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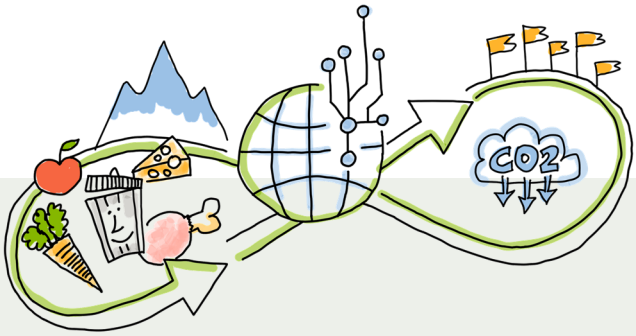
CEFoodCycle

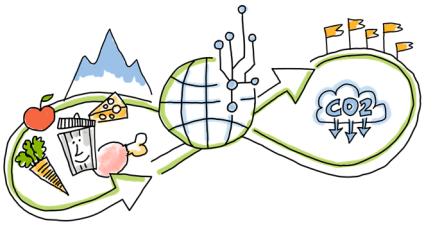


CEFoodCycles

Scaling foodcycle.ai: From vision to execution

O3.3 Part 2

This project is co-funded by the European Union through the Interreg Alpine Space programme.



This document is part of the research project CEFoodCycle: Circular Economy: Mapping Food Streams and Identifying Potentials to Close the Food Cycle (Interreg AS).

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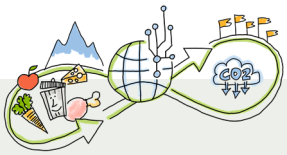

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Interreg Alpine Space

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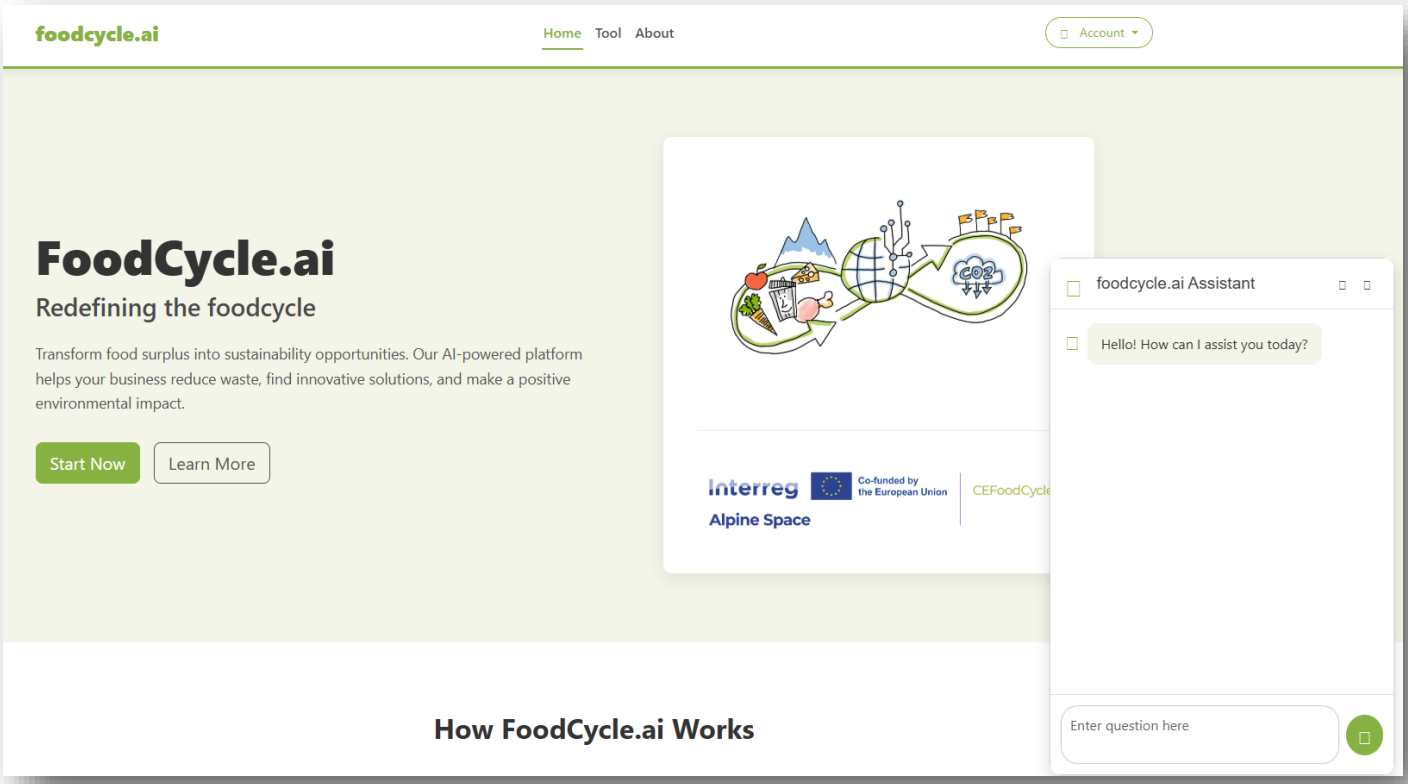
CEFoodCycle

This document represents part 2 of an Output 3.3 of the project CEFoodCycle. An in-depth analysis of selected business models identified data needed to develop an intelligent digital LCA Service system **Foodcycle.ai**.



Translating ideas into business potential

Pilot regions of our project have become a **joint, innovative space** for the hospitality sectors, farmers and companies that develop solutions based on a common transnational Circular economy (CE) framework involving closed food cycles. **Circular business models** were developed, showcasing their impact on regional value creation and innovation in local businesses. *Co-operation* helped our business models capitalise on the green economy by evaluating the potential of food waste.

A critical aspect of the CEFoodCycle initiative is the exploration of **digitalisation opportunities** to enhance business models, particularly through developing a Life Cycle Assessment (LCA) and a digital operating system that links waste to solutions. How to start the process? Several aspects need to be taken into account.

Assessing circular business models to identify digital information points

Circular business models were developed and tested through diverse pilot actions that address food waste prevention, reuse, and transformation into valuable products. To support these models with data-driven decision-making and **scalability**, it is essential to identify **key** (digital) **information points** needed for a **digital operating system**. Assessing circular business models involves **understanding how each pilot closes the food loop** — from the material and resource perspective (**environmental impact**), through the financial viability (**economic impact**), to the value stakeholders generate (**social impact**). From a **technical** standpoint, this includes evaluating waste input streams, the efficiency of processing technologies, the integration of digital tools and logistical feasibility of collecting, transforming, and distributing new products.

Whether repurposing spent grains into high-protein feed, transforming bakery surpluses for redistribution, or upcycling apple peels, old bread, or coffee grounds into edible or functional products, each pilot highlights opportunities to track, monitor, and optimise closed-loop processes.

*When combined, **financial viability, scalability** and **environmental impact** ensure that a circular business model is economically sound, socially responsible, and environmentally sustainable.*

Connecting hubs and pilots with AI-driven decision support

To effectively assess business models for the design of a *digital operating system*, many structured **data points** must be collected. Below is a checklist of essential information to collect:

- **General overview of each pilot:**
  - name and location,
  - business model description (*What specific circular economy solution does it implement?*),
  - primary aim (*e.g., waste reduction, resource efficiency, alternative food production, etc.*),
  - stakeholder involvement:
    - roles in the supply chain (key players: food producers/ suppliers, waste managers, processors/tech providers, policymakers/authorities, consumers/ end-users);
    - data-sharing needs across the network;
    - value creation at each stage of the cycle.
- **Material and process mapping:**
  - type and origin of inputs (e.g., food waste types - bakery, brewery, production byproducts),
  - material flow (processing technologies used, e.g., fermentation, redistribution, insect bioconversion),
  - output products (e.g., edible protein, new food products, bio-based materials, etc.),
  - waste conversion efficiency (e.g., % biomass yield, CO_2 reduction, nutrient recovery).
- **Economic model:**
  - revenue streams and product pricing,
  - cost structures related to circular transformation (e.g., logistics, processing, certification),
  - added value from upcycled outputs and market potential.

- **Environmental indicators:**
  - ◊ CO_2 footprint, energy/water/land use, biodiversity impact,
  - ◊ nutrient flows and footprint,
  - ◊ packaging and distribution footprint (e.g., logistics emissions, storage efficiency),
  - ◊ product's lifecycle phases,
  - ◊ comparative LCA data of circular vs. linear alternatives,
  - ◊ regulatory compliance (e.g., feed safety, hygiene, transport).

Extra step: *Define digitalisation needs by integrating digital solutions to optimise loops!*

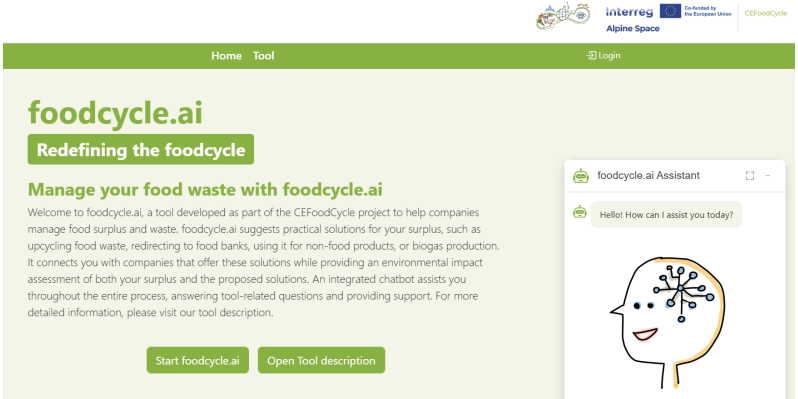
A comprehensive approach to **digitalising** circular food systems requires effective data-collection methods and integration strategies. Whether gathered manually or through automated systems, accurate tracking of resource inputs, process efficiencies, and waste outputs is vital for evaluating environmental impacts. Combining data from various sources across the food supply chain provides a *holistic perspective*, helping to identify where improvements can be made. Real-time monitoring of input-output flows enables immediate process adjustments, enhancing both efficiency and sustainability. The design of *user interfaces* must consider the diverse needs of stakeholders, including farmers, food processors, waste managers, and policymakers, ensuring that each group can easily access and interpret the relevant data. Equally important is *interoperability with existing platforms* and tools, such as food banks, logistics systems, and **LCA databases**. Integrating datasets from different actors requires standard formats and protocols. **AI tools** can further enhance decision-making, for example, by forecasting demand for surplus food redistribution.

The current gaps in LCA methodologies tailored to closed food loops must be addressed to improve assessment accuracy. Moreover, data privacy and security must be considered, particularly when handling sensitive information about waste streams or resource use. Lastly, there is a need for policy updates and standardisation to support the implementation and long-term viability of digital tools in circular economy practices.

UNDERSTANDING OF LCA

*In the CEFoodCycle project, we started by defining a **cross-regional Alpine-wide LCA methodology** related to food waste, using existing research combined with empirical research (qualitative and quantitative analysis) to underly the context of LCA in food streams and identify specific parameters that helped the hubs to understand specific challenges related to particular regions. This step led to the development of **joint syllabi**, including LCA data management of food streams and CO_2 emission impact in defined product categories as part of educational materials and a **transfer kit** for closed food cycles. All documents together form **guidelines** that can interest pilot organisations.*

More and more companies are choosing to conduct an LCA of their products to gain a competitive edge in the market. If they wish to dive deeper into the LCA process, hubs support those involved by offering a consulting session with an expert or organising a workshop or webinar.



Ready to conduct your LCA? For more information, see solutions developed in the CEFoodCycle project (O1.1)! With the help of our Intelligent Digital LCA Service System, you can choose to jump straight to obtaining your LCA report. The collected LCA data are integrated into the online platform Foodcylce.ai. The user can ask the Chatbot questions and receive additional information while obtaining an LCA report.

ECONOMICAL IMPACT AND BENEFITS

Financial viability determines whether the circular business model makes economic sense, both in the short and long term. The goal of this evaluation is to ensure the model not only reduces waste but also creates enough value to sustain itself without long-term reliance on grants. Organisations have to define whether the model works with different inputs (e.g., other types of food waste) or in different contexts (urban vs. rural), is the system modular, meaning flexible and adaptable (e.g., small BSF plants for farms vs. industrial-scale insect farming), are there enough willing partners in other regions (e.g., producers, logistics, tech providers) to replicate the model, legal and policy frameworks allow scaling (e.g., feed safety, food donation laws), technology is ready to be deployed without high technical barriers, can digital data from other pilots or regions be easily integrated into a common digital operating system, etc.

Organisations should assess:

- **market demand** (*Is there real, growing demand for the product? E.g., sustainable pet feed, eco-packaging, or food with "zero-waste" labels*),
- **subsidies or incentives** (*Are there public funds, tax benefits, or green investments that support the business?*),
- **revenue streams** (*Where does the income come from? E.g., selling upcycled products like insect protein, dried apple peels, or surplus food redistribution services.*),
- **cost structure** (*What are the fixed and variable costs involved? E.g., logistics, preprocessing, permits, technology, human resources, investments.*),
- **return on investment (ROI)** (*How long until the model becomes profitable?*),
- **price competitiveness** (*Can the circular product compete with traditional alternatives? E.g., soymeal vs. insect meal.*).

ENVIRONMENTAL IMPACT

To show measurable improvements in environmental performance over traditional linear business models— not just “less harm”, but a **positive regenerative effect** — an evaluation of the environmental impact of the model has to be prepared.

Organisations should assess:

- **waste reduction** (*How much food waste is prevented, reused, or transformed?*),
- **resource efficiency** (*How well are inputs of energy and nutrients converted into valuable outputs?*),
- **circularity index** (*What % of materials are re-entering the system rather than being discarded?*),
- **avoided impacts** (*What emissions or resource extraction would have occurred in a linear model? E.g., replacing soymeal with insect protein avoids deforestation.*),
- **LCA** (emissions, water usage, land use, biodiversity impacts across the product’s or service’s life cycle).

SOCIAL IMPACT

Should social information matter?

Considering the social aspect of your innovation is also important because it reveals risks and opportunities related to **trust, transparency, and collaboration** within and beyond the supply chain, ensures **digital equity** so new tools for optimisations are not only available for large or tech-savvy players, ensures broader sustainability, and it also strengthens **public acceptance**, which is key to policy alignment and long-term success.

To support a **just transition** to circular models, aks yourself:

- Who is involved in the pilots? Are vulnerable or underrepresented groups (e.g., small farmers, local processors) part of the loop?
- What is the role of community-based actors (schools, municipalities, cooperatives)?
- Do stakeholders have access to digital tools and the capacity to use them?
- Is training provided to ensure equal participation in digital transitions?
- Do new approaches create new jobs or skills?
- Has food redistribution improved?
- Are stakeholders satisfied with your circular solutions?
- Are social norms and consumption habits considered (e.g., attitudes toward insect feed, reused food)?
- *CEFoodCycle project-specific: Can the AI platform accommodate culturally sensitive or region-specific practices?*

INSIGHTS INTO *CEFoodCycle* BUSINESS MODELS FOR FOOD-WASTE CYCLES

In this section we outline the impacts (main benefits and constraints) of the proposed regional alternatives on population, industry, agriculture and the environment from social, environmentala and economic perspectives. When describing the business model of each **CEFoodCycle pilot**, it was essential to include core elements that define **how the pilot creates, delivers**, and **captures value** within the circular food economy. Economic viability depends on the consistency of input supply, processing costs, and market acceptance of the final products. Below is a structured approach based on the *business model canvas*.

Value proposition

- What **specific challenge** in the food system does the pilot address (e.g., food waste, inefficient resource use, supply-demand mismatch)?
- How does the pilot **create value** for different stakeholders (e.g., cost savings, new revenue streams, regulatory compliance, sustainability impact)?
- What are the **main benefits** for the food industry, policymakers, and consumers?

Customer segments

- Who are the **key customers** or beneficiaries of the pilot (e.g., food producers, waste management companies, retailers, policymakers)?
- What **challenges** do these customers face, and how does the pilot solve them?
- Does the pilot **serve niche markets** (e.g., insect-based feed for reptiles, circular bio-fertilizers) or **mass-market applications**?

Key activities

- What are the **core operations** involved in implementing the circular business model?
- What **technologies** and **processes** are used (e.g., LCA analysis, digital, AI-driven demand forecasting)?
- What are the **main steps** from raw material intake to the final product?

Key partners

- Which **organisations, businesses**, or **institutions** collaborate in the pilot?
- How do partners contribute (funding, technology, logistics, expertise)?
- What **role** do policymakers and regulatory bodies play in supporting scalability?

Revenue streams

- What are the **main sources of revenue** for the pilot (product sales, licensing fees, circular economy incentives)?
- Does the business model include subscription, pay-per-use, or one-time purchase models?
- How does the pricing strategy **compare** to **traditional** food waste management costs?

Cost structure

- What are the **key expenses** (e.g., logistics, energy consumption, processing technology, maintenance)?
- How does the expected **return on investment** (ROI) compare to the initial and ongoing costs?
- Are there any **policy incentives** or **grants** supporting financial viability?

DIGITALIZATION AND LCA INTEGRATION

How does the pilot use data and technology?

- ◊ *What **digital tools** are integrated?*
- ◊ *How does the pilot **track** and **analyde** environmental impact using LCA?*
- ◊ *What **data points are collected** to ensure sustainability and compliance?*

*A core component of the CEFoodCycle project is the alignment of business models with sustainability and digitalisation objectives. This is achieved through integrating **LCA** and using a **digital platform**.*

*The **digitalisation aspect** provides real-time tracking of inputs and outputs, helping stakeholders reduce food waste and CO_2 emissions while improving efficiency. **LCA** serves as the backbone for measuring environmental impact across food streams.*

***AI-driven analytics** optimise feed conversion efficiency.*

***LCA modelling** measures CO_2 footprint, water usage, and nutrient recycling.*

Foodcycle.ai — Sustainability and future scenarios

We identified three possible scenarios describing potential futures for the tool:

Scenario 1 — Expiration

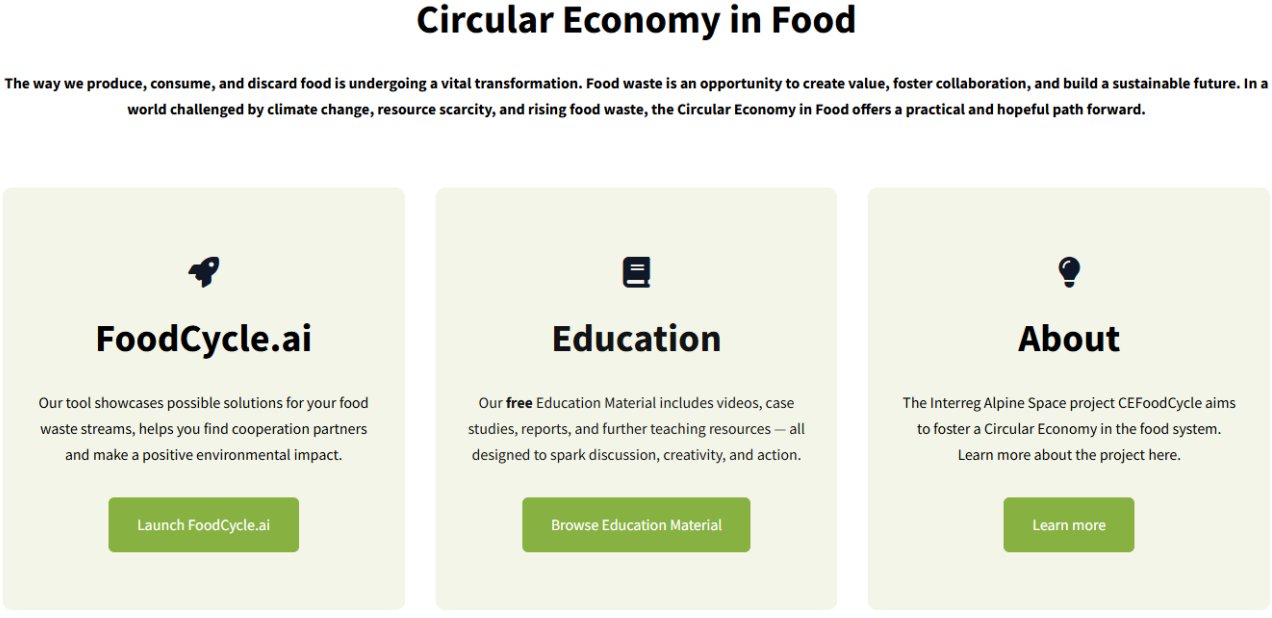
This scenario foresees the complete discontinuation of the Foodcycle.ai. The platform becomes inaccessible, no further development or support is provided, and no additional data or integrations are added. Although there are no ongoing costs, the tool's potential and value are entirely lost.

Scenario 2 – Bare Minimum

In this scenario, the Foodcycle.ai remains accessible online with minimal maintenance, hosted by a project partner. Active development, improvements, or integration of new datasets or features are not planned. User support is not guaranteed. The approximate annual operational cost is around €530, covering essential items such as API access, domain registration, and legal compliance.

Scenario 3 – Further Enhancement

This scenario involves continuous maintenance and strategic development of the tool, including integration of new datasets and possibly connectivity with external systems (e.g., VCG system). Achieving this scenario requires securing additional funding, technical resources, and staffing, including a dedicated software developer and external hosting. Under this scenario, Foodcycle.ai could effectively support broader regional and European-level circular economy initiatives.



https://foodcycle.ai/

COMPARATIVE ANALYSIS OF SCENARIOS BY COUNTRIES

Table 1: Potential scenarios by partners and countries.

Country	Scenario	Partner	Role	Key resources	Adoption conditions
	2	CCI NCA	food hub coordination	communication, awareness raising	low added value for stakeholders; upgraded features (list, infrastructure and routes info on public services)
	2	AVITEM	regional promoter		
	2	AIE	regional promoter	staff time, awareness raising	no funds; limited active use
	3	FHS	food hub coordination	server, curriculum, dissemination	needs educational integration; potential hosting support
	3	HM	strategic partner, educator	students and staff engagement, curriculum, R&D	policy integration; R&D support; new partner co-development
	3	UCB	content contributor, promoter	promotion, CE expertise	clarified governance & ownership; ability to reuse for new topics
	3	E-Institute	strategic partner, regional lead	project manage-ment, CE networks	needs roadmap, training, multilingual support
	3	BSC Kranj	food hub coordination	local stakeholder network	alignment with national food waste policies
	2	LAMORO	regional promoter	communication, awareness raising	needs external co-funding or strong private sector buy-in
	3	IDM	food hub coordination	network support, awareness raising	needs technical support; user license model possible

The experience of developing and piloting the Foodcycle.ai tool across five Alpine countries offers valuable insights and lessons for other stakeholders and consortiums looking to initiate or scale up CE business models in the food sector. The following recommendations focus on ensuring long-term impact, operational viability, and cross-sectoral cooperation:

1. Establish a clear governance model from the start.

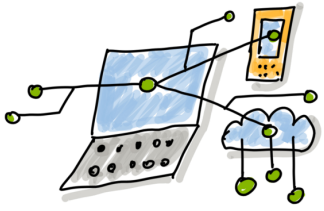
2. Secure mixed funding for sustainability.

3. Design for modularity and sectoral expansion.

4. Engage stakeholders through embedded education and communication.

5. Monitor, evaluate and communicate value.

6. Foster replication through open-access resources.



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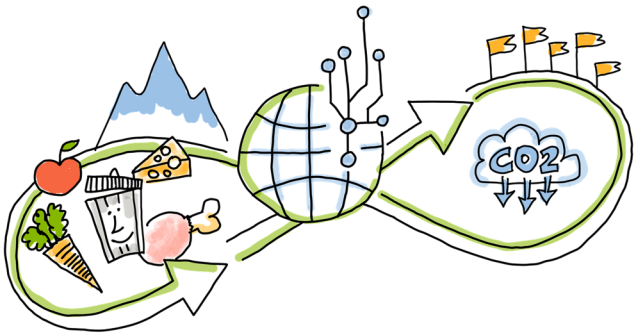

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