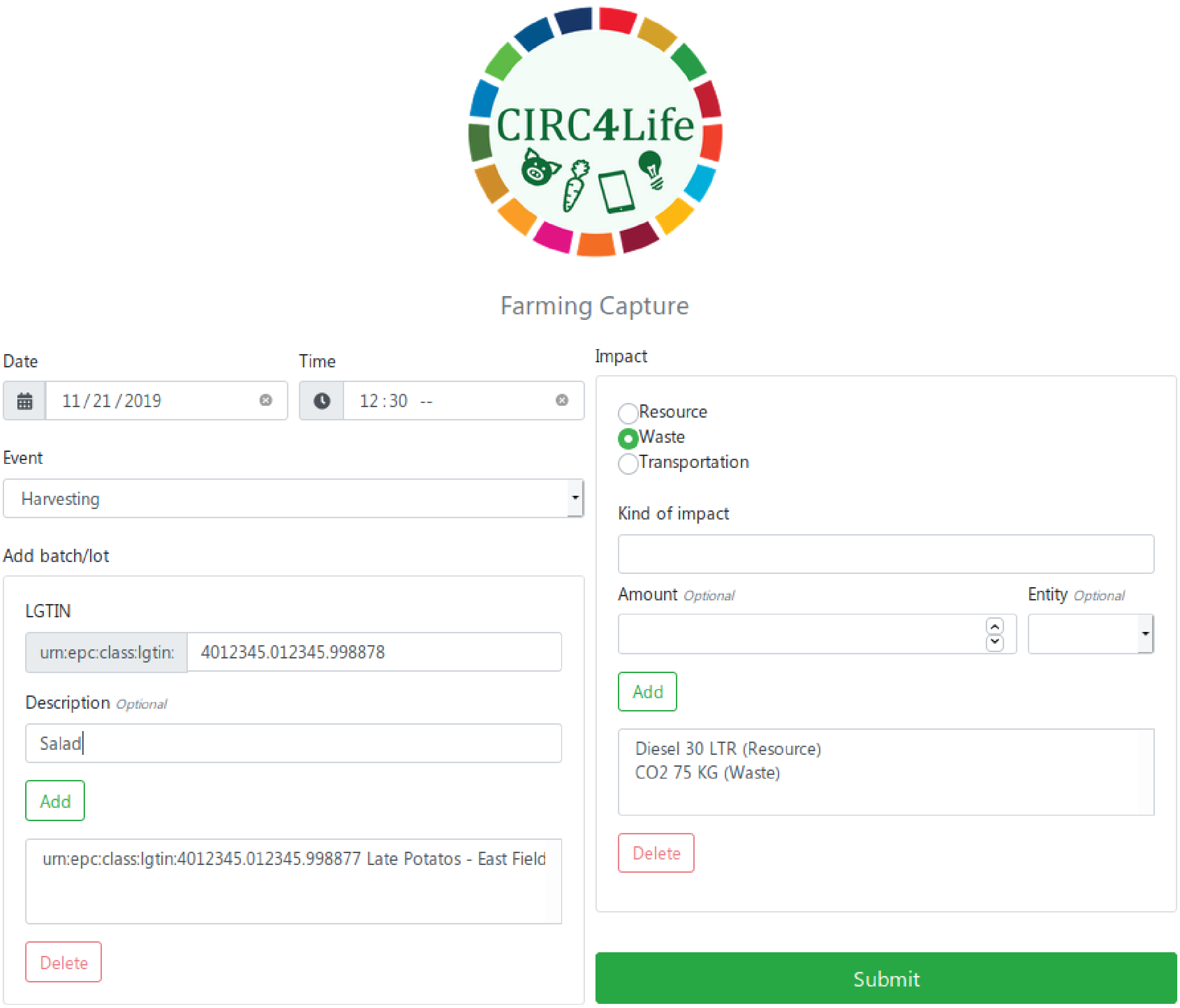


Figure 1: Farming Capture Web User Interface

In order to capture traceability data and in particular primary data on concrete impacts, EECC has developed a capturing application including a web user interface (see Figure 1). In an environment where data is not yet digitalized, a user interfaces is the most straight forward tool in order to transfer data from the analogue into the digital world. Since the LCA tool integration is still in progress and data formats and interfaces have not been defined, the impact input is currently very general. As soon as the LCA tools inputs become clearer, the impact capturing user interface will provide more guidance, i.e. dropdown/search fields to select those inputs, which can subsequently be processed by the LCA tool.

What is fully functional is the supply chain transparency provided by traceability, see Figure 7. Concretely, the whole process chain from seeding over watering, fertilising, weeding, etc. to the harvesting, processing and selling of a batch of vegetables is digitally represented and can be captured by the Traceability Tool.

2.1.3 Tracking Impacts in General

The tools developed within CIRC4Life are not only applicable in the specific context of the project. From the outset, all tools are developed to be usable in a much broader scope. This ensures that the outcome of the project can be applied in other industry sectors and hence scale up

The JSON-based RESTful web services developed in this project can be understood as a preview to the EPCIS standard version 2.0, which is currently under development under active participation of EECC. The current EPCIS standard version 1.2 describes XML-based SOAP interfaces only. Using standardised interfaces ensures interoperability with software developed elsewhere and greatly reduces the manpower needed in order to adapt the results of CIRC4Life to other contexts. Providing a modern JSON-based interface provides ease of use, in particular since open API specifications and a swagger-ui make the developed APIs very accessible and easy to test and experiment with.

The impact tracking extension to the EPCIS standard that was developed in CIRC4Life is used throughout the whole value chain, but in particular to track individual item or batch specific impacts from the production phase. Using this extension beyond the project scope is a goal for the exploitation phase and will, if successful, introduce the impacts extension into the EPCIS standardisation process beyond version 2.0.

Concretely, the Traceability Module contains general purpose capturing applications, which provide APIs to track any EPCIS event. This is the JSON analogue to the standard EPCIS 1.2 SOAP capturing interface, which is provided as well, for compatibility reasons. The Traceability Module also contains a generic Impact Capturing Endpoint. This can be used in order to digitalize data which is not available in digital form or not in a standardised format and to hence make it accessible, in particular to online eco-scoring methods developed within CIRC4Life. These generic interfaces where developed because the need for a very flexible solution was identified early in the project. The Traceability Tools need to be able to adapt to developments in the CEBMs and requirements which only become clear after the planned specification phase finished. To cope with such flexible requirements, the generic interfaces where developed along with the use case specific ones to mitigate the risk of changes in requirements. New requirements are now indeed arising after the planned end of the development phase of the Traceability Module.

2.2 Supporting the Goals of the Sustainable Production CEBM

In this section, we review goals of the circular economy business model (CEBM) and how the traceability tools are used in order to support those.

2.2.1 Increasing Recyclability by Designing and Producing for Circularity

Capturing all ingredients/materials used in all components of a product is very useful, if not essential, for effective recycling. In particular for plastics, it is difficult and hence economically unfeasible to determine the exact composition. This means that the recycled material is a mix of unknown fractions/proportions and the resulting secondary plastic is of lower quality than the primary one. See Figure 2 for a schematic depiction.

For exactly this use case, EECC has recently created a demonstration for using an identifier imprinted on a plastic foil in order to track its production process and further life cycle seamlessly from cradle to grave. By knowing how the foil was made, it becomes possible to effectively recycle it into high quality secondary raw materials with a well-defined composition which can truly be re-cycled and not just down-cycled to lower quality materials or products. This demonstrator was developed and presented by EECC together with Reifenhäuser, a

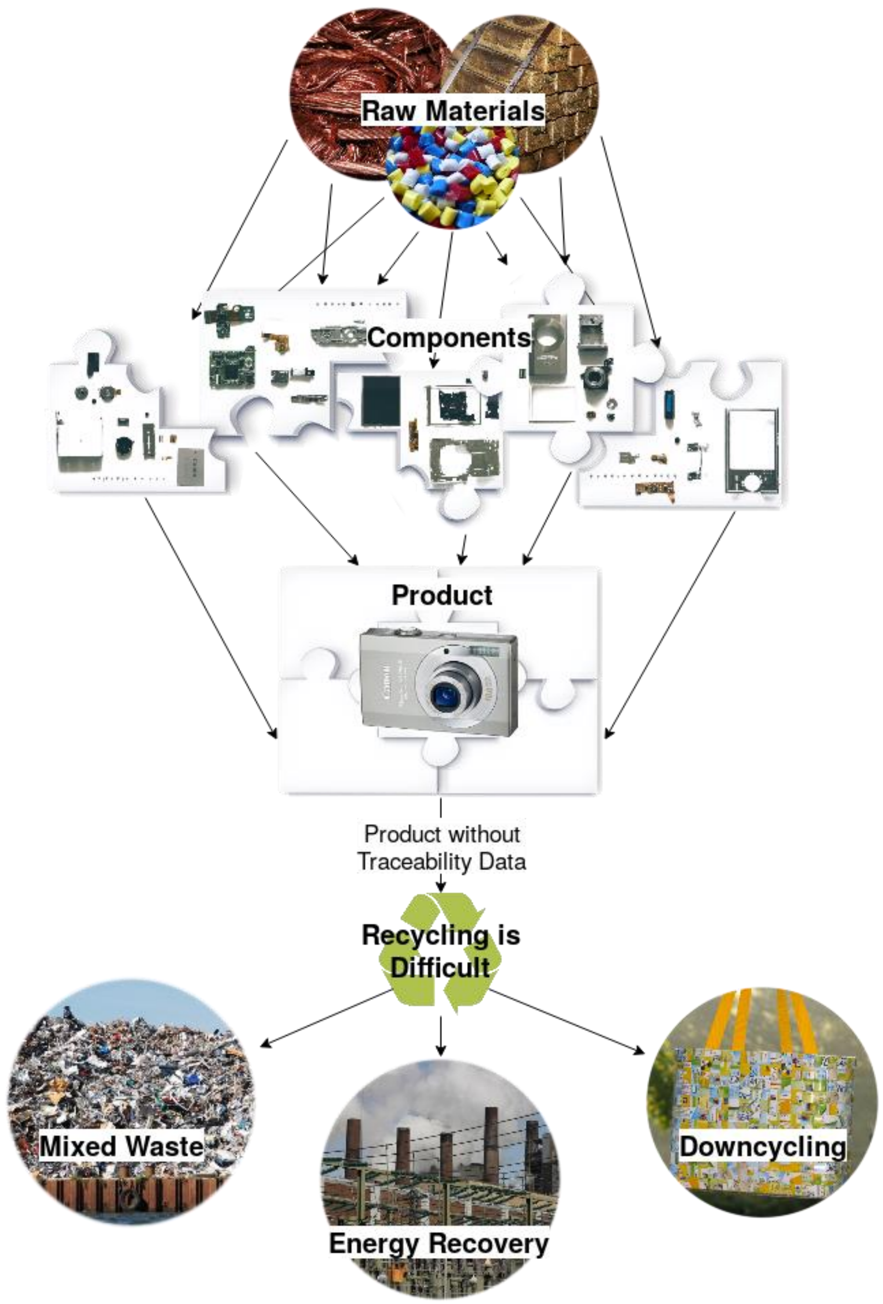


Figure 2: State of the Art: Recycling Products without Knowing the Composition

major German extrusioneers group, outside the CIRC4Life project on EECC's Innovation Day and a major trade fair.

In CIRC4Life, a wider perspective is applied and the focus is not on plastic foil. Given that a product that arrives at the recycling facility can be traced back to its origin and information about parts and components and even their material composition is available, the recycling of a product becomes possible on a new level. It can now be feasible to disassemble the product and re-use parts, e.g. screws, but also more complex parts. If the product is still in the market, repairing or refurbishing it for re-use can be feasible. Traceability can help from the ICT side to enable these second life pathways, but, of course, designing the product such that it is easy to disassemble and reassemble is also important. By tracking the fractions of products that can effectively be repaired, fractions of components that can be extracted and re-used, etc., a feedback loop from the recycler to the producer and product designer can be established to facilitate the creation of more reusable and hence more sustainable products. See Figure 3 for a schematic depiction.

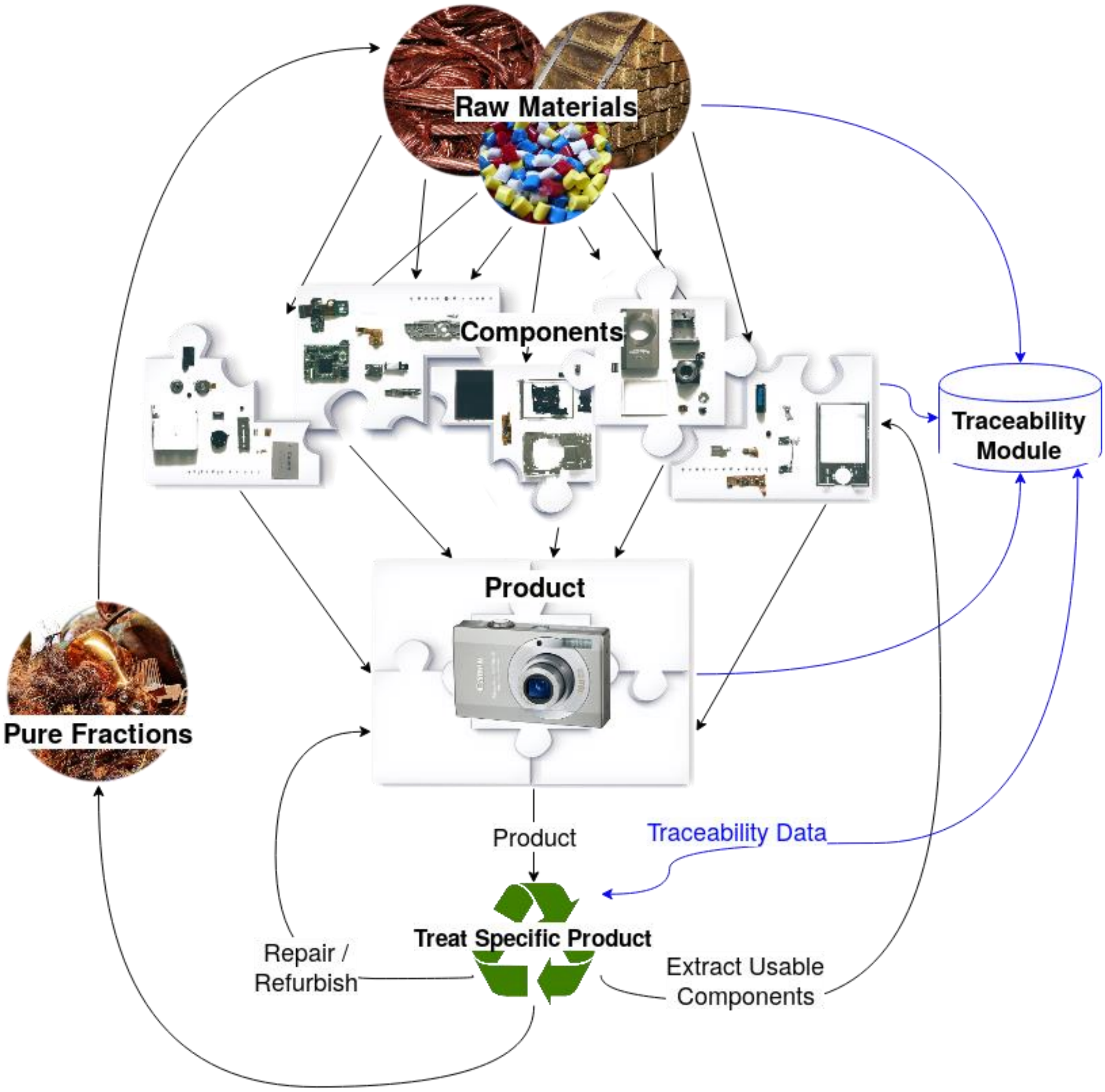


Figure 3: Recycling Individual Products with their Composition Known through Traceability

2.2.2 Reducing the Total Impact of Products through Fair and Accurate Assessment

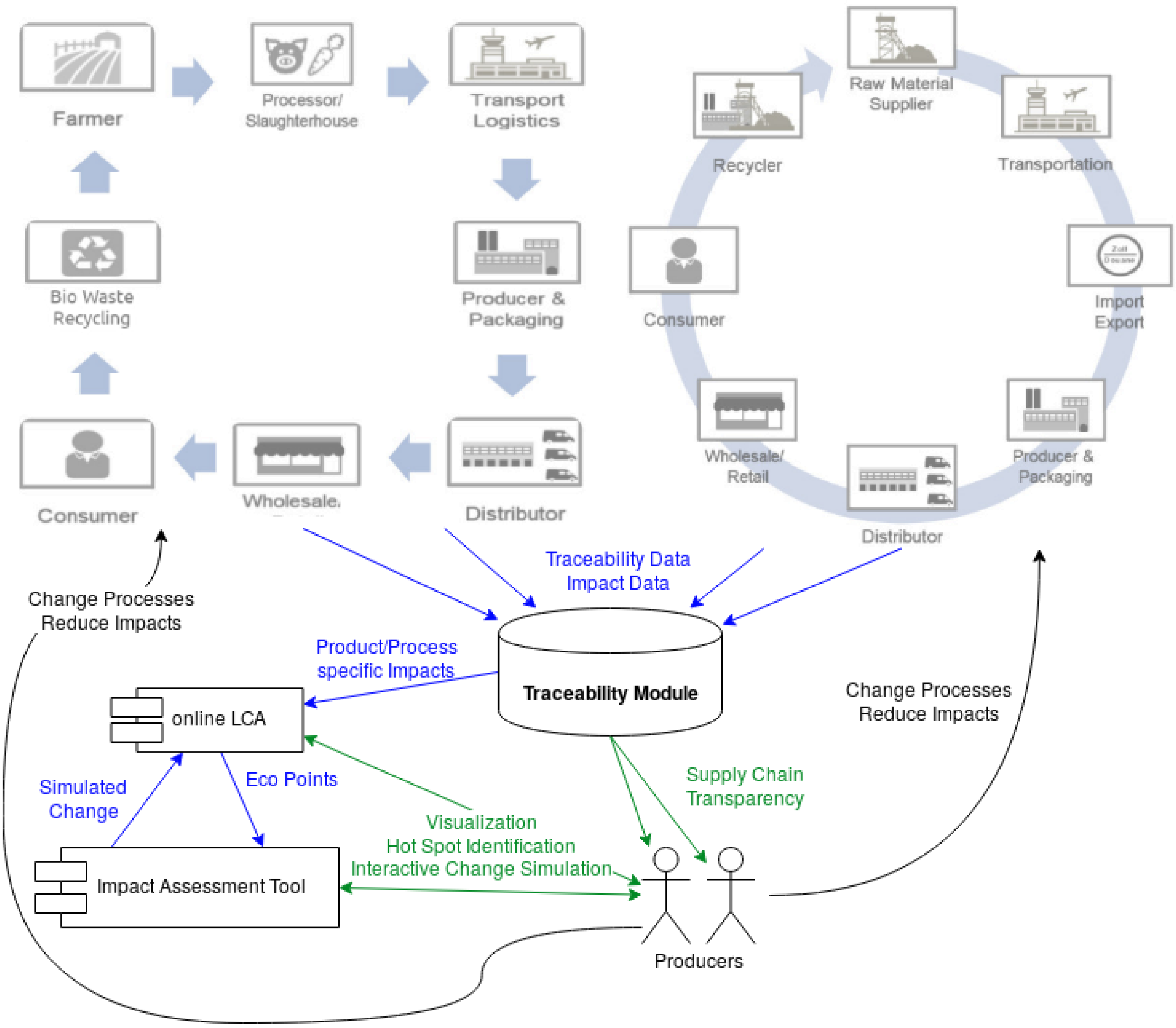


Figure 4: Using Real Time Data to Iteratively Improve Production Processes and Reduce Impacts

To assess the ecological performance of a product, a life cycle assessment (LCA) needs to be performed. To achieve an accurate, specific and hence trustworthy result, the use of primary data is highly preferable. Due to the fact that today more generic/average secondary data than primary data is used for LCA, caused by a lack of transparency in the supply chain, it is impossible for consumers to compare products of the same type with regard to their sustainability. In order to increase the transparency for the consumer, it is crucial to use dynamic data in a standardised way. Each partner of the product's life cycle is able to forward his primary data, e.g. energy/water consumption or emissions, along the supply chain. Based on these dynamically collected data, the overall LCA on product level is possible. A visualisation of the information, for example in the form of eco-points on an eco-label, could help the consumer to make an informed buying decision on the spot.

Given that schemes of incentivising the producer to design products which are more recyclable and have smaller overall ecological impacts work, the producers not only need an efficient feedback mechanism to learn from the recycler about the overall sustainability of his product. Also, during production, a more local feedback loop is needed in order to help the product designer in fulfilling the goal of producing products with low overall impact. In CIRC4Life, the Impact Assessment Tool has been developed to serve this purpose. Using traceability data, it can be tracked whether the hypothetical improvements in the eco-score of a product from a change in design do materialise in reality, see Figure 4. Unfortunately, traceability data is not yet integrated into the tool due to lacking interfaces of the online LCA tool.

3 Implementation of the Traceability Solutions in Sustainable Consumption

The traceability tools are used for the interaction between producers, retailers and consumers in order to monitor a product's sustainability. End-users are enabled to view sustainability information, such as the detailed impacts of the production processes underlying the eco-points calculation, to a degree controlled by the partners providing this data. Using a product's unique ID, which is printed on an auto-ID Label attached to products in store, the end-users can access the product eco-information via a suitable application. The data to be displayed here are provided by the Traceability Module.

3.1 Encouraging Eco-friendly End-Consumer Buying Decisions

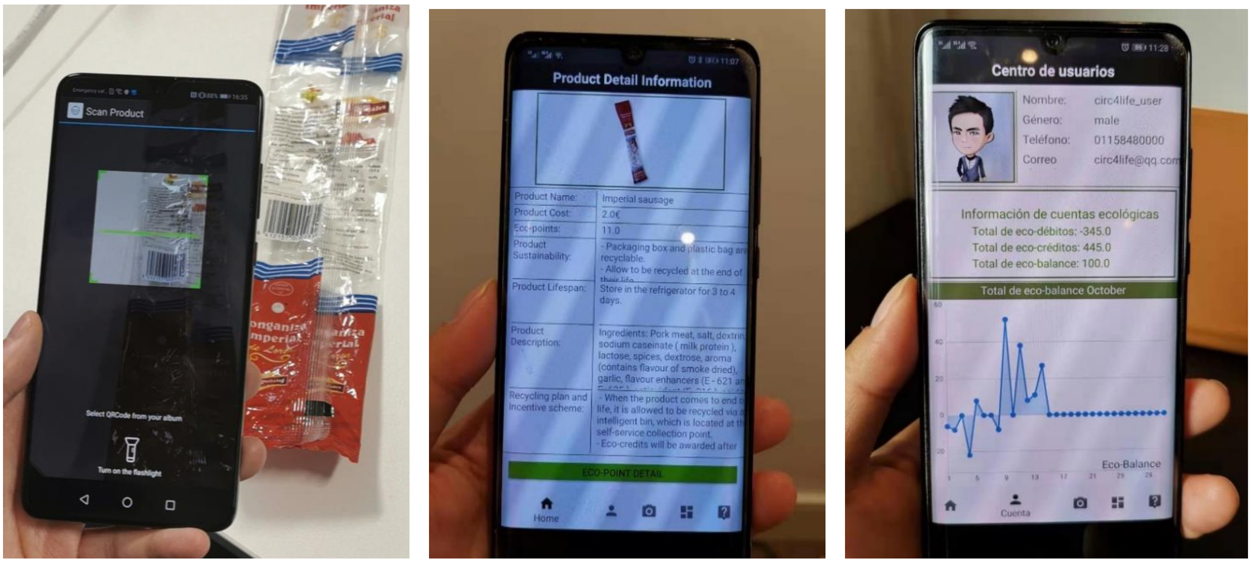
3.1.1 Eco Shopping

In order to allow consumers to make a sustainable buying decision at the point of sale, it is necessary to make products comparable. In order to give a fair and transparent rating of a product's sustainability, it is important to have accurate and realistic product specific data. Therefore, on the one hand, the data collection along the whole supply chain is necessary (see Section 2.1) and on the other hand, the aggregation and communication of these is essential, but challenging.

NTU has conceptionally and technically developed the concept of eco-shopping, which provides a function for consumers to obtain a product's eco-information. This information consists of an accumulated numeric value, the so-called eco-points, but additionally the consumer can get fine grained information on impacts from the manufacturing process. This is realised by an additional data carrier, e.g. a barcode or QR-code, which is attached to the product (see Figure 5 a). In order to display information about an individual batch or even individual product, the EAN containing the GTIN, i.e. the standard barcode which can be found on each fast-moving consumer good today, is not sufficient, since it only identifies the product class and does not contain batch number or serial. A specific eco-label which shows the eco-points of a product can include such a serialised code, e.g. a GS1 Digital Link. See Section 3.1.5 for more details on the eco-label. Consumers can also use the eco-shopping mobile app developed by NTU in the CIRC4Life project to view eco-points and more detailed information, which will help them select sustainable products. The eco-points shown in the mobile phone are calculated through the online LCA tool, also developed by NTU, which applies the ReCiPe method to analyse seventeen midpoint indicators and three endpoint indicators. The integration of this tool to automatically perform the calculation and provide APIs to integrate with the other ICT tools is still under discussion.

3.1.2 Eco Accounting

Through the eco-shopping mobile app, consumers can also access their eco-accounts. This is a tool to motivate consumers for sustainable behaviour by providing a score that can be e.g. shared on social networks in order to compete with peers. This eco-balance score is computed by subtracting the eco-points from bought products as eco-debits from the eco-credits earned via recycling/reusing. The eco-balance is designed such as to reflect the consumer's overall impact on environment. The consumer can track the information of his purchasing and recycling activities and the impacts of each of his actions in a unified score. The app also shows a chart with the monthly eco-balance to motivate improving over time. See Figure 5 for pictures of the application running on a mobile phone.



(a) Scan the barcode (b) Get sustainability information (c) Consumer eco-account

Figure 5: The Eco-shopping App

3.1.3 Point of Sales (POS) System

When purchasing products in the store, the customer will receive a receipt that shows both cash payment information and the eco-debits related to each item purchased, which is shown in Figure 6. This will facilitate the consumer to track the sustainability of each product, hence guide him to buy more sustainable products. To this end, the retailer system for accounting of consumer purchasing is being developed by NTU, which is separate from the shop's existing cashing system. The shop assistant is required at the demonstration to use the two systems to complete the purchase process. The retailing system is implemented via the following procedure:

1. At the check-out point, consumer scans the QR code shown on the ID card or mobile phone, which allows the consumer to gain access to the eco-account.
2. The shop assistant scans the barcode attached to the product to get the product's eco-points.
3. The printer prints out the customer receipts showing both cash payment information and the eco-debits related to each item purchased.
4. The system will record the eco-debits of products into the consumer's eco-account located at the ICT platform. Eco-debit is used to show the customer's negative ecological impact resulting from the products purchased.

This implementation of Eco-Shopping will be demonstrated in ALIA's local store. ALIA will install the equipment and consumers will receive two tickets, the normal one, and the one with the eco-debits and eco-account information.

Figure 6: Receipt showing both the eco-points and cash payment information

3.1.4 Supply Chain Transparency

Visualizing traceability data can be used as a way for evidence-based advertising of e.g. local production. By revealing certain aspects of the supply chain to the end customer, suppliers can prove certain claims, in particular about sustainable production. See Figure 7 for an example of how traceability information (even without data on impacts) can be used in order to clearly communicate where and under which circumstances a product was made, e.g. where an animal was raised.

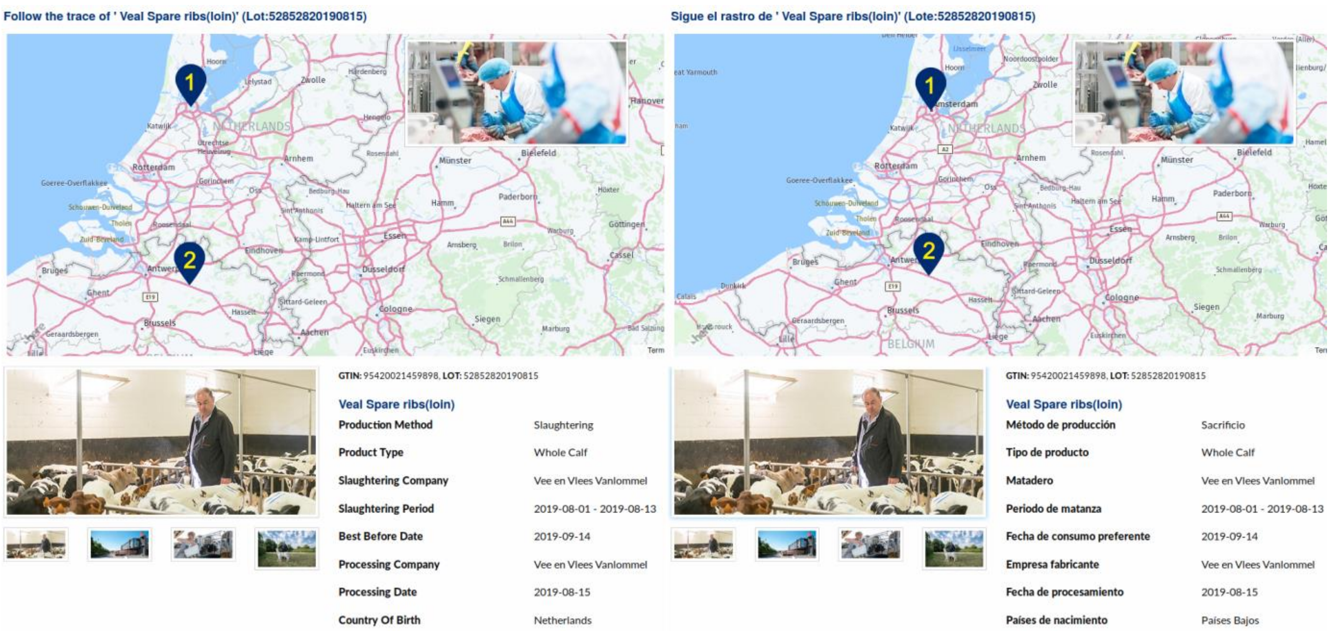


Figure 7: Example for Supply Chain Transparency through Traceability

Furthermore, Traceability information can be used in order to show primary data, i.e. the concrete impacts from the production of this individual product, to the end customer. This way, a customer can understand how a higher/lower eco score comes about and he can hence build trust in the abstract scoring method.

Even without showing the detailed information about all the negative impacts of a product directly, the primary data from traceability can be used to compute the eco-points for each product dynamically. This enables customers to even compare different batches of the same product class, but, more importantly, the individual scores computed from real time data of the individual product/batch is much more accurate/reliable than a score that is computed from estimates and average values. This conceptually improves the value of the eco-point method as a whole and trust into this new system can be generated by communicating this in an appropriate way to the end customer.

Vice versa, the buying of the product is tracked and hence a products life cycle can be traced further after the production and selling until the product arrives at the recycling station. This enables a much more holistic assessment of the products overall impacts, including the usage, than the conventional way of only evaluating data from the production stage.

3.1.5 Eco Labels

Since the beginning of the project, a concept to realise the eco-shopping (as described in Section 3.1.1) has been developed and a concept for producing individual labels displaying the dynamic eco-points was already present in e.g. Deliverable 5.1 Figure 2. Since then, LAU has created great visual designs and evaluated which design is best received by users in their living labs and surveys (see Figure 8).

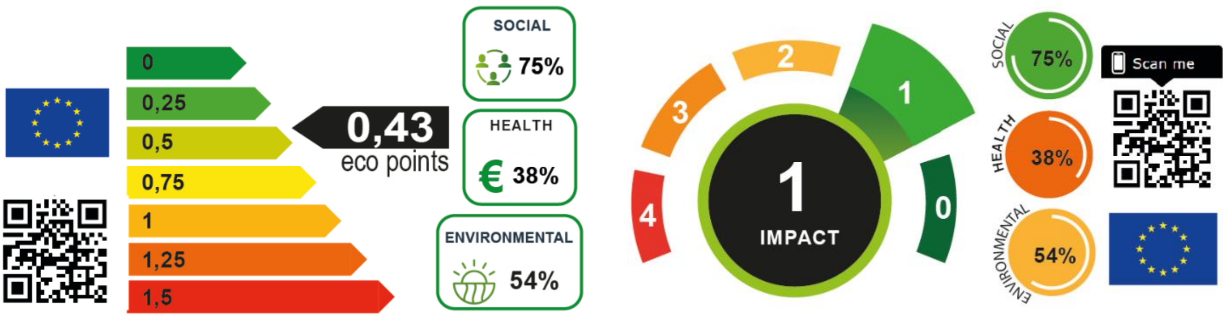


Figure 8: Different Well Received Options for the Eco-Label Designs. Created by LAU as part of Task 7.2.

A challenge in designing the labels was that it is not yet clear which scores exactly will be computed by the online LCA tool and how the resulting values will be scaled, normalised, or otherwise brought into a comprehensible form to be presented to the customer. The current design illustrates two variants. The Impacts, i.e. the eco-points, are shown in a to be defined absolute scale, whilst the other LCA endpoints are shown as percentiles relative to a population of other products in the same category. The latter approach has the advantage of inherent meaning, while the former can be easier used for accounting eco-points from very different products.

The Traceability Module captures and provides the primary data for the online LCA computation from which the label is generated as a visible result. See Figure 9 for a depiction of the data flow and conceptual integration. The technical integration with the online LCA tool by NTU, in particular interfaces definitions, are still work in progress. Currently the eco-shopping application by NTU only shows product information on class level and the products have to be manually included in the app. The app hence only shows a fixed and pre computed value of eco-points for a whole class, as of the time of writing.

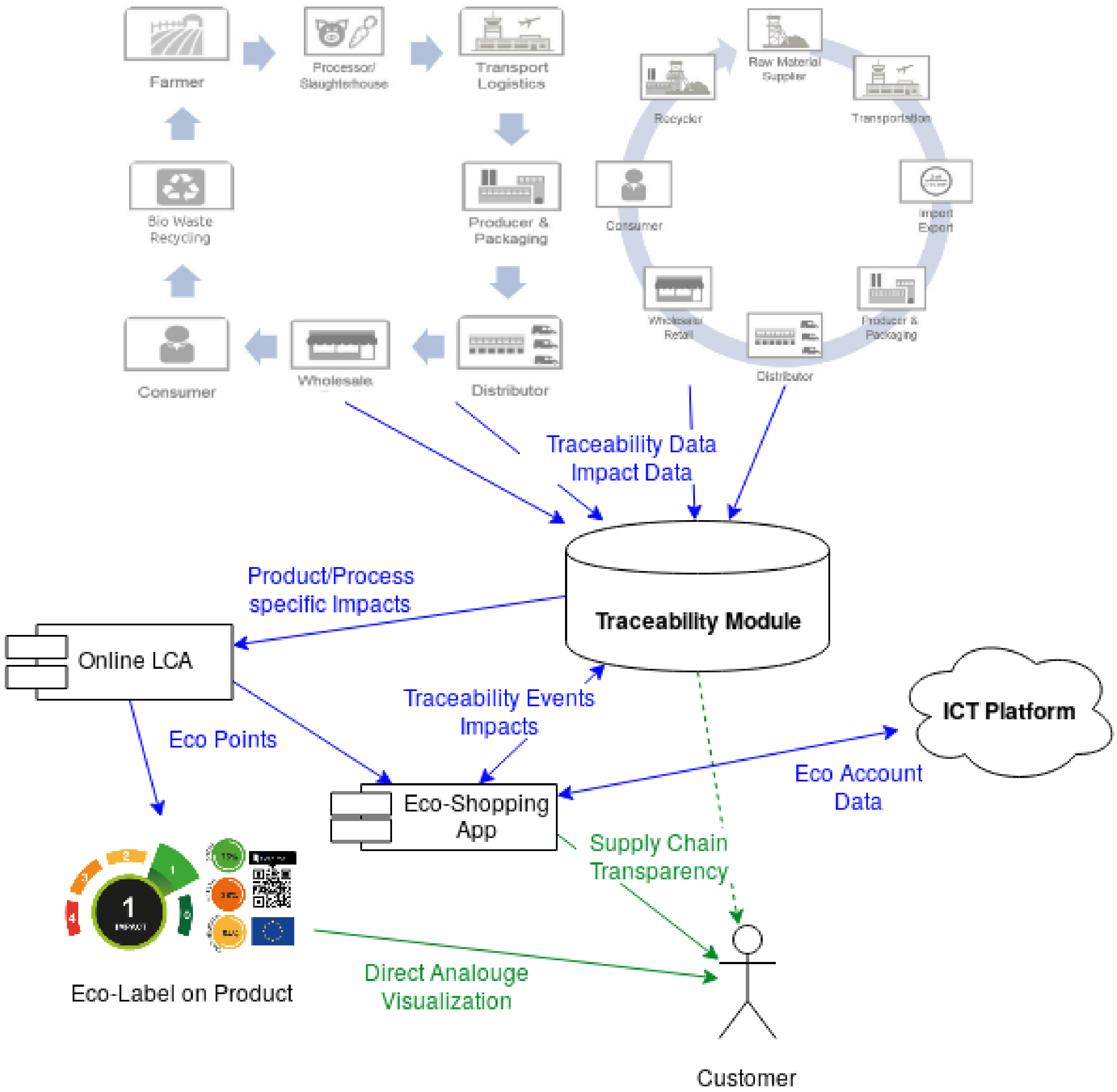


Figure 9: Traceability in Eco-Shopping and Eco-Label generation

3.2 Extending Lifetime

The ecological performance of a product can be greatly improved if the product is well maintained and repaired instead of disposed and hence its lifetime is extended. The Sustainable Consumption CEBM has developed leasing and repair schemes in order to achieve this goal.

3.2.1 Repairing and take back of domestic lamps

ONA will demonstrate this CEBM with lamps sold from their shop. Once the consumer wants to replace a lamp with another or when a lamp is broken, ONA will facilitate the option of 'take back' providing the consumer with the opportunity of repairing or recycling this item. Once the company inspects the lamp, they will consider the option of collecting suitable components for second hand use or deconstruction and recycling of the lamp to gain materials. To this end, ONA decided to track their lamps through their existing web shop and not to use any traceability tools developed in CIRC4Life.

Sustainable consumption will be encouraged by showing the eco-points information of the new domestic lighting in ONA's online store, providing valuable information to help consumers on their sustainable purchase decisions. Consumers will be able to create an eco-account on ONA's website where the user will access and monitor their eco-debits. To this end, ONA's website will, to some degree, integrate with the ICT Platform, but ONA decided to only display static eco point information based on secondary data computed in manual LCA. ONA is currently not planning to make use of the dynamic eco labels introduced in Section 3.1.4, but discussions are ongoing.

The collaborative recycling will be demonstrated by extending the lamps recycling practices to the end-user, allowing the citizens to contact the company to ensure that the product is deposited in the recycling centres or can be repaired (in case of tear or failure) to return it to the market as a second hand product. Also here, ONA does not want to make use of the processes and technologies developed in the Recycling and Reuse CEBM and described in Section 4.

3.2.2 Sustainable Industrial Lighting

KOS aims to develop sustainable CEBMs with a focus on creating vital business models. In Leasing or even product functionality as a service business models, the producer has an inherent incentive to extend the lifetime of his products, contrary to many currently run business models in which shorter product life time or even planned obsolescence leads to higher selling rates and hence higher revenue for the producer.

For the sustainable business models in which the producers also own the products during their whole lifetime, tracing a product also in the usage phase becomes much more important. As explained in Section 2.2.1, it is crucial to know exactly which components are used in which product in order to be able to repair them effectively. Additionally, predictive maintenance becomes possible only through information about the individual products.

3.2.2.1 The Leasing Business Model

KOS has developed a new modular design for their industrial lighting LED luminaire in CIRC4Life. In terms of business models, KOS develops a leasing service in which a full maintenance cover is included. Due to the vast energy savings that LED lighting can offer, especially within the industrial sector, the estimated saving on a client's electricity bill should be able to cover the leasing service charge without extra financial burden. Flexible payment plans can be provided to suit the customer's individual financial situations. In summary, the leasing service proposed provides following benefits:

- Small monthly payment to cover the cost of the products, installation and ongoing maintenance fee.
- The monthly fee will be covered by the electricity cost saved each month.
- Hustle free, the fitting will be regularly checked and fixed if necessary.
- The typical leasing duration is 3 to 5 years and the leasing contract can be as long as 10 years to minimise the monthly payment, although a long leasing can be a risk both for customers and the leasing company.
- The leasing contracts can be flexible, and the contract can be transferred and updated if there is a better option available or terminated early as long as the remaining financial cost is covered.

The following Figure 10 shows two types of payment plans: stepped payment plan and flat payment plan, which KOS plans to offer, using a 10 years leasing contract as an example for illustration purpose.

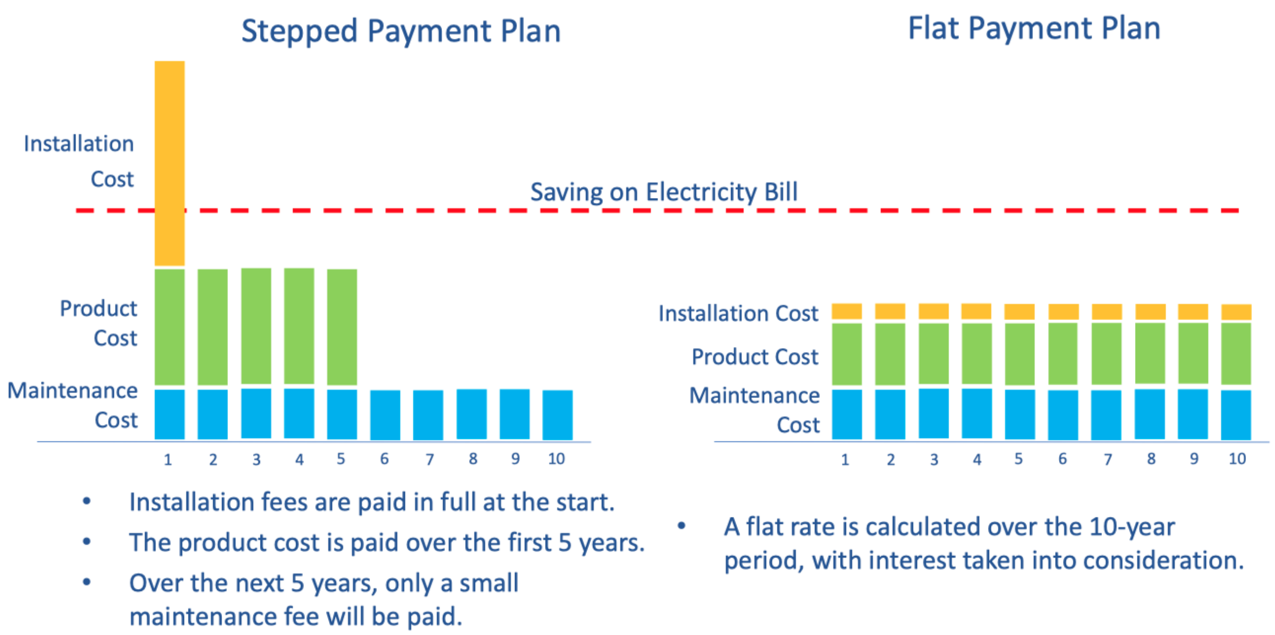


Figure 10: Two types of leasing payment plans

The ultimate objective of this is to apply a circular economy approach instead of a linear one, to create a more sustainable model of consumption within industrial LED lighting by extending the product's life considerably through the encouragement of reusability and the minimisation of waste.

The Traceability Module will be used to track which lamps are installed where and in particular to track maintenance, such as repairs. This enables KOS to compare the real maintenance costs to the expected ones and to calculate KPIs for the viability of the new business model.

3.2.2.2 Selling Light Hours Instead of Lamps

A more advanced alternative to leasing lamps is to sell light hours. This concept is sometimes called "Usage as a Service" (UaaS) and is conceptually very similar to the flat payment plan in leasing as depicted in Figure 10. The difference is that instead of a fixed amount per month and lamp, the customer only pays per hour for which the lamp has been turned on. This can be attractive for installations with varying degrees of usage, e.g. if no artificial light is needed in summer, or if the facility is not permanently in use.

This business model needs traceability even more than the leasing business model, since it is crucial to track the number of light hours for which the lamps where used. Having this data available then also enables predictive maintenance as explained in the next section.

The development of a UaaS model will only be considered as a next step after the Leasing model has been developed and proven to be viable and vigorous in reality.

3.2.2.3 Predictive Maintenance

For both business models described above, predictive maintenance, i.e. exchanging parts before they break, can be a useful addition. In its simplest form, parts can be exchanged at about the time that they reach their average life time after installation. This only requires very basic traceability information, namely when the lamp was installed or the part was last changed.

If the time for which the lamp has been switched on is tracked, as is necessary for UaaS, this time can be used instead of installation time, since it is known to be a better indicator for the expected remaining life time of components. In this case, also e.g. the number of times the light has been switched on and off can easily be determined and used for maintenance prediction, because this is known to be a good predictor for the failure of e.g. transformers.

Offering predictive maintenance increases the convenience factor for the customer a lot, since the producer can, to a certain degree, guarantee that the product will never fail. This can be turned into a business model by charging the consumer at an appropriate rate for the service while guaranteeing a larger payback if the product should fail despite the predictive maintenance.

KOS is currently evaluating the implementation of a predictive maintenance business model based on traceability, although this is not originally in scope of KOS' CIRC4Life activities.

The accuracy of failure prediction can even be enhanced further through using machine learning (KI) and monitoring more of the relevant environmental conditions, such as humidity, and internal parameters, such as component temperature. Such techniques may be evaluated in follow up projects.

4 Implementation of the Traceability Solutions in Collaborative Recycling/Reuse

The traceability tools are used to track products all the way through their end of life phase and into the next cycle. The traceability information gathered during production or product usage can be utilised in order to repair/refurbish or recycle a product. This aspect is discussed in Section 2.2.1, see in particular Figure 3. To encourage end-customers to return broken products into the recycling/reuse system, an incentive scheme based on eco-credits and procedures for collecting and repairing/recycling products has been developed in the Collaborative Recycling and Reuse Business Model. Traceability tools are used throughout to enable these processes by tracking returned products and their treatment. Furthermore, traceability information also enters the eco-credit calculation.

The Recycling and Reuse CEBM, in particular the electronics recycling demonstration task, started early in the project to develop very concrete plans to demonstrate their use case. Thanks to this, concrete processes where developed with concrete requirements on the ICT systems and WP 4 and 5 have developed the flow depicted in Figure 13. All tools by ICCS and EECC as well as the intelligent bin are fully developed and integrated. Of course, the proof of the pudding lies in the eating, hence further adaptions are expected to be done once the End User Application is finalised and integrated and the whole system will be tested in Living Labs in 2020.

The meat recycling demonstration changed scope slightly towards bio waste recycling, but the processes are anyway very similar to the electronics recycling. Once the pending amendment of the grant agreement to change the scope from meat to bio waste recycling will eventually be resolved and the demonstration proceeds refining its processes, integration of all ICT systems into this demonstration is expected with only very minor changes compared to electronics recycling.

4.1 Electronics Recycling and Reuse

One of the main business cases developed and implemented in CIRC4Life is the collection of electronics items, such as tablets, in specific “intelligent” bins and their subsequent recycling or reuse. See e.g. the “Electronics Recycling and Reuse” User Story in D5.2 for more details.

The Traceability Module supports this case by storing all relevant events for each individual item. Concretely, the disposal of an item into the bin, the collection of the waste and finally the assessment by the recycler, including the outcome, are tracked. This enables the end user Application to show process information to the user and for example answer the questions:

- Where is my tablet?
- I think it is still working and good for reuse, does the recycler agree?
- Will I obtain any incentive?

Figure 11 shows a high-level view on the business model. The traceability system support this model in the following steps:

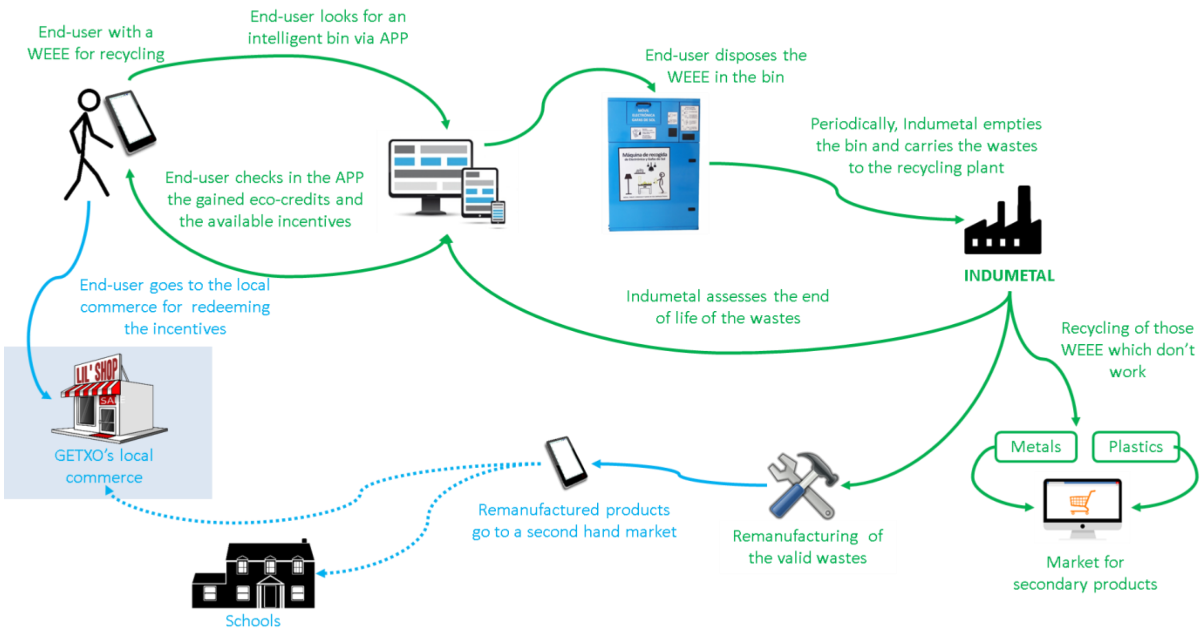


Figure 11: Schematic depiction of the Collaborative Recycling and Reuse Business Model

Assessment of the wastes

When the wastes arrive at Indumetal's facilities, workers assess the end of life state of the wastes in order to determine if the product can be remanufactured or has to be recycled. Once assessed, the worker scans the bar code stuck on the waste, using the web-based user interface developed by EECC which is shown in Figure 12. The worker has to fill in the state of the waste and the estimated lifetime. If the item is known to the ICT Platform, the other fields are automatically completed, otherwise a category (tablet, mobile phone, etc.) has to be chosen and an identifier has to be entered. This is preferably the GTIN and serial number of the product, if known. Otherwise, the brand and model name can also be given in text form.

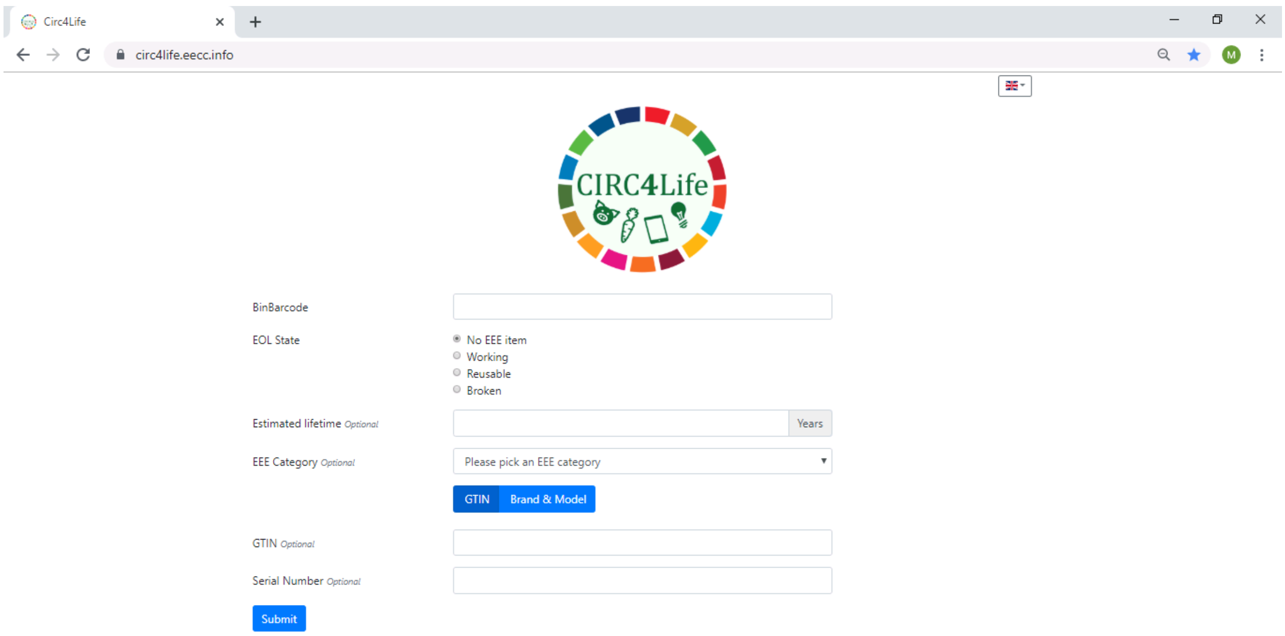


Figure 12. EEE assessment graphical capturing interface of the Traceability Module

End-user feedback

Once the eco-credits have been calculated, the ICT Platform provides this information to the End User Application, but the state of the EEE can be queried throughout from the Traceability Module.

4.2 Bio-Waste Recycling

For the recycling of the meat products by the consumer, a bio-waste intelligent bin is proposed to be set up in the region of Murcia. This bin will collect not only meat waste, but different kinds of bio-waste.

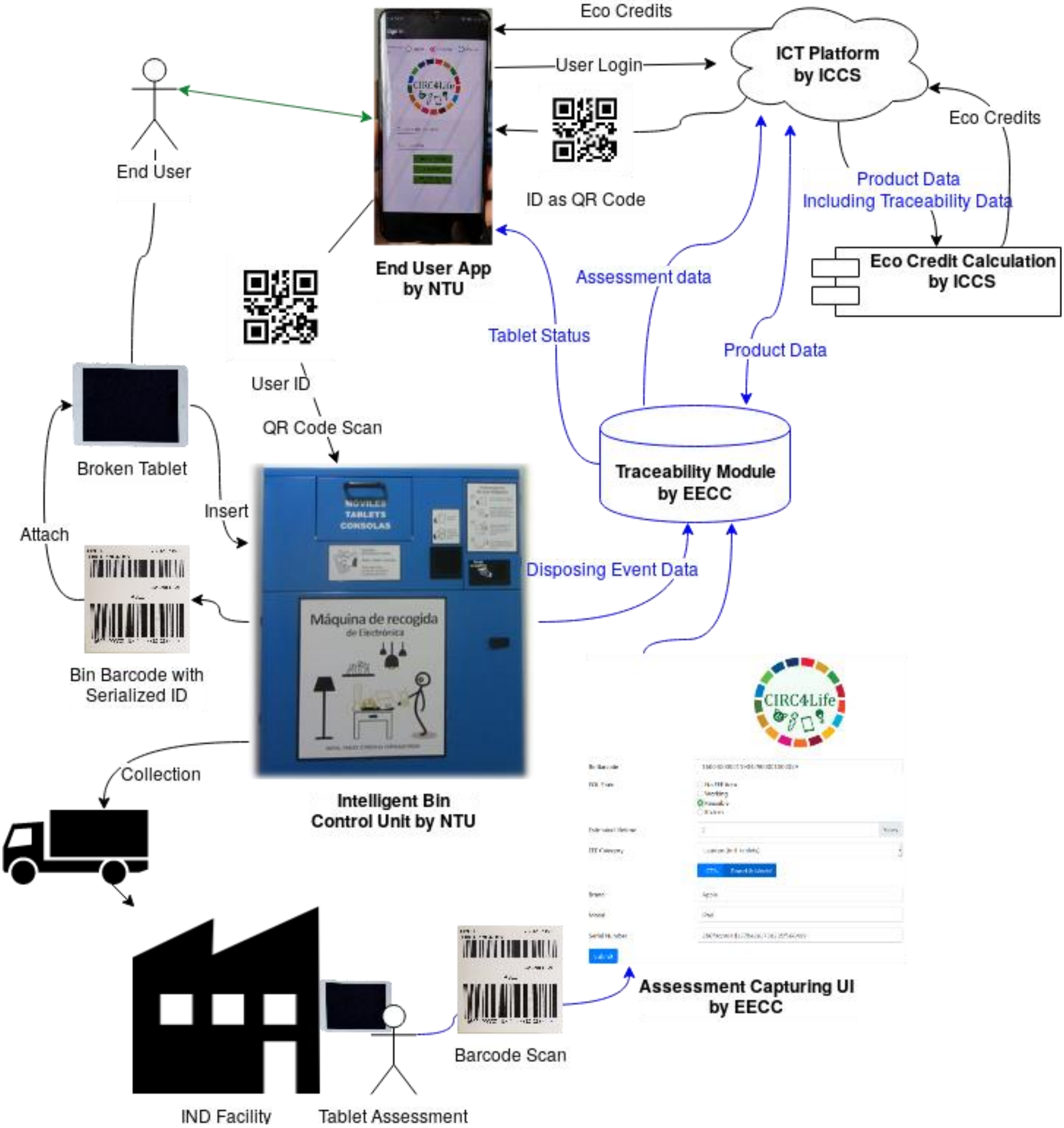


Figure 13: Detailed View on Data Flow and ICT Systems Interaction

The Bio-Waste recycling uses the same user account system as the eco-shopping and tablet recycling demonstrations, hence every has a unique ID and can identify himself to the bin with through QR code as in the EEE demonstration. The intelligent bin prints a bar code sticker with the identification code data of the user, a time stamp, bin ID and serial, just as for EEE. The user will stamp the sicker in the biowaste bag, so the traceability is ensured and will dispose the biowaste. ALIA will collaborate with recycling managing authorities at local level, so they will check that the biowaste has been correctly disposed and will send ALIA the related information. Then, the information will be included in the traceability system. To this end, a similar user interface as shown in Figure 12 is to be used. Conversations are in progress between ALIA and recycling managing authorities.

This information will be uploaded in the ICT platform of CIRC4Life project, so the users will be able to receive the eco-credits associated to their recycling practices. These eco-credits will be converted into incentives, similar to the EEE demonstration. The intelligent system of the bin will be connected to the Traceability Module in order to provide the data of the disposed waste (the same data as on the barcode).

After the collection has been developed, next step should be defining the most appropriated valorisation of this waste. For this approach ALIA will collaborate with another H2020 project (LIVERUR, 2018), which will use the biowaste collected for the development of new value products. As there is no need to ensure the traceability of the biowaste for the development of new products after the collection and once the local recycling managers have registered the dispose of the bag of biowaste, the traceability will not continue further. The possibility of including the products developed with this biowaste e.g. via the Brokerage Tool is currently being discussed.

5 Integration of the Traceability Module with the other ICT Systems

The ICT eco-system architecture of CIRC4Life has been developed from a very early phase of the project on, according to the project's schedule. Deliverables 4.1, 4.2, 5.1, and 5.2 have been completed as planned containing the outcomes of the respective tasks. Nevertheless, since most of the CEBM and demonstration tasks and work packages have developed essential concepts only after the submission of, in particular, D 4.1 and D 5.1, the ICT systems are all more or less developed in an agile way and based on flexible designs in order to be able to cater for the CEBMs' needs, as soon as they become clear one by one. This is particularly true for the Traceability Module, which was developed to be able to capture and share all data that could be useful for the CEBMs, but new interfaces are added whenever a demonstration case becomes more concrete and it turns out that a more specific interface can make the usage of traceability tools for a concrete demo simpler or more convenient.

EECC has implemented a continuous deployment strategy with an automated build pipeline which is fully operational since 3 July 2019 and has deployed more than 30 Releases until November 2019. For ease of integration, the latest version of the documentation, including a full human as well as machine readable Open API Specification, is automatically compiled and deployed with each release, see (EECC, 2019). This enables all partners to integrate with the endpoints provided by the Traceability Module. So far, the ICT-Platform by ICCS and partially also the Eco-Shopping Application by NTU have successfully integrated with the provided Endpoints. Of course, EECC actively supports all partners in the integration.

At the time of writing, the only other partner providing documented API endpoints for integration is ICCS, see (ICCS, 2019). WP4 took the lead in defining the OAS format to be used and the ICT-Platform was the first component to offer endpoints for integration, with the Traceability Module following suit shortly after.

The end user mobile application for eco-shopping and recycling is currently integrating with the ICT Platform as well as the Traceability Module by consuming their endpoints. This integration makes good progress and timely completion is expected, in particular since it is necessary to for the realisation of the processes depicted in Figure 11 and more technically in Figure 13 and which are crucial for the demonstration of the Collaborative Recycling and Reuse CEBM.

5.1 Integration with the Interoperability Layer

After thorough discussions with EECC, ENV decided to demonstrate the integration of tools under the umbrella of the interoperability layer with the Traceability Module by using the standard EPCIS 1.2 SOAP interfaces. This standard is publicly available, see (GS1 Global, 2016), and the advantage of using the standard interface is that the resulting system is fully interoperable with any other standard conformal implementation. EECC consults ENV in the standard conformal usage of the interface but has also offered to provide a more specific RESTful webservice. EECC takes part in the development of the forthcoming EPCIS 2.0 standard, which will standardise JSON based interfaces for all existing SOAP endpoints. The EPCIS 2.0 standard is not yet finished, but EECC offers a preview version of the newly defined standard JSON interfaces. The integration with the Interoperability Layer can be completed either way and EECC is consulting ENV in order to facilitate the demonstration of a successful connection.

The direct data exchange between the Interoperability Layer and the Traceability Module is not integrated into any of the CEBMs and will hence be implemented for demonstrating general principles only. The communication is always initiated by the Interoperability Layer consuming endpoints of the Traceability Module, hence no APIs on the side of the Interoperability Layer are planned or required.

5.2 Integration with the ICT-Platform

The bi-directional communication between the Traceability Module and the ICT-Platform is a vital part of integrating both of them into the Collaborative Reuse and Recycling CEBM as explained in Section 4. This integration involves the traceability Module consuming protected REST endpoints of the ICT-Platform via authorisation provided from the ICCS Access Control Manager. All Authentication and Authorization of end-users and client application of the ICT Platform is implemented with the Keycloak (Red Hat, 2019) Access Control Manager server. All registered end-users and client applications use the OpenID Connect (OpenID, 2019) layer on top of the OAuth 2.0 protocol (OAuth, 2019). With this authentication method, the client requests an access token from the Access Control Manager by providing his unique credentials. Every protected REST endpoint can be accessed only by a trusted application that bears a valid Access Token provided by the Access Control Manager.

The ICT Platform provides a REST API to the Traceability Module that covers the following functionality:

- Eco-credits calculation/estimation: a coarse version of the specialized Eco-credits calculation module that allows the client to get a calculated number on a specific product item paired with its lifetime and end of life state. Additionally, REST endpoints with eco-credits estimation if a specific product or product type was recycled today. This endpoint is not used directly by the Traceability Module, but it is to be used by the End User Mobile Application in order to give the end user an estimate for the eco credits that he will get for recycling a product.
- Consumer Eco-account purchase history access: a list of consumer's past purchased items, in order to check if the currently recycled item is one of them. This endpoint is integrated with the Traceability Module. Concretely, the functionality of the Recycling Assessment Capturing UI uses the purchase history in order to automatically complete product information, such as serial number and GTIN, if possible.
- Recycling company assessment update: it is possible to update the consumer's Eco-account with the result of the recycled item assessment, effectively changing his Eco-balance and recycled item history. This is the most important communication channel between the ICT Platform and the Traceability module for the Collaborative Recycling and Reuse demonstrations. Integration is successfully accomplished.
- Standardized list of supported product type keys: in order to identify a product waste type with confidence, the ICT Platform has incorporated a subset of the Product Harmonized System and Electronic product UNU-KEY codes into its database. The API allows to retrieve a full list of the supported codes and their corresponding product waste type. This is used by the Traceability Module for the Recycling Assessment UI in order to provide the worker with a choice of categories for the assessed item.

See Figure 13 for a detailed visual depiction of the interactions between the various ICT Systems for this CEBM. Every blue arrow in Figure 13 represents an interaction of the ICT Platform with the Traceability Module through a specific interface. All these interactions have been tested at the Technical Meeting in Cologne at 22 and 23

October 2019. All tests and hence the whole integration of the Traceability Module with the ICT Platform regarding all processes related to the Collaborative Recycling and Reuse CEBM are successfully accomplished.

For the other two CEBMs, interaction with the online LCA tool is a crucial part of the overall ICT system, see Figure 4 and Figure 9. Unfortunately, the online LCA tool is not available for integration, yet, hence also the discussion whether the data flow should be routed through the ICT Platform or through direct interactions as depicted in the afore mentioned figures was postponed. From the experience gained so far and given that relevant endpoints of the Traceability Module as well as the ICT Platform are already up and running, further integration of these two systems is expected to be easily accomplishable, if the need for such further interaction arises in the development of the CEBMs.

5.3 Integration with the Recycling Module

The recycling Module consists of an additional application that NTU has added to the intelligent bin's control unit in order to be able to send the data from the bin directly to an endpoint of the traceability module, instead of the bin just sending emails as provided by the bin supplier. This integration is a part of the ICT systems' interactions necessary for the Collaborative Recycling and Reuse CEBM as depicted in Figure 13.

The integration has been implemented and tested and is successfully accomplished.

5.4 Integration with the End User Tools

5.4.1 Brokerage System

Traceability data is available from the Traceability Module's interfaces and e.g. data about material from recycled tablets could be used in the Brokerage system when offering those materials. However, no integration of the Brokerage System with the Recycling demonstrations is currently planned. Traceability data from the production of intermediate products from the food sector could also be used for the Brokerage Tool, but also here no integration of the tool is planned. The Traceability Module is ready for integration if plans of integration of the Brokerage System into one or the other CEBM are developed.

5.4.2 End User Mobile Application

The integration of the mobile application by NTU is currently being accomplished in pace with the development of the app itself. EECC is supporting NTU in establishing the connection to the endpoints offered by the Traceability Module and in the transformation of the data. Since this integration is needed for the Collaborative Recycling and Reuse CEBM as depicted in Figure 13, timely completion is expected.

6 References

- CIRC4Life, 2018. *Deliverable 1.3: Report on the development of eco-point methods,* Nottingham: CIRC4Life Project Deliverable.
- EECC, 2019. *CIRC4Life Traceability Module - Open API Specifications.* [Online] Available at: https://circ4life.eecc.info/doc/oas/
- European Union, 2018. *EUR-Lex.* [Online] Available at: https://eur-lex.europa.eu
- fTRACE GmbH, 2018. *About fTRACE.* [Online] Available at: https://www.ftrace.com/en/gb/about [Zugriff am 12 12 2018].
- GS1 Global, 2008. *Case Study: Traceability in Fresh Foods.* [Online] Available at: https://www.gs1.org/sites/default/files/docs/casestudies/traceability_case_study_egypt.pdf
- GS1 Global, 2015. *A Global Farm Registry for the United Nations.* [Online] Available at: https://www.gs1.org/sites/default/files/docs/retail/gln-for-farms.pdf
- GS1 Global, 2016. *EPC Information Services (EPCIS) Specification - Release 1.2,* Brussels: Global Standards One.
- GS1 Global, 2017. *Core Business Vocabulary (CBV)Specification - Release 1.2.2,* Brussels: Global Standards One.
- GS1 Global, 2017. *EPC Tag Data Standard,* Brussels: Global Standards One.
- GS1 Global, 2017. *Fruit and Vegetable Master Data Attribute Implementation Guide.* [Online] Available at: https://www.gs1.org/docs/freshfood/Fruit_Vegetable__Master_Data_Attribute-ImpGuide.pdf
- GS1 Global, 2018. *GS1 General Specifications - Release 18,* Brussels: Global Standards One.
- GS1 Global, latest. *EPCIS and CBV Standard.* [Online] Available at: http://www.gs1.org/epcis
- GS1 Global, latest. *System of GS1 Standards.* [Online] Available at: http://www.gs1.org/standards
- GS1 Global, latest. *Traceability Standard.* [Online] Available at: https://www.gs1.org/traceability/traceability/2-0
- GS1 Global, kein Datum *GS1 Identification Keys.* [Online] Available at: http://www.gs1.org/id-keys
- Huijbregts, M. A. J. et al., 2017. ReCiPe2016: a harmonised life cycle impact assessment method at midpoint and endpoint leve. *The International Journal of Life Cycle Assessment,* Issue 2.
- ICCS, 2019. *CIRC4Life ICT Platform.* [Online] Available at: https://circ4life.iccs.gr/

- International Organization for Standardization, 2017. *SO/IEC 19987:2017: Information technology -- EPC Information Services (EPCIS) Standard,* ISO: Geneva.
- LIVERUR, 2018. *Living Lab research concept in Rural Areas.* [Online] Available at: https://cordis.europa.eu/project/rcn/214746/factsheet
- OAuth, 2019. *OAuth 2.0.* [Online] Available at: https://oauth.net/2/
- OpenID, 2019. *OpenID Connect.* [Online] Available at: https://openid.net/connect/
- Red Hat, 2019. *Keycloak.* [Online] Available at: https://www.keycloak.org/