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Agro2Circular

D7.5 – Evaluation framework and methodology

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Authors: Barbara Branchini, Aran Blanco (KVELOCE); Carlos Serra, Alfonso Gallego (UVEG); Essi Paronen (VTT); Edoardo Croci, Federico Cornacchia, Benedetta Lucchitta, Tania Molteni, Tommaso Penati (UB).

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Executive Summary

This report constitutes Deliverable "D7.5: Evaluation framework and methodology", which is the main outcome of Task "T7.2: Evaluation framework".

The **purpose** of this report is to detail the evaluation framework and methodology that will be used to assess the environmental, socio-cultural and socio-economic feasibility and the potential A2C systemic solution impact. The objective of the evaluation is twofold: it is aimed at assessing the environmental, socio-cultural and socio-economic feasibility on one side, and on the other, the potential impact of the Agro2Circular solution. Moreover, the evaluation is closely related to the multidimensional model for adoption of A2C systemic solution: key outcomes from the evaluation will drive conclusions on the replicability and scalability determinants of the generated A2C Circular Economy Business Models (CEBMs).

Chapter 1 provides the overall evaluation framework, based on analysis of the evaluation purpose and object. The A2C evaluation will use a theory-based approach and the Life-Cycle Sustainability Assessment (LCSA) multidimensional model.

According to the *theory-based approach*, the evaluation will be focused on the intervention processes, results and underlying change mechanisms, which need to be identified and analysed in depth and collaboratively with partners in charge of the intervention development and implementation.

In line with the *Life-Cycle Sustainability Assessment (LCSA)* model, the evaluation will imply the assessment of all environmental, social and economic negative impacts and benefits of a product throughout its life cycle and the contemporary application of the three perspectives.

Chapter 2, 3 and **4** detail the conceptual framework and main methodological features of the three life cycle techniques: environmental Life-Cycle Assessment (LCA), Life Cycle Costing (LCC) and Social Life Cycle Assessment (S-LCA).

The background for the integration of the three perspectives and techniques is the *triple bottom line* (people, planet and prosperity) of sustainability, referring to the idea that for achieving more sustainable futures, environmental, economic as well as social impacts of activities have to be taken into account within a systemic perspective.

The **evaluation boundaries** will be further identified for each assessment dimension (environmental, social and economic) along the evaluative process, unveiling the main processes, outcomes and mechanisms of change, and validated collaboratively with technical partners in charge of the process's implementation and deployment.

To this end, specific activities, such as workshops and bilateral meetings, will be held, aimed at fine-tuning the environmental, social and economic evaluations and nurture the related deliverables (D7.6-D7.9).

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List of abbreviations

Abbreviation	Definition
GHG	Greenhouse Gas
A2C	Agro2Circular
GWP	Global Warming Potential
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
PEF	Product Environmental Footprint
F&VW	Fruits & Vegetable Wastes
CEBMs	Circular Economy Business Models
DIS	Data Integration System
LCSA	Life Cycle Sustainability Assessment
UNEP	United Nations Environment Programme
SETAC	Society of Environmental Toxicology and Chemistry
SCP	Sustainable Consumption and Production
LCM	Life Cycle Management
LCC	Life Cycle Costing
S-LCA	Social Life Cycle Assessment
SDG	Sustainable Development Goals

Glossary

Conceptual framework: A system of concepts, assumptions, expectations and theories that structures the research by identifying the research variables and their relationships. It assists with identifying the problem and framing the research questions. Related terms: theoretical framework.

Characterisation: calculation of the magnitude of the contribution of each classified input/output to their respective environmental footprint impact categories, and aggregation of contributions within each category.

Environmental impact category: class of resource use or environmental impact to which the life cycle inventory data are related.

Functional unit: defines the qualitative and quantitative aspects of the function(s) and/or service(s) provided by the product being evaluated. The functional unit definition answers the questions ‘what?', ‘how much?', ‘how well?', and ‘for how long?'.

Impact: Positive and negative, primary and secondary long-term effects produced by a development intervention, directly or indirectly, intended or unintended [1].

Input: The financial, human and material resources used in a programme or policy. For example, training materials produced.

Life Cycle Assessment: compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.

Life cycle inventory: combined set of exchanges of elementary, waste and product flows in a LCI dataset.

Life cycle impact assessment: phase of life cycle assessment that aims to understand and evaluate the magnitude and significance of the potential environmental impacts for a system throughout the life cycle.

Outcome: The likely or achieved short-term and medium-term effects of a programme or policy’s outputs, such as a change in vaccination levels or key behaviours.

Output: The immediate effects of programme/policy activities, or the direct products or deliverables of programme/policy activities. For example, the number of vaccines administered.

Theory of Change: A ‘theory of change’ explains how activities are understood to produce a series of results that contribute to achieving the final intended impacts. It can be developed for any level of intervention – an event, a project, a programme, a policy, a strategy or an organization.

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1 Overall evaluation framework

Evaluation purpose

The Agro2Circular (A2C) project will develop at laboratory scale new technologies for the upcycling of Fruits & Vegetable agri-food Wastes (F&VW) and non-renewable multilayer plastics into new high added value products with application in the food, nutraceutics and cosmetic sectors.

The developed technologies will be then integrated and scale up in a demonstrator in Murcia (Spain), and their performance in the industrial environment evaluated.

The objective of the evaluation is twofold: it is aimed at assessing the environmental, socio-cultural and socio-economic feasibility on one side, and on the other, the potential impact of the Agro2Circular solution.

Moreover, the evaluation is closely related to the multidimensional model for adoption of A2C systemic solution: key outcomes from the evaluation will drive conclusions on the replicability and scalability determinants of the generated A2C Circular Economy Business Models (CEBMs).

Accordingly, the evaluation framework relies on a *theory-based approach*, which is particularly convenient to understand why an intervention produces intended and unintended effects and to which interventions these findings can be transferred and what determines the degree of transferability. The goal is to answer the "why does it work?" question by identifying the Theory of Change behind the programme and assessing its success by comparing theory with actual implementation [2].

The Theory of Change explains how activities are understood to produce a series of results that contribute to achieving the expected final impacts. It can be developed for any level of intervention, be it an event, a project, a program, a policy, a strategy or an organisation. In an impact evaluation, the Theory of Change is useful to establish what data need to be collected and how they should be analysed.

In order to develop a Theory of Change, it is important to ensure that the theory adequately represents what the intervention pursues and how it does it, in a way that satisfies its future users. It is possible to develop a Theory of Change when the objectives and activities of an intervention can be identified and planned in detail in advance.

Evaluation object

The object of the environmental, socio-cultural and socio-economic evaluation is the Agro2Circular systemic solution. A2C is a territorial systemic solution for the upcycling of fruit & vegetable and multilayer plastic residues generated in the agrifood sector into high added value products to be used in the food, nutraceutics and cosmetic sectors, powered

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by a digital tool and constructed upon a systemic approach with high replicable/scalable potential (Figure 1).

Figure 1 A2C technical approach

The solution entails the following main processes:

1. Extraction and purification of bioactive substances from Fruit and Vegetables (F&V) wastes by a hybrid strategy of green solvents and sustainable advanced extraction technologies.
2. Production of a range of new formulations using the bioactive substances extracted from wastes for their application in cosmetic, nutraceutics and food.
3. Recycling of the multilayer plastics coming from agriculture and post-industrial packaging.
4. Upcycling of the recycled plastics coming from agriculture and post-industrial packaging to obtain high added value materials.
5. Developing an A2C Data Integration System for the traceability of materials and a predictive tool allowing the selection of the best upcycling option for each material from the existing alternatives.

The technologies development and processes deployment will take place at small (laboratory) and pilot scale, in real settings. Both will be assessed from an integrated perspective, i.e. environmental, social and economic, nurturing the A2C multidimensional model and self-assessment tool to facilitate replication and scalability.

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Evaluation approach

In line with the evaluation purpose and theory-based approach, the evaluation will be focused on the intervention processes, results and underlying change mechanisms, which need to be identified and analysed in depth and collaboratively with partners in charge of the intervention development and implementation.

The A2C processes, results and outcomes were systematised within the solution Theory of Change (Figure 2), based on the project documents analysis.

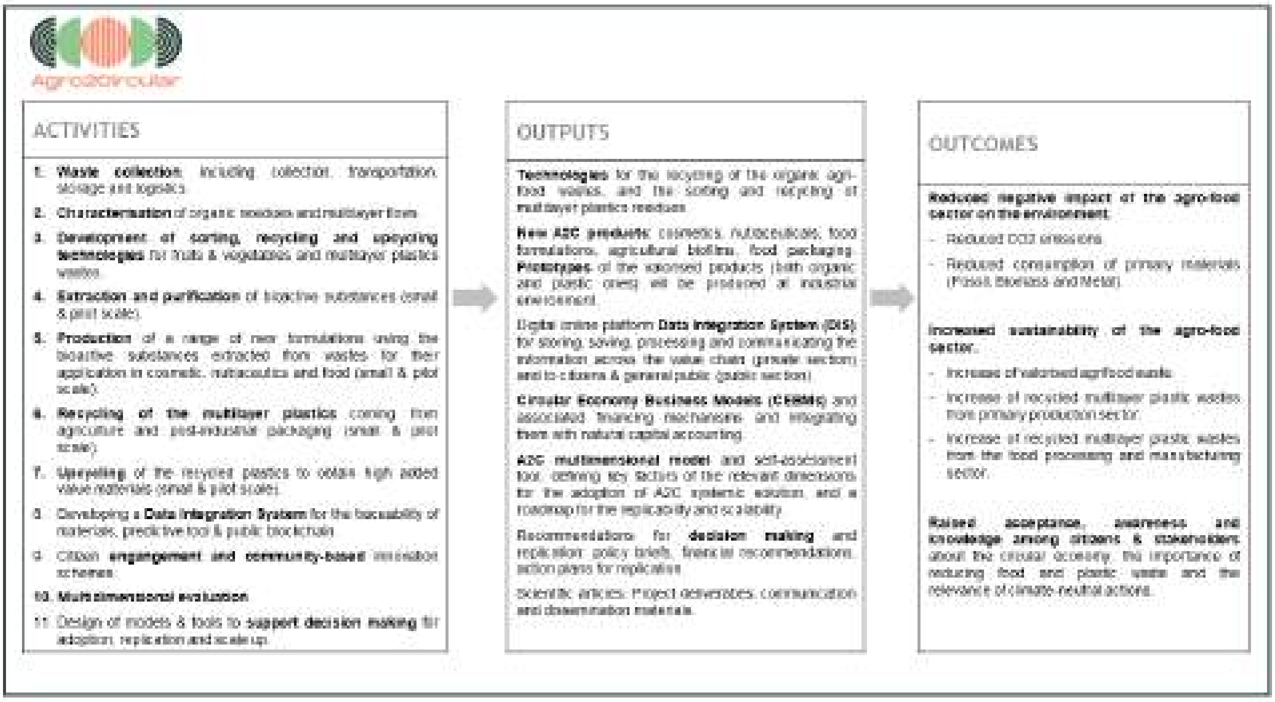

Figure 2 A2C Theory of Change

The A2C evaluation will follow a systemic approach, based on the intervention Theory of Change, and a multidimensional perspective, covering the environmental, social and economic dimensions.

Evaluation boundaries

The A2C Theory of Change will be furtherly detailed along the evaluative process, unveiling the main processes, outcomes and mechanisms of change, and validated collaboratively with technical partners in charge of the process's implementation and deployment.

The evaluation boundaries will be identified for each assessment dimension (environmental, social and economic) accordingly, under a joint effort for alignment.

To this end, specific activities, such as workshops and bilateral meetings, will be held, involving evaluation experts (KVELOCE, VTT, UVEG and UB) and technical partners, and

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where different techniques can be used, like systems or outcome mapping, process tracing, or building the Theory of Change.

These activities will allow fine-tuning the environmental, social and economic evaluations and nurture the related deliverables (D7.6-D7.9).

Life-Cycle Sustainability Assessment approach

The A2C evaluation framework is based on a multidimensional perspective combined within the *Life Cycle Sustainability Assessment* (LCSA), based on the life cycle thinking and the environmental sustainability integration with economic models, ecological models and social theories [3].

Life cycle thinking is about going beyond the traditional focus on production sites and manufacturing processes so that the environmental, social, and economic impact of a product over its entire life cycle, including the consumption and end of use phase, is taken into account [4].

The United Nations Environment Programme (UNEP) and the Society of Environmental Toxicology and Chemistry (SETAC) have used the life cycle approach since the 1990s and, more specifically, since 2002, through the UNEP/SETAC Life Cycle Initiative, which has contributed, inter alia, to the Marrakech Process on Sustainable Consumption and Production (SCP) and to the development of a 10-Year Framework of Programmes on SCP and to UNEP's Green Economy Initiative [5].

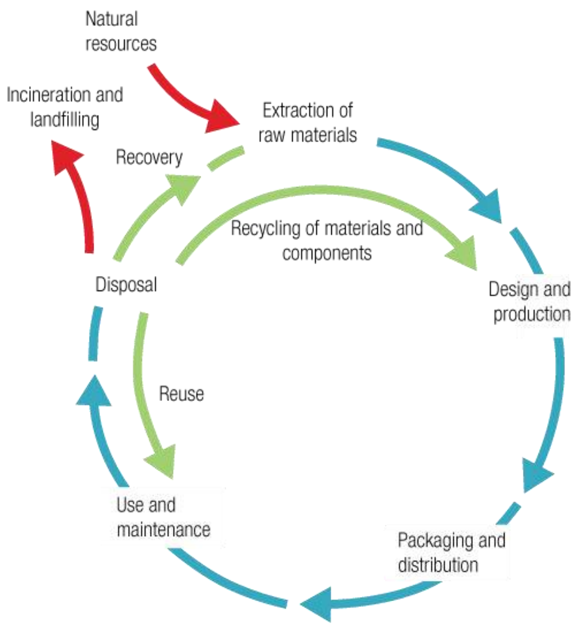

Figure 3 A typical product lifecycle diagram

Source: https://www.lifecycleinitiative.org/starting-life-cycle-thinking/what-is-life-cycle-thinking/.

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The aim of the Life Cycle Initiative consists of putting life cycle thinking into practice and improving the supporting tools through better data and indicators. Its mission is to develop and disseminate practical tools for evaluating the opportunities, risks, and trade-offs associated with products and services over their entire life cycle to achieve sustainable development[1].

A life cycle approach enables product designers, service providers, government agents and individuals to make choices for the longer term. Life cycle thinking is made operational through Life Cycle Management (LCM). It is an integrated concept for managing the total life cycle of goods and services towards more sustainable production and consumption.

LCM uses various procedural and analytical tools for different applications and is applicable for primary and secondary sectors of economic activity as well as other for organisations, expanding its scope to all stakeholders in the value chain [4]. Life Cycle Management integrates economic, social and environmental aspects into an institutional context.

Indeed, the life cycle approach is rooted into the sustainability concept for the following characteristics: (1) the system thinking, i.e., the capability of understanding and addressing a system by analysing the linkages and interactions between the elements that compose the entirety of the system; (2) the interdisciplinary approach, whose most evident example is given in the impact assessment phase [6]. Accordingly, a Life Cycle Sustainability Assessment has been developed, expanding the Life Cycle Assessment practice and boundaries.

The *Life Cycle Sustainability Assessment* implies the evaluation of all environmental, social and economic negative impacts and benefits of a product throughout its life cycle and how to use the result to support decision-making processes [5].

The background for the LCSA definition is the *triple bottom line* (people, planet and prosperity) of sustainability, referring to the idea that for achieving more sustainable futures, environmental, economic as well as social impacts of activities have to be taken into account within a systemic perspective [7].

1 https://www.lifecycleinitiative.org/starting-life-cycle-thinking/life-cycle-approaches/.

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Figure 4 Triple bottom line of sustainability

Source: based on [8].

The LCSA approach is based on the concept that the assessment of sustainability performance of product or service should be carried out by the contemporary application of the three perspectives, and implementation of the three life cycle techniques: environmental Life-Cycle Assessment (LCA), Life Cycle Costing (LCC) and Social Life Cycle Assessment (S-LCA).

The A2C Life Cycle Sustainability Assessment will combine techniques and results under the LCA, LCC and S-LCA perspectives, and will nurture the A2C multidimensional model for replication and self-assessment.

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2 Environmental assessment framework

Definition of the environmental evaluation framework – Life Cycle Assessment as method

Life cycle assessment (LCA) is a quantitative method for assessing the potential environmental impacts of a product or a service. The LCA principles are presented in ISO 14040 and 10444 standards. Modelling the life cycle of a product is based on interlinked unit processes that are connected to each other with material or energy flows. Each process consists of inputs and outputs, which connect the process to previous and following processes. Besides the ISO Standards, the LCA carried out in the project will also follow the Product Environmental Footprint (PEF) methodology developed by the European Commission. The PEF methodology aims to provide a methodology that enables measuring environmental impact in a common way among LCA practitioners.

Figure 5 shows the typical life cycle stages included in a LCA study. The stages include the production of raw materials and energy, manufacturing of the product, all transportations, distribution, use phase, and final disposal of the product or other end-of-life treatment [9,10].

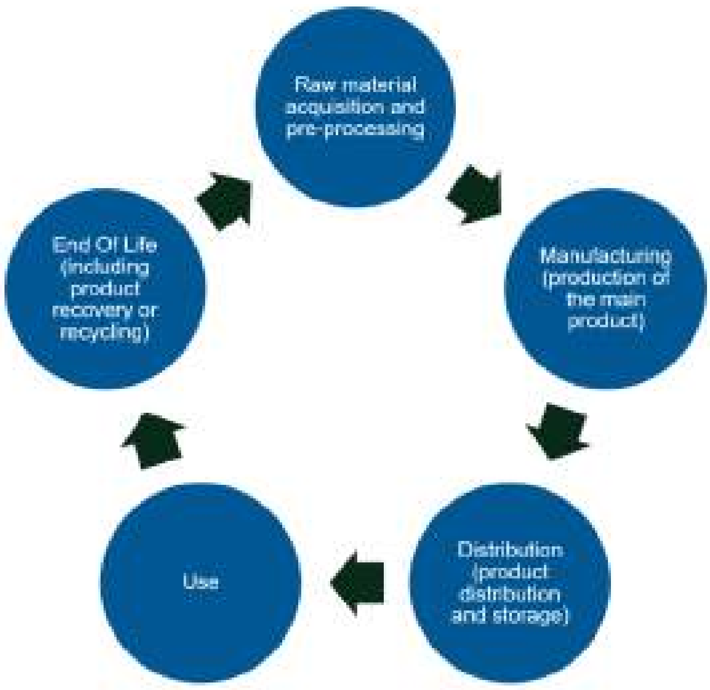

Figure 5 Life cycle stages that should be at least included in a LCA study according to PEF methodology.

Besides these stages, other stages and sub-stages can be added. [10].

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Life Cycle Assessment phases

According to the ISO 14040 standard [11] for life cycle assessment, LCA has four phases: goal and scope definition, life cycle inventory (LCI), life cycle impact assessment (LCIA) and interpretation of results as in Figure 6. The LCA process is normally iterative and some phases might need to be revised during the calculation process. The stages are presented briefly next.

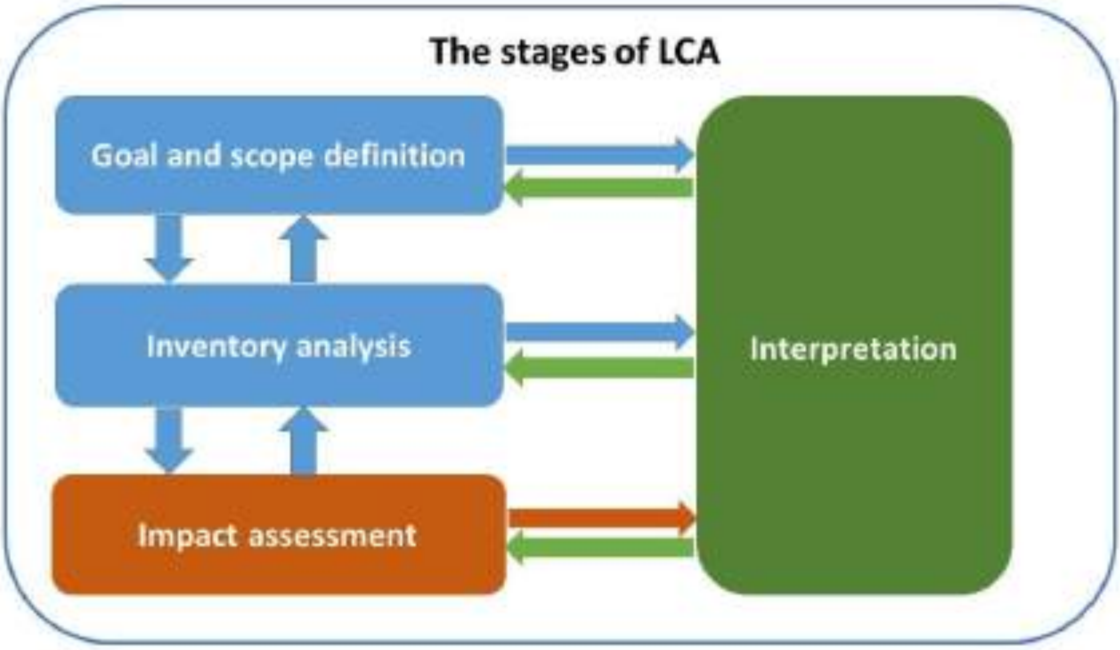

Figure 6 The four phases of Life Cycle Assessment according to ISO 14040.

Source: image from [9].

Goal and scope stage describes the study's objective, purpose and audience, sets the system boundaries and lists the assumptions and possible scenarios needed in the calculation [1,2]. Functional unit is also defined at this stage. Functional unit describes the need that is fulfilled with the product or service. Typical functional units are numbers of product (e.g. one bottle or a computer) or amounts of product (e.g. 1000 MWh or 1 litre of milk).

The life cycle inventory (LCI) includes data collection and a balance calculation to all unit processes in the life cycle. The results of LCI are presented as inputs and outputs of the entire system [9]. Figure 7 shows the input and output flows that are used in the data collection stage.

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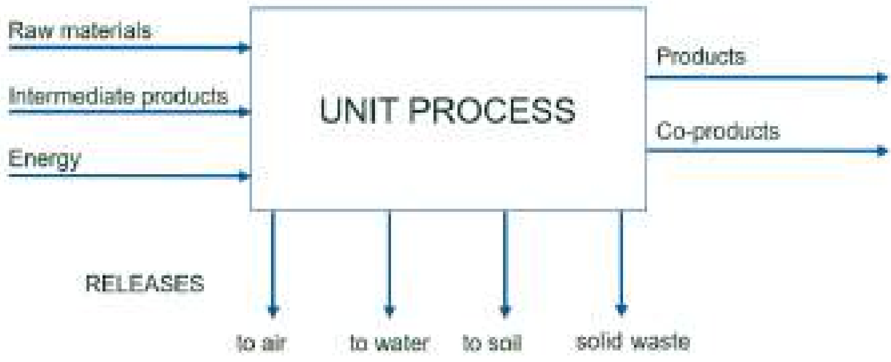

Figure 7 Collected data in the Life cycle inventory stage.

Source: adapted partly from [10].

The data sources of the inputs and outputs can be divided to primary and secondary. Primary data is directly from the product manufacturer and/or its subcontractors. Secondary data is from commercial databases or literature. A general principle is that the more primary data a LCA study has, the more reliable results can be obtained. The data collection stage is time-consuming but carrying it out adequately will be beneficial for the next stages of the LCA.

The life cycle impact assessment stage converts the LCI results into environmental impacts. For example, in a carbon footprint calculation, the emitted greenhouse gases (GHG) from the inventory calculation are converted into global warming potentials (GWP) in the impact assessment stage. There are several impact assessment methods with different optional characterisation, normalisation and weighting factors. The LCA standards do not determine which impact assessment methods should be used in a study. The PEF methodology [10], however, recommends 16 impact assessment categories. The selection of the method should be done in the goal and scope definition phase, considering the spatial and temporal aspects of the study [9]. In the next chapter the impact assessment methods are listed.

The interpretation of the results is based on all three previous stages of the assessment. The results are presented per functional unit defined in the goal and scope stage. The interpretation is a continuous process in which the consistency of the previous stages is evaluated. Finally, in the interpretation stage the identification of significant issues, conclusions, limitations and recommendations are presented.

Description of proposed environmental evaluation indicators

PEF methodology includes various environmental impact categories and impact category indicators which are listed in Table 1. The most relevant categories for Agro2Circular project will be defined in further stages of the project. Based on preliminary information, suitable ones could be e.g. climate change, acidification, eutrophication and resource use.

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Table 1 Environmental Footprint impact categories with respective impact category indicators, units and characterisation models [10].

EF impact category	Impact category indicator	Unit	Characterisation model
Climate change, total	Global warming potential (GWP100)	kg $CO_{2\ eq}$	Bern model - Global warming potentials (GWP) over a 100-year time horizon (based on IPCC 2013)
Ozone depletion	Ozone depletion potential (ODP)	kg CFC-11 $_{eq}$	EDIP model based on the ODPs of the World Meteorological Organisation (WMO) over an infinite time horizon (WMO 2014 + integrations)
Human toxicity, cancer	Comparative toxic unit for humans (CTU_h)	CTUh	Based on USEtox2.1 model (Fantke et al. 2017), adapted as in Saouter et al., 2018
Human toxicity, non-cancer	Comparative toxic unit for humans (CTU_h)	CTUh	Based on USEtox2.1 model (Fantke et al. 2017), adapted as in Saouter et al., 2018
Particulate matter	Impact on human health	Disease incidence	PM model (Fantke et al., 2016 in UNEP 2016)
Ionising radiation, human health	Human exposure efficiency relative to U_{235}	kBq U235 $_{eq}$	Human health effect model as developed by Dreicer et al. 1995 (Frischknecht et al, 2000)
Photochemical ozone formation, human health	Tropospheric ozone concentration increase	kg NMVOC $_{eq}$	LOTOS-EUROS model (Van Zelm et al, 2008) as applied in ReCiPe 2008
Acidification	Accumulated exceedance (AE)	mol H+ $_{eq}$	Accumulated exceedance (Seppälä et al. 2006, Posch et al, 2008)
Eutrophication, terrestrial	Accumulated exceedance (AE)	mol N $_{eq}$	Accumulated exceedance (Seppälä et al. 2006, Posch et al, 2008)
Eutrophication, freshwater	Fraction of nutrients reaching freshwater end compartment (P)	kg P $_{eq}$	EUTREND model (Struijs et al, 2009) as applied in ReCiPe
Eutrophication, marine	Fraction of nutrients reaching marine end compartment (N)	kg N $_{eq}$	EUTREND model (Struijs et al, 2009) as applied in ReCiPe
Ecotoxicity, freshwater	Comparative toxic unit for ecosystems (CTU_e)	CTUe	Based on USEtox2.1 model (Fantke et al. 2017), adapted as in Saouter et al., 2018
Land use	Soil quality index	Dimensionless (pt)	Soil quality index based on LANCA model (De Laurentiis et al. 2019) and on the LANCA CF version 2.5 (Horn and Maier, 2018)
Water use	User deprivation potential (deprivation-weighted water consumption)	m^3 water eq of deprived water	Available WAter REmaining (AWARE) model (Boulay et al., 2018; UNEP 2016)
Resource use, minerals and metals	Abiotic resource depletion (ADP ultimate reserves)	kg Sb $_{eq}$	van Oers et al., 2002 as in CML 2002 method, v.4.8

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EF impact category	Impact category indicator	Unit	Characterisation model
Resource use, fossils	Abiotic resource depletion – fossil fuels (ADP-fossil)	MJ	van Oers et al., 2002 as in CML 2002 method, v.4.8

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3 Social evaluation framework

Definition of the social evaluation framework

The purpose of this section is to describe the social evaluation framework that will be used to measure, assess and analyse the social impact of the A2C systemic solution. The social evaluation framework consists of a series of indicators categorised within different dimensions, which operationalise and structure the concept of 'social impact'.

Social Life-Cycle Assessment (SLCA) is a tool whose inception is based on the attempt to build a comprehensive approach to product chains aligned with Sustainable Development Goals (SDG's). This insight is deeply connected to the three pillars of sustainability, in which SLCA is supposed to deploy the interplay between industrial processes and social impacts (see Section on *Life-Cycle Sustainability Assessment approach*, p. 12). Following the definition provided by UNEP Handbook [12, p. 20], SLCA is "**a methodology to assess the social impacts of products and services across their life cycle**", delivering systematic data that can be operationalised through quantitative as well as qualitative methods. The methodology is oriented towards a set of predefined stakeholders encompassing a broad range of social interests and that account for the main drivers of social changes.

This definition, however, remains open and needs more robust support. Hence the reasons why it is steadily stated that SLCA framework needs further improvements [13]. It should be highlighted that this need for improvement arises from the short lifetime of the assessment model, that dates from the beginning of the 2000 decade [14]. Its purpose must be considered within wider efforts to achieve a comprehensive, scaled-up Life Cycle Assessment, called the Life Cycle Sustainability Assessments (LCSA) that pivots upon three pillars: altogether with the SLCA, the Environmental-LCA and the Life Cycle Costing (LCC). Yet this prospect is still incomplete, due to difficulties to adjust their different objectives, as well as to level up the databases whereby the information is obtained.

This situation has not hampered an increasing number of studies applying SLCA to deem social impacts. Thus, next steps need to dig into the specific concept of what a **social impact** is, in order to enhance conclusion consistency. Moltesen et al. [15] argue that social impacts cannot be analysed if there is no category translating social interests into operational concepts. Addressing this challenge, the UNEP publish the Methodological Sheets [16], proposing a set of impact subcategories, framed within specific stakeholder categories (Table 2).

That is the baseline from which the UNEP methodology starts, as it will be explained in the following section. A fundamental aspect of this methodology needs to be pointed out at this stage, since it influences the **Theory of Change** model implied within the framework. As it could be reported, the approach seeks to establish direct causality pathways going from the industrial product chain to the specified stakeholders. Methodologically, it could be stated that the latter ones could be regarded as influenced actors, while the assessed product chain

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would be the influencing one. If assuming SLCA is aimed at supporting decision-making processes both at the public and private dimensions, it must be then argued that conclusions drawn from it should be able to promote changes on the described dynamics.

That is to say, SLCA approach endeavours to influence the action exerted by the industrial company, which at the end is responsible for the social impacts**. Hence it is assumed that the role of the companies, i.e., the company's behaviour, can actually determine the result of the assessment.** Yet, the study of Jørgensen et al. [17] states that the debate whether directly focusing on industrial processes or on company's behaviour remains open.

Table 2 Stakeholder categories and impact subcategories

Stakeholder category	**Impact subcategory**
Workers	Freedom of association and collective bargaining
	Child labour
	Fair salary
	Working hours
	Forced labour
	Equal opportunities/discrimination
	Health and safety
	Social benefits/social security
Consumers	Health and safety
	Feedback mechanism
	Consumer privacy
	Transparency
	End of life responsibility
Local community	Access to material resources
	Access to immaterial resources
	Delocalization and migration
	Cultural heritage
	Safe and healthy living conditions
	Respect of indigenous rights
	Community engagement
	Local employment
	Secure living conditions
	Public commitments to sustainability issues
	Contribution to economic development
Society	Prevention and mitigation of armed conflicts
	Technology development
	Corruption
Value chain actors, not including consumers	Fair competition
	Promoting social responsibility
	Supplier relationships
	Respect of intellectual property rights

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Methodological framework

The premises in which SLCA is grounded have become a source of debate, but they directly affect some essential aspects of the assessment methodology. According to the proposal provided by the UNEP [12] and aligned with the LCA modelling schemes, the main points of the A2C approach towards SLCA are presented below.

Goal and scope definition

The main goal is to evaluate the social impact of the A2C systemic solution, based on:

1. Innovative green hybrid extraction, purification and stabilisation routes to obtain bioactives from F&V wastes.

2. First recycling value chain for post-industrial multilayer films by combining innovative sorting, physical delamination, enzymatic depolymerisation, decontamination and mechanical recycling and upcycling.

3. Digital platform for the agri-food sector, traceability in real time and decision support tool for optimal valorisation routes.

4. A2C multidimensional model and tools fostering the territorial development of circular economy and enabling its replication/scalability, constructed through public engagement and co-creation processes.

The scope of the assessment will include all industrial companies that compose the A2C consortium. As a general rule, two key evaluation moments are established: ex-ante and ex-post. Thus, it will be possible to establish a comparison in terms of social impact, on the one hand, between the industrial companies that comprise the consortium and, on the other hand, to globally assess the impact of the development of the project during the defined time horizon, on the behaviour of the different actors involved.

The different A2C dimensions proposed for inclusion in the SLCA framework are presented in the table below, and are based on both the Methodological Sheets [16] and Reinales et al. [18]:

Table 3 Specific stakeholder categories and impact subcategories proposed for the A2C's SLCA

Stakeholder category	Impact subcategory
Workers	Fair salary
	Working hours
	Equal opportunities/discrimination
	Health and safety
	Training and education
Consumers	Health and safety
	End of life responsibility
Local community	Access to material resources
	Safe and healthy living conditions

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Stakeholder category	Impact subcategory
Society	Community engagement
	Local employment
	Contribution to economic development
	Technology development
Value chain actors, not including consumers	Fair competition
	Promoting social responsibility
	Supplier relationships

Levels

The boundaries of the assessment will be subject to a multi-level scheme, characterised by the aggregation of indicators at various nested level, to be taken into consideration where relevant to the specific objectives of the assessment:

- **Organisation-based evaluation**. The aggregation of indicators at the organisational level (in particular of the industrial entities participating as partners in the consortium) will allow a comparison and assessment of the degree of their involvement in the circularity of production processes and in the local economy.
- **Product-based evaluation**. The social impact assessment at product level will aggregate all impacts generated along the value chain.
- **Actions-based evaluation**. The evaluation at action level will make it possible to assess specific aspects of the tasks envisaged in the framework of the project.

Data-gathering methods

Data-gathering will be the starting point for assigning value to the indicators proposed in the next section. Data will be collected primarily through consultation with the companies involved, registers and questionnaires. Both data collection and reporting of outputs will always respect the provisions of the Data Management Plan on personal data. For reasons of simplicity, outputs will only include quantitative information.

Description of proposed social evaluation indicators

The selection of indicators was made on the basis of the above-mentioned stakeholder categories and impact sub-categories, as well as the following suitability criteria:

- **Relevance**: significant importance for the evaluation process, in terms of a strong link to the subthemes of the framework and significance for the underlying Theory of Change.
- **Measurability**: capability of being measured, preferably as objectively as possible.
- **Reliability**: consistency and measurability over time, in the same way by different observers.
- **Timeliness**: measurement at time intervals relevant and appropriate in terms of programme goals and activities.

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- **Comparability**: comparability between the different scenarios (sites, timeframe) of the project.
- **Clarity**: ease of understanding, communicability, capacity to tell narratives.
- **Availability**: expected data availability.

The selected indicators are summarised below and detailed in **Annex 1. Description of S-LCA selected indicators**.

Table 4 S-LCA selected indicators

Impact subcategory	**Indicators**
Workers	
Fair salary	Median employee net wage income
	Ratio of the net wage of the lowest paid worker to the minimum wage
Working hours	Flexibility
	Variability of age
	Gender-Balanced Representation Index
	Ratio of basic wage of men to women
Health and safety	Safety training
	Protective equipment availability
Training and education	Training program
	Training for workers
Local community	
Access to material resources	Environmental management system
	Material origin
Safe and healthy living conditions	Management effort to minimise use of hazardous substances
Community engagement	Number of meetings with community stakeholders
	Number of local events/workshops
Local employment	Workforce hired locally
	Spending on locally-based suppliers

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Impact subcategory	Indicators
Value chain actors	
Fair competition	Prevention of anti-competitive behavior
Promoting social responsibility	Promotion of Corporate Social Responsibility
Supplier relationships	Responsible Supply
Consumer	
Health and safety	Labelling
End-of-Life responsibility	Information about End-of-Life options
Society	
Contribution to economic development	Total taxation per capita
Technology development	Technology transfer
	Investments in technology development/transfer

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4 Economic evaluation framework

The objective of this section is to present the proposed economic evaluation approach, namely Life Cycle Costing (LCC), that is going to be employed by Bocconi University (UB) under WP7 of the A2C Project. This approach will constitute the economic component of the evaluation framework for the environmental, socio-cultural, and socio-economic assessment of the A2C processes defined in Task 7.2.

Theoretical framework - The LCC approach

Life Cycle Costing (LCC) is a methodology that entails the systematic economic evaluation of the costs of an asset throughout its life cycle, covering all stages from acquisition of the (raw) material, through processing and maintenance, to final disposal or product supply, over a specified time period of interest [19]. Ultimately, this systematic approach aims at comparing the (total) life-cycle costs between alternative product or process systems to identify their cost-effectiveness considering all relevant economic factors both in terms of initial costs and future operational costs [19], [20], [21]. Thus, the consideration of all the costs associated with alternative products or processes represents a means of displaying hidden costs and the distribution of net costs or savings within the considered value chain [22], [23]. The LCC approach can provide support for cost-effective decision-making processes on alternative projects and at different levels of their life cycle stages [23], [24]. As an alternative to traditional accounting, when new processes or products are being considered, the LCC approach can provide crucial insights concerning the magnitude and composition of the costs potentially incurred already during the development phase [25], [26].

Over time, LCC has evolved from a purely economic approach to a sustainability-relevant approach, by taking into account not only private costs but also externalities [27], [28]. An externality is defined as a consequence of an activity that affects parties other than the organisation undertaking the activity, for which the organisation is neither compensated nor penalised through markets or regulatory mechanisms [29]. Externalities can be environmental or non-environmental. The scale of the impact on the environment can be based on the outputs of the LCA approach. Non-environmental externalities include social impacts, which are considered in the S-LCA approach [28]. Externality costs represent the result of the internalisation of environmental and social impacts by assigning monetary values to their respective effects [22], [30].

The sum of private and externality costs constitutes social costs. In addition, following the distinction presented by Martinez-Sanchez et al. [30], a further differentiation can be made between budget costs, transfers, and externality costs, with the first two types of costs representing the private costs (also known as "internal" costs). More specifically, on one hand, budget costs may occur only once during the product or process life cycle (e.g., capital investment concerning a technology used in the considered process), or be recurrent (e.g.,

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operating and maintenance costs). On the other hand, transfers are monetary flows that only represent a redistribution of income among stakeholders, such as (environmental) taxes and subsidies [22], [30].

Based on the types of costs considered in the LCC approach, the main literature on product or process life cycle sustainability distinguishes three types of LCC approaches: Conventional life cycle costing (C-LCC), Environmental LCC (E-LCC), and Societal LCC (S-LCC). C-LCC considers internal costs. E-LCC considers internal costs and external costs expected to be internalised through transfers. S-LCC considers internal costs and further external costs. The selection of the approach to be adopted depends on the assessment goals [30].

The LCC approach is generally implemented in macro phases such as the following, adapted from De Menna et al. [22]:

- Definition of the functional units and system boundaries
- Cost modelling (cost categories, externalities, discounting etc.)
- Evaluation of impacts

Depending on the object and scope of the LCC approach, the details of the boundaries, the relevant cost categories to be considered in the assessment, and the way they are aggregated and quantified may vary [23], [31]. Several choices must be made in terms of categories of costs, their aggregation, the allocation of costs, and the discounting of future costs. Depending on the industry or sector to which the LCC analysis is applied, different cost categories shall be taken into account [22]. For instance, as far as LCCs of waste management are regarded, Rigamonti et al. [32] divides costs according to the specific stages of collection (including transport and a first processing), treatment, and final disposal.

These aspects are essential for the implementation of the LCC approach and should be established at the beginning of the evaluation process [31].

Methodological framework - Application of the LCC approach to the A2C technological systemic solution model

From the perspective of an integrated consideration of environmental, socio-cultural, and socio-economic assessments within the scope of Task 7.2 under WP7 of the A2C project, it can be noted that the LCC approach relies on the same perspective as the LCA approach. This is important because, to carry out a holistic evaluation of the A2C processes, the economic, social, and environmental assessments have to be aligned and possibly integrated. However, instead of focusing on environmental impacts like the LCA, LCC considers the costs that occur throughout the life cycle of a product or process [31]. Specifically, in the context of A2C, the LCC approach will be applied to processes.

The main goal of the LCC analysis is to account for all the costs incurred during the life cycle of the A2C technical approach processes and compare them with the costs of currently

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adopted processes (Business As Usual – BAU scenario) in traditional agri-food waste management, considering private costs as well as externality costs. Based on the macro-phases generally observed for the application of the LCC approach (mentioned in the theoretical framework section), UB defined four methodological steps to conduct the LCC (Figure 8).

Figure 8 The four steps of the LCC approach proposed by UB

1. The first step is the **identification of the A2C stages** (intended as activities related to the waste management systems such as collection, treatment, and final disposal; [30], [32]) and definition of the system boundaries to be taken into account during the implementation of the LCC approach.
2. The second step is the **definition of the cost categories** to be considered in relation to the different A2C stages.
3. The third step consists in **performing the economic evaluation** by collecting and analysing the required data.
4. The last methodological step is the **integration of the results of the LCC approach** with the outputs of the LCA and S-LCA approaches.

Currently, UB is working on the first two steps, which are described in more detail in the paragraphs below. All steps will be further discussed and finalised with the WP7 partners.

Identification of A2C stages

The first step, namely 'Identification of A2C stages', is essential to identify the appropriate A2C stages to focus on during the analysis. It should be noted that, especially when LCC, LCA, and S-LCA approaches are carried out in parallel, it is important that the considered A2C stages and system boundaries are in alignment, to allow a proper final comparison and eventual integration of the results [30]. Consequently, concerning this last point, a more detailed discussion will have to be addressed with the WP7 partners both in relation to the alignment of the targeted A2C stages and to the possibility of eventually integrating the results of LCC, LCA, and SLCA. Figure 9 presents, based on the current working draft, an overview of the different A2C cycle stages that will probably be considered for the application of the LCC approach by UB. Reference was made to the subdivision of the waste management system stages considered in studies such as Martinez-Sanchez et al. [30] and Rigamonti et al. [32], adapting it to the A2C technological systemic solution in the way deemed most appropriate.

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The first stage that is likely to be considered is the transport of organic and plastic waste from the collection site to the treatment plant. The second stage is the processing and recycling of organic and plastic waste into new products using different processes. The last stage is the transport of the end products of the waste processing stage from the treatment plant to the end markets/other plants where they will be subject to further processing.

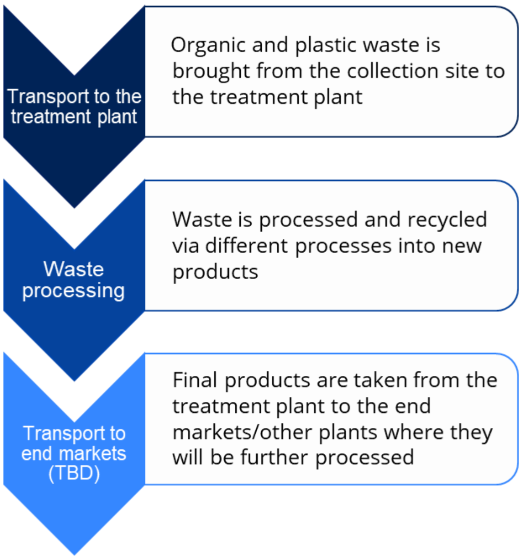

Figure 9 Overview of the tentative A2C cycle stages to be considered for the application of the LCC approach by UB (based on the current working draft)

Definition of cost categories

The next step of the LCC is to define the cost categories related to the different stages. Three main cost blocks can be identified, which correspond to the A2C stages:

1. **Transport costs from waste collection sites to the treatment plant** (i.e., fuel costs of vehicles, personnel costs of drivers, transit insurance, etc.);
2. **Waste processing costs**: costs related to the processes used to upcycle waste (i.e., equipment costs, utility costs, labour costs etc.);
3. **Transport costs to end markets**: product transport costs from the manufacturing plant to end markets (cosmetics, food, nutraceuticals, plastics, and packaging).

Based on the analysis of the existing literature on LCCs of waste management systems, several cost categories have been identified for inclusion in the LCC analysis of the A2C processes. Table 5 summarises such cost categories. All definitions have been taken from NORSOK standard [33] and Cost Accounting Standard [34] and adapted to the A2C case if needed. The cost categories will be refined and updated based on discussion with the technological partners and partners in charge of the evaluation.

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Table 5 Selected cost categories and their descriptions.

Cost categories	**Description**
Transport costs	the cost of freight, cartage, transit insurance and cost of operating fleet and other incidental charges
Equipment and material purchase costs	the total purchase cost associated with the equipment and materials necessary to set up the process. This item will consider the yearly price of the equipment by dividing its price over the expected life of the asset
Installation costs	the total cost of installing the systems and equipment
Maintenance costs	the total cost incurred to maintain the capacity of performance of the facility and equipment
Labour costs	the cost of the needed man-hours per year to operate and maintain the facility/equipment. This includes man-hours associated with upcycling processes and with the treatment of wastes
Energy consumption costs	the total energy consumption cost for the facility and systems. It shall include the cost of fuel required to generate the power
Water consumption costs	the total water consumption cost for the facility and systems

The proposed working hypothesis for the LCC is to consider also the *externality costs*, that is, the costs occurring outside the A2C economic system and representing the internalisation of environmental and social impacts generated throughout the process. This hypothesis will be discussed and agreed with project partners in the next steps of the Task.

The LCC analysis could also comprise the revenues from the sales of the final products which will be obtained from the upcycling of waste. Kim et al. [35] included the benefits deriving from by-products by using their unit market price and used such values to carry out a cost-benefit analysis to compare the different waste disposal alternatives; with respect to LCC, instead, Escobar et al. [36] translated the co-products generated into revenues for waste managers and considered them as negative costs for waste treatment facilities. Revenues are also included as negative costs in the LCC analysis performed by Rivera and Azapagic [37], which assumes chicken waste to be sold to the rendering industry. Therefore, the positive cash flows associated with the sales of final products to the end markets or to other manufacturing plants will be subtracted from the total costs of the A2C processes.

Figure 10 associates the three proposed main cost blocks to the cost categories related to each of them.

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	Cost categories							Revenues
A2C stages	Transport costs	Equipment and material purchase costs	Installation costs	Maintenance costs	Labor costs	Energy and water consumption costs	Costs of environmental externalities	Sales of final products
Transport to manufacturing plant	●						●	
Waste processing		●	●	●	●	●	●	●
Transport to end markets	●						●	

Figure 10 A2C stages and their associated cost categories.

The preliminary division of A2C stages distinguishes between the two phases of transport occurring before and after the main waste processing phase. For each stage, their associated cost blocks, and related cost categories have been identified. In particular, for transporting organic and plastic waste from the collection facility to the manufacturing plant and for transporting the final products to the end markets, transport costs, labour costs and costs of environmental externalities have been included; other cost categories such as equipment and material purchase costs, installation costs, energy and water consumption costs, concern the waste processing stage, along with the aforementioned labour and environmental externalities costs which are found across the different stages of the A2C processes. Finally, revenues from the sales of products to end markets or to other manufacturing plants will be also taken into account. However, they are not associated to a particular stage of the A2C process but are the outcome of the process itself.

All costs shall be expressed in terms of a reference unit, which is yet to be defined. A valid option could be €/kg of processed waste. Such a reference unit finds correspondence in the existing literature, where euros per tonne [35] or kg of food waste [37] has been adopted in several LCC analyses. The choice between kg or tonne depends on the amount of waste available for treatment and on the processing capacity of the technologies involved in the upcycling process.

Double-counting issues in the LCC will be specifically addressed and discussed with other partners, both within the economic evaluation and when integrating the results of the LCC with LCA and S-LCA, as the possibility of risk of double counting across Life Cycle Sustainability Assessment approaches in the integration phase of the respective outputs is well-known [38], [39], [40].

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Open issues

This section presents open issues to be addressed by UB in collaboration with WP7 partners in the coming months concerning the identification of A2C process stages, the reference unit, and the technologies to be attributed to the BAU scenario to be considered for comparison.

Identification of A2C process stages

As highlighted in the previous chapters, it is important that the considered A2C stages and system boundaries are in alignment between the different evaluation frameworks, therefore a key aspect will be that partners jointly define and agree how the A2C process should be divided into stages and which ones should be included in the evaluation.

Concerning the identification of A2C process stages, it should be considered whether it is appropriate to include the transport of products to the end markets as part of the A2C processes. This issue ties back with the fact that it is important to align the considered stages especially when the LCC, LCA, and S-LCA are carried out in parallel.

Reference unit

About the reference unit, €/kg of processed waste could be an option: since the proposed evaluation units are the upcycling processes, whose costs will be compared with conventional processes, the proposed reference unit for the LCC analysis is the quantity of processed waste. Therefore, total costs would be expressed as €/kg of processed waste.

BAU scenario

Concerning the BAU scenario to be used as a comparison against the new processes, an option could be selecting the current most adopted processes.

These issues, particularly the one concerning the technologies to be considered for comparison, will be addressed in the coming months also by means of a dedicated workshop and a survey addressed to the partners (technical experts) of the A2C project.

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6 ANNEXES

Annex 1. Description of S-LCA selected indicators

Workers

Fair salary

Median employee net wage income	
Definition	Median employee net wage income
Justification	Median employee net wage income provides a measure of central tendency that is less sensitive to outliers.
Calculation formula	If n is odd, $M_e = x_{(n+1)/2}$; if n is even, $M_e = \frac{x_{(n/2)}+x_{(n/2)+1}}{2}$
Unit	Euros
Baseline definition	Ex-ante
Data source	Consultation with industrial companies (register)
Frequency of monitoring	Ex-ante; ex-post
Level	Organisation

Ratio of the net wage of the lowest paid worker to the minimum wage	
Definition	Ratio of the net wage of the lowest paid worker to the minimum wage
Justification	The indicator provides a measure of the gap between the company's lowest outlier wage and the minimum wage.
Calculation formula	$R_i = x_{min,\ i}$ / Minimum wage; where R_i is the ratio of the i company and $x_{min,\ i}$ represents de lowest paid worker (in euros) of the i company.
Unit	Euros; $[0, +\infty)$
Baseline definition	Ex-ante
Data source	Consultation with industrial companies (register)
Frequency of monitoring	Ex-ante; ex-post

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Level	Organisation

Working hours

Flexibility	
Definition	Employee's self-perceived quantification of the extent to which the company provides adequate flexibility for work-life balance, rest and overtime.
Justification	The indicator provides a synthetic, albeit mainly subjective, measure of different dimensions involved in work-life balance.
Calculation formula	NA
Unit	Likert scale (1 to 7)
Baseline definition	Ex-ante
Data source	Questionnaire
Frequency of monitoring	Ex-ante; ex-post
Level	Organisation

Equal opportunities/discrimination

Diversity of nationality of birth	
Definition	Inverse Simpson Index applied to nationality of birth (by governance bodies and employee category)
Justification	The index provides a proxy for the actual number of birth nationalities that are represented in the organisation.
Calculation formula	$\frac{1}{\lambda} = \frac{1}{\sum_{i=1}^{R} p_i^2}$, where R is the total number of birth nationalities, and p_i is the proportion of people who belong to each category.
Unit	[0, + ∞)
Baseline definition	Ex-ante
Data source	Questionnaire

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Frequency of monitoring	Ex-ante; ex-post
Level	Organisation

Variability of age	
Definition	Coefficient of variation of age, breakdown by governance bodies and employee category
Justification	The indicator provides a measure of the relative dispersion of the ages of employees and managers in relation to the mean.
Calculation formula	$CV_{ij} = s_{ij} / \underline{x}_{ij}$, where CV_i represents the coefficient of variation for the i governance body or employee category of the j company; s_{ij} is the sample standard deviation for the i governance body or employee category of the j company; and $\underline{x}_{ij}$ is the sample mean for the i governance body or employee category of the j company
Unit	[0, + ∞)
Baseline definition	Ex-ante
Data source	Consultation with industrial companies (register)
Frequency of monitoring	Ex-ante; ex-post
Level	Organisation

Gender-Balanced Representation Index	
Definition	Gender-Balanced Representation Index (by governance bodies and employee category)
Justification	The index provides a simple measure of how balanced the representation of men and women is.
Calculation formula	$GBRI_i = 1 – p_{max, i}$; where $p_{max, i}$ is the proportion of the majority group of the I company.
Unit	[0, 0.5]
Baseline definition	Ex-ante
Data source	Consultation with industrial companies (register)

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Frequency of monitoring	Ex-ante; ex-post
Level	Organisation

Ratio of basic wage of men to women	
Definition	Ratio of basic wage of men to women by employee category (by governance bodies and employee category)
Justification	The index provides a simple measure of the wage gap size.
Calculation formula	$R_i = x_{m,i} / x_{w,i}$; where $x_{m,i}$ represents the basic wage of men of the i company, and $x_{w,i}$ is the basic wage of women of the i company.
Unit	Euros; $[0, +\infty)$
Baseline definition	Ex-ante
Data source	Consultation with industrial companies (register)
Frequency of monitoring	Ex-ante; ex-post
Level	Organisation

Health and safety

Safety training	
Definition	Presence of safety training in the company
Justification	The indicator verifies whether a company implements adequate and sufficient safety training in order to reduce work-related risks.
Calculation formula	NA
Unit	{0, 1}
Baseline definition	Ex-ante
Data source	Consultation with industrial companies
Frequency of monitoring	Ex-ante; ex-post

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Level	Organisation

Protective equipment availability	
Definition	Presence of protective equipment in the company, available to the employees.
Justification	The indicator verifies whether a company has available protective equipment to reduce work-related hazards, of adequate quality and in sufficient quantity.
Calculation formula	NA
Unit	{0, 1}
Baseline definition	Ex-ante
Data source	Consultation with industrial companies
Frequency of monitoring	Ex-ante; ex-post
Level	Organisation

Training and education

Training program	
Definition	Presence of a training program focused on technological innovations.
Justification	The indicator verifies whether a company implements an adequate and regular training programme among its employees, focused on training in technological innovations.
Calculation formula	NA
Unit	{0, 1}
Baseline definition	Ex-ante
Data source	Consultation with industrial companies
Frequency of monitoring	Ex-ante; ex-post
Level	Organisation

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Training for workers	
Definition	Hours of training per employee receiving training
Justification	The indicator represents an approximation of the intensity of the training received by the employees benefiting from this programme.
Calculation formula	$TW_i = h_i / N_i$; where h_i represents the number of training hours, and N_i the total number of employees receiving training.
Unit	$[0, +\infty)$
Baseline definition	Ex-ante
Data source	Consultation with industrial companies
Frequency of monitoring	Ex-ante; ex-post
Level	Organisation

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Local community

Access to material resources

Environmental management system	
Definition	Presence of a certified environmental management system
Justification	The indicator verifies whether the company has a certified environmental management system.
Calculation formula	NA
Unit	{0, 1}
Baseline definition	Ex-ante
Data source	Consultation with industrial companies
Frequency of monitoring	Ex-ante; ex-post
Level	Organisation

Material origin	
Definition	Proportion of recycled/re-used materials used in the manufacture of a product.
Justification	As the upcycling of multilayer plastic films is one of the main elements of the A2C systemic solution, it is expected to increase significantly.
Calculation formula	$p_i = n_i / N_i$, where p_i is the proportion of recycled/re-used materials of the i product; n_i represents the kg of recycled/re-used material used in the manufacture of x kg of i product; and N_i represents the total amount of materials (in kg) used in the manufacture of x kg of i product.
Unit	[0, 1]
Baseline definition	Ex-ante
Data source	Consultation with industrial companies
Frequency of monitoring	Ex-ante; ex-post
Level	Organisation; product

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Safe and healthy living conditions

Management effort to minimise use of hazardous substances	
Definition	Presence of specific hazardous waste minimisation protocols
Justification	An improvement in this aspect is expected, as the use of hybrid extraction processes based on green technologies allows for a reduction in the use of organic solvents, which is associated with a reduction in the generation of hazardous waste and the emission of volatile organic compounds.
Calculation formula	NA
Unit	{0, 1}
Baseline definition	Ex-ante
Data source	Consultation with industrial companies
Frequency of monitoring	Ex-ante; ex-post
Level	Organisation; product

Community engagement

Number of meetings with community stakeholders	
Definition	Number of formal meetings held annually with local stakeholders (associations, NGOs, local government institutions, companies, etc.).
Justification	The indicator is a proxy for the intensity and frequency of interactions between local stakeholders.
Calculation formula	NA
Unit	$k \in \mathbb{N}$
Baseline definition	Ex-ante
Data source	Consultation with stakeholders
Frequency of monitoring	Ex-ante; ex-post

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Level	Organisation; product; action

Number of local events/workshops	
Definition	Number of events held annually by the company, in order to disseminate the innovations.
Justification	The indicator is a proxy for the company's engagement with the local economic ecosystem.
Calculation formula	NA
Unit	$k \in \mathbb{N}$
Baseline definition	Ex-ante
Data source	Consultation with stakeholders
Frequency of monitoring	Ex-ante; ex-post
Level	Organisation; product; action

Local employment

Workforce hired locally	
Definition	Proportion of locally hired workers over total new hires.
Justification	The indicator is a proxy for the organisation's involvement with the local workforce.
Calculation formula	$p_i = n_i / N_i$, where p_i is the proportion of locally hired workers of the i company; n_i represents the number of locally hired workers; and N_i represents the total new hires of i company.
Unit	[0, 1]
Baseline definition	Ex-ante
Data source	Consultation with industrial companies
Frequency of monitoring	Ex-ante; ex-post
Level	Organisation

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Spending on locally-based suppliers	
Definition	Proportion of spending on locally-based suppliers over total expenditure on materials, equipment and services
Justification	The indicator is a proxy for the organisation's involvement with the local supply of goods and services, as well as for the weight of local suppliers in the manufacture of a product.
Calculation formula	$p_i = n_i / N_i$, where p_i is the proportion of spending on locally-based suppliers of the i company or i product; n_i represents the spending on locally-based suppliers (in euros) of the i company or i product; and N_i represents the total amount of spending on suppliers (in euros) of the i company or i product.
Unit	[0, 1]
Baseline definition	Ex-ante
Data source	Consultation with industrial companies
Frequency of monitoring	Ex-ante; ex-post
Level	Organisation; product

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Value chain actors

Fair competition

Prevention of anti-competitive behaviour	
Definition	Presence of documented statement or procedures (policy, strategy etc.) to prevent engaging in or being complicit in anti-competitive behaviour
Justification	The indicator verifies whether there are documents, plans or strategies in place at the company, sector or product level that restrict anti-competitive behaviour. Competitiveness is a key pillar for sustainability and the prevention of the formation of oligopolies and monopolies with high decision-making power.
Calculation formula	NA
Unit	{0, 1}
Baseline definition	Ex-ante
Data source	Consultation with industrial companies
Frequency of monitoring	Ex-ante; ex-post
Level	Organisation; product

Promoting social responsibility

Promotion of Corporate Social Responsibility	
Definition	Accreditation of Corporate Social Responsibility Compliance
Justification	The indicator verifies whether a company has an accreditation of Corporate Social Responsibility Compliance.
Calculation formula	NA
Unit	{0, 1}
Baseline definition	Ex-ante
Data source	Consultation with industrial companies
Frequency of monitoring	Ex-ante; ex-post

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Level	Organisation; product

Supplier relationships

Responsible Supply	
Definition	Seal of quality/management system required for suppliers
Justification	The accreditation of a quality management system represents a guarantee of product standards.
Calculation formula	NA
Unit	{0, 1}
Baseline definition	Ex-ante
Data source	Consultation with industrial companies
Frequency of monitoring	Ex-ante; ex-post
Level	Organisation; product

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Consumer

Health and safety

Labeling	
Definition	Information available regarding features
Justification	The existence of labels on the product about its characteristics provides useful information to the consumer.
Calculation formula	NA
Unit	{0, 1}
Baseline definition	Ex-ante
Data source	Consultation with industrial companies of the plastics sector.
Frequency of monitoring	Ex-ante; ex-post
Level	Organisation; product

End-of-Life responsibility

Information about End-of-Life options	
Definition	Clear information is provided to consumers through labels about the available end-of-life options.
Justification	The existence of labels on the product on the behaviour that the consumer should adopt at the end of the product's life provides useful information to the consumer.
Calculation formula	NA
Unit	{0, 1}
Baseline definition	Ex-ante
Data source	Consultation with industrial companies.
Frequency of monitoring	Ex-ante; ex-post
Level	Organisation; product

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Society

Contribution to economic development

Total taxation per capita	
Definition	Total taxes paid in the last tax year, by all typologies, per capita (organisation); and per product unit (product).
Justification	Taxes paid represent a proxy for the social contribution of each company and/or product.
Calculation formula	Taxation per capita = Total taxes paid / total staff Taxation per product unit = Total taxes paid / total product units
Unit	Euros
Baseline definition	Ex-ante
Data source	Consultation with industrial companies (register)
Frequency of monitoring	Ex-ante; ex-post
Level	Organisation; product

Technology development

Technology transfer	
Definition	Involvement in technology transfer program or projects
Justification	The indicator verifies whether the company is actively involved in technology transfer programs or projects; or whether a specific product has been developed within this framework.
Calculation formula	NA
Unit	{0, 1}
Baseline definition	Ex-ante
Data source	Consultation with industrial companies
Frequency of monitoring	Ex-ante; ex-post

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Level	Organisation; product

Investments in technology development/transfer	
Definition	Share of investment in technology development and/or transfer over total investment, all items
Justification	This indicator is a proxy for the effort made by the organisation in development and/or technology transfer, as well as the degree of technological innovation that a product incorporates.
Calculation formula	$p_i = n_i / N_i$, where p_i is the proportion of investment in technology development and/or transfer over total investment, all items, of the i company or i product; n_i represents the investment in technology development and/or transfer (in euros) of the i company or i product; and N_i represents the total investment, all items (in euros), of the i company or i product.
Unit	[0, 1]
Baseline definition	Ex-ante
Data source	Consultation with industrial companies
Frequency of monitoring	Ex-ante; ex-post
Level	Organisation; product

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