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Methodology for identifying and selecting indicators to monitor the transition of rural agrifood businesses towards a circular economy and sustainability

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CERAS: Advancing Circular Economy and Sustainability in Rural Business Activities. Skills for the Future

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Executive Summary

The CERAS project, "Advancing Circular Economy and Sustainability in Rural Business Activities: Skills for the Future," developed a methodology for identifying, selecting and operationalising indicators capable of monitoring the transition of rural agrifood Small and Medium-sized Enterprises (SMEs) towards Circular Economy (CE) and sustainability. The framework was developed across the CERAS partner context in Romania, Greece, Slovenia, Catalonia (Spain) and Albania, with particular emphasis on three agrifood processing subsectors: meat processing, dairy processing, and fruit/vegetable and juice processing. The underlying premise is that existing sustainability and CE monitoring systems are often designed for larger enterprises or regulated installations and do not always reflect the scale, resources, data availability and operational characteristics of rural agrifood SMEs. CERAS therefore sought to develop a framework that is sufficiently comprehensive to capture environmental, social and economic transition while remaining applicable at business level.

The methodology was designed as a multi-stage evidence-to-monitoring process rather than as a simple compilation of sustainability indicators. The analytical framework first established common system boundaries concerning geography, sector, value-chain coverage, sustainability and CE dimensions, and indicator typology. Rurality was defined using an OECD/Eurostat-compatible approach, while the sectoral focus was narrowed to meat, dairy and juice/vegetable processing because these activities display distinct profiles of resource consumption, waste and by-product generation, labour and occupational risks, and opportunities for circularity. The framework nevertheless retains a broader value-chain perspective, encompassing input supply, production, processing, distribution, retail, consumption and waste management where relevant.

Two complementary conceptual dimensions structure the monitoring system. Sustainability is represented through its environmental, social and economic pillars, while Circular Economy is represented through resource efficiency and loop closure, reduction, reuse, recovery and recycling, eco-design, circular business models, by-product and waste valorisation, and bio-based cycles. In parallel, all indicators are classified according to an Input–Process–Output–Impact logic chain. Inputs represent the resources and capacities committed to transition; processes capture organizational and operational changes; outputs measure immediate results; and impacts represent broader or longer-term sustainability outcomes. This distinction enables CERAS to monitor not only whether performance improves, but also the mechanisms through which the transition occurs.

Candidate indicators were initially identified through a structured desk-based protocol incorporating peer-reviewed academic literature, policy and institutional frameworks, industry and management standards, and existing agriculture, sustainability and CE indicator systems. Partner organizations contributed additional scientific and country-specific evidence and reviewed the developing indicator dataset. The initial structured pool comprised 41 environmental, 38 economic and 30 social indicators, creating a broad evidence base rather than a predetermined dashboard. Each candidate indicator was documented through standardized fields including indicator name and code, description, sustainability dimension, CE relevance, Input–Process–Output–Impact level, unit, data requirements, calculation formula, monitoring frequency, desired direction of change, boundary conditions and supporting evidence.

The broad candidate pool was subsequently subjected to a systematic process of analysis, harmonisation and reduction. Four main filters were applied. First, indicators were assessed against the specific sustainability and CE hotspots of meat, dairy and fruit/vegetable/juice processing. Second, double materiality was considered through separate assessment of impact materiality and financial materiality. Third, indicators were evaluated from the business perspective using six criteria: cost impact, revenue impact, risk exposure, managerial control ability, data availability and strategic alignment. Fourth, the resulting shortlist was checked to maintain balance across the sustainability dimensions and the Input–Process–Output–Impact logic chain. This approach deliberately avoided relying on a single ranking criterion or automatically retaining indicators solely because they received high numerical scores.

The business-relevance assessment was further strengthened through weighted multi-criteria evaluation. Particular importance was assigned to risk exposure and strategic alignment, followed by cost impact, managerial control ability, revenue impact and data availability. Partner evaluations on 1–5 scales were harmonised using triangular fuzzy numbers so that uncertainty inherent in expert judgement could be represented rather than treated as exact numerical measurement. Weighted fuzzy scores were then defuzzified and used to support indicator prioritisation. A compliance safeguard ensured that indicators considered mandatory or strategically necessary would not be removed purely because of a lower business-preference score. Following hotspot screening, materiality assessment and harmonisation, 45 indicators—18 environmental, 15 social and 12 economic—entered the consolidated evaluation pool.

A major methodological decision was to impose logic-chain and sustainability-dimension balance on the final indicator architecture. Selecting indicators solely according to overall rank would have over represented certain topics while leaving important monitoring gaps. CERAS therefore selected the two highest-priority indicators within each Input, Process, Output and Impact category for each sustainability dimension. This resulted in a final harmonized core of 24 indicators: eight Environmental, eight Social and eight Economic indicators, with two indicators at each logic-chain level within every dimension.

The final environmental block covers key issues including water and energy inputs, heat recovery, separate collection and traceable segregation, total waste generation, refrigerant leakage, water scarcity and transport-related emissions. The social block addresses OHS investment, permanent employment, traceability and transparency of circular inputs, agrifood symbiosis governance, employee training, active CE partnerships, employee retention and competence attainment. The economic block covers resource-cost dependency, investment in reusable packaging and reverse logistics, quality assurance for secondary/by-product inputs, Material Flow Cost Accounting, short food supply chains, waste-disposal dependency, material productivity and value added per FTE. Together, these indicators allow the framework to follow a transition pathway from resources and capacities, through organisational change and implementation, to measurable results and longer-term effects.

1. Introduction and Purpose

The CERAS project ("Advancing Circular Economy and Sustainability in Rural Business Activities: Skills for the Future") has developed a monitoring framework for assessing the transition of rural agrifood Small and Medium-sized Enterprises (SMEs) towards circular economy (CE) and sustainability practices across five partner countries: Romania, Greece, Slovenia, Catalonia (Spain), and Albania. The project starts from the premise that existing EU, national and voluntary CE and sustainability monitoring instruments—including permitting regimes such as the Industrial Emissions Directive, corporate reporting standards such as the CSRD and its VSME variant, and international benchmarks—are primarily calibrated to large or environmentally permitted installations and consequently do not adequately address smaller, sub-threshold rural agrifood businesses. The transition of these businesses from predominantly linear production systems towards CE and sustainability requires a monitoring framework capable of capturing not only environmental performance, but also economic viability, social conditions, organizational change and the progressive closure of resource loops. Such a framework must be sufficiently comprehensive to represent the multidimensional nature of the transition while remaining applicable at business level.

The methodology developed for this purpose uses a structured desk-based indicator-identification and configuration protocol. Its primary objective is to establish an evidence-based pool of indicators suitable for monitoring the progress of rural agrifood businesses towards CE and sustainability, with particular emphasis on three subsectors that are important to the rural economies of the partner regions:

- Meat processing
- Dairy processing and
- Fruit/vegetable and juice processing.

The methodology documented in this report followed a staged process in which a broad candidate indicator pool was first identified from scientific, policy, institutional and sectoral sources; the indicators were subsequently documented and classified within a common database; their relevance to sustainability and CE was established; and the resulting pool was prepared for evaluation, prioritization and eventual reduction.

This approach structured the work around six major stages: definition of framework and scope, annotated bibliographic review, development of an indicator database, validation against existing frameworks, evaluation of the indicator set, and preparation of guidelines and reporting templates.

Following the initial desk-based identification of Circular Economy (CE) and sustainability indicators, a second methodological phase was undertaken to analyse, harmonize, evaluate and reduce the candidate indicator pool into a coherent monitoring framework suitable for agrifood processing businesses.

The analysis focused particularly on three processing activities: meat processing; dairy processing; and fruit/vegetable and juice processing.

The purpose of this phase was not simply to retain the indicators receiving the highest numerical scores. Rather, it was to develop a balanced and operational monitoring framework that simultaneously:

1. reflects the main sustainability and CE hotspots of the three processing sectors;
2. captures environmental, economic and social dimensions;
3. incorporates both impact and financial materiality;
4. reflects the perspective and priorities of agrifood businesses;
5. favours indicators that can realistically be measured and influenced by businesses;
6. retains indicators necessary for regulatory and strategic alignment;
7. maintains balance across the Input–Process–Output–Impact logic chain;
8. accommodates sector-specific indicators where a common cross-sector indicator would not adequately represent an important hotspot.

The analysis used the environmental, economic and social shortlists, the partners' evaluations, the evaluation protocol and the consolidated fuzzy-evaluation workbook developed for the project.

2. Identification and Configuration of Indicators to Monitor the Transition to a Circular Economy and Sustainability in Rural Agrifood Businesses

2.1 Definition of the analytical framework: scope and system boundaries

Before any indicator could be identified, the desk protocol required the project team to fix the system boundaries of the exercise along five axes: geography, sector, value-chain stage, transition dimensions, and indicator typology. These boundaries, summarized in Table 2.1, condition every subsequent methodological step, from the literature search strategy to the classification scheme applied to individual indicators.

2.1.1 Geographic scope: defining "rural"

CERAS adopted the operational definition of rurality first used in the Multitraces project (ERASMUS plus: 2019-1-RO01-KA203-063870), which is grounded in the OECD/Eurostat "degree of urbanization" approach. This approach classifies territorial units—originally Local Administrative Units and, at EU level, typically NUTS 3 regions under Regulation (EC) No 1059/2003 (European Parliament & Council, 2003)—according to population density and settlement size. It distinguishes predominantly rural areas (more than 50% of the population living in rural communities), predominantly urban areas (less than 15%), and intermediate areas (15–50%). The population thresholds delimiting NUTS regions are reproduced in Table 2.2.

The classification has since been refined using a 1 km² population-grid method that distinguishes rural grid cells, urban clusters (moderate density) and urban centers (high density). It is further differentiated by proximity to a Functional Urban Area (FUA), following Dijkstra and Poelman (2008, 2014): rural areas within a FUA, rural areas with access to a FUA, and remote rural areas whose economies depend heavily on the export of primary production. This layered definition allowed CERAS to situate the partner territories consistently within a single EU-comparable rural typology, rather than relying on national administrative definitions that vary across the five partner countries.

2.1.2 Sectoral scope: agrifood businesses and processing subsectors

The desk protocol defined rural agrifood businesses broadly as predominantly Small-to-Medium Enterprises and family farms spanning the full food chain: primary producers (farms, livestock, aquaculture, poultry, beekeeping, organic and tree farming), agrifood processing (small-scale value-adding units such as flour milling, fruit juice and jam production, meat processing and dairy processing), input suppliers, and agri-tech and services providers. The protocol recommended that the indicator identification approach concentrate on primary producers and processing, and CERAS narrowed this further still to three processing sub-sectors that correspond to the profile of the project's case-study enterprises: meat processing, dairy processing, and juice/vegetable processing. This focus is useful because these processing systems exhibit different resource-use profiles, waste and by-product streams, labour and safety issues, and opportunities for circularity. For example, the significance of animal welfare and occupational safety is particularly pronounced in meat processing; dairy processing creates opportunities associated with water, energy and by-product valorisation; while fruit, vegetable and juice processing is characterized by substantial organic residual streams, seasonal production patterns and opportunities for food-loss prevention and bio-based valorisation.

The sub-sectoral focus is reflected throughout the indicator datasets, where a substantial share of environmental and economic indicators speak directly to processing-stage operations — clean-in-place water and energy use, by-product and residue valorisation, packaging design, and cold-chain logistics — rather than to on-farm primary production alone, even though several livestock- and farm-level indicators are also retained to cover upstream linkages. Therefore, the indicator system is intended to capture not only internal firm performance but, where appropriate, the relationship of agrifood processors with their rural territorial economy, including local employment, local procurement, partnerships and resource exchanges.

2.1.3 Value chain coverage

To avoid a narrowly firm-level view of circularity, the framework's value-chain boundary spans input supply, farming, processing, distribution, retail, consumption and waste management. Coverage across these stages is re-examined explicitly during the validation step of the protocol (Section 2.2.4), ensuring that the indicator set does not cluster disproportionately around a single stage—processing in particular—at the expense of upstream or downstream circularity.

2.1.4 Transition dimensions: sustainability and circular economy

Two overlapping transition dimensions structure the indicator identification work. The sustainability dimension covers environmental aspects (resource efficiency, pollution, biodiversity), social aspects (jobs, skills, community well-being) and economic aspects (profitability, resilience, competitiveness). The circular economy dimension covers resource loops (reduce, reuse, recover, recycle), product-service systems, eco-design and durability, valorisation of by-products and waste, and bio-based cycles and nutrient cycling. This dual perspective is important. An indicator can therefore be relevant because it measures conventional sustainability performance, because it measures the transition towards circular resource flows, or because it performs both functions.

For example, reducing total water input improves environmental sustainability through resource efficiency, whereas increasing internally reused or recycled water specifically provides evidence of water-loop closure. Similarly, employee training is a social sustainability variable, but training specifically devoted to waste valorisation, renewable energy, water reuse, recycling or eco-design represents organizational capacity for the CE transition.

2.1.5 Indicator typology

Consistent with standard monitoring-and-evaluation practice, every candidate indicator is classified according to its position in the production process: Input indicators (e.g., energy or water consumption), Process indicators (e.g., certification adoption or waste-segregation systems), Output indicators (e.g., waste quantities, emissions or revenue from circular products), and Outcome/Impact indicators (e.g., employment levels, biodiversity status or GHG intensity). This four-level typology, rather than the sustainability or CE dimension, is the primary organizing axis of the indicator dataset and is discussed further in Section 2.2.3.4.

Table 2.1. System boundaries and scope adopted for the indicator identification approach

Dimension	Definition adopted in CERAS
Geography	Rural areas, operational definition according to the OECD/ Eurostat degree-of-urbanization approach; see Section 2.1
Sector	Agrifood businesses, focused on primary producers and processing; narrowed for CERAS to meat, dairy, and juice/vegetable processing SMEs
Value chain stage	Input supply, farming, processing, distribution, retail, consumption, waste management
Transition Dimensions	Sustainability (environmental, social, economic) and Circular Economy (resource loops, product-service systems, eco-design/durability, by-product and waste valorisation, bio-based cycles and nutrient cycling)
Indicator typology	Input, Process, Output, and Outcome/Impact indicators

Table 2.2. Population size constraints for NUTS level regions (number of inhabitants)

NUTS level	Minimum population	Maximum population
NUTS level 1 regions	3,000,000	7,000,000
NUTS level 2 regions	800,000	3,000,000
NUTS level 3 regions	150,000	800,000

Source: Eurostat (2025) Regional Statistics Yearbook, as reproduced in the CERAS Desk-Based Protocol.

2.2 The desk-based protocol

Indicator identification follows a desk-based protocol organized into six sequential steps, summarized in Table 2.3 and detailed in the sub-sections below. The protocol is explicitly iterative rather than strictly linear: partner contributions to Steps 2 and 3 continue in parallel, and the validation and evaluation steps (4 and 5) are designed to feed back into the dataset before a final, reduced indicator set is fixed.

Table 2.3. The six-step desk-based protocol

Step	Focus	Key activities and outputs
1	Define framework and scope	Fix system boundaries – geography, sector, value-chain stage, transition dimensions, indicator typology.
2	Annotated bibliographic review	Compile an annotated bibliography across four knowledge categories, using desk-accessible databases and a defined keyword search string, filtered by inclusion/exclusion criteria.
3	Indicator database construction	Extract indicator name, description, unit, frequency, scale and data source from each source; classify by sustainability dimension and CE category; tag for sectoral/agricultural relevance.
4	Validation and quality-control	Benchmark the draft set against leading sustainability-reporting frameworks and against CE/agrifood-specific frameworks; check coverage across all value-chain stages.
5	Evaluation of the indicator set	Define evaluation criteria; score and rank indicators to reduce the draft pool to a manageable, prioritized core set.
6	Guidelines and reporting template	Produce a standardized indicator sheet per selected indicator and monitoring/reporting guidelines (data collection methods, responsible unit, reporting intervals, territorial aggregation).

2.2.1 Defining framework and scope

The first step, described in Section 2.1, fixes the system boundaries within which the remaining five steps operate. Specifically, it sets out the adopted definition of rural areas and the typology of agrifood businesses from which the meat, dairy and juice/vegetable processing subsectors were selected.

2.2.2 Annotated bibliographic review

Candidate indicators were identified through an annotated bibliographic and documentary review rather than relying on a single existing indicator framework.

The protocol specifies four principal categories of evidence:

1. peer-reviewed academic literature
2. policy and institutional frameworks, including EU, OECD, UN, FAO and national sources
3. industry and management standards, including ISO and ESG-related frameworks and
4. existing indicator systems developed for agriculture, sustainability and circular economy.

The proposed search environment included Scopus, Web of Science, Google Scholar and ResearchGate for scientific evidence, together with institutional sources including FAO, OECD, Eurostat, UNEP, UNCTAD, European Commission CE monitoring resources, ISO standards and agrifood industry reports. The initial search concept combined terms related to “Circular economy”, “Sustainability” and “Agrifood indicators.”

The purpose of the search was not simply to compile frequently reported sustainability variables. Sources were examined for explicit indicators, metrics, calculation approaches and monitoring frameworks that could potentially be operationalized at agrifood-business level.

The evidence-screening procedure established explicit eligibility criteria. Sources were considered relevant when they addressed CE or sustainability in rural agrifood contexts and proposed or applied indicators, metrics or monitoring frameworks. Preference was given to publications from the preceding ten years, while allowing older seminal contributions to be retained. This provided a useful compromise between methodological currency and continuity with established measurement concepts.

For the processing-focused application, an additional practical screening principle can be inferred from the resulting dataset: an indicator should be capable of meaningful interpretation at the firm, processing operation, product, value-chain or relevant territorial level.

Indicator identification was designed as a collaborative process involving project partners, rather than as a literature exercise undertaken by a single research team.

The protocol required partners to review the preliminary indicator dashboard, propose additional indicators where necessary, complete the associated indicator fields, and contribute supporting evidence. In particular, each partner was asked to provide at least ten peer-reviewed publications, together with relevant official and country-specific sources, to support existing or newly proposed indicators.

This procedure performed three methodological functions. First, it increased evidence coverage by drawing on multiple disciplinary and national perspectives. Second, it allowed the preliminary dataset to be subjected to an initial form of expert scrutiny, identifying omissions and indicators whose relevance may be sector- or country-specific. Third, it reduced dependence on indicators developed exclusively at EU macroeconomic level by introducing evidence relevant to the operational realities of agrifood businesses.

2.2.3. Construction of the indicator dataset

2.2.3.1 Evidence collection

The evidence collected through the desk review was transformed into a structured indicator dataset, which contained three principal indicator families:

- 41 environmental indicators
- 38 economic indicators, and
- 30 social indicators coded in a spreadsheet form (see Appendix A).

Thus, the dataset represents a deliberately broad candidate pool rather than a final monitoring dashboard.

The protocol specifies that each candidate indicator should be documented in terms of its name, description, quantitative or qualitative unit, monitoring frequency, measurement scale and likely data source. The spreadsheet operationalizes and extends this principle. Its principal fields shown in Table 2.4 include:

Table 2.4. The descriptive fields of the indicator dataset

Indicator field	Description
Indicator code	Unique identifier (e.g., ENV01, ECON1, SOC2)
Indicator name	Short descriptive title
Proposed by	Partner institution that submitted the indicator
Indicator description	Brief explanation of what the indicator measures
Indicator level	Classification per production-process stage: Input, Process, Output, or Impact
Category	Sub-classification specific to the indicator level (e.g., “Resource Input – Energy”, “Health, Safety & Well-being”)
Relevance	Justification of the indicator's contribution to sustainability (S) and/or circular economy (CE) monitoring
Unit	Unit of measurement
Data Requirements	Data inputs needed to compute the indicator
Formula	Computation method
Notes	Boundary conditions, definitions, and measurement caveats
Frequency	Recommended monitoring interval (e.g., monthly, quarterly, annually)
Direction	Desired direction of change (“Up” or “Down”)
Academic basis	Scientific/institutional evidence (peer-reviewed or institutional reference justifying inclusion of the indicator)
Partner academic basis	Additional supporting evidence

This structure is particularly valuable because it moves the dataset beyond a simple list of indicators. Each indicator becomes a defined monitoring object with an operational measurement protocol.

2.2.3.2 Configuration according to the sustainability dimensions

All candidate indicators were first allocated to one of the three principal sustainability dimensions.

Environmental indicators

The environmental dataset addresses areas including energy, water, material inputs, packaging, waste and resource outflows, emissions, environmental management practices, food-system circularity and broader environmental impacts. For example, the dataset differentiates between Total Water Input and Reused/Recycled Water Input Share. This distinction is methodologically important. The former measures resource demand, while the latter explicitly captures the degree to which the business is closing an internal water loop.

Economic indicators

The economic indicator pool covers themes such as resource operating costs, investment and finance, circular procurement, circular value generation, economic management practices, transport, local value creation and business resilience. This allows CE monitoring to extend beyond environmental efficiency and capture whether circularity contributes to—or imposes requirements upon—the economic viability and competitiveness of the business.

Social indicators

The social dataset encompasses employment and job quality, occupational health and safety, CE skills, employee participation, territorial linkages, governance and partnerships, human capital, social resilience, responsible consumption and other sector-specific social issues. Examples include CE and sustainability training hours per FTE, OHS investment per FTE, local/regional procurement, agrifood business symbiosis governance, traceability and transparency, employee retention, skills attainment and workplace injury indicators.

2.2.3.3 Configuration according to Circular Economy relevance

A second classification layer establishes how each indicator contributes to CE monitoring.

The original protocol identifies major CE categories encompassing:

- resource use and efficiency, particularly materials, water and energy

- waste and emissions management
- circular business models, including reuse, repair, recycling and bio-based loops
- environmental performance
- social and territorial integration, including local employment and community linkages.

Agrifood-specific tags were additionally envisaged for issues such as waste, water management, by-product valorisation, traceability and certification.

This classification is critical because it establishes the conceptual link between each monitoring indicator and the mechanism of transition. The indicator dataset therefore records not only *what changes*, but also *why that change constitutes evidence of CE or sustainability progress*.

2.2.3.4 Input–Process–Output–Impact logic chain

A particularly important feature of the methodology is classification of indicators according to their position in the transition logic chain:

Input → Process → Output → Outcome/Impact

The protocol explicitly identified these four types, giving examples such as energy consumption for inputs, certification or waste-segregation systems for processes, waste quantities/emissions/circular-product revenues for outputs, and employment or biodiversity status for outcomes and impacts. This classification provided considerably more analytical information than a conventional monitoring indicators list.

Inputs represent resources and capacities committed to the transition, for example, energy, water, investment, labour or CE training.

Processes capture organizational or operational changes introduced to enable transition, for example, management systems, traceability arrangements, risk assessments or circular procurement practices.

Outputs measure the immediate measurable results generated by these activities, for example, recovered materials, trained employees, circular revenues or active partnerships.

Outcomes/Impacts capture the more substantive changes in environmental, economic or social performance that emerge from the transition.

The environmental dataset was already highly balanced in this respect, containing approximately ten indicators at each stage (10 inputs, 10 processes, 11 outputs and 10 impacts). This structure was particularly useful for later indicator reduction because selection could be undertaken without inadvertently producing a dashboard composed almost entirely of either operational inputs or lagging impact measures.

2.2.3.5 Configuration of individual indicator specifications

Following identification and classification, each candidate indicator was configured so that it could eventually be implemented consistently across businesses.

For quantitative indicators, this required specification of:

Unit of measurement. Examples include kWh per functional unit, m^3 per tonne of production, percentages, €/FTE, hours/FTE and incident rates.

Data requirements. The dataset specifies the raw data necessary to calculate each monitoring indicator—for example utility bills, production quantities, employee records, procurement expenditure or OHS records.

Calculation formula. Explicit formulas convert raw business data into standardized metrics.

Measurement frequency. Indicators are assigned appropriate intervals such as monthly or annual reporting.

Direction of improvement. The dataset identifies whether improved CE/sustainability performance is normally associated with an increase (Up) or decrease (Down) in the monitoring indicator.

Notes and boundaries. These clarify inclusions, exclusions and risks of double counting.

This level of configuration is essential for comparability. For example, measuring total water use without defining whether internally recirculated water is counted as a new input could produce misleading comparisons. The dataset addresses such issues by separating external water inputs from internally reused or recycled flows.

2.2.3.6 Sector-specific relevance to meat, dairy and fruit/vegetable processing

The common dataset should be understood as a core candidate pool, not as an assumption that every indicator has identical importance for every processing activity. The subsequent sector-screening stage therefore evaluated indicator relevance separately for:

Meat processing, where occupational health and safety, animal welfare, energy and water consumption, wastewater, organic residuals, traceability and by-product valorisation can become particularly important;

Dairy processing, where water and energy efficiency, wastewater, refrigeration, whey and other by-product valorisation, traceability and industrial symbiosis are particularly pertinent; and

Fruit/vegetable and juice processing, where seasonal resource utilization, organic residues, water use, packaging, food loss, donation and alternative valorisation pathways can be important.

The methodological advantage is that a common cross-sector monitoring core can ultimately coexist with hotspot-specific modules, rather than developing three unrelated indicator systems.

2.2.4 Validation and quality control

Once the preliminary indicator pool has been assembled, the protocol required validation against existing sustainability reporting, such as the ESRS, GRI, and EU Taxonomy Regulation and CE/agrifood frameworks, including the Ellen MacArthur Foundation's Material Circularity Indicator methodology and ISO standards on environmental management, energy management, and material flow cost accounting. It also called for a value-chain coverage check, covering inputs, processing, packaging, distribution/logistics, retail and consumption, and end-of-life/valorisation.

This stage aimed to answer four fundamental questions:

1. ***Conceptual validity:*** Does the indicator genuinely represent sustainability and/or CE transition?
2. ***Evidence validity:*** Is its use supported by credible academic, institutional or sectoral evidence?
3. ***Operational validity:*** Can the required data realistically be obtained from agrifood businesses?
4. ***Coverage validity:*** Does the overall pool adequately represent environmental, economic and social dimensions, CE mechanisms, value-chain hotspots and the Input–Process–Output–Impact chain?

Duplicates and strongly overlapping indicators could therefore be identified before formal prioritization.

2.2.5 Evaluation of the indicator set

The desk protocol deliberately separated indicator identification from indicator valuation. After the dataset was established and bench marked, evaluation criteria were defined and indicators were subsequently scored and ranked (Appendix B).

In the CERAS methodology subsequently developed, this was operationalized through four successive filters:

Stage 1 – Processing-hotspot relevance

Indicators were scored for their relevance to meat, dairy and fruit/vegetable/juice processing.

Stage 2 – Double materiality

Indicators were evaluated from both impact-materiality and business/financial-materiality perspectives.

Stage 3 – Business relevance

Indicators were assessed against six business criteria: cost impact, revenue impact, risk exposure, managerial control ability, data availability and strategic alignment.

Stage 4 – Logic-chain balancing

The highest-ranked indicators were not selected mechanically. The reduced set was checked to retain appropriate representation of inputs, processes, outputs and impacts, as well as environmental, economic and social dimensions. This produced a more defensible selection procedure than simply retaining indicators with the highest literature frequency or highest aggregate score.

2.2.6 Preparation for business-level monitoring and reporting

The final stage converted selected indicators into standardized indicator sheets. According to the protocol, each selected indicator should contain its definition, rationale, calculation methodology, data sources, unit and frequency, and correspondence with relevant frameworks.

Reporting guidance should additionally establish:

- who within the business is responsible for collecting each variable
- source records and evidence requirements
- baseline year
- monitoring and reporting interval

- quality-control procedures
- treatment of missing data
- normalization by production or another functional unit where required
- procedures for aggregation across firms or at rural cluster/territorial level

The original protocol explicitly anticipates business-level data-collection responsibilities, reporting intervals and baselines, and potential aggregation at cluster or territorial level.

2.3. Overall methodological workflow

The complete methodology can therefore be represented as follows:

- Define scope and system boundaries
- Define sustainability and CE dimensions
- Conduct structured desk review
- Apply source inclusion/exclusion criteria
- Extract candidate indicators
- Integrate partner and country-specific evidence
- Construct ENV–ECO–SOC indicator dataset
- Define units, formulas, data requirements, frequency and direction
- Classify by CE mechanism and thematic category
- Classify by Input–Process–Output–Impact
- Validate against established frameworks and value-chain coverage
- Assess relevance to meat, dairy and fruit/vegetable processing
- Apply double-materiality screening
- Evaluate business relevance
- Rank and reduce indicators
- Rebalance the reduced set across the logic chain
- Develop indicator sheets and reporting protocol
- Establish baseline and monitor transition over time.

3. Analysis and Harmonisation of the Identified Indicators to Monitor the Transition to a Circular Economy and Sustainability in Rural Agrifood Businesses

3.1. Starting indicator pool

The harmonization process began with the broader indicator datasets generated during the desk-research phase.

The files contained 41 environmental indicators, 38 economic indicators, and 31 social indicators.

The candidate indicators differed substantially in their characteristics. Some represented direct resource inputs, such as energy or water consumption; others represented organizational practices, such as traceability or material flow cost accounting; others measured immediate outputs, such as waste generation; and others represented longer-term effects such as material productivity, employee retention or water scarcity.

Consequently, direct ranking of the initial indicators would have been inappropriate without first establishing common analytical conventions.

The analysis therefore followed a sequential process of harmonization, progressing from screening to evaluation, aggregation, balancing and final selection.

3.2 Harmonization of the indicators

3.2.1 Harmonization according to sustainability dimension

The first level of harmonization involved assigning each indicator to one of three sustainability dimensions:

Environmental

Indicators describing resource consumption, resource-loop closure, waste, pollution, emissions, water, energy and broader environmental performance.

Economic

Indicators describing the financial implications of resource use, circular investment, circular revenues, operating costs, productivity, resilience and circular business models.

Social

Indicators describing employment, skills, occupational health and safety, workforce stability, participation, partnerships, territorial relationships and other social consequences of the CE transition.

This classification enabled environmental, economic and social indicators to be evaluated separately before being recombined into a common framework.

3.2.2 Harmonization according to the logic chain

Each indicator was also assigned to one of four positions in a common monitoring logic: Input → Process → Output → Impact.

Input indicators

Measure resources or capacities committed to the CE and sustainability transition.

Examples include:

- total water input
- total energy input
- circular CAPEX
- OHS investment per FTE
- CE training hours per FTE.

Process indicators

Measure whether organizational or operational mechanisms supporting the transition have been established.

Examples include:

- heat recovery;
- separate collection and traceable segregation;
- material flow cost accounting;
- quality assurance for secondary inputs;
- traceability and transparency for circular inputs;
- agrifood business symbiosis governance.

Output indicators

Capture direct and relatively immediate results of business activities.

Examples include:

- total waste generated;
- waste disposal dependency;
- share of employees trained;
- active CE partnerships;
- sales through short food supply chains.

Impact indicators

Capture broader or longer-term performance effects.

Examples include:

- water scarcity footprint;
- material productivity;
- employee retention rate;
- skills competence attainment;
- value added per FTE.

Logic-chain classification was particularly important because a CE monitoring framework dominated only by inputs would indicate what businesses were investing or consuming without demonstrating results, whereas a framework consisting only of impacts would provide insufficient information on how and why transition was occurring. The evaluation protocol therefore explicitly required representation of inputs, processes, outputs and impacts.

3.3. Sector-specific hotspot analysis

The first substantive screening stage assessed whether indicators were relevant to the characteristic sustainability and CE hotspots of the three processing activities.

The protocol identified the following principal hotspots.

Meat processing

- high energy demand associated particularly with refrigeration and chilling
- high water consumption and wastewater loads
- animal and processing by-products
- refrigerant leakage
- cold-chain logistics

Dairy processing

- thermal energy use
- water and chemicals associated with cleaning-in-place
- whey valorisation
- packaging
- cold storage

Fruit/ vegetable processing

- washing water
- organic residues such as pomace and peels
- seasonal employment
- energy requirements for pasteurisation
- wastewater organic loads

Indicators were therefore scored for their relevance to each processing hotspot.

This procedure served two purposes. First, it removed indicators whose relevance was mainly associated with primary agricultural production rather than processing. Second, it prevented the use of a completely generic agrifood indicator system that would overlook major differences between meat, dairy and fruit/vegetable processing.

Common and sector-specific indicators

The process distinguished between cross-sector indicators, applicable to all three processing activities and sector-specific indicators, retained when they represented a significant hotspot in only one processing activity.

For example, the social assessment explicitly retained:

- mortality before slaughter; and
- transport stress index

as meat-sector-specific indicators, while:

- food donation rate

was identified as particularly relevant to fruit/vegetable processing.

This modular approach avoided forcing specialized indicators into the common core while ensuring important sector-specific effects are not lost.

3.4 Double-materiality screening

Following hotspot screening, indicators were subjected to a double-materiality assessment. Two distinct questions were considered:

Impact materiality: Does the issue measured by the indicator generate a significant impact on the environment or society?

Financial materiality: Does the issue create a significant financial risk or opportunity for the business?

Each dimension was scored according to the following Table 3.1:

Table 3.1. Scoring protocol

Score	Interpretation
0	Not significant
1	Moderate
2	High

The two scores could consequently produce a combined materiality score ranging from 0 to 4. Indicators receiving low scores in both dimensions were candidates for removal.

This step was important because it prevented the indicator selection from being driven exclusively either by sustainability impacts or by business considerations.

An indicator could therefore remain relevant because it represents:

- a significant environmental/social impact
- a significant business risk or opportunity   or

- both

This double-materiality screening substantially reduced the original candidate pool before the detailed business evaluation.

3.5 Harmonization of indicator specifications

Before business scoring, the indicator definitions were reviewed to improve comparability.

The following attributes were harmonized wherever applicable:

- indicator name
- definition and system boundary
- sustainability dimension
- logic-chain level
- CE relevance
- unit of measurement
- data required
- calculation formula
- direction of desired change
- monitoring frequency
- applicability to the three processing sectors

Particular attention was given to indicators with similar meanings.

For example, metrics associated with resource efficiency were distinguished from metrics measuring circular resource use. Likewise, workforce training intensity was differentiated from training coverage and actual competence attainment because they represent different stages of the logic chain: training resources → training participation → competence attained.

Harmonization therefore aimed to avoid both duplication and loss of causal information.

3.6. Business-relevance evaluation

After hotspot and materiality screening, the remaining indicators were evaluated from the perspective of agrifood businesses.

Six criteria (Table 3.2) were used and scored on a **1–5 scale**, where higher values indicate stronger business relevance.

Table 3.2. Criteria for rural agrifood business-relevance evaluation

Criteria	Evaluation description
Cost impact	Does the indicator relate materially to the business cost structure?
Revenue impact	Does it support value creation or new revenue opportunities?
Risk exposure	Does it represent regulatory, supply, environmental, labour or other business risk? Does it represent regulatory, supply, environmental, labour, or other business risk?
Management control ability	Can management influence the issue directly and document it through traceable evidence?
Data availability	Can the indicator realistically be measured using available business data?
Strategic alignment	Does it support CE/sustainability objectives and relevant reporting or regulatory expectations?

These criteria and their intended interpretation are specified in the evaluation protocol.

This stage introduced an important distinction between an indicator that is theoretically relevant and one that is decision-useful for an agrifood business.

3.7. Weighting of the business criteria

The consolidated evaluation workbook applied the following predetermined weights uniformly across all indicators. These weights were fixed inputs to the scoring model (Table 3.3):

Table 3.3. Weights for the rural agrifood business-relevance evaluation criteria

Business criterion	Final weight
Cost impact	20%
Revenue impact	10%
Risk exposure	25%
Management control ability	15%
Data availability	5%
Strategic alignment	25%
Total	100%

The weighting gives the greatest influence to risk exposure and strategic alignment, followed by cost impact and managerial control ability. Data availability receives the lowest weight, preventing an indicator from being excluded solely because its measurement currently requires additional data collection. Data feasibility remains relevant, but it does not override materiality or strategic significance.

3.8. Collection and consolidation of partner evaluations

Business-relevance scoring was undertaken collaboratively. The final aggregation workbook consolidated 315 evaluation records from seven Excel evaluation files covering the environmental, economic and social candidate indicators. The partner scores therefore constituted a multi-evaluator assessment rather than a single-expert judgement.

Missing assessments were retained as missing values rather than artificially imputed. The consolidated workbook consequently reports the minimum number of valid evaluations across criteria (n minimum) for each indicator.

The shortlisted indicators were evaluated by all 10 contributors, namely the 5 academic experts, one from each country partner university and the 5 business experts, one from each country partner companies. A small number had lower coverage—for example six or five valid assessments—making the completeness measure important for interpretation.

3.9. Fuzzy harmonization of the 1–5 evaluations

The six business-relevance criteria were assessed on an ordinal 1–5 scale. These ratings express expert judgements and should not be interpreted as error-free quantitative measurements. To preserve the imprecision associated with linguistic assessments, each crisp rating was transformed into a triangular fuzzy number (TFN), following the fuzzy-set approach introduced by Zadeh (1965).

Let i denote an indicator, j one of the six business-relevance criteria, and k an evaluator. The corresponding rating was represented by the TFN in Equation (3.9-1).

$$\tilde{x}_{ijk} = \left(l_{ijk}, m_{ijk}, u_{ijk}\right), \qquad l_{ijk} \leq m_{ijk} \leq u_{ijk} \tag{3.9-1}$$

In this expression, l is the lower or conservative value, m is the modal or most plausible value, and u is the upper or optimistic value. The conversion adopted in the consolidated CERAS evaluation is shown in Table 3.4.

Table 3.4. Fuzzy conversion of the 1–5 business-relevance scale

Score	Interpretation	Triangular fuzzy number
1	Very low / exclude	(1, 1, 2)
2	Low / probably exclude	(1, 2, 3)
3	Moderate / neutral	(2, 3, 4)
4	High / probably include	(3, 4, 5)
5	Very high / include	(4, 5, 5)

For each indicator–criterion combination, the individual TFNs were aggregated across the available partner assessments. If K_{ij} valid evaluations were available, the group fuzzy score and its three components were calculated using Equations (3.9-2) and (3.9-3a–c).

$$\bar{\tilde{x}}_{ij} = \left(\bar{l}_{ij}, \bar{m}_{ij}, \bar{u}_{ij}\right) \tag{3.9-2}$$

$$\bar{l}_{ij} = \frac{1}{K_{ij}} \sum_{k=1}^{K_{ij}} l_{ijk} \tag{3.9-3a}$$

$$\bar{m}_{ij} = \frac{1}{K_{ij}} \sum_{k=1}^{K_{ij}} m_{ijk} \tag{3.9-3b}$$

$$\bar{u}_{ij} = \frac{1}{K_{ij}} \sum_{k=1}^{K_{ij}} u_{ijk} \tag{3.9-3c}$$

Only non-missing assessments entered K_{ij}; missing values were not imputed. The number of valid assessments was retained as a data-completeness diagnostic, together with $K_i(\min) = \min_j(K_{ij})$, the smallest criterion-specific sample size available for indicator i.

The component-wise arithmetic mean is appropriate because the inputs are direct 1–5 ratings of indicator performance. Accordingly, this stage is a direct fuzzy aggregation procedure and does not involve pairwise comparisons or consistency testing. The result is one consensus TFN for every indicator and evaluation criterion.

3.10. Weighted fuzzy evaluation

The six aggregated fuzzy criterion scores were combined using the fixed business-relevance weights adopted in Section 3.7. Let w_j denote the weight of criterion j. The weights were normalized according to Equation (3.10-1).

$$\sum_{j=1}^{6} w_j = 1, \qquad w_j \geq 0 \tag{3.10-1}$$

Table 3.5. Business-relevance weighting vector used in the CERAS evaluation

Business criterion	**Weight**
Cost impact	0.20
Revenue impact	0.10
Risk exposure	0.25
Management controllability	0.15
Data availability	0.05
Strategic alignment	0.25
Total	1.00

These values form the normalized weighting vector w = (0.20, 0.10, 0.25, 0.15, 0.05, 0.25). The highest weights are assigned to risk exposure and strategic alignment, while data availability receives the lowest weight so that temporary data limitations do not override materiality or strategic relevance.

For indicator i, the overall weighted fuzzy evaluation was calculated as the weighted sum of the six aggregated criterion TFNs, as shown in Equation (3.10-2).

$$\tilde{S}_i = \sum_{j=1}^{6} w_j \otimes \bar{\tilde{x}}_{ij} = (L_i, M_i, U_i) \tag{3.10-2}$$

Because the criterion weights are non-negative crisp values, scalar multiplication and fuzzy addition were applied component-wise, as shown in Equations (3.10-3a–c).

$$L_i = \sum_{j=1}^{6} w_j \, \bar{l}_{ij} \tag{3.10-3a}$$

$$M_i = \sum_{j=1}^{6} w_j \, \bar{m}_{ij} \tag{3.10-3b}$$

$$U_i = \sum_{j=1}^{6} w_j \, \bar{u}_{ij} \tag{3.10-3c}$$

The resulting TFN combines cost impact, revenue impact, risk exposure, management control ability, data availability and strategic alignment in a single evaluation while preserving the lower, central and upper interpretations of the partner judgements. Since the criterion weights sum to one, L_i, M_i and U_i remain on the original 1–5 evaluation scale.

3.11. Defuzzification and ranking

A crisp score was required to rank the indicators. The final TFN was therefore defuzzified using the centroid, or centre-of-area, method.

$$S_i = \frac{L_i + M_i + U_i}{3} \tag{3.11-1}$$

The defuzzified score S_i remains on the original 1–5 evaluation scale. Indicators were ranked in descending order of S_i, with higher values indicating stronger combined business relevance. For transparency, the fuzzy result was compared with the conventional crisp weighted mean. Let $\bar{r}_{ij}$ denote the arithmetic mean of the original non-missing 1–5 ratings for indicator i and criterion j. The conventional score C_i and its difference from the fuzzy result Δ_i were calculated using Equation (3.11-2).

$$C_i = \sum_{j=1}^{6} w_j \, \bar{r}_{ij}, \qquad \Delta_i = S_i - C_i \tag{3.11-2}$$

Reporting C_i, S_i and Δ_i makes the effect of the fuzzy transformation explicit. The width of the final triangular fuzzy interval, B_i, was also retained as an uncertainty diagnostic and was calculated using Equation (3.11-3).

$$B_i = U_i - L_i \tag{3.11-3}$$

A larger value of B_i indicates a wider fuzzy interval and therefore greater imprecision in the aggregated expert assessments, even when two indicators have similar centroid scores.

Table 3.6. Decision classes for interpretation of the defuzzified fuzzy score

Defuzzified score S_i	Decision class
$S_i \geq 4.00$	Priority
$3.00 \leq S_i < 4.00$	Retain
$2.00 \leq S_i < 3.00$	Low priority
$S_i < 2.00$	Discard candidate

The decision classes provide an interpretable screening rule in addition to the ordinal rank. They are not automatic exclusion thresholds. As specified in the subsequent stages of the CERAS methodology, compliance requirements, sector-specific hotspots, data completeness and balance across the Input–Process–Output–Impact logic chain must also be considered before the final indicator set is confirmed.

3.12. Compliance safeguard

The evaluation protocol introduced a further safeguard following business scoring: the shortlisted indicators should be checked against relevant sustainability and CE requirements.

Importantly, an indicator that is mandatory or strongly expected should not automatically be removed because of a relatively low business score.

This avoids a purely business-preference-based dashboard that could exclude important regulatory or sustainability metrics.

The harmonization procedure therefore treats quantitative ranking as decision support rather than an automatic selection algorithm.

3.13. Reduction to the harmonized evaluation pool

Following hotspot relevance assessment, double-materiality screening and indicator harmonisation, the pool entering the consolidated fuzzy analysis contained 45 indicators, numbered in Table 3.7:

Table 3.7. Indicators per category

Dimension	Indicators evaluated
Environmental	18
Social	15
Economic	12
Total	45

The social set already illustrates the reduction strategy particularly clearly. It contained a cross-sector core together with three optional indicators:

- mortality before slaughter – meat-specific
- transport stress index – meat-specific

- food donation rate – particularly relevant to fruit/vegetable processing.

Thus, the reduced evaluation pool retained sectoral specificity without allowing specialist indicators to dominate the common framework.

3.14. Logic-chain balancing of the final set

A simple ranking of the 45 indicators would have favoured some combinations of dimensions and indicator levels while leaving gaps elsewhere. Consequently, the final harmonization step deliberately imposed logic-chain balance.

The final dashboard applied the following rule: select the two highest-ranked indicators within each logic-chain level and sustainability dimension.

3 dimensions × 4 logic-chain levels × 2 indicators = 24 indicators

Therefore:

- Environmental = 8 indicators
- Social = 8 indicators
- Economic = 8 indicators

and, within every dimension:

- 2 Inputs
- 2 Processes
- 2 Outputs
- 2 Impacts

This represents an evolution from the earlier evaluation protocol, which initially envisaged a final set of approximately 12–18 indicators and 3–5 indicators at each logic level. The current implementation instead prioritized strict analytical balance, producing a 24-indicator harmonized framework (Appendix C).

3.15. Resulting balanced indicator architecture

The resulting structure is shown in the following Table 3.8:

Table 3.8. The selected indicators to monitor the transition of rural agrifood businesses to a circular economy and sustainability

Dimension	Input	Process	Output	Impact
Environmental	Total Water Input	Heat recovery rate	Total waste generated	Water scarcity footprint
	Total Energy Input	Separate collection & traceable segregation	Refrigeration leakage factor	Transport emissions per raw-material collection
Social	OHS investment per FTE	Traceability & transparency for circular inputs	Share of employees trained	Employee retention rate
	Share of permanent employment	Agrifood business symbiosis governance	Active CE partnerships maintained	Skills competence attainment
Economic	Resource Cost Dependency	QA protocol for secondary/by-product inputs	Sales through Short Food Supply Chains	Material productivity
	Investment in reusable packaging/reverse logistics	Material Flow Cost Accounting	Waste disposal dependency	Value added per FTE

This architecture is important because it allows a business to monitor not merely isolated sustainability performance, but a transition pathway. For example: Investment/resources → organizational change → operational result → longer-term performance can be monitored simultaneously.

3.16. Treatment of low-scoring structurally important indicators

One important consequence of logic-chain balancing is that the final 24 indicators are not simply the global top 24 indicators.

For example, some second-ranked indicators within an Impact category have fuzzy scores below 3.00 and therefore fall into the "Low priority" class. Nevertheless, they may be retained because they provide information that would otherwise be absent from that particular dimension and logic-chain position.

This is explicitly recognized in the final dashboard. Accordingly, the methodology distinguishes between statistical/evaluation priority—how highly an indicator performs in the weighted fuzzy business evaluation—and framework priority—whether the indicator is necessary to achieve a complete, balanced and interpretable CE monitoring architecture. This distinction is central to the harmonization methodology.

3.17. Cross-sector harmonization versus sector modules

The final framework should be implemented using a core-plus-module architecture.

Core indicators

The 24-indicator balanced set provides a common analytical basis for comparison among meat, dairy and juice/vegetable processing businesses.

Sector-specific modules

Additional indicators can be activated where a processing hotspot requires more detailed monitoring.

Examples already identified in the files include:

Meat

- mortality before slaughter
- transport stress index
- slaughter-related resource efficiency indicators

Dairy

- cleaning-in-place water intensity
- whey/by-product valorisation
- milk/raw-material collection transport performance

Juice/vegetables

- food donation rate
- organic residue valorisation

- packaging and food-loss indicators

This arrangement supports comparability without sacrificing sector relevance.

3.18. Data-quality and harmonization safeguards

Several safeguards should accompany implementation of the framework.

i) Consistent definitions

The same indicator definition and calculation formula should be applied across firms and reporting years.

ii) Stable functional units

Intensity indicators should use clearly defined denominators such as:

- tonne of processed product
- litre of milk/juice
- FTE
- turnover
- unit of packaging
- tonne-kilometre

iii) Clear system boundaries

Businesses should specify whether measurements cover:

- one processing facility
- all company facilities
- owned logistics only
- outsourced activities
- upstream suppliers or
- downstream distribution.

iv) Avoidance of double counting

Related indicators must remain analytically distinct. For example:

- OHS investment is an input
- risk assessment is a process

- incident rate is an output/performance result.

Similarly:

- training hours represent training intensity
- employees trained represent coverage
- competence attainment represents the resulting capability

v) Directionality

For each monitoring indicator, the expected direction of improvement should be fixed:

- Up, where increasing values represent transition progress
- Down, where decreasing values represent improvement

vi) Evidence traceability

Business scoring and subsequent monitoring should rely, wherever possible, on traceable records such as invoices, meters, production records, HR systems, permits, contracts and waste-transfer records. The evaluation protocol explicitly connects managerial control ability with the availability of such traceable evidence.

3.19. Overall methodological sequence

The complete analysis and harmonization methodology can therefore be represented as follows:

Initial ENV–ECO–SOC indicator dataset
↓
Standardize names, definitions, units, direction and logic-chain level
↓
Map indicators to meat, dairy and juice/vegetable processing hotspots
↓
Remove indicators with insufficient processing relevance
↓
Apply impact + financial double-materiality screening
↓
Resolve overlaps and retain sector-specific indicators as optional modules

↓

Evaluate remaining indicators against six business-relevance criteria

↓

Collect assessments from project/business partners

↓

Apply agreed criterion weights

↓

Convert 1–5 evaluations to triangular fuzzy numbers

↓

Aggregate partner evaluations

↓

Calculate weighted fuzzy scores

↓

Defuzzify and rank indicators

↓

Assign Priority / Retain / Low-priority / Discard-candidate classes

↓

Conduct compliance safeguard

↓

Balance ENV–ECO–SOC dimensions

↓

Balance Input–Process–Output–Impact levels

↓

Construct common core + sector-specific modules

↓

Final harmonized CE & Sustainability monitoring framework

4. Overall Monitoring Circular Economy and Sustainability Index (OMCESI) to monitor the transition to a circular economy and sustainability in rural agrifood businesses

Section 4 defines the Overall Monitoring Circular Economy and Sustainability Index (OMCESI) as the final operational component of the CERAS methodology. Sections 2 and 3 established the evidence base, the indicator dataset, the harmonization process and the reduction of the broad candidate set into a balanced core architecture. Chapter 4 explains how the selected indicators are transformed into a composite monitoring index that can be applied at the level of rural agrifood businesses and, where appropriate, aggregated at sectoral or territorial level.

OMCESI is not intended to replace the detailed indicator dashboard. Rather, it provides a structured synthesis of the dashboard, allowing businesses, project partners and training users to interpret progress through a single transparent and reproducible scoring framework. The detailed indicators remain the primary evidence. The index is a derived monitoring instrument that summarizes that evidence while preserving the hierarchy of environmental, social and economic sustainability.

The methodological challenge addressed by OMCESI is that circular economy and sustainability performance cannot be measured through a single physical variable. Rural agrifood businesses combine water, energy, packaging, waste, by-products, labour, skills, occupational safety, cooperation, cost resilience and local value creation. The index therefore requires three methodological operations: first, the indicators must be placed in a coherent hierarchy; second, their relative importance must be estimated; and third, business-level performance values must be normalized into comparable scores before aggregation.

The index uses a hierarchical weighting structure. The first level compares the three dimensions of sustainability and circular transition: Environmental, Social and Economic. The second level compares the indicators located inside each dimension. This means that an indicator receives two weights: a local weight within its dimension and a global weight derived by multiplying its local weight by the weight of its parent dimension. This avoids an unstructured mixture of indicators and ensures that environmental, social and economic priorities remain visible in the final score.

For the CERAS application, the relative weights were obtained through a Fuzzy Analytic Hierarchy Process (Fuzzy AHP). Individual pairwise comparisons were first converted into triangular fuzzy numbers. The participants' fuzzy judgement were then aggregated using the fuzzy geometric mean, and the final priority weights were derived with the Fuzzy Inverse of Column Sum Method (FICSM). The resulting weights were defuzzified using the centroid approach and normalized to sum to one. All equations in this section are presented as Word-compatible editable text rather than as equation objects, so that they remain readable in different versions of Microsoft Word and LibreOffice.

4.1 Purpose, scope and conceptual position of OMCESI

The purpose of OMCESI is to convert the harmonized CERAS indicator architecture into a monitoring index suitable for rural agrifood businesses. In the context of this deliverable, an index is understood as a composite measure that combines several normalized indicators into a single score through an explicit weighting rule. The index does not eliminate the need to examine the underlying indicators. Its value lies in organizing them into a common interpretive structure and in supporting comparison over time, between business units, or across sectoral modules.

The scope of OMCESI follows the scope fixed earlier in the methodology. It refers to rural agrifood businesses, with particular relevance to meat processing, dairy processing and fruit/vegetable and juice processing. It is designed for businesses that may not have the administrative capacity or legal obligation to implement large-enterprise sustainability reporting systems but nevertheless need a practical framework for monitoring circularity and sustainability transition. The index therefore emphasizes indicators that are meaningful at business level, feasible to collect, and capable of being influenced by management decisions.

The index is transition-oriented. A high score should not be interpreted as proof that a business has achieved circularity in an absolute sense. Instead, it indicates that the business performs well against the selected CERAS indicators and the priorities assigned to them. OMCESI is thus a monitoring tool rather than a certification system. It can support baseline diagnosis, annual monitoring, training activities, identification of weak areas and communication of progress to local stakeholders.

A central design principle is interpretability. The final score should be understandable to business managers and trainers. For this reason, the model reports not only the overall OMCESI score but also the Environmental, Social and Economic dimension scores. This prevents a business from receiving a satisfactory total score while having a serious weakness hidden inside one dimension. The OMCESI dashboard should therefore always present at least four values: the total index, the Environmental score, the Social score and the Economic score.

Table 4.1. Methodological components required for reproducible OMCESI calculation

Component	Role in the methodology
Final indicator list	Defines the 24 indicators entering the index.
Hierarchy	Organizes the model into ENVIRONMENTAL, SOCIAL and ECONOMIC blocks.
Pairwise comparisons	Elicits expert judgements on relative importance.
Fuzzy transformation	Represents judgement uncertainty through triangular fuzzy numbers.
Group aggregation	Combines the participants' judgement by fuzzy geometric mean.
FICSM	Derives fuzzy local weights from each aggregated fuzzy comparison matrix.
Defuzzification	Converts fuzzy weights into crisp values for reporting.
Normalization and scoring	Transforms business data into comparable 0-100 scores.
Quality diagnostics	Reports CR, agreement, dispersion and data coverage.

4.2 Hierarchical architecture of the index

OMCESI is structured as a two-level hierarchy. Level 1 contains the three sustainability dimensions: Environmental, Social and Economic. Level 2 contains the indicators located within each dimension. The selected architecture contains eight indicators per dimension, giving 24 core indicators in total. This balanced structure is consistent with the final harmonized architecture developed in Section 3 and supports comparison across dimensions while retaining enough detail for operational interpretation.

The use of a hierarchy is important because the relative importance of an indicator depends partly on the importance of its dimension. For example, an environmental indicator with a high local weight may also have a high global weight if the Environmental dimension receives a strong dimension weight. Conversely, an indicator can be locally important inside a dimension but have a lower global weight if the parent dimension receives a smaller weight. This is not a limitation; it is the logic of hierarchical weighting.

The model distinguishes between local and global weights. Local weights are calculated within each block. The DIM block compares Environmental, Social and Economic dimensions. The ENVIRONMENTAL block compares ENV01 to ENV08. The SOCIAL block compares SOC01 to SOC08. The ECONOMIC block compares ECON01 to ECON08. Each block is therefore a separate AHP comparison matrix. Global weights are calculated after the block-level weights have been obtained.

The final score is built in two equivalent forms. The preferred reporting form is hierarchical: the Environmental, Social and Economic scores are calculated first and are then combined using the dimension weights. The expanded form multiplies every indicator score directly by its global weight. The two forms are mathematically equivalent when the global weights are calculated as the product of the dimension weight and the corresponding local indicator weight. The hierarchical form is preferable in the report because it makes the sustainability structure explicit.

Equation (4.1). Hierarchical OMCESI score

$$OMCESI = W_{ENV} \times Score_{ENV} + W_{SOC} \times Score_{SOC} + W_{ECON} \times Score_{ECON}$$

where W_ENV, W_SOC and W_ECON are the dimension weights, and Score_ENV, Score_SOC and Score_ECON are the normalized and weighted dimension scores. The equation shows that the three pillars are not mixed without structure; each pillar contributes through its own score and its own dimension weight.

Equation (4.2). Global indicator weight

$$Global\ Weight_{d,i} = Dimension\ Weight_{d} \times Local\ Weight_{d,i}$$

where d denotes the dimension and i denotes the indicator inside that dimension. Global weights are useful for ranking all indicators together, but the model should still be presented hierarchically because the local and dimension-level interpretation is more informative for business planning.

4.3 Final OMCESI indicator architecture

The final OMCESI architecture contains 24 indicators. The environmental block captures resource input, operational circularity, waste, emissions and environmental impact. The social block captures occupational health and safety, employment quality, training, traceability, partnerships and skills. The economic block captures resource cost exposure, circular investment, quality management for secondary inputs, material accounting, short food supply chains, waste-disposal dependency, material productivity and value added.

Table 4.2. OMCESI hierarchy and block structure

Block	Level	Items compared	Output weight type
DIM	Level 1	Environmental, Social, Economic	Dimension weights
ENVIRONMENTAL	Level 2	ENV01 to ENV08	Environmental local weights
SOCIAL	Level 2	SOC01 to SOC08	Social local weights
ECONOMIC	Level 2	ECON01 to ECON08	Economic local weights

The balanced architecture is useful for communication and training because each dimension has the same number of indicators. However, equality in the number of indicators does not imply equality of importance. Importance is determined by the Fuzzy AHP weighting procedure described below.

4.4 Expert elicitation and pairwise-comparison protocol

The weighting stage was based on pairwise comparisons completed by the expert panel (5 academic expert and 5 business expert evaluations) through a google online platform[1] (Appendix D). Pairwise comparison is appropriate when respondents can more reliably compare two items at a time than assign absolute weights to all items simultaneously. Each participant compared the elements inside each block using the Saaty scale. For the DIM block, the participants compared Environmental, Social and Economic dimensions. For each Level 2 block, the participants compared the eight indicators within that dimension (Saaty, 1980).

Each block was treated independently. This is important because the comparison of Environmental against Social and Economic has a different meaning from the comparison of ENV01 against ENV02 or SOC01 against SOC02. A separate matrix was therefore

[1] Can be accessed at https://script.google.com/macros/s/AKfycbxepAy_ISs9vUV31RpRf7H8ub0d-fCRKUZDOcrVjHC2paBTXsy_EIC5Ol3RVoVvb7ty/exec

constructed for each participant and each block. In the latest dataset, ten participant matrices were extracted for each of the four blocks, producing 40 matrices in total.

The Saaty scale expresses relative importance. A value of 1 indicates equal importance. Values greater than 1 indicate that the row item is preferred to the column item. Reciprocal values indicate the opposite preference. The reciprocal structure means that if item A is judged to be five times more important than item B, then item B is assigned one fifth of the importance of item A in the opposite cell.

Table 4.3. Interpretation of the pairwise-comparison scale

Crisp value	Interpretation
1	Equal importance
2	Weak to moderate preference
3	Moderate preference
5	Strong preference
7	Very strong preference
9	Extreme preference
1/3, 1/5, 1/7, 1/9	Reciprocal preference for the column item

The pairwise-comparison protocol also produced a Consistency Ratio (CR) for every individual matrix. The CR was used as a logical-consistency safeguard before aggregation. In the latest dataset, all matrices passed the CR threshold and were retained.

4.5 Transformation of crisp judgements into triangular fuzzy numbers

Fuzzy AHP was used because expert judgements in sustainability and circular economy assessment are not perfectly precise. When a participant selects a value such as 5, the judgement means strong preference, but it does not necessarily imply a perfectly exact numerical ratio. The fuzzy transformation represents this imprecision by replacing each crisp Saaty value with a triangular fuzzy number (Zadeh, 1965; Buckley, 1985).

A triangular fuzzy number has three components: a lower value, a middle value and an upper value. In this section these components are written as (l, m, u). The middle value corresponds to the original Saaty judgement. The lower and upper values define a plausible interval around it. For example, the crisp judgement 5 can be represented as

(4, 5, 6). Equal importance is represented as (1, 1, 1). The value 9 is represented as (8, 9, 9) to remain within the Saaty scale.

Reciprocal judgements are handled by inverting the triangular fuzzy number. If the direct fuzzy judgement is (l, m, u), its reciprocal is written as (1/u, 1/m, 1/l). This preserves the reciprocal logic of AHP while allowing uncertainty around the judgement.

Equation (4.3). Transformation of a direct crisp judgement

$$a_{ij} > 1 \Rightarrow A_{ij} = (l_{ij}, m_{ij}, u_{ij})$$

Example after Equation (4.3)

$$a_{ij} = 5 \Rightarrow A_{ij} = (4, 5, 6)$$

Equation (4.4). Reciprocal triangular fuzzy judgement

$$A_{ji} = (\frac{1}{u_{ij}}, \frac{1}{m_{ij}}, \frac{1}{l_{ij}})$$

The letters l, m and u mean lower, middle and upper fuzzy values; the subscripts i and j identify the row and column item in the pairwise-comparison matrix.

4.6 Group aggregation of participant judgements

The next stage combines the fuzzy judgements of the expert panel. Because pairwise-comparison ratios are multiplicative, the geometric mean is preferred to the arithmetic mean for group aggregation. The fuzzy geometric mean is applied separately to the lower, middle and upper components of the triangular fuzzy numbers.

Let K be the number of retained experts in a block. For a given pair of items i and j, expert k provides a triangular fuzzy judgement A_ij,k = (l_ij,k, m_ij,k, u_ij,k). The aggregated group judgement is obtained by taking the K-th root of the product of the K expert values for each fuzzy component.

Equation (4.5a). Aggregated lower fuzzy component

$$L_{ij} = (l_{ij,1} \times l_{ij,2} \times \ldots \times l_{ij,K})\text{^}(1/K)$$

Equation (4.5b). Aggregated middle fuzzy component

$$M_{ij} = (m_{ij,1} \times m_{ij,2} \times \ldots \times m_{ij,K})\hat{}(1/K)$$

Equation (4.5c). Aggregated upper fuzzy component

$$U_{ij} = (u_{ij,1} \times u_{ij,2} \times \ldots \times u_{ij,K})\hat{}(1/K)$$

Equation (4.6). Aggregated group fuzzy judgement

$$A_{group,ij} = (L_{ij}, M_{ij}, U_{ij})$$

The result is one aggregated fuzzy pairwise-comparison matrix per block. In the latest OMCESI dataset, K = 10 for DIM, ENVIRONMENTAL, SOCIAL and ECONOMIC. The aggregation method therefore combines all retained expert judgements while preserving fuzzy uncertainty.

4.7 Weight derivation using the Fuzzy Inverse of Column Sum Method (FICSM)

FICSM means Fuzzy Inverse of Column Sum Method. It is the method used in this deliverable to derive fuzzy local weights from each aggregated fuzzy pairwise-comparison matrix. It should be distinguished from the group aggregation step. The group aggregation step combines expert participants. FICSM then converts the aggregated fuzzy matrix into weights (Ahmed & Kılıç, 2019).

The idea of FICSM is simple. In a pairwise-comparison matrix, each column contains the judgements made against one reference item. FICSM first calculates the fuzzy sum of each column. It then normalizes every fuzzy judgement in that column by multiplying it with the inverse of the fuzzy column sum. After this column-wise normalization, the fuzzy weight of each row item is obtained by averaging the normalized values across the row.

This method is close in spirit to the classical AHP column-normalization logic, but it is applied to triangular fuzzy numbers. It keeps the lower, middle and upper values separate throughout the normalization step. Only after the fuzzy local weights have been obtained are they defuzzified into crisp weights for reporting and index calculation.

The method can be explained in four operations: column summation, inversion of the fuzzy column sum, fuzzy normalization and row averaging. These operations are shown below using Word mathematical equation objects.

Equation (4.7). Fuzzy column sum

$$C_j = (\Sigma_i L_{ij}, \quad \Sigma_i M_{ij}, \quad \Sigma_i U_{ij})$$

Equation (4.8). Inverse fuzzy column sum

$$C_j^{-1} = \left(\frac{1}{\Sigma_i U_{ij}}, \frac{1}{\Sigma_i M_{ij}}, \frac{1}{\Sigma_i L_{ij}}\right)$$

Equation (4.9). Fuzzy column normalization

$$N_{ij} = A^{\mathrm{G}}{}_{ij} \times C_j^{-1}$$

Equation (4.10). Normalized triangular fuzzy value

$$N_{ij} = \left(\frac{L_{ij}}{\Sigma_i U_{ij}}, \frac{M_{ij}}{\Sigma_i M_{ij}}, \frac{U_{ij}}{\Sigma_i L_{ij}}\right)$$

Equation (4.11). Fuzzy weight by row averaging

$$W_i = \frac{1}{n} \Sigma_j N_{ij}$$

Equation (4.12). Fuzzy weight components

$$W_i = (w^{\mathrm{L}}{}_i, w^{\mathrm{M}}{}_i, w^{\mathrm{U}}{}_i)$$

The lower component of the normalized value uses the upper part of the column sum in the denominator. The upper component uses the lower part of the column sum in the denominator. This ordering is not an error; it follows the inversion rule for triangular fuzzy numbers. The inverse of (l, m, u) is (1/u, 1/m, 1/l).

FICSM is useful in this application for three reasons. First, it is transparent and easy to reproduce. Second, it remains fully fuzzy until the defuzzification stage. Third, it produces normalized local weights that can be directly integrated into the hierarchical OMCESI model. For these reasons, FICSM was selected as the main fuzzy weight-derivation method in the final script.

4.8 Defuzzification and final normalization of weights

The output of FICSM is a fuzzy weight for each item in each block. A crisp value is required for reporting, ranking and calculation of the index. The fuzzy weight is therefore defuzzified using the centroid method. The centroid method calculates the arithmetic mean of the lower, middle and upper fuzzy components.

The defuzzified values are then normalized so that the weights inside each block sum to one. This final normalization step is necessary because the centroid values are relative priority values but may not sum exactly to one after fuzzy arithmetic and defuzzification.

Equation (4.13). Centroid defuzzification

$$Defuzzified\ Weight_i = \frac{Lower\ Weight_i + Middle\ Weight_i + Upper\ Weight_i}{3}$$

Equation (4.14). Normalized local weight

$$Local\ Weight_i = \frac{Defuzzified\ Weight_i}{\sum_i Defuzzified\ Weight_i}$$

After normalization, the local weights in the DIM block sum to one, the local weights in the ENVIRONMENTAL block sum to one, the local weights in the SOCIAL block sum to one, and the local weights in the ECONOMIC block sum to one. This was confirmed in the R output for the latest dataset.

4.9 Consistency assessment of individual pairwise-comparison matrices

Before fuzzy aggregation, each expert participant matrix was checked using the AHP Consistency Ratio (CR). The CR evaluates whether the set of pairwise comparisons is logically coherent. For example, if item A is judged more important than item B and item B more important than item C, the comparison between A and C should not contradict this pattern strongly.

The conventional acceptance threshold used in this methodology was CR less than or equal to 0.10. Matrices with CR above this threshold would require revision or exclusion, depending on the protocol. In the latest OMCESI dataset, all matrices passed the threshold and were retained. This means that the individual answers were internally consistent enough to be aggregated.

Table 4.4. CR results for the latest OMCESI FICSM dataset

Block	Matrices extracted	Matrices used	Mean CR	Maximum CR	Assessment
DIM	10	10	0.0120	0.0462	Very good
ECONOMIC	10	10	0.0252	0.0567	Good
ENVIRONMENTAL	10	10	0.0386	0.0978	Acceptable
SOCIAL	10	10	0.0315	0.0918	Acceptable

CR should not be interpreted as a measure of consensus among participants. It measures whether each participant was internally consistent. Agreement among participants requires separate diagnostics, discussed in the next section.

4.10 Inter-participant agreement and consensus diagnostics

A group AHP model should distinguish between consistency and agreement. Consistency asks whether each participant answered logically. Agreement asks whether the participants ranked the items similarly. The final OMCESI weights are mathematically valid because the CR criteria were satisfied and the matrices were correctly aggregated. However, the strength of expert consensus must be assessed separately.

Three agreement and dispersion diagnostics were used: Kendall's coefficient of concordance W, mean pairwise Spearman rank correlation and the coefficient of variation of individual weights. Kendall's W ranges from 0 to 1, where values closer to 1 indicate stronger agreement in rankings. Spearman correlation captures the average similarity of participant rankings. The coefficient of variation describes how much individual weights vary around the mean for each indicator (Kendall, 1939).

The latest dataset showed significant agreement only for the Environmental block. Agreement for Economic, Social and DIM was weaker and not statistically significant at the 0.05 level. This does not invalidate the aggregation, but it means that the final weights should be interpreted as an aggregated expert-priority model rather than as evidence of strong consensus across all blocks.

Table 4.5. Inter-participant agreement diagnostics for the latest dataset

Block	Kendall W	p-value	Mean Spearman	Interpretation
ENVIRONMENTAL	0.388	0.0009	0.325	Moderate and statistically significant agreement
ECONOMIC	0.180	0.1233	0.081	Weak, non-significant agreement
SOCIAL	0.204	0.0765	0.110	Weak to low-moderate, not significant at 0.05
DIM	0.176	0.2053	0.236	Weak, non-significant agreement

The interpretation of the final model should therefore be cautious. The Environmental indicators have the strongest consensus basis. Economic, Social and dimension-level priorities are still usable as aggregated priorities, but they reflect more heterogeneous expert views. This limitation should be reported transparently because it improves, rather than weakens, the methodological credibility of the deliverable.

4.11 Final FICSM weights and interpretation of the calibrated OMCESI model

The latest FICSM run produced the following Level 1 dimension weights. Environmental has the highest weight, followed by Social and Economic. The model is therefore still environmentally led, but Social also receives substantial importance.

Table 4.6. Final dimension weights in the latest OMCESI FICSM model

Dimension	Weight
Environmental	0.3926
Social	0.3379
Economic	0.2695

Equation (4.15). Calibrated OMCESI model

$$OMCESI = 0.3926 \times Score_{ENV} + 0.3379 \times Score_{SOC} + 0.2695 \times Score_{ECON}$$

The global indicator weights are obtained by multiplying the local indicator weights by the parent dimension weight. The highest-priority group in the latest dataset consists of ENV07, ENV05 and ENV02. Their global weights are very close, so they should be interpreted as a priority cluster rather than as a sharply separated rank order.

Table 4.7. Top global indicator weights in the latest OMCESI FICSM model

Rank	Indicator	Global weight
1	ENV07 - Water scarcity footprint	0.0659
2	ENV05 - Total waste generated	0.0658
3	ENV02 - Total Energy Input	0.0649
4	SOC05 - Share of employees trained	0.0560
5	SOC01 - OHS investment per FTE	0.0553
6	ENV01 - Total Water Input	0.0549
7	SOC08 - Skills Competence Attainment	0.0489
8	ECON01 - Resource Cost Dependency	0.0465
9	ECON07 - Material productivity	0.0463
10	ENV04 - Separate collection and traceable segregation	0.0458

The exact rank order should not be overinterpreted when differences are very small. In particular, ENV07, ENV05 and ENV02 form a leading environmental cluster with almost identical global weights. The same logic applies to other indicators whose weights differ only slightly. For decision-making, priority clusters are often more informative than exact ordinal ranks.

4.12 Indicator scoring and normalization

The Fuzzy AHP and FICSM procedures produce weights. They do not by themselves produce a business performance score. To calculate OMCESI for a business, raw indicator values must first be transformed into normalized scores. The normalized score should be expressed on a common scale, preferably 0 to 100, where 0 represents poor performance and 100 represents full attainment of the benchmark, target or best-practice threshold.

The normalization rule depends on the desired direction of the indicator. Some indicators are benefit indicators, where higher values are better. Others are cost or pressure indicators, where lower values are better. Some indicators may be target-based, where the best score is achieved by approaching a defined target rather than simply increasing or decreasing.

Equation (4.16). Normalization of benefit indicators

$$Score_i = 100 \times \frac{Value_i - Minimum_i}{Target_i - Minimum_i}$$

Equation (4.17). Normalization of cost indicators

$$Score_i = 100 \times \frac{Maximum_i - Value_i}{Maximum_i - Target_i}$$

Equation (4.18). Normalization of binary indicators

$$Score_i = 100\ if\ criterion\ is\ met;\ otherwise\ 0$$

The score should be capped at 0 and 100 to avoid extreme values dominating the index. For indicators with sector-specific thresholds, the normalization rule should use the relevant meat, dairy or fruit/vegetable processing benchmark. For qualitative indicators, scoring rubrics should be defined before data collection so that the scoring process remains consistent across businesses.

Table 4.8. Recommended normalization approach by indicator type

Indicator type	Example	Recommended scoring approach
Higher is better	Share of employees trained	Benefit normalization
Lower is better	Total energy input per unit output	Cost/pressure normalization
Target-based	Water reuse target	Distance from target
Binary/process	Formal traceability procedure	0/100 or staged maturity score
Ordinal maturity	Governance or partnership maturity	Predefined 0-25-50-75-100 rubric

4.13 Calculation of dimension scores and total OMCESI score

After normalization, each dimension score is calculated as the weighted sum of the normalized indicator scores inside that dimension. Local weights are used at this stage. The dimension score therefore shows performance within the dimension, independently of how much weight the dimension has in the total index.

The total OMCESI score is then calculated by multiplying each dimension score by its dimension weight and summing the three results. This two-step calculation is preferable for reporting because it makes it possible to identify whether a business is strong or weak in a specific pillar.

Equation (4.19). Environmental dimension score

$$Score_{ENV} = \sum_{i \in ENV} Local\ Weight_{ENV,i} \times Normalized\ Score_{ENV,i}$$

Equation (4.20). Social dimension score

$$Score_{SOC} = \sum_{i \in SOC} Local\ Weight_{SOC,i} \times Normalized\ Score_{SOC,i}$$

Equation (4.21). Economic dimension score

$$Score_{ECON} = \sum_{i \in ECON} Local\ Weight_{ECON,i} \times Normalized\ Score_{ECON,i}$$

Equation (4.22). Total OMCESI score

$$OMCESI = W_{ENV} \times Score_{ENV} + W_{SOC} \times Score_{SOC} + W_{ECON} \times Score_{ECON}$$

If all normalized indicator scores are measured on a 0 to 100 scale, then each dimension score and the total OMCESI score will also lie between 0 and 100, provided that all weights are non-negative and sum to one. This makes the result easier to communicate to businesses and training users.

4.14 Treatment of missing data and data coverage

Missing data are likely in small rural agrifood businesses. The methodology should therefore distinguish between poor performance and missing information. A missing value should not automatically be scored as zero unless the absence of data itself represents non-compliance with a required monitoring practice.

If a small number of indicators are missing within a dimension, the available local weights may be re-normalized within that dimension. However, this should be allowed only when data coverage exceeds a minimum threshold. Otherwise, the dimension score should be flagged as incomplete. A useful coverage indicator is the share of dimension weight for which valid data are available.

Equation (4.23). Data-coverage weight share

$$Coverage_d = \Sigma_{i \in d,valid}\, Local\ Weight_{d,i}$$

Equation (4.24). Re-normalized local weight

$$Adjusted\ Weight_{d,i} = \frac{Local\ Weight_{d,i}}{Coverage_d}$$

A dimension score based on low data coverage is less reliable than a score based on complete data. Therefore, every OMCESI dashboard should show the total score, the dimension scores and the coverage values. This avoids creating a misleading impression of precision when important data are absent.

4.15 Interpretation of OMCESI scores

OMCESI scores should be interpreted as monitoring results, not as certification outcomes. A business with a high score performs well against the selected and weighted CERAS indicators. A low score indicates that the business has weaknesses relative to the selected benchmarks or targets. The total score is useful for summary communication, but improvement planning should be based on the dimension scores and the indicator contribution table.

Table 4.9. Suggested interpretation of OMCESI scores

Score range	Indicative interpretation
0-20	Very weak transition performance or very limited evidence
21-40	Early-stage transition with major improvement needs
41-60	Moderate transition performance with mixed strengths and weaknesses
61-80	Advanced transition performance in several areas
81-100	Very strong performance against the adopted scoring framework

These classes are indicative and should not be treated as regulatory thresholds. They are intended to support training, interpretation and communication. Sector-specific applications may adjust the classes if empirical pilot data show that the score distribution is strongly skewed.

4.16 Business-level implementation workflow

The business-level implementation of OMCESI should follow a standard workflow. First, the business confirms the relevant sector module and reporting year. Second, data are collected for each selected indicator using the indicator sheets. Third, raw values are checked for completeness, units and direction of improvement. Fourth, raw values are normalized into 0 to 100 scores. Fifth, dimension scores and the total OMCESI score are calculated. Sixth, the score is interpreted together with the contribution analysis and data-quality notes.

The workflow should be repeated over time using the same scoring rules so that progress can be monitored. If the normalization benchmarks or weights are changed, the index version must be clearly documented. Otherwise, changes in the score may reflect methodological changes rather than real business improvement.

Table 4.10. Operational workflow for applying OMCESI at business level

Step	Action	Output
1	Confirm sector module and reporting period	Scope statement
2	Collect raw indicator data	Indicator dataset
3	Validate units, boundaries and completeness	Cleaned dataset
4	Normalize raw values	0-100 indicator scores
5	Apply local and dimension weights	Dimension and total scores
6	Review data quality and contribution analysis	Interpretation dashboard
7	Define improvement actions	Transition action plan

4.17 Data quality, uncertainty and reporting safeguards

The reliability of OMCESI depends on both the quality of the weights and the quality of the business data. Data quality should therefore be reported explicitly. At minimum, the dashboard should record whether data were measured directly, estimated from records, or estimated using expert judgement. The same score has a different level of credibility depending on the data-quality level behind it.

Uncertainty also arises from the weights. The agreement diagnostics show that some blocks have weaker expert consensus. This means that exact rank interpretation should be cautious, especially in the Economic, Social and DIM blocks. The model remains valid as an aggregated priority structure, but the report should not claim strong consensus where agreement indicators do not support it.

A further safeguard is sensitivity analysis. The model can be recalculated after removing one expert participant at a time, or by comparing FICSM weights with an alternative fuzzy

AHP weight-derivation method. If the top indicators remain stable, confidence in the model increases. If rankings change substantially, the report should present clusters rather than exact ordinal ranks and should consider further expert discussion (Ahmed & Kılıç, 2019).

Data coverage must also be reported. A high OMCESI score based on incomplete data is less informative than a moderate score based on complete data. Therefore, every dashboard should include a coverage indicator for each dimension and for the total index. The coverage indicator should be based on the share of weights for which valid data are available rather than simply on the number of indicators reported.

4.18 Use of OMCESI for training, benchmarking and transition planning

OMCESI is particularly suitable for training and capacity-building activities. Trainers can use the hierarchy to explain how circular economy and sustainability are connected. Environmental indicators show resource and emission pressures; social indicators show skills, safety, stability and cooperation; economic indicators show cost resilience, productivity and value creation. The index therefore supports an integrated understanding of transition rather than a narrow view of circularity as waste management only.

For business benchmarking, OMCESI should be applied carefully. Comparisons are meaningful when businesses operate in comparable subsectors and when the same scoring rules are used. Differences in production volume, product mix, seasonal operation and rural logistics should be documented. It may be useful to compare a business primarily against its own baseline and only secondarily against other businesses. Sector-specific modules can improve fairness where common indicators do not fully capture subsector hotspots.

For transition planning, the most useful output is not only the total score but the contribution analysis. A contribution table identifies which indicators reduce the score most strongly. A business may then choose actions such as improving energy monitoring, reducing water losses, strengthening employee training, formalizing circular economy partnerships, investing in reusable packaging or implementing material flow cost accounting. The action should be linked to both indicator weight and operational feasibility.

The final OMCESI model can also support reporting to stakeholders. Rural agrifood businesses often need a simple but credible way to communicate progress to local authorities, cooperatives, customers and training providers. The index can provide this communication layer, provided that the underlying indicators remain accessible and transparent. The score should never be reported without the dimension breakdown and data-quality notes.

4.19 Methodological limitations and recommended future refinements

The OMCESI methodology has several limitations that should be acknowledged. First, the weighting model is based on expert judgement. Expert judgement is appropriate for multi-criteria sustainability problems, especially where objective market or policy weights are unavailable, but it remains context-dependent. The final weights reflect the composition, expertise and interpretations of the participating panel.

Second, internal consistency does not imply consensus. The final matrices passed the CR threshold, but agreement analysis indicated heterogeneous levels of rank agreement across blocks. Environmental priorities were more strongly aligned than Economic, Social and DIM priorities in the latest dataset. This means that the aggregated weights should be interpreted as a group-priority compromise rather than a universal expert consensus.

Third, the index depends on normalization choices. If different benchmarks or targets are used, business scores may change even when weights are unchanged. This is common to composite indices and reinforces the need to document scoring rules and avoid comparing scores produced under different normalization protocols.

Future refinements should include leave-one-participant-out sensitivity analysis, comparison with an alternative fuzzy weighting method, sector-specific calibration of normalization thresholds, and pilot testing with actual business data. These refinements would strengthen confidence in the index and help distinguish between methodological priorities and practical data-collection constraints.

The complete OMCESI calculation sequence can be summarized as follows. First, the final 24 indicators are confirmed and documented. Second, the indicators are organized into the DIM, ENVIRONMENTAL, SOCIAL and ECONOMIC AHP blocks. Third, participant pairwise-comparison matrices are collected and checked for internal consistency. Fourth, crisp Saaty judgements are converted into triangular fuzzy numbers. Fifth, participant fuzzy judgements are aggregated using the fuzzy geometric mean. Sixth, FICSM is applied to derive fuzzy local weights from the aggregated matrices. Seventh, fuzzy weights are defuzzified using the centroid method and normalized. Eighth, local weights are multiplied by dimension weights to obtain global weights. Ninth, business-level indicator values are normalized to 0 to 100 scores. Tenth, dimension scores and the total OMCESI score are calculated.

The methodological sequence ensures that the index is reproducible. Every output can be traced back to an input: pairwise judgements produce weights; business data produce scores; weights and scores together produce the index. This traceability is essential for training, reporting and future revision of the methodology.

The final OMCESI should therefore be reported with four components: the total score, the three dimension scores, the indicator-level score table and the quality diagnostics. Reporting only the total score would hide the information needed for improvement planning. Reporting the full structure makes the index useful as a transition-management tool rather than merely a ranking device.

5.CONCLUSIONS

The CERAS methodology provides an integrated framework for identifying, selecting, harmonizing and operationalizing indicators capable of monitoring the transition of rural agrifood businesses towards Circular Economy (CE) and sustainability. The methodology was developed specifically in response to the characteristics of rural Small and Medium-sized Enterprises (SMEs), for which existing sustainability and CE monitoring systems are often either too aggregated, oriented towards large companies, or insufficiently adapted to the operational realities of smaller processing businesses. The framework therefore sought to combine methodological robustness with practical applicability at business level, with particular attention to meat, dairy, and fruit/vegetable and juice processing.

A principal contribution of the methodology is that indicator selection was treated as a structured transition-monitoring problem rather than simply as the compilation of a sustainability indicator list. The process began by establishing explicit geographical, sectoral, value-chain and conceptual boundaries and distinguishing sustainability performance from CE transition mechanisms. Sustainability was represented through its environmental, social and economic dimensions, while CE was addressed through resource efficiency and loop closure, reuse and recovery, waste and by-product valorisation, circular business models, eco-design and related organizational changes. At the same time, all indicators were classified according to the Input–Process–Output–Impact logic chain, allowing the monitoring system to capture not only final performance but also the resources committed, organizational changes introduced and immediate results that contribute to longer-term transition outcomes.

The desk-based protocol resulted in a deliberately broad initial evidence base rather than prematurely restricting the framework to a small number of familiar indicators. Candidate indicators were derived from academic, institutional, policy, industry and existing monitoring sources and were consolidated through contributions from project partners. The initial database contained environmental, economic and social indicator families and documented each indicator using standardized descriptive and operational fields, including definition, level, relevance, unit, data requirements, formula, frequency, direction of desired change and supporting evidence. This transformation of individual indicators into defined monitoring objects was essential for ensuring that subsequent comparison and evaluation were based on harmonized concepts rather than indicator titles alone.

A second important conclusion concerns the value of progressive indicator reduction. Rather than selecting indicators solely on the basis of literature frequency, expert preference or one-dimensional ranking, CERAS applied successive analytical filters. Indicators were first assessed against processing-specific hotspots in meat, dairy and fruit/vegetable/juice businesses. They were subsequently screened through double materiality, considering both impact materiality and financial materiality; evaluated against six business-relevance criteria—cost impact, revenue impact, risk exposure, managerial control ability, data availability and strategic alignment—and finally checked for balance across sustainability dimensions and the logic chain. This multi-stage procedure considerably strengthens the relevance of the final monitoring system because an indicator must demonstrate not only conceptual association with CE or sustainability but also practical significance for the businesses expected to use it.

The business-relevance evaluation further ensured that the framework reflected the perspective of rural agrifood enterprises. The adopted weighting scheme placed greatest emphasis on risk exposure and strategic alignment, followed by cost impact and managerial control ability, while data availability received a lower weight so that important indicators would not be eliminated simply because firms do not yet collect the required information systematically. This is particularly relevant for SMEs undergoing transition: limited current data availability can itself reveal a capability gap that should be progressively addressed rather than serving as a reason to exclude a material issue from monitoring.

The use of fuzzy methods constituted an additional methodological strength. Partner evaluations necessarily contained elements of judgement and uncertainty. Their transformation into triangular fuzzy numbers, aggregation and subsequent weighted evaluation allowed these qualitative assessments to be combined without treating 1–5 ratings as perfectly precise measurements. The subsequent use of Fuzzy AHP and the Fuzzy Inverse of Column Sum Method (FICSM) within OMCESI provided a transparent mechanism for converting aggregated expert judgements into local and global weights while maintaining the hierarchical distinction between Environmental, Social and Economic performance. The resulting model therefore goes beyond a simple additive checklist and establishes a reproducible multicriteria structure for synthesising heterogeneous CE and sustainability information.

A particularly important outcome of the harmonisation process was the decision not to select the final indicators mechanically according to overall ranking. A purely score-based approach would have produced uneven representation of sustainability dimensions and transition stages. The final architecture therefore selected two indicators at each Input, Process, Output and Impact level within each sustainability dimension, resulting in a balanced core of 24 indicators: eight environmental, eight social and eight economic indicators. This balance is methodologically significant because it permits the framework to answer four complementary questions: what resources is the business committing to the transition; what processes and organisational mechanisms are changing; what direct results are being produced; and whether these changes ultimately translate into improved environmental, social and economic performance.

The resulting common core does not imply that meat, dairy and fruit/vegetable processing are treated as identical systems. CERAS instead adopts a core-plus-module architecture. The 24 common indicators provide the basis for comparability across firms and subsectors, while additional indicators can be activated for sector-specific hotspots. Examples identified during the methodology include animal mortality and transport stress for meat processing, cleaning-in-place water performance and whey valorisation for dairy, and food donation, organic-residue valorisation and food-loss indicators for fruit/vegetable and juice processing. This approach provides an appropriate compromise between standardisation and sector sensitivity and should improve the transferability of the methodology to heterogeneous rural agrifood SMEs.

The Overall Monitoring Circular Economy and Sustainability Index (OMCESI) provides the final operational layer of the methodology. OMCESI is designed as a synthesis of the detailed dashboard rather than a substitute for it. The primary evidence remains the individual indicators, while the composite index provides businesses, trainers and other users with an interpretable overall measure of transition progress. Its hierarchical structure preserves separate Environmental, Social and Economic dimension scores before combining them into an overall score, thereby avoiding the loss of information that would result from treating all 24 indicators as an undifferentiated pool. Business data can be normalised onto a common 0–100 scale, weighted within each dimension and subsequently aggregated into dimension scores and an overall OMCESI value, enabling repeated monitoring through time.

The calibrated weighting results indicate that the current model is environmentally led but not environmentally exclusive. Environmental, Social and Economic dimensions received weights of approximately 0.393, 0.338 and 0.270, respectively. At indicator level, water scarcity footprint, total waste generated and total energy input form the highest-priority cluster, followed closely by social indicators concerning employee training and occupational health and safety, while resource cost dependency and material productivity feature strongly within the economic dimension. These results reinforce the multidimensional character of CE transition: resource efficiency remains central, but successful transition also depends upon workforce capabilities, safe working practices, organisational cooperation and economic resilience.

At the same time, the results should be interpreted with appropriate caution. The consistency diagnostics support the mathematical validity of the pairwise comparisons, but consistency should not be confused with consensus. Agreement was strongest and statistically significant for the Environmental block, whereas Economic, Social and overall dimension-level priorities showed more heterogeneous expert views. Consequently, small differences between final weights should not be interpreted as evidence of sharply distinct priorities. In practical application, priority clusters are more meaningful than exact ordinal rankings, particularly where indicator weights are very close. This consideration also reinforces the value of preserving the complete dashboard alongside the composite OMCESI score.

Implementation quality will ultimately determine the usefulness of the framework. Consistent system boundaries, functional units, baselines, definitions, evidence sources and reporting periods are necessary if scores are to be compared across years or businesses. The methodology therefore emphasises explicit reporting of data quality and coverage and distinguishes direct measurement from estimates derived from records or expert judgement. Sensitivity testing is also recommended because both expert-derived weights and normalisation benchmarks can influence the resulting composite score. The report accordingly identifies future refinement priorities including leave-one-participant-out sensitivity analysis, comparison with alternative fuzzy weighting approaches, sector-specific calibration of normalisation thresholds and, importantly, pilot testing with actual business data.

Overall, the CERAS methodology establishes a transparent, multidimensional and adaptable monitoring architecture for rural agrifood SMEs. Its principal value lies not in producing a single sustainability ranking, but in enabling businesses to identify where they currently stand, which areas are driving or constraining their transition, and where management actions and investments should be directed. Repeated application using stable definitions, weights and scoring rules can transform the framework from a one-off assessment into a genuine transition-monitoring system. The combination of the detailed indicator dashboard, sector-specific modules and OMCESI can therefore support business self-assessment, bench marking, training, strategic planning and, where appropriate, aggregation at sectoral or territorial level. OMCESI should consequently be understood as a decision-support and learning instrument for continuous improvement, capable of making the transition towards a more circular, resilient and sustainable rural agrifood economy measurable, interpretable and actionable.

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APPENDICES

Appendix A. Initial list of indicators

Table A1. Environmental indices

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
ENV01	Total Energy Input	Total energy consumed	Input	Resource Input (Energy)	S: Energy efficiency & GHG mitigation CE: reduction in energy consumption	KWh/functional unit	Utility bills	Total Energy Input (kWh/FU) = (electricity used + purchased heat/steam + energy from fuels) ÷ functional units	Include electricity, gas, biomass, fuels used on-site	Monthly	Down
ENV02	Renewable Energy Share	Share of total energy from renewable sources (solar, wind, biomass, etc)	Input	Resource Input (Energy)	CE: bioenergy loops, decentralized rural renewables	% (Percentage)	Energy by carrier (kWh); renewable portion evidence.	Renewable Energy Share (%) = (Renewable final energy consumed kWh / Total final energy consumed kWh) × 100	Use final energy basis; avoid double counting (don't claim the same kWh twice).	Monthly	Up
ENV03	Total Water Input	Total external water withdrawn/received for on-site operations during the reporting period, normalized by functional unit.	Input	Resource Input (Water)	S: Water efficiency & reduced freshwater stress CE: water recirculation and reduced withdrawals	m^3 / functional unit (e.g., m^3/tonne output)	External water volumes by source (mains/ground/surface/delivered); functional output data.	Total Water Input (m^3/FU) = (Mains + Groundwater + Surface water + Delivered water) / Functional Units	Counts external inflows only. Do not include internally reused/recycled water here (covered by Env4).	Monthly	Down
ENV04	Reused/recycled water input share	Share of total water used in operations that is supplied by internally reused/recycled water (recirculated process water,	Input	Resource Input (Water)	CE: water loop closure, reduced external withdrawals	% (Percentage)	Volume of reused/recycled water (m^3); external water input or total water used.	Reused/Recycled Water Share (%) = [Reused/Recycled water (m^3) / (External Water Input (m^3) + Reused/Recycled water (m^3))] × 100	Define what qualifies (e.g., recirculated cooling water, treated wastewater reused). Exclude once-through water; avoid	Monthly	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
		treated effluent reused on-site), expressed as a percentage.							double counting across loops.		
ENV05	Total Packaging Material Input by Type	Total mass of packaging materials used, by material type, normalized by functional unit.	Input	Resource Input (Materials)	S: materials efficiency & waste prevention CE: reduced packaging, increased recyclable/renewable content and design for circularity	kg packaging / functional unit (plus breakdown by type: kg plastic, paper/cardboard, glass, metal, wood, composite/other)	Procurement/GRN data or packaging BOM (by material type); functional output data.	Packaging Input by Type (kg/FU) = Packaging material purchased/used (kg, by type) / Functional Units	Use a consistent type taxonomy (e.g., paper/cardboard; plastics by polymer; glass; metals; wood; composites). If BOM-based, reconcile periodically with procurement to avoid drift.	Monthly	Down
ENV06	Recycled/secondary material content share	Recycled/secondary material content share	Input	Resource Input (Materials)	S: reduced virgin resource use & upstream impacts CE: increase secondary inputs, close material loops	% (Percentage)	Material inputs by type (kg); recycled content % by supplier/spec (or certification); total material input.	Recycled/Secondary Content Share (%) = (Recycled material input ÷ Total material input) × 100	Separate post-consumer vs post-industrial where possible; avoid double counting internal rework.	Monthly	Up
ENV07	By-product/residue inputs used as feedstock	Mass of by-products/residues used as feedstock, per functional unit.	Input	Resource Input (By-product)	S: resource efficiency & reduced waste CE: industrial symbiosis, cascading use of biomass/by-products	kg (or tonnes) / functional unit (e.g., kg/tonne output)	By-product/residue quantities received (kg); type/source; functional output (FU).	By-product Feedstock Input (kg/FU) = (kg subproducts used) / (Functional Units)	Define eligible by-products (exclude primary raw materials); track by type/source; if moisture varies, also report dry mass.	Monthly	Up
ENV08	Fleet fuel input	Total fuel consumed by the organization's owned/controlled fleet during the reporting	Input	Resource Input (Transport)	S: reduced fuel use & air emissions CE: efficient logistics, reduced transport intensity	L or MJ (or kWh for EV) / functional unit (e.g., L/tonne output) or	Fuel card/invoice records by fuel type; odometer/telematics (optional); functional output (or tonne-km).	Fleet Fuel Input (per FU) = Total fuel used ÷ Functional Units	Separate by fuel type (diesel, petrol, LNG, biodiesel, electricity).	Monthly	Down

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
		period, normalized by functional unit (or by tonne-km where applicable).				per tonne-km					
ENV09	Energy management system in place	Formal energy management system (e.g., ISO 50001) implemented and active for defined sites/activities.	Process	Process (Management Practices and Operational Controls)	S: energy efficiency governance & continual improvement CE: enables systematic reduction of energy inputs and related impacts	Binary (0/1) and/or % coverage	ISO 50001 certificate or EnMS documents; scope (sites/activities covered); latest audit or management review record.	Binary: 1 if EnMS is active; otherwise 0. Coverage (%): (Energy under EnMS scope ÷ Total energy) × 100	Report status (certified/implemented/planned) and scope (sites covered). Update when these change.	Monthly	Up
ENV10	Preventive maintenance and efficiency program coverage	% of key assets/lines covered by a documented preventive maintenance and efficiency program.	Process	Management Practices and Operational Controls	S: efficiency, reliability, reduced losses/leaks CE: supports reduced resource inputs and longer asset life	% coverage	Asset register; PM schedule/work orders (CMMS); list of efficiency actions logged (optional).	Coverage (%) = (Number of in-scope assets with PM & efficiency plan active ÷ Total number of in-scope assets) × 100	Define “in-scope assets” (e.g., top 80% energy users; boilers, compressors, chillers, pumps, production lines).	Monthly	Up
ENV11	Water reuse	% of total water used that comes from reused/recycled water (operational reuse performance).	Process	Management Practices and Operational Controls	S: water efficiency & reduced freshwater stress CE: closing water loops and reducing external inputs	% (Percentage)	Reused/recycled water volume (m³); external water input.	Water Reuse (%) = [Reused/Recycled water (m³) ÷ (External Water Input (m³) + Reused/Recycled water (m³))] × 100	Although categorized as “Process”, this is a process-performance proxy tied to operational controls. If you prefer a purely qualitative process KPI, use a maturity score (0–3) for reuse systems in place; keep this %.	Monthly	Up
ENV12	CIP/cleaning	% of CIP lines/equipmen	Process	Management Practices and	S: reduced water/chemical/energy	% coverage	CIP lines list; CIP procedures/recipe	Coverage (%) = (Number of in-	Define “optimized/valid	Monthly	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
	optimization program	t covered by a formal cleaning optimization program (validated recipes + monitoring)		Operational Controls	use & wastewater load CE: reduced resource inputs and effluents through operational control		s; basic CIP logs or validation record.	scope CIP circuits under optimized/validated program ÷ Total in-scope CIP circuits) × 100	ated" (e.g., recipe setpoints established, verified, and monitored).		
ENV13	Eco-design / packaging redesign process adopted	Eco-design process in place and used for packaging changes.	Process	Management Practices and Operational Controls	S: reduced material use & impacts CE: design for recyclability, reuse, lightweighting, increased secondary content	Binary (0/1) and/or % projects covered	Eco-design procedure + project list (reviewed vs total).	Binary: 1 if process is adopted and active; else 0. Optional coverage (%): (Packaging projects reviewed under eco-design process ÷ Total packaging projects) × 100	For monthly reporting, coverage may be more informative than binary. Define what counts as a "packaging project" (new SKU, format change, material change, weight change).	Monthly	Up
ENV14	Reusable packaging system implemented	Implementation status and operational coverage of a reusable packaging system (returnable transport items / refillable or returnable packs), including defined return loops, cleaning/inspection where relevant, and tracking of cycles.	Process	Management Practices and Operational Controls	S: reduced packaging waste & impacts CE: reuse loops, waste prevention, reduced virgin packaging demand	Binary (0/1) and/or % coverage	List of reusable packaging formats in use; shipments/units using reusable vs total; (optional) return records/cycle counts.	0/1: 1 if active, else 0. Coverage (%): (Projects reviewed ÷ Total packaging projects) × 100	Prefer coverage over binary for monthly tracking. Optionally add companion KPI: average reuse cycles (turns/unit) and loss rate (% not returned).	Monthly	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
ENV15	Separate collection and traceable segregation	% of target waste/material streams that are source-separated and traceably recorded through handover.	Process	Management Practices and Operational Controls	S: pollution prevention & compliance CE: higher-quality recycling, reduced contamination, improved recovery rates	% coverage	Target stream list; segregation SOP/map; records/tickets by stream.	Coverage (%) = (Streams with separation + records ÷ Total target streams) × 100	Define "target streams" (e.g., paper/cardboard, plastics by type, metals, glass, organics, hazardous). "Traceable" = documented quantities by stream (internal logs and/or contractor weigh tickets).	Monthly	Up
ENV16	Total waste generated	Total mass of waste generated from on-site operations during the reporting period, normalized by functional unit (includes hazardous + non-hazardous; exclude product/by-product intended for sale/use).	Output	Resource outflows and waste	S: pollution prevention & resource efficiency CE: waste prevention and reduced disposal	kg (or tonnes) / functional unit	Waste transfer notes/weighbridge tickets by waste stream; internal waste logs; functional output data.	Formula (simplified): Total Waste (kg/FU) = Total waste generated (kg) ÷ Functional Units	Report split at minimum: hazardous vs non-hazardous; and optionally by destination (recycled, composted, energy recovery, landfill). Avoid double counting internally reused scrap (count only when it leaves the process as "waste").	Monthly	Down
ENV17	Waste diverted from disposal	% of total waste diverted from disposal via reuse/recycling/composting/AD (and defined	Output	Resource outflows and waste	S: reduced landfill/incineration impacts CE: increased recovery, higher circularity of outflows	% (and/or kg/FU)	Waste by destination; total waste; optional output (FU).	Diversion rate (%) = (Diverted waste ÷ Total waste) × 100	Define "disposal"; state whether energy recovery counts; avoid inflating diversion (report by route if possible).	Monthly	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
		recovery routes).									
ENV18	By-products valorised	% (and/or kg/FU) of by-products/residues sent to valorisation routes rather than disposal.	Output	Resource outflows and waste	S: waste prevention & reduced disposal impacts CE: cascading use and industrial symbiosis	% (and/or kg/FU)	By-products by type and destination; total by-products; optional output (FU).	Valorisation rate (%) = (Valorised by-products ÷ Total by-products generated) × 100;	Define “by-product” vs “waste” (i.e., intended use and quality specifications). Recommend reporting route hierarchy (highest-value uses first).	Monthly	Up
ENV19	Wastewater discharge volume	Total wastewater discharged off-site, per functional unit.	Output	Water outflows	S: reduced pollution load & water efficiency CE: tighter water loops reduce discharge volumes	m^3 / functional unit (and/or total m^3)	Discharge volume (meter/invoice) by point/destination; output (FU).	Wastewater Discharge (m^3/FU) = Discharged wastewater (m^3) ÷ Functional Units	If multiple discharge points, sum across points. Track separately by destination (municipal sewer vs direct discharge vs tanker). Pair with pollutant load indicators (COD, N, P) for impact relevance.	Monthly	Down
ENV20	Key wastewater pollutant loads	Pollutant mass loads discharged (COD/BOD, TSS, TN, TP as minimum), per functional unit.	Output	Water outflows	S: reduced aquatic pollution & compliance CE: process optimization and water-loop closure reduce pollutant releases	kg pollutant / functional unit (and/or total kg/month), reported per parameter	Discharge flow (m^3); lab results for concentrations (mg/L) per parameter; functional output data.	Load (kg/FU) = (Concentration (mg/L) × Flow (m^3) × 0.001) ÷ Functional Units	Use flow-weighted concentrations if multiple samples. Report by discharge point and sum. Specify sampling frequency and whether values are measured or estimated.	Monthly	Down

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
ENV21	Food loss/waste mass	Total food loss and food waste generated, per functional unit.	Output	Food system circularity	S: reduced resource loss & emissions CE: prevention and cascading use of edible/by-product streams	kg (or tonnes) / functional unit (and/or total kg/month)	Food waste weights/logs by source; output (FU).	Food loss/waste (kg/FU) = Total food loss + waste (kg) ÷ Functional Units	Define boundary and stages included (processing, storage, distribution). Separate edible food waste vs inedible parts/by-products	Monthly	Down
ENV22	GHG emissions intensity	Total greenhouse gas emissions (tCO_2e) from operations over the reporting period, normalized by functional unit	Impact	Energy & Climate impact	S: climate change mitigation CE: reduced virgin inputs, energy demand, waste and related emissions	tCO_2e / functional unit (e.g., tCO_2e/tonne output)	Activity data (fuels, electricity/heat, refrigerants); emission factors ($kgCO_2e$/unit); functional output data.	GHG intensity (tCO_2e/FU) = (Scope 1 + Scope 2 (+ selected Scope 3)) ÷ Functional Units	Specify boundary and method (GHG Protocol). For Scope 2, state location-based and/or market-based. Keep emission factors consistent across months/years.	Monthly	Down
ENV23	Water scarcity footprint	Water consumption weighted by local scarcity factors, per functional unit.	Impact	Water impact	S: reduced water-stress impacts CE: reduced net withdrawals via reuse/recirculation	m^3 world-eq / functional unit	Water consumption by source/location (m^3 = withdrawals − returns); basin/location factor set; functional output data.	Water scarcity footprint (m^3 world-eq/FU) = Σ(Consumption_loc × Scarcity factor_loc) ÷ Functional Units	Use consumption (not just withdrawal). If multiple sites/basins, calculate per location and sum. State the factor method used and year/version for consistency.	Monthly	Down
ENV24	Soil Organic Carbon	Soil organic carbon stock (or %SOC) for the defined land area.	Impact	Land/Soil impact	S: soil health, resilience, erosion risk CE: nutrient/biomass cycling, regenerative	t C/ha (stock) and/or % SOC (concentration)	Soil sampling results (SOC %, bulk density, sampling depth); area (ha).	SOC stock (t C/ha) = SOC% × Bulk density × Depth × 10,000	SOC changes slowly; measurement is typically annual or every 3–5	Monthly	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
					practices, carbon sequestration				years. If you must report monthly, carry-forward last measured value and flag “no new measurement this month”.		
ENV25	Biodiversity /Habitat protection	% (and/or ha) of managed area under habitat protection or restoration management.	Impact	Biodiversity	S: ecosystem integrity & biodiversity conservation CE: land stewardship, regenerative practices, reduced land degradation	% of area (and/or ha)	GIS/land register (ha by land-use); mapped protected/restored areas; management plan evidence (buffer zones, set-asides, habitat actions).	Habitat protection coverage (%) = (Protected + restored habitat area (ha) ÷ Total managed area (ha)) × 100	Define “protected/restored” (e.g., legally protected, conservation easement, designated set-asides, riparian buffers, documented restoration with management plan).	Monthly	Up
ENV26	Circular Inflow rate	Share of total material inputs that are circular inflows (secondary/recycled inputs and other eligible recovered inputs), expressed as a percentage (mass basis).	Impact	Circularity impact	S: reduced virgin resource extraction & upstream impacts CE: closing material loops by increasing secondary inputs	% (Percentage)	Material inputs by type (kg); recycled/secondary fraction per input (supplier specs/certification); total material input.	Circular Inflow Rate (%) = (Circular material input ÷ Total material input) × 100	Define what counts as “circular inflow” (and whether bio-based is included); avoid double counting internal rework.	Monthly	Up
ENV27	Feed self-sufficiency ratio	Proportion of total animal feed requirements that are produced on	Input	Resource Input (Materials)	CE: closing nutrient loops & reducing external inputs S: farm resilience and local resource use	% (Percentage)	Amount of feed produced on farm (kg DM/year); total feed consumed (kg DM/year)	(Feed produced on farm ÷ Total feed consumed) × 100	Use dry matter (DM) basis for all feed types; include purchased forage,	Annually	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
		the farm itself, indicating dependence on external inputs and the level of circular nutrient use within the farming system.							concentrates and by-products; calculate annually.		
ENV28	Enteric methane intensity	Amount of methane emitted from ruminant digestion per unit of animal product (e.g., milk or meat), representing greenhouse gas efficiency of livestock production.	Impact	Energy & Climate impact	S: climate change mitigation CE: low-emission livestock systems	kg CH_4 / functional unit (e.g., kg CH_4/ton milk or kg CH_4/kg meat)	Number of animals by category; feed intake or milk/meat production; emission factor	Total enteric CH_4 emissions ÷ Product output	Apply recognized emission factors (IPCC Tier 1–2 or national model); use the same functional unit as other GHG indicators (e.g., kg milk or carcass weight).	Annually	Down
ENV29	Nitrogen surplus per hectare	Difference between nitrogen inputs (fertilizers, manure, feed) and nitrogen outputs (products and crops) per unit of land area, indicating potential nutrient losses to air and water.	Output	Land/Soil impact	S: prevention of eutrophication & soil degradation CE: optimized nutrient cycling	kg N / ha·year	Fertilizer N input; manure N applied; purchased feed N; sold products N; cultivated land area	(Total N inputs − Total N outputs) ÷ Agricultural land area	Include all nitrogen sources (fertilizer, manure, feed imports, biological fixation); outputs include milk, meat and crops sold; use utilized agricultural area only.	Annually	Down
ENV30	Manure nutrient	Share of nutrients contained in	Process	Food system circularity	CE: nutrient recycling and waste valorisation	% (Percentage)	Total manure nutrients produced (N, P);	(Recovered manure nutrients ÷ Total	Count nutrients reused in fertilization or	Annually	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
	recovery rate	manure that are effectively reused in crop production or other applications instead of being lost to the environment, reflecting nutrient circularity and resource efficiency.			S: reduced fertilizer dependence		nutrients applied to crops or reused; nutrients disposed/lost	manure nutrients produced) × 100	processing; exclude storage losses and volatilization; calculate separately for N or P if data available.		
ENV31	Antibiotic treatment frequency	Number of antimicrobial treatment events administered to animals within a defined period relative to herd size, indicating health management quality and antimicrobial stewardship in livestock production.	Impact	Circularity impact	S: antimicrobial resistance & animal welfare CE: responsible production systems	treatments / animal·year	Number of treatments administered; number of animals; observation period	Number of treatments ÷ (Number of animals × period in years)	Count treatment courses, not doses; include all administration routes; normalize to average herd size during the year.	Quarterly	Down
ENV32	Pasture biodiversity index	Measure of plant species diversity and ecological richness in grazed pasture, reflecting ecosystem health,	Impact	Biodiversity	S: ecosystem resilience & soil health CE: regenerative land management	species richness index (score)	Plant species count per sampling plot; number of plots sampled; pasture area	Total number of plant species recorded ÷ Number of sampling plots (or standard diversity index method)	Sample during main growing season; avoid recently reseeded areas; use consistent plot size and number each year.	Annually	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
		resilience, and regenerative grazing practices.									
ENV33	Cleaning-in-place water intensity	Volume of water used for automated equipment cleaning per unit of processed product, representing hygiene efficiency and water resource management in food processing.	Input	Resource Input (Water)	S: water efficiency CE: process optimization and water recirculation	m^3 / functional unit (e.g., m^3/ton product)	Total cleaning water consumption; production quantity during same period	Cleaning water used ÷ Production quantity	Include only cleaning water, not cooling or processing water; measure over same period as production data.	Monthly	Down
ENV34	Slaughter yield efficiency	Proportion of usable carcass weight obtained from live animal weight, indicating resource efficiency and loss minimization during slaughter operations.	Process	Food system circularity	CE: biomass utilization & waste reduction S: resource efficiency	% Percentage	Live animal weight; carcass weight after slaughter	(Carcass weight ÷ Live animal weight) × 100	Use hot carcass weight unless specified otherwise; exclude condemned parts; average multiple animals for reliability.	Monthly	Up
ENV35	Packaging recyclability index	Percentage of packaging materials that can be recycled within existing waste management	Output	Circularity impact	CE: material loop closure S: reduced environmental pollution	% recyclable material	Mass of recyclable packaging materials; total packaging mass used	(Recyclable packaging mass ÷ Total packaging mass) × 100	Consider recyclability in the local waste management system; multi-layer materials count as non-	Annually	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
		systems, representing circularity and environmental performance of product packaging.							recyclable unless separable.		
ENV36	Refrigeration leakage factor	Annual loss of refrigerant gases from cooling systems relative to total refrigerant charge, indicating potential climate impact from fugitive emissions.	Output	Energy & Climate impact	S: GHG reduction CE: improved cooling system management	% refrigerant charge / year	Refrigerant charge in system; refrigerant refilled or lost annually	(Annual refrigerant refilled or lost ÷ Total refrigerant charge) × 100	Calculate yearly using maintenance refill records; include accidental leaks and servicing losses.	Annually	Down
ENV37	Heat recovery rate	Share of thermal energy captured and reused from industrial processes compared to total heat demand, reflecting energy efficiency and circular energy use.	Process	Process (Management Practices and Operational Controls)	CE: energy cascading & efficiency S: lower fossil energy demand	% recovered heat	Total heat demand; recovered/reused heat energy	(Recovered heat energy ÷ Total heat demand) × 100	Count only heat reused internally; exclude theoretical recovery potential; measure over representative production period.	Monthly	Up
ENV38	COD load per product	Amount of organic pollution (chemical oxygen demand) discharged in	Output	Water outflows	S: water pollution reduction CE: product loss prevention	kg COD / functional unit (e.g., kg COD/ton product)	COD concentration in effluent; wastewater flow volume; production quantity	(COD concentration × Effluent volume) ÷ Production quantity	Use average laboratory COD results; ensure effluent flow corresponds to sampling period;	Monthly	Down

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
		wastewater per unit of production, indicating material losses and water pollution intensity.							convert mg/L to kg properly.		
ENV39	Odour emission potential	Estimated intensity of odor-causing emissions released during production activities, representing nuisance impact on surrounding communities and air quality.	Impact	Circularity impact	S: community wellbeing CE: improved waste handling	OUe/m³ air or OUe/s (odour units)	Odour concentration measurement or emission factor; airflow rate or emission source data	Odour concentration × Airflow rate	Use standardized olfactometry methods where possible; estimate airflow rate for area sources; seasonal variation may be significant.	Annually	Down
ENV40	Microplastic release risk	Potential quantity of microscopic plastic particles entering wastewater or the environment during processing or packaging operations, indicating emerging pollution risk.	Output	Resource outflows and waste	S: ecosystem protection CE: sustainable material use	mg microplastics / functional unit (e.g., mg/kg product or mg/L effluent)	Microplastic concentration in wastewater/effluent; effluent volume or product mass	(Microplastic concentration × Effluent volume) ÷ Production quantity	Filter samples according to standard protocols; avoid contamination during sampling; report detection limits when concentrations are low.	Annually	Down
ENV41	Transport emission per raw	Greenhouse gas (GHG) emissions generated	Impact	Energy & Climate impact	S: transport decarbonization CE: optimized supply chains	kg CO_2e / functional unit (e.g., kg	Distance travelled for collection; vehicle type and fuel consumption;	Transport GHG Emissions (kg CO_2-eq/FU) = Σ (Transport Activity	Use real fuel consumption if available; otherwise apply	Monthly	Down

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
	material collection	throughout transport chain operations associated with the movement of raw materials, products and packaging, reflecting transport efficiency and supply chain footprint.				CO_2e/1000 L milk)	quantity of products transported; logistics records; fuel purchase data; emission factors	× Emission Factor) ÷ Functional Units Produced, where: Transport Activity = Distance × Load Transported	emission factors per vehicle type; include full collection route distance.		

Table A2 Economic Indicators

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
ECON1	Circular Capital Expenditure (CAPEX)	Capital Expenditure (CAPEX) to circular technology, that is reuse/recycling infrastructure, resource-efficiency retrofits, valorisation equipment, reusable packaging systems	Input	Investment & Finance	Measures financial commitment to the transition.	% of Total CAPEX	Circular Investment (CI) (€), Total CAPEX (€).	CI/CAPEX X 100	Resources committed to circular tech (e.g., anaerobic digesters for meat waste, water recycling for dairy).	Annually	Up
ECON2	CE-related R&D / innovation spend	Share of turnover spent on redesigning processes or valorizing by-products (e.g., R&D for pomegranate peel extraction).	Input	Investment & Finance	Critical for innovation in value-added products.	% of Turnover	R&D Spend on CE (€), Total Turnover (€).	CE R&D/Total turnover X 100	An indicator of commitment to CE transition.	Annually	Up
ECON3	Green/transition finance mobilised for CE	Ratio of total CE CAPEX that was mobilised by external funding	Input	Investment & Finance	Provides a direction of the company in following CE principles to access funding	ratio	External funds raised for CE purposes, total CAPEX in CE and non CE activities	Funds green / Total CAPEX X 100	Could also include EU, national and other funding sources.	Annually	Up
ECON4	Spend on secondary/by-product inputs	Expenditure on recycled/by-product inputs (e.g., recycled PET for juice bottles) vs. virgin material	Input	Circular procureme nt	Tracks economic commitment to closing loops	% of Procurement	Cost of Virgin Inputs (Cv), Cost of Secondary Inputs (Cs).	Cs/(Cs+Cv) X 100	External inputs	Annually	Up
ECON5	Investment in reusable packaging /	Tracks the capital expenditure (CAPEX) allocated	Input	Circular procureme nt	High. This input metric predicts	% (Ratio)	Investment in reusable assets & systems	reuse / total × 100	Includes cost of crates, bottles,	Annually or rolling 12-month	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
	reverse logistics systems	to purchasing reusable assets (e.g., crates, kegs, bottles) and the infrastructure to retrieve them (reverse vending, washing lines).			future circular capability. Without upfront investment in the "Reverse Loop," a firm cannot shift from single-use to reuse. It demonstrates financial commitment to "Closing the Loop."		(reuse in €) Total Packaging/Logistics Investment (total in €)		washing facilities, and reverse-logistics software. Excludes operational transport costs (that is OPEX).		
ECON6	Energy procurement cost	Tracks the total monetary cost of purchasing external energy (electricity, natural gas, diesel). Measures the financial exposure to volatile fossil fuel markets.	Input	Resource Operating Cost	Energy is often the 2nd largest OPEX in food processing (after raw materials). Reducing this Input Cost through renewables or efficiency directly improves the "Economic Resilience" (Margin).	€ / month	Total Electricity Bill (€), Total Fuel Bill (Gas/Oil), Total Production Volume (optional for intensity).		To measure efficiency, you can normalize this as "Energy Cost per Unit" (€ / kg of output). A shift to own-generated biogas drives this cost toward zero.	Monthly	Down
ECON7	Water procurement & treatment cost	Tracks the total cost of the water cycle: purchasing fresh water + treating wastewater +	Input	Resource Operating Cost	Food & Beverage firms often pay twice for water (Input + Discharge). This indicator	€ / month	Municipal Water Bill, Cost of chemicals/energy for onsite treatment,			Monthly	Down

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
		sewage discharge fees.			drives the business case for onsite recycling (e.g., MBR systems) to cut both bills simultaneously.		Sewage/Effluent fees.				
ECON8	Waste management cost	Tracks the direct financial cost of managing non-product output. Includes collection fees, tipping/gate fees (landfill taxes), and bin leasing.	Input	Resource Operating Cost	This is a "Penalty" indicator. In a Linear Economy, this is a fixed cost. In a Circular Economy, this cost must trend toward zero (or become a revenue stream via by-product sales).	€ / month	Tipping fees per ton (Landfill/Incineration), Transport/Collection fees, Mass of waste (tons).		Does not include internal labor. Focuses on external invoices paid to Waste Management Companies.	Monthly	Down
ECON9	Distribution/logistics cost	Tracks the total operational cost of transporting finished goods to customers (Outbound). Includes fuel, driver wages, vehicle maintenance, and 3PL fees.	Input	Transport	Logistics is a major cost center and carbon hotspot. Optimizing this (via route planning or load consolidation) reduces both €/kg and CO_2/kg.	€ / month	Fuel costs, Lease/Maint costs, Driver wages, Outsourced transport fees.		In a Circular model, this must be optimized alongside Reverse Logistics. The goal is to maximize "Value per km" and eliminate empty running.	Monthly	Down

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
ECON10	Resource Cost Dependency	Cost of energy, water, and waste disposal per unit of output.	Input	Resource Operating Cost	Tracks exposure to resource price volatility, crucial for rural monitoring.	€ / tonne output	Total Energy/Water Bill/ Transport costs, Production Volume (tonnes).			Monthly	Down
ECON11	Material flow cost accounting (MFCA) / cost-to-serve accounting implemented	Assigns financial costs to waste streams.	Process	Economic Management Practices enabling Circularity	A "leading indicator" identifying where money is lost in mass loss.	Binary 0/1 (or % coverage)	Documents attesting to the implementation of MFCA in the company's operations	Audit of waste streams with assigned monetary values.	MFCA focuses on identifying and reducing waste to improve resource efficiency	Annually	Up
ECON12	Eco-design / design-for-circularity stage-gate	Tracks whether a mandatory "Circularity Check" exists in the R&D process. A product cannot move from "Concept" to "Production" without passing specific eco-design criteria (e.g., recyclability > 90%).	Process	Economic Management Practices enabling Circularity	80% of a product's environmental cost is locked in at the design phase. This indicator ensures circularity is not an afterthought but a "Gatekeeper" requirement.	Binary 0/1	Existence of formal circular criteria in the Product Lifecycle Management (PLM) system, Verification record.		Based on ISO 14006 (Eco-design Management). For the pilot, a simple "Yes" requires a documented checklist used in the last product launch.	Annually	Up
ECON13	Quality assurance protocol for secondary/by-product inputs	Tracks the existence of specific QA/QC procedures for inspecting incoming recycled materials or by-products. Unlike virgin materials, secondary inputs have high	Process	Economic Management Practices enabling Circularity	"Perceived Risk" is the #1 barrier to reuse. Without a formal QA protocol (e.g., testing recycled plastic for toxins or food	Binary 0/1	Documented QA standard for secondary inputs (e.g., "Spec Sheet for Recycled PET"), Evidence of batch testing.			Annually or upon change	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
		variability (impurities, contamination).			waste for pathogens), procurement managers will revert to virgin materials.						
ECON14	Preventive maintenance / efficiency programme	Percentage of critical assets covered by efficiency programs.	Process	Economic Management Practices enabling Circularity	A primary lever for controlling energy/water costs in rural SMEs.	Binary 0/1 (or % Assets)	Assets under maintenance contract / Total Assets.			Annually	Up
ECON15	Reverse logistics process performance tracking	Measures the efficiency of the "Take-Back" system. Unlike simple collection, this tracks the success rate of retrieving functional assets (crates, kegs) versus total units shipped.	Process	Economic Management Practices enabling Circularity	If you don't track the "Return Rate," you cannot manage the asset loop. A low rate (<90% for crates) implies "Leakage" (theft/loss), which destroys the economic model.	% (Return Rate	Quantity of units successfully retrieved (returned). Quantity of units sent to market (shipped)	Returned/shipped X 100	Can be weighted by value or volume. High performance = High Return Rate. Low performance = High Replacement Cost.	Monthly	Up
ECON16	Revenue from by-products / valorised residuals	Income from "waste" (e.g., selling pomegranate seeds, whey protein from milk, blood meal etc.) vs. core product.	Output	Circular value generation	Measures if waste is successfully becoming a product.	% of Turnover	Revenue from By-products (Rby), Total Rev.	Rby/Rtotal X 100		Annually	Up
ECON17	Avoided waste disposal cost	Savings from not paying disposal fees due to internal recycling.	Output	Resource efficiency	Demonstrates the business case for "decoupling".	€ / year	Mass diverted (t), Cost of disposal [Landfill Fee	Total ops cost/number of trips		Annually	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
							(€/t). Logistics cost, Carbon tax or other relevant measures]				
ECON18	Returnable packaging cycle cost	Cost per trip of reusable crates/bottles.	Output	Circular operations performance	Critical for rural logistics economics.	€ / cycle	Total Packaging Ops Cost, Number of Cycles.	Total ops cost/number of trips		Monthly	Down
ECON19	Payback/IRR on circular investments	Return on Investment for circular tech.	Impact	"Decision-grade" indicator for feasibility.	% (IRR) or Years	Project-based	CAPEX (cost of the circular equipment), Revenue form by-products (Rby), Cost of dumping fees (avoided) - Ca, operating cost of the circular machine Cops	(Rby+Ca-Cops)/CAPEX X100		Project based	Up
ECON20	Resource Cost Exposure Ratio	The indicator measures the financial risk or "exposure" posed by the resource cost (energy + water+materials + waste) relative to turnover	Impact	Economic Sustainability & Resilience	Tracks economic resilience and decoupling.	Ratio	Costs (Ce, Cw, Cm, Cwaste), Turnover (total revenue).	Costs/Turnover X 100		Annually	Down
ECON21	Value added per Full-Time-Equivalent (FTE)	The indicator measures the economic value or net output (revenue minus non-labor costs) generated by each standardized full-time employee, including part-time staff adjusted	Impact	Economic Sustainability & Resilience	Critics argue Circular Economy (CE) relies on low-wage labor. This metric proves if your CE model drives productivity (doing more	€ / FTE	Gross Value Added (Revenue - Cost of Goods/Services bought) [GVA], Full-Time Equivalent employees (FTE)	GVA/FTE X 100	Value Added is a better measure than Revenue because it strips out the cost of inputs, isolating the value	Annually	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
		to full-time hours. It serves as a key productivity metric, with higher values indicating greater efficiency and stronger human capital utilization.			with better skills) rather than just adding bodies.				created by the firm's labor and capital.		
ECON22	Operating Margin/EBITDA Margin Stability	Measures the core profitability of the business operations, excluding tax and interest. It tracks whether the transition to circularity (e.g., service models, reuse) is stabilizing or eroding the profit margin over time.	Impact	Economic Sustainability & Resilience	This is the "Proof of Concept." Circular models often have higher OPEX (labor/logistics) but lower CAPEX (longer asset life). This metric verifies if the net effect is a healthier margin.	Trend (slope)	EBITDA: Earnings Before Interest, Taxes, Depreciation, Amortization. Total Revenue {Revenue}	EBITDA/REVENUE X100	We look for Volatility (σ) or Trend. A stable or rising margin suggests the business is resilient to shock (e.g., raw material price spikes).	Monthly	Up
ECON23	Resource productivity	Economic efficiency of resource use (economic value generated per unit of material consumed).	Output	Production and consumption	A key indicator for decoupling economic growth from material consumption.	€/tonă	Annual GDP (Gross Domestic Product) from Eurostat national accounts. Annual DMC (Domestic Material Consumption) , from Eurostat Economy-Wide Material Flow	Resource Productivity=DMC/GDP, GDP = Gross Domestic Product, DMC = Domestic Material Consumption.	Same reference year for both GDP and DMC, Harmonized units: GDP in EUR or PPS and DMC in tonnes.	Annually	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
							Accounts (EW-MFA)				
ECON24	Share of agri-food sales through Short Food Supply Chains (SFSC)	The proportion of agri-food sales achieved via short food supply chains (direct sales, local cooperatives, farmers' markets, local farm-to-fork schemes) in total agri-food sales.	Output	Circular business models / Local valorisatio n (SFSC)	Short food supply chains reduce intermediary steps, support local valorisation, and can decrease losses/waste and the logistical footprint.	% of total agri-food sales	Numerator:co mpany sales through SFSC during the reporting period. Denominator: the same company's total agrifood sales during the same reporting period	SFSC % = (sales through short food supply chains ÷ total agri-food sales) × 100,	The indicator requires local data collection (statistics/su rveys). The association with novel food technologies and circular-econ omy practices can strengthen traceability and local valorisation within SFSCs.	Annually	Up
ECON25	Material productivity	Economic value generated per unit of material input.	impact	Circular business models / Local valorisatio n (SFSC)	Captures decoupling between economic performance and resource use.	€ Gross value added / kg raw materials	Gross Value Added (GVA, €); raw material consumption (kg)	Material Productivity = Gross Value Added (€)÷ Raw Material Consumptio n	Higher values indicate greater economic value created per unit of physical material input	Annually	Up
ECON26	Local sourcing rate	Share of inputs procured locally.	input	Circular business models / Local valorisatio n (SFSC)	Supports territorial circularity and rural resilience.	% (percentage)	Value, volume of sales through SFSC (direct sales, cooperatives,	Value/volu me of sales through SFSC		Annually	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
							farmers' markets, D2C).				
ECON27	Investment in sustainability/circularity	Resources allocated to circular improvements.	Input	Economic Management Practices enabling Circularity	Indicates strategic commitment and transition readiness.	€ / year or % (percentage)	Total agri-food sales (national / sector level).			Annually	Up
ECON28	Value added per animal	Economic value generated by each livestock animal after subtracting variable production costs, indicating productivity and profitability of animal production.	Impact	Investment & Finance	Shows whether biological production efficiency translates into real economic value creation	€ / animal·year	Annual revenue (€); Raw material consumption (kg).	(Total livestock revenue − Variable production costs) ÷ Number of animals		Annually	Up
ECON29	Protein conversion efficiency	Amount of edible animal protein produced relative to the protein content of feed consumed, measuring biological and resource efficiency of livestock production.	Process	Economic Management Practices enabling Circularity	Lower feed input per protein output reduces costs and strengthens circular resource use	kg edible protein / kg feed protein	Local purchases (€); Total purchases (€).	Edible protein produced ÷ Feed protein intake	Use edible protein only; express feed on dry matter basis to ensure comparability.	Quarterly	Up
ECON30	By-product revenue share	Percentage of total company income derived from sale or valorisation of secondary products and processing residues.	Output	Circular procurement	Indicates if processing residues are becoming profit streams instead of disposal costs.	% of turnover	Sustainability investments (€); Turnover / CAPEX (€).	Revenue from by-products ÷ Total turnover × 99	Include whey, blood, fat, manure or downgraded products sold; exclude internal	Quarterly	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
									reuse transfers.		
ECON31	Energy cost intensity	Total expenditure on energy per unit of product output, indicating economic exposure to energy consumption.	Input	Resource Operating Cost	Tracks vulnerability of profitability to energy prices and efficiency improvements.	€ / functional unit (e.g., €/ton product or €/1000 L milk)	Total livestock revenue (€), Variable production costs (€), Number of animals	Total energy cost ÷ Production output		Monthly	Down
ECON32	Feed price vulnerability	Degree to which production costs are affected by fluctuations in purchased feed prices.	Impact	Resource Operating Cost	Measures exposure of farm margins to volatile external feed markets.	ratio (cost change % / feed price change %)	Total edible protein produced (kg), Total feed protein intake (kg)	% change in total production cost ÷ % change in feed price	Use multi-year price series; a single year can be distorted by market shocks.	Annually	Down
ECON33	Shelf-life loss cost	Economic losses associated with products discarded due to expiration or quality deterioration before sale.	Output	Resource Operating Cost	Identifies preventable profit loss from unsold or expired products.	€ / year (or € / functional unit)	Revenue from by-products (€), Total company turnover (€)	Quantity discarded × Product unit value	Include retail returns and expired stock; do not include planned donations.	Annually	Down
ECON34	Circular revenue ratio	Share of total revenue generated from recovered, recycled, or reused materials and secondary value streams.	Impact	Circular procurement	Demonstrates whether circular activities contribute meaningfully to total income.	% of turnover	Total energy cost (€), Production output (functional unit)	Revenue from recycled/reused streams ÷ Total revenue × 100		Annually	Up
ECON35	Waste disposal dependency	Proportion of total waste that requires external disposal instead of reuse or recovery.	Output	Resource Operating Cost	High dependency signals a linear model; reduction indicates	% of total waste disposed	Feed purchase price history (€ per kg), Total feed cost (€), Total	Waste disposed externally ÷ Total waste generated × 100		Monthly	Down

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
					circular transition.		production cost (€)				
ECON36	Local sourcing rate	Percentage of raw materials or inputs obtained from local or regional suppliers.	Input	Circular procurement	Strengthens regional economic loops and reduces supply risk and transport cost exposure.	% of procurement	Quantity of expired/discarded product (kg), Product unit value (€ per kg)	Value of local purchases ÷ Total procurement value × 100	Define local radius consistently (e.g., <150 km) before calculating.	Annually	Up
ECON37	Contract farmer stability index	Average duration and continuity of supply agreements with partner farmers, reflecting supply chain reliability.	Impact	Economic Management Practices enabling Circularity	Stable contracts improve supply security and enable long-term circular practices.	years (average contract duration	Revenue from recycled/reused streams (€), Total revenue (€)	Sum of contract durations ÷ Number of contracts		Annually	Up
ECON38	Local market share	Proportion of total sales occurring within the local or regional market area.	Impact	Transport	Higher local sales improve logistics efficiency and rural economic resilience.	% of sales volume	Mass of waste disposed externally (kg), Total waste generated (kg)	Local sales volume ÷ Total sales volume × 100		Annually	Up

Table A3. Social Indicators

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
SOC1	Total employment FTE (Full Time Equivalent)	Total number of full-time employees engaged in the business operations,based on total hours worked and regardless of employment type.	Input	Employment and job quality	Employment is central to rural sustainability and in CE transitions circular practices mαy alter labour intensity	Number of FTE	Total hours worked (all employees), standard full-time hours annually	FTE= Total hours worked (all employees)/Standard full-time hours (per period)	Total hours worked refers to the sum of all hours paid to employees (including part-time and part-year staff). The standard full-time hours refers to the defined annually hours for one full-time employee (e.g., 40 hours/week or 2,080 hours/year)	Annually	Up
SOC2	Share of permanent employment	The indicator measures the percentage of employees holding contracts with no specific end date, compared to the total number of employees (including temporary staff). A higher share indicates greater labor market stability and job security, while a lower share suggests flexible, short-term work arrangements.	Input	Employment and job quality	Indicates employment stability in rural regions	% of employees	Total number of employees, Total number of employees with permanent contracts	Share of permanent employment (%) = (Number of employees with permanent contracts/Total Number of employees) X 100	Employees aged 15+, typically 15-67	Annually	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
SOC3	CE & Sustainability Training hours per FTE	Hours of training linked to CE & Sustainability practices (eg. waste valorisation, renewable energy management, water reuse and recycling, eco-design etc.) standardized per FTE	Input	Skills for CE transition	Supports resource capacities committed to social sustainability & CE	hours/FTE	Total hours of CE & Sustainability training, Number of FTEs	Training hours per FTE= Total hours of CE & Sustainability training /Total number of FTEs	Total Training Hours refers to the sum of all hours spent by employees on CE or Sustainability-related training over a specific period. Total FTEs refers to the total number of full-time equivalent employees, allowing for comparison across different employment types (part-time/full-time).	Annually	Up
SOC4	CE dedicated workforce share	Share of FTE assigned to CE and Sustainability practices (eg. waste valorisation, renewable energy management, traceability, etc.)	Input	Skills for CE transition	Represents fundamental impacting of circular practices in organizational design.	% FTE	Total FTE, CE dedicated FTE	CE Dedicated Workforce Share = Number of employees in CE Activities (FTE)/ Total number of employees (FTE)	CE Dedicated Workforce includes the employees involved in R-strategies (Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover).	Annually	Up
SOC5	Occupational, Health and Safety (OHS) investment per FTE	It measures the average financial amount a company spends on safety, health, and wellbeing initiatives for each employee. It tracks the	Input	Health, Safety & Well-being	Circular processes (e.g., waste sorting, bioenergy handling) often require new safety considerations	€/FTE	OHS expenditure, Total number of FTE	OHS Investment per FTE = Total OHS costs /Total number of FTE employees	Total OHS Expenditure includes costs for safety equipment, training, medical check-ups, safety staff, and protective clothing.	Annually	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
		financial resources allocated to preventing workplace injuries and improving employee safety.									
SOC6	Local/Regional Procurement Share	Share of procurement spending within local/regional rural territory	Input	Territorial local loops	Supports local multiplier effects and territorial CE loops	%	Total Local/Regional Procurement Spend, Total Procurement Spend	Local/Regional Procurement Share (%) = [Total Value of Local/Regional Procurement/ Total Procurement Value (Total Spend)] X 100	Total value of local/regional procurement is the monetary value (EUR) of goods/services sourced within defined local/regional boundaries. The Total Procurement Value is the total monetary value of all procurement contracts.	Annually	Up
SOC7	Formal CE collaboration agreements	Includes contracts/MoUs with by-product partners, pooling systems, cooperatives, municipalities	Input	Collaboration capacity for circular loops	Supports capacity for circular loops	Count (Number of formal Agreements) or %	Number of Agreements in Current Period, Number of Agreements in Previous Period	Growth (%) = [(Agreements in Current Period - Agreements in Previous Period)/ Agreements in Previous Period] X 100	These agreements include MOUs, joint ventures, or contractual agreements specifically focused on circular strategies like reuse, repair, or recycling.	Annually	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
SOC8	Skills plan for CE and sustainability in place	It indicates the firm has a documented, actionable strategy to identify, develop, and deploy the capabilities necessary to transition from linear models to circular practices. This involves training workers in repair, recycling, sustainable design, and systems thinking to close resource loops.	Process	Skills and participation processes	Management practices enabling social sustainability & CE	YES/NO	Approved (or not approved) Skills plan for CE & Sustainability	The forumula is typically an audit check: Plan existence = YES, if a written, approved plan exists; Plan existence = NO, if no plan exists	This is a, qualitative process indicator (often part of ESG or other reporting framework) designed to track the implementation of policies.	Annually	Up
SOC9	OHS risk assessment updated for circular operations	Includes re-evaluating workplace hazards to account for non-linear processes like recycling, repair, and remanufacturing. It ensures safety when handling unknown waste, using	Process	OHS processes	Management practices enabling social sustainability & CE	YES/NO	Updated or not OHS risk assessment for CE	Updated OHS risk assessment for CE = YES, Non-updated OHS risk assessment for CE = NO	The OHS updated assessments focus on identifying new hazards, such as exposure to unknown chemicals in recycled materials, or increased safety risks during disassembly and sorting operations. Overall, they over waste sorting, by-product handling, reuse systems, chemical substitutions	Annually	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
		recycled materials, or operating new, greener technologies, focusing on managing risks associated with waste-to-resource transitions.									
SOC10	Worker participation mechanism active	Refers to the frequency of meetings for safety improvement and the process of reviewing, modifying, and improving the firm's formal program for collecting, evaluating, and implementing employee ideas. It involves modernizing how suggestions are submitted, updating reward structures, or new themes to boost engagement, efficiency, and	Process	Skills and participation processes	Management practices enabling social sustainability & CE	% or ratio of active OHS mechanisms	Number of Planned OHS mechanisms, Number of Active OHS Mechanisms	Mechanism Activity Rate (%) = (Number of Active OHS Mechanisms / Total Number of Planned OHS Mechanisms) X 100	OHS Mechanisms include safety committee meetings, safety walk-throughs, hazard report logs, employee surveys	Quarterly	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
		cost-saving efforts.									
SOC11	Agrifood business symbiosis governance	The indicator refers to the mechanisms, strategies, and institutions, such as local authorities, regulations, and partnerships, which facilitate collaboration between businesses of the agrifood sector to exchange materials, energy, and by-products (e.g., meat plant sending heat to nearby greenhouse).	Process	Governance for CE networks	Management practices enabling social sustainability & CE	Count (Number of symbiotic partnerships)	Active contracts or MoUs with other firms	Number of symbiotic partnerships		Annually	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
SOC12	Traceability and Transparency Process for Circular Inputs	It includes the systematic tracking of the origin, processing, and destination of materials generated during production, rather than the primary product. It involves assigning unique batch identifiers to these materials, documenting their raw material sources, production date/conditions, and shipping routes to ensure quality control, regulatory compliance, and safety, allowing companies to quickly locate specific batches if issues arise.	Process	Governance for CE networks	Management practices enabling social sustainability & CE	% of total material input	Mass of Traced Circular Inputs, Total Mass of Material Input	Traceability (%) = (Mass of Traced Circular Inputs / Total Mass of Material Input) X 100	This often forms part of a broader Material Circularity Indicator, which tracks materials from virgin stock to reuse, measuring how restorative material flows are. It requires verification of circular content (recycled, reused, or renewable) in the inflow.	Annually	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
SOC13	Share of employees trained	Share of workforce completing CE and sustainability related training	Output	Internal capacity building	Supports social sustainability & CE practices	% of the total workforce	Number of employees trained in CE & Sustainability, Total number of employees	Employees trained in CE & Sustainability (%) = (Number of employees trained in CE & Sustainability / Total Number of employees) X 100	This indicator is crucial for assessing internal capacity bulding. A common indicator in ESG reporting	Monthly	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
SOC14	Total Recordable Incident Rate (TRIR)	TRIR is a standardized, lagging safety metrics used to measure the frequency of workplace injuries per 100 hours worked. TRIR, which uses 200,000 hours to represent 100 full-time employees, normalize data to compare safety performance across companies of different sizes.	Output	Health and Safety outputs	Supports social sustainability	Incidents /100 full-time workers /year.	Number of recordable incidents (injuries and illnesses) over a year, Total hours worked by all employees	TRIR = (Number of Recordable Incidents X 200000)/Total hours worked by all employees	The number of incidents is the sum of all recordable injuries and illnesses for the period. The total hours worked refer to the actual hours worked by all employees (including temporary staff), excluding vacation, sick leave, or unpaid breaks. The value of 200000 is the standard benchmark representing 100 employees working 40 hours per week for 50 weeks per year.	Annually	Down

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
SOC15	Active CE partnerships maintained	The indicator measures the number of ongoing, collaborative relationships between the firm and organizations, governments, or stakeholders focused on implementing circular or sustainable business models. It highlights the collaborative, socio-institutional efforts required to CE transition	Output	CE territorial outputs	Supports rural sustainability & CE practices	Count (absolute number of formal or informal partnerships)	Signed active MoUs, or contracts of partnership agreements or documented collaborative activities	SUM of all active, functional partnership agreements	Partnerships are considered active if they have conducted at least one joint activity (meeting, report, project) within the specified reporting timeframe (year).	Annually	Up
SOC16	Apprenticeships/traineeships offered	The indicator describes the availability and volume of structured, employer-based training programs that combine paid on-the-job training with formal education leading to a nationally recognised qualification. It	Output	Direct employment outcomes	It supports rural sustainability by fostering rural youth retention	Number of individuals or % of total employment	Number of apprentices/trainees on December 31, Total employment	Absolute Volume = Total number of apprentices/trainees on 31 December, Rate = (Total Apprenticeships/traineeships offered/ Total Employment) X 100		Annually	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
		measures opportunities to earn while learning.									
SOC17	Employee retention rate	It describes a Human Resource (HR) metric measuring the percentage of employees who remain with a firm over a specific period, excluding new hires. It gauges organizational health, employee satisfaction, and the success of retention strategies, with high rates generally indicating 10% or lower turnover.	Impact	Work resilience	It supports social sustainability by fostering HR retention; it reflects rural skills scarcity	%	Number of employees at start of period, number of employees at end of period, number of new hires during period	Employee retention rate (%) = [(No. of employees at end of period−No. of new hires during period)/Number of employees at start of period] X 100	Example: If the company starts with 100 employees, ends with 95 and hired 5 new during the specified period the retention rate = [(95-5)/100] X 100 = 90%. A retention rate of 85% or more is considered good.	Annually	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
SOC18	Skills Competence Attainment	The indicator assesses the level of knowledge, skills, and attitudes an individual has acquired at a specific point in time. It validates the successful mastery and application of skills to meet specific standards, such as CE & sustainability related tasks, rather than just measuring years of schooling.	Impact	Human capital & capability	Supports social sustainability & CE practices	% of workforce certified /competent in CE tasks	Number of employees certified/competent in CE tasks over a specified period, Total number of employees	Skills Competence Attainment (%) = (Number of employees attained competency in CE tasks/ Total number of employees) X 100	Data for this indicator is often gathered through performance evaluations, skill-use assessments, and competency-based questionnaires.	Annually	Up
SOC19	Consumer Behaviour and Sentiment Toward Food Waste	This indicator measures consumers' behavioural patterns, emotions, and perceptions related to food waste, derived from qualitative interviews and sentiment analysis (word cloud, term frequency, sentiment	Process	Social / Behavioural Sustainability Indicator (Responsible Consumption)	This indicator supports circular-economy goals by identifying behavioural drivers of food waste, enabling interventions that reduce resource loss throughout the agri-food chain. Understandin	Because this is a qualitative-behavioural indicator, it uses: Sentiment score (range −1 to +1, based on sentiment analysis) Frequen	To compute/track this indicator, the following are required: Transcribed semi-structured interviews with consumers Text preprocessing (cleaning, tokenisation, frequency	There is no single numerical formula, but the indicator is calculated using standard sentiment-analysis equations and clustering procedures. 1. Sentiment score Sentiment Score=∑(polarity	This is a purely social-behavioural indicator. Ideal for monitoring consumer attitudes, awareness, and food-waste prevention behaviour. It serves as an early-warning indicator for designing education, communication, and behavioural-change programs. It complements quantitative food-waste indicators by explaining why waste occurs, not only how much.	Every 2–3 years, or whenever new qualitative consumer data is collected for food-waste behavioural monitoring.	Higher positive sentiment = better (greater consumer awareness, responsibility, sustainability mindset). Higher frequency of negative terms (waste, risk, problems) = worse (more dissatisfaction or negative behaviours).

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
		score distribution, and cluster analysis). It captures how Romanian consumers describe their food purchasing, cooking practices, household waste management, and attitudes toward the agri-food chain, as well as their emotional responses (anticipation, joy, surprise, dissatisfaction) linked to food waste behaviour.			g emotions, awareness levels, and household practices helps develop targeted strategies that promote responsible consumption, reduce avoidable waste, and strengthen sustainable food systems aligned with CE and SDG 12 (Responsible Consumption and Production).	cy of keywords (number of occurrences in interviews) Cluster membership (Epicureans, Organised, Refined, Minimalists) Proportion (%) of emotional states (anticipation, joy, surprise, negative emotions <1%)	analysis) Word cloud data (key terms: food, chain, agri-food, waste, reduce) Sentiment scores (positive, neutral, negative) Term association matrices Cluster outputs (four consumer behaviour types) All are extracted through R packages such as tidytext, sentimentr, quanteda, igraph.	of terms)/number of sentiment terms 2. Term frequency TF=count of term occurrences in interview corpus 3. Cluster assignment Algorithmic clustering (R packages: tidytext, quanteda, igraph) groups respondents into four behavioural clusters based on linguistic patterns and sentiment. (Epicureans, Organised, Refined, Minimalists).			Cluster movement toward “Organised” and “Refined” = improvement. Cluster dominance of “Minimalists” with low involvement = risk flag.
SOC20	Local employment Rate	Share of workforce residing locally.	Input	Employment and job quality	Measures territorial embeddedness of the company.	%	Local employees; Total employees.			annually	

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
SOC21	Gender balance	Distribution of employment by gender.	impact	Social / Behavioural Sustainability Indicator (Responsible Consumption)	Reflects inclusiveness and social sustainability dynamics.	%	Women employees; Total employees.			annually	
SOC22	Injury frequency rate	Number of workplace injuries occurring per employee or per working hours, indicating occupational health and safety performance.	Impact	Health, Safety & Well-being	Indicates effectiveness of workplace safety practices and risk management in labour-intensive circular operations.	Injuries / 100 employees / year	Number of recorded workplace injuries, Total number of employees	(Number of injuries ÷ Total employees) × 100		Monthly	Down
SOC23	Worker retention rate	Percentage of employees remaining employed over a defined period, reflecting job stability and workplace satisfaction.	Impact	Work resilience	Reflects workforce stability and attractiveness of rural employment conditions.	% of employees	Number of employees remaining during period, Total employees at start of period	(Employees remaining at end of period ÷ Employees at start of period) × 100	Exclude seasonal workers if employment is inherently seasonal; calculate annually.	Annually	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
SOC24	Skilled labour ratio	Share of employees with certified technical training or professional qualifications relative to the total workforce.	Input	Human capital & capability	Demonstrates capacity of the organisation to operate advanced and circular production processes.	% of workforce	Number of certified/qualified workers, Total workforce size	(Number of qualified workers ÷ Total workforce) × 100	Count officially certified or documented qualifications only.	Annually	Up
SOC25	Gender equality index	Measure of gender balance in employment, considering representation across roles and responsibility levels within the organization.	Impact	Employment and job quality	Supports fair employment opportunities and inclusive workforce participation.	Ratio or % female representation	Number of male and female employees by role/level, Total workforce	(Number of female employees ÷ Total employees) × 100 (or female/male ratio)	Include only verified external complaints; exclude internal employee grievances.	Annually	Up
SOC26	Community complaint frequency	Number of complaints received from local stakeholders regarding company activities within a reporting period.	Impact	Territorial local loops	Measures social acceptance of operations and relationship with surrounding communities.	Number of complaints / years	Number of complaints recorded	Number of complaints ÷ Reporting period	Include only structured training (courses, workshops); exclude routine supervision.	Monthly	d

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
SOC27	Training hours per employee	Average number of hours of professional training provided to each employee annually.	Process	Skills and participation processes	Strengthens employee competence for sustainability and circular practices implementation.	Hours / employee·year	Total training hours provided, Total number of employees	Total training hours ÷ Total employees	Exclude animals euthanized for veterinary reasons unrelated to handling.	Annually	Up
SOC28	Mortality before slaughter	Percentage of animals that die before slaughter during housing, handling, or transport stages.	Impact	Health, Safety & Well-being	Indicates quality of animal handling practices and ethical production standards.	% of animals	Number of animals dead before slaughter, Total animals handled	(Animals dead before slaughter ÷ Total animals handled) × 100		Monthly	d
SOC29	Transport stress index	Indicator of animal welfare during transport based on observed stress conditions such as overcrowding, travel duration, or injuries.	Process	Health, Safety & Well-being	Assesses welfare conditions during logistics and responsible supply chain management.	Welfare score (index)	Transport duration, Stocking density, Number of injured animals, Environmental conditions (temperature/humidity)	Composite score based on weighted factors (injuries + overcrowding + duration + temperature) ÷ number of animals		Monthly	d
SOC30	Food donation rate	Share of safe edible food diverted from waste and donated for human consumption.	Output	CE territorial outputs	Demonstrates contribution to social value creation and reduction of food waste.	% of edible surplus	Quantity of food donated (kg), Total edible surplus food (kg)	(Food donated ÷ Total edible surplus) × 100	Include only safe and legally compliant food donations for human consumption.	Monthly	Up

Indicator code	Indicator name	Indicator description	Indicator level	Category	Relevance	Unit	Data requirements	Formula	Notes	Frequency	Direction
SOC31	Nutritional density index	Measure of nutritional value provided per unit of product, considering key nutrients such as protein, vitamins, and minerals relative to energy content.	Impact	Human capital & capability	Reflects contribution of products to public health and societal wellbeing.	Nutrient score per 100 kcal (or index score)	Nutrient composition data (protein, vitamins, minerals), Energy content per product unit	Sum of beneficial nutrients ÷ Energy content	Use standardized nutrient database values or laboratory analysis for consistency.	Annually	Up

Appendix B. Reduced list of indicators

Table B1. Environmental indices

Indicator code	Indicator name	Indicator description	Indicator level	Cost impact	Revenue impact	Risk exposure	Management control ability	Data availability	Strategic alignment
ENV01	Total Energy Input	Total energy consumed	Input	5-Absolutely include	3-Significant	5-Absolutely include	5-Absolutely include	5-Absolutely include	5-Absolutely include
ENV02	Renewable Energy Share	Share of total energy from renewable sources (solar, wind, biomass, etc)	Input	4-Very significant	4-Very significant	4-Very significant	4-Very significant	5-Absolutely include	5-Absolutely include
ENV03	Total Water Input	Total external water withdrawn/received for on-site operations during the reporting period, normalized by functional unit.	Input	5-Absolutely include	3-Significant	5-Absolutely include	5-Absolutely include	5-Absolutely include	5-Absolutely include
ENV04	Reused/recycled water input share	Share of total water used in operations that is supplied by internally reused/recycled water (recirculated process water, treated effluent reused on-site), expressed as a percentage.	Input	4-Very significant	4-Very significant	4-Very significant	4-Very significant	4-Very significant	5-Absolutely include
ENV11	Water reuse	% of total water used that comes from reused/recycled water (operational reuse performance).	Process	4-Very significant	4-Very significant	4-Very significant	4-Very significant	4-Very significant	5-Absolutely include
ENV14	Reusable packaging system implemented	Implementation status and operational coverage of a reusable packaging system (returnable transport items / refillable or returnable packs), including defined return loops, cleaning/inspection where relevant, and tracking of cycles.	Process	3-Significant	4-Very significant	4-Very significant	4-Very significant	4-Very significant	5-Absolutely include
ENV15	Separate collection and traceable segregation	% of target waste/material streams that are source-separated and traceably recorded through handover.	Process	4-Very significant	3-Significant	5-Absolutely include	5-Absolutely include	5-Absolutely include	5-Absolutely include

Indicator code	Indicator name	Indicator description	Indicator level	Cost impact	Revenue impact	Risk exposure	Management control ability	Data availability	Strategic alignment
ENV16	Total waste generated	Total mass of waste generated from on-site operations during the reporting period, normalized by functional unit (includes hazardous + non-hazardous; exclude product/by-product intended for sale/use).	Output	5-Absolutely include	3-Significant	5-Absolutely include	5-Absolutely include	5-Absolutely include	5-Absolutely include
ENV19	Wastewater discharge volume	Total wastewater discharged off-site, per functional unit.	Output	4-Very significant	2-Barely significant	5-Absolutely include	4-Very significant	5-Absolutely include	5-Absolutely include
ENV20	Key wastewater pollutant loads	Pollutant mass loads discharged (COD/BOD, TSS, TN, TP as minimum), per functional unit.	Output	4-Very significant	2-Barely significant	5-Absolutely include	4-Very significant	4-Very significant	5-Absolutely include
ENV23	Water scarcity footprint	Water consumption weighted by local scarcity factors, per functional unit.	Impact	3-Significant	3-Significant	5-Absolutely include	2-Barely significant	2-Barely significant	5-Absolutely include
ENV29	Nitrogen surplus per hectare	Difference between nitrogen inputs (fertilizers, manure, feed) and nitrogen outputs (products and crops) per unit of land area, indicating potential nutrient losses to air and water.	Output	3-Significant	2-Barely significant	5-Absolutely include	3-Significant	3-Significant	5-Absolutely include
ENV33	Cleaning-in-place water intensity	Volume of water used for automated equipment cleaning per unit of processed product, representing hygiene efficiency and water resource management in food processing.	Input	4-Very significant	2-Barely significant	3-Significant	5-Absolutely include	4-Very significant	4-Very significant
ENV36	Refrigeration leakage factor	Annual loss of refrigerant gases from cooling systems relative to total refrigerant charge, indicating potential climate impact from fugitive emissions.	Output	4-Very significant	2-Barely significant	5-Absolutely include	4-Very significant	4-Very significant	5-Absolutely include

Indicator code	Indicator name	Indicator description	Indicator level	Cost impact	Revenue impact	Risk exposure	Management control ability	Data availability	Strategic alignment
ENV37	Heat recovery rate	Share of thermal energy captured and reused from industrial processes compared to total heat demand, reflecting energy efficiency and circular energy use.	Process	5-Absolutely include	3-Significant	4-Very significant	4-Very significant	4-Very significant	5-Absolutely include
ENV38	COD load per product	Amount of organic pollution (chemical oxygen demand) discharged in wastewater per unit of production, indicating material losses and water pollution intensity.	Output	4-Very significant	2-Barely significant	5-Absolutely include	4-Very significant	4-Very significant	5-Absolutely include
ENV40	Microplastic release risk	Potential quantity of microscopic plastic particles entering wastewater or the environment during processing or packaging operations, indicating emerging pollution risk.	Output	3-Significant	2-Barely significant	5-Absolutely include	2-Barely significant	2-Barely significant	4-Very significant
ENV41	Transport emission per milk collection	Greenhouse gas emissions generated during farm milk collection logistics per volume of milk transported, reflecting transport efficiency and supply chain footprint.	Impact	4-Very significant	3-Significant	4-Very significant	3-Significant	3-Significant	4-Very significant

Table B2. Economic indices

Indicator code	Indicator name	Indicator description	Indicator level	Cost impact	Revenue impact	Risk exposure	Management control ability	Data availability	Strategic alignment
ECON1	Circular Capital Expenditure (CAPEX)	Capital Expenditure (CAPEX) to circular technology, that is reuse/recycling infrastructure, resource-efficiency retrofits, valorisation equipment, reusable packaging systems	Input	3-Significant	3-Significant	5-Absolutely include	5-Absolutely include	5-Absolutely include	5-Absolutely include
ECON5	Investment in reusable packaging / reverse logistics systems	Tracks the capital expenditure (CAPEX) allocated to purchasing reusable assets (e.g., crates, kegs, bottles) and the infrastructure to retrieve them (reverse vending, washing lines).	Input	3-Significant	3-Significant	5-Absolutely include	5-Absolutely include	5-Absolutely include	5-Absolutely include
ECON10	Resource Cost Dependency	Cost of energy, water, and waste disposal per unit of output.	Input	5-Absolutely include	4-Very significant	5-Absolutely include	4-Very significant	5-Absolutely include	5-Absolutely include
ECON11	Material flow cost accounting (MFCA) / cost-to-serve accounting implemented	Assigns financial costs to waste streams.	Process	4-Very significant	3-Significant	3-Significant	3-Significant	2-Barely significant	4-Very significant
ECON13	Quality assurance protocol for secondary/by-product inputs	Tracks the existence of specific QA/QC procedures for inspecting incoming recycled materials or by-products. Unlike virgin materials, secondary inputs have high variability (impurities, contamination).	Process	2-Barely significant	3-Significant	5-Absolutely include	4-Very significant	4-Very significant	4-Very significant

Indicator code	Indicator name	Indicator description	Indicator level	Cost impact	Revenue impact	Risk exposure	Management control ability	Data availability	Strategic alignment
ECON15	Reverse logistics process performance tracking	Measures the efficiency of the "Take-Back" system. Unlike simple collection, this tracks the success rate of retrieving functional assets (crates, kegs) versus total units shipped.	Process	3-Significant	2-Barely significant	4-Very significant	4-Very significant	4-Very significant	5-Absolutely include
ECON16	Revenue from by-products / valorised residuals	Income from "waste" (e.g., selling pomegranate seeds, whey protein from milk, blood meal etc.) vs. core product.	Output	2-Barely significant	5-Absolutely include	3-Significant	5-Absolutely include	5-Absolutely include	4-Very significant
ECON21	Value added per Full-Time-Equivalent (FTE)	The indicator measures the economic value or net output (revenue minus non-labor costs) generated by each standardized full-time employee, including part-time staff adjusted to full-time hours. It serves as a key productivity metric, with higher values indicating greater efficiency and stronger human capital utilization.	Impact	4-Very significant	4-Very significant	3-Significant	3-Significant	5-Absolutely include	3-Significant
ECON24	Share of agri-food sales through Short Food Supply Chains (SFSC)	The proportion of agri-food sales achieved via short food supply chains (direct sales, local cooperatives, farmers' markets, local farm-to-fork schemes) in total agri-food sales in Romania.	Output	3-Significant	5-Absolutely include	4-Very significant	4-Very significant	4-Very significant	5-Absolutely include
ECON25	Material productivity	Economic value generated per unit of material input.	Impact	5-Absolutely include	3-Significant	4-Very significant	3-Significant	2-Barely significant	4-Very significant
ECON35	Waste disposal dependency	Proportion of total waste that requires external disposal instead of reuse or recovery.	Output	5-Absolutely include	2-Barely significant	5-Absolutely include	4-Very significant	4-Very significant	5-Absolutely include

Indicator code	Indicator name	Indicator description	Indicator level	Cost impact	Revenue impact	Risk exposure	Management control ability	Data availability	Strategic alignment
ECON36	Local sourcing rate	Percentage of raw materials or inputs obtained from local or regional suppliers.	Input	4-Very significant	3-Significant	5-Absolutely include	4-Very significant	4-Very significant	4-Very significant

Table B3. Sociall indices

Indicator code	Indicator name	Indicator description	Indicator level	Cost impact	Revenue impact	Risk exposure	Management control ability	Data availability	Strategic alignment
SOC2	Share of permanent employment	The indicator measures the percentage of employees holding contracts with no specific end date, compared to the total number of employees (including temporary staff). A higher share indicates greater labor market stability and job security, while a lower share suggests flexible, short-term work arrangements.	Input	3-Significant	2-Barely significant	3-Significant	4-Very significant	5-Absolutely include	3-Significant
SOC3	CE & Sustainability Training hours per FTE	Hours of training linked to CE & Sustainability practices (eg. waste valorisation, renewable energy management, water reuse and recycling, eco-design etc.) standardized per FTE	Input	4-Very significant	4-Very significant	4-Very significant	5-Absolutely include	4-Very significant	5-Absolutely include
SOC5	Occupational, Health and Safety (OHS) investment per FTE	It measures the average financial amount a company spends on safety, health, and wellbeing initiatives for each employee. It tracks the financial resources allocated to preventing workplace injuries and improving employee safety.	Input	5-Absolutely include	2-Barely significant	5-Absolutely include	5-Absolutely include	4-Very significant	5-Absolutely include
SOC9	OHS risk assessment updated for circular operations	Includes re-evaluating workplace hazards to account for non-linear processes like recycling, repair, and remanufacturing. It ensures safety when handling unknown waste, using recycled materials, or operating new, greener technologies, focusing on managing risks associated with waste-to-resource transitions.	Process	4-Very significant	2-Barely significant	5-Absolutely include	5-Absolutely include	3-Significant	5-Absolutely include

Indicator code	Indicator name	Indicator description	Indicator level	Cost impact	Revenue impact	Risk exposure	Management control ability	Data availability	Strategic alignment
SOC11	Agrifood business symbiosis governance	The indicator refers to the mechanisms, strategies, and institutions, such as local authorities, regulations, and partnerships, which facilitate collaboration between businesses of the agrifood sector to exchange materials, energy, and by-products (e.g., meat plant sending heat to nearby greenhouse).	Process	3-Significant	5-Absolutely include	4-Very significant	3-Significant	2-Barely significant	5-Absolutely include
SOC12	Traceability and Transparency Process for Circular Inputs	It includes the systematic tracking of the origin, processing, and destination of materials generated during production, rather than the primary product. It involves assigning unique batch identifiers to these materials, documenting their raw material sources, production date/conditions, and shipping routes to ensure quality control, regulatory compliance, and safety, allowing companies to quickly locate specific batches if issues arise.	Process	4-Very significant	4-Very significant	5-Absolutely include	4-Very significant	3-Significant	5-Absolutely include
SOC13	Share of employees trained	Share of workforce completing CE and sustainability related training	Output	3-Significant	3-Significant	3-Significant	5-Absolutely include	5-Absolutely include	4-Very significant
SOC14	Total Recordable Incident Rate (TRIR)	TRIR is a standardized, lagging safety metrics used to measure the frequency of workplace injuries per 100 hours worked. TRIR, which uses 200,000 hours to represent 100 full-time employees, normalize data to compare safety performance across companies of different sizes.	Output	5-Absolutely include	2-Barely significant	5-Absolutely include	4-Very significant	5-Absolutely include	5-Absolutely include

Indicator code	Indicator name	Indicator description	Indicator level	Cost impact	Revenue impact	Risk exposure	Management control ability	Data availability	Strategic alignment
SOC15	Active CE partnerships maintained	The indicator measures the number of ongoing, collaborative relationships between the firm and organizations, governments, or stakeholders focused on implementing circular or sustainable business models. It highlights the collaborative, socio-institutional efforts required to CE transition	Output	3-Significant	5-Absolutely include	4-Very significant	3-Significant	3-Significant	5-Absolutely include
SOC17	Employee retention rate	It describes a Human Resource (HR) metric measuring the percentage of employees who remain with a firm over a specific period, excluding new hires. It gauges organizational health, employee satisfaction, and the success of retention strategies, with high rates generally indicating 10% or lower turnover.	Impact	4-Very significant	3-Significant	4-Very significant	3-Significant	5-Absolutely include	4-Very significant
SOC18	Skills Competence Attainment	The indicator assesses the level of knowledge, skills, and attitudes an individual has acquired at a specific point in time. It validates the successful mastery and application of skills to meet specific standards, such as CE & sustainability related tasks, rather than just measuring years of schooling.	Impact	4-Very significant	4-Very significant	4-Very significant	4-Very significant	3-Significant	5-Absolutely include
SOC22	Injury frequency rate	Number of workplace injuries occurring per employee or per working hours, indicating occupational health and safety performance.	Impact	5-Absolutely include	2-Barely significant	5-Absolutely include	4-Very significant	5-Absolutely include	5-Absolutely include

Indicator code	Indicator name	Indicator description	Indicator level	Cost impact	Revenue impact	Risk exposure	Management control ability	Data availability	Strategic alignment
SOC28	Mortality before slaughter	Percentage of animals that die before slaughter during housing, handling, or transport stages.	Impact	4-Very significant	3-Significant	5-Absolutely include	4-Very significant	3-Significant	4-Very significant
SOC29	Transport stress index	Indicator of animal welfare during transport based on observed stress conditions such as overcrowding, travel duration, or injuries.	Process	3-Significant	2-Barely significant	5-Absolutely include	3-Significant	2-Barely significant	4-Very significant
SOC30	Food donation rate	Share of safe edible food diverted from waste and donated for human consumption.	Output	2-Barely significant	3-Significant	3-Significant	4-Very significant	4-Very significant	4-Very significant

Appendix C. Finally Selected indicators

Table C1. Finally selected indicators

Domain	Indicator level	Code	Indicator
Environmental	Input	ENV01	Total Water Input
Environmental	Input	ENV02	Total Energy Input
Environmental	Process	ENV03	Heat recovery rate
Environmental	Process	ENV04	Separate collection and traceable segregation
Environmental	Output	ENV05	Total waste generated
Environmental	Output	ENV06	Refrigeration leakage factor
Environmental	Impact	ENV07	Water scarcity footprint
Environmental	Impact	ENV08	Transport emission per raw material collection
Social	Input	SOC01	Occupational, Health and Safety (OHS) investment per FTE
Social	Input	SOC02	Share of permanent employment
Social	Process	SOC03	Traceability and Transparency Process for Circular Inputs
Social	Process	SOC04	Agrifood business symbiosis governance
Social	Output	SOC05	Share of employees trained
Social	Output	SOC06	Active CE partnerships maintained
Social	Impact	SOC07	Employee retention rate
Social	Impact	SOC08	Skills Competence Attainment
Economic	Input	ECON01	Resource Cost Dependency
Economic	Input	ECON02	Investment in reusable packaging / reverse logistics systems
Economic	Process	ECON03	Quality assurance protocol for secondary/by-product inputs

Domain	Indicator level	Code	Indicator
Economic	Process	ECON04	Material flow cost accounting (MFCA) / cost-to-serve accounting implemented
Economic	Output	ECON05	Share of agri-food sales through Short Food Supply Chains (SFSC)
Economic	Output	ECON06	Waste disposal dependency
Economic	Impact	ECON07	Material productivity
Economic	Impact	ECON08	Value added per Full-Time-Equivalent (FTE)

Appendix D. Final aggregated index

D1. Selection of weights between categories

For each row, choose the intensity of preference between the two items. The value **1** means equal importance. Values **2–9** closer to Item A mean increasing preference for Item A. Values **2–9** closer to Item B mean increasing preference for Item B.

Item A	Item A is more important								Equal	Item B is more important								Item B
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Environmental	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	Social
Environmental	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	Economic
Social	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	Economic

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D2. Selection of weights for the environmental indices

For each row, choose the intensity of preference between the two items. The value 1 means equal importance. Values 2–9 closer to Item A mean increasing preference for Item A. Values 2–9 closer to Item B mean increasing preference for Item B.

Item A	Item A is more important								Equal	Item B is more important								Item B
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
ENV01 – Total Water Input	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ENV02 – Total Energy Input
ENV01 – Total Water Input	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ENV03 – Heat recovery rate
ENV01 – Total Water Input	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ENV04 – Separate collection and traceable segregation
ENV01 – Total Water Input	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ENV05 – Total waste generated
ENV01 – Total Water Input	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ENV06 – Refrigeration leakage factor
ENV01 – Total Water Input	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ENV07 – Water scarcity footprint
ENV01 – Total Water Input	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ENV08 – Transport emission per raw material collection
ENV02 – Total Energy Input	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ENV03 – Heat recovery rate
ENV02 – Total Energy Input	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ENV04 – Separate collection and traceable segregation
ENV02 – Total Energy Input	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ENV05 – Total waste generated

ENV02 – Total Energy Input	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ENV06 – Refrigeration leakage factor
ENV02 – Total Energy Input	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ENV07 – Water scarcity footprint
ENV02 – Total Energy Input	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ENV08 – Transport emission per raw material collection
ENV03 – Heat recovery rate	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ENV04 – Separate collection and traceable segregation
ENV03 – Heat recovery rate	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ENV05 – Total waste generated
ENV03 – Heat recovery rate	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ENV06 – Refrigeration leakage factor
ENV03 – Heat recovery rate	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ENV07 – Water scarcity footprint
ENV03 – Heat recovery rate	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ENV08 – Transport emission per raw material collection
ENV04 – Separate collection and traceable segregation	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ENV05 – Total waste generated
ENV04 – Separate collection and traceable segregation	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ENV06 – Refrigeration leakage factor
ENV04 – Separate collection and traceable segregation	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ENV07 – Water scarcity footprint
ENV04 – Separate collection and traceable segregation	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ENV08 – Transport emission per raw material collection
ENV05 – Total waste generated	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ENV06 – Refrigeration leakage factor
ENV05 – Total waste generated	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	ENV07 – Water scarcity footprint

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
ENV05 – Total waste generated	◯ 9	◯ 8	◯ 7	◯ 6	◯ 5	◯ 4	◯ 3	◯ 2	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5	◯ 6	◯ 7	◯ 8	◯ 9	**ENV08 – Transport emission per raw material collection**
ENV06 – Refrigeration leakage factor	◯ 9	◯ 8	◯ 7	◯ 6	◯ 5	◯ 4	◯ 3	◯ 2	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5	◯ 6	◯ 7	◯ 8	◯ 9	**ENV07 – Water scarcity footprint**
ENV06 – Refrigeration leakage factor	◯ 9	◯ 8	◯ 7	◯ 6	◯ 5	◯ 4	◯ 3	◯ 2	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5	◯ 6	◯ 7	◯ 8	◯ 9	**ENV08 – Transport emission per raw material collection**
ENV07 – Water scarcity footprint	◯ 9	◯ 8	◯ 7	◯ 6	◯ 5	◯ 4	◯ 3	◯ 2	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5	◯ 6	◯ 7	◯ 8	◯ 9	**ENV08 – Transport emission per raw material collection**

D3. Selection of weights for the economic indices

For each row, choose the intensity of preference between the two items. The value **1** means equal importance. Values **2–9** closer to Item A mean increasing preference for Item A. Values **2–9** closer to Item B mean increasing preference for Item B.

Item A	Item A is more important								Equal	Item B is more important								Item B
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
ECON01 – Resource Cost Dependency	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ECON02 – Investment in reusable packaging / reverse logistics systems
ECON01 – Resource Cost Dependency	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ECON03 – Quality assurance protocol for secondary/by-product inputs
ECON01 – Resource Cost Dependency	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ECON04 – Material flow cost accounting (MFCA) / cost-to-serve accounting implemented
ECON01 – Resource Cost Dependency	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ECON05 – Share of agri-food sales through Short Food Supply Chains (SFSC)
ECON01 – Resource Cost Dependency	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ECON06 – Waste disposal dependency
ECON01 – Resource Cost Dependency	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ECON07 – Material productivity
ECON01 – Resource Cost Dependency	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ECON08 – Value added per Full-Time-Equivalent (FTE)

ECON02 – Investment in reusable packaging / reverse logistics systems	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ECON03 – Quality assurance protocol for secondary/by-product inputs
ECON02 – Investment in reusable packaging / reverse logistics systems	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ECON04 – Material flow cost accounting (MFCA) / cost-to-serve accounting implemented
ECON02 – Investment in reusable packaging / reverse logistics systems	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ECON05 – Share of agri-food sales through Short Food Supply Chains (SFSC)
ECON02 – Investment in reusable packaging / reverse logistics systems	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ECON06 – Waste disposal dependency
ECON02 – Investment in reusable packaging / reverse logistics systems	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ECON07 – Material productivity
ECON02 – Investment in reusable packaging / reverse logistics systems	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ECON08 – Value added per Full-Time-Equivalent (FTE)
ECON03 – Quality assurance protocol for secondary/by-product inputs	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ECON04 – Material flow cost accounting (MFCA) / cost-to-serve accounting implemented
ECON03 – Quality assurance protocol for secondary/by-product inputs	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ECON05 – Share of agri-food sales through Short Food Supply Chains (SFSC)
ECON03 – Quality assurance protocol for secondary/by-product inputs	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ECON06 – Waste disposal dependency

ECON02 – Investment in reusable packaging / reverse logistics systems	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ECON07 – Material productivity
ECON02 – Investment in reusable packaging / reverse logistics systems	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ECON08 – Value added per Full-Time-Equivalent (FTE)
ECON03 – Quality assurance protocol for secondary/by-product inputs	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ECON04 – Material flow cost accounting (MFCA) / cost-to-serve accounting implemented
ECON03 – Quality assurance protocol for secondary/by-product inputs	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ECON05 – Share of agri-food sales through Short Food Supply Chains (SFSC)
ECON03 – Quality assurance protocol for secondary/by-product inputs	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ECON06 – Waste disposal dependency
ECON03 – Quality assurance protocol for secondary/by-product inputs	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ECON07 – Material productivity
ECON03 – Quality assurance protocol for secondary/by-product inputs	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ECON08 – Value added per Full-Time-Equivalent (FTE)
ECON04 – Material flow cost accounting (MFCA) / cost-to-serve	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	ECON05 – Share of agri-food sales

ECON04 – Material flow cost accounting (MFCA) / cost-to-serve accounting implemented	◯ 9	◯ 8	◯ 7	◯ 6	◯ 5	◯ 4	◯ 3	◯ 2	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5	◯ 6	◯ 7	◯ 8	◯ 9	ECON06 – Waste disposal dependency
ECON04 – Material flow cost accounting (MFCA) / cost-to-serve accounting implemented	◯ 9	◯ 8	◯ 7	◯ 6	◯ 5	◯ 4	◯ 3	◯ 2	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5	◯ 6	◯ 7	◯ 8	◯ 9	ECON07 – Material productivity
ECON04 – Material flow cost accounting (MFCA) / cost-to-serve accounting implemented	◯ 9	◯ 8	◯ 7	◯ 6	◯ 5	◯ 4	◯ 3	◯ 2	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5	◯ 6	◯ 7	◯ 8	◯ 9	ECON08 – Value added per Full-Time-Equivalent (FTE)
ECON05 – Share of agri-food sales through Short Food Supply Chains (SFSC)	◯ 9	◯ 8	◯ 7	◯ 6	◯ 5	◯ 4	◯ 3	◯ 2	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5	◯ 6	◯ 7	◯ 8	◯ 9	ECON06 – Waste disposal dependency
ECON05 – Share of agri-food sales through Short Food Supply Chains (SFSC)	◯ 9	◯ 8	◯ 7	◯ 6	◯ 5	◯ 4	◯ 3	◯ 2	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5	◯ 6	◯ 7	◯ 8	◯ 9	ECON07 – Material productivity
ECON05 – Share of agri-food sales through Short Food Supply Chains (SFSC)	◯ 9	◯ 8	◯ 7	◯ 6	◯ 5	◯ 4	◯ 3	◯ 2	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5	◯ 6	◯ 7	◯ 8	◯ 9	ECON08 – Value added per Full-Time-Equivalent (FTE)
ECON06 – Waste disposal dependency	◯ 9	◯ 8	◯ 7	◯ 6	◯ 5	◯ 4	◯ 3	◯ 2	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5	◯ 6	◯ 7	◯ 8	◯ 9	ECON07 – Material productivity
ECON06 – Waste disposal dependency	◯ 9	◯ 8	◯ 7	◯ 6	◯ 5	◯ 4	◯ 3	◯ 2	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5	◯ 6	◯ 7	◯ 8	◯ 9	ECON08 – Value added per Full-Time-Equivalent (FTE)
ECON07 – Material productivity	◯ 9	◯ 8	◯ 7	◯ 6	◯ 5	◯ 4	◯ 3	◯ 2	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5	◯ 6	◯ 7	◯ 8	◯ 9	ECON08 – Value added per Full-Time-Equivalent (FTE)

D4. Selection of weights for the social indices

For each row, choose the intensity of preference between the two items. The value **1** means equal importance. Values **2–9** closer to Item A mean increasing preference for Item A. Values **2–9** closer to Item B mean increasing preference for Item B.

Item A	Item A is more important								Equal	Item B is more important								Item B
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
SOC01 – Occupational, Health and Safety (OHS) investment per FTE	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	SOC02 – Share of permanent employment
SOC01 – Occupational, Health and Safety (OHS) investment per FTE	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	SOC03 – Traceability and Transparency Process for Circular Inputs
SOC01 – Occupational, Health and Safety (OHS) investment per FTE	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	SOC04 – Agrifood business symbiosis governance
SOC01 – Occupational, Health and Safety (OHS) investment per FTE	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	SOC05 – Share of employees trained
SOC01 – Occupational, Health and Safety (OHS) investment per FTE	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	SOC06 – Active CE partnerships maintained
SOC01 – Occupational, Health and Safety (OHS) investment per FTE	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	SOC07 – Employee retention rate

SOC01 – Occupational, Health and Safety (OHS) investment per FTE	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	**SOC08 – Skills Competence Attainment**
SOC02 – Share of permanent employment	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	**SOC03 – Traceability and Transparency Process for Circular Inputs**
SOC02 – Share of permanent employment	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	**SOC04 – Agrifood business symbiosis governance**
SOC02 – Share of permanent employment	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	**SOC05 – Share of employees trained**
SOC02 – Share of permanent employment	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	**SOC06 – Active CE partnerships maintained**
SOC02 – Share of permanent employment	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	**SOC07 – Employee retention rate**
SOC02 – Share of permanent employment	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	**SOC08 – Skills Competence Attainment**
SOC03 – Traceability and Transparency Process for Circular Inputs	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	**SOC04 – Agrifood business symbiosis governance**
SOC03 – Traceability and Transparency Process for Circular Inputs	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	**SOC05 – Share of employees trained**

SOC03 – Traceability and Transparency Process for Circular Inputs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**SOC06 – Active CE partnerships maintained**
SOC03 – Traceability and Transparency Process for Circular Inputs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**SOC07 – Employee retention rate**
SOC03 – Traceability and Transparency Process for Circular Inputs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**SOC08 – Skills Competence Attainment**
SOC04 – Agrifood business symbiosis governance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**SOC05 – Share of employees trained**

SOC04 – Agrifood business symbiosis governance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**SOC06 – Active CE partnerships maintained**
SOC04 – Agrifood business symbiosis governance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**SOC07 – Employee retention rate**
SOC04 – Agrifood business symbiosis governance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**SOC08 – Skills Competence Attainment**
SOC05 – Share of employees trained	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**SOC06 – Active CE partnerships maintained**

SOC05 – Share of employees trained	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	**SOC07 – Employee retention rate**
SOC05 – Share of employees trained	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	**SOC08 – Skills Competence Attainment**
SOC06 – Active CE partnerships maintained	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	**SOC07 – Employee retention rate**
SOC06 – Active CE partnerships maintained	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	**SOC08 – Skills Competence Attainment**
SOC07 – Employee retention rate	○ 9	○ 8	○ 7	○ 6	○ 5	○ 4	○ 3	○ 2	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	**SOC08 – Skills Competence Attainment**