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- CIRC4Life-H2020-IND-CE-2016-2017/CIRC-2017/TwoStage

A circular economy approach for lifecycles of products and services

Report on sustainable (environmental, social and economic) impact analysis

Deliverable 1.2

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Document Responsible	Jonathan Smith (JS)
Contributors	JS, NTU, CIR, KOS, ONA, SWE, CEPS, ALIA, ICCS, IEIA
Reviewed by	NTU, REC
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Summary

In CIRC4Life the four industry partners selected five products to be analysed for their environmental and social impacts, with the aim of understanding what the current impacts are, how to reduce those impacts, and how that can be communicated to customers and other parts of the supply chain. Task 1.2 is pivotal to functions in several other tasks and work packages within the project.

To carry out this analysis of impacts, toolsets needed to be developed, underpinned by an innovative approach to LCA analysis. The Impact Assessment Tool should be created that features both Environmental and Social LCA analysis through an Online LCA function, coupled with weighting options, and a decision-making tool to enable users to use informed decision making for design of new products or systems.

Analysis of the five products resulted in Eco-point scores for all products, which will also feed in directly to the Eco credits, debits and eco points, a key output of the project. The environmental and social impact analyses all provide recommendations on how the business can reduce the impacts of the products it creates, which is explored further in Task 1.5.

Task 1.2 has shown how an innovative approach to impact analysis can offer users a detailed understanding of the impacts of their products, which has been tested in real life scenarios. Furthermore, the Impact Assessment Tool offers uses more interaction and options than traditional LCA approaches, and an ability to obtain insight into the processes that determine the impact of their products, and therefore can make informed decisions on how to reduce those impacts.

For businesses the ability to reduce environmental and social impacts means a route towards a lower carbon footprint, reduced resource use, less waste produced, more socially responsible products, and opportunities to gain business in the established ‘green economy’ and emerging ‘circular economy’.

Finally an assessment of how this solution can be improved, scaled up, taken to market and become a tool of real value to businesses in the EU and beyond, demonstrates that this CIRC4Life solution has the potential to be of great value to businesses operating in a world aiming at lower impacts from all sectors of society.

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Acronyms and abbreviations

Abbreviation	Description
LCA	Life Cycle Assessment
PEF	Product Environmental Footprint
LCI	Life Cycle Inventory
EU	European Union
UN	United Nations
E-LCA	Environmental Life Cycle Analysis
S-LCA	Social Life Cycle Analysis
WP	Work Package
T 1.2	Task 1.2
T 1.1	Task 1.1
TRL	Technology Readiness Level
SDK	Software Development Kit
UI	User Interface
J-SON LD	JavaScript Object Notation for Linked Data

1 Introduction

The aim of Task 1.2 is to 'analyse the environmental, social and economic impacts ('impacts') of products through their life-cycle, using existing and new innovative methods of impact analysis'.

The analysis of impacts has been undertaken on five products from the four industry partners in the consortium (JS, ALIA, KOS and ONA); organic potatoes, pork sausage, pork lion, LED high bay lighting, and LED domestic table lamp. This has been enabled through the development of toolsets, which are combined into the Impact Assessment Tool (section 3).

From the calculation of impacts, results were obtained for each of the products (section 4). These results were analysed and converted to eco points (section 5). The culmination of this work demonstrates how impacts on products can be measured, analysed and be made useful to businesses.

This Task relates to many other Tasks and Work Packages in the project (section 6). There is also potential for further development of the Tool in a manner which could make it usable by businesses, in supply chains, and as a tool for interacting with consumers (section 7).

This report contains the results of the Life Cycle Impact Assessment of five reference products from three different sectors: vegetables, meat supply chain and LED lighting; using existing and new innovative methods of impact analysis. These results represent a reference scenario for the future assessment of innovation solutions that will be developed in CIRC4Life project. In addition, they may be used in calculation of eco-points, and subsequently used for eco-credits and eco-accounting. Furthermore, they will be used as a basis for further work in project´s Work Packages 2 and 3.

2 Toolsets for Impact Analysis

The first part of the design process for creating toolsets was to scope the boundaries. These were determined within the following frameworks:

- Calculating the environmental and social analysis of products defined in T 1.1. These are listed in Table 2-1.
- Scoping the production processes of products (see Deliverable 1.1).
- Understanding the required weighting options to calculations and results.
- Connecting with an Online LCA platform.
- Understanding the needs of industry partners and assessing how the decision-making tool can provide business benefits to industry partners.

Table 2-1 Products to be analysed

Project Partner	Product 1	Product 2 (if applicable)
JS	Potatoes	
KOS	LED high bay lighting	
ONA	LED table lamp	
ALIA	Cured sausage	Cured pork loin

To aid the process of toolset development, an assessment of current environmental analysis tools was done, to understand which tools exist (whether free or paid-for services), what they do, and how the Impact Assessment Tool could complement, or indeed substitute what they currently do. This document is shown in Appendix 1.

Following analysis of these other tools, it was deemed that the Impact Assessment Tool offered something suitably unique and filling a gap in the market, to ensure that the project believes it is worth investing in and will create something of value for businesses. It was noted that no existing tools combined impact analysis from multiple sources, combined with decision making functionality and an ability to alter weightings.

Defining the structure and functionality of the Tool was supported by the document 'Business benefits of the Impact Assessment Tool' shown in Appendix 2. This is a form of co-creation, by engaging the project's industry partners (JS, ALIA, ONA and KOS) in the process of designing the Tool to meet their needs. The document described the preferred environmental, social and economic/business indicators and outcomes of the Tool, and which weightings are important to them.

A summary of these desired features can be seen in Table 2-2 below.

Table 2-2 Desired features of Impact Assessment Tool

Environmental	Social	Business
Carbon footprint	Social impact/LCA	Decision making/business improvement
Ecological footprint	Engagement of staff	Ability to work with supply chain
Land use	Human health impacts	Benchmarking with other businesses
Water use		Translate in to financial benefits
Toxins/chemicals in supply chain		Assess benefits of products
Waste generated		Detailed analysis of impacts (on the business)
Material flows		Good marketing opportunities
Life Cycle Assessment		Business opportunities throughout the supply chain

Links to UN Sustainable Development Goals

This Task has clear links with the following Goals (bold for main connections):

- 3 – Health and well-being: the ability of consumers to understand the impacts of products and choose products that are healthier and with lower impacts.
- 6 – Clean water: The Tool assesses water consumption in the creation of products. By measuring and communicating this to consumers and the supply chain, the aim is to minimise water use in production. Furthermore, the E-LCA analysis assesses whether negative impacts of water use are associated with the product.
- 7 – Affordable and clean energy: as above for water, the impact of energy use in products is detailed in the E-LCA analysis, and the drive for products is to use low carbon forms of energy use. Furthermore, at the Product Design stage, there is an incentive and driver to design products with lower energy use (e.g. LED lamps).
- 8 – Decent work and economic growth: these circular economy solutions aim to create business opportunities from products with reduced environmental and social impacts.
- 9 – Industry, Innovation and Infrastructure: the business solutions being tested here are innovative products within industrial sectors.
- 11 – Sustainable cities and communities: the products and methodologies being tested here will support the requirements of sustainable living.
- 12 – Responsible consumption and production: the fundamental remit of the CIRC4LIfe project is to enable consumers to buy products with lower social and environmental impacts, and to be rewarded for doing so.
- 13 - Climate Action: a strong driver for all products tested in this methodology is for low carbon production and consumption, enabling consumers to live more sustainably and reduce their carbon emissions.
- 15 – Life on Land: four of the products tested here are agricultural (meat and vegetables. This Tool enables farmers and growers to have a competitive advantage when selling their low-impact food products.
- 17 – Partnerships for the Goals: the remit of the whole project is to create solutions that are joined up across supply chains, integrated with consumers, and have clear policy advantages for decision makers.

Figure 2-1 UN Sustainable Development Goals

2.1 Impact Assessment Tool

The Impact Assessment Tool[1] ('the Tool') was created to combine several facets of calculations and user functionality. It is a Web Application created for the needs of Task 1.2 for Work Package 1, developed by ICCS, with input from other T 1.2 partners.

The goal of the Tool is to present a user-friendly interface showcasing the ecological impact of a product. The interface displays the product's components (e.g. materials), its production cycle, its usage and lifecycle. The Tool includes search form functionality in order to retrieve products from the ICT Platform database. Each product can be displayed in a form page that displays all the basic properties (model, brand, manufacturer, etc.) and the life-cycle data structure (resources, impact assessment methods, etc.). The user of the Tool, made up of businesses and supply chain actors, is allowed to modify specific properties and assess the displayed eco-friendliness factors, that change accordingly. In the current version of the Tool the eco-friendliness is measured by the computation of the Eco-Credits (recyclability computation), as is described in the deliverable D2.4, usable for reusable or recyclable products.

Economic impacts of products are not included in the Tool. This function was investigated but found to be very difficult to incorporate, due to the huge number of variables in costs, retail prices and profit margins. For example, input costs for just one product such as an LED Table Lamp, can vary according to supplier, world market, time of manufacture, and retail market (affecting retail price). Combine this with wide variations in manufacturing conditions, such as local taxation, wage rates, and environmental regulations, and the

[1] Note this is synonymous with the 'Impact Analysis Tool', as referred to in the description of work for Task 1.2

economic picture is extremely complex. It was felt however that this would be worthy of further investigation in future versions of this Tool.

2.1.1 Technical Description of Impact Assessment Tool

The development of the tool is based on the software development kit (SDK) [Google Web Toolkit] (http://www.gwtproject.org/). This SDK is an open-source and freely licensed software tool build on top of the [Java](java.com) language and software platform. It is a toolkit that allows programmers to write code using the Java language and output complex browser-based Web applications. This allows the productive development of high-performance Web Applications without the hassle of directly using multiple language and software SDKs (HTML, JavaScript libraries, CSS, etc.) and handling browser and device intricacies.

This facilitated the integration with server side Java applications, as each Web Application is usually consisted of a client part that gets compiled to a HTML, JavaScript, CSS module and a server part that conforms to the [Java Servlet](https://www.oracle.com/technetwork/java/javaee/servlet/index.html) technology. It does not completely remove the need for Web technologies like HTML and CSS, but it greatly facilitates the usage of them and hides many of the quirks that different systems and browsers may have. With the Google Web Toolkit, you can write software using Java language APIs and deploy them as client-side HTML/CSS/JavaScript, plus server-side support of Servlets for Java Web Containers.

2.1.2 Overview of Impact Assessment Tool

A welcome page for the Impact Assessment Tool, requires the login of the users and protects the application

Figure 2-2 Impact Assessment Tool Welcome Page

Once the user logs in then at the welcome page a search functionality allows the user to retrieve any product that is stored in the ICT system central database, as described in the deliverable D4.1.

Figure 2-3 Impact Assessment Tool Search Page

The Tool supports English, Spanish and Basque Languages. Spanish and Basque are selected because Demonstration 2 and Demonstration 4 will run in Spain and Basque Country so, in order to ensure higher replicability (because of the possible lack of knowledge in English in Spain for most mid-to-high age people).

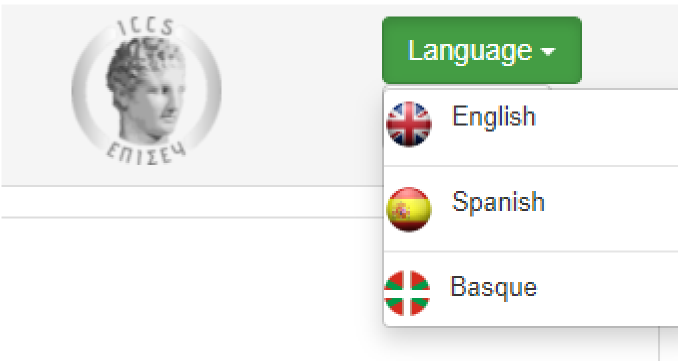

Figure 2-4 Languages supported by Impact Assessment Tool

Once the search is done a list of matching products is returned to the user.

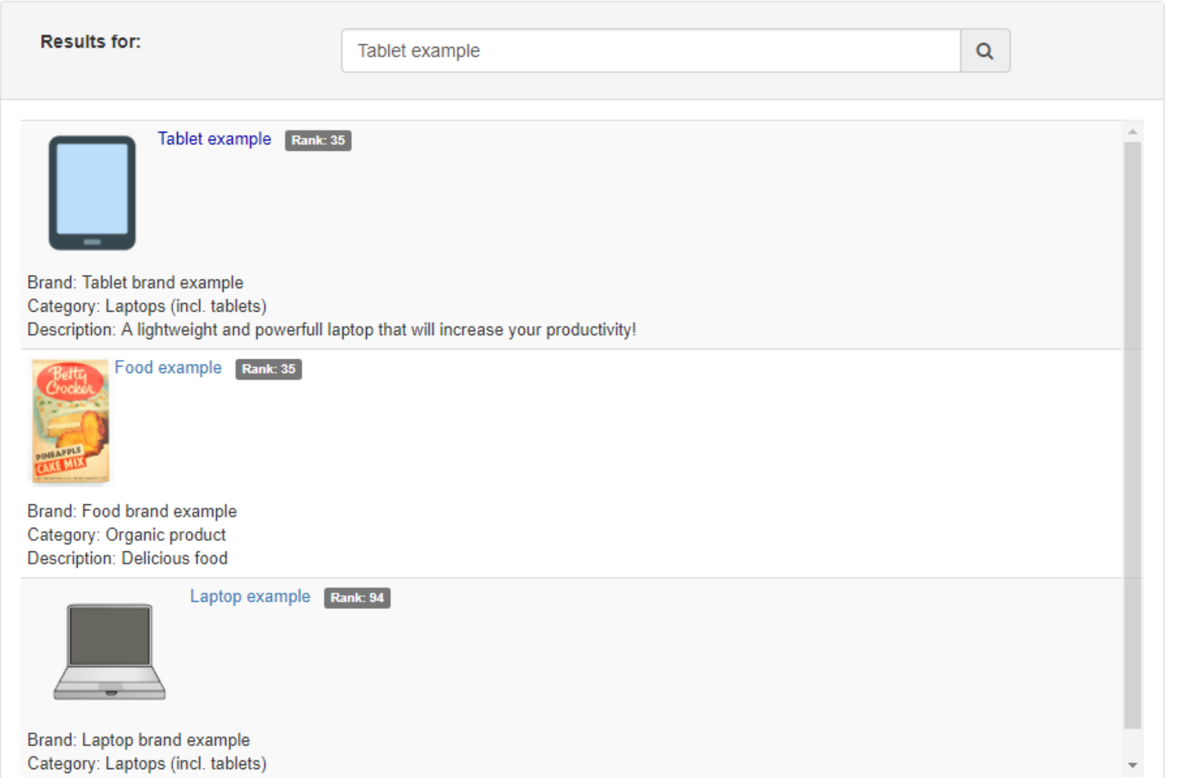

Figure 2-5 Impact Assessment Tool, list of Products

Once a product is selected all the information related to this product is displayed in four different tabs:

I. General
II. Lifecycle
III. Resources
IV. JSON-LD Record

The UI is created dynamically based on the information that is included in the JSON-LD record that is retrieved from the database. This allows the usage of a common UI for various type of products.

Figure 2-6 Impact Assessment Tool, Product Information Page

On the Resources Tab, a button allows the further assessment of the products, by computing their Eco Credits. The user can alter certain parameters, such as lifetime, new or used and recyclability, which affects the associated eco-credits.

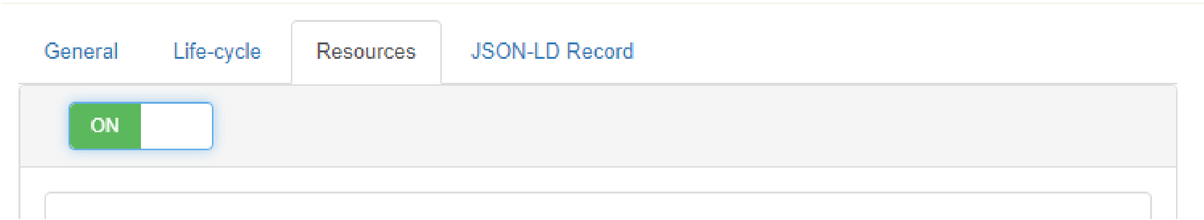

Figure 2-7 Impact Assessment Tool, Assessment Activation

Example 1: The lifetime of a tablet affects the total Eco Credits of it as it can be seen in the following screenshots.

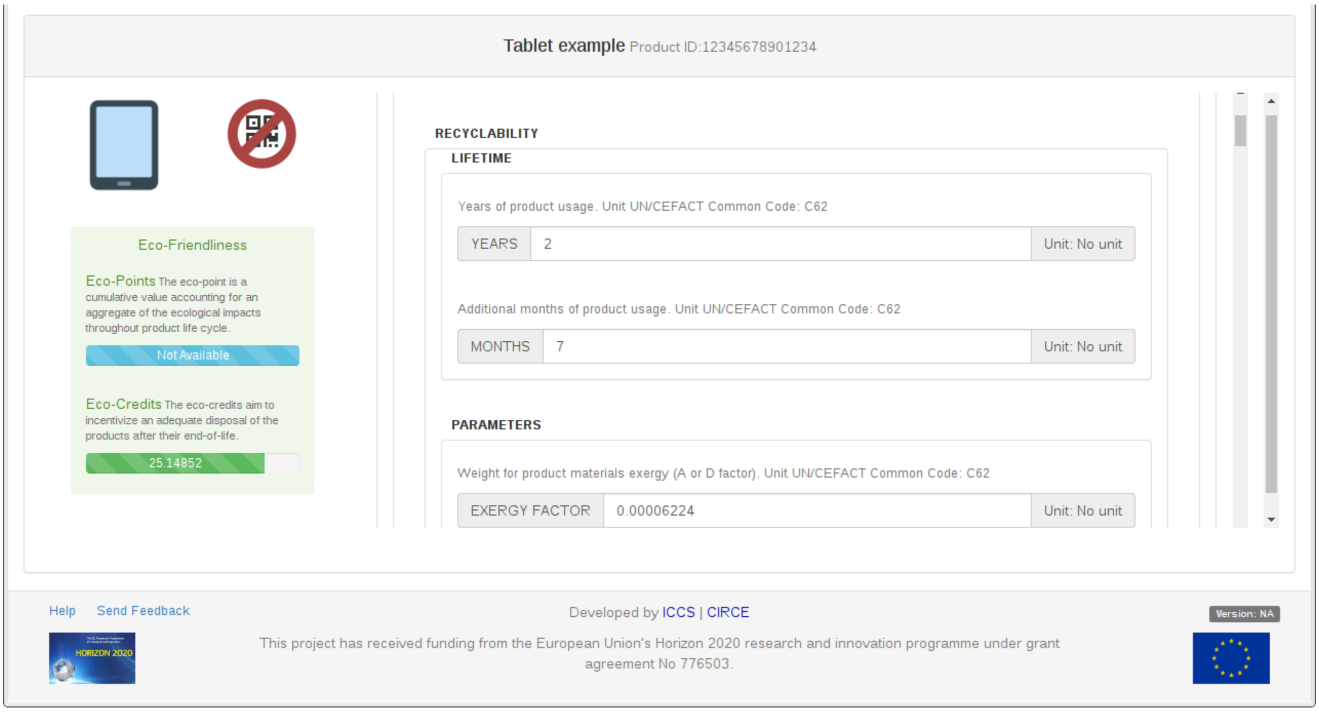

Figure 2-8 Total Eco Credits for a tablet used for 2 years and 7 months

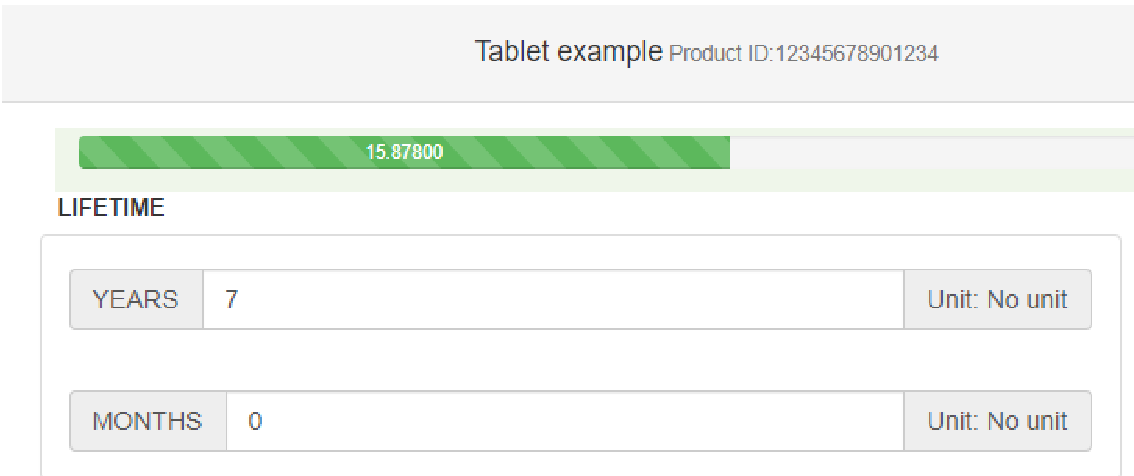

Figure 2-9 Total Eco Credits for a table used for 7 years

All the other factors that affect the recyclability of the products, as detailed in D2.4 can be updated in order to compute the total new amount of Eco Credits.

Example 2: The mass of specific materials affects the total Eco Credits of products.

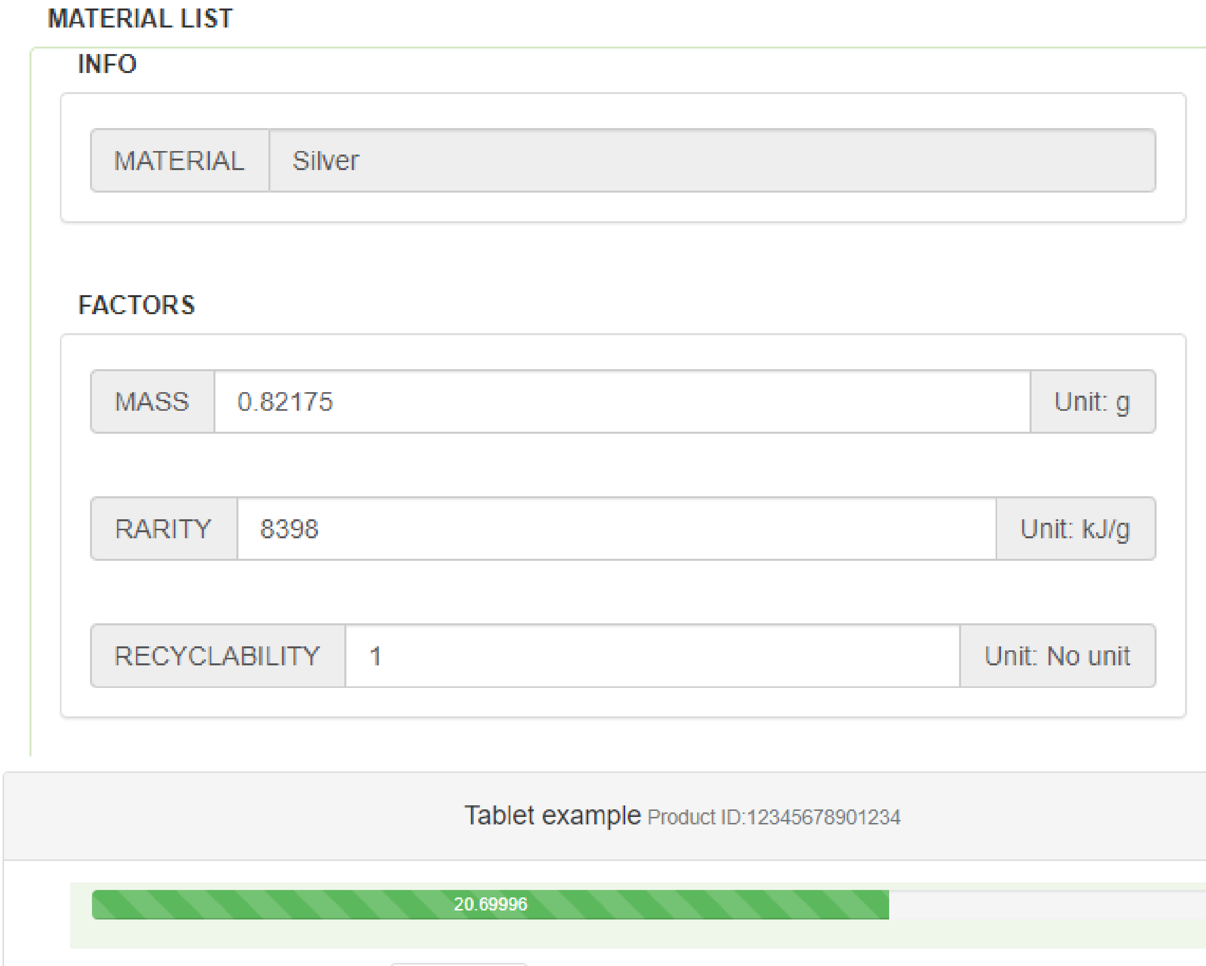

Figure 2-10 Total Eco Credits for mass of Silver 0.82175

By turning off the assessment functionality, all the values return to the default value and the associated Eco Credits of the standard product as saved in the database is displayed.

Figure 2-11 Impact Assessment Tool, Turn off Assessment

Other data sources

PEF results from a three-year multi-stakeholder testing period labelled the Environmental Footprint (EF) pilot phase which lasted from 2013 to 2016. Regarding the products involved in CIRC4Life sectors, only the meat sector is involved in the pilot, but at present the pilot is discontinued. General 'PEF Guide'[2] and the 'Product Environmental Footprint Category Rules Guidance' including instructions for meat sector are developed and available for interested parties. Nevertheless, Product Environmental Footprint Category Rules (PEFCRs) and the Environmental Footprint database have only been finalised for sectors[3] that are not directly relevant to the CIRC4Life project, excluding the Feed or Food Producing Animals – which is the only one of five processes examined in the LCA analysis for meat products.

Regarding the application of PEF, in a conservative manner, the results from pilots should be analysed once finished in order to implement functionalities in the impact assessment tool related to PEF.

Nevertheless, PEF has been applied in the CIRC4Life project to some extent. The PEF instructions[4]on modelling issues related to slaughterhouse and rendering for pigs have been used for the purposes of the performing of LCA of meat products. The results are presented in: The Life Cycle Assessment of meat products (internal report) and this deliverable (section4.3).

Regarding the health and water impacts, and myEcoCost method https://www.myecocost.eu/ (combining of carbon and material footprints), they are all included by means of the LCA impact method used in CIRC4Life developed tools (ReCiPe). These corresponding impacts are identified in the developed online LCA tool.

2.2 Weighting Options

Enabling the user to give weightings to different elements of the impacts, according to specifics of their business, local conditions, or national policies allows for more flexible and tailored results. For example, water becomes more important in water-stressed regions, and a country with a policy focus on increasing recycling levels and reducing waste might see that as an issue that demands a higher weighting.

Weighting is a process involved in the LCA approach that has a lack of consensus. From some user's perspectives, economic impacts would be more relevant, meanwhile for others water/GHG will be extremely important and for others, the impact on biota or social wellness would be more relevant.

The list of desired weighting options was determined by consultation with industry partners and are laid out in Appendix 3. The following were considered to be of value to the industry partners:

- Water
- Carbon
- Energy
- Social
- Capital items
- Waste

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[2] Annex to Commission Recommendation 2013/179/EU on the use of common 710methods to measure and communicate the life cycle environmental performance of products and organisations (April 2013)

[3] https://ec.europa.eu/environment/eussd/smgp/PEFCR_OEFSR_en.htm [Access 4.10.2019]

[4] Included in the Product Environmental Footprint Category Rules Guidance

It was therefore recommended that these are the weighting options incorporated into the Impact Assessment Tool.

Regarding the CIRC4Life tools developed, a recyclability approach for reusable or recyclable products has been developed. This approach is an innovative approach not directly connected to Environmental LCA or Social LCA but to the raw materials, the state of the product at the end of its lifetime, and the amount of time that the product has been used. These parameters could be weighted according to the preferences of the users of the Tool.

The parameters were selected based on the eco credits methods in Deliverable 2.4. They are:

- End of life (years)
- New or used
- Recyclability

Unfortunately, this approach cannot be extended to the food sectors (food is not reusable and only recyclable in some ad-hoc scenarios), which instead should be weighted by Environmental LCA and Social LCA parameters. In this way, not by means of the tools developed, but by means of consultations, vegetable and meat sectors were consulted for Social LCA before the study, in order to weight the categories.

2.3 Online LCA Tool

The leading LCA software (e.g. SimaPro, GaBi, openLCA) is desktop-based software operating environment so that they are not able to perform flexible and collaborative LCA services and LCI data sharing functions, which restrain the LCA performance for product environmental performance evaluation at the level of value chain. There are a few web based LCA application that offer basic LCA functions with limited databases and methodologies. For example, the web based LCA software, Sustainable Minds, only provides TRACI methodology (Bare 2011) with pre-defined datasets that is a custom database and does not allow users to import other LCI databases. This type of web based LCA software is more suitable for users without much LCA knowledge or that want quick and straightforward LCA results.

CIRC4Life aims to develop a robust Online LCA tool offering almost the same level functions as the desktop based LCA software can provide, including LCI database import/export and modification, product lifecycle modelling, life cycle impact evaluation, and multiple analytical results presentation models, etc.

The Online LCA tool is available from (http://h2020.circ4life.net/) (Figure 2-12), CIRC4Life consortium members can access this tool by their assigned credentials, which is ready to perform the comprehensive LCA services and functions. This is currently only for use by CIRC4Life project partners, but in a move towards future commercial exploitation, this tool would be used by external businesses.

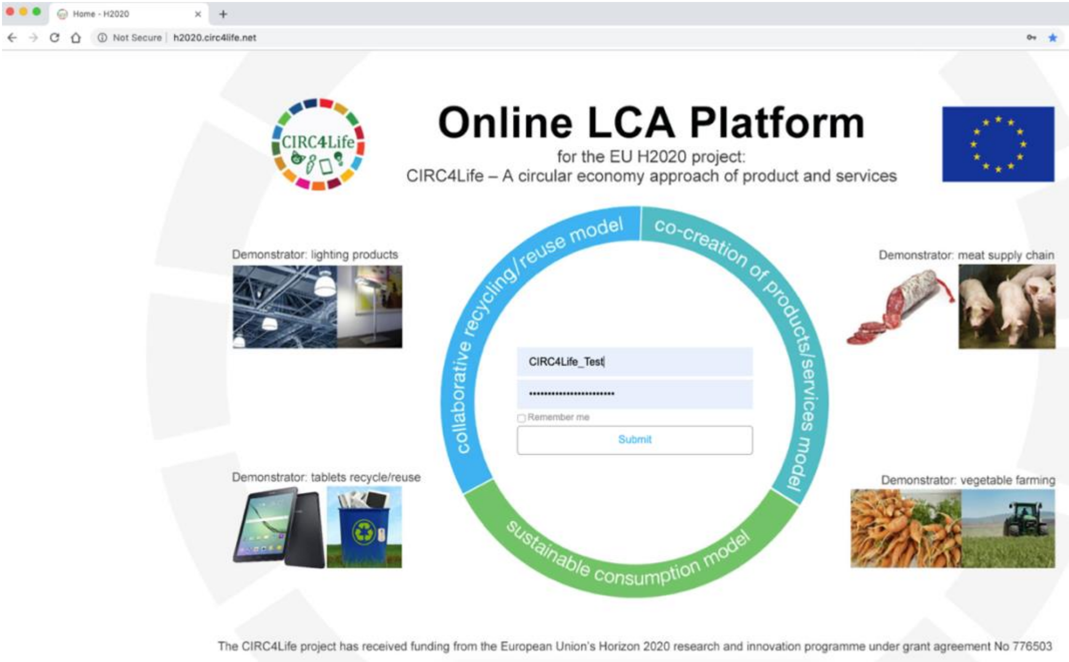


Figure 2-12 Login page of CIRC4Life online LCA tool

Users can create as many products as they need in the online LCA tool, by clicking the 'Products' button in the navigation, and 'New Products' afterwards. In the 'Product Information' dialogue, users need input the basic product information (e.g. product name, product barcode) (Figure 2-13). Once the product creation is complete in the tool, users can manage (i.e. edit, delete) the product information through the 'Product Management' (Figure 2-14).

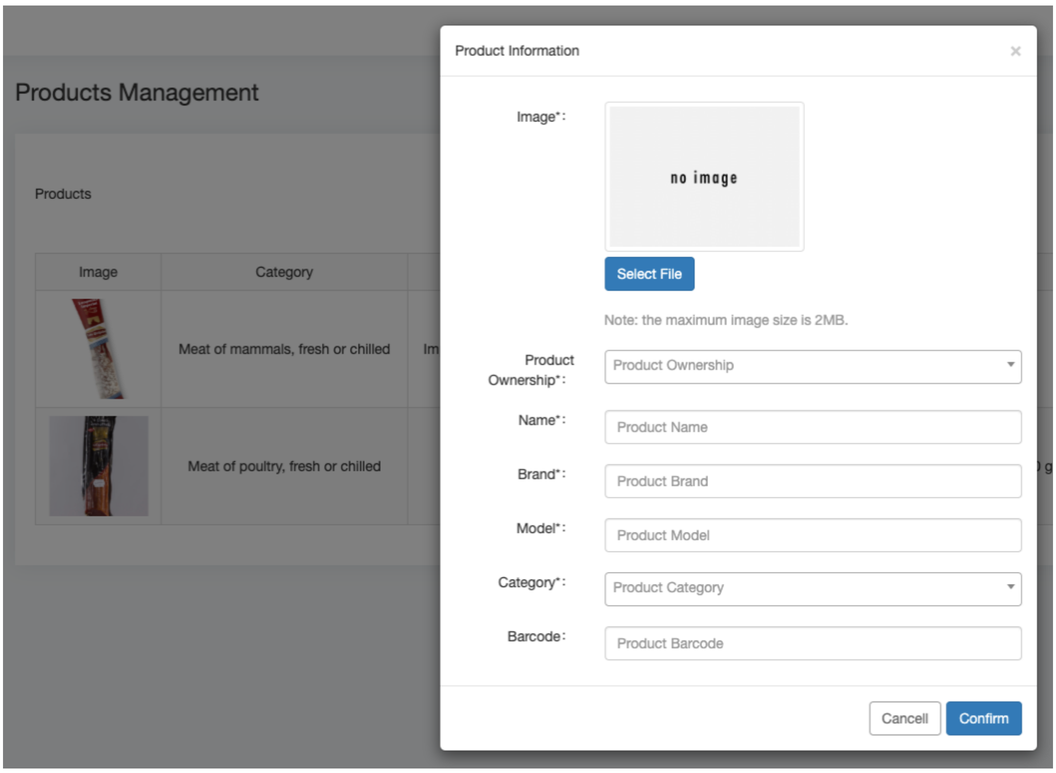


Figure 2-13 Product information input dialogue box

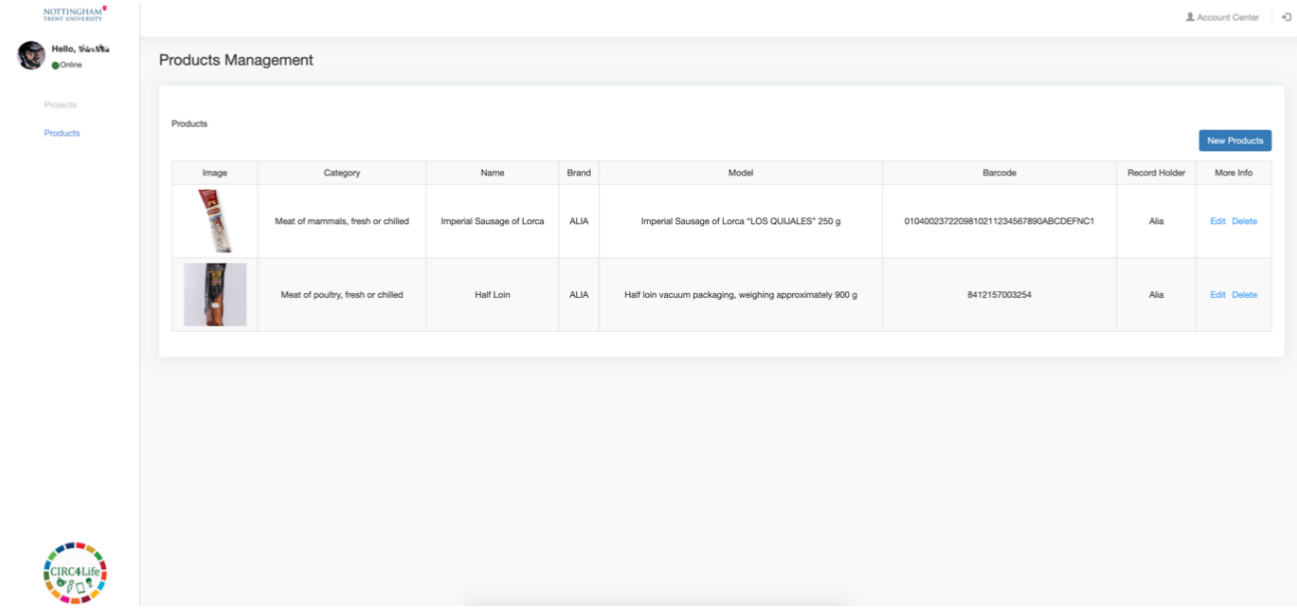


Figure 2-14 Product management module

Each LCA is performed in a 'Project' in this online LCA tool, users can create a project by clicking the 'Projects' in the navigation. Some basic project information can be input the 'Project Info' dialogue box (Figure 2-15). Once the project creation is complete in the tool, users can manage (i.e. edit, delete) the projects through the 'Project Management' (Figure 2-16). Three rules are designed behind the setup of products and projects:

- 'Project 'can only select the products that are already created in the 'Products';
- Once a product is used in one project, this product's information cannot be edited anymore;
- Users can delete a project, then delete the product associated with this project.

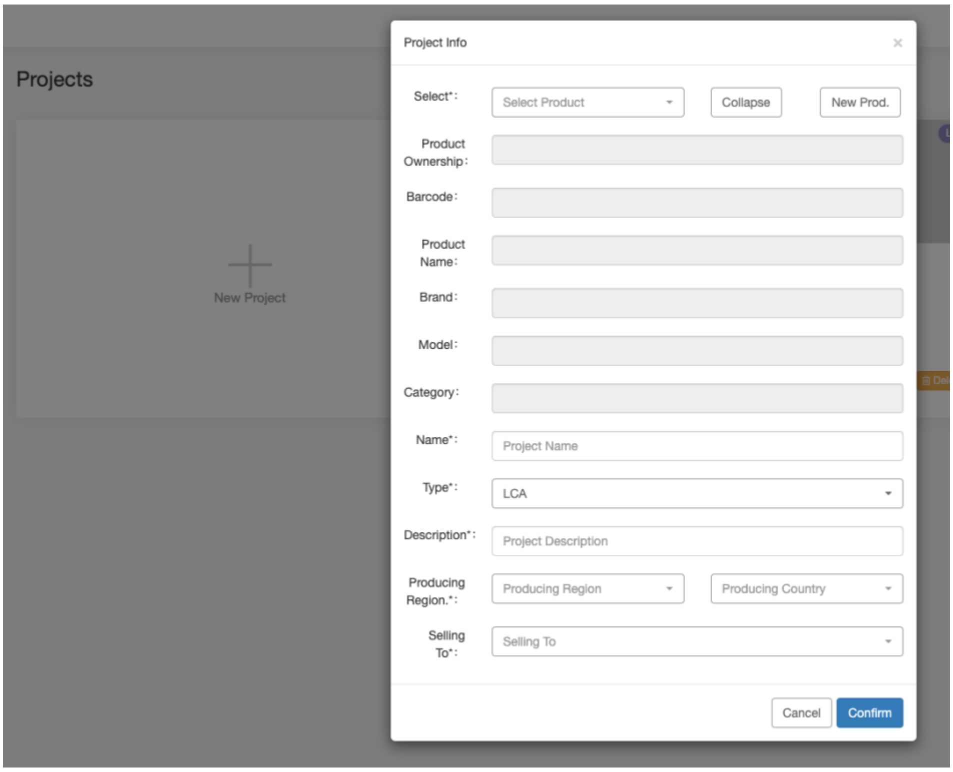


Figure 2-15 Project information input dialogue box

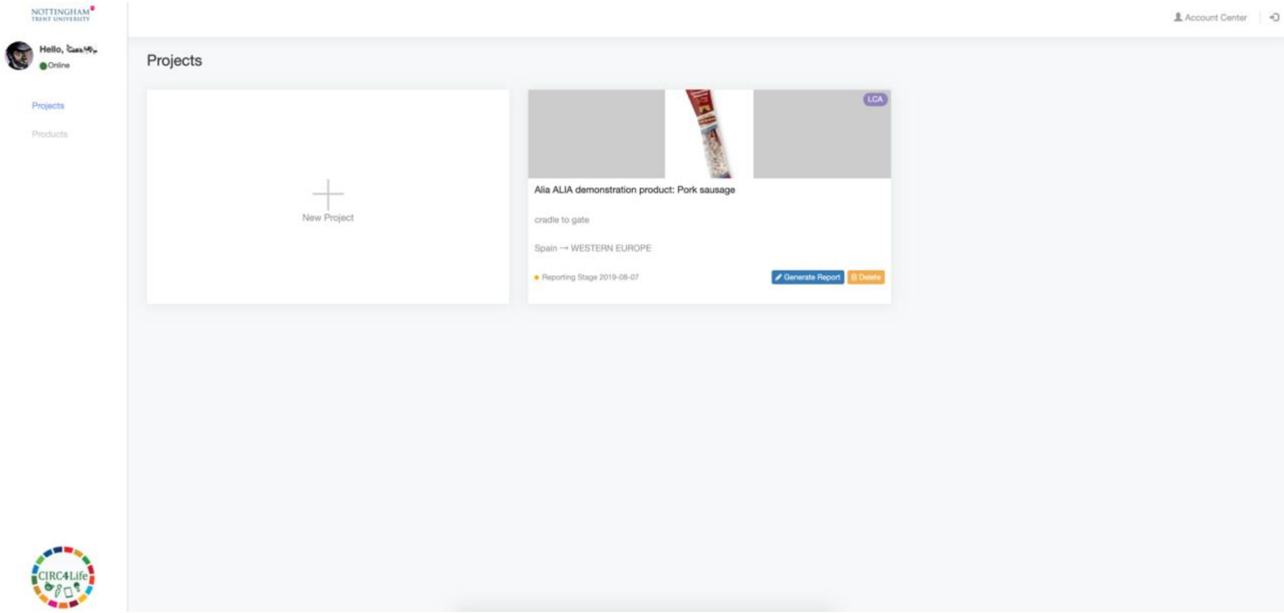


Figure 2-16 Project management module

One of the features of this online LCA tool is that it enables it to generate a standard exportable LCA report. Clicking 'Generate Report' button in the project management module (Figure 2-17), the first step of performing LCA in this tool is triggered, which is to define the project 'Scope and Functional Unit' (i.e. the assessment unit, declared unit, and quantity of the assessment target) (Figure 2-17).

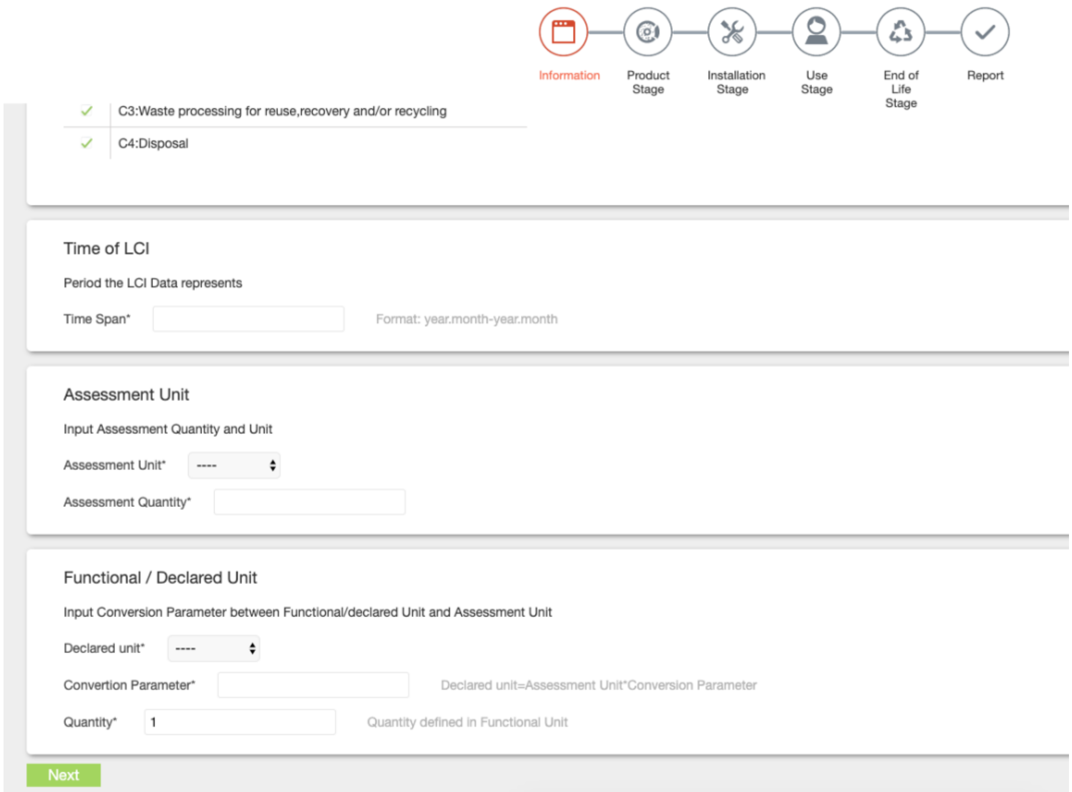


Figure 2-17 Define page for Project scope and functional unit

The next step is to input the life cycle inventory (LCI) data for different life cycle stages of the product. The product stages in this tool are defined as 'Product Stage', 'Installation Stage', 'Use Stage', 'End of Life Stage' along with certain sub-stages under each of them (Figure 18). The code of each product stage is set with reference to ISO 21930 to illustrate the life cycle stages more obviously and easier for modelling and reporting. This design is intended to provide an overview direction to instruct users where they should categorize those LCI datasets into.

Though the product stages (A1-C4) are not covered in a project assessment scenario, user cans leave this stage empty. For the product stages that users need to self-define, which can be achieved through filling a 'Description' cell in each data input table as the example shown in Figure 2-18. This is clearer than numbering these sub-stages, as when the product stages become a certain size, users maybe lost with these numbering over time.

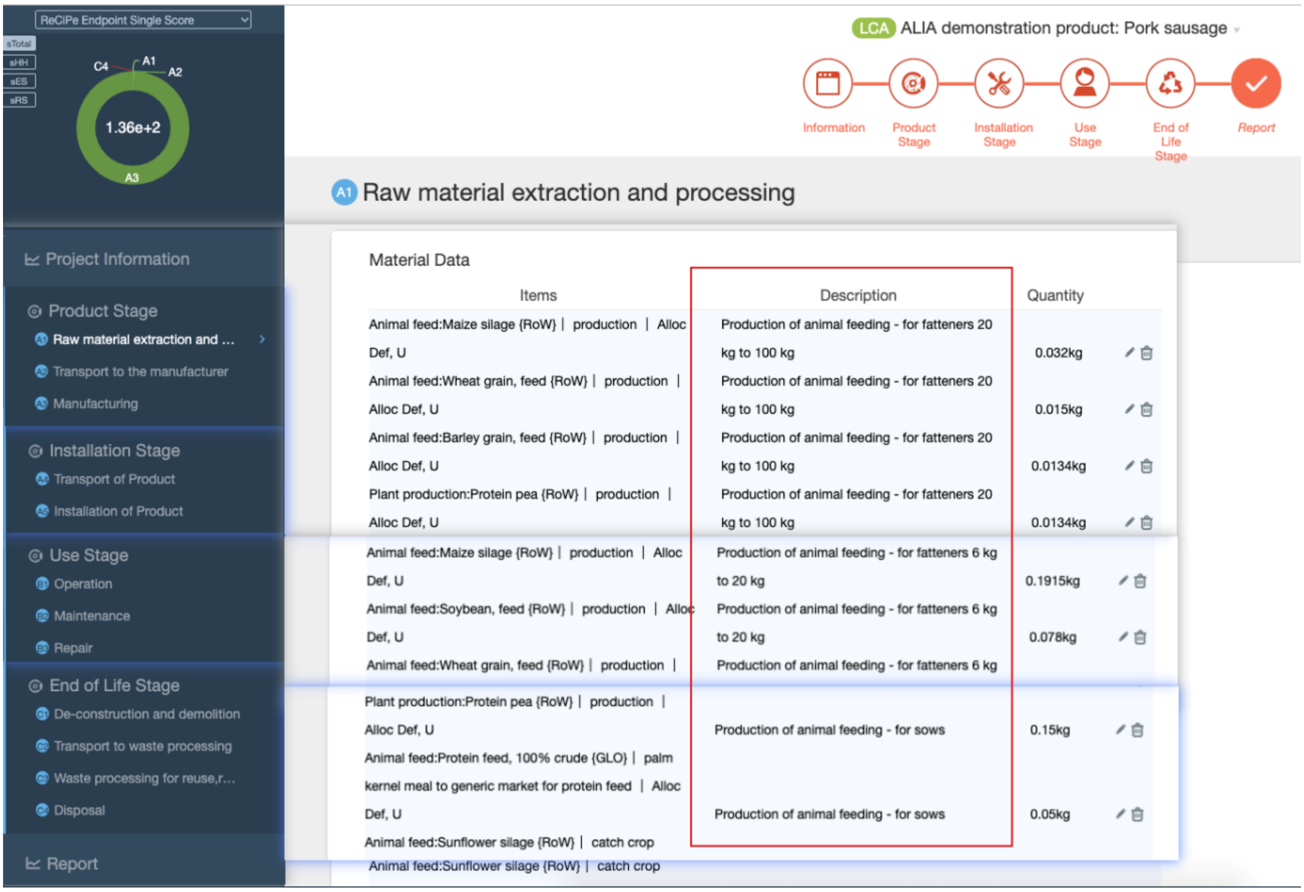


Figure 2-18 LCI data input page for illustrative purpose

When entering the LCI dataset into the online LCA tool, for users who don't know what to look for here, the right sequence is to start from the second line below the 'Items' to browse from these drop-down lists (left to right) to select the feasible process through categories, for users who familiar with LCI datasets, input a short key words in the first line of 'items', the related processes will pop up (Figure 2-19).

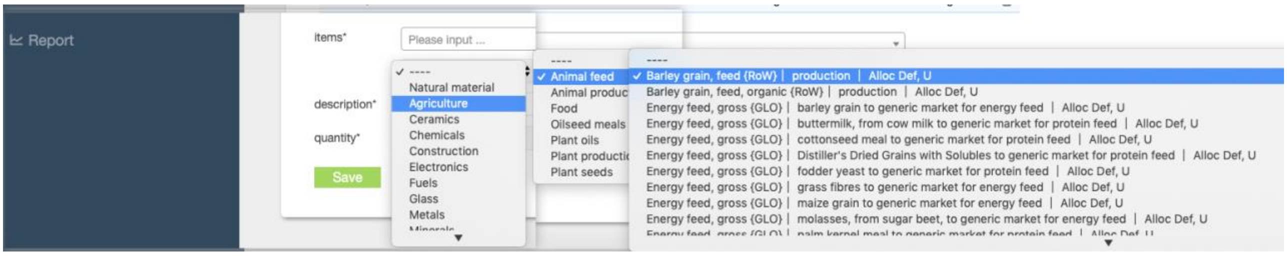


Figure 2-19 Entering LCI dataset into the online LCA tool (illustrative purpose)

Ecoinvent v3.5 database is embedded in this online LCA tool, which describes background processes, e.g., transportation, grave or electricity production (see Figure 2-20, Figure 2-21, Figure 2-22, Figure 2-23)for examples illustrating embedded LCI datasets from a variety of sectors or processes). Ecoinvent database is considered as a particularly robust and complete database, both in terms of technological and environmental coverage. It surpasses other commercial databases, from quantitative (number of included processes) and qualitative (quality of the validation processes, data completeness, transparency, etc.) perspectives. This database can be used in ISO-compatible LCAs and it is internationally recognized by experts in the LCA field.

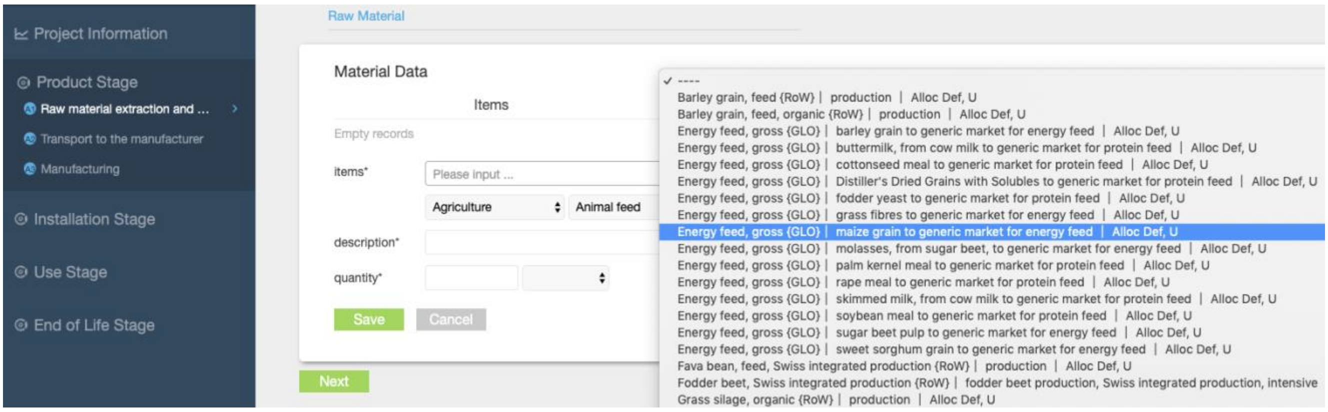


Figure 2-20 An example showing LCI material datasets

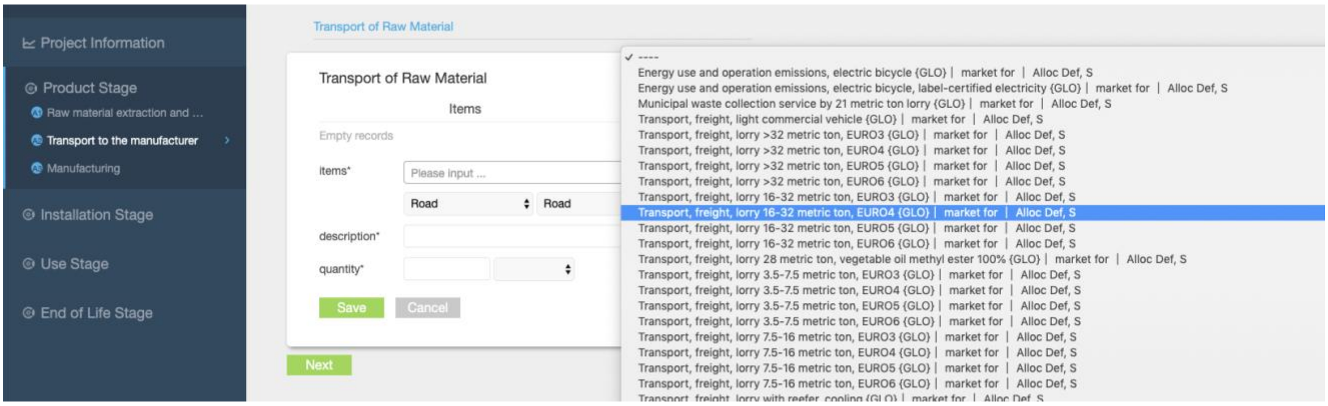


Figure 2-21 An example showing LCI transportation datasets

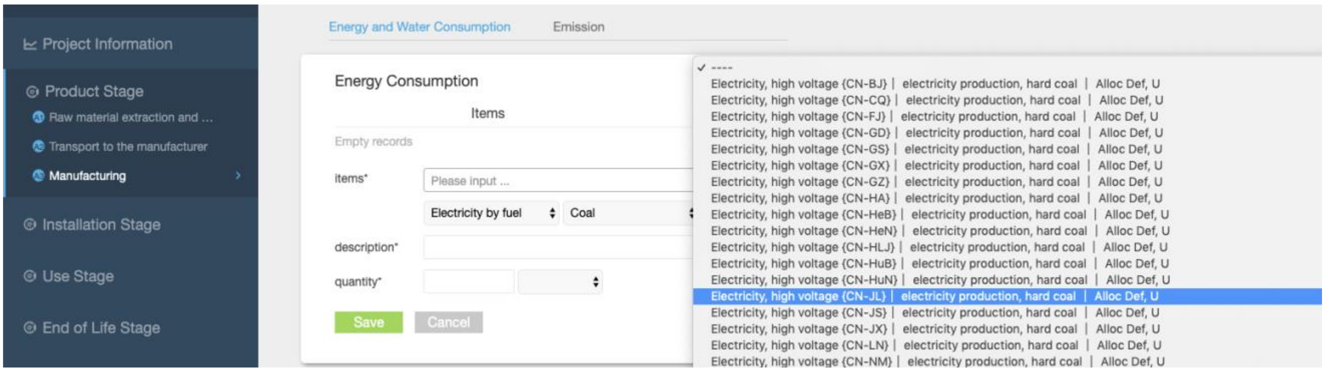


Figure 2-22 An example showing LCI electricity datasets

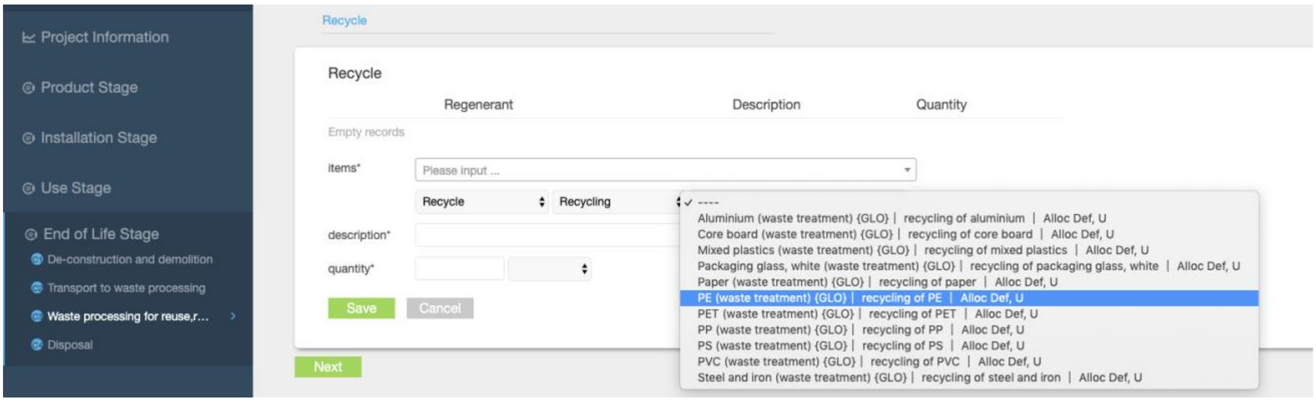


Figure 2-23 An example showing LCI waste processing datasets

After completing the LCI dataset input, users are able to see a draft of online report by clicking the 'Report' button in the navigation (Figure 2-24). LCA report background information can be edited by clicking 'Report Edit' button, which support users to fill a series of project background information, e.g. LCA Calculation Rules, explanations for different product stages.

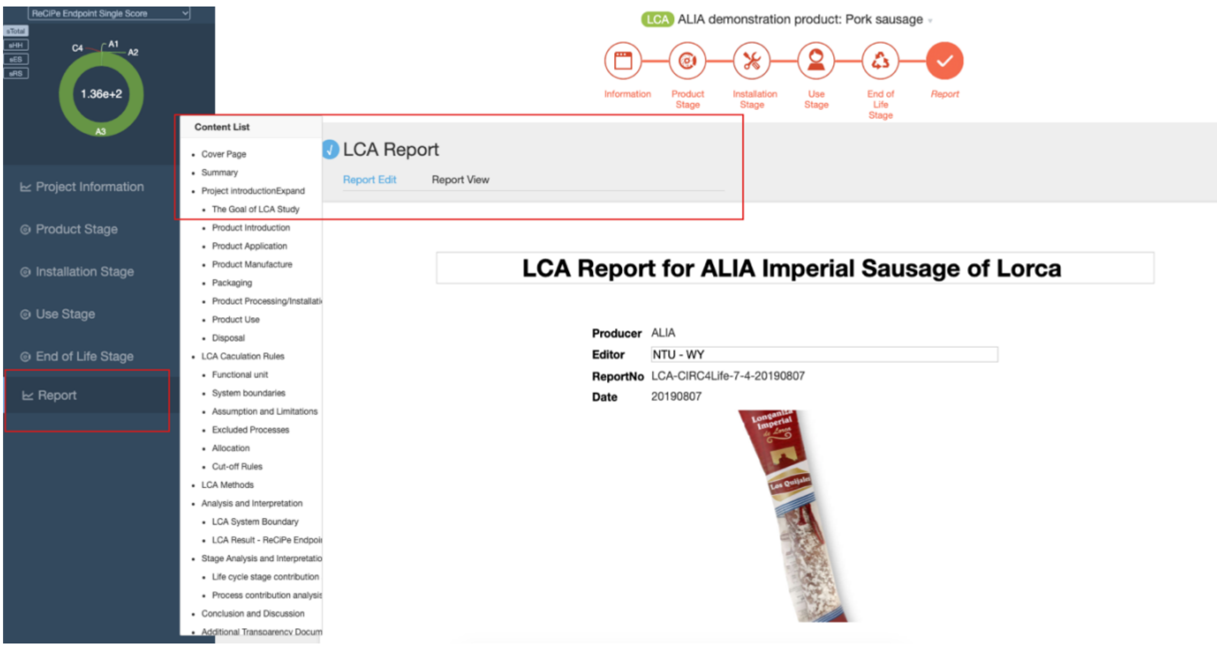
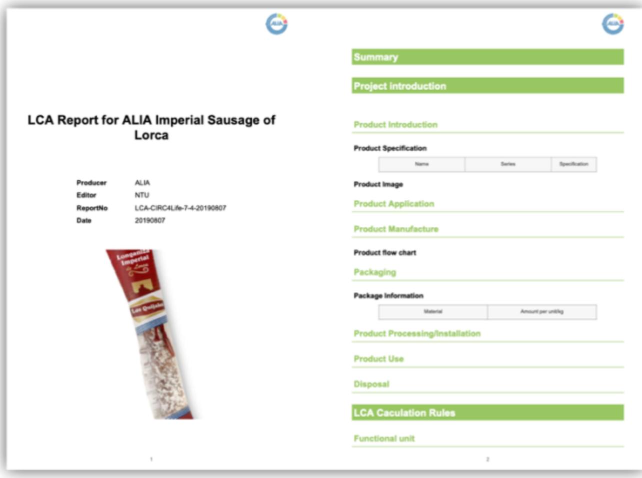


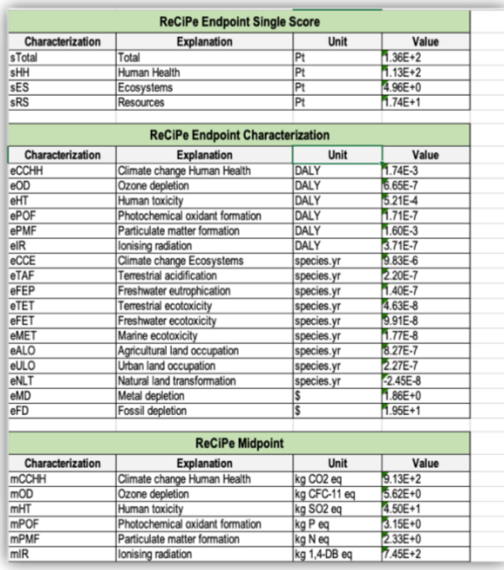
Figure 2-24 LCA results reporting page

Clicking the 'Report View' button (Figure 2-24), the project calculation result page will pop up, this page presents the results with different tables, bar charts, Sankey diagrams, showing the values and contribution percentages of each product process or stages within the defined LCA scenario by a user.

Figure 2-25 Results presentation page of online LCA tool (for illustrative purposes)

All the presented results in the 'Report View' can be exported as a PDF file by clicking 'Download' button (Figure 2-25), the exported PDF file (**Error! Reference source not found.**26) will accurately present the results and contents as shown in the online page. Additionally, the Single Score, Endpoint and Midpoint results of selected LCA method in the online LCA tool are also exportable in an Excel spreadsheet format (**Error! Reference source not found.**26).





ReCiPe Endpoint Single Score			
Characterization	Explanation	Unit	Value
sTotal	Total	Pt	1.36E+2
sHH	Human Health	Pt	1.13E+2
sES	Ecosystems	Pt	4.96E+0
sRS	Resources	Pt	1.74E+1

ReCiPe Endpoint Characterization			
Characterization	Explanation	Unit	Value
eCCHH	Climate change Human Health	DALY	1.74E-3
eOD	Ozone depletion	DALY	6.65E-7
eHT	Human toxicity	DALY	5.21E-4
ePOF	Photochemical oxidant formation	DALY	1.71E-7
ePMF	Particulate matter formation	DALY	1.60E-3
eIR	Ionising radiation	DALY	3.71E-7
eCCE	Climate change Ecosystems	species.yr	9.83E-6
eTAF	Terrestrial acidification	species.yr	2.20E-7
eFEP	Freshwater eutrophication	species.yr	1.40E-7
eTET	Terrestrial ecotoxicity	species.yr	4.63E-8
eFET	Freshwater ecotoxicity	species.yr	9.91E-8
eMET	Marine ecotoxicity	species.yr	1.77E-8
eALO	Agricultural land occupation	species.yr	8.27E-7
eULO	Urban land occupation	species.yr	2.27E-7
eNLT	Natural land transformation	species.yr	-2.45E-8
eMD	Metal depletion	$	1.86E+0
eFD	Fossil depletion	$	1.95E+1

ReCiPe Midpoint			
Characterization	Explanation	Unit	Value
mCCHH	Climate change Human Health	kg CO2 eq	9.13E+2
mOD	Ozone depletion	kg CFC-11 eq	5.62E+0
mHT	Human toxicity	kg SO2 eq	4.50E+1
mPOF	Photochemical oxidant formation	kg P eq	3.15E+0
mPMF	Particulate matter formation	kg N eq	2.33E+0
mIR	Ionising radiation	kg 1,4-DB eq	7.45E+2

Figure 2-26 Online LCA results are presented in exported PDF file (left) and spreadsheet (right)

2.4 Decision Making Tool

Live eco scores are calculated by the Impact Assessment Tool. With the Tool, users can change certain parameters to assess the impacts of hypothetical scenarios. This could include modelling a new production process, a new product, or service.

Note that the decision-making tool is intrinsically linked to the Weighting options and can be used in conjunction with them (it can be seen as an additional functionality of the Decision-making tool). This is based on the same approach as the one where PEF is involved. Until consensus is reached for each sector, decision making is only based on user preferences. In the EcoProWine (CIP-EIP-Eco-Innovation-2011) project, several wine makers were involved in order to weight different environmental parameters after several and continued discussions. In this way, normalising a decision-making process could be extended to other products by means of PEF pilots and then apply the normalisation to ReCiPe indicator.

2.5 Waste Management Decision Making Tool

An action that was transferred from Task 2.2 to Task 1,2, due to a mismatch in timescales, was the creation of a Waste management decision making tool.

The fundamental requirement, as detailed in Task 2.2 work description is:
"Preliminary business models aiming at a widespread uptake of the aforementioned solutions for collaborative reuse and recycling of waste food will be developed, taking into account existing barriers identified in the analysis phase. Measurement of impacts of different recycling and reuse options will be provided to quantify benefits, using tools developed for Task 1.2."

Due to the nature of the Impact Assessment Tool, this particular requirement has been created by JS as a specific, standalone Calculator based on carbon emissions of different waste and recycling options. This can be viewed in Appendix 4 and is included as a spreadsheet alongside D1.2 in the CIRC4Life SharePoint.

The spreadsheet has been developed from UK emissions factors on 28 different types of materials, including plastics, metals, glass, paper and more. The treatment options include landfill, recycling or composting.

The functionality enables users to enter data in tonnes of waste materials, either in landfill, recycling or composting, and immediately understand what the related carbon emissions are, according to which waste management option is chosen. An example is shown in Figure 2-27, where 1 tonne of various materials are compared against each other, both for landfill and recycling.

Item		Units	Landfill			Recycling		
			Amount	Factor	kg CO2e	Amount	Factor	kg CO2e
Aggregate	Average	tonnes	1	1.26	1.26	1	-2	-2.00
Batteries	Domestic	tonnes	1	75.94	75.94	1	-205	-205.00
	Vehicle	tonnes	1	75.94	75.94	1	-435	-435.00
Scrap metal		tonnes	1	8.99	8.99	1	-3577	-3577.00
Oil		tonnes				1	-2759	-2759.00
Tyres	All vehicles	tonnes				1	-636	-636.00
Electrical items	Fridges & freezers	tonnes	1	8.99	8.99	1	-853	-853.00
	Other	tonnes	1	8.99	8.99	1	-1107.5	-1107.50
	Light bulbs/tubes	tonnes				1	-779	-779.00
Wood	All types	tonnes	1	828.12	828.12	1	-444	-444.00

Figure 2-27 Waste management tool - example calculations

By using this Waste management decision making tool, users are able to assess the relative merits, in terms of carbon emissions, of recycling or composting versus landfill. This can be used in two scenarios; firstly, to accurately assess the carbon footprint of current waste management systems. Secondly, to assess the carbon footprint of a future waste management system, and/or use this for informed decision making on different materials and waste handling.

Successful application of this tool can lead businesses to reductions in landfill, reduced carbon footprint of waste systems, and a greater understanding of the recyclability and carbon impact of various materials that may end up as waste during the processes of production, processing, distribution and retail.

2.6 Innovation

The Impact Assessment Tool is innovative in several ways. On the aspect of measuring impacts, the very inclusion of a wide range of social impacts of products is a great step forward in understanding how products impact not just the environment, but also people. Furthermore, there is direct integration of environmental and social impacts.

In terms of interaction, the Tool directly integrates with other tools and methods developed in the project. The Impact Assessment Tool is connected to Decision Making Tool which can support businesses in understanding the environmental impacts of choices at the Product Design level. Furthermore, it integrates with the Eco-point Method, eco-credits and eco-cost account which will be used by consumers and are innovations in themselves.

There are a few online LCA tools (e.g. Sustainable Minds) that are able to offer basic LCA functions with limited databases and methodologies, which are more suitable for users without much LCA knowledge or demanding quick and straightforward LCA results. However, the Online LCA tool developed in this task is a novel and robust LCA service system that provides comprehensive LCA functions, e.g. customize LCA methods, performing real-time online calculations, etc.

3 Implementation of Impact Analysis

The analysis was split in to two complimentary processes:

- Environmental LCA ('E-LCA')
- Social LCA ('S-LCA')

Scoping was undertaken in T 1.1, so the boundaries of study for each product are known. This can be seen in Appendix 1 of Deliverable 1.1.

3.1 Social Life Cycle Impact Assessment

Based on ISO 14040:2006, and 14044: 2006, S-LCA presents some methodological particularities that are defined hereafter, and which are amended to the functional units' characteristics. Thus, the social impact assessment is made in a similar way as the environmental life cycle assessment, and in agreement with it since the initial stages for the analysis design and configuration are the same. The four main phases of a Life Cycle Assessment are related to each other as depicted in Figure 28.

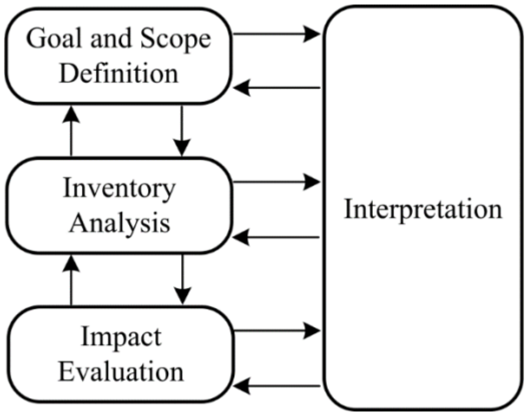


Figure 3-1 Principal phases of an LCA study (International Organisation for Standardisation, 2006)

The first step defines the goal and scope of the analysis, starting by defining the functional unit of the assessment. In this case, the assessment is focused on products, and the functionality is given by one complete unit of product ready for consumption: 1 kg of salads and 1 kg of potatoes (vegetable food), 1 kg of pork sausage and 1kg of pork loin (meat supply chain), and 1 unit of table lamp (domestic lighting product) and industrial LED lamp (industrial lighting). In this step, the scope of the analysis is also determined based on the goals of the study. The largest scope is a cradle-to-cradle analysis that comprises all life cycle stages, including material disposal and end of life of the products. Based on the agreed scope, the inventory of inputs/outputs of each life cycle stage per functional unit is retrieved, either from own sources, or from appropriate databases.

The impact evaluation for S-LCA consists in the aggregation of all social impacts weighed by the national and sectoral risk factors, and it is provided in comparable medium risk hours. Assessment of most impacting stages and activities may be done, as well as comparisons with possible scenario planning. Finally, the interpretation of the results allows to iterate the analysis among the previous steps.

On the other hand, in order to conduct a comprehensive and comparable social evaluation, S-LCA approach is disaggregated by subcategories, which are socially relevant topics or aspects. These subcategories can be classified by impact category and stakeholder categories. Stakeholder category can be defined as a group of agents, which foreseeable have common interests in accordance with their relationship with the product system under study (Fontes, 2014). Figure 3-2 describes relationships between the main stakeholders associated with business and products. Considering the lack of scientific or international accepted inventory classification models as concluded by (Hsu, et al., 2013), this approach can become a solid foundation for subcategories structuration.

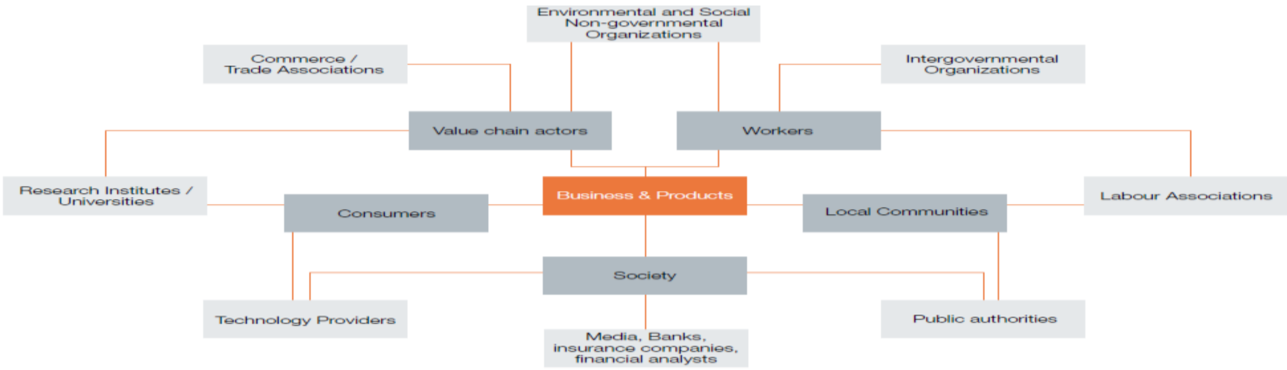


Figure 3-2 Relationship between stakeholders (United Nations Environment Programme, 2009)

It must be highlighted that, unlike environmental and economic approaches, S-LCA relies on indicators that may be: i) quantitative, ii) semi-quantitative and iii) qualitative. In fact, it is recommended a parallel work with both, quantitative and qualitative indicators, due to quantitative indicators may not cover social dimensions completely (Grießhammer, et al., 2006). It must be noted that, consumers stakeholder category includes end-consumers and intermediate consumers within the supply chain and that, value chain actors do not consider consumers.

Thus, the methodology proposed for S-LCA implementation in this report is presented in Figure 3-3 and calculated by means of SimaPro software under the framework of the database PSILCA. It should be mentioned that this methodology was applied from the systemic approach for social sustainability assessment proposed by Rafiaani, et al., (2017) and Gimeno-Frontera, et al., (2018).

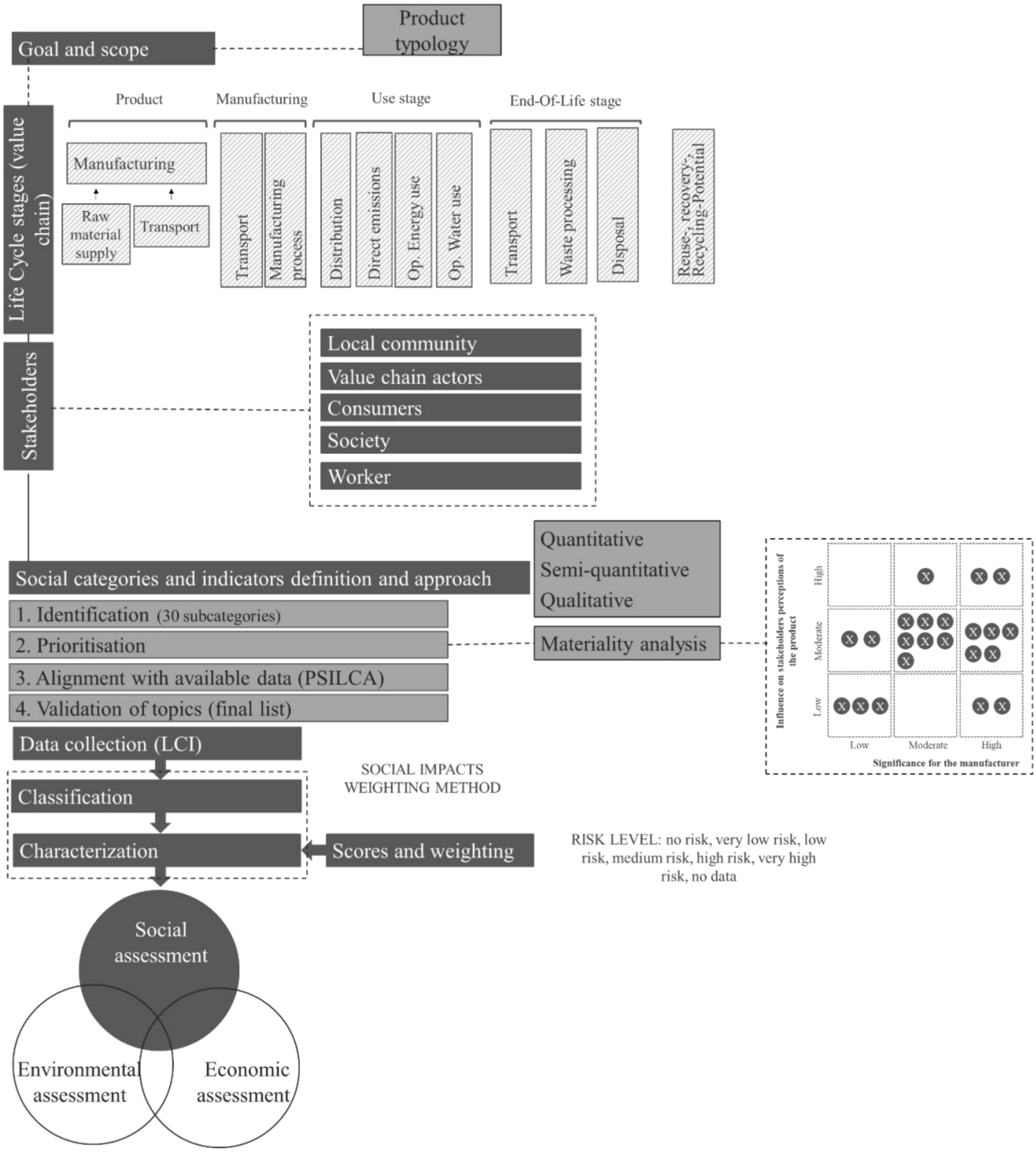


Figure 3-3 Overall methodology proposed for S-LCA implementation

Social sustainability is a wide concept, which covers several definitions and can be approached through different methodologies. Rafiaani, et al., (2017) and Florman, et al. (2016) list general and specific social impact assessment methodologies launched since 1997, as for example, Social Return on Investment (SROI) and Social Value Metrics. More specifically, (Rafiaani, et al., 2017), compare within bio-based economy the Social Impact Assessment (SIA), Socio-Economic Impact Assessment (SEIA) and Social Life Cycle Assessment (S-LCA).

Social aspects are conducted from a Life Cycle Assessment point of view. Thus, standards ISO 14040:2006 (International Organisation for Standardisation, 2006) and 14044: 2006 (International Organisation for Standardisation, 2006) stablish S-LCA framework. Thus, S-LCA is a procedure for social impacts analysis within products' life cycle, which assesses social and socio-economic features of products, as well as, potential positive and negative impacts (United Nations Environment Programme, 2009). It has to be highlighted that existing social impact methodologies at product level foster flexibility due to relative immaturity and specific background requirements (Fontes, 2014).

Social LCA analysis was undertaken by CIRCE and NTU, in conjunction with all industry partners (JS, ALIA, ONA, KOS).

Social impacts are weighed by risk level which corresponds to the PSILCA Social Life Cycle Impact Analysis method v1.00 an using SimaPro v8.5.2.0 software.

Table 3-1 PSILCA risk level weights. (PSILCA Social Life Cycle Impact Analysis method v1.00)

RISK LEVEL	WEIGHT
VERY HIGH RISK	5
HIGH RISK	2
MEDIUM RISK	1
LOW RISK	0.5
VERY LOW RISK	0.25
NO RISK	0
NO DATA	0.5

Based on: i) the social categories and indicators definition approach, ii) finding out the level of importance of each subcategory for the company and for the company customers and stakeholders with a materiality analysis and iii) by developing the life cycle inventories of input/output per process (including calculation of the process inputs in 2011 US$ in order to refer to PSILCA database), the social life cycle assessment of the reference products follows the steps below:

- Specific social data collection from company and sector to assess the level of risk for each selected indicator.
- Calculation of the worker hours of the main activity in hours per $ of output. This is calculated as a ratio of the unit labour costs ($/h) and the mean hourly wage per employee, as presented below:

$$Worker\ hours = \frac{Unit\ labour\ costs}{Mean\ hourly\ labour\ cost\ (per\ employee)}$$

Where:

$$Unit\ labour\ costs = \frac{Compensation\ of\ employees\ (in\ USD\ per\ country - specific\ sector\ and\ year)}{Gross\ output\ (in\ USD\ per\ country - sector\ and\ year)}$$

- Construct the simulation models in SimaPro v8.5.2.0, using self-made processes supported by the built-in industries and commodities available per country and sector in PSILCA.
- Perform the LCI assessment by simulation using SimaPro v8.5.2.0.
- Interpret the results.
- Adjust model and iterate.

3.1.1 Organic Potatoes

The PSILCA process "Organic: Growing of vegetables/UK" is the starting point to create a process as similar as possible to the actual performance of Scilly Organics. 11 out of 39 indicators (Table 3-2) are updated according with the information collected from the industrial partner, resulting in a better performance in favour of Scilly Organics. The result of the materiality analysis is also represented in a scale from 1 (low significance, low influence) to 6 (high significance, high influence) to identify the indicators of major importance from Scilly Organics' perspective and how is the level of risk in each case:

- 9 indicators receive an importance equal to 6, seven of them with a risk value of "low" and "very low". Living wage per month and "presence of enough safety measures" are assessed as "very high risk" and "high risk" respectively. Both cases are out of the scale of the company level and are nation/sector indicators, so the role of Scilly Organics to enhance them is very limited.
- Only 4 indicators are valued with an importance of 4. From those, "unemployment rate in the country" have a "medium risk" valorisation, being again a nation-wide indicator. "women in the labour force" and "gender gap" are two indicators where Scilly Organics demonstrates a better performance in respect with the organic agricultural sector. In both cases, the risk level was descended from medium/high to low/very low.
- 8 indicators have an importance qualification of 2. All of them are related to the stakeholder "society" and are measured at national scale, so their risk assessment is as initially stated in the database.
- Most indicators (17) possess an importance level of 1, meaning that they are not relevant for the company and the rest of stakeholders. Even so, Scilly Organics (SO) reduces the risk level on 5 of them, all related to the extraction of material resources (biomass for energy production, use of industrial water, etc.).

Table 3-2 Social risk assessment table for Salad and potatoes

Indicator	Unit	SO Metric	SO Risk Assessment	Materiality Analysis	PSILCA risk Assessment (UK)	SCALE
Living wage, per month*	USD	947-1197	Very high risk	6	Very high risk	Nation
Minimum wage, per month*	USD	1709	Low risk	6	High Risk	Nation
Sector average wage, per month*	USD	2371	Low risk	6	Very low risk	Sector
Hours of work per employee, per week	h	42	low risk	6	low risk	Company
Women in the labour force	% of economically active female population	50	Low risk	4	medium risk	Company
Men in the labour force	% of economically active male population	50	Low risk	4	low risk	Company
Gender wage gap	%	0	Very low risk	4	very high risk	Company
Accident rate at workplace	#/year	None in past 12 months	Very low risk	6	Very low risk	Company
Fatal accidents at workplace	#/year	None	Very low risk	6	low risk	Company
DALYs due to indoor and outdoor air and water pollution	DALYs per 1000 inhabitants in the country	-	Very low risk	6	Very low risk	Nation
Presence of sufficient safety measures	OSHA cases per 10000 employees in the sector	-	High Risk	6	High Risk	Sector
Workers affected by natural disasters	%	-	Very low risk	6	Very low risk	Nation
Trade union density as a % of paid employment total	%	7.2 (UK); Scilly Organics – none	No data	1	high risk	Company
Right of Association	ordinal 0-3	-	no risk	1	no risk	Company
Right of Collective bargaining	ordinal 0-3	-	no risk	1	no risk	Company
Right to Strike	ordinal 0-3	-	no risk	1	no risk	Company
Contribution of the sector to economic development	%	-	No opportunity	2	No opportunity	Sector
Public expenditure on education	USD/year	-	medium risk	2	medium risk	Nation
Illiteracy rate, male	%	-	low risk	2	low risk	Nation
Youth illiteracy rate, male	%	-	Very low risk	2	Very low risk	Nation
Illiteracy rate, female	%	-	Very low risk	2	Very low risk	Nation
Youth illiteracy rate, female	%	-	Very low risk	2	Very low risk	Nation
Illiteracy rate, total	%	-	very low risk	2	very low risk	Nation
Youth illiteracy rate, total	%	-	medium risk	2	medium risk	Nation
Pollution level of the country	Text	-	Low risk	1	Low risk	Nation

Indicator	Unit	SO Metric	SO Risk Assessment	Materiality Analysis	PSILCA risk Assessment (UK)	SCALE
Contribution of the sector to environmental load CO2	Text	Farming directly accounts for 9% of UK carbon emissions, and indirectly around 18%	Very low risk	1	Very low risk	Sector
Drinking water coverage	%	100	very low risk	1	very low risk	Nation
Sanitation coverage	%	100	very low risk	1	very low risk	Nation
Level of industrial water use, out of total withdrawal	%	None	Very low risk	1	low risk	Company
Level of industrial water use, out of total actual renewable	%	None	Very low risk	1	low risk	Company
Extraction (total) of fossil fueles	t/cap	0	Very low risk	1	Very low risk	Company
Extraction (total) of biomass related to area	t/cap	0	very low risk	1	high risk	Company
Extraction (total) of ores	t/cap	0	very low risk	1	very low risk	Company
Extraction (total) of biomass related to population	t/cap	0	very low risk	1	low risk	Company
Extraction (total) of industrial & const. minerals	t/cap	0	very low risk	1	low risk	Company
Presence of certified environmental management systems	# of CEMS per 100000 employees	-	Low risk	1	Low risk	Sector
Unemployment rate in the country	%	-	medium risk	4	medium risk	Nation
Violations of mandatory health and safety standards - violations of lwas and employment regulations?	#	0	very low	6	High risk	Sector
Presence of anti-competitive behaviour or violation of anti-trust and monopoly legislation	Cases per 10000 employees in the sector	-	no data	1	no data	Sector

Another method to tailor the analysis to the reality of Scilly Organics is to calculate the medium risk hours as a ratio of the unit labour costs ($/h) and the mean hourly wage per employee. In the PSILCA Database, the default value for the process "organic: Growing of vegetable/uk" is 0.0045 med hour risks. The value calculated for Scilly Organics is 0.0528, this is eleven times the value stated before, indicating a worst performance with respect of the sector. Using this calculated value might over penalize a company that do not correspond to an agricultural industry, but to a small family business. For Scilly Organics, it is understood that owners are at the same time workers, and that the difference between salary and turnover is difficult to establish.

For this reason, the default value is decided as the best option to conduct the social impact of Scilly Organics for two main reasons. First, the quality of the default value is guaranteed by the database itself, as it has been calculated using more sources and information that are not available for the company in analysis. Second, using a value that is one magnitude higher that the default one could result in unfair calculations for a small business with high social and environmental commitment.

The next step is the construction of the model according with the LCI and the previous results. The final model stem from an iterative process for the selection of the most adequate processes available in the PSILCA Technosphere. In summary, the model for potatoes production and for salad production is as follows.

- Manufacture of materials such as steel, wood, netting, paints and glass locally made in the UK. The only material outside the UK is the machinery tyres that are produced in India. These materials account for 0.44 USD on the final price both potatoes and salad.
- Other inputs such as packaging, fuel and services (insurance, banking, etc) are also included, adding an extra 0.34 USD on both products.
- Labour is introduced toward the tailored process, the one containing the adjusted risk levels, with different values for each product. As already explained, labour cost is calculated as a percentage of the final price given that the ratio between annual cost of personnel and annual turnover is known. For potatoes, the labour cost is calculated as 1.299 per kg, whereas for Salad the value ascends at 9.091 USD per Kg.
- The indirect costs are also included as "other business activities" as the difference between the final price and all the cost stated above. For potatoes, this value is 1.008 USD and 11.769 USD for Salad.

3.1.2 Pork Sausage and Pork Loin

As done with the previous product, the analysis starts by calculating the PSILCA metrics for risk assessment of the company ALIA in the Spanish meat product sector. Each of the indicators selected are classified by scope (national, sectoral, or company-specific) and then by existence in PSILCA database. The relative importance level for the company and its stakeholders is given by the materiality analysis in a scale from 1 to 9. Value equal to 1 meaning not important, and 9 extremely important. The indicator index is calculated according to the PSILCA database definition and compared against the risk level factors to assign risk levels. Results are shown in Table 3-3.

Table 3-3 ALIA's risk level assessment matrix.

Indicator	Unit	SCALE	Company interest (1-9)	Metric value	ALIAS's risk
Living wage, per month	USD	Nation	4	1,000 €	high risk
Minimum wage, per month	USD	Nation	4	1.11	medium risk
Sector average wage, per month	USD	Sector	4	2.6	very low risk
Hours of work per employee, per week	h	Company	4	40	low risk

Indicator	Unit	SCALE	Company interest (1-9)	Metric value	ALIAS's risk
Women in the labour force	% of economically active female population	Sector	9	0.47	medium risk
Men in the labour force	% of economically active male population	Sector	9	1.17%	Very low risk
Gender wage gap	%	Company	9	15%	medium risk
Accident rate at workplace	#/year	Company	9	612	very low risk
Fatal accidents at workplace	#/year	Company	9	0.00	very low risk
DALYs due to indoor and outdoor air and water pollution	DALYs per 1000 inhabitants in the country	Nation	9	PSILCA	very low risk
Presence of sufficient safety measures	OSHA cases per 100000 employees in the setcor	Sector	9	Yes	high risk
Workers affected by natural disasters	%	Nation		0.00	no risk
Trade union density as a % of paid employment total	%	Company	6	10%	very high risk
Right of Association	ordinal 0-3	Nation	6	3.00	no risk
Right of Collective bargaining	ordinal 0-3	Nation	6	3.00	no risk
Right to Strike	ordinal 0-3	Nation	6	3.00	no risk
Contribution of the sector to economic development	%	Sector	6	2.1%	Low opportunity
Public expenditure on education	US$/y	Nation	6	3.8%	high risk
Illiteracy rate, male	%	Nation	6	1.2%	very low risk
Youth illiteracy rate, male	%	Nation	6	0.4%	very low risk
Illiteracy rate, female	%	Nation	6	2.3%	low risk
Youth illiteracy rate, female	%	Nation	6	0.4%	very low risk
Illiteracy rate, total	%	Nation	6	1.8%	low risk
Youth illiteracy rate, total	%	Nation	6	0.4%	very low risk
Pollution level of the country	Text	Nation	9	PSILCA	low risk
Contribution of the sector to environmental load CO2	Text	Sector	9	no data	n.a.
Drinking water coverage	%	Nation	9	100%	very low risk
Sanitation coverage	%	Nation	9	99.0%	low risk
Level of industrial water use, out of total withdrawal	%	Company	4	5.0%	very low risk
Level of industrial water use, out of total actual renewable	%	Company	4	5.0%	medium risk
Extraction (total) of fossil fueles	t/cap	Company	4	0.00	very low risk
Extraction (total) of biomass related to area	t/m2	Company	4	0.00	very low risk
Extraction (total) of ores	t/cap	Company	4	0.00	very low risk
Extraction (total) of biomass related to population	t/cap	Company	4	0.00	low risk
Extraction (total) of industrial & const. minerals	t/cap	Company	4	0.00	very low risk
Presence of certified environmental management systems	# CEMS per 10000 employee	Sector	4	40.82	low risk
Unemployment rate in the country	%	Nation	6	11.2%	medium risk

Indicator	Unit	SCALE	Company interest (1-9)	Metric value	ALIAS's risk
Work force hired locally	%			100%	very low risk
Percentage of spending on locally based suppliers	%			90%	low risk
Violations of mandatory health and safety standards	#	Sector	9	-	no risk
Presence of anti-competitive behaviour or violation of anti-trust and monopoly legislation	Cases per 10000 employees in the sector	Sector	3	PSILCA	low risk
Presence of policies to prevent anti-competitive behaviour	Y/N		3	Yes	

The areas where the company should focus to limit the social impact of its products are those scored as highly important (importance >= 6) and classified as high or very high risk, especially if they refer to sectoral or company-wide indicators. We can find the following:

- Trade union density as a % of paid employment total (Imp 6, very high risk). The ratio of workers joining a worker union is only 10%. Workers should be encouraged to join a trade union and participate actively.
- Presence of sufficient safety measures, measured as OSHA cases per 100,000 employees in the sector (Imp 9, high risk). No data available at company level, but high risk at sector level in Spain. Especial care should be paid.
- Public expenditure on education (Imp 6, high risk). Nation-wide indicator. Currently 3.8% of GDP. Improvements are expected in a midterm.
- Contribution of the sector to economic development (imp 6, low opportunity). Sectoral indicator. Meat sector is just 2.1% of Spanish GDP. Sector as a whole should focus on increasing the value added of meat products to boost exports.
- Women in the labour force (Imp 9, medium risk). The ratio of female workforce should increase from the current 25%.
- Gender wage gap (Imp 9, medium risk). There is a 15% gender wage gap ratio, calculated as the difference between male and female median wages divided by the higher median wage, in percentage points. This gap should be addressed and reduced.
- Unemployment rate in the country (Imp 6, medium risk). Nation-wide indicator. Improvements are expected in a midterm. Now at 13.9%. Lorca’s local unemployment 11.6%.

There are other areas where ALIA outperforms in terms of social impact. These areas suppose a competitive advantage and care should be paid not to lose them. They are the following:

- Sector average wage per month. This sectoral indicator has been converted into a company indicator. Since ALIA’s average wage exceeds by 2.8 times the living wage of the country, the assessed associated risk is very low.
- Men in labour force. Men (75%) are not under-represented in ALIA’s workforce structure compared to national standards (65% of male active population in 4T 2018), hence there is a very low risk in this indicator. In terms of women, they are under-represented as 25% of female workers are far below the 53% of female active population in 4T 2018) giving a medium risk in this area. (EPA 4T 2018, INE).
- Rights for freedom, association and strike at national level are legally warranted in Spain and there are no risks in these aspects.
- Contribution to economic development is high risk in terms for public expenditure on education at national level (only 3.8% of 2018’s GDP), but in terms of illiteracy there is no or very low risk.
- In terms of safe and healthy living conditions, national wide indicators such as drinking water coverage and sanitation coverage are very low risk.

- In terms of access to material resources, water use, fossil fuel extraction, biomass and ore extraction are all assessed as low and very low risk at regional and national level.
- In terms of local employment, 100% of workers are hired locally according to the company. Hence there is a very low risk to mitigate the medium risk of the unemployment rate at regional (14.5%) and at national level (15.8%). In the same way, more than a 90% of spending is reported to be with local based suppliers.
- Finally, the ISO 14001 certification in ALIA allows to assess a low risk for presence of certified environmental management systems, compared to a medium risk at national sectoral level.

We take the 2011's US dollar to Euro exchange rate to convert today's costs in euros into 2011's costs in dollars. The exchange rate at 31/12/2011 was 0.75 euros per dollar. We assume similar levels of currency devaluation in the time period.

The model of activities is made up by 4 main impact contributors that include:

- **Agricultural products used for animal feed manufacturing**, all coming from nearby suppliers at regional and national level. The input of the process in economic terms is 0.69 US$ of agricultural raw materials per kg of pork meat. This process is external and provided by external ALIA's suppliers.
- **Animal food manufacturing.** This process is fully run by ALIA and the input is 3.69 kg of agricultural raw material per kg of animal food or 0.69 US$ of raw materials per functional unit, plus an amount of other inputs like water, energy, labour, transport, packaging and other costs, totalling 0.94 US$ per kg of pork meat.
- **Farming and breeding.** The input of this process is 3.06 kg of animal food per kg of alive animal. Per functional unit, we input 0.94 US$ of animal food and 0.85 US$ of energy, labour, water, medicines, transport and other costs. The process is entirely done at ALIA's premises.
- **Pork meat product manufacturing.** Including slaughtering, product manufacturing and distribution. The process is made by ALIA's partner "Los Quejigos". It needs 1.24 kg of alive animal per kg of meat. The input is 1.8 US$ of alive meat per kg of produced meat. Other inputs at slaughtering account for 0.75 US$ per kg of meat. This process is common, but different meat is used for the two processes under analysis. Therefore, two different processes have been designed according to the product to analyse:
  - **Pork Sausage manufacturing**. 1.35 kg of pork meat, sausage quality, is used per kg sausage product. Inputs at manufacturing and distribution amount at 2.53 US$ of pork meat and 6.13 US$ of other costs.
  - **Pork Loin manufacturing**. 1.4 kg of pork meat, pork loin quality, is used per kg of loin product. Inputs at manufacturing and distribution amount at 4 US$ of pork meat and 6.42 US$ of other costs.

The final input cost for the pork sausage value chain is 8.7 US$/kg while the input cost for pork loin is 10.4 US$/kg. The full cost distribution in US$ is in Figure 3-4.

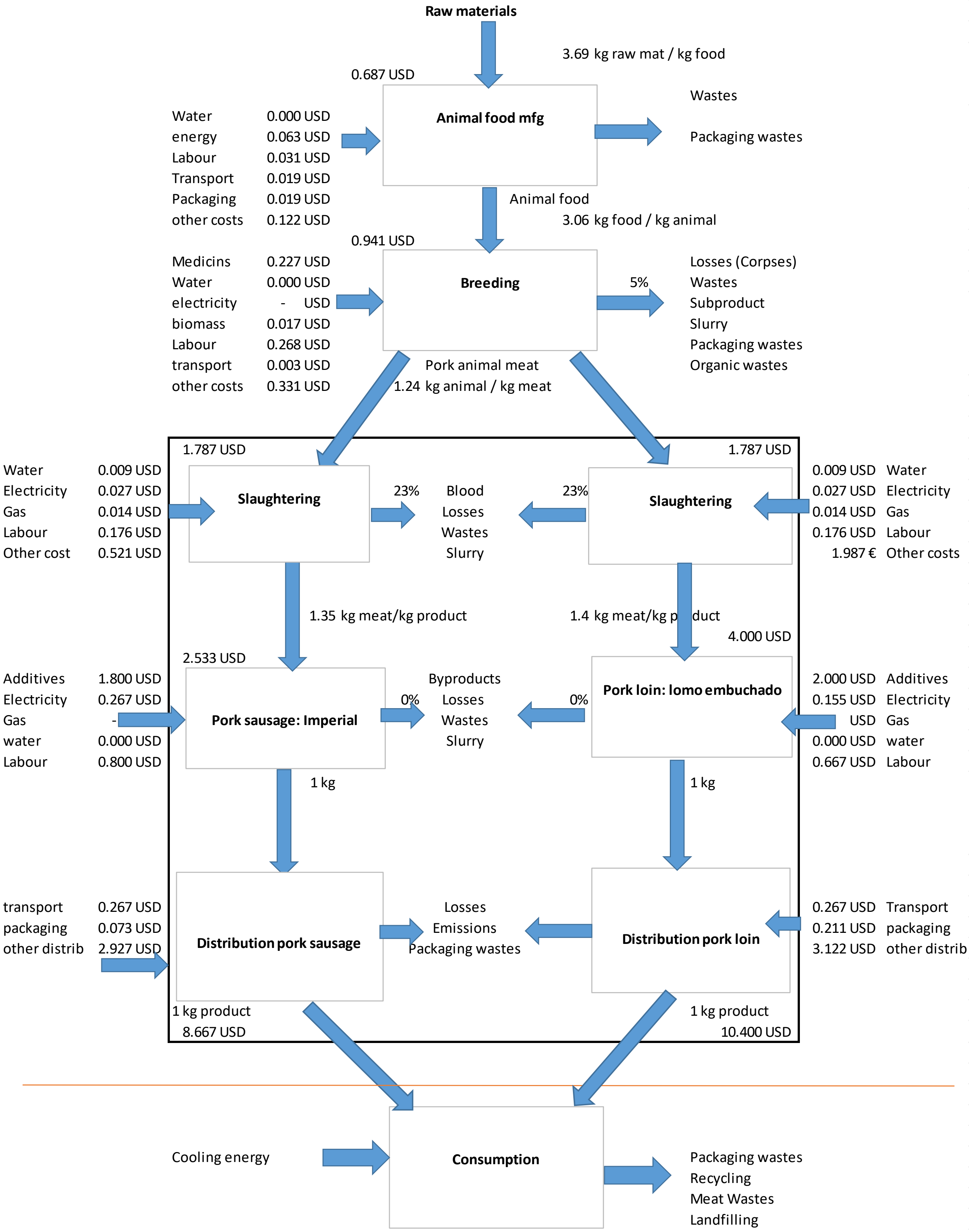


Figure 3-4 ALIA's process flowchart and S-LCA input / output scheme in 2011 US$

3.1.3 Table Lamp

Bearing in mind that the ratio of annual cost of personnel/annual turnover is 0,75 for the reference year and the mean hourly labour cost per employee is 38€/h (42 US$/h considering an exchange rate of 0,897 €/US$), the worker hours of the main activity (in hours per $ of output) is 0,01770 h/US$. In order to have a comparable value with PSILCA database ones, the exchange rate considered for 2011 US$ is 0.75 €/US$. As explained previously, we neglect differences between the two currencies' depreciation rates, as both economies have had similar inflation levels in the period. Thus, the worker hours of the main activity (in hours per $ of output) for 2011 is 0,01480 h/US$. This is higher than PSILCA's value for the reference sector in Spain: Manufacture of domestic appliances/Commodities/Spain (0,01028 h/US$). Other manufacture of materials such as steel, wood, netting, paints and glass locally made in the UK. The only material outside the UK is the machinery tyres that are produced in India.

- Other inputs such as packaging, fuel and services (insurance, banking, etc) are also included, adding an extra 0.34 USD on both products.
- Labour is introduced toward the tailored process, the one containing the adjusted risk levels, with different values for each product. As already explained, labour cost is calculated as a percentage of the final price given that the ratio between annual cost of personnel and annual turnover is known.

The indirect costs are also included as "other business activities" as the difference between the final price and all the cost stated above. For potatoes, this value is 1.008 USD and 11.769 USD for Salad reference sectors where the worker hours of the main activities are lower than ONA could be:

- Manufacture of lighting equipment and electric lamps/Commodities/ Great Britain (0,01020 h/US$),
- Electric lamp bulb and part manufacturing/Commodities/United States (0,01012 h/US$),
- Lamp & lighting fixtures/Commodities/Singapore (0,002369 h/US$)
- Electric lamps and lighting equipment/Commodities/Taiwan (0,009456 h/US$).

On the other hand, ONA´s worker hours of the main activity are lower than Incandescent electric lamps or discharge, arc lamps, electric lighting equipment, and parts and pieces/Commodities/Argentina (0,09039 h/US$).

After a deep analysis comparing the aforementioned reference sectors in PSILCA (mainly geographic and socio-economic situation in each country) and considering that the Spanish reference sector is not specifically related only with the lighting sector, it has been selected the Manufacture of domestic appliances/Commodities/Spain as reference sector for the analysis in this report. The aim is to make a comparative analysis evaluating the changes of the database in risk assessment and worker hours (h/US$) and considering also the module created in SimaPro software with ONA´s LCI.

In this sense, the analysis starts by calculating the PSILCA metrics for risk assessment of the company ONA in the Spanish lighting sector. Each of the indicators selected are classified by scope (national, sectoral, or company-specific) and then by existence in PSILCA database. The relative importance level for the company and its stakeholders have been considered related to manufacturing and packaging, transport, use and end-of-life activities (included in the materiality analysis). The indicator index is calculated according to the PSILCA database definition and compared against the risk level factors to assign risk levels. Results are shown in Table 3-4.

Table 3-4 ONA's risk level assessment matrix.

Indicator	Units	SCALE	Metric value	ONA's risk
Living wage, per month	USD	Nation	1,000	High risk
Minimum wage, per month	Ratio	Nation	1.11	Medium risk
Sector average wage, per month	Ratio	Sector	1.5	Medium risk
Hours of work per employee, per week	h	Company	40	Low risk
Women in the labour force	% of economically active female population	Sector	50	medium risk
Men in the labour force	% of economically active male population	Sector	50	Very low risk
Gender wage gap	%	Company	-19,58	Medium risk
Accident rate at workplace	#/year	Company	0	Very low risk
Fatal accidents at workplace	#/year	Company	0	Very low risk
DALYs due to indoor and outdoor air and water pollution	DALYs per 1000 inhabitants in the country	Nation	PSILCA	
Presence of sufficient safety measures	OSHA cases per 100000 employees in the sector	Sector	0	Very low risk
Workers affected by natural disasters	%	Nation	0	Very low risk
Trade union density as a % of paid employment total	%	Company	0	Very high risk
Right of Association	ordinal 0-3	Nation	3.00	No risk
Right of Collective bargaining	ordinal 0-3	Nation	3.00	No risk
Right to Strike	ordinal 0-3	Nation	3.00	No risk
Contribution of the sector to economic development	%	Sector	Less than 1%	No opportunity
Public expenditure on education	US$/y	Nation	3.8%	High risk
Illiteracy rate, male	%	Nation	1.4%	Very low risk
Youth illiteracy rate, male	%	Nation	0.4%	Very low risk
Illiteracy rate, female	%	Nation	3.1%	Low risk
Youth illiteracy rate, female	%	Nation	0.4%	Very low risk
Illiteracy rate, total	%	Nation	1.8%	Low risk
Youth illiteracy rate, total	%	Nation	0.4%	Very low risk
Pollution level of the country	Text	Nation	PSILCA	
Contribution of the sector to environmental load CO2	Text	Sector	no data	n.a.
Drinking water coverage	%	Nation	100	Very low risk
Sanitation coverage	%	Nation	99	Low risk
Level of industrial water use, out of total withdrawal	%	Company	Less than 5%	Very low risk
Level of industrial water use, out of total actual renewable	%	Company	Less than 5%	Medium risk
Extraction (total) of fossil fueles	t/cap	Company	0	Very low risk

Indicator	Units	SCALE	Metric value	ONA's risk
Extraction (total) of biomass related to area	t/m2	Company	0	Very low risk
Extraction (total) of ores	t/cap	Company	0	Very low risk
Extraction (total) of biomass related to population	t/cap	Company	0	Very low risk
Extraction (total) of industrial & const. minerals	t/cap	Company	0	Very low risk
Presence of certified environmental management systems	# CEMS per 10000 employee	Sector	0	Very high risk
Unemployment rate in the country	%	Nation	11.2%	medium risk
Violations of mandatory health and safety standards	#	Sector	-	no risk
Presence of anti-competitive behaviour or violation of anti-trust and monopoly legislation	Cases per 10000 employees in the sector	Sector	PSILCA	

3.2 Environmental Life Cycle Assessment

Separately, environmental LCA analysis was carried out on all products, led by IEIA and NTU, in conjunction with all industry partners. The Life Cycle Analysis was carried out according to the PN-EN ISO 14040:2009. A Life Cycle Assessment (LCA) is comprised of four phases, as shown in Figure 3-5

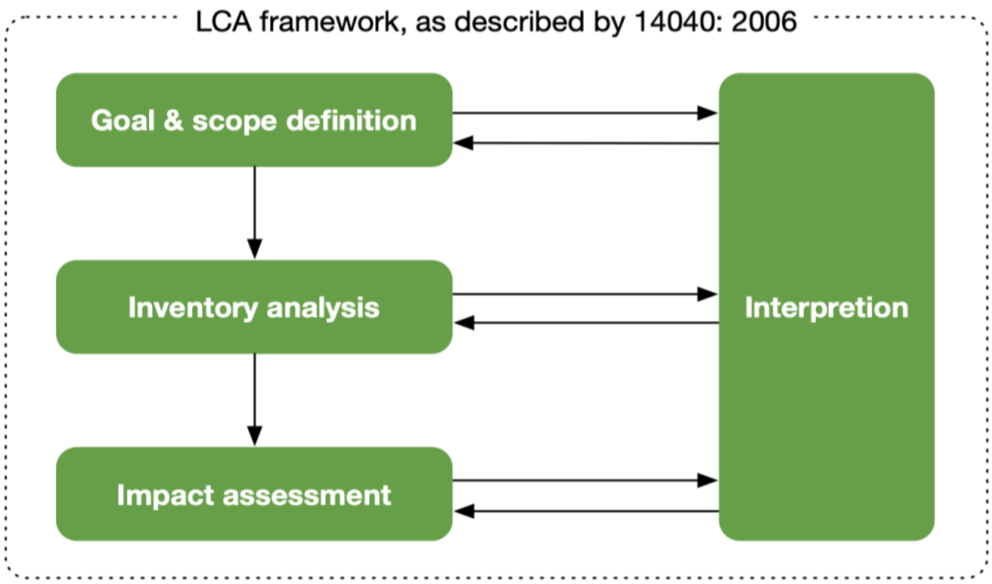


Figure 3-5 Life cycle assessment methodology

i. **Goal and scope definition**: defining the purposes of the study, determining the boundaries of the system life cycle in question and identifying important assumptions that will be made;
ii. **Inventory analysis**: compiling a complete record of the important material and energy flows throughout the lifecycle, in additional to releases of pollutants and other environmental aspects being studied;
iii. **Impact assessment**: using the inventory compiled in the prior stage to create a clear and concise picture of environmental impacts among a limited set of understandable impact categories; and
iv. **Interpretation**: identifying the meaning of the results of the inventory and impact assessment relative to the goals of the study.

LCA is best practiced as an iterative process, where the findings at each stage influence changes and improvements in the others to arrive at a study design that is of adequate quality to meet the defined goals.

The principles, framework, requirements and guidelines to perform an LCA are described by the international standards ISO 14040 series (ISO, 2006).

3.2.1 Goal and Scope

The LCA in WP1 is articulated around:

- Task 1.1: mapping of products' life cycle and main business activities for CIRC4Life industrial partners (M1-M4)
- Task 1.2: a detailed LCA aimed at identifying environmental impact causes related to products' life cycle (M4-M12)
- Task 1.3: The LCA results (i.e. single score of ReCiPe method) will be used to demonstrate the eco-Point method in CIRC4Life project (M1-M10)

The results of this LCA are not intended for public disclosure but only destined to the members of the consortium (including the Commission Services). Additionally, the target audiences of this report are developers and managers from industrial partners in CIRC4Life.

3.2.2 Life Cycle Impact Assessment Method

The life cycle impact assessment (LCIA) provides the basis for analysing the potential contributions of resource extractions and emissions in an LCI to a number of potential impacts. The impacts are calculated using characterization factors recommended in internationally recognized impact assessment methods.

According to ISO 14044 (ISO, 2006), LCI flows of materials, energy and emissions into and out of each product system are classified into impact categories by the type of impact their use or release has on the environment. Then, they are characterised into their contribution to an indicator representing the impact category. The category indicator can be located at any intermediate position between the life cycle inventory results and the resulting damage (where the environmental effect occurs) in the cause-and-effect chain. The damage represents changes in environmental quality and a category indicator is a quantifiable representation of this change.

The ReCiPe method (Goedkoop et al., 2009) is adapted in this study. The ReCiPe framework links all types of life cycle inventory results via several midpoint categories to three endpoints (damage oriented) categories (human health, ecosystems, resources). ReCiPe method was developed in 2008 by RIVM National Institute for Public Health and the Environment, CML, PRé Consultants and the Radboud University Nijmegen on behalf of the Dutch Ministry of Infrastructure and the Environment (RIVM, 2018).

The detailed life cycle assessment focuses on the three ReCiPe end-point indicators (Table 3-5) over the entire life cycle of the processes.

Table 3-5 ReCiPe endpoint indicators description (Goedkoop et al., 2009)

Endpoint Indicator	Endpoint Indicator Description	Impact Category
Human Health	This indicator measures the potential impact on human health caused by emissions associated with a product, process or organization. It takes into account human toxicity, accounting for both mortality (years of life lost due to premature death) and morbidity (rate of incidence of a disease). The impact metric is expressed in DALY ("disability-adjusted life years").	• Climate change Human Health • Ozone depletion • Ionising radiation • Photochemical oxidant formation • Human toxicity • Particulate matter formation
Ecosystems	Ecosystem quality can be described in terms of energy, matter and information flow. In the ReCiPe model the information flow at the species level is used. This means accepting the assumption that the diversity of species adequately represents the quality of ecosystems. This model gives the results as the potentially disappeared fraction of species (PDF) per unit area (m 2 or m 3) over a specified time period (yr).	• Agricultural land occupation • Climate change Ecosystems • Freshwater ecotoxicity • Freshwater eutrophication • Marine ecotoxicity • Natural land transformation • Terrestrial acidification • Terrestrial ecotoxicity • Urban land occupation
Resources	Resource depletion is modelled using the geological distribution of mineral and fossil resources and assesses how the use of these resources causes marginal changes in the efforts to extract future resources. The model is based on the marginal increase in costs due to the extraction of a resource. In terms of minerals, the effect of extraction is that the average grade of the ore declines, while for fossil resources, the effect is that not only conventional fossil fuels but also less conventional fuels need to be exploited, as the conventional fossil fuels cannot cope with the increasing demand. The marginal cost increase is the factor that represents the increase of the cost of a commodity r ($/kg), due to an extraction or yield (kg) of the resource r. The unit of the marginal cost increase is dollars per kilogramme squared ($/kg 2).	· Metal depletion · Fossil fuel depletion

For the purposes of the LCA of meat products, SimaPro tool, Release 8.5.2.0 was used. The objective of the analysis was to assess the environmental performance of the production of pork products, including cured pork sausage and cured pork loin, in its lifecycle from the production of feed for pigs, the pig farm, via slaughterhouse to meat processing plant. This is based in the Murcia Region of Spain.

LCA took into account following phases:

- Assessment of production of food for pigs.
- Assessment of farming of pigs.
- Assessment of slaughterhouse activities.
- Assessment of processing of meat.
- Assessment of distribution of products.

The analysis was carried out in three steps:

- Defining the purpose and the scope of research.
- Analysis of a data set of inputs and outputs - Life Cycle Inventory.
- Life Cycle Impact Assessment, including interpretation of the results.

Inventory data for the production of meat products were provided by SAT- ALIA, and for some parameters the values from the Ecoinvent™ database version 3 were adjusted based on the information provided, expert knowledge and literature.

For the purposes of interpretation of the results, ReCiPe method was selected to calculate the product eco-points to measure environmental impacts of products. ReCiPe calculates seventeen midpoint indicators and three endpoint indicators. Midpoint indicators concern single environmental problems. Endpoint indicators show the environmental impact on three higher aggregation levels. Converting midpoints to endpoints simplifies the interpretation of the LCIA results. Environmental impact potentials calculated in this study concern endpoint level and are aggregated into the three endpoint categories: damage to human health, damage to ecosystems and damage to resource availability.

4 Analysis Results

4.1 Industrial LED Lighting Products

4.1.1 Environmental LCA

4.1.1.1 Functional Unit

Object of analysis is one unit of a KMSD100LLBE lighting product for general industrial use. KMSD100LLBE is a 100W LED Low Bay Luminaire from Kosnic Lighting Ltd, as shown in Figure 4-1. Function of KMSD100LLBE is to provide high lumen output and daylight colour temperature light in general industrial areas. The Low bay LED luminaires offer energy savings and high performance, replacing conventional lighting in general industrial areas, manufacturing, warehousing, leisure facilities and retail environments.

The 100W LED low bay is also available with a factory fitted microwave sensor behind the frosted diffuser allowing further control and energy savings. The optional built-in microwave sensor can be set to lower the light level, or completely turn it off once motion has ceased. The light can also be prevented from coming on if the ambient light level measured at the fitting is above one of the pre-set levels. Settings include detection area, hold time and daylight sensor level. The detailed technical specifications are listed in Table 4-1.

Figure 4-1 The 100W LED Low Bay Luminaire Under Assessment

Table 4-1 Technical Specifications of KMSD100LLBE

Product Code	KMSD100LLBE-W65-WHT	KMSD100LLBE/S-W65-WHT
Power (W)	100	100
Voltage	220-240Vac 50-60Hz	220-240Vac 50-60Hz
Current (mA)	448	448
Protection	Class I, IP20	Class I, IP20
Power Factor	0.97	0.97
Luminous Flux (lm)	11500	11500
Beam Angle (°)	120	120
CCT (K)	6500K Day Light	6500K Day Light
CRI	83	83
Lifetime (h)	40000	40000
Dimmable	No	No
Switching Cycles	50000	50000
Start Time (s)	0.35	0.35
Warm-up time to 60% (s)	Instant full light	Instant full light
Diffuser	Frosted polycarbonate.	Frosted polycarbonate.
Length (mm)	600	600
Width (mm)	327	327
Depth (mm)	84	84
Mercury (mg)	0	0
Lumen Maintenance Factor at Lifetime	0.75	0.75
Ambient Temperature (°C)	-20 to 40	-20 to 40
Optional Sensor	No	Yes
Sensor Type		Microwave
Detection Range		6m height (max) 12m radius (10 / 50 / 75 / 100%)
Detection Angle		360°
Operation Time		5sec / 30sec / 90sec / 3min / 20min / 30min
Ambient Light Thresholds at Sensor		2lux / 10lux / 25lux / 50lux / Disabled
Standby Power (W)		≤1.0
HF System (GHz)		5.8
Sensor Output (mW)		<0.5

The luminaire consists of three assembly parts: housing, electronic device, fasten members, which is illustrated in Figure 4-2. The housing is the shell of the luminaire that provides space for configuration of the core electronic devices. The electronic device part is the vital member which provide the feature function, this part includes two LED drivers, a LED panel, junction box and electronic press button, all the assembly parts are joint with the fasten members.

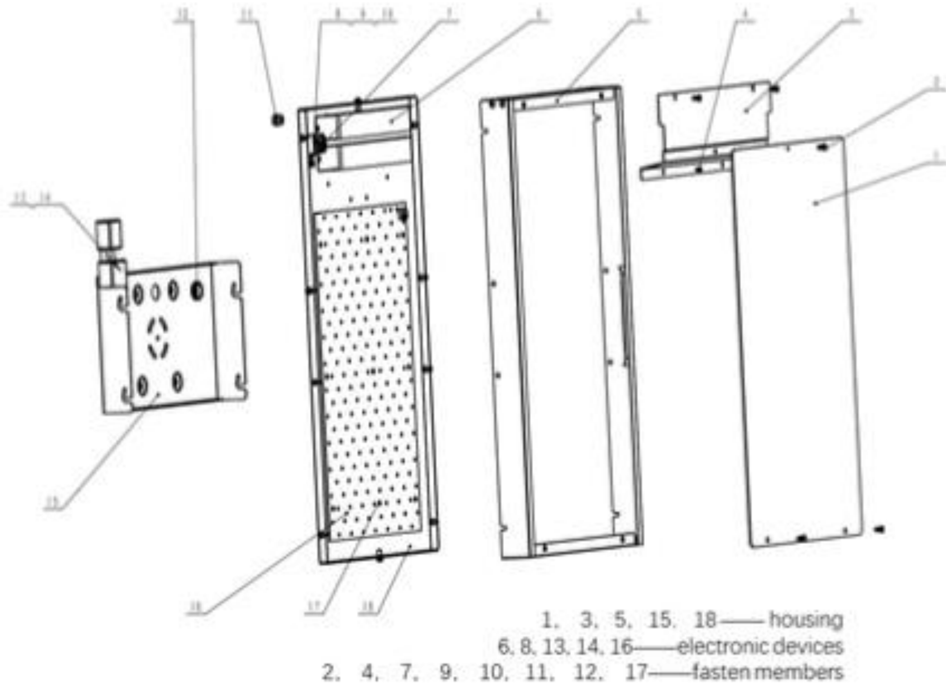


Figure 4-2 The Assembly of KMSD100LLBE

4.1.1.2 System Boundary

Figure 4-3 illustrates the product system boundary under the E-LCA and S-LCA study. For the E-LCA study, all life cycle stages are considered in the system boundary, including raw material acquisition, manufacture of the pre-product, product assemble, packaging, distribution (transportation), use stage and, end-of-life (EoL) treatment are under study.

In manufacturing stage, pre-product production including raw material acquisition, product assemble, energy consumption, waste/emissions generation disposal during manufacturing are considered, packaging and transportation activities during manufacture are also considered within the boundary.

Transportation during distribution is within the study boundary. The LED lighting product is manufactured in China (Hangzhou) then shipping to UK for wholesaling.

Energy use during use stage is taken into account in the assessment. It is assumed that the LED lighting product will be in service until the end of its useful life, which is 40,000 hours. Maintenance is excluded because the information was not available.

End-of-life is within the boundary as well, Three EoL scenarios are analysed addressing the different EoL options: (1) Base scenario. In this case, it is considered that the entire EoL LED lighting product is directly sent to waste bin as solid waste and went through the corresponding processing method which is landfill. The packaging wastes are separated from the general waste bin then incinerated. (2) Scenario 2 (S2). It is assumed that electrical devices in the LED lighting product are disassembled from the product and placed in recycle waste bin and finally sent for material recovery. Other parts of the lighting product are disposed as general solid waste.

The waste packaging materials are processed the same as in Scenario 3 (S3). In this scenario, the LED lighting producer and distribution company (Kosnic) are assumed to provide a take back scheme, in which the lighting product after the use phase will be collected by the company for further material processing. The lighting product will be disassembled, the electrical devices are repaired and refurbished for producing new LED lighting. Other useful materials in housing, such as Aluminium, steel and plastic, are recycled or upcycled. The paperboard for packaging is remanufactured as new packaging material. The remaining materials from the used lighting product are treated as general non-hazard solid wastes.

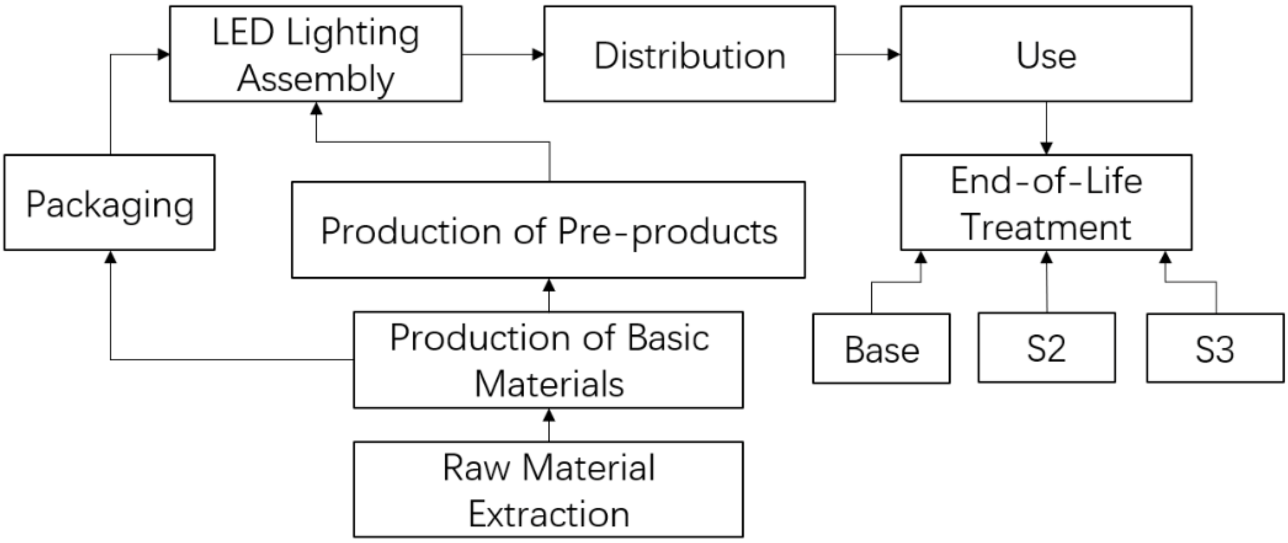


Figure 4-3 System Boundary for E-LCA

4.1.1.3 Life Cycle Inventory

The lighting product is manufactured and assembled in Hangzhou (China) by Kosnic (UK) Lighting Ltd. The input-output data such as material use, information of pre-product and energy consumption is company owned data that was acquired by interviewing the engineer of the company. The background data, such as raw material extraction and production of the basic materials was derived from the Ecoinvent 3 database which is built-in the online LCA platform.

The LED lighting product is assembled at plant in China (Hangzhou) and transported to wholesaler in the UK by ship. Transportation information was obtained through Google Maps by distance searching from Hangzhou (China) to London (UK).

KMSD100LLBE is 100W Low Bay Luminaire with input voltage of 220~240V. It is assumed that the LED lighting product will be in service until the end of its useful life. The energy usage during use phase was calculated by multiplication of the power (100W) and useful lifetime (40000h). Bill of material and process related data are listed in Table 4-2.

The EoL phase was modelled with three EoL scenarios to address the different EoL options: Base scenario, scenario 2 (S2) and scenario 3 (S3), the detailed information and process data is listed in Table 4-2. The waste process data was selected from Ecoinvent database and the weight of the waste materials was from the component data from Kosnic.

Table 4-2 Bill of Material and Process Related Data of KMSD100LLBE

Assembly Component	Material	Amount	Unit	Ecoinvent Process
Housing	Plastic	0.29	kg	Thermoplasts: Polyethylene, high density, granulate {RoW} | production | Alloc Def, U
	Steel	2.199	kg	Ferro:Steel, low-alloyed, hot rolled {RoW} | production | Alloc Def, U
	Aluminium	1.1	kg	Alloys:Aluminium alloy, AlLi {RoW} | production | Alloc Def, U
LED driver (pre-product)	Plastic	0.252	kg	Thermoplasts:Polyethylene, high density, granulate {RoW} | production | Alloc Def, U
	printed circuit board	0.688	kg	Printed wiring board:Printed wiring board, surface mounted, unspecified, Pb containing {GLO} | production | Alloc Def, U
LED lighting board	LED	0.32	kg	Component:Light emitting diode {GLO} | production | Alloc Def, U
	Aluminium	0.012	kg	Alloys:Aluminium alloy, metal matrix composite {RoW} | aluminium alloy production, Metallic Matrix Composite | Alloc Def, U
Other plastic members	Plastic	0.027	kg kg	Thermoplasts:Polyethylene, high density, granulate {RER} | production | Alloc Def, U
Fasten members	Steel	0.07838	kg	deep drawing, steel, 650 kN press, automode | deep drawing, steel, 650 kN press, automode | APOS, S - RoW
	Plastic	0.0016	kg	extrusion, plastic pipes | extrusion, plastic pipes | APOS, S - RoW
Packaging	bord box	1.17	kg	Corrugated board:Corrugated board box {RoW} | production | Alloc Def, U
	plastic	0.0003	kg	Thermoplasts:Packaging film, low density polyethylene {RoW} | production | Alloc Def, U
	paper	0.0004	kg	Graphic paper:Printed paper, offset {RoW} | offset printing, per kg printed paper | Alloc Def, U
	plastic form	0.066	kg	polystyrene production, extruded, CO2 blown | Alloc Def, U
Energy imput				
Electricity		4000	kw/h	Photovoltaic:Electricity, low voltage {RoW} | electricity production, photovoltaic, 3kWp slanted-roof installation, multi-Si, panel, mounted | Alloc Def, U
Transportation				
Shipping		56451.96	kg*km	Water:Transport, freight, sea, transoceanic ship {GLO} | market for | Alloc Def, S

4.1.1.4 Environmental Life Cycle Impact Assessment

The environmental assessment was conducted with the ReCiPe endpoint hierarchist. Endpoint method has its advantage since the results are easier to understood and communicated, in addition, one of the goals of the study is to obtain the total impact points for further research use.

The analysis of the three endpoint impact categories regarding ecosystems, resources and human health. The Life cycle stage contribution results in endpoint impact categories are shown in Figure 4-4. The results suggest that, 60% of total impacts are generated from production stage. Among the three impact categories, production accounts for around 57% and 61% on resources and human health categories respectively, while contributes 43% to ecosystem. Followed by use phase which plays an important role to the environmental burden in each impact category, especially on ecosystem which accounts for nearly 60% of the total score of the category. Other life cycle stages account for minimal percentage of impact.

The single scores of the assessed LED lighting after normalisation and weighting are presented in Table 4-3. As presented, the total score of the per product's lifecycle is 120 Pt. Among the related impact categories, impact on human health presents the most (79.1 Pt), followed by resources which is 38 Pt. The given product system has a minor impact on ecosystems according to the evaluation (2.68 Pt).

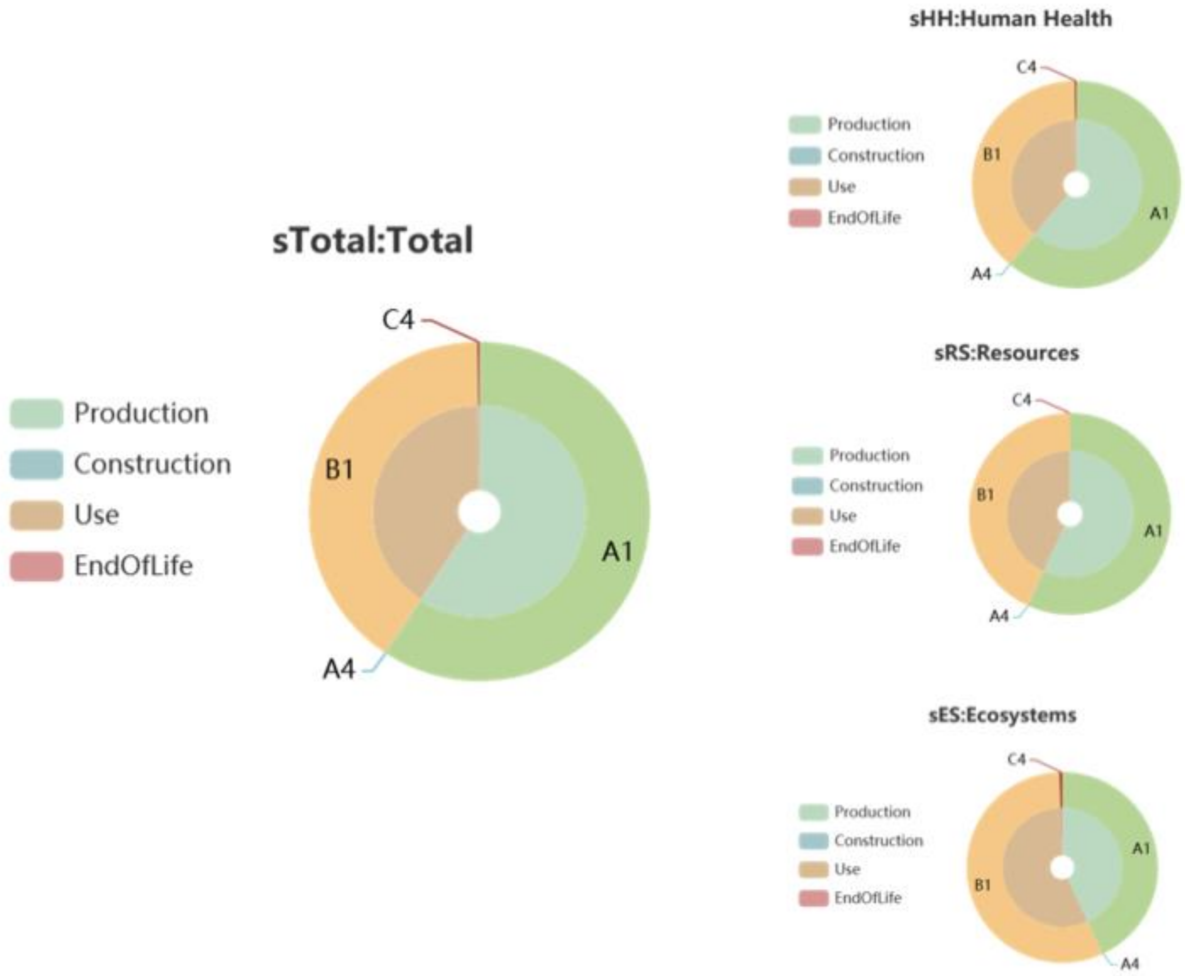


Figure 4-4 Life Cycle Stage Contribution Results in Endpoint Impact Categories

Table 4-3 Single Score Results

Characterisation	Explanation	Unit	Value
sTotal (eco-point score)	Total	Pt	120.00
sHH	Human Health	Pt	79.10
sES	Ecosystems	Pt	2.68
sRS	Resources	Pt	38.00

A further break-down of contributions on total impact throughout all life cycle stages is listed in Table 4-4. It is demonstrated that independent from product life cycle stages, manufacture of electronic devices (LED driver and LED light board together) is the hotspot process. LED driver is the key process which most of the potential impacts of electronic devices are reason from. Another hotspot process is production of electricity.

Production of other assembly members, end of life treatment, as well as other processes like packaging and transportation together (presents as others), account for very small percentage of the total impact in each category.

Table 4-4 Contribution Tree Within All Life Cycle Stages

	Process	Contribution%
Total 100%	All	100
	LED Driver	45.79
	Electricity	40.5
	LED Light Board	11.83
	Housing	1.41
	EoL Treatment	0.2
	Others	0.27

4.1.1.5 Interpretation

The environmental performance of the assessed LED lighting product is dominated by the production phase. Use of the product in the base scenario also plays a notable role in the environmental burden. In the meantime, Transportation and EoL phase contribute very limited impacts to the total environmental profile. As the manufacture stage is input-output intensive stage where the majority consumption of materials and energy have taken place.

Impacts of Use stage mainly come from the consumption of electricity, since production of electricity requires a large number of material and transportation inputs even though photovoltaic power is applied in the analysis, the emissions generated from the whole production process also lead to several environmental issues, consequently, contributing more impacts compares to other life cycle stages.

Independent from product life cycle stages, the main impact of the entire environmental impact originates from three processes:

- wire printed board production,
- electricity production
- light emitting diode production

These processes relate to the production of LED driver, electricity and LED light panel respectively. Wire printed board production is the predominate hotspot process of the whole life cycle. The extraction of the precious metal material, such as gold and silver etc., together with transportation during the extraction as well as the fabrication of the pre-product, are the main impact contributors on the resource impact category.

The emissions from extraction, fabrication and other processes during the production of the wire printed board, are the major ascriptions to high impacts on human health, since emissions on soil, water mostly contain heavy metals which are hazard consequently causing severe potential damages directly or indirectly to human health. Similar causation for the LED light panel production. For ecosystems, electricity production accounts for the main environmental burden. Yet in the assessment case, photovoltaic power is applied thus alleviates the environmental burden on ecosystem compares to other electricity production methods since the emissions during the electricity generation are less. However, photovoltaic power might cause environmental burden on other impact categories due to the production of the photovoltaic equipment and transportation activities during the electricity production.

Results from assessment of the EoL scenarios show that, there is no obvious change on the total environmental impact regarding disposal electronic devices independently or not. Yet it influences the total impacts dramatically if the waste materials/assembly parts are reusable, for example the electronic devices can be repaired and reused as a component in new products. Furthermore, the analyses of EoL scenarios discovered that the environmental impact regarding the treatment of the waste electronic product is similar, namely, to be landfilled or under recovery process affects the environmental impact to the similar degree. Only materials recovery or repair is meaningful for improving the whole environmental performance of the LED product.

Eco Point score = 120

4.1.1.6 Recommendations

Recommendations on a company level with addressing different issues are given based on the analysis results. The recommendations provided are also in accordance of criteria of EU ecolabel of lighting sources. The official EU mark for greener products on lighting sources is intended to guarantee:

- Reduction of energy consumption;
- Limitation use of mercury;
- Limitation use of substances harmful to the environment and human health;
- High quality and durability of the product;
- Social responsibility.

Some of the requirements, such as limitation use of mercury or use of hazards substances, are not a concern for the analytical product in this study. First, the LED lighting product is mercury free, meanwhile, apart from conventional lighting product, LED lighting product is considered as non-hazard product at present. However, non-hazardous substances contained in the product, such as gold and silver, result in considerable environmental burden due to the extraction of the material and an opportunity in waste management, which should be considered as an opportunity to improve the environmental performance. Better social performance could be achieved with further social engagement.

The recommendations regarding eco-redesign or opportunities towards environmental sustainability on company level are as follows:

- Redesign of the LED driver. For short-term: redesign the circus board; eliminate or reduce the precious metal input within components in electric devices, substitute the material with other materials. In a long-term, with the take back scheme, remanufacture of the LED driver by replacing or repairing the dis-function components instead of manufacturing the driver with brand new components;
- Improve the energy efficiency by replacing the light emitting diode with higher luminous efficiency product;
- Reduce housing material, refine the product’s dimension;
- Reduce housing material, refine the product’s dimension;
- Use recycled aluminium instead of aluminium alloy;
- Use recycled plastic material, make sure chlorine content in the plastic parts are not greater than 50%;
- If there are hazard substances which present in mixtures, make sure the concentration of the hazard substance is lower than 0.1%;
- Implement modular design for easily assemble and disassemble;
- Improve power control system for energy efficiency;
- Use recycled packaging material (80% post-consumer cardboards and 50% recycled plastic materials;
- Provide user guide of use information covers mode setting, end-of-life options for self-operating of the LED product (other option is provided by the company, such as whole life cycle service);

4.1.2 Social LCA

Overall, the social sustainability performance of the LED lighting product is dominated by the production stage, including the raw material extraction and pre-product production as well as assembly. Other life cycle stages contribute to less social burdens, especially End of life treatment, the social impact is minimum.

From a stakeholder perspective, ‘local community’ is under major risk due to the extraction of metal material, especially precious material for electrical elements production. Very high risk of sanitation and polluting problems along the extraction and manufacturing processes are identified, which also contributes to the environmental burden in the local community.

Workers are also involved in negative social problems. Overall, the only highlighted social problem is ‘Association and bargaining rights’ which is more or less the common social problem. Nevertheless, this stakeholder is assessed in-depth thanks to the data availability of final production but there are no other outstanding issues revealed, such as forced labour related issues. The direct social problems from final product production are not severe according to the results, yet opportunities are identified to improve the performance by addressing the salary equality and safety measures during the pre-product production linked processes.
‘Public sector corruption’ is another hotspot social issue that laid in value chain actor. In this case is mainly affected by electronic sector, however, it is a social problem which is out of hand to solve only on company level. Better implementation within the value chain actor stakeholder could be achieved by pay more attention to the sustainability along the supply chain.

There is no social hotspot allocated in society or consumers stakeholders. Further, positive social effect is detected in stakeholder society. The product is manufactured in China then distributed in UK and worldwide, therefore, the main beneficial country is China despite the target market is in UK. Production stage and packaging are the two key contributors in boosting the economy. Specifically, production of electronic elements, metal product, plastic materials as well as the packaging activities are directly linked to the positive effect.

Among the components, electric devices are the main contributor to most of the negative impacts except for 'contribution of economic development'. In 'contribution of economic development' category, electronic devices accounts for notable (more than 2 hours per unit) positive effects on both Chinese and US's economic development. The positive effects mainly because of processes related to transportation and fundamental material mining which help to boost the local economic.

The assessment results also reveal that, China is the major influenced country by the potential social risks since most of the production activities are taken place in China. Social risks also linked to United States and other Asian Countries on some of the categories, such as Biomass Consumption, Gender Wage Gaps, etc., however, those risks are very small per unit.

4.1.2.1 Recommendations

Recommendations with addressing different issues are given based on the assessment of analysis results. The recommendation contains measures on company level also in policy level or sector level, the main goal is to improve the performance in local community, workers and value chain actor. According to the results, several social issues are related to environmental load during production and distribution activities, these issues directly impact on the local community, recommendation regarding the above issues are:

- Popularising certified environment management system.
- Improvement of public infrastructure regarding sanitation.
- Improvement of working conditions in the mining sector as well as the pre-product production companies, by working with the supply chain.
- Promotion of sustainable consumption and production system.
- Improvement of social responsibilities by formalising of industry standards.
- Promotion of fair salary and workers' rights.

On a company level, the company itself performances rather good on social aspects. However, there are still issues detected during the investigation. For example, it is recognised that male employees often have more salary than their female counterparts. In addition, the component supply companies may link to irresponsible environmental behaviours during production. Furthermore, the LED driver, which is produced by the assembly company, is revealed as a hotspot process which is the major contributor to many impact categories. Recommendations are made to address the above issues on company level:

- Promotion of salary equality.
- Improvement of social responsibility by selection of certified upstream suppliers.
- Implementation of sustainable production.
- Establishment of a take back scheme.

4.2 Table lamp

4.2.1 Environmental LCA

4.2.1.1 Function and Functional Unit

The function of ONA lighting products is to provide efficient lighting service in a domestic environment. The functional unit quantifies the performance of a product system and is used as a reference unit for which the life cycle assessment study is performed, and the results are presented. It is therefore critical that this parameter is clearly defined and measurable.

The function of a luminaire is to produce a specific quantity and quality of light for a period of time. The quantity of light is measured with the luminous flux (lm) emitted by the luminaire, and the quality of light is mainly measured with the correlated colour temperature (CCT) and the colour rendering index (CRI). Therefore, the functional unit used in this LCA is considered as the production of 948 lm of light (quantity of light) of CCT=4000 K, and CRI=65 (quality of light) for 40,000 hours.

Therefore, the function unit in this study is defined below:

Functional unit = 1 luminaire providing lighting service 948 Lumens per hour + 40,000 working hours

4.2.1.2 Product General Description

The ONA luminaire is a table lamp (Figure 4-5) and its' technique specification is listed in Table 4-5**.**

Figure 4-5 ONA table lamp product

Table 4-5 The technical specification of the ONA lighting product

Item	Amount
LED useful lifetime	40,000 hours
Energy consumption (luminaire)	6.7 Watts
Luminous flux (Luminaire)	102.5 Lm
Luminaire efficacy	15.29 Lm/Watts
Light source efficacy	56.66 Lm/Watts
Luminous flux (Light source)	340 Lm
CRI (light source)	65
CCT (light source)	4000 °K
Beam angle - vertical spread (luminaire)	102.1°
Beam angle- horizontal spread (luminaire)	96.3°

4.2.1.3 System Boundaries

The setting of system boundaries identifies the stages, processes and flows considered in the LCA and should include:

- All activities relevant to achieve the present LCA study objectives and therefore necessary to carry out the studied function; and
- All the processes and flows that significantly contribute to the potential environmental impacts.

This section describes the life cycle stages of the studied systems and determines which processes and flows are included in the LCA, i.e., what is considered to be in the system and is therefore analysed, and what is outside the system boundaries and therefore not included in the assessment.

The boundaries of this assessment comprise cradle-to-grave luminaire’s life cycle processes. The processes related with the packaging (i.e., manufacturing, transport, use and end of life of packaging) have been excluded. Thus, the product life cycle stages included are: Extraction of materials, manufacturing (assembly), transportation, use and End of Life (EoL) of the luminaire. Below can be seen a diagram (Figure 4-6) of the life cycle stages included in the assessment of the luminaire.

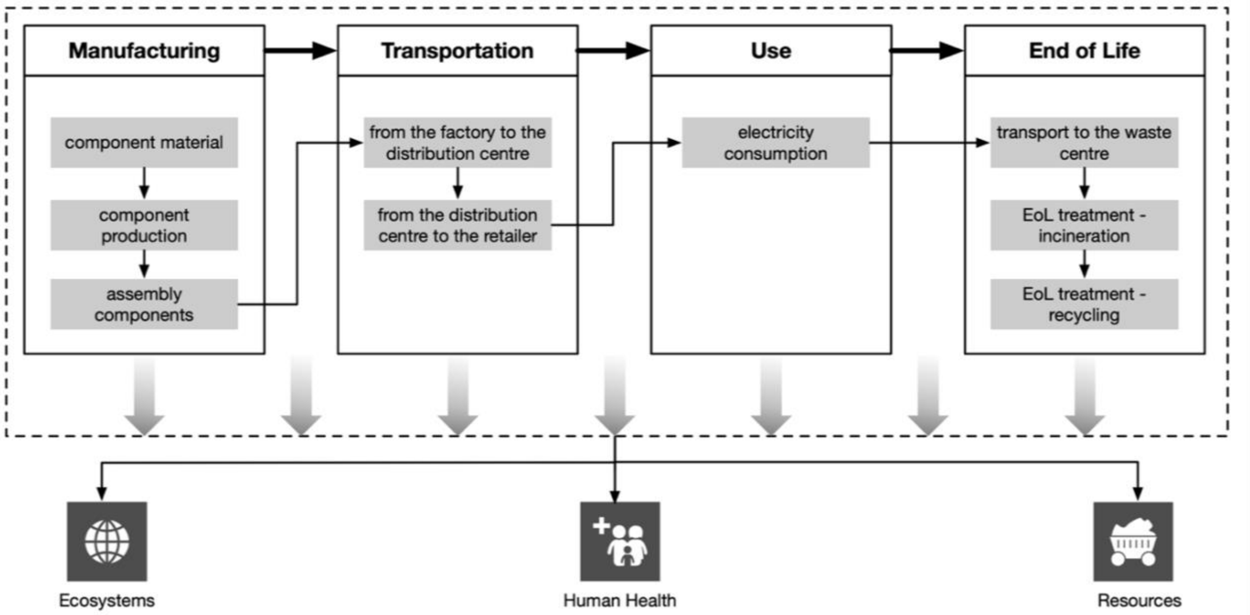


Figure 4-6 A schematic system for the luminaire life cycles

4.2.1.4 Key Data for Materials and Processes

A Life Cycle Inventory is a compilation table of all energy and raw materials inputs and waste/emissions outputs associated with a product system. It is calculated by summing all LCI's of the relevant processes throughout the identified product system. The structure and the key parameters of the luminaire are presented in Figure 4-7 and Table 4-6.

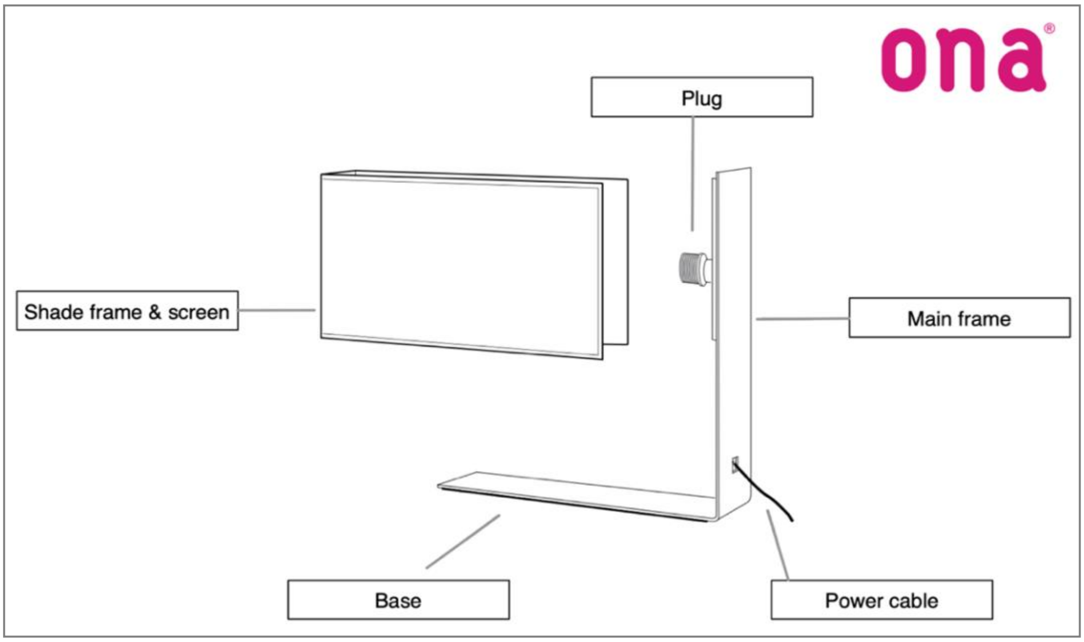


Figure 4-7 Luminaire exploded view

Table 4-6 Key parameters for the materials

Flow	Amount	unit
base	872	g
Cable (including socket)	94	g
lamp frame	28	g
main frame	2836	g
plug	9	g
shade frame	344	g
shade screen	104	g
switch	8	g
aluminium external case	10	g
capacitor	4	g
heat sink plate	14	g
inductors	1	g
joint-ring	1	g
LED	1	g
LED metal support	14	g
LED power supply	3	g
light diffuser	11	g
metal thread	12	g
plastic internal structure	18	g
Printed Circuit Board (PCB)	5	g
resistor	0.6	g
screws	1	g
Total	4390.6	g

4.2.1.5 Life Cycle Impact Assessment Results

This section presents first the LCIA results for default and sensitivity scenarios. The goal is to identify and understand the most influencing stages or parameters to overall comparative LCA results.

In this section the total environmental impact of the ONA luminaire is highlighted, the differences of the various product's life cycle stages and the possible drivers for the various impact assessment indicators.

Figure 4-8 shows the impacts of the functional unit's life cycle, based on the input given in section 3.1 from the default scenario. Due to the multi-indicator approach, results in the chart are presented in a relative way, normalized to the highest impact of each environmental impact categories among four life cycle stages; however absolute value and also relative value in percentage are available in Table 4-7 for transparency.

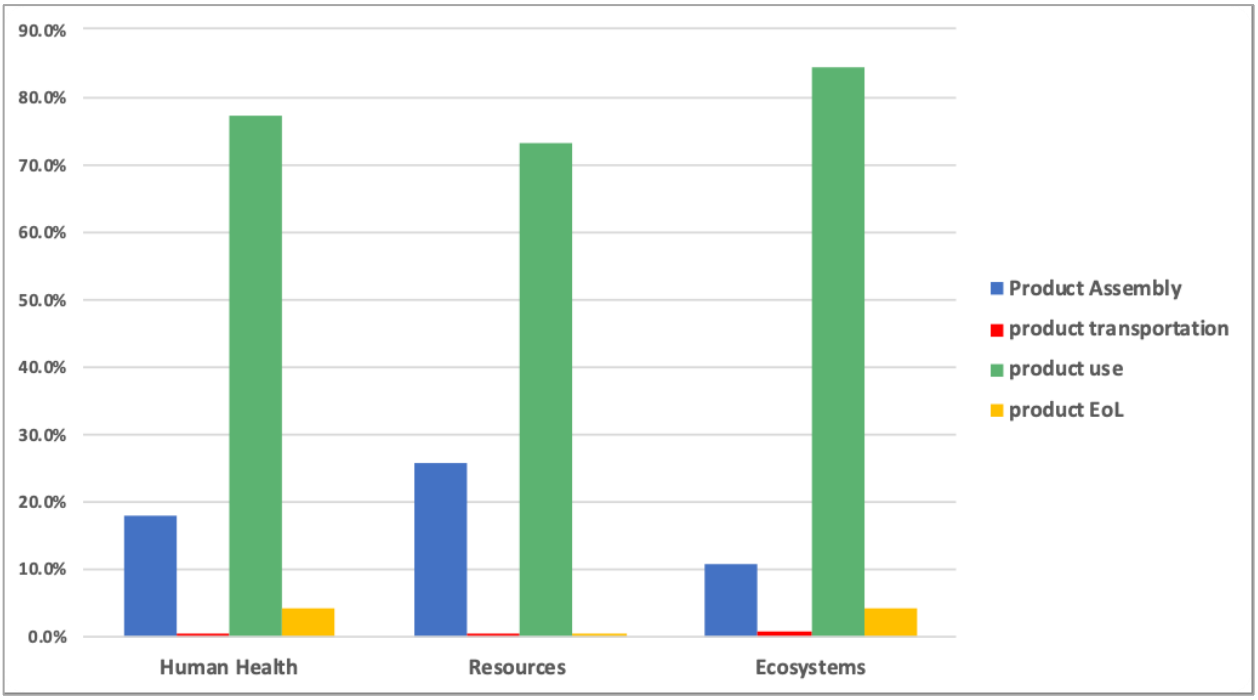


Figure 4-8 Life cycle impact results for the functional unit with the default scenario

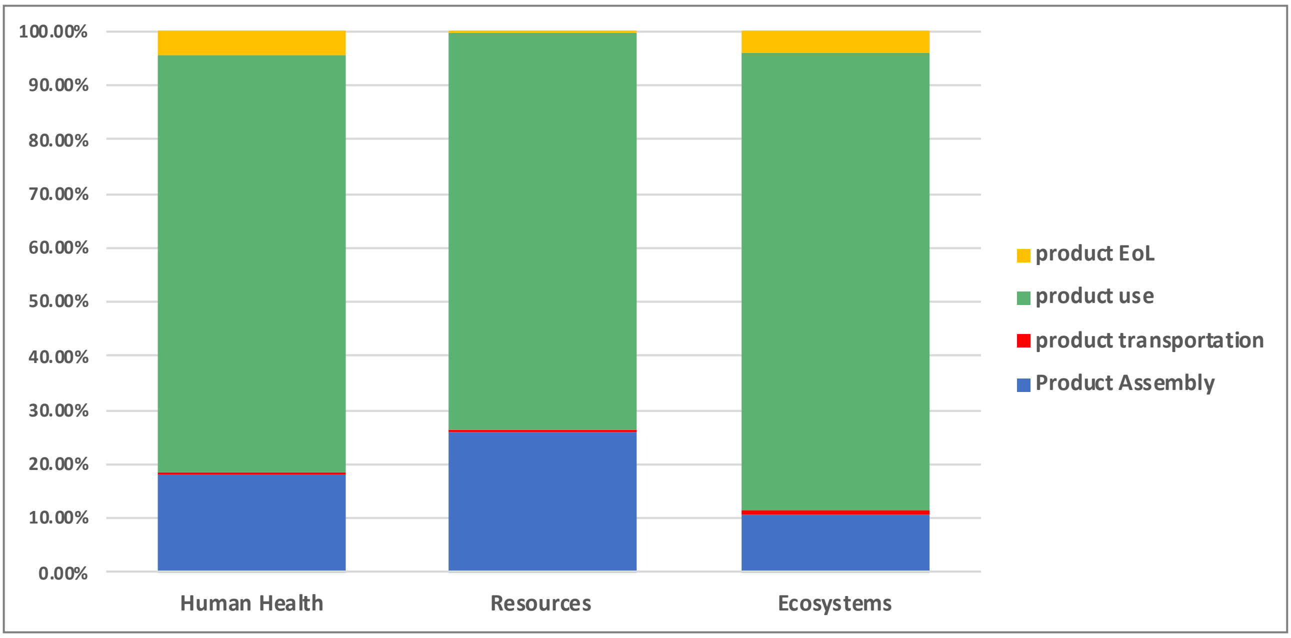


Figure 4-9 Environmental impact (endpoint) per impact category of the luminaire the default scenario

Overall, it appears that the functional unit has higher impacts in the product use and assembly (manufacturing) stage compared to the other stages (transportation). Additionally, human health, resources, ecosystems are dominated by product use and product assembly.

For human health and ecosystems impact, it shows more than 70% of impact come from product use, the rest 30% are associated with product assembly. These values might change depending on the functional unit's life span. In the default scenario, it's assumed to be 40,000 hours.

Table 4-7 Life cycle impact results of product stages under default scenario

Scenario	Product Life Stage	Human Health	Resources	Ecosystems
Default	Product Assembly	7.39E-05 (DALY)	3.00243 ($)	1.93E-07 (species.yr)
Default	product transportation	2.28E-06 (DALY)	0.07365 ($)	1.18E-08 (species.yr)
Default	product use	0.00032 (DALY)	8.53885 ($)	1.52E-06 (species.yr)
Default	product EoL	1.78E-05 (DALY)	0.03863 ($)	7.43E-08 (species.yr)
Percentage normalized to the highest value per impact category				
Default	Product Assembly	18.00%	25.76%	10.74%
Default	product transportation	0.56%	0.63%	0.66%
Default	product use	77.11%	73.27%	84.47%
Default	product EoL	4.34%	0.33%	4.14%

With the ReCiPe method, the single score (Total) for the ONA luminaire is 44.40057 points, as it is shown in Table 4-8. The values per environmental indicator in the benchmark will be used to compare the ONA benchmark product.

Table 4-8 Total environmental impact results – single score of the ONA luminaire

Impact category	Amount	Unit
Agricultural land occupation	0.08898	points
Climate Change	0.7686	points
Freshwater ecotoxicity	0.00586	points
Freshwater eutrophication	0.00272	points
Marine ecotoxicity	0.00105	points
Natural land transformation	0.01152	points
Terrestrial acidification	0.00138	points
Terrestrial ecotoxicity	0.00143	points
Urban land occupation	0.01537	points
Climate Change	5.38194	points
Human toxicity	1.57414	points
Ionising radiation	0.00711	points
Ozone depletion	0.00054	points

Particulate matter formation	1.17977	points
Photochemical oxidant formation	0.00029	points
Fossil depletion	27.43086	points
Metal depletion	8.22901	points
Total	**44.40057**	**points**

4.2.1.6 Interpretation

Overall, it shows that major impacts come from the electricity power generation process in product use stage, and steel production process in the product assembly stage. Also, the luminaire's useful life span is the key factor affecting the impacts.

Among all of the luminaire's components, the main frame contributes the most impacts (10.9% for Human Health, 7.4% for Ecosystems, 20.5% for Resources), which could be considered by the product engineers to replace with other materials instead of steel.

The disposal treatment doesn't have much effect for the environmental impacts of the end of life luminaire with a longer life span (i.e. beyond 20,000 hours). Also, recycling the luminaire's components (e.g. frame, cable) can significantly reduce the resource impacts, which proves the necessity of offering an incentive scheme to encourage consumers to implement more recycling.

The total single score of Human Health, Ecosystems, and Resources for the luminaire in default scenario is 43.68986 points, which is the value of eco-point for ONA domestic lighting product in CIRC4Life project. This eco-point value is rounded up as 44 Points for clear understanding purpose for the general consumers. Also, the eco-point value will be used to support the eco-credit calculations for the lighting product.

Eco-point = 44 Point

4.2.1.7 Recommendations for Sustainable Production

It is important to highlight that there are some features which cannot be accounted for in the environmental impact assessment but that nonetheless contribute to further reduction in its environmental impacts.

Below are listed the main products' features offered by the manufacturer, ONA, contributing to reduce further its environmental impact.

Easy disassembly to facilitate repair/upgrade/recycle:
The benchmark luminaire can be dismantled with a screwdriver easily/fast. Easier/faster disassembly have several benefits: 1) It can facilitate repair, and hence increase its lifespan, 2) It can facilitate upgrade and hence increase its lifespan, and 3) It can facilitate separation of materials at End of Life, and hence recycling.

Longer warranty:
5 years warranty (instead of the 2 years typical standard) contributes to a luminaire longer lifespan. Customers may be more inclined to keep the luminaire if it can be serviced for free for a longer period of

time. This also contributes to recover components and materials during a longer period of time by the company and increases customer satisfaction.

WEEE registration:
ONA has been now registered with the WEEE, which contribute to higher recycling rates of the luminaire.

Recycling scheme to ensure luminaires return:
A system has been designed and put in place to contribute to the extension of the lifespan of the luminaire as long as possible, and to ensure that once its end of life arrives, as much material as possible is re-used and recycled, instead of being landfilled or burnt for energy recovery. The system encourages repair, upgrade, re-use and recycling of the luminaire.

Compliance with RoHS:
The full luminaire complies with RoHS directive, so no toxic materials above the thresholds allowed have been used.
Applying results of this LCA into the sustainable production will be detailed in the Deliverable 1.5 - Report of sustainable design and manufacturing methods that will be due on M18.

4.2.2 Social LCA

4.2.2.1 Functional Unit

The selected functional unit is 1 unit of Table lamp with a reference useful life of 40,000 h. This is a standard luminaire which can provide ambient lighting. The technical specifications are presented by Casamayor, et al., (2017) and summarised in Table 4-9.

Table 4-9 Technical specifications of the luminaire (Casamayor, et al., 2017)

Characteristic	Unit	Value
Weight	g	4,390
Dimensions: x,y,z	cm	41x44x10
Luminous flux of luminaire	lm	102
Illuminance on luminaire's base	lx	882
Luminaire efficacy	lm/W	15
Power consumption of luminaire	W	6.7
Light output ratio	LOR	0.3
Correlated colour temperature (CCT)	K	4,000
Colour rendering index		65
Luminous flux of light source	lm	340
Light source efficacy	lm/W	56
Light source useful life	h	40,000
Light source		LED bulb: E-Core GLS 6W (neutral white) Toshiba

4.2.2.2 Flowchart

Figure 4-10 presents the different stages and main inputs considered for the assessment for the declared functional unit.

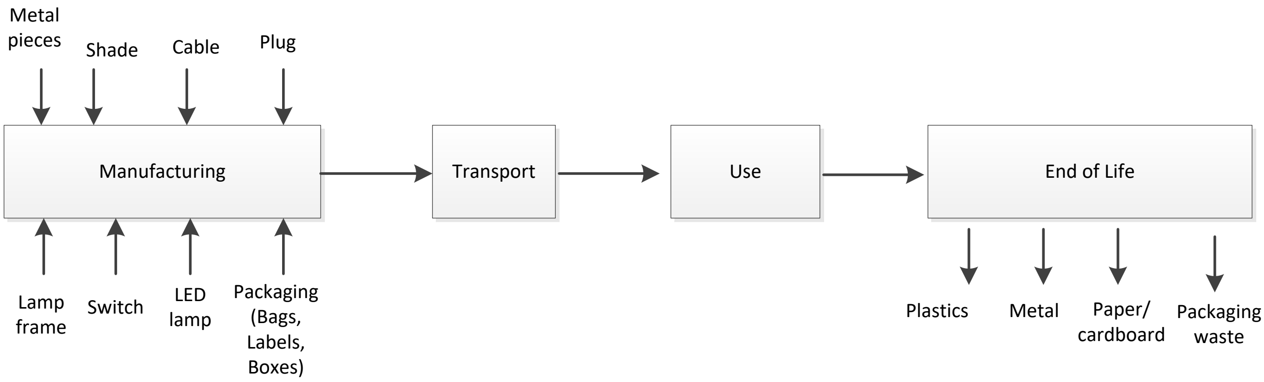


Figure 4-10 ONA's simplified process flowchart. Source: own with data from ONA

4.2.2.3 Boundaries of the System

The boundaries of the study comprise cradle to grave approach. Thus, the product life cycle stages considered includes the following stages:

- **Product:** extraction and production of materials.
- **Manufacture:** Manufacturing activities including packaging.
- **Transportation:** Main destination country: Spain.
- **Use:** The expected useful life of the product considered is 40,000 h. This useful life is considered as a long by the study of (Casamayor et al., 2017). Maintenance activities are out of the scope of the analysis.
- **End of life:** end of life scenario considered for the product and packaging.

Table 4-10 shows the results of the S-LCA of Table Lamp performing the LCI assessment by simulation using SimaPro v8.5.2.0 and PSILCA v2 database. It should be mentioned that the LCI in monetary terms has been worked out. Thus, all cost values and product price were converted into 2011's US$ using the 0.75 €/US$ exchange rate

Table 4-10 ONA´s Table Lamp S-LCA absolute results per impact indicator

Impact Category	Unit	Total	Cable	Lamp frame	LED lamp	Metal pieces	Plug	Shade	Switch	Packaging	Manufacture of domestic appliances /Commodities /ES	Other transport material n.e.c./ Commodities/ES	Other business services/ Commodities/ ES	Production and distribution of electricity/ Commodities/ ES	Recycling /Industries/ ES
Minerals consumption	MC med risk	30.17	0.33	0.05	0.32	6.35	0.10	8.95	0.07	1.04	1.42	0.88	7.85	2.73	0.05
Non-fatal accidents	**NFA med risk**	**64.17**	**0.42**	**0.14**	**0.85**	**17.86**	**0.18**	**16.52**	**0.15**	**2.01**	**3.31**	**1.91**	**14.70**	**6.01**	**0.12**
DALYs indoor/outdoor air & water pollut.	**DALY med ris**	**7.90**	**0.08**	**0.01**	**0.08**	**1.51**	**0.02**	**2.80**	**0.02**	**0.32**	**0.34**	**0.21**	**1.86**	**0.64**	**0.02**
Association and bargaining rights	**ACB med risk**	**20.31**	**0.43**	**0.03**	**0.16**	**2.93**	**0.11**	**9.17**	**0.06**	**1.02**	**0.60**	**0.58**	**4.13**	**1.07**	**0.03**
International migrant stock	IMS med risk	34.88	0.26	0.06	0.40	8.18	0.10	8.25	0.07	0.99	1.68	1.03	10.08	3.72	0.06
Youth illiteracy	**YI med risk**	**27.82**	**0.28**	**0.04**	**0.25**	**5.11**	**0.08**	**10.61**	**0.06**	**1.19**	**1.15**	**0.68**	**6.19**	**2.11**	**0.06**
Weekly hours of work per employee	**WH med risk**	**20.08**	**0.14**	**0.03**	**0.21**	**4.45**	**0.05**	**5.45**	**0.04**	**0.64**	**0.95**	**0.57**	**5.53**	**1.97**	**0.04**
Violations of employ. laws & regulations	**VL med risk**	**30.71**	**0.24**	**0.05**	**0.36**	**6.53**	**0.08**	**9.44**	**0.06**	**1.09**	**1.35**	**0.97**	**7.48**	**3.00**	**0.05**
Net migration	NM med risk	15.63	0.12	0.03	0.19	3.90	0.04	3.35	0.03	0.41	0.76	0.42	4.57	1.79	0.03
Indigenous rights	IR med risk	16.00	0.19	0.02	0.12	2.14	0.05	8.17	0.03	0.90	0.44	0.42	2.80	0.69	0.03
Pollution	**P med risk h**	**25.62**	**0.39**	**0.04**	**0.23**	**4.54**	**0.11**	**9.98**	**0.07**	**1.12**	**1.12**	**0.71**	**5.51**	**1.75**	**0.05**
Frequency of forced labour	FL med risk	7.15	0.07	0.01	0.07	1.42	0.02	2.50	0.02	0.28	0.26	0.19	1.69	0.61	0.02
Goods produced by forced labour	GFL med risk	0.73	0.01	0.00	0.01	0.09	0.00	0.34	0.00	0.04	0.01	0.01	0.15	0.05	0.00
Anti-competitive behaviour	**AC med risk**	**11.44**	**0.11**	**0.02**	**0.12**	**2.51**	**0.04**	**3.38**	**0.03**	**0.39**	**0.55**	**0.30**	**2.98**	**1.00**	**0.02**
Corruption	C med risk h	92.81	0.86	0.16	1.17	20.82	0.28	29.96	0.21	3.45	4.74	2.47	20.83	7.70	0.17
Illiteracy	**I med risk h**	**60.28**	**0.67**	**0.09**	**0.54**	**10.99**	**0.19**	**23.77**	**0.13**	**2.66**	**2.27**	**1.39**	**12.96**	**4.48**	**0.14**
Fossil fuel consumption	FF med risk	7.44	0.07	0.01	0.07	1.45	0.02	2.46	0.02	0.28	0.41	0.22	1.81	0.60	0.01
Workers affected by natural disasters	**ND med risk**	**9.31**	**0.15**	**0.01**	**0.09**	**1.76**	**0.04**	**3.24**	**0.03**	**0.37**	**0.42**	**0.27**	**2.21**	**0.71**	**0.02**
Internt. migrant workers. in sector/site	IMW med risk	32.07	0.25	0.05	0.36	7.44	0.08	8.27	0.06	0.96	1.27	1.01	9.05	3.22	0.06
Unemployment	**U med risk h**	**68.17**	**0.39**	**0.13**	**0.88**	**18.22**	**0.17**	**12.06**	**0.14**	**1.52**	**3.42**	**1.85**	**20.68**	**8.57**	**0.13**
Biomass consumption	**BM med risk**	**59.93**	**0.48**	**0.09**	**0.58**	**11.43**	**0.16**	**20.71**	**0.12**	**2.36**	**2.33**	**1.74**	**14.97**	**4.84**	**0.11**
Child Labour	CL med risk	23.74	0.44	0.03	0.19	3.50	0.11	11.07	0.07	1.23	1.07	0.55	4.30	1.14	0.04
Drinking water coverage	**DW med risk**	**14.14**	**0.14**	**0.02**	**0.13**	**2.48**	**0.04**	**5.52**	**0.03**	**0.62**	**0.99**	**0.37**	**2.84**	**0.92**	**0.03**
Education	**E med risk h**	**41.53**	**0.36**	**0.07**	**0.46**	**9.21**	**0.12**	**11.66**	**0.09**	**1.36**	**1.99**	**1.13**	**10.92**	**4.07**	**0.08**
Fair Salary	**FS med risk**	**86.23**	**1.01**	**0.13**	**0.83**	**16.46**	**0.30**	**30.57**	**0.20**	**3.47**	**3.79**	**2.23**	**20.37**	**6.71**	**0.16**
Safety measures	**SM med risk**	**36.47**	**0.43**	**0.09**	**0.43**	**10.94**	**0.15**	**10.33**	**0.12**	**1.27**	**1.43**	**1.00**	**7.32**	**2.87**	**0.09**
Gender wage gap	**GW med risk**	**45.86**	**0.28**	**0.07**	**0.37**	**8.49**	**0.11**	**13.46**	**0.08**	**1.55**	**1.63**	**1.02**	**14.98**	**3.71**	**0.10**

Impact Category	Unit	Total	Cable	Lamp frame	LED lamp	Metal pieces	Plug	Shade	Switch	Packaging	Manufacture of domestic appliances /Commodities /ES	Other transport material n.e.c./ Commodities/ES	Other business services/ Commodities/ ES	Production and distribution of electricity/ Commodities/ ES	Recycling /Industries/ ES
Trafficking in persons	TP med risk	15.64	0.21	0.02	0.14	2.72	0.06	6.12	0.04	0.69	1.03	0.37	3.22	1.00	0.03
Fatal accidents	**FA med risk**	**9.92**	**0.10**	**0.02**	**0.11**	**1.91**	**0.03**	**3.55**	**0.02**	**0.40**	**0.41**	**0.30**	**2.30**	**0.76**	**0.02**
Social security expenditures	SS med risk	25.77	0.36	0.04	0.22	4.40	0.10	10.66	0.06	1.19	0.99	0.64	5.33	1.73	0.05
Industrial water depletion	**WU med risk**	**43.37**	**0.38**	**0.07**	**0.43**	**8.40**	**0.12**	**13.82**	**0.09**	**1.59**	**2.33**	**1.51**	**11.03**	**3.51**	**0.07**
Trade unionism	TU med risk	99.28	0.66	0.17	1.11	22.19	0.25	27.40	0.20	3.22	4.47	2.81	26.74	9.88	0.19
Sanitation coverage	**SC med risk**	**42.55**	**0.49**	**0.06**	**0.33**	**6.29**	**0.14**	**20.22**	**0.10**	**2.25**	**1.43**	**0.92**	**8.07**	**2.17**	**0.07**
Health expenditure	**HE med risk**	**76.42**	**0.71**	**0.12**	**0.76**	**15.32**	**0.23**	**25.97**	**0.16**	**2.97**	**3.31**	**1.87**	**18.38**	**6.46**	**0.15**
Certified environmental management syst.	**CMS med risk**	**76.22**	**0.55**	**0.10**	**0.57**	**11.78**	**0.18**	**26.35**	**0.13**	**2.97**	**3.67**	**2.41**	**21.66**	**5.71**	**0.14**

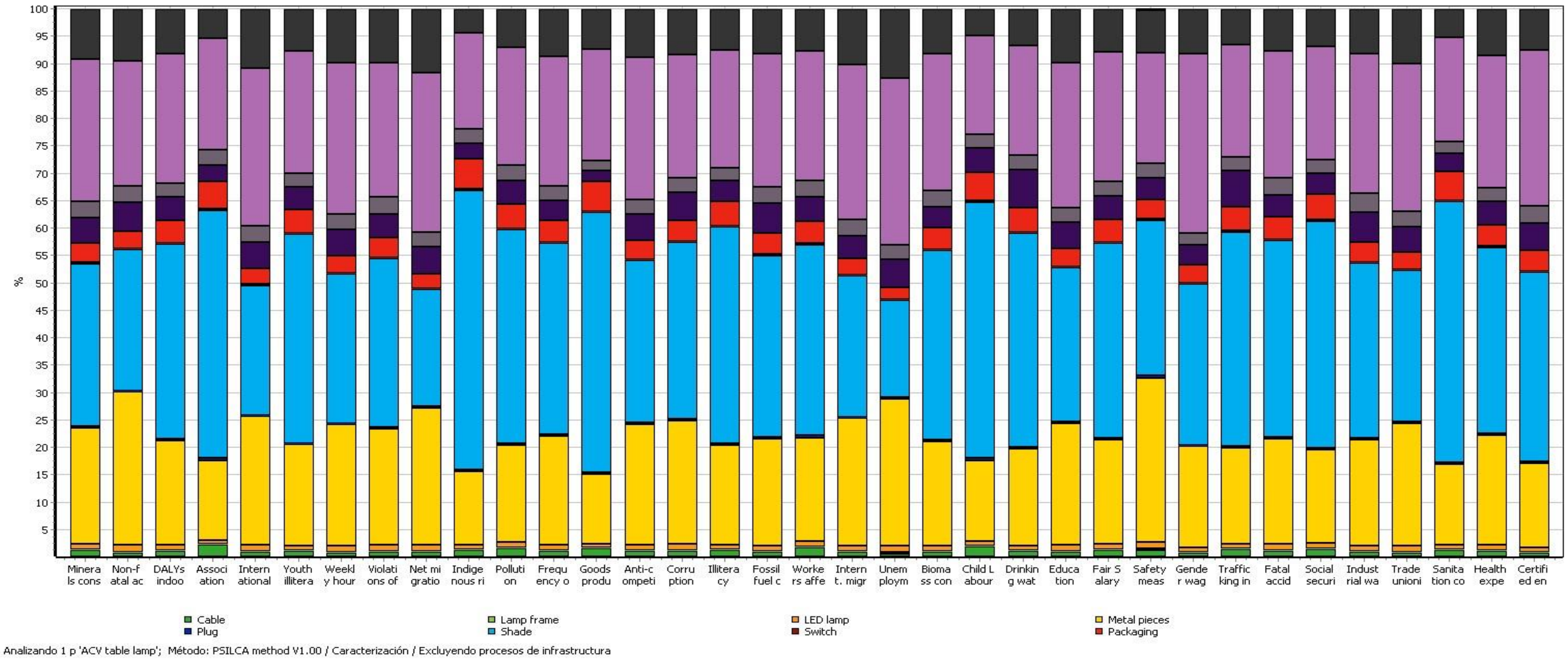


Figure 4-11 Contribution of the stages in ONA´s Table Lamp S-LCA results

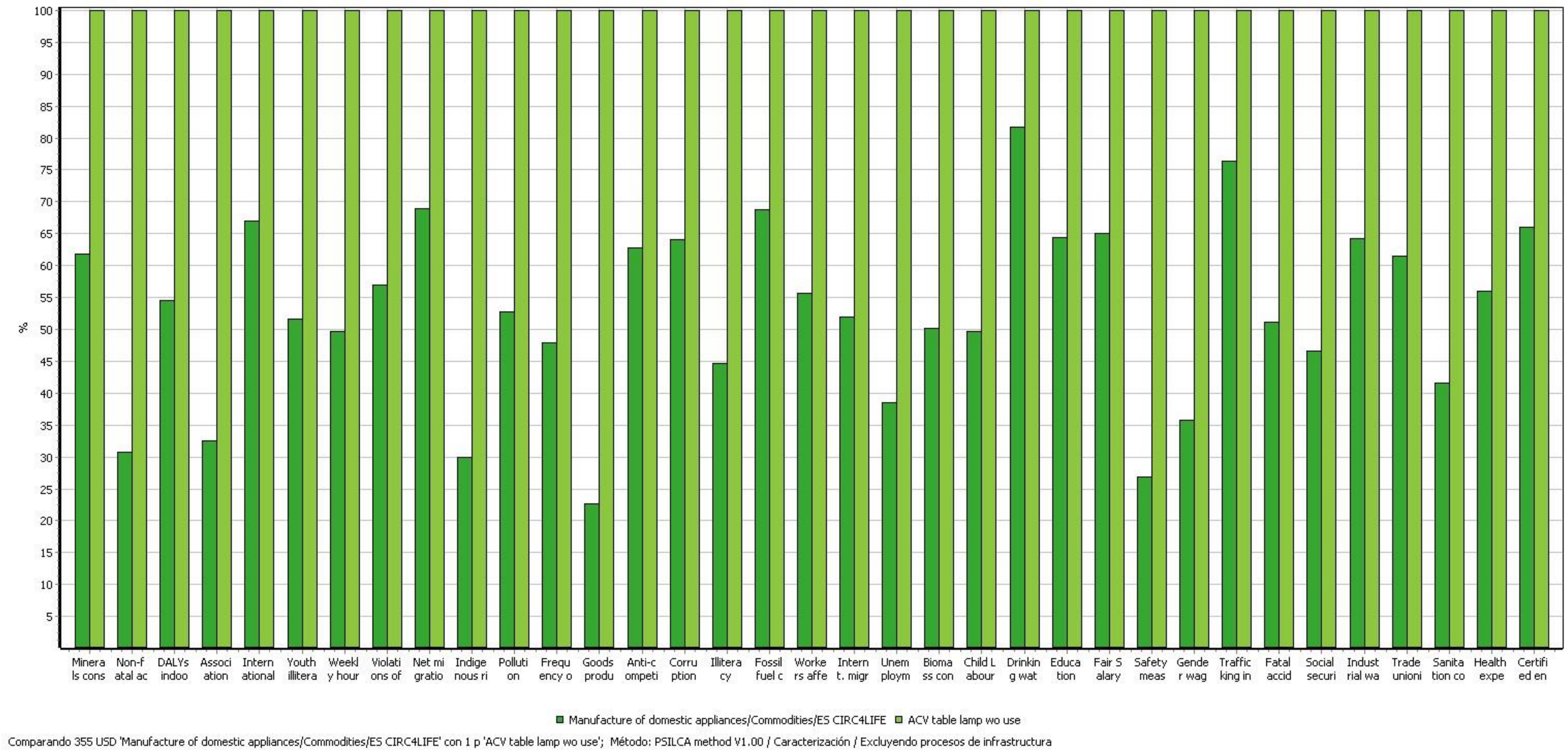


Figure 4-12 Table Lamp S-LCA vs PSILCA reference sector

As can be seen in Figure 4-11, the metal pieces plus the shade represent more than 45% if the impact in all social impact categories. The category of "Other business services/Commodities/ES" also represents an important part of the impact. This category represents the "indirect costs", which are all costs related to business activities as the difference between the final price and all the cost stated in LCI. In this case, the indirect costs estimated for the Table Lamp is 109.6 US$ which represents 37% of the final price of the product. It should be mentioned that an important part of this percentage corresponds to the commercial margin of the company. In addition, use phase (electricity consumption during 40.000 hours of lifetime) corresponds to 51,9 US$ being the fourth most important variable in terms of social impact.

Table 4-11 Comparative results of Table Lamp S-LCA vs PSILCA reference sector

Categoría de impacto	Unidad	Manufacture of domestic appliances/Commodities/ES	S-LCA table lamp w/o use
Minerals consumption	MC med risk	16.97	27.44
Non-fatal accidents	NFA med risk	17.85	58.16
DALYs indoor/outdoor air & water pollut.	DALY med ris	3.96	7.26
Association and bargaining rights	ACB med risk	6.26	19.24
International migrant stock	IMS med risk	20.85	31.17
Youth illiteracy	YI med risk	13.26	25.71
Weekly hours of work per employee	WH med risk	9.00	18.12
Violations of employ. laws & regulations	VL med risk	15.79	27.70
Net migration	NM med risk	9.55	13.84
Indigenous rights	IR med risk	4.57	15.31
Pollution	P med risk h	12.59	23.87
Frequency of forced labour	FL med risk	3.14	6.54
Goods produced by forced labour	GFL med risk	0.15	0.67
Anti-competitive behaviour	AC med risk	6.55	10.44
Corruption	C med risk h	54.59	85.11
Illiteracy	I med risk h	24.94	55.80
Fossil fuel consumption	FF med risk	4.71	6.84
Workers affected by natural disasters	ND med risk	4.79	8.60
Internt. migrant workers. in sector/site	IMW med risk	15.00	28.85
Unemployment	U med risk h	22.94	59.60
Biomass consumption	BM med risk	27.67	55.10
Child Labour	CL med risk	11.22	22.61
Drinking water coverage	DW med risk	10.79	13.21
Education	E med risk h	24.15	37.46
Fair Salary	FS med risk	51.67	79.52

Safety measures	SM med risk	9.03	33.60
Gender wage gap	GW med risk	15.06	42.15
Trafficking in persons	TP med risk	11.19	14.64
Fatal accidents	FA med risk	4.68	9.16
Social security expenditures	SS med risk	11.20	24.04
Industrial water depletion	WU med risk	25.62	39.86
Trade unionism	TU med risk	54.95	89.39
Sanitation coverage	SC med risk	16.79	40.38
Health expenditure	HE med risk	39.20	69.95
Certified environmental management syst.	CMS med risk	46.54	70.

In order to compare these results with the Spanish representative sector in PSILCA, Table 4-11 and Figure 4-12 shows the comparative results of the Table Lamp S-LCA and the Manufacture of domestic appliances/Commodities/Spain. It should be mentioned that for the reference sector, the worker hours estimated for ONA of 0.01480 h/US$ and ONA´s risk levels factors for the indicators studied were considered. In addition, since PSILCA database covers a cradle to gate approach, comparison is made accordingly.

4.2.2.4 Recommendations

Through the materiality analysis, it was identified the Access to material resources (local community), Health and Safety (consumers), fair salary (workers) and contribution to economic development (society) are among the subcategories with a high significance for ONA in relation with the product analysed. In addition, they have also identified the access to material resources (local community) and Health and Safety (consumers) as relevant subcategories with a high influence on stakeholders' perceptions of the product. Risk estimation made in the Social Life Cycle Impact assessment evaluate the aforementioned categories pointing out the following:

- The presence of certified environmental management systems has a value of very high risk. A certification in environmental management systems (CEMS) (e.g. ISO 14001) is recommended to improve this score.
- The Level of industrial water use has a better score (very low risk vs low risk) in comparison to the reference sector in PSILCA.
- The low percentage of employees organised in trade unions has a score of very high risk, that can be improved promoting related activities in the company.
- The null ratio of accidents at workplace has a very low risk score in comparison to the reference sector in PSILCA. Internal activities to maintain this ratio is recommended.
- Even gender wage gap has a negative value (-19,58%) this represents a medium risk in social terms. However, still being a better score in comparison to the reference sector in PSILCA (high risk).

Regarding the S-LCA results, attention should be paid during the selection of materials for the proposed innovation, mainly those related to replace or improve the scores of the metal pieces (mainly virgin stainless steel and Iron) and the shade. In addition, it must be taken into account that indirect costs (including commercial margin) have a representative impact in each indicator studied. This is a characteristic of this sector where products are designed in ONA and then send to the providers for its manufacturing. Finally, due the use phase has also a representative impact in the results, options with a lower power of lamp could improve the final scores.

4.3 Meat Products

4.3.1 Environmental LCA

For the purposes of the LCA of meat products, SimaPro tool, Release 8.5.2.0 was used. The objective of environmental LCA was to assess the environmental performance of the production of pork products, including cured pork sausage and cured pork loin, in its lifecycle from the production of feed for pigs, the pig farm, via slaughterhouse to meat processing plant. This is based in the Murcia Region of Spain.

LCA took into account following phases:

- Assessment of production of food for pigs.
- Assessment of farming of pigs.
- Assessment of slaughterhouse activities.
- Assessment of processing of meat.
- Assessment of distribution of products.

The analysis was carried out in four steps:

- Defining the purpose and the scope of research.
- Analysis of a data set of inputs and outputs - Life Cycle Inventory.
- Life Cycle Impact Assessment
- Interpretation of the results.

4.3.1.1 Functional Unit

The functional unit adopted for the study is 1 kg of meat products: 1 kg of pork sausage and 1 kg of pork loin - as final product to the customer although they do not represent the actual products. For the purposes of the demonstration of eco-point application for CIRC4Life project the results obtained within the study was converted into a pack of products:

- cured pork sausages: Longaniza Imperial de Lorca of the weight of about 250 g.
- cured pork loin: Lomo Embuchado Mitades of the weight of about 900g**.**

4.3.1.2 System Boundary

The production chains of pork cured sausage and pork cured loin consist of different production steps: feed production, pig housing, slaughtering, meat processing. This study is a ‘cradle to gate’ life cycle assessment in which the consumption and post-consumption stage are excluded from analysis. The system boundary of the LCA of meat products is presented in Figure 4-13.

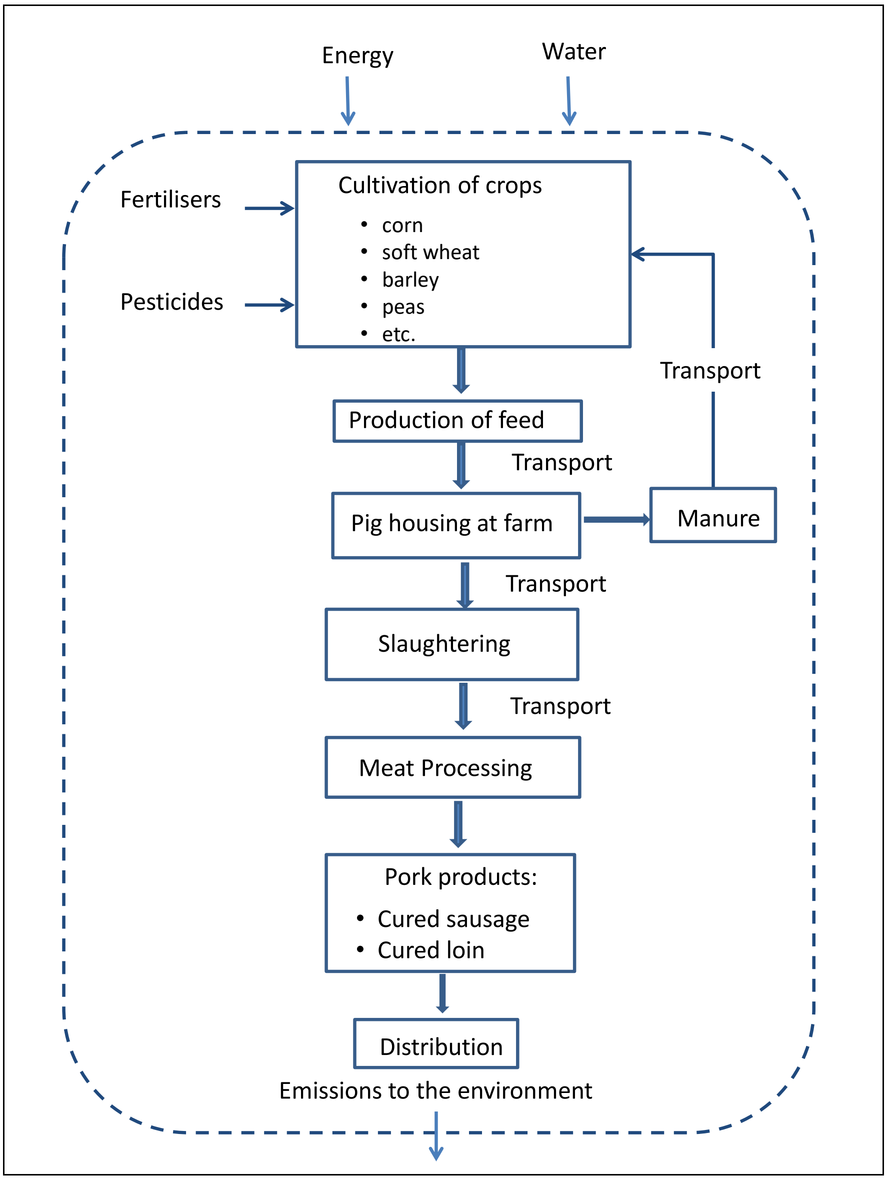


Figure 4-13 The overview of the system boundary of the LCA of meat products

4.3.1.3 Life Cycle Inventory

Inventory data were provided by SAT- ALIA and for some parameters the values from the Ecoinvent™ database version 3 were adjusted based on the information provided and expert knowledge and literature. The inventory data is presented in The Life Cycle Assessment of meat products (internal Report).

4.3.1.4 Life Cycle Impact Assessment Results

Cured Pork Loin.

The main driver for all impact categories is the feed production phase. The two phases: pig farming and slaughterhouse have twice lower environmental impacts then the production phase. This phase is sensitive to the source of feed compounds (especially in the case of soya). Meat processing has a comparably small influence than other phases.

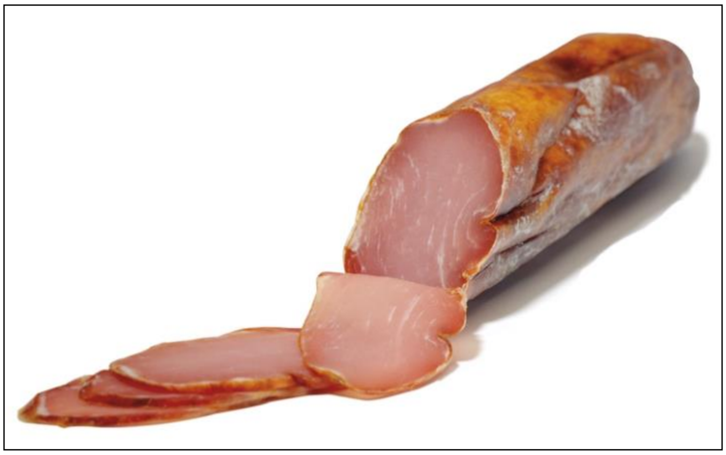
The most important impacts of the full life cycle of cured pork loin production concern human health and ecosystem. The impact on resources is relatively low.

The single score of the FU 1 kg cured pork loin is 420 mPt (0.420 Pt). The single score of the product of weight 0,9kg which are sold to consumers is 378 mPt (0.378 Pt).

The main processes contributing to impact damage of human health are pig farming, feed production. Slaughtering activities and meat processing have a slightly smaller impact in this category.

The main process contributing to impact damage of ecosystems is feed production. The other phases, including slaughtering, pig farming and meat processing are less important in this category.

The main processes contributing to damage to resources are meat processing, slaughtering and feed production.



Eco-point = 0.42 Points

Cured pork sausage

The main driver for all impact categories is the feed production phase. The two phases: pig farming and slaughterhouse have twice lower environmental impacts than phase of feed production phase. Meat processing – opposite to the production of cured loin – also has a big influence on the environment.

The most important impacts of the full life cycle of the cured sausage production, just like in the case of cured loin production concern human health and ecosystem. The impact on resources is relatively low.
The single score of the FU 1 kg cured pork sausage is 462 mPt (0.462 Pt). The single score of the product of weight 0.25g which are sold to consumers is 115.5 mPt (0.1155 Pt).

The main processes contributing to damage to human health are meat processing and feed production. Pig farming slaughtering activities are characterised by slightly smaller impact.

The main process contributing to damage to ecosystems is feed production. The other phases, including meat elaboration, pig farming and slaughterhouse are relatively of minor importance.

The main process contributing to damage to resources is meat processing. Slaughtering, feed production and pig housing have smaller impact in this category.

Eco-point = 0.462 Points

Recommendations

- It is recommended to use waste materials from agricultural production for animal feed production. It is very important that the waste originates in food production processes based on locally available materials.
- It is crucial to pay attention to the origin of agricultural raw materials used for the production of feed. It is preferred to use locally produced materials.
- Pig farming causes emissions of gases to the environment related to stable and manure management and for this reason it is recommended to use air protection solutions.
- Animal wastes should be managed in a sustainable way thanks to which it will be possible to obtain maximum benefits for the company with a minimum impact on the environment. Animal manures are valuable sources of nutrients and organic matter for use in the maintenance of soil fertility and crop production. It can be also used for energy production with consecutive production of residual material from fermentation that can be used as fertiliser.
- Implementation of effective and environmental-friendly methods of utilisation of dead animals is a crucial element of waste management. At the same time, it is important to keep the level of mortality of the stock as low as possible considering also the humanitarian aspects of husbandry.
- It is recommended for pig farms to use renewable energy for heating purposes, based on biomass preferably from local sources.
- For feed production, pig farming and meat processing it is recommended to use renewable electricity. One of the options might be electrical energy from cogeneration based on local sources, or renewable energy from the grid.
- Transport plays an important role in all phases of meat production and processes. Increasing of effectiveness of transport will minimise its negative environmental effects

4.3.2 Social LCA

The products under analysis are curated pork meat, in two qualities and formats:

- curated pork sausage, with commercial name: “Longaniza imperial”. It is presented in 250 g pieces
- Curated pork loin, with commercial name: “Lomo embuchado”. It is presented in 900 g pieces

The products are manufactured by ALIA. ALIA is an agri-food cooperative with 245 workers dealing with animal food manufacturing, animal breeding and pork meat products, located in Lorca (Spain). The company encircles vertically all the activities and processes needed to fully produce ready-to-eat pork meats starting by animal feed products, following by pork breeding and slaughtering, and finishing by packaging and distribution. The company's section that produces meat final products is called "Los Quijales".

4.3.2.1 Functional Unit

For each product, 1 kg of product is selected as functional unit. The product consists of 1 kg of pork meat and the associated packaging film, delivered to the end user purchasing spots.

4.3.2.2 Flowchart

The main process steps are:

- Animal feed manufacturing. The main outputs are food for brittles and food for piglets. 0.92% of all the animal food goes to the Alia's farm
- Farm where piglets get born and grow up. The output are 9 months-old pigs of about 110 kg each. There are an average 5% losses in the process.
- Slaughtering. The main consumption is energy and labour. 85 kg of meat per animal are used for meat products manufacturing.
- Pork Sausage manufacturing. 1.35 kg of a given quality pork meat is used for 1 kg of sausage product.
- Pork loin manufacturing. 1.4 kg of a given quality pork meat is used for 1 kg of pork loin product.
- Packaging and transport by ALIA's own means. External retailer distribution is out of this analysis.

We take the 2011's US dollar to Euro exchange rate to convert today's costs in euros into 2011's costs in dollars. The exchange rate at 31/12/2011 was 0.75 euros per dollar. We assume similar levels of currency devaluation in the time period.

The model of activities is made up by four main impact contributors that include:

- **Agricultural products used for animal feed manufacturing**, all coming from nearby suppliers at regional and national level. The input of the process in economic terms is 0.69 US$ of agricultural raw materials per kg of pork meat. This process is external and provided by external ALIA's suppliers.
- **Animal food manufacturing.** This process is fully run by ALIA and the input is 3.69 kg of agricultural raw material per kg of animal food or 0.69 US$ of raw materials per functional unit, plus an amount of other inputs like water, energy, labour, transport, packaging and other costs, totalling 0.94 US$ per kg of pork meat.
- **Farming and breeding.** The input of this process is 3.06 kg of animal food per kg of alive animal. Per functional unit, we input 0.94 US$ of animal food and 0.85 US$ of energy, labour, water, medicines, transport and other costs. The process is entirely done at ALIA's premises.
- **Pork meat product manufacturing.** Including slaughtering, product manufacturing and distribution. The process is made by ALIA's partner "Los Quejigos". It needs 1.24 kg of alive animal per kg of meat. The input is 1.8 US$ of alive meat per kg of produced meat. Other inputs at slaughtering account for 0.75 US$ per kg of meat. This process is common, but different meat is used for the two processes under analysis. Therefore, two different processes have been designed according to the product to analyse:
  - **Pork Sausage manufacturing**. 1.35 kg of pork meat, sausage quality, is used per kg sausage product. Inputs at manufacturing and distribution amount at 2.53 US$ of pork meat and 6.13 US$ of other costs.
  - **Pork Loin manufacturing**. 1.4 kg of pork meat, pork loin quality, is used per kg of loin product. Inputs at manufacturing and distribution amount at 4 US$ of pork meat and 6.42 US$ of other costs.

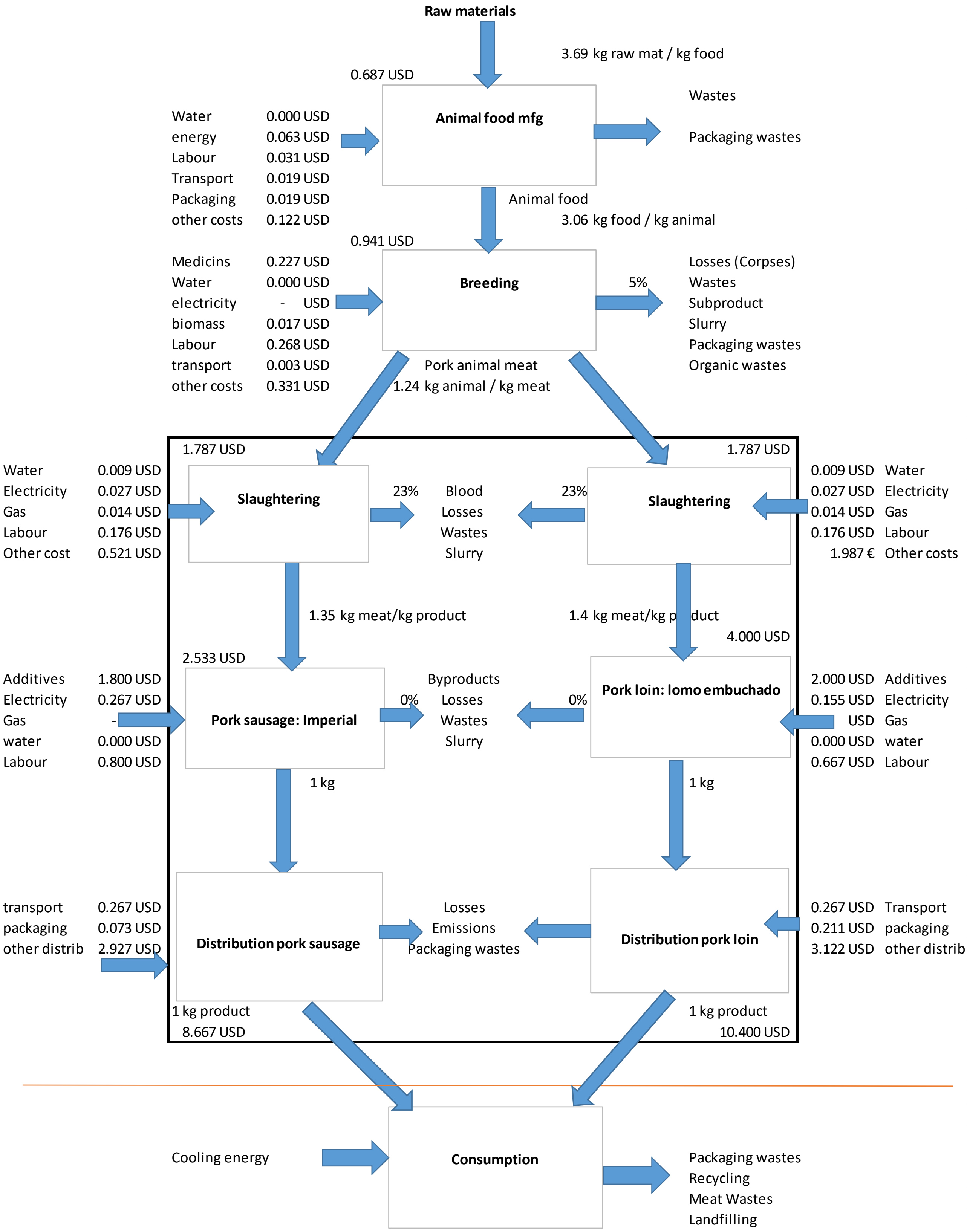


Figure 4-14 ALIA's process flowchart and S-LCA input / output scheme in 2011 US$

The final input cost for the pork sausage value chain is 8.7 US$/kg while the input cost for pork loin is 10.4 US$/kg.

With the results of the Social Life Cycle Impact Assessment and the social risks assessed, two new processes called "manufacture of meat products ALIA sausage" and "manufacture of meat products ALIA pork loin" are created and calibrated, taking as a basis the PSILCA manufacturing of meat products in Spain. Using the new ratio of cost per hour and dollar of output calculated, the results are expressed in medium risk average hours for every social impact indicator. In absolute terms, results per each life cycle category are indicated in Table 4-12, where relevant indicators for the main subcategories described are marked in bold. It is important to remark that, although expressed in medium risk hours, comparisons between indicators should not be made.

Table 4-12 ALIA's pork sausage social LCA absolute results per impact indicator and life cycle stage

Impact category	Unit	Total Pork sausage	Products of agriculture	feeds for farm	Farming	Sausage mfg ALIA
Minerals consumption	MC med risk	0.203	0.033	0.016	0.040	0.114
Non-fatal accidents	**NFA med risk**	**0.566**	**0.068**	**0.042**	**0.098**	**0.359**
DALYs indoor/outdoor air & water pollut.	**DALY med ris**	**0.043**	**0.007**	**0.003**	**0.008**	**0.024**
Association and bargaining rights	**ACB med risk**	**0.043**	**0.012**	**0.003**	**0.007**	**0.022**
International migrant stock	IMS med risk	0.282	0.042	0.023	0.058	0.160
Youth illiteracy	**YI med risk**	**0.137**	**0.024**	**0.011**	**0.027**	**0.076**
Weekly hours of work per employee	**WH med risk**	**0.136**	**0.023**	**0.012**	**0.030**	**0.071**
Violations of employ. laws & regulations	**VL med risk**	**0.277**	**0.044**	**0.023**	**0.056**	**0.155**
Net migration	NM med risk	0.134	0.020	0.011	0.028	0.076
Indigenous rights	IR med risk	0.036	0.009	0.002	0.005	0.019
Pollution	**P med risk h**	**0.110**	**0.021**	**0.009**	**0.020**	**0.060**
Frequency of forced labour	FL med risk	0.041	0.007	0.003	0.008	0.023
Goods produced by forced labour	GFL med risk	0.002	0.001	0.000	0.000	0.001
Anti-competitive behaviour	**AC med risk**	**0.076**	**0.013**	**0.006**	**0.015**	**0.043**
Corruption	C med risk h	0.468	0.079	0.038	0.090	0.261
Illiteracy	**I med risk h**	**0.276**	**0.048**	**0.021**	**0.054**	**0.152**
Fossil fuel consumption	FF med risk	0.044	0.008	0.003	0.008	0.025
Workers affected by natural disasters	**ND med risk**	**0.047**	**0.009**	**0.004**	**0.009**	**0.026**
Internt. migrant workers, in sector/site	IMW med ris	0.211	0.037	0.017	0.045	0.112
Unemployment	**U med risk h**	**0.542**	**0.090**	**0.053**	**0.137**	**0.262**
Biomass consumption	**BM med risk**	**0.318**	**0.060**	**0.027**	**0.066**	**0.164**
Child Labour	CL med risk	0.052	0.014	0.004	0.007	0.027
Drinking water coverage	**DW med risk**	**0.063**	**0.012**	**0.005**	**0.011**	**0.036**
Education	**E med risk h**	**0.297**	**0.046**	**0.024**	**0.060**	**0.167**
Fair Salary	**FS med risk**	**0.461**	**0.080**	**0.036**	**0.087**	**0.258**
Safety measures	**SM med risk**	**0.393**	**0.055**	**0.022**	**0.075**	**0.240**
Gender wage gap	**GW med risk**	**0.332**	**0.050**	**0.025**	**0.067**	**0.189**
Trafficking in persons	TP med risk	0.065	0.012	0.005	0.011	0.036
Fatal accidents	**FA med risk**	**0.045**	**0.008**	**0.004**	**0.009**	**0.025**

Impact category	Unit	Total Pork sausage	Products of agriculture	feeds for farm	Farming	Sausage mfg ALIA
Social security expenditures	SS med risk	0.105	0.020	0.008	0.020	0.057
Industrial water depletion	**WU med risk**	**0.270**	**0.048**	**0.021**	**0.051**	**0.150**
Trade unionism	TU med risk	0.736	0.113	0.059	0.150	0.415
Sanitation coverage	**SC med risk**	**0.123**	**0.029**	**0.009**	**0.020**	**0.065**
Health expenditure	**HE med risk**	**0.444**	**0.073**	**0.035**	**0.088**	**0.248**
Certified environmental management syst.	**CMS med risk**	**0.386**	**0.090**	**0.049**	**0.101**	**0.146**

In relative terms, the distribution of the 4 main processes reflect a higher share of the manufacturing process, as inputs are also relatively higher than the rest of the process, in both products. Slaughtering, manufacturing and distribution and commercialization account for 54% to 60% of total social LCA impacts in both products. The second most important process is farming (about 20%), followed by agricultural products (15%). Figure 4-15 shows the ALIA´s pork sausage S-LCA relative result per life cycle step.

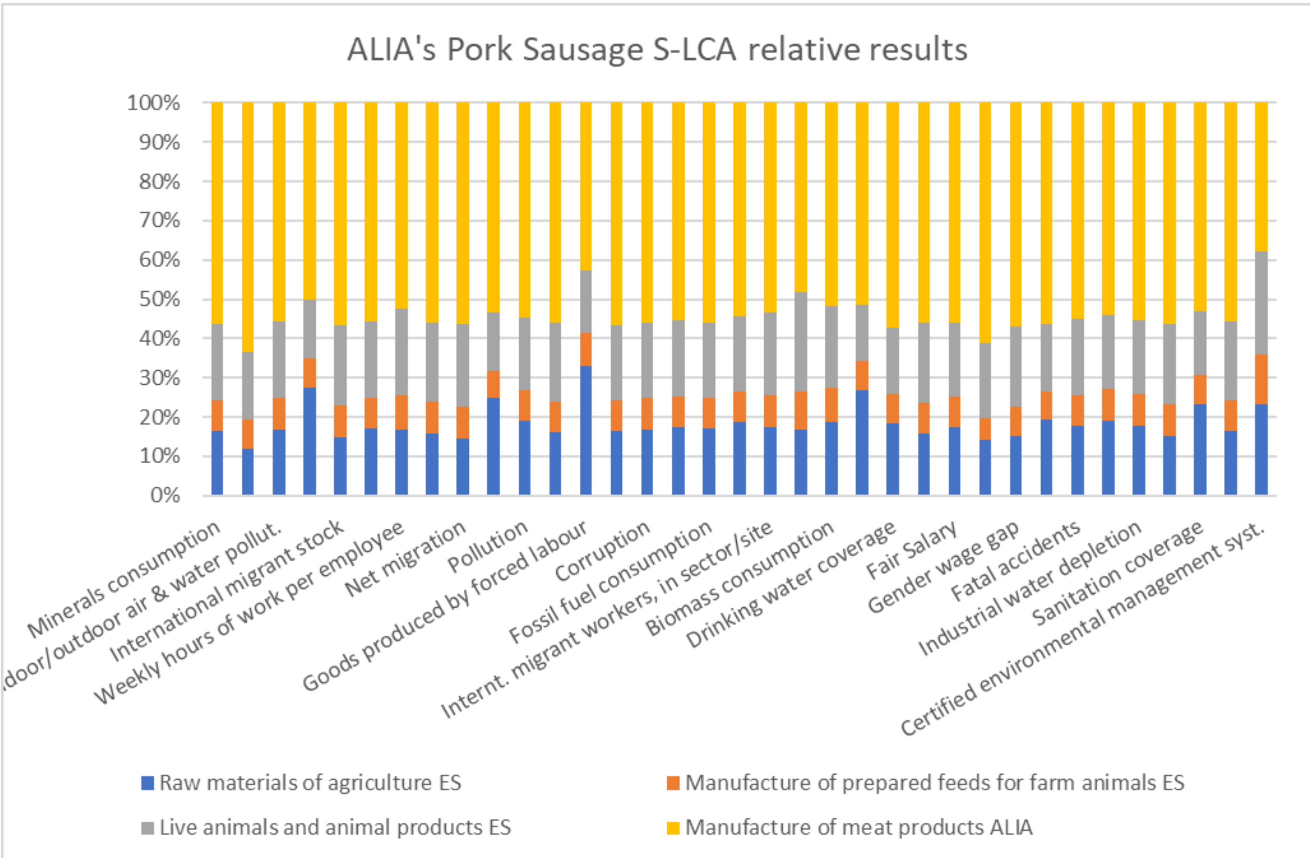


Figure 4-15 ALIA's pork sausage Social LCA relative result per life cycle step.

The absolute results for pork loin are shown in Table 4-13. Values are higher than for pork sausage, due to the higher input value in the mfg of pork loin with respect to the sausage (more pork meat and higher quality meat).

Table 4-13 ALIA's pork loin social LCA absolute results per impact indicator and life cycle stage

Impact category	Unit	Total Pork loin	Products of agriculture	feeds for farm	Farming	pork loin ALIA
Minerals consumption	MC med risk	0.232	0.033	0.016	0.040	0.143
Non-fatal accidents	**NFA med risk**	**0.658**	**0.068**	**0.042**	**0.098**	**0.450**
DALYs indoor/outdoor air & water pollut.	**DALY med ris**	**0.049**	**0.007**	**0.003**	**0.008**	**0.030**
Association and bargaining rights	**ACB med risk**	**0.049**	**0.012**	**0.003**	**0.007**	**0.027**
International migrant stock	IMS med risk	0.323	0.042	0.023	0.058	0.200
Youth illiteracy	**YI med risk**	**0.156**	**0.024**	**0.011**	**0.027**	**0.096**
Weekly hours of work per employee	**WH med risk**	**0.154**	**0.023**	**0.012**	**0.030**	**0.090**
Violations of employ. laws & regulations	**VL med risk**	**0.317**	**0.044**	**0.023**	**0.056**	**0.194**
Net migration	NM med risk	0.154	0.020	0.011	0.028	0.095
Indigenous rights	IR med risk	0.040	0.009	0.002	0.005	0.024
Pollution	**P med risk h**	**0.126**	**0.021**	**0.009**	**0.020**	**0.076**
Frequency of forced labour	FL med risk	0.047	0.007	0.003	0.008	0.029
Goods produced by forced labour	GFL med risk	0.002	0.001	0.000	0.000	0.001
Anti-competitive behaviour	**AC med risk**	**0.087**	**0.013**	**0.006**	**0.015**	**0.054**
Corruption	C med risk h	0.534	0.079	0.038	0.090	0.328
Illiteracy	**I med risk h**	**0.314**	**0.048**	**0.021**	**0.054**	**0.191**
Fossil fuel consumption	FF med risk	0.051	0.008	0.003	0.008	0.031
Workers affected by natural disasters	**ND med risk**	**0.053**	**0.009**	**0.004**	**0.009**	**0.032**
Internt. migrant workers, in sector/site	IMW med risk	0.240	0.037	0.017	0.045	0.141
Unemployment	**U med risk h**	**0.609**	**0.090**	**0.053**	**0.137**	**0.329**
Biomass consumption	**BM med risk**	**0.360**	**0.060**	**0.027**	**0.066**	**0.206**
Child Labour	CL med risk	0.059	0.014	0.004	0.007	0.034
Drinking water coverage	**DW med risk**	**0.072**	**0.012**	**0.005**	**0.011**	**0.045**
Education	**E med risk h**	**0.340**	**0.046**	**0.024**	**0.060**	**0.209**
Fair Salary	**FS med risk**	**0.527**	**0.080**	**0.036**	**0.087**	**0.324**
Safety measures	**SM med risk**	**0.454**	**0.055**	**0.022**	**0.075**	**0.302**
Gender wage gap	**GW med risk**	**0.380**	**0.050**	**0.025**	**0.067**	**0.237**
Trafficking in persons	TP med risk	0.074	0.012	0.005	0.011	0.046
Fatal accidents	**FA med risk**	**0.051**	**0.008**	**0.004**	**0.009**	**0.031**
Social security expenditures	SS med risk	0.120	0.020	0.008	0.020	0.071
Industrial water depletion	**WU med risk**	**0.308**	**0.048**	**0.021**	**0.051**	**0.188**
Trade unionism	TU med risk	0.842	0.113	0.059	0.150	0.521
Sanitation coverage	**SC med risk**	**0.140**	**0.029**	**0.009**	**0.020**	**0.082**
Health expenditure	**HE med risk**	**0.508**	**0.073**	**0.035**	**0.088**	**0.311**
Certified environmental management syst.	**CMS med risk**	**0.423**	**0.090**	**0.049**	**0.101**	**0.183**

Figure 4-16 features the relative percentual distribution of social impacts per impact category and per life cycle step on a 100%-scale basis. As an average, 62% of the impacts are slaughtering, pork loin manufacturing and distribution, while fabrication of feeds for animals is only 7% as an average. Farming is the second most impacting stage with 18% average impact over the total.

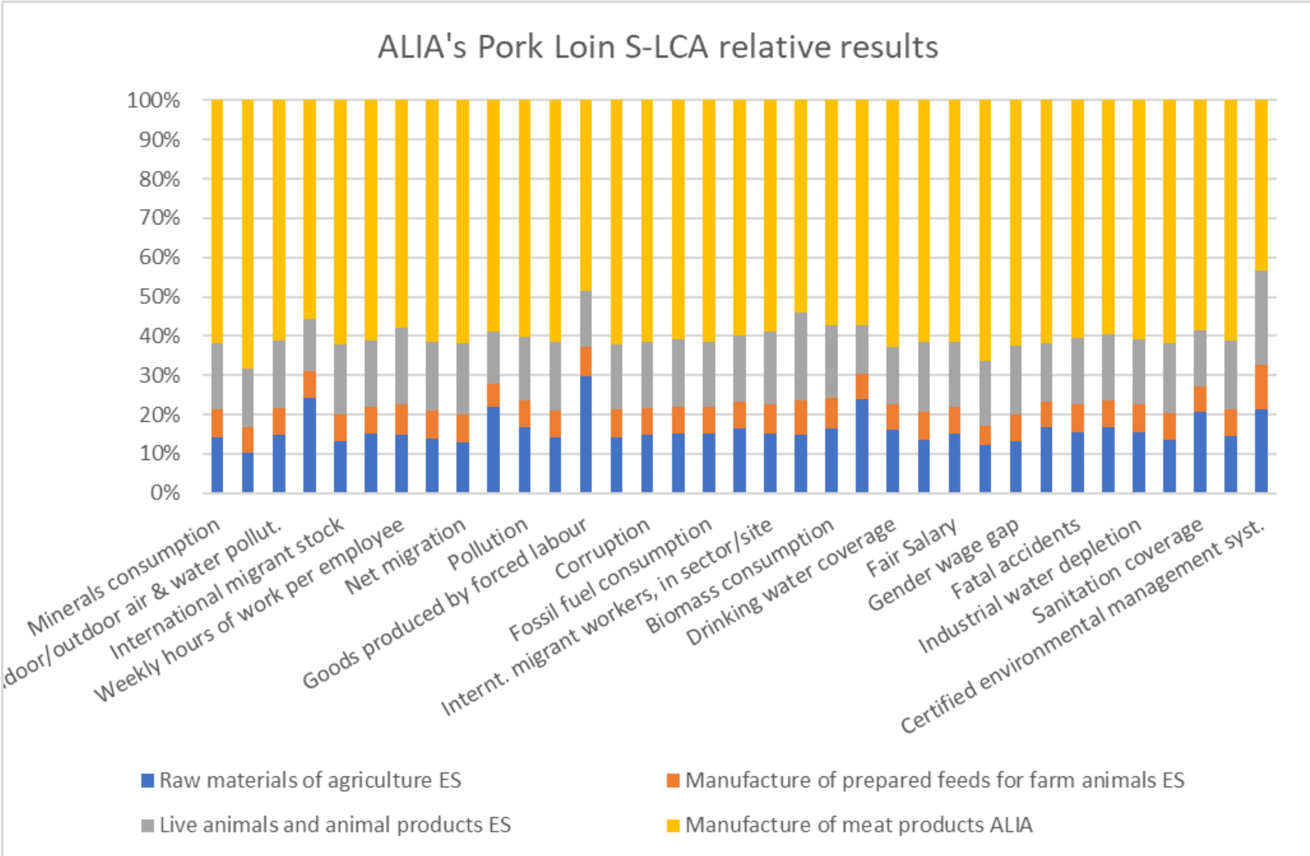


Figure 4-16 ALIA's pork Loin Social LCA relative result per life cycle step.

One kg of pork loin has a 9% to 14% higher social impact than the same amount of pork sausage, as it uses 7% more pork meat. Note that the quality of this meat is also different. The comparison of social impacts of 1 kg of each product per social impact category is presented in Figure 4-17.

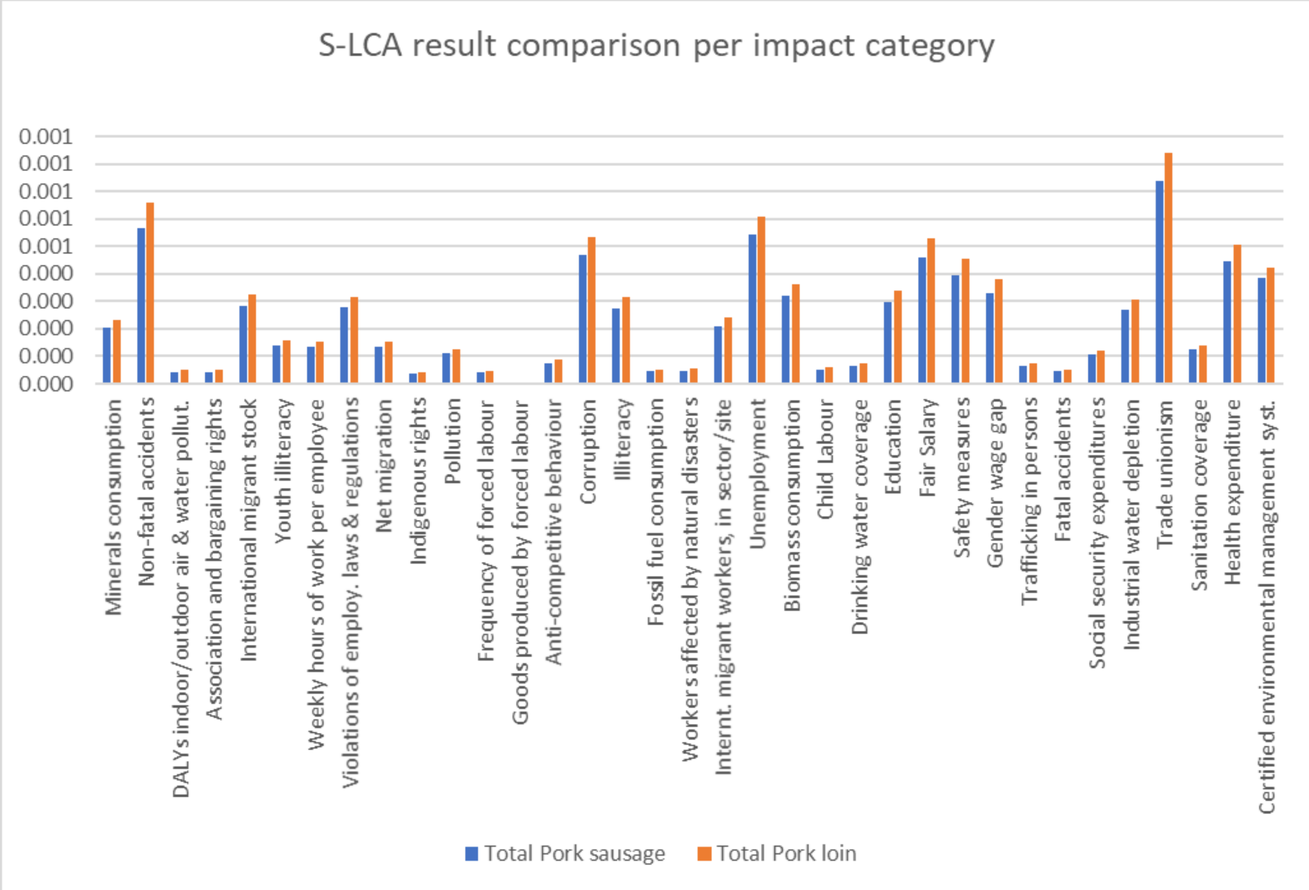


Figure 4-17 Social LCA result comparison between 1 kg of pork sausage and 1 kg of pork loin.

The interest of a social-LCA on a product is the comparative analysis with other products and process options. For this reason, it has been deemed of interest to compare ALIA's product with a similar-value meat product produced in Spain, taken from the PSILCA database. Let's take as a reference 1 kg of ALIA's pork loin and compare it with a similar value of other meat product manufactured in Spain. Table 4-14 shows the Social LCA result comparison between ALIA's pork loin and an average meat product of similar value in Spain.

Table 4-14 Social LCA result comparison between ALIA's pork loin and an average meat product of similar value in Spain. Source: PSILCA.

Impact category	pork loin mfg ALIA	Meat product mfg avg ES	comparison mfg %
Minerals consumption	0.143	0.192	-25%
Non-fatal accidents	**0.450**	**0.620**	-27%
DALYs indoor/outdoor air & water pollut.	**0.030**	**0.040**	-25%
Association and bargaining rights	**0.027**	**0.033**	-17%
International migrant stock	0.200	0.272	-26%
Youth illiteracy	**0.096**	**0.127**	-25%
Weekly hours of work per employee	**0.090**	**0.143**	-37%
Violations of employ. laws & regulations	**0.194**	**0.265**	-27%
Net migration	0.095	0.130	-27%
Indigenous rights	0.024	0.029	-17%
Pollution	**0.076**	**0.099**	-23%
Frequency of forced labour	0.029	0.039	-25%
Goods produced by forced labour	0.001	0.001	-17%
Anti-competitive behaviour	**0.054**	**0.073**	-26%
Corruption	0.328	0.441	-26%
Illiteracy	**0.191**	**0.253**	-25%
Fossil fuel consumption	0.031	0.042	-25%
Workers affected by natural disasters	**0.032**	**0.042**	-25%
Internt. migrant workers, in sector/site	0.141	0.185	-24%
Unemployment	**0.329**	**0.628**	-48%
Biomass consumption	**0.206**	**0.323**	-36%
Child Labour	0.034	0.041	-17%
Drinking water coverage	**0.045**	**0.058**	-22%
Education	**0.209**	**0.283**	-26%
Fair Salary	**0.324**	**0.429**	-24%
Safety measures	**0.302**	**0.441**	-32%
Gender wage gap	**0.237**	**0.355**	-33%
Trafficking in persons	0.046	0.059	-22%
Fatal accidents	**0.031**	**0.041**	-25%
Social security expenditures	0.071	0.094	-24%
Industrial water depletion	**0.188**	**0.259**	-27%
Trade unionism	0.521	0.704	-26%
Sanitation coverage	**0.082**	**0.103**	-20%
Health expenditure	**0.311**	**0.418**	-25%
Certified environmental management syst.	**0.183**	**0.256**	-28%

As an average, results of social impacts are 26% lower for ALIA's products, moving from -17% to -48% due to the higher productivity of ALIA's process compared to the PSILCA 2011's meat product in Spain, and the lower risk in many areas. In the case of the sausage, the difference is up to 29% lower average social impact in favour of ALIA's product.

The different distribution of Gender wage gap impact along the life cycle for each chosen ALIA's product is shown in Figure 4-18.

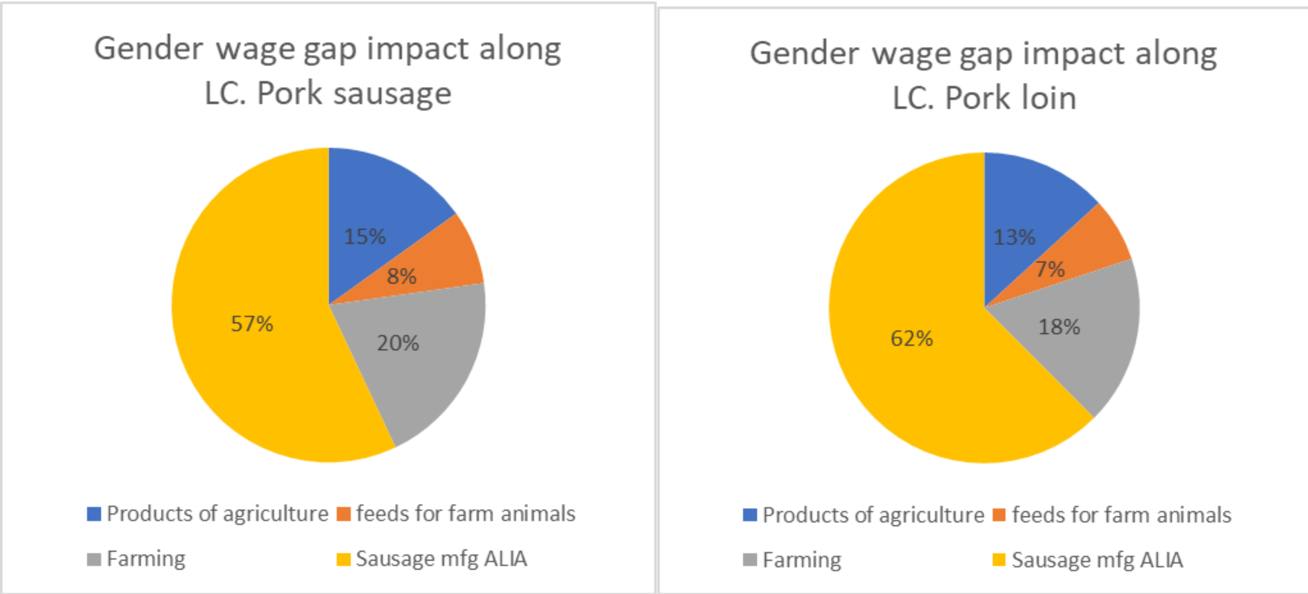


Figure 4-18 Gender wage gap impact distribution along Life Cycle stages for both ALIA's products in percentage.

A clearer distribution for pork loin in terms of US$ and percentage values can be seen in Figure 4-19.

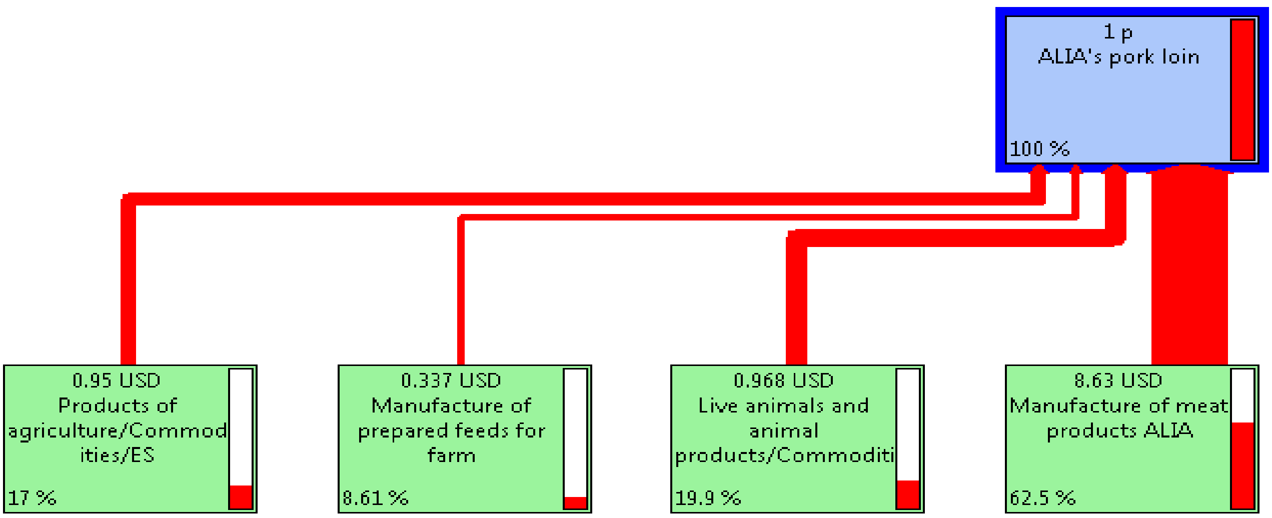


Figure 4-19 Gender wage gap impact along Life Cycle stages for ALIA's pork loin in US$ and percentage.

The social impact categories where the company is doing well compared to average national values are:

- Unemployment at national and regional levels: This difference is due to the great improvement in unemployment rates from PSILCA's reference year (2011), exceeding 20% unemployment rate, to 2018's rates, still high but below 15%. Unemployment expects to continue decreasing in the following years although at a slower pace. However, it remains an area of medium risk

- Weekly hours per employee. According to the company, ALIAs's workers carry out 40-hour working weeks. No extra hours are reported for ALIA's workers.
- Biomass consumption: ALIA's farm use olive seeds and almond shell as a fuel for winter. However, the mild weather pushes this consumption down to sustainable levels.
- Gender wage gap. Although real and positive (women are worst paid than men), the gap is lower than the sector average. However, it remains an area of medium risk.

The areas where the social LCA reflects worse results than the sector average are:

- Association and bargaining rights. The company should encourage higher degrees of Union membership.
- Sanitation coverage. It is very high country-wide, but it does not reach 100% yet.
- Other indicators like child labour and forced labour simply have no variation and are indicators with low or no risk.

4.3.2.3 Recommendations

The most interesting social aspects from the point of view of the company, either for the significance into the business or for the influence on customer's perception of the products, are: worker discrimination, health and safety for workers, consumers and local community, contribution to economic development, local employment and end of life responsibility.

In terms of social impact, the main areas or risk that should be addressed from the side of the company are the amount of women in the labour force (25% of the total workforce), the gender wage gap (15% of difference between male and female median wages with respect to men median wage), and the trade union density (10% of workforce are members of worker unions). Other risky areas are national wide like the high unemployment rate or the low public expenditure on education, or sectoral wide like the low contribution of the meat sector to the total national GDP that offers low opportunities in this activity sector.

In terms of product social impact, 1 kg of pork loin has an average of 12 points higher social impact than the same amount of pork sausage, despite that it takes only 7% more pork meat to produce. This is due to the different quality of the meat used at each product. The comparison with similar value meat products produced in Spain show around a 30% lower impact in favour of ALIA's products in most of the impact categories under analysis. A higher productivity and risk assessment reduction would contribute to a lower social impact of the products. As for the life cycle stage contribution, around a 60% of the impact comes from the product manufacturing (62% for the pork loin and 57% for the sausage), whereas for farming it is around 19% and for agricultural raw materials it is around 14%.

The areas where the company should focus to limit the social impact of its products are those scored as highly important (importance >= 6) and classified as high or very high risk, especially if they refer to sectoral or company-wide indicators. We can find the following:

- Trade union density as a % of paid employment total (Imp 6, very high risk). The ratio of workers joining a worker union is only 10%. Workers should be encouraged to join a trade union and participate actively.
- Presence of sufficient safety measures, measured as OSHA cases per 100,000 employees in the sector (Imp 9, high risk). No data available at company level, but high risk at sector level in Spain. Especial care should be paid.
- Public expenditure on education (Imp 6, high risk). Nation-wide indicator. Currently 3.8% of GDP. Improvements are expected in a midterm.

- Contribution of the sector to economic development (imp 6, low opportunity). Sectoral indicator. Meat sector is just 2.1% of Spanish GDP. Sector as a whole should focus on increasing the value added of meat products to boost exports.
- Women in the labour force (Imp 9, medium risk). The ratio of female workforce should increase from the current 25%
- Gender wage gap (Imp 9, medium risk). There is a 15% gender wage gap ratio, calculated as the difference between male and female median wages divided by the higher median wage, in percentage points. This gap should be addressed and reduced.
- Unemployment rate in the country (Imp 6, medium risk). Nation-wide indicator. Improvements are expected in a midterm. Now at 13.9%. Lorca's local unemployment 11.6%

There are other areas where ALIA outperforms in terms of social impact. These areas suppose a competitive advantage and care should be paid not to lose them. They are the following:

- Sector average wage per month. This sectoral indicator has been converted into a company indicator. Since ALIA's average wage exceeds by 2.8 times the living wage of the country, the assessed associated risk is very low.
- Men in labour force. Men (75%) are not under-represented in ALIA's workforce structure compared to national standards (65% of male active population in 4T 2018), hence there is a very low risk in this indicator. In terms of women, they are under-represented as 25% of female workers are far below the 53% of female active population in 4T 2018) giving a medium risk in this area. (EPA 4T 2018, INE)
- Rights for freedom, association and strike at national level are legally warranted in Spain and there are no risks in these aspects.
- Contribution to economic development is high risk in terms for public expenditure on education at national level (only 3.8% of 2018's GDP), but in terms of illiteracy there is no or very low risk.
- In terms of safe and healthy living conditions, national wide indicators such as drinking water coverage and sanitation coverage are very low risk.
- In terms of access to material resources, water use, fossil fuel extraction, biomass and ore extraction are all assessed as low and very low risk at regional and national level.
- In terms of local employment, 100% of workers are hired locally according to the company. Hence there is a very low risk to mitigate the medium risk of the unemployment rate at regional (14.5%) and at national level (15.8%). In the same way, more than a 90% of spending is reported to be with local based suppliers.
- Finally, the ISO 14001 certification in ALIA allows to assess a low risk for presence of certified environmental management systems, compared to a medium risk at national sectoral level.

4.4 Organic Potatoes

4.4.1 Environmental LCA

4.4.1.1 Functional Unit

In 2018, approximated 1.5 tons of potatoes and 2 tons of horticultural crops are yielded from a piece of planting land of 2 hectares in JS organic farm. The land size for planting potatoes is approximated 0.15 hectares. Horticultural crops include carrots, onions, broccoli, kale, chard, tomatoes, cucumbers, beetroot, squash, lettuce, leeks, courgettes, and low weight crops.

The organic potato is selected as the analytics target in this study, as it is the most yielded product that is able to represent the overwhelming planting resources and activities in the JS organic farm. Considering the farm is located in the island, the soil features and annual rainfall varies from the mainland, the geographical and planting period have to be identified in the functional unit as follows:

One potato (approx. 150g) planted in 0.15 hectares land with coastal soil environment in 2018.

4.4.1.2 System Boundary

The yielded organic potatoes of the farm are only on sale to the local restaurants, hotel and residents, which are usually delivered by bicycle and boat, therefore the impacts of distribution of planting farm product is not considered in this farm system.

Overall, main activities and resources related to the organic potato planting are classified as: Overhead, Capital, Fuel, Machinery operations, Fertility, Packaging and Disposal. Certain minor building activities occur in the farm year by year, in 2018, a new water tank was built, greenhouse was repaired, and polytunnel recovered, which are all considered in the farm system modelling, which is depicted in Figure 4-20.

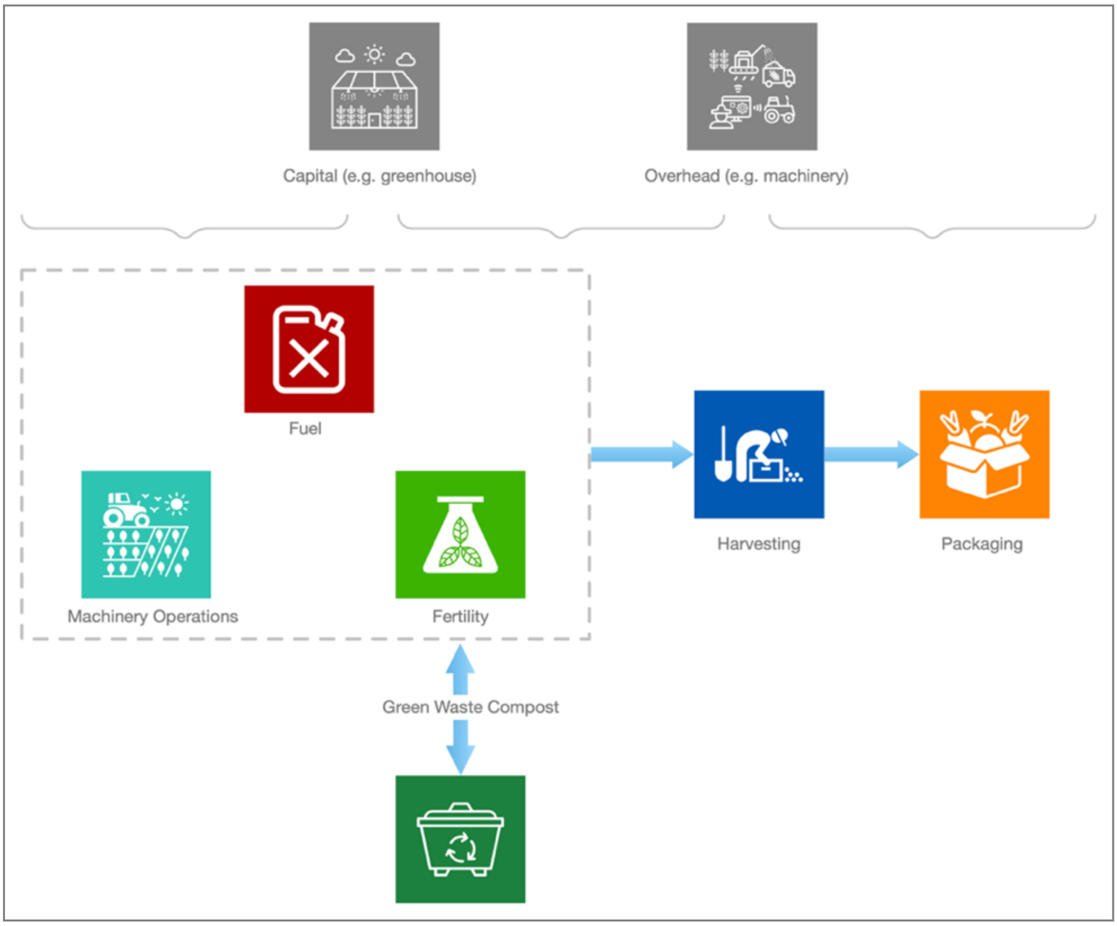


Figure 4-20 Scheme of the boundaries of JS organic farm system

4.4.1.3 Life Cycle Inventory

The life cycle inventory (LCI) is an inventory of input/output data that relates to the functional unit of the system being studied (ISO, 2006). The quality of LCA results is dependent on the quality of data used in the study. The foreground processes are based on activity data collected from project partner, JS organic farm and literatures. The foreground data are described in this section.

The secondary LCI data describing background processes (e.g., electricity production) are in large part from the latest ecoinvent database (version 3.5) with adaptations. Ecoinvent database is consider as a particularly robust and complete database, both in terms of technological and environmental coverage. It surpasses other commercial databases, from quantitative (number of included processes) and qualitative (quality of the validation processes, data completeness, transparency, etc.) perspectives. This database can be used in ISO-compatible LCAs and it is internationally recognized by experts in the LCA field.

The data inventory includes the majority of resources and flows in JS organic farm to harvest the functional unit in 2018, which are presented in Table 4-15.

Table 4-15 Key parameters of JS organic farm in 2018

JS Organic Farm General Information		Amount	Unit
land total size		2	hectare
land size for planting potatoes		0.15	hectare
Yield of potatoes per year		1500	kg
Yield of other horticultural crops per year		2000	kg
Product Stage/Category	**Name**	**Amount**	**Unit**
Overhead	Office electricity	181	kWh
Overhead	Wood logs	100	kg
Overhead	Wood (Pine/Spruce)	1	m3
Overhead	Tyres	16	kg
Capital	Concrete	0.5	m3
Capital	Bird netting	2.2	kg
Capital	Glass	10	kg
Capital	Polytunnel cover (Greenhouse)	60	kg
Capital	Polytunnel frame steel (Greenhouse)	88	kg
Capital	Storage tank steel (irrigation water storage)	75	kg
Capital	Storage tank EDPM (irrigation water storage)	50	kg
Fuels	Red diesel	190	Litres
Fuels	Petrol	40	Litres
Fuels	Lubricants	27	Litres
Fertility	Potato seed	200	kg
Fertility	Green waste compost	10	m3
Fertility	Plant raising media - Vermiculite (100 Litres)	8.2	kg
Packaging	Plastic bags	27	kg
Packaging	Paper bags	8	kg
Packaging	Boxes (Cardboard)	15	kg
Packaging	Silage sheet	15	kg

4.4.1.4 Life Cycle Impact Assessment Results

In this section it is highlighted the environmental impacts of the functional unit, the differences of the product's life cycle stages and the possible drivers for the various impact assessment indicators.

Figure 4-21 shows the overall impacts of the functional unit's life cycle, based on the input given in section 2.5. Due to the multi-indicator approach, results in the chart are presented in a relative way, normalized to the highest impact of each environmental impact categories among seven life cycle stages/categories.

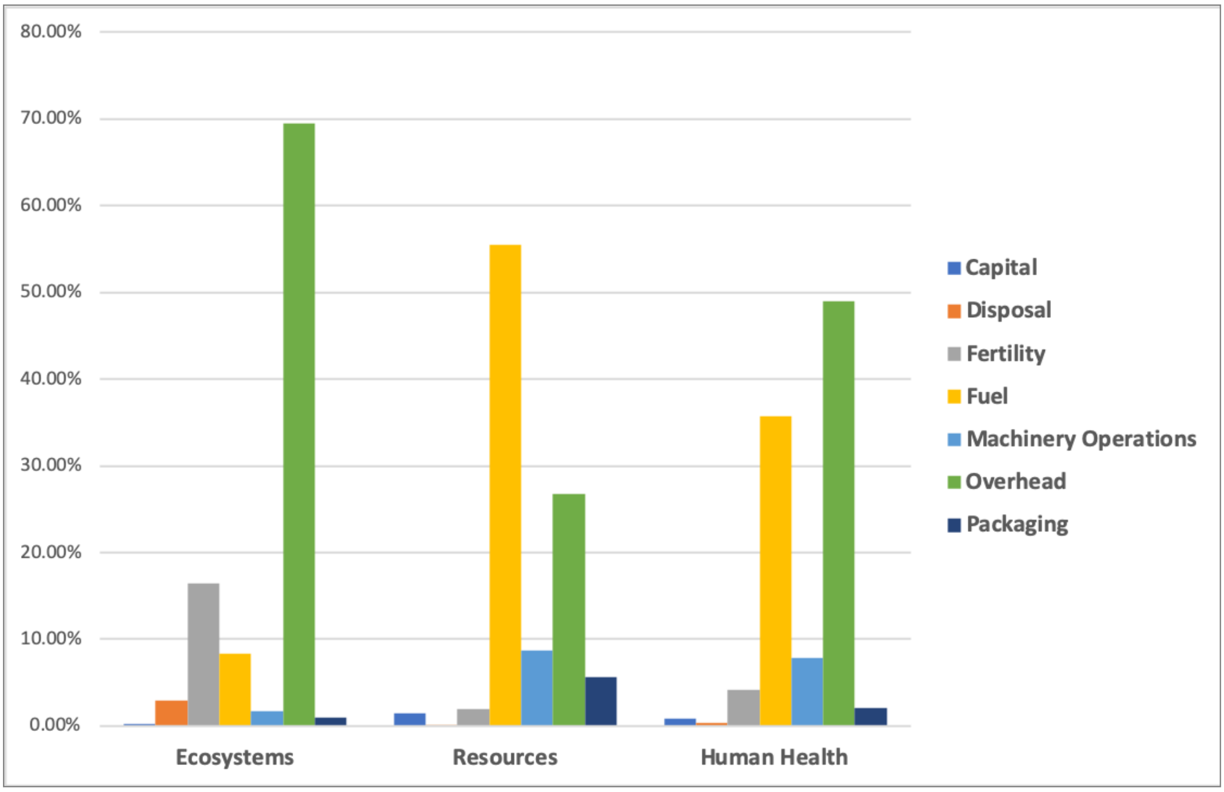


Figure 4-21 : Life cycle impact results for 1 yielded organic potato from JS farm in 2018

Overall, Figure 4-22 shows that the functional unit has higher impacts in the Overhead and Fuel stage compared to the other stages. Additionally, human health, resources, ecosystems impacts are dominated by Overhead and Fuel.

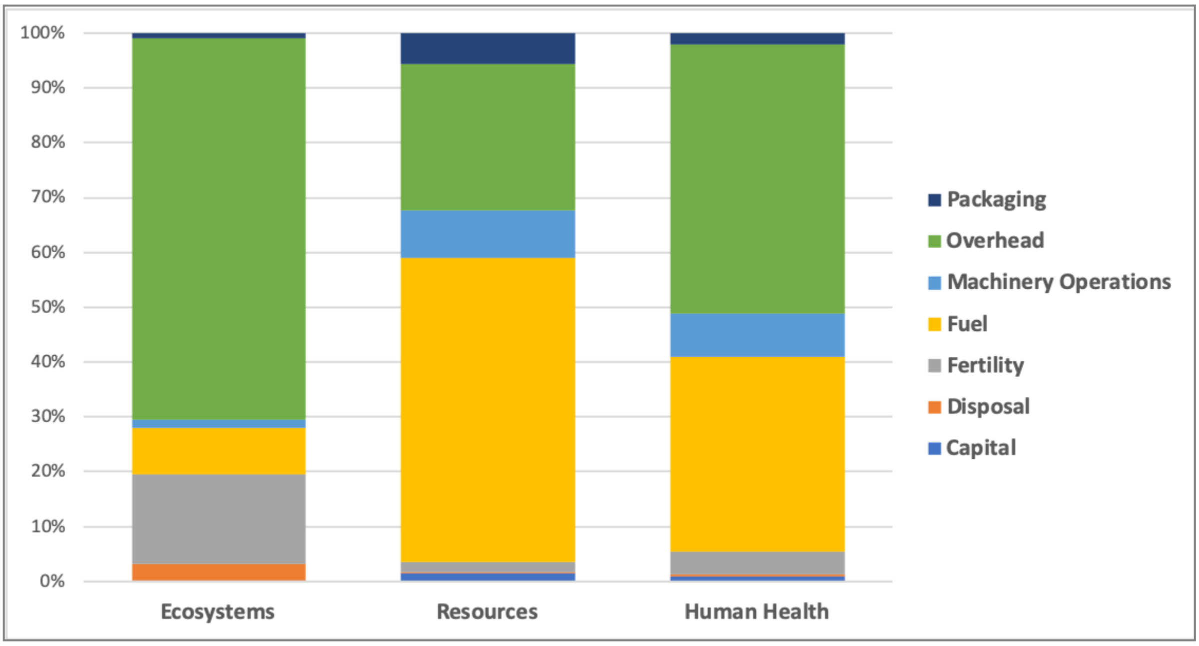


Figure 4-22 Each impact category results of 1 1 yielded organic potato from JS farm in 2018

For ecosystems impact category, more than 70% of impact come from Overheads, and approximately 20% of impacts are associated with Fertility. For resource and human health impact categories, Overheads and Fuel contribute the most impacts.

Weighting entails multiplying the results of each of the impact categories with a weighting factor that expresses the relative importance of the impact category. The weighted results all have the same unit and can be added up to create one single score for the environmental impact of a product system. The single score will enable users to select the optimum options according to their sustainability criteria and preferences.

With the ReCiPe method, the single score (Total) for the functional unit (i.e. per potato from the JS organic farm), which is rounded to 0.05 points, as it is shown in Table 4-16.

Table 4-16 Total environmental impact results – single score of the JS organic potato (per potato)

Impact category	Amount	Unit
Ecosystems - Agricultural land occupation	0.01611	points
Ecosystems - Climate Change	0.00244	points
Ecosystems - Freshwater ecotoxicity	2.31E-06	points
Ecosystems - Freshwater eutrophication	4.11E-06	points
Ecosystems - Marine ecotoxicity	4.54E-07	points
Ecosystems - Natural land transformation	0.00029	points
Ecosystems - Terrestrial acidification	9.93E-06	points
Ecosystems - Terrestrial ecotoxicity	9.78E-06	points
Ecosystems - Urban land occupation	0.00014	points
Human Health - Climate Change	0.00286	points
Human Health - Human toxicity	0.00046	points
Human Health - Ionising radiation	3.59E-06	points
Human Health - Ozone depletion	7.69E-07	points
Human Health - Particulate matter formation	0.00308	points
Human Health - Photochemical oxidant formation	1.24E-06	points
Resources - Fossil depletion	0.02023	points
Resources - Metal depletion	0.00188	points
Total	0.04752	points

Overall, the LCA shows the electricity consumption (Overhead) and Fuel (production and consumptions) are the major contributors for the environmental performance of the organic potato life cycles, considering the total amount of consumed electricity (181 kWh) and Fuel (257 Litres) in 2018 are already relatively low, and both materials can't be influenced by JS organic farm. Therefore, the third contribution, green manures and compost production are highlighted, the main contributors from which are emissions of diesel burning and electricity consumption of agricultural machines (i.e. mulching, sowing, tillage and harrowing). Main pollutants are nitrate to water, Dinitrogen monoxide, nitrogen oxides that emitted to air.

However, major data related to the green manure process are from the Ecoinvent database that may not fully represent this specifically analysed case, as more suitable for intensive farm conditions, and this process in particular will be subjected to further refinement.

The aggregated single score of Human Health, Ecosystems, and Resources for the functional unit, i.e. one organic potato is 0.04752 points, which is the value of eco-point for JS Organic farm demonstrator in CIRC4Life project. This eco-point value is rounded up as 0.05 Points for clear understanding purpose for the general consumers. Also, the eco-point value will be used to support the eco-credit calculations for the farm food products.

Eco-point = 0.05 Points (per potato)

4.4.1.5 Carbon footprint

For the past 10 years, Scilly Organics has completed a carbon footprint report using the Farm Carbon Calculator https://farmcarbontoolkit.org.uk/carbon-calculator. This Calculator has been co-created by Jonathan Smith, owner of Scilly Organics and partner in CIRC4Life, JS.

The Farm Carbon Calculator is an online carbon footprinting tool for farmers and growers in the UK. It is comprehensive, covering Scope 1,2 and 3 carbon (GHG) emissions, as well as all carbon sequestration assets. As a user-friendly tool it is designed to be used by farmers.

The Calculator requires information on a wide range of inputs and processes. The scoping of the carbon footprint report is the same as that of the LCA studies carried out in this Task, as previously defined in Task 1.1, but it also includes carbon sequestration. Emissions and sequestration are calculated from actual use of products, or processes. This includes the following:

- Fuels and electricity
- Business travel
- Use of materials
- Embodied energy in capital items
- Nitrous oxide from soil management and leguminous crops
- Livestock (Scilly Organics has none)
- Purchased fertility inputs
- Agro-chemicals (Scilly Organics has none)
- Waste and recycling
- Distribution to point of sale
- Sequestration in soils and biomass on farm

In particular, Scilly Organics measures the changes in soil organic matter across the farm each year. This is translated in to gains or losses in terms of carbon dioxide (CO2). On the whole, the gains in soil organic matter observed annually translate into very significant amounts of CO2 sequestered.

The boundaries of the calculation are the same as those used for the LCA calculation, as are the functional units. The only difference in land is that it includes some woodland, which takes the overall area of the farm up to 2.6 hectares.

The data was collated, entered in to the Calculator, and analysed by Jonathan Smith in April 2019. All of the data relates to the business, and is based on the previous 12 months, with the exception of capital items (tractors and buildings) which includes everything under 10 years old. The results of that calculation are shown below, in Figure 4-23, and the results discussed.

4.4.1.6 Results

Farm Carbon Cutting Toolkit

Published on *Farm Carbon Cutting Toolkit* (https://farmcarbontoolkit.org.uk)

Scilly Organics 2018

Emissions

	C0₂e (kg/year)	% total emissions
Fuel	1,148	27.45%
Materials	626	14.97%
Capital Items	1,670	39.93%
Livestock	0	0.00%
Fertility	642	15.35%
Agro-chemicals	0	0.00%
Distribution	0	0.00%
Waste	96	2.30%
Total:	**4,182**	**100%**

Sequestration

	C0₂ (kg/year)	% total sequestration
Field Margins	111	0.17%
Soil Organic Matter	36,035	55.82%
Orchards & Vineyard	240	0.37%
Wetland	0	0.00%
Woodland & Hedges	23,154	35.86%
Woodland (detailed analysis)	5,020	7.78%
Total	**64,560**	**100.00%**

Figure 4-23 Scilly Organics carbon footprint 2018

The results are displayed in terms of greenhouse gas (carbon) emissions and carbon sequestration. The main sources of carbon emissions are:

- Fuels, mostly diesel use in tractors, over 27%
- Capital items, comprising embodied energy in buildings and tractors, nearly 40%
- Fertility, mostly nitrous oxide emissions from green manures and compost production

The total carbon emissions were 4.18 tonnes of CO2e per year.

The main elements of sequestration were:

- Soils, from gains in soil organic matter, 55%

- Woodland and hedges, encompassing all the hedges on the farm and some areas of woodland, 35%

Total carbon sequestration came to 64.56 tonnes of CO2 for the year, a significantly higher figure than the total emissions. This means there is a net carbon balance of -60.38 tonnes CO2e per year.

Table 4-17 details the carbon balance in total, per hectare and per tonne of vegetables.

Table 4-17 Carbon balance of Scilly Organics

	Carbon balance (tonnes of CO2e per year)
Total	-60.38
Per hectare	-23.22
Per tonne of vegetable	-17.25

Taking this approach of including carbon sequestration into account, it’s demonstrated that there is potential for food products to be carbon negative – i.e. more carbon is sequestered than emitted during the production of those products.

In this instance, whenever a consumer buys vegetable from Scilly Organics, they are contributing in a completely positive way to climate change, whereby their carbon footprint actually reduces with every product they buy from Scilly Organics.

4.4.2 Social LCA

4.4.2.1 Functional Unit

For each product, 1 kg of product is selected as functional unit.

The production ensures to follow organic certified practices, avoiding the use of any pesticides, herbicides or artificial fertilisers, and conducting the soil management that minimise erosion, improve soil structure and increase biodiversity and soil’s organic matter. Water, energy and material consumption is minimised as much as possible. Figure 4-24 shows the salad and potatoes process flowchart.

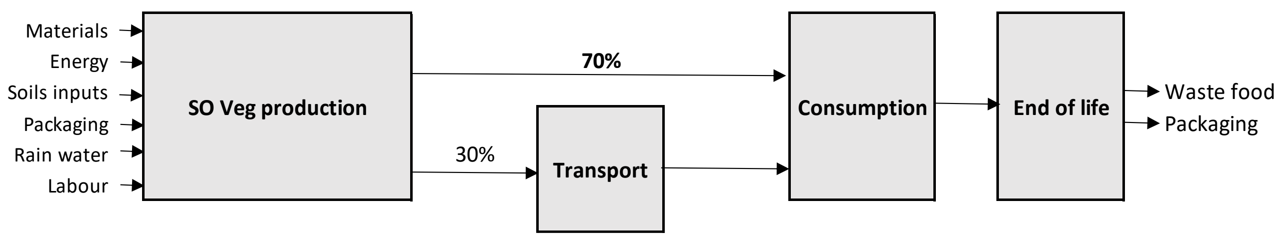


Figure 4-24 Salad and potatoes process flowchart.

4.4.2.2 System Boundaries

The Environmental Policy of Scilly Organics requires the implementation of sustainable procedures that minimizes the carbon footprint, the waste production (the farm produces its own compost), the use of water and energy (Scilly Organics uses only rainwater and electricity from renewable sources) and promotes businesses with local suppliers. These characteristics produce that all the stages involved in the production of organic salad and potatoes are concentrated in the farm itself, with only the acquisition of few raw materials and consumables, such as seeds, packaging material or fuel for machinery and heating.

The distribution of products is not included in the analysis given that the 70% of Scilly Organics production is sold locally through a stall located at walking distance from the farm. The other 30% is transported to the neighbouring islands by boat, obtaining just 85m per produced Kg. The buyers are local hotels and cafés.

Similarly, consumption and end-of-life are not included due to lack of information about end users. Scilly Organics products should be able to last at least four days in good condition when refrigerated, and it is assumed that the salad and potatoes are consumed freshly obtaining the most from these organic vegetables. The packaging is the only waste associated to these products, but Scilly Organics use packaging fully recyclable, biodegradable and compostable (recycled paper bags). Transit plastic packaging is usually reused by Scilly Organics and the local business. It is estimated that only 0.049 kg of waste is produced per each kg of vegetable.

In this sense, the system boundaries are limited to the inputs, outputs and processes of the production stage:

- Manufacture of materials such as steel, wood, fuel, paint, netting, and others described in de LCI.
- Third party services associated to the production such as banking and insurance.
- Electricity production from renewable sources.
- Usage of rainwater and the production of compost for self-consumption.
- Hours of labour required to produce 1 kg of Salad and 1 kg of potatoes.

As mentioned on the previous section, the medium risk ours selected to perform the analysis are those that the PSILCA databased includes by default. This decision is reflected in the following comparison between Scilly Organics and its sector. By having the same value of medium risk hours, the only difference is the risk level assessment explained above. For those impact categories that do not suffer changes in their risk assessment, the S-LCA would remain identical. However, for those impact categories that Scilly Organics demonstrates to have a better social performance, by reducing the risk level, a difference would be reflected in the comparison. Table 4-18 states the relevance of this difference, being “gender gap”, “violations of employees regulations” and “biomass consumption” the impact categories with a higher level of performance in terms of medium risk hours.

Table 4-18 Comparison of risk hours between Scilly Organics and the organic agricultural sector.

Impact Category	Unit	Scilly Organic Production	Organic: Growing of vegetables/UK	Comparison %
Non-fatal accidents	NFA med risk	0.328	0.328	0.0%
DALYs indoor/outdoor air & water pollut.	DALY med risk	0.186	0.186	0.0%
Association and bargaining rights	ACB med risk	0.335	0.335	0.0%
Youth illiteracy	YI med risk	0.644	0.644	0.0%
Weekly hours of work per employee	WH med risk	0.404	0.404	0.0%
Violations of employ. laws & regulations	VL med risk	0.797	0.967	-17.6%
Pollution	P med risk h	0.553	0.553	0.0%
Anti-competitive behaviour	AC med risk	0.301	0.301	0.0%
Illiteracy	I med risk h	1.018	1.018	0.0%
Workers affected by natural disasters	ND med risk	0.242	0.242	0.0%
Unemployment	U med risk h	0.360	0.360	0.0%
Biomass consumption	BM med risk	1.821	2.089	-12.8%
Drinking water coverage	DW med risk	0.288	0.288	0.0%
Education	E med risk h	0.715	0.715	0.0%
Fair Salary	FS med risk	3.257	3.354	-2.9%
Safety measures	SM med risk	1.093	1.093	0.0%
Gender wage gap	GW med risk	1.546	2.009	-23.0%
Fatal accidents	FA med risk	0.226	0.250	-9.7%
Industrial water depletion	WU med risk	0.857	0.906	-5.4%
Sanitation coverage	SC med risk	0.663	0.663	0.0%
Health expenditure	HE med risk	1.423	1.423	0.0%
Certified environmental management syst.	CMS med risk	2.331	2.331	0.0%

Materials required by Scilly Organics products are low priced if compared with the cost of work required. In other words, for the Social LCA, the cost of personnel and the indirect cost are the ones with the highest weight and influence in the result. Not only is the quantity of material per produced Kg low, but they are also acquired locally, reducing the chances of having inputs from markets where stakeholders, such as workers of local community, are less protected. Even in the case of potatoes production, which final price is relatively low, the requirements of labour are the most influential ones, as can be seen in the following tree chart (Figure 4-25).

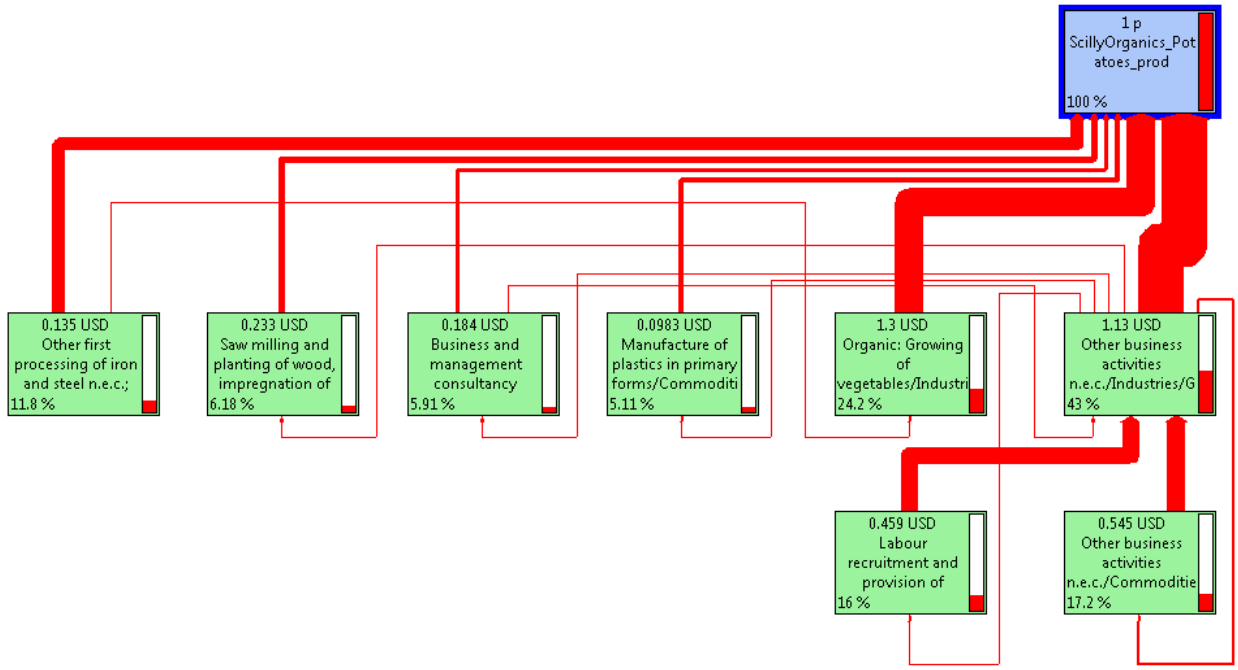


Figure 4-25 Scilly Organics Social LCA relative result per product.

Finally, just to compare how is the social performance of both products in regard with each other, Figure 4-26 indicates the relevance of the non-material inputs on the medium risk hours. Potatoes results are on average a 15% of the calculations made for salads. Again, this correspond to a higher price and its associated cost of personnel.

Table 4-19 Comparison of risk hours between Potatoes and Salad production in Scilly Organics

Impact category	Unit	Potatoes	Salad
Certified environmental management syst.	CMS med risk	0.651	5.047
Health expenditure	HE med risk	0.416	2.594
Sanitation coverage	SC med risk	0.193	0.950
Industrial water depletion	WU med risk	0.213	1.475
Fatal accidents	FA med risk	0.059	0.378
Gender wage gap	GW med risk	0.529	4.376
Safety measures	SM med risk	0.204	1.261
Fair Salary	FS med risk	0.895	6.443
Education	E med risk h	0.193	1.328
Drinking water coverage	DW med risk	0.083	0.472
Biomass consumption	BM med risk	0.564	4.076
Unemployment	U med risk h	0.089	0.644
Workers affected by natural disasters	ND med risk	0.063	0.400
Illiteracy	I med risk h	0.351	1.729
Anti-competitive behaviour	AC med risk	0.085	0.661
Pollution	P med risk h	0.154	0.912
Violations of employ. laws & regulations	VL med risk	0.175	1.238
Weekly hours of work per employee	WH med risk	0.125	1.005
Youth illiteracy	YI med risk	0.201	1.184
Association and bargaining rights	ACB med risk	0.091	0.421
DALYs indoor/outdoor air & water pollut.	DALY med ris	0.054	0.348
Non-fatal accidents	NFA med risk	0.071	0.469

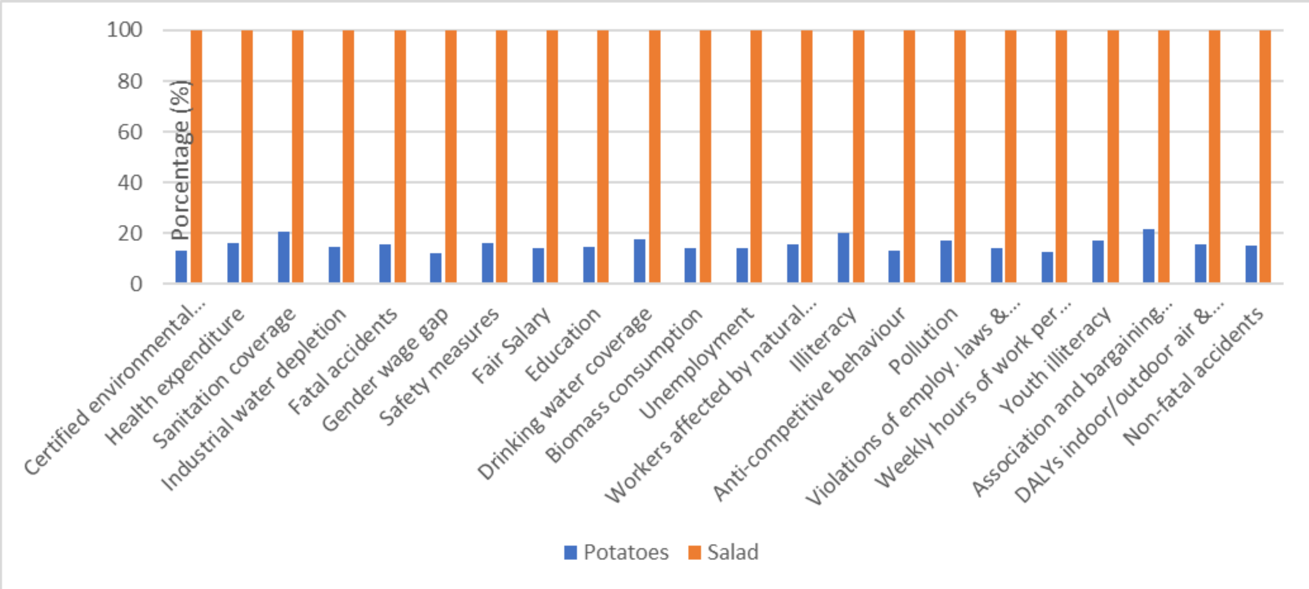


Figure 4-26 Scilly Organics Social LCA relative result per product.

4.4.2.3 Recommendations

Scilly Organics' commitment to deliver fair and healthy products is easily reflected in a better social performance with respect of its own sector. Issues associated to the average wage, gender gap, women in the labour force, fatal accidents at the workplace, usage of industrial water and biomass are better assessed in terms of risk level. Several of them, also are identified as of high importance from the company's perspective.

Other categories, also of relevance for Scilly Organics, in which the risk valorisation remained as high or very high, the company, being a small business, has almost no chances to improve. This is caused by the nature of indicators such as "living wage" and "unemployment rate" that are nation-level statistics or "presence of sufficient safety measures" that is calculated for the whole sector.
Finally, the low level of materials to produce both potatoes and salads generates that most of the social impacts depends on the labour requirements. This could indicate that an improve on the workers conditions might enhance the social performance of the company. But again, Scilly Organics is a small family business that hardly compares to the characteristics of big industries, and where owners are workers as well.

Nonetheless, the analysis performed serves as a baseline to evaluate the social efficiency of future improvements.

5 Social LCA in the eco-point approach

LCA is often considered to be a valuable framework in integrating sustainability into product development and assessment due to its systematic procedures. Environmental LCA primarily considers environmental impacts along supply chains, from extraction of raw materials to the End-of-Life of products. Social LCA (S-LCA) shares the life cycle perspective with environmental LCA but has social impacts as its focus. Similar to environmental LCA, S-LCA adopted the same framework which is comprised of four main steps: goal and scope, life cycle inventory analysis, life cycle impact assessment, and interpretation.

This report has presented the S-LCA's historical development, implementation procedures, and recent studies. The S-LCA methods were expounded which include the checklist method, scoring method, database method and empirical method. The review shows that much attention has been paid to apply database method into the S-LCA in the recent studies, which lead the CIRC4Life project to use database method to conduct S-LCA for the demonstrators.

PSILCA database is employed in SimaPro and openLCA application for conducting CIRC4Life S-LCA studies. PSILCA enables the use of weighing factors to assess the level of risk of each indicator according to a risk scale moving from very high risk to very low risk, including a "no risk" level. Assessment is made using normalised values by activity sector and country. Risk level allocation limits are also documented and can be tailored with specific national, sectoral or corporate data. The impact evaluation for a S-LCA consists in the aggregation of all social impacts weighed by the national and sectoral risk factors, and it is provided in comparable risk assessment. Therefore, S-LCA results cannot be combined into a single value, unlike the eco-point value in CIRC4Life.

Furthermore, the S-LCA studies enables the assessment of more than 70 types of social impacts categories from 5 different stakeholders. The selection of impact categories is determined by the data source, company characteristics, and the study objectives, which also cause uncertainties and challenges to develop a framework to weight and harmonise the social impacts and environmental impacts. It is also noted that S-LCA is still much less developed and used than Environmental LCA. One of the reasons for CIRC4LIfe incorporating S-LCA in the calculation of product impacts was to be innovative and push the boundaries of established practice.

In CIRC4Life, the S-LCA results will be provided by means of references, or reports to communicate with the end users, in order to demonstrate a higher level of product performance, alongside sustainability attributes, is thus helpful to encourage consumers to purchase and use more sustainable products.

6 Conclusions

This Task has found that through the application of a novel approach to LCA analysis, including social LCA, can be applied to a range of products that are fundamentally different in nature. By using an online LCA approach the user of the Impact Assessment Tool has the ability to weight different options and use it as a decision-making tool. This is a unique function that is not available in other impact measurement tools.

The calculated impacts of the five diverse products studied in Task 1.2 are expressed in eco-points. These will be further used in future tasks in the project to communicate the impact of products to consumers, enabling them to make informed decisions about the environmental and social impacts of products they buy, or indeed to choose between different products they are considering buying.

Successful testing of the Tool in real life, with example products, shows that there is potential for it to be scaled up and taken to market. Further development ideas and approaches are outlined, which could see the Impact Assessment Tool used to offer genuine positive choices to the consumer when trying to buy more sustainable products in a circular economy context.

As a Demonstration project, CIRC4Life has developed toolsets that work with businesses in real life situations. They are, however, still prototypes and therefore are at TRL6 (Technology Readiness Level), not at TRL9, which is a measure of whether they are ready for the marketplace and to be used for day to day use by businesses and in supply chains.

Further development could include:

- Connecting with multiple data sources for impact analysis.
- More development on user interface.
- Have the ability to ‘copy’ a product project in the calculation stage.
- Testing with other sectors, scales and business types.
- Benchmarking with other businesses.
- Connect to the opportunity for marketing products or services.
- Business opportunities throughout the supply chain.
- Real time data LCA data directly from production and distribution processes.
- Incorporation of impacts on financial and economic impacts, such as variable costs, retail price and profitability.

To get from TRL6 (the level of this project) to TRL9 – after development, needs testing with businesses (with inexperienced people as the users), make amendments, then develop a wider pilot project. This large-scale pilot would require the Tool operating in supply chains of various products and services (and more than in this project), integrating with producers, retailers, distributors and consumers, along with regulatory bodies if necessary.

Once a large-scale pilot is proven, the Tool would be ready to be taken to the wider market and implemented in everyday production and consumption systems. At this point the drivers towards products and services with lower impacts could become reality and transform the economy towards one with lower emissions, use of fewer resources, generates less waste, and offers wide scale business opportunities for an eco-economy.

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8 Appendices

Appendix 1 - Impact tools currently existing in the marketplace

Sector	Name of tool	Website
Carbon footprint	Cool Farm Tool	https://coolfarmtool.org/
	Farm Carbon Calculator	https://farmcarbontoolkit.org.uk/carbon-calculator
	EX-ACT carbon balance tool	http://www.fao.org/tc/exact/ex-act-home/en/
	Scope 3	https://quantis-suite.com/Scope-3-Evaluator/
	OSCAR	https://oscar.post/#/dc
Ecological footprinting	Footprint calculator	https://www.footprintcalculator.org/
	Ecological Footprint Calculator	http://ecologicalfootprint.com/
	One Planet Living Calculator	http://calculator.bioregional.com/
	Product Attributes to Impact Algorithm	https://paia-tool.com/#/
Consumer tools	Eat Low Carbon	http://www.eatlowcarbon.org/
	Food emissions carbon calculator	http://www.foodemissions.com/foodemissions/Calculator.aspx
LCA	SimaPro	https://simapro.com/about/
	GaBi	http://www.gabi-software.com/spain/index/
	Open LCA	http://www.openlca.org/
	Umberto	https://www.ifu.com/en/umberto/
	Air.e LCA	https://www.solidforest.com/software-airelca-precios.html
	e-DEA	http://esu-services.ch/software/e-dea/
	Earth smart	https://www.earthshiftglobal.com/software/earthsmart-lca-software
	Sustainable Minds	http://www.sustainableminds.com/software
	Solidworks	https://www.solidworks.com
Consumer tools	Ecological Footprint Calculator	http://www.footprintcalculator.org/
	Svalna – Beräkna din miljöpåverkan	https://svalna.se/
	Klimatkalkylatorn	https://www.klimatkalkylatorn.se/
	My climate impact	http://www.minklimatpaverkan.se/
	Klimatvågen	http://klimatvagen.se/
	Klimatkontot (Climate Account)	https://www.klimatkontot.se/
	Matkalkylatorn	https://www.wwf.se/wwfs-arbete/mat-och-jordbruk/matkalkylator/1731023-matkalkylatorn
	Calculator of CO2 emission	https://ziemianarozdrozu.pl/
Circular economy tools	The Material Circularity Indicator (MCI)	https://www.ellenmacarthurfoundation.org/programmes/insight/circularity-indicators
	The Circular Economy Toolkit (CET)	http://circulareconomytoolkit.org/

Appendix 2 - Business benefits of the Impact Analysis Tool

Understanding what the benefits of the Impact Analysis Tool ('Tool') are to its potential users is essential in the process of its development. To enhance the understanding of the IT team in what is required by users, the Industry Partners were consulted on what the benefits of this Tool would bring to their business.

They were asked about three key issues: environmental, social, and business. No scoring or weighting was given to each issue; what's important to understand is how the Tool should be developed in order to bring maximum benefit to users.

Findings
Having consulted all the Industry Partners (JS, ALIA, ONA & KOS), understanding the following issues were reported as being important to those partners' businesses:

Environmental:

- Carbon footprint
- Ecological footprint
- Land use
- Water use
- Toxins/chemicals in supply chain
- Waste generated
- Life Cycle Assessment
- Material flows

This has shown that businesses see, and require, a wide range of environmental benefits to the Tool. Therefore during the Tool's development the environmental impacts listed above should (a) be included in the calculation(s) of impacts, and (b) be visible to users in as much detail as possible.

Ensuring that businesses can extract as much detail as possible from the Tool is essential in its successful functionality. That is not to say that it cannot also, in parallel, display results in a more condensed format for easier and quicker understanding.

Social:

- Social impact/LCA
- Engagement of staff
- Human health impacts

Again these were quite consistent across all four partners, so it is recommended that the above issues are considered to be at the forefront of development considerations on social outputs.

'Engagement of staff' is taken to mean that the results of the Impact Analysis should be engaging for the staff of that business – i.e. that it enhances the ethical credentials of the business and offers greater transparency. Furthermore it could be thought of in terms of the way in which results are presented to make them easily understood.

Business:
The Tool should enable:

- Decision making/business improvement
- Ability to work with supply chain
- Benchmarking with other businesses

- Translate into financial benefits
- Assess benefits of products
- Detailed analysis of impacts (on the business)
- Good marketing opportunities
- Business opportunities throughout the supply chain

It should also aim to be:

- Accurate
- Comprehensive and in depth
- User friendly

It's quite striking that the business benefits of such a Tool are quite clear to Industry Partners, and they are quite consistent amongst partners. Some of these qualities, such as benchmarking, will not be possible in any real sense during this project, but must be borne in mind for possible future development.

Some of the functionality will be addressed by the Decision-Making Tool, whereas others will form a part of the core Impact Analysis Tool.

Appendix 3 - Weighting options for the Impact Analysis Tool

Introduction
One of the innovations of the Impact Analysis Tool is for the user to be able to apply weightings to the environmental and social impacts of their products. For example, a farm in a water scare region could apply a higher weighting to water use in the production process. Equally, a company that has built their identity around being 'low carbon' may wish to use a weighting option on carbon.

There are many possible weighting options that could be used in the Impact Analysis Tool. Enabling weighting options for all possible factors could be very time consuming and not necessarily very appropriate.

As CIRC4Life is an Innovation project, it is not under the same parameters that a commercial and public tool would be. Because of that the project team decided to work with the project's industry partners to assess what the most useful weighting options would be for their businesses, and therefore the usefulness of this particular functionality of the Tool to industry.

Findings
Having consulted all the Industry Partners (JS, ALIA, ONA & KOS), the following weighting options were listed as being useful and/or important for the businesses. No scoring was given as such, but importance of weightings could be ascertained at a later date if required.

- **Water**
- **Carbon**
- **Energy**
- **Social**
- **Capital items**
- **Waste**

It is therefore recommended that these are the weighting options incorporated into the Impact Analysis Tool.

Further recommendations
Having a limited number of weighting options is sensible and justifiable for an Innovation project. However, it needs to be acknowledged, in Deliverable 1.2, that a commercial product would include a much broader range of options to be inclusive of a much wider range of products, services and scenarios.

Appendix 4 - Waste and recycling calculation sheet

Waste

This spreadsheet works out the GHG emissions from waste, and the savings from recycling materials

Enter data in white boxes, as applicable.

Item		Units	Landfill Amount	Factor	kg CO2e	Recycling Amount	Factor	kg CO2e	Composting/AD Amount	Factor	kg CO2e
Aggregate	Average	tonnes	1	1.26	1.26	1	-2	-2.00			
Batteries	Domestic	tonnes	1	75.94	75.94	1	-205	-205.00			
	Vehicle	tonnes	1	75.94	75.94	1	-435	-435.00			
Scrap metal		tonnes	1	8.99	8.99	1	-3577	-3577.00			
Oil		tonnes				1	-2759	-2759.00			
Tyres	All vehicles	tonnes				1	-636	-636.00			
Electrical items	Fridges & freezers	tonnes	1	8.99	8.99	1	-853	-853.00			
	Other	tonnes	1	8.99	8.99	1	-1107.5	-1107.50			
	Light bulbs/tubes	tonnes				1	-779	-779.00			
Wood	All types	tonnes	1	828.12	828.12	1	-444	-444.00			
Glass	Mixed	tonnes	1	8.99	8.99	1	-314	-314.00			
Cans	Mixed	tonnes	1	8.99	8.99	1	-3577	-3577.00			
	Steel	tonnes	1	8.99	8.99	1	-862	-862.00			
	Aluminium	tonnes	1	8.99	8.99	1	-8143	-8143.00			
Plastics	Average	tonnes	1	8.99	8.99	1	-1024	-1024.00			
	HDPE	tonnes	1	8.99	8.99	1	-1149	-1149.00			
	LDPE	tonnes	1	8.99	8.99	1	-972	-972.00			
	PET	tonnes	1	8.99	8.99	1	-2192	-2192.00			
	PP	tonnes	1	8.99	8.99	1	-1184	-1184.00			
	PVC	tonnes	1	8.99	8.99	1	-1549	-1549.00			
Municipal waste		tonnes	1	586.51	586.51				1	10.204	10.20
Organic wastes	Food and drink	tonnes	1	626.96	626.96				1	10.204	10.20
	Green	tonnes	1	579.04	579.04				1	10.204	10.20
Paper		tonnes	1	1041.88	1041.88	1	-459	-459.00			
Cardboard		tonnes	1	1041.88	1041.88	1	-120	-120.00			
Clothing		tonnes	1	445.03	445.03	1	-3376	-3376.00			
Mattresses		tonnes				1	-1241	-1241.00			
Paint		tonnes				1	86	86.00			
Totals					5419.39			-36873.50			30.61
Combined totals											-31423.50