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A circular economy approach for lifecycles of products and services

Report on the development of eco-point methods

Deliverable 1.3

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Executive Summary

The background research was conducted including the ecoCost method developed by the FP7 myEcoCost project, product environmental footprints (PEF) and LCIA methods. Based on the results of the background research, the ReCiPe method is selected to calculate the eco-points. The results also indicated that the PEF is an important tool to measure environmental impact but has not reached at the stage for implementation in practical applications, and, hence, CIRC4Life is unable to implement it in the eco-point method at this moment, but a PEF-LCA study will be conducted in the demonstration phase of the project to identify synergies, complementarities and differences between PEF and the eco-point method.

The eco-accounting infrastructure consists of an eco-point method and an eco-accounting platform:

- The eco-point is a cumulative value accounting for an aggregate of the ecological impacts throughout product life cycle. The eco-point is calculated based on the ReciPe method by summing-up its three end-point values of damages to human health, ecosystem and resources diversity. Based on the eco-point, the eco-point method utilises ‘eco-debit’ to show the customer’s negative ecological impact resulted from the products purchased, ‘eco-credit’ to credit customers’ positive behaviour of long-time use and recycling end-of-life products, ‘eco-shopping’ for consumers to gain the ecological information of the products to be purchased, and ‘consumer eco-account’ to record consumers’ ecological footprints.
- The eco-accounting platform provides the mechanism to implement the eco-points, eco-debits and eco-credits, and their applications in sustainable production, eco-shopping, recycle/reuse and consumer eco-accounts.

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Acronyms and abbreviations

Abbreviation	Description
E.C	European Commission
EoL	End of Life
FP7	Seventh Framework Programme, European Union research and
GHG	Greenhouse Gas
GWP	Global Warming Potential
ICT	Information & Communication Technology
ILCD	International Reference Life Cycle Data
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
LCIA	Life Cycle Impact Assessment
OEF	Organizational Environmental Footprint
PEF	Product Environment Footprint
UNEP	United Nations Environment Programme
SETAC	Society of Environmental Toxicology and Chemistry
AEL	Alkaline Water Electrolysis
QALYs	Quality Adjusted Life Years
DALYs	Disability Adjusted Life Years

1 Background Research and Eco-point Calculation Method Selection

1.1 Eco-cost method

Supported by the EU FP7 environmental programme, the myEcoCost project www.myecocost.eu developed an approach by utilisation of information and communication technology (ICT) and traceability techniques to measure ecoCost of products. The ecoCost is a numerical measure of the product's environmental impact through the product's supply chain, from manufacture, assembly, and transportation, right to its disposal. This is adapted by the current CIRC4Life project as the foundation for the further development of the Eco-point approach.

In myEcoCost method, the ecoCost scores are derived from two indicators, material foot prints and carbon footprints (von Geibler *et al.*, 2013). After investigation, the current CIRC4Life project develops the eco-point method by applying more indicators rather than focusing on the two indicators due to the following considerations:

Material Footprint

The Material Footprint as an input-oriented indicator is part of the MIPS-concept (Material Input Per Service unit) (Schmidt-Bleek, 2000) developed by the Wuppertal Institute for Climate, Environment and Energy. The calculation of MIPS is divided into abiotic material, biotic material, air, water and soil movement. As all emissions and related impacts result from the extraction of natural resources it is assumed that a reduction of input leads to a decrease of emissions and environmental impacts (Saurat and Ritthoff, 2013).

MIPS is able to measure the overall raw material consumption of a certain product or service throughout its entire life cycle (Wiesen, Saurat and Lettenmeier, 2014). This means the application scope is limited, particularly, it cannot be applied for the environmental impact assessment in the recycling and waste scenario. This characteristic of MIPS is not applicable to meet CIRC4Life objective that using eco-point and eco-credit approach to record products' environmental impact through the entire life cycle and encourage recycling behaviours. Therefore, the core indicator of Eco-cost (i.e. MIPS) is not feasible for the eco-Point approach in CIRC4Life project.

Carbon Footprint

Carbon Footprint was selected as a satellite indicator of the Eco-cost method because it focuses on air emissions. The Carbon Footprint is a derivative of the ecological footprint invented in 1991 by the Canadian ecologists William Rees and Mathis Wackernagel (Wackernagel and Rees, 1998). Carbon Footprint is the overall amount of carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions (e.g. methane, laughing gas, etc.) associated with a product (ISO, 2006b). For the calculation of the Carbon Footprint, Global Warming Potential (GWP) factors defined by the Intergovernmental Panel on Climate Change (IPCC) (Metz, Meyer and Bosch, 2007) was used in Eco-cost method. The Carbon Footprint calculation considers the overall GWP as defined in the IPCC 2007 model for a time period of 100 years (Weidema *et al.*, 2013).

Carbon footprint is basically a 'Mono-criterion' analysis as it focuses on only one environmental impact, climate change, by GHG emission. LCA methods, in addition to GHG (Greenhouse Gas), take environmental releases and all other material inputs throughout the life cycle into account and assesses all the potential direct and indirect impacts on the environment. Thus, the LCA method is a 'Multi-Criteria' analysis that assesses multiple environmental impacts. There are various LCA methods. Considering the Carbon Footprint impact category in the mid-point level there is e.g. ReCiPe (Huijbregts *et al.*, 2016), CML (Guinée *et al.*, 2002), IMPACT 2002+ (Humbert *et al.*, 2015), EDIP 2003 (Hauschild and Potting, 2005). Therefore, using an existing robust LCA method to consider the carbon impacts along with other environmental impact categories is able to capture environmental impacts related to characteristics of the four types of demonstration products in CIRC4Life project, instead of focusing on the carbon impact category alone.

Concluding remarks

According to the review of the method developed by the myEcoCost project, the following issue is identified, and the method developed by the CIRC4Life will address the issue:

The Eco-cost method does not combine different indicators to one single score. It is not possible to further develop the eco-point method (e.g. eco-credit, eco-debit) that meets the need of the CIRC4Life. To solve this issue, this project will provide a means to put indicators together in order to generate a single score (eco-point), which will be applied in different areas (e.g. eco-shopping, consumer eco-account and production sustainability assessment).

1.2 Product environment footprint (PEF)

The Directorate-General for the Environment of the European Commission and the Joint Research Centre worked together to develop the methodology of the 'Environmental Footprint'. The methodology refers to a way to measure the environmental performance of products (Manfredi et al. 2012), which is so called product environmental footprints (PEF), by adopting a life cycle approach and basing on the material, energy, emission and waste flows occurring throughout the supply chains. Various standards and guiding documents served as references for an attempt to develop a harmonised European methodology, which include International Reference Life Cycle Data System (ILCD) Handbook (Institute for Environment and Sustainability (IES), 2010), ISO 14040/44 (ISO, 2006b), WRI/WBCSD GHG protocol (WRI, 2011), ISO 14025 (ISO, 2000), PAS 2050 (British Standards Institution, 2008), etc.

The European Commission developed a dashboard of environmental performance indicators to illustrate complex resource use impacts. This dashboard contains the categories material use, land, water, and carbon (Manfredi et al., 2012). Within the Product Environmental Footprint concept, a more comprehensive range of impact categories is suggested in Product Environmental Footprint Category – Rules Guidance (European Commission, 2018), which are presented in Table 1.

Table 1 Environmental impact categories for the EU dashboard and PEF

EU Dashboard	Environmental Impact Categories of PEF
Abiotic resources Biotic resources Land use Water	Climate change; Ozone depletion; Human toxicity, cancer; Human toxicity, non-cancer; Particulate matter; Ionising radiation; Photochemical ozone formation; Acidification; Eutrophication, terrestrial; Eutrophication, freshwater; Eutrophication, marine; Ecotoxicity, freshwater; Land use; Water use; Resource use, minerals and metals; Resource use, fossils.

26 pilots have been conducted to assess PEF from November 2013 to December 2016. (European Commission, no date). The results of these pilot activities have been reported in the 'Assessment of different communication vehicles for providing Environmental Footprint information' in 2018 (Lupiáñez-Villanueva *et al.*, 2018), which is the EU official report for PEF development so far. One of the critical comments in this report is quoted:

> 'The Recommendation clarified that these methods are not intended to directly support comparisons or comparative assertions, i.e. claims of overall superiority or equivalence of the environmental performance of one product compared to another, and that such comparisons require the development of additional PEF category rules or OEF sector rules that complement the general

> guidance, in order to further increase methodological harmonisation, specificity, relevance and reproducibility for a given product-type'.

This means the development of PEF are still in the impact category harmonization phase. It will be a long process over time for PEF to reach the stable practical phase. The suggested work for PEF development include to develop "PEF category rules or OEF sector rules'(Lupiáñez-Villanueva *et al.*, 2018).

Except this report mentioned above, there is also a technical review report from the scientific perspective regarding the PEF pilot actives and results (European Commission, 2017), which commented that:

> 'The PEF 'pilot phase is considered by many to be a good opportunity for the LCA harmonization at EU level and beyond Europe. The level of technical discussion and the large participation of LCA experts and industry is considered a strong point. However, some feel that the aim of the process is unclear or unrealistic, and a number have doubts about the robustness and the feasibility of the methodology.'

The two reports offer authority conclusions for the PEF development in the level of policy making and scientific approach, respectively. Indicators covering all environmental categories of the EU dashboard are necessary, but to integrate the diverse PEF indicators, while PEF is currently still in a transition phase, is beyond the scope of the CIRC4LIFE project. Once the specific rules (e.g. sector and product category rules) are set by the European Commission, it should be considered to integrate links to PEF in the CIRC4Life project.

From the above review, we can conclude that the PEF is an important tool to measure environmental impact. However, it has not reached the stage for implementation in practical applications, therefore we are unable to implement it in our eco-point method at this moment, but we shall keep our eyes on it in order to consider how to implement it as soon as the PEF is available. A PEF-LCA study will be conducted in the demonstration phase of the project to identify synergies, complementarities and differences between PEF and the eco-point method.

1.3 LCIA methods

In order to select a suitable method to calculate the eco-point of the CIRC4Life project, a thorough literature review was conducted, which is recorded in the following:

- The article "Review of life cycle impact assessment (LCIA) methods and inventory databases" (Wu and Su, 2018) reviews 13 life cycle impact assessment methods and compares the differences among the main LCIA methods. The methods which were investigated include: Ecological Footprint, Cumulated Energy Demand, CML, Eco-indicator 99, IMPACT 2002+, USEtox 2.01, EDIP 2003, IMPACT World+, ReCiPe, ILCD 2011 Midpoint, TRACI 2.1, LC-Impact, and Ecological Scarcity 2013. For more information about the LCIA methods, please see the **Appendix** 'Brief descriptions and environmental impact categories of major LCIA methods.
- The document "Methods and tools for environmental assessment of products" (CIRC4Life, 2018) reviews 5 methods and 3 tools for product environment assessment. The methods contain Life cycle analysis, Carbon Footprint, The Ecological Footprint, Product environmental Footprint, Organisation Environmental Footprint (Greenhouse Gas Protocol, BPX 30-323-0, PAS 2050, and Exergy analysis). The tools for circular economy development include The Material Circularity Indicator (MCI), The Circular Economy Toolkit (CET), and Circular Economy Indicator Prototype (CEIP).

1.4 Selection of Eco-point calculation method

Based on the reviews of the above myEcoCost method, PEF, and various LCIA methods, ReCiPe is selected to calculate the product eco-points to measure environmental impacts of products due to its following major advantages:

- ReCiPe is one of the most recent and harmonized indicator approaches available in life cycle impact assessment (LCIA) (Huijbregts et al. 2016).
- ReCiPe calculates eighteen midpoint indicators and three endpoint indicators to express the relative severity on the environmental impact categories. Midpoint indicators focus on single environmental problems, for example climate change or acidification. Endpoint indicators show the environmental impact on three higher aggregation levels, being the 1) effect on human health, 2) biodiversity and 3) resource scarcity.
- ReCiPe can combine LCA results as a single score via weighting, which allows to easily compare the environmental impact of different products or scenarios (Kalbar et al. 2017). Weighting is the final step in Life Cycle Impact Assessment. This facilitates decision making, since it is immediately clear whether a product's impact is higher than, lower than or similar to the alternatives. It is much easier to explain a single score for environmental impact than it is to explain 3 to 17 different scores per product or scenario. Further, the single score can be used to develop eco-point method, such as eco-credit and eco-debit. Although the application of a single score is still debatable, it does facilitate the compassion of the environmental impact of different products and decision for the development and consumption of sustainable products.
- Unlike other methods (such as Eco-Indicator 99, EPS Method, LIME, and Impact 2002+), ReCiPe does not include potential impacts from future extractions in the impact assessment but assumes such impacts have been included in the inventory analysis (Huijbregts et al. 2016).

2 The Eco-point Method

The Eco-point method is to account the sustainability of products purchased and recycled, which includes three basic items: eco-point, eco-debit and eco-credit. The eco-debit reflects the negative impact of the product generated through its value chain, while the eco-credit is a positive value to credit recycling activities. Both eco-debit and eco-credit are derived from eco-point which is calculated using a life cycle impact assessment method. The eco-point method can be applied in the eco-accounts for both consumers and manufactures. These are further detailed in the following sections.

2.1 Eco-point Value

Eco-point is a cumulative value, which accounts for an aggregate of the ecological impacts throughout the product's whole supply chain. Eco-point is produced via utilising the method of life cycle impact assessment (LCIA). One of the most commonly used LCIA methods is ReCiPe (Golsteijn, 2017), which applies seventeen midpoints and three endpoints to assess the impact of product. CIRC4Life will develop a method to combine three endpoints, i.e. human health, ecosystem and resource, to produce an eco-point, as shown in

Figure 2.1.

To obtain the midpoints and the endpoints, the following impact elements are considered: the impacts of materials used, production/ manufacturing process, packaging, transportation and human labour involved in the production process, overhead of ecological cost, product service life, design for disassembly, product re-use, recycling, and disposal *(Su and Ren, 2011)*. The above impact elements are applied to the product's assembly, which is formed by the sub-assemblies with a number of components. The impact elements are utilised as the input parameters of LCIA method in order for calculating midpoints, endpoints, and eco-point as illustrated in Figure 2.1.

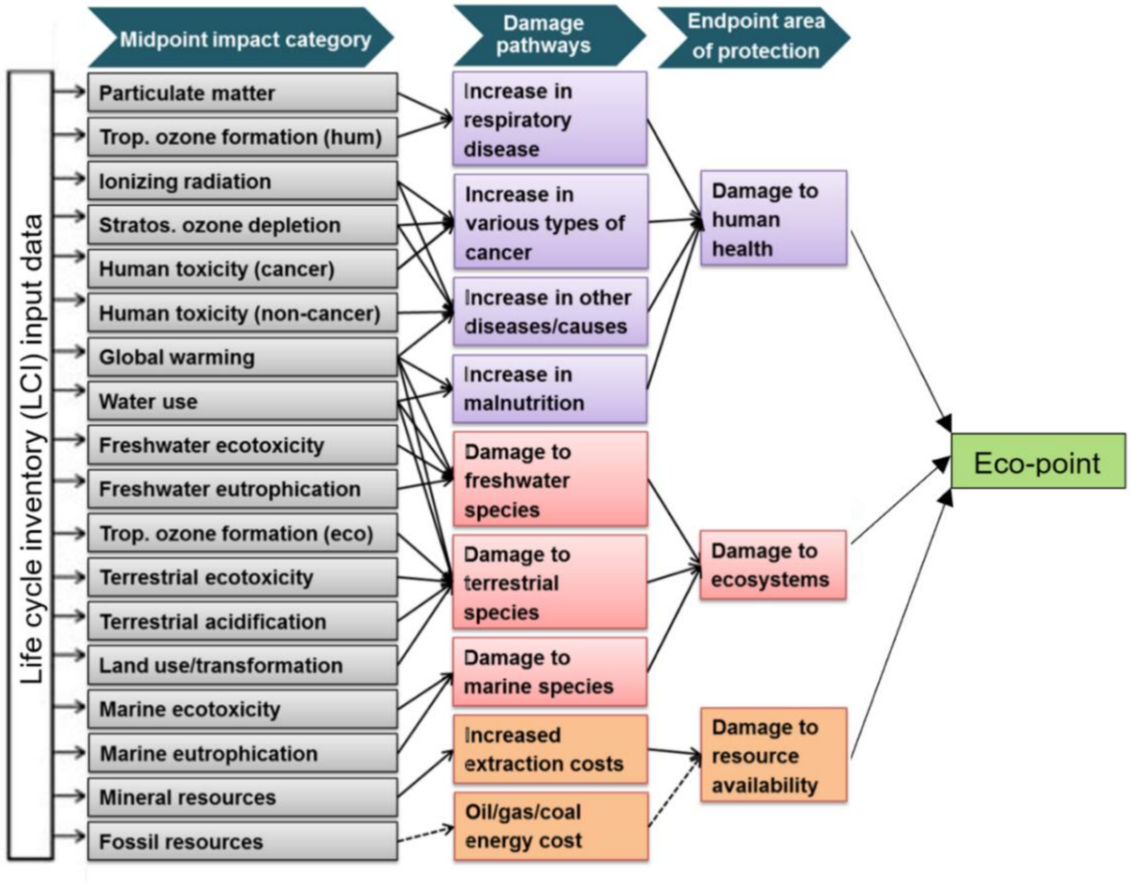

Figure 2.1 Calculation of the eco-points based on the ReCiPe method

2.2 Utilisation of Eco-point in Eco-accounting and Eco-shopping

In this research, the following new concepts and related methods are developed based on the eco-point:

(1) **Eco-debit, which** is used to show the customer's negative ecological impact resulting from the products purchased Figure 2.2. Within the eco-point approach, each product is associated with an eco-point, which is calculated through the product value chain, in which the use stage is included. The product eco-point is then converted to the consumer eco-debits. The eco-point is an absolute value. Considering that the eco-debit represents a negative impact, and in contrast with the eco-credit stated below, the eco-debit value is assigned with a negative sign '-'. For example, if the eco-point of a book is 9, then the eco-debit value of the book is -9.

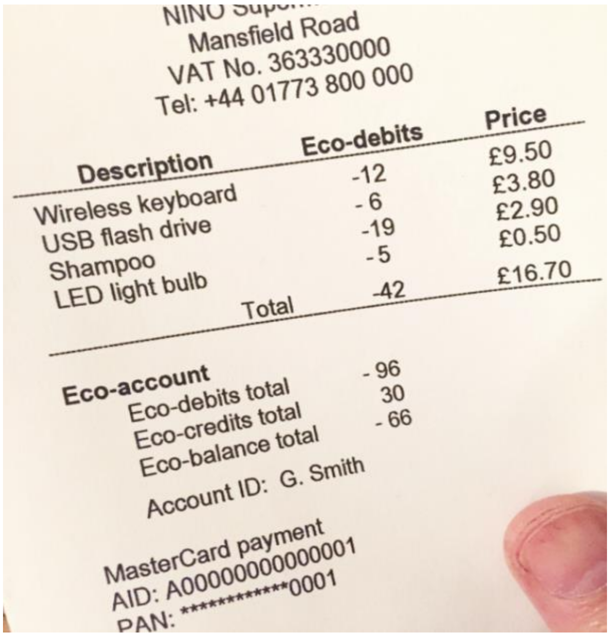

Figure 2.2 The customer receipt showing the price and eco-account items of the products purchased

In the sustainable consumption, the eco-debit is applied as a way to assess the ecological impact of products purchased, based on the following considerations:

1) The eco-debit is developed based on the eco-point. Although the eco-point and the eco-debit apply the same amount (different signs), they are different concepts and have different applications. The eco-point indicates a measure to assess the environmental impact of products, while the eco-debit is applied to show the consumers' negative behaviour related to their purchasing activities.

2) The eco-debit is a negative value. The larger the eco-debit value of the product, the smaller the impact of the product on the ecology. For example, if the eco-debits of one product are -1 and the eco-debits of another product are -10, then the former shows that the product is more sustainable. There is no maximum value in the eco-debits.

   In contrast to the eco-debit, the eco-point is a positive amount (absolute value). As presented in Section 2.1, the eco-point is derived from ReCiPe method, which indicates that when the eco-point value of the product is large, it means that the product generates severe ecological impact. In other words, a product with large eco-point value is less sustainable than that with small eco-point value.

   In general, people anticipate that high value represents good sustainability (small impact) of the product. The concept of the eco-credit complies with people's general way of thinking.

3) The eco-debit reflects the negative impact, while the eco-credit, which is stated in the sub-section 2.2.(2), represents the positive impact. The different signs, '-' and '+', help to understand the impact of the product from the both positive and negative perspectives.

The eco-point is calculated throughout the product's whole value chain, in which the use and distribution stages have been included. In the use stage, the average/estimated values of impact elements, e.g. life time, eletricity and water used, etc. are utilised as input parameters for calculating the eco-points. During the distribution stage, the transportation from warehouse to selling point (retailer) is considered in the calculation.

Since the eco-point and the eco-debit represent the same quantity, the impacts of the use and distribution are reflected by the eco-debit too.

(2) **Eco-credit**, which is used to credit the customer's positive behaviour for their longer-time use, and their sorting process for later recycling or reuse of the products. Eco-credit value could be higher than Eco-debit value due to longer use time, and hence, we may have to trace the actual life span and the designed one. The eco-credits are calculated based on the eco-points, with the particular conversions proposed by WP2 team of this project (*CIRC4Life D2.4 team, 2019*):

- In the case of WEEE (waste electrical and electronic equipment), such as tablets:

$$Eco - credits = A \cdot \sum_{i=1}^{n} a_i \, rarity_i + B \cdot EoL \text{ state} + \mathrm{C} \cdot lifetime\ factor \qquad (1\text{-}1)$$

where **A** and **B** are parameters which reflect the importance of raw materials and reuse capacity and **C** is the Eco-points of the product. **Rarity** indicates the physical value of raw materials, '**EoL state**' indicates the state value of the product at the end-of-life, and '**lifetime factor**' indicates the length of time that a product is utilised compared to the expected life span.

- In the case of organic urban waste, the state of the EoL products and the lifetime factor is not possible, so the formula is simplified:

$$Eco - credits = D \cdot b_{ch,organic\ waste} \cdot m_{organic\ waste} \qquad (1\text{-}2)$$

where $b_{ch,organic\ waste} \cdot m_{organic\ waste}$ indicates chemical exergy that shows the rarity of organic materials, and **D** is a coefficient of the above factor.

In the above formulas, rarity is an important application of eco-credit, which is part of the Eco-point method. Considering the recyclability and exergy consumption, the impacts of the materials used are further assessed in the eco-point method. Eco-credits wanted to act as a double accounting (because materials are also used in eco-points) in order to highlight the importance of avoid rare materials to be disposed in landfill due to the large amount of exergy required to prepare them to be used at factories.

For the detailed information about the Eco-credit please see deliverable D2.4 'Eco-credits method final definition*' (CIRC4Life D2.4 team, 2019)*.

(3) **Consumer's eco-account**, which is to record consumers' eco-debits and eco-credits related to purchasing and recycling activities and, hence, it enables consumers to record and track their daily footprints on the environment. The eco-balance is calculated based, as it would happened in a bank account, on the sum of the eco-debits (expenses) and eco-credits (incomes), resulting in the value of eco-balance i.e.

$$EcoB = EcoD + EcoC \qquad (1\text{-}2)$$

where **EcoD** is eco-debits and **EcoB** is eco-balance which reflects the consumer's overall impact footprints, as shown in the Table 2.

Table 2 Example of a consumer eco-account page Example of a consumer eco-account page

Products	eco-debits (via purchasing)	eco-credits earned (via use and recycling/reuse)	eco-balance
book	-9	11	2
computer	-18	13	-5
Total	-27	24	-3

(4) **Eco-shopping,** which enables consumers to view the eco-points and sustainable manufacture information of products using their smartphones in the stores. Consumers can scan the barcode, QR and/or RFID tags embedded in the products placed on the store shelf to obtain the product's sustainability information, which will help the consumers to select more sustainable products.

3 The Eco-accounting Platform

The eco-accounting platform is developed to implement the eco-point method, including 'eco-point', 'eco-debit', 'eco-credit', and 'eco-balance', with the special concerns on the product's sustainability. The following functions are provided by the platform:

- The consumer can utilise the smartphone to scan the data identifier embedded in the product to view the product's eco-points and sustainable manufacturing information in the store, and then retrieve the eco-debits through purchasing the products.
- When the consumers' products come to the end-of-life (EoL), they recycle the products and then get the eco-credits. The eco-credits could be paid in cash or the equivalent to the consumer.
- The consumer's eco-account records both the eco-debits obtained via purchasing and the eco-credits obtained via recycling/reuse. Then, the eco-balance is calculated based on the sum of the eco-debits and eco-credits, in order to reflect the overall impact footprints of consumers.
- The eco-point value can be used as an indicator to assess the product's sustainable impact throughout the production process. In order to reduce the eco-point value Relevant aspects affecting the eco-point values within the production process need to be investigated, and then necessary sustainable production methods can be implemented in the production.

The eco-accounting platform utilises the information and communication technologies to collect and process the data for the calculation of eco-points, and then apply the eco-points obtained into the different areas, including eco-shopping, recycling/reuse, consumer's eco-account, and product sustainability assessment, as shown in Figure 3.3.

Within the eco-accounting platform, a large amount of dynamic data are captured from the product supply chain, in order to provide the inputs for the calculation of eco-points. Subsequently, the life-cycle assessment (LCA) is conducted utilising the LCA method and related tools. With the Web-based user interfaces, the LCA tools, such as SimaPro or openLCA, are enabled to online calculate the eco-points with the data bridging method. Based on the eco-points obtained, the eco-debits and eco-credits are developed, which reflect the consumers' negative and positive impacts on the environment, respectively.

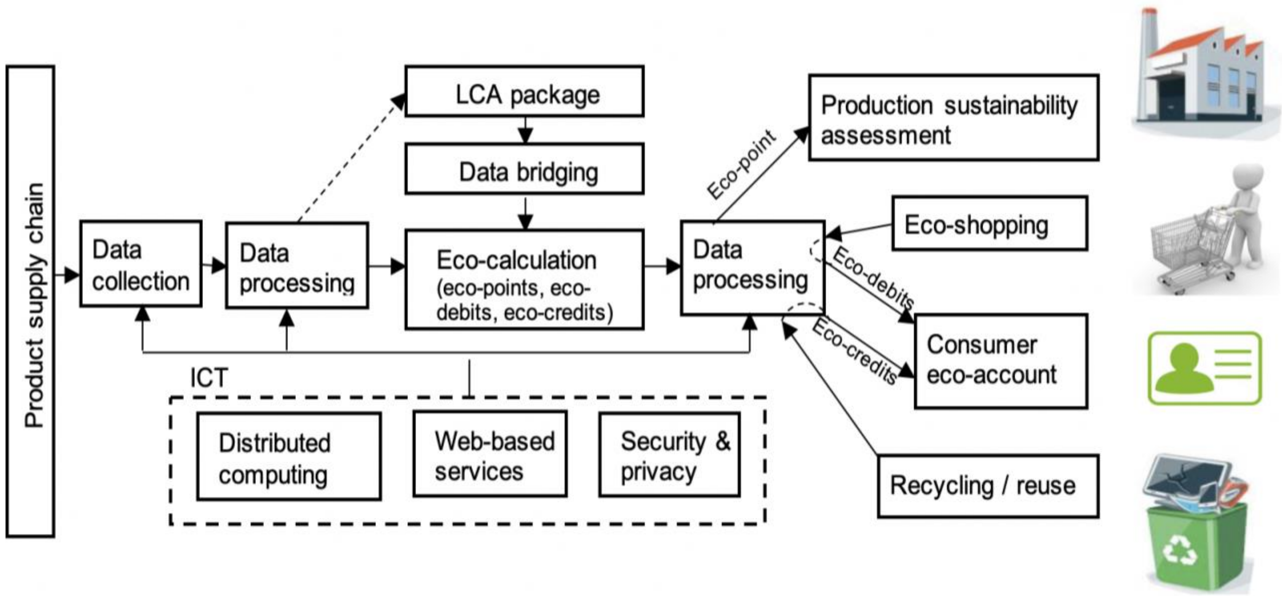

Figure 3.3 The eco-accounting platform

4 Concluding Remark

The background research was conducted including the ecoCost method developed by the FP7 myEcoCost project, product environmental footprints (PEF) and LCIA methods. Based on the results of the background research, the ReCiPe method is selected to calculate the eco-points. A PEF-LCA study will be conducted in the demonstration phase of the project to identify synergies, complementarities and differences between PEF and the eco-point method.

The eco-accounting infrastructure consists of the eco-point method and the eco-accounting platform, which are summarised as follows:

(1) The Eco-point method is derived from 'eco-point', which is used to assess the overall ecological impacts of products throughout their value chain. Eco-point is calculated by applying a method of life cycle impact assessment (LCIA).

The Eco-point method is to account the sustainability of products purchased and recycled. Based on the eco-point, the Eco-point method utilises the following concepts and relevant methods:

- 'eco-debit', to account for the consumer's negative impact generated from the products purchased,
- 'eco-credit,' to reflect the consumer's positive behaviour related to their recycling activities.
- 'eco-account', to record and track their footprints on the environment,
- 'eco-shopping', enabling consumers to gain the ecological information of the products to be purchased.

(2) The eco-accounting platform provides the means to implement the Eco-point method, such as eco-debits and eco-credits, and its application in eco-accounting and shopping. With the eco-accounting platform, the ICTs are applied to collect and handle a number of dynamic data from the value chain, which provide inputs for the eco-point calculation. Further, online LCA is conducted with user-friendly interfaces, and eco-points of products are calculated. Based on the eco-points, eco-debits and eco-credits are developed and utilised in the different areas, such as consumer eco-account, eco-shopping and recycling.

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Appendix: Brief descriptions and environmental impact categories of major LCIA methods

Methods	***Descriptions***	***Midpoint Impact Categories***		***Endpoint Impact Categories***
Ecological Footprint	It considers biologically productive land and sea area to produce all consumed products and absorb generated waste (Hischier et al. 2010)	land occupation climate change nuclear energy use		global hectar (Consumption of hectare with global average bioproductivity, gha)
Cumulated Energy Demand	It assesses primary energy required for production, use and disposal of a product (Hischier et al. 2010).	fossil nuclear primary forest biomass	geothermal solar wind water	Non-renewable resources, renewable resources
CML	It assesses specific impact categories and this method is divided into two versions: baseline and non-baseline. It only assesses midpoints' impacts (Guinée 2002).	depletion abiotic resources climate change stratospheric ozone depletion human toxicity marine ecotoxicity	fresh-water aquatic eco-toxicity terrestrial ecotoxicity photo-oxidant formation acidification eutrophication	N/A
Eco-indicator 99	It replaces Eco-indicator 95, and covers all emission categories and parts of the resource categories (PRé 2015).	climate change ozone layer depletion acidification/eutrophication carcinogenic fossil resources	Ionizing radiation ecotoxicity land use mineral resources respiratory organic respiratory inorganic	human health, ecosystem quality resource depletion

IMPACT 2002+	It is mainly based on Eco-indicator 99 & CML 2002 linking 14 midpoint categories to four damage categories (Weisbrod & Van Hoof 2011).	human toxicity respiratory effects Ionizing radiation ozone depletion photochemical oxidant aquatic ecotoxicity terrestrial ecotoxicity	aquatic acidification aquatic eutrophication terrestrial acid/nutr land occupation global warming non-renewable energy mineral extraction	human health ecosystem quality climate change natural resources
USEtox 2.01	It is a scientific consensus model for assessing human and ecotoxicological impacts of chemical emissions in life cycle assessment (Rosenbaum *et al.*, 2008).	freshwater ecotoxicity	carcinogenic non-carcinogenic	ecosystem quality human toxicity
EDIP 2003	It is a follow-up of the EDIP 97 methodology, and it covers only emission categories and considers midpoint impacts (Ciroth 2014).	global warming ozone depletion acidification terrestrial eutrophication aquatic eutrophication (N-eq, P-eq) Ozone formation (human, vegetation)	human toxicity (exposure route via air, water, soil) ecotoxicity (water acute, water chronic, soil chronic) waste (hazardous, slags/ashes, bulk waste, radioactive waste)	N/A
IMPACT World+	It is developed as a joint major update to IMPACT 2002+, EDIP, and LUCAS methodology, and it assesses local and regional impact categories (Bulle et al. 2014).	human toxicity photochemical ozone formation ozone layer depletion global warming	ecotoxicity acidification eutrophication water land use resource use	human health ecosystem quality resources and ecosystem services

ReCiPe	It is a follow up of Eco-indicator 99 and CML 2002 methods that integrates and harmonizes midpoints and endpoint approaches (Goedkoop et al. 2009).	climate change ozone depletion terrestrial acidification freshwater eutrophication marine eutrophication human toxicity photochemical oxidant formation particulate matter formation terrestrial ecotoxicity	freshwater ecotoxicity marine ecotoxicity ionising radiation agricultural land occupation urban land occupation natural land transformation depletion of fossil fuel resources depletion of mineral depletion of freshwater resources	human health ecosystem quality resources
ILCD 2011 Midpoint	It analyses the emissions into air, water and soil, as well as the resources consumed in terms of their contributions to different impacts on human health, natural environment, and natural resources (European Commission 2011b).	climate change ozone depletion human toxicity particulate matter/respiratory inorganics photochemical ozone formation	ionizing radiation impacts acidification eutrophication ecotoxicity land use and resource depletion	N/A
TRACI 2.1	It is a tool for the reduction and assessment of chemical and other environmental impacts (Bare 2011). It is a midpoint oriented LCA method (Hischier et al. 2010).	acidification ecotoxicity eutrophication ozone depletion smog depletion climate change	resource depletion (fossil fuels) human health (air pollutants criteria, carcinogenic, non-carcinogenic)	N/A

LC-Impact	It is an environmental assessment method focused on a global level, and spatially differentiated characterization factors are developed to support the assessment on a regionalized scope (Ponsioen et al. 2014).	water stress climate change toxicity photochemical ozone formation particular matter formation lionising radiation	ozone depletion eutrophication land stress acidification fossil resource scarcity mineral resource scarcity	human health ecosystem quality resources
Ecological Scarcity 2013	It weights environmental impacts with eco-factors, which are derived from political targets or environmental laws (Frischknecht & Knöpfel 2014)	water sources energy sources mineral sources land use global warming ozone layer depletion main air pollutants and PM carcinogenic substances into air heavy metals into air water pollutants POP into water	heavy metals into water pesticides into soil heavy metals into soil radioactive substances into air radioactive substances into water noise non-radioactive waste to deposit radioactive waste to deposit deposit waste	environmental loading points