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SUSTAVIANFEED

ALTERNATIVE ANIMAL FEEDS IN MEDITERRANEAN POULTRY BREEDS TO OBTAIN SUSTAINABLE PRODUCTS

Guidelines for Circular Economy Business Models

DELIVERABLE 4.3

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Document Responsible	Juan Cortés Ortiz
Contributors	All
Reviewed by	ALIA
Approved by	ALIA

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SUMMARY

This project proposes solutions to the problems associated with the feeding of poultry for feed production. Among various resources, the project proposes innovative solutions to convert waste into feed, improve the efficiency of natural resource use and reduce environmental impact. This document invites to explore a different approach to agri-food production, transforming how we understand sustainability in poultry farming. Through the implementation of circular economy models, it aims to showcase concrete strategies and success stories that illustrate how the reuse of by-products, the optimisation of water and energy use, and collaboration between leading companies can redefine the agri-food sector.

With a practical and applicable approach, the document aims to provide a detailed guide for the development of sustainable models in poultry production and assesses their economic, social and environmental viability, showing the transformative potential of the circular economy. The document is presented as a practical and simple guide for any professional, researcher or entrepreneur interested in leading the change towards a more sustainable, resilient and competitive agriculture. At the same time, the document shows a glimpse example of the application of CEBM mainly in the Region of Murcia.

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Acronyms and abbreviations

Abbreviation	Description
BSF	Black Soldier Fly
CEBM	Circular Economy Business Model
TLCEBM	Three Layered Circular Economy Business Model

1 Introduction

The traditional economy consists mainly of a process of extracting raw materials, processing them, manufacturing goods, using them and finally disposing of them in landfills. Those items that we dispose of are considered waste because, by their nature, they would produce some kind of damage to the environment in which we live. On the contrary, in nature there is no such waste, since, in a way, what one organism produces, has a function to be exploited by the next organism, creating eternal cycles (see figure 1) of production and use that guarantee the sustainability of life. The circular economy builds on nature to create efficient production cycles and use in a sustainable way. Therefore, one of the fundamental premises of the circular economy concept is that the waste from one production process is the resource to start another production process. As might be expected, the production processes that can be integrated into the circular economy are those that include products that are recyclable and most significantly those that are organic in nature. There are several practices that are very well implemented with the circular economy such as:

1. **Waste is a resource**: This would be the main characteristic. Intuitively, all biodegradable materials move from one process to the next, producing valuable products at each stage. Those materials that are not biodegradable must have the capacity to be reused.

2. **Re-use**: this consists of using certain wastes or their parts to create other products that can still function in other applications.

3. **Repair:** which allows the same objects to be used repeatedly or at least until they can no longer be repaired.

4. **Recycling**: once the life cycle of a product is over, breaking it down and reforming its parts to be part of other processes.

5. **Revalorization:** which consists of using waste in other applications that have a value such as energy production.

6. **Functional economy**: which proposes the elimination of the sale of goods and the introduction of a concept of renting goods on a pay-as-you-go basis. Once the object is no longer functional, it's still functional parts could be reused.

7. **Renewable energy sources**: Eliminating fossil fuels throughout the life of the product, manufacture, use, reuse and recycling.

8. **Eco-design**: which creates products to take into account the impact of the product throughout its entire life cycle and reduces it from the moment it is planned to be created.

9. **Industrial and territorial ecology**: which organizes the economy of proximity by organizing industry to manage the flows of materials, energy and services.

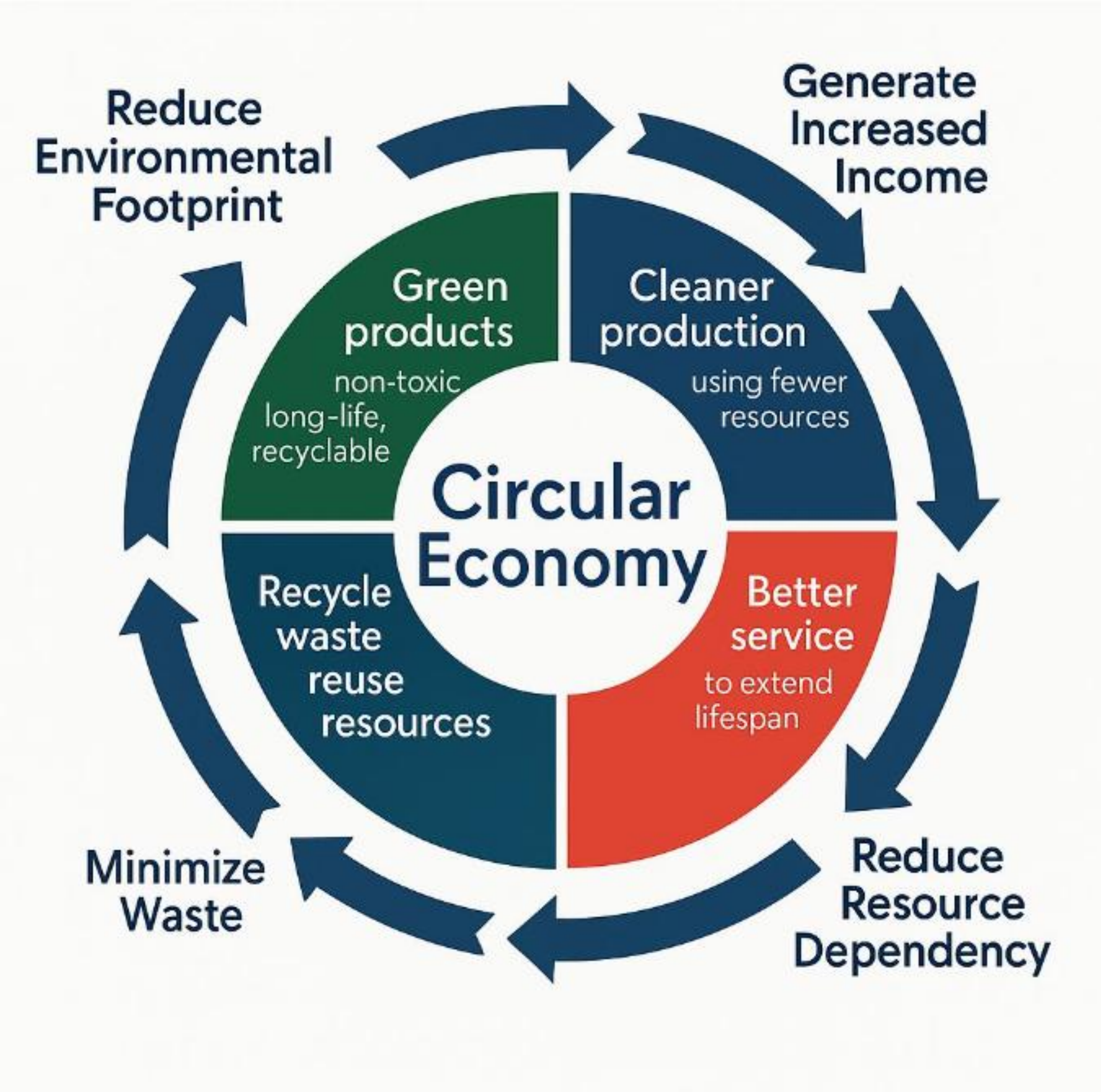

Figure 1. Scheme of circular economy approach

The circular economy is an economic model that seeks to optimize the use of resources, minimizing waste and promoting sustainability in production processes. In the agri-food sector, this approach is particularly relevant given that agriculture and food production are key sectors for global food security, but they are also major generators of waste and intensive consumers of natural resources.

The concept of circular economy in agribusiness focuses on closing resource cycles by reusing, recycling and valorising by-products and waste generated along the agri-food value chain. There are various ways of applying the circular economy in the agribusiness sector, such as:

1. Recycling of nutrients and organic waste: One of the important parts of the circular economy in agriculture is the reincorporation of organic waste into the production cycle. For example, agricultural

waste such as crop residues, leaves and stalks can be composted to produce natural fertilizers, reducing reliance on chemical fertilizers and improving soil health.

2. Use of by-products: Many by-products of the agri-food industry, which were previously considered waste, can be transformed into new products. One example is the use of fruit peels or vegetable waste to produce biogas or to produce animal feed, thus reducing waste and generating added value.

3. Optimization of water and energy resources: The circular economy also promotes the efficient use of water and energy in agriculture. Drip irrigation systems, rainwater harvesting and the implementation of renewable energy technologies on farms are practices that contribute to the reduction of resource consumption and the reduction of environmental impact.

4. Sustainable product and packaging design: In the food industry, the circular economy drives the design of products that generate less waste or are easier to recycle. This ranges from creating biodegradable packaging to reducing food losses through improvements in the supply chain and inventory management.

5. Innovation in production and distribution: The implementation of advanced technologies, such as precision agriculture and artificial intelligence, allows optimizing the use of inputs, improving yields and reducing waste along the entire agri-food value chain. In addition, business models based on proximity between producers and consumers, such as local markets or consumer cooperatives, also contribute to closing the cycles of the circular economy.

The transition to a circular economy in agribusiness not only helps to reduce environmental impacts but can also be a key strategy to increase the sector's resilience to challenges such as climate change, resource scarcity and fluctuations in international markets. Figure 2 shows examples of circularity in business models either in the agro or in the manufacturing sector.

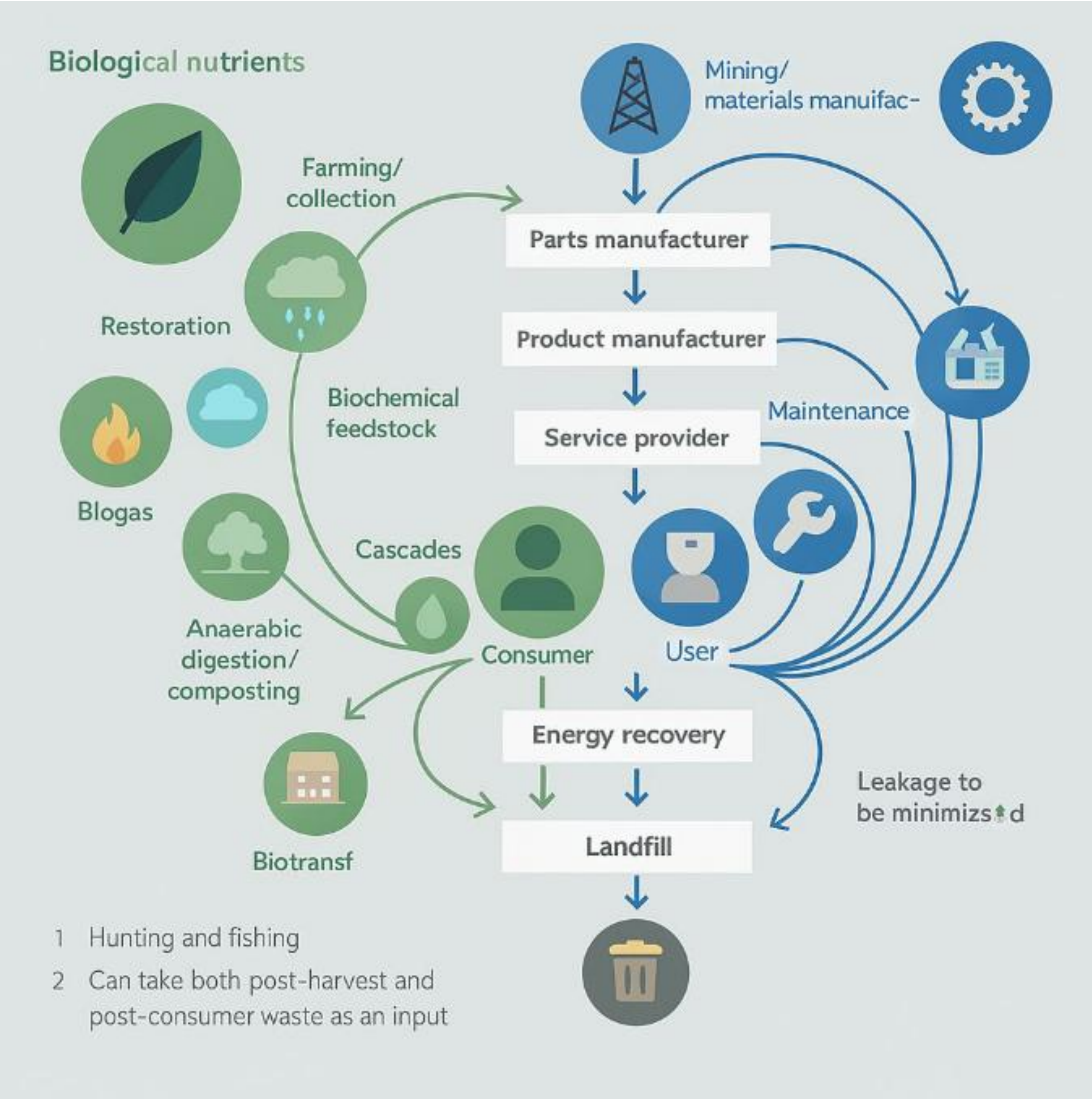

Figure 2. Scheme of CEBM interacting in the economy

Importance of sustainability in the agri-food industry.

There are several reasons why sustainability is important in the agri-food sector, such as food losses, environmental damage, economic viability or social welfare among others, which are described below.

The economic production losses and food waste in the agri-food industry.

Food waste and losses represent one of the most critical and complex challenges for the global agri-food industry, with profound economic repercussions. These phenomena not only imply an inefficient use of natural resources and increased pressure on the environment but also have a significant economic impact affecting all actors in the supply chain, from farmers to final consumers.

a. Impact on agricultural production

Food losses occur mainly in the early stages of the supply chain, such as production, storage and handling. Factors such as inefficient agricultural practices, lack of adequate infrastructure and adverse weather conditions contribute to large quantities of food being lost before reaching the market. According to FAO estimates, approximately 14% of food produced globally is lost between harvest and retail (FAO, 2019). These losses represent not only a direct waste of food, but also a significant economic loss for producers, who invest in inputs, labour and time that do not translate into income.

b. Losses in the supply and distribution chain

At the distribution stage, logistical inefficiencies and lack of adequate preservation technology increase food losses. For example, in developing countries, the lack of refrigeration systems during transport can lead to premature spoilage of perishable products, generating economic losses for both farmers and intermediaries (Gustavsson et al., 2011). In addition, in saturated markets, food that is not sold quickly is often discarded, representing inventory losses that affect profit margins for retailers and distributors.

c. Costs to consumers and society

Food wastage at the consumption stage also has significant economic repercussions. In many developed countries, consumers buy more food than they need, leading to large quantities of food ending up in the trash. This behavior not only represents a direct loss to households but also has a social and environmental cost by increasing demand for unnecessary food production, raising food prices and contributing to global food insecurity (Parfitt, Barthel, & Macnaughton, 2010).

d. Economic damage at macroeconomic level

At the macro level, food waste and losses contribute to the inefficiency of the global agri-food system. Food waste is estimated to have an annual economic cost of approximately USD 1 trillion globally (FAO, 2014). This enormous cost includes the loss of potential income for farmers, the additional costs for waste management and the impact on price stability in the market. In addition, food waste can destabilise markets, especially in times of scarcity, exacerbating price volatility and hurting the most vulnerable economies (HLPE, 2014).

As can be seen, food waste and losses in the agri-food industry are not only an ethical and environmental problem, but also a major source of economic damage at multiple levels. Reducing these losses requires a coordinated approach ranging from improvements in agricultural and logistical practices to changes in consumer behavior. Effectively addressing this problem would not only improve the efficiency of the agri-food system but also provide substantial global economic benefits.

Sustainability in the agri-food industry has become a central issue in policy and practice globally, especially within the European context. This importance lies in the need to ensure that food production systems can meet the needs of the present without compromising the ability of future generations to meet their own needs. Sustainability in this sector is not only about environmental protection, but also about economic viability and social welfare. In order to achieve sustainability, it is necessary to consider

Environmental Protection

The agri-food industry has a significant impact on the environment, from land use to greenhouse gas emissions and water consumption. Adopting sustainable practices, such as organic farming, crop rotation and reducing the use of pesticides and chemical fertilizers, is crucial to minimizing this impact. These practices help to preserve biodiversity, improve soil quality and reduce pollution of water resources (Garnett, 2013).

Economic Viability

For sustainability to be effective, it must also be economically viable. This means that sustainable agricultural and food practices must be profitable for producers and affordable for consumers. The implementation of innovative technologies, such as precision farming and the use of renewable energy can help reduce long-term costs and improve production efficiency (Pretty, 2008). In addition, promoting short marketing channels and supporting local markets contributes to economic sustainability by reducing import dependency and improving the sector's resilience to global market fluctuations (Marsden et al., 2000).

Social Welfare

Sustainability also involves promoting social welfare. This includes ensuring fair working conditions for agri-food workers, promoting equity in access to quality food, and ensuring long-term food security. Policies that support small-scale farmers, promote fair trade and ensure transparency in the supply chain are key to achieving these goals (Smith et al., 2010).

Contribution to Achieving the Sustainable Development Goals (SDGs)

Sustainability in the agri-food industry is also crucial to the achievement of the UN Sustainable Development Goals (SDGs), particularly those related to ending poverty (SDG 1), zero hunger (SDG 2), decent work and economic growth (SDG 8), climate action (SDG 13), and the life of terrestrial ecosystems (SDG 15). The adoption of sustainable practices in this sector contributes directly to the achievement of these goals, promoting inclusive development that respects the natural environment.

This makes it clear that sustainability in the agri-food industry is essential to ensure a future in which food production is sufficient, equitable and environmentally friendly. In the framework of European projects, adopting sustainable practices is not only a responsibility, but also an opportunity to lead in innovation and in the creation of a resilient and prosperous agri-food sector.

Entering in the Circular Economy Business Model

The circular economy is positioning itself as an essential approach to sustainability in various sectors, and the agri-food sector is no exception. This economic model seeks to break away from the traditional linear economy of "take, make and dispose of" and instead establishes a system where resources are used more efficiently, minimizing waste and maximizing the value of products during their life cycle. As described above, a model that is adapted to sustainability could include the following links in the value chain.

Utilization of agricultural by-products

One of the most common circular economy models in the agricultural sector is the use of by-products. Instead of discarding waste generated during agricultural production, it can be reused in the creation of new products. For example, crop residues such as fruit peels or cereal residues can be converted into biofuels, bioplastics, or even organic fertilizers (Ravindran & Jaiswal, 2016). This approach not only reduces waste but also provides a new source of income for producers, diversifying and strengthening their business model.

Nutrient recycling in closed farming systems

Nutrient recycling is another key model within the circular economy in agriculture. This model promotes the use of organic waste to reintroduce nutrients into the agricultural system, closing the nutrient cycle and reducing reliance on synthetic chemical fertilizers. For example, composting plant waste and animal manure can generate a natural fertilizer that improves soil fertility and promotes sustainable agricultural production (Ghisellini, Cialani, & Ulgiati, 2016). This approach not only decreases production costs but also improves environmental sustainability.

Innovation in sustainable packaging

Another emerging model is sustainable packaging innovation. Instead of using single-use plastic packaging, agri-food companies are adopting biodegradable, recyclable or reusable packaging. This not only helps to reduce environmental impact but also responds to growing consumer demand for more sustainable products (Lacy & Rutqvist, 2015). In addition, some businesses are exploring the use of edible packaging, made from agricultural by-products, which further contributes to waste reduction.

Regenerative agriculture and circular supply chains

Regenerative agriculture, which focuses on restoring and enhancing agricultural ecosystems, aligns closely with the principles of the circular economy. This model includes practices such as crop rotation, agroforestry and managed grazing, which regenerate soil health and increase biodiversity by closing nutrient and water cycles (Rhodes, 2017). By applying these principles, supply chains become more circular, minimizing the use of external inputs and reducing the environmental footprint of food production.

Reducing food waste

Reducing food waste is central to circular economic business models in the agri-food sector. Companies across the supply chain are adopting strategies to reuse or redistribute food that would otherwise go to waste. This ranges from optimizing harvesting and storage processes to transforming imperfect products into processed food or ingredients for other uses (Papargyropoulou et al., 2014). These practices not only help to reduce waste but can also create new business opportunities and increase the efficiency of the food system.

As can be seen, the agri-food sector is one of the sectors that can best apply circular business models by reducing the losses that occur in the centers where food is produced, distributed and consumed. By maximizing the value of resources and minimizing waste, these models not only improve environmental sustainability, but also offer new economic and competitive opportunities for companies in the sector. The transition to a circular economy in agriculture is therefore not only desirable, but necessary to ensure a more sustainable and resilient future (See D 4.1 for some examples of agrifood supply chain) .

How to create a business model based on the circular economy in the agri-food sector

Developing a business model based on the circular economy within the agri-food sector requires a reconfiguration of traditional approaches to prioritize sustainability, resource efficiency, and waste reduction. Generally speaking, the way to create such business models is based on a step-by-step approach to creating such a business model (see Figure 3)

Figure 3: steps to create a business model

1. Initial diagnosis and definition of purpose.

The first step in creating a circular business model is to conduct a thorough diagnosis of current operations. This involves identifying all resources used, from raw materials to energy and water, and mapping the flow of these resources along the value chain. In addition, the main sources of waste and inefficiencies must be identified.

The company's purpose should align with the principles of the circular economy: minimizing waste, keeping resources in use for as long as possible and regenerating natural systems. For example, an agri-food company might define its purpose as "maximizing the sustainability of agricultural production by reducing waste and reusing by-products".

2. Identification of opportunities for circularity.

Once the diagnosis has been made, the next step is to identify opportunities for circularity (see Figure 4). These may include:

a) Reuse of agricultural by-products: Transforming waste from agricultural production (such as husks, pulp, or pruning residues) into new products, such as biogas, compost, or ingredients for other foodstuffs.
b) Implementation of clean technologies: Use technologies that reduce resource consumption, such as efficient irrigation systems, renewable energies (e.g. solar energy for greenhouses), and precision farming techniques that optimize the use of inputs.

c) Closing nutrient cycles: Employ methods that allow nutrient recycling on the farm itself or in collaboration with other farms. This may include composting, use of biofertilizers or implementation of regenerative agriculture practices. However, for the purpose of this project, interaction with other entities is preferred.
d) Designing durable and recyclable products: Creating agri-food products that are easily recyclable or have an extended shelf life, thus minimizing waste.

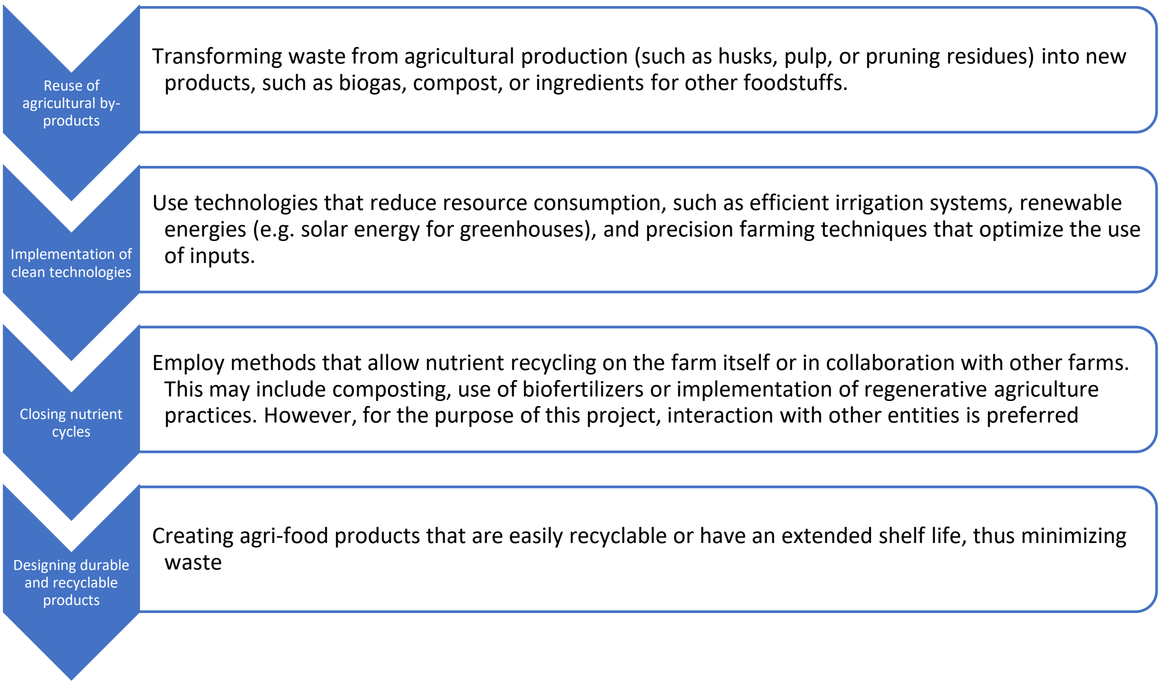

Figure 4: Identification of opportunities for circularity at any step of the value chain

3. Business model design

Once the opportunities have been identified, the creation of the CEBM can proceed. A good tool for the design is to use a CEBM CANVAS (see figure 5) Such a model should address the following aspects:

a) Value proposition: Define how the company offers value to its customers in a circular way. For example, a company can offer organic agricultural products produced using sustainable methods that regenerate the soil, or food made from recycled or reclaimed ingredients that would have been wasted.

b) Distribution channels and logistics: Establish how products will be distributed in a way that minimizes waste and maximizes efficiency. This may include the use of returnable or biodegradable packaging and optimization of transport routes to reduce the carbon footprint.

c) Customer relations: Educate and engage customers on the importance of the circular economy by offering incentives for returning packaging or participating in recycling programs.

d) Key partners: Identify and establish partnerships with other companies or organizations that can provide or exploit waste, share resources or collaborate in ecosystem regeneration.

e) Income streams: Diversify income sources by taking advantage of all by-products and waste, offering complementary services such as sustainability consultancy or the sale of processed by-products.

Circular Economy Business Model (CEBM) Canvas

Key partners:	Key CE resources:	CE value proposition:	Value creation and sharing:	Customer insights:
Who are the key partners? Feed manufacturers. Insect's companies. Technical and academic partners. Farmers (especially smallholders). Consumer and farmers associations. Retailers. **What are their roles (QH)? (in order)** Elaborating alternative feed. Insects rearing. Safety, nutritional and quality analysis as well as the environmental, social and economic evaluation. Actors to implement the developed solutions. Promoting the project approach. Offering the sustainable products. **How do the partners benefit from cooperation?** Each stage of the value chain benefits from sustainability and cost saving. **How does the customer experience the partners?** It is informed by consumer and farmers associations and in trade-fairs, workshops, awareness campaigns, etc.	**What CE materials and immaterial resources are required?** Agricultural by-products to feed insects and to include in the nutritional formula **Ecosystems:** **How do we develop multi-stakeholder value creation (CE strategies)** By valorization of agricultural waste Reducing nutritional needs in feed formula thanks to insects **How do we utilize and develop partners and resources?** Each of them has an specific role which is also needed for the development of the whole approach and a successful implementation.	**What is the CEBM value?** Sustainable nutritional formula to implement sustainable farming systems for high-quality and affordable poultry products. **What are the elements of CEBM?** Regional by-products and agricultural leftovers valorisation and avoid of organic waste. **What is unique in this CEBM?** Inclusion of insects in order to reduce the need of imported protein sources and study of the specific conditions of each region. **How does CEBM address CE?** Valorizing by-products and agri-food leftovers, using local ingredients and adapting the activities to local conditions.	**What is the value for customer?** Farmers: competitive and targeterd way of producing high-quality poultry products without adding high costs to the process. Consumer: product with high-added value because of its sustainability, and relevant sustainable information for the decision making. **What customer' challenges this CEBM solves?** To get sustainable products in an affordable way and to be able to decide which are the most sustainable products. **How can we support interaction between us and the company?** By organizations of trade fairs, workshops and other kind of events as well as with the support of online platforms.	**Why does the customer uses CEBM?** Farmers: it offers them new possibilities to develop and commercialize sustainable products. Consumers: feeling of reward related to the products' sustainability and curtomer awareness. **What are the benefits for a customer:** Farmers: Economic. Consumers: Functional, Emotional, Ethical, Social.

Cost structure:	Revenue logic:
What are the costs inherent in CEBM? Infrastructure for insects farming Logistics of agriculture by products Manufacturing costs of new nutritional formula	**What is the earning logic?** Sustainable feed manufacturers and farmers sectors benefit. The sustainability of the sector will increase their benefits. **How is revenue shared among key partners?** The key partners benefit because of the development of new business opportunities for all of them. **What are the KPIs of the CEBM success?** Comparison between the purchase of sustainable products and the number of farmers using this approach before and after.

Table 6. SUSTAvianFEED Circular Economy Business Model Canvas

Figure 5. CEBM CANVAS proposed by SUSTAvianFEED project

4. Implementation and prototyping

Before implementing on a large scale, it is advisable to prototype the circular business model in a specific part of the business. This allows for fine-tuning processes, identifying potential problems and refining the value proposition. For example, a farm could start a pilot project of composting agricultural waste to produce organic fertilizers and sell them in local markets.

5. Scaling and continuous optimization

Once the model has been tested and fine-tuned, the circular business is scaled up. This includes integrating circular practices throughout the operation, expanding into new markets and creating a continuous feedback loop for system improvement.

Furthermore, the circular economy requires a focus on continuous optimization. It is crucial to keep innovating, looking for new ways to reduce resource use, reuse materials and regenerate natural systems.

6. Impact measurement and communication

Finally, it is essential to measure the impact of circular activities. This involves establishing key performance indicators (KPIs) related to waste reduction, resource efficiency, and environmental regeneration. Communicating these results to customers, investors and other stakeholders can strengthen the company's reputation and increase commitment to sustainability.

This process not only minimizes environmental impact and operating costs, but also promotes a circular economy model, where waste is reused or transformed into new resources, adding value to both the agricultural and food service sectors.

2 Implementation

2.1 General considerations

The construction of a CEBM can be carried out in many ways, but for the development of this deliverable, a step-by-step process has been used to systematise the realisation of the CEBM. Each of the sections is elaborated with certain indications as to what information is interesting to obtain, how to organise the information or what operations should be carried out to reach conclusions and the creation of the model. However, it is not necessary to strictly follow all the points, and these points are reflected in the document so that it is up to the reader who intends to apply the guide to decide how extensive he/she wants to make his/her CEBM and how reliable he/she wants to present his/her conclusions. The information is rather agro focused as the SUSTAvianFEED project is focused on sustainable chicken production.

The information developed in this section is used as the basis for section 5. CEBM Murcia region, although in this case it is not carried out in its entirety but rather in a more summarised process that facilitates understanding of the model.

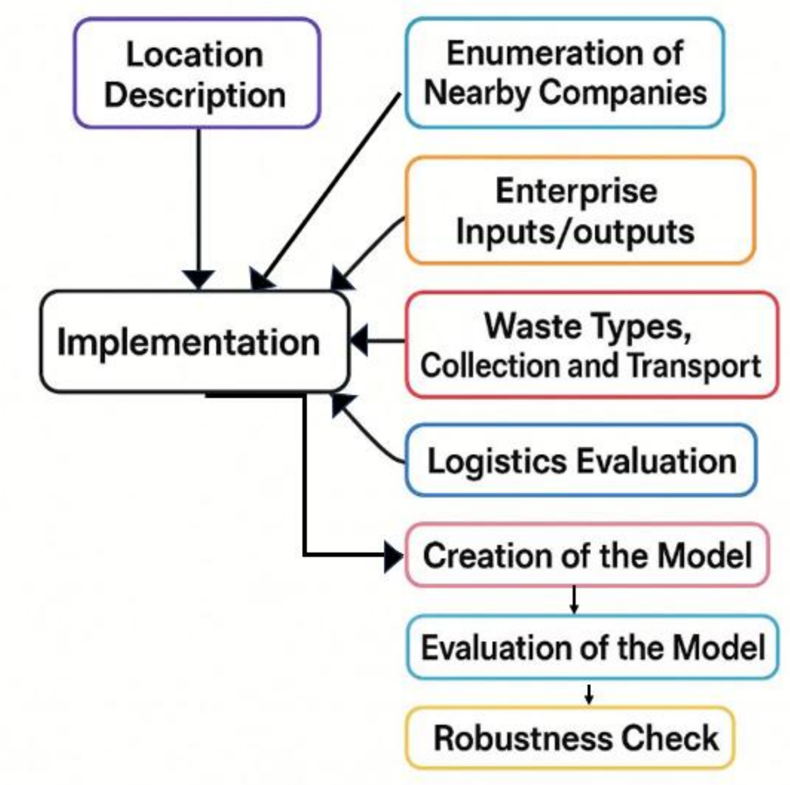

Figure 6. Scheme of info gathering and model creation to implement the design of the CEBM

2.2 Location description

Circular Economy models rely heavily on logistics in the movement of goods, as local use of products is expected and the carbon footprint associated with transport is minimized. To get a good overview of the possibilities and complexity of the model, it is necessary to start with a description of the localization.

Several factors are relevant in describing the geographical distribution but the key values to consider are:

Geographical Location

Coordinates: Latitude and longitude, relevant to climatic conditions affecting crops and livestock. This can be replaced by a descriptive geographical map.

Market access: Distance and accessibility to local and regional markets for the sale of agricultural and livestock products. This criterion affects the decision as to which goods are most in demand and worth generating.

Transport routes: Transport infrastructure to move agricultural and livestock products (roads, rural roads, railways).

2. Physical Aspects of the Territory

Topography: Relief of the terrain, which influences the type of grazing and cultivation. Identification of flat areas for cultivation and slopes for grazing. This also affects the creation of the model by determining the location of critical points.

Climate: Detailed information on temperatures, rainfall, and seasonality, which affect crop cycles and animal husbandry. This criterion is fundamental for one of the links in the model created here that depends on BSF production.

Soil: Soil types and their suitability for both agriculture and grazing. Carrying capacity of the soil for grazing.

Water Resources: Availability of water for irrigation and livestock, including natural water sources, wells and irrigation systems. It also influences decision-making, especially in locations where water is a scarce commodity.

3. Agronomic and Livestock Aspects

Crop types: Main crops that are integrated with the livestock activity (fodder, cereals, legumes). The type of crop also influences the by-products generated at field level that could potentially be used in the system.

Agricultural Yields: Productivity of crops related to animal feed and for sale.

Livestock: types of livestock (cattle, sheep, goats, pigs, etc.), predominant breeds, farming methods (extensive, intensive), pasture management.

Feed and Forage: Fodder production, available pastures, feed supplementation for livestock.

Management practices: Crop and livestock management techniques, pasture rotation, integrated crop and livestock management, sustainability practices.

4. **Agricultural and Livestock Infrastructure**

Irrigation systems: Availability and use of irrigation systems for both crops and pastures.

Livestock infrastructure: pens, stables, milking systems, animal handling areas, fodder storage.

Agricultural and Livestock Technology: Level of mechanisation, use of technology in animal husbandry (sensors, electronic identification), crop technology.

5. Socio-Economic Aspects Related to Agriculture and Livestock

Rural Population: Demographics, employment in the agricultural and livestock sector, roles of the population in these activities.

Land ownership and tenure: ownership structure of agricultural and livestock land, use rights, leasing.

Markets and Trade: Marketing channels for agricultural and livestock products, prices, access to local and international markets.

Government policies and support: Subsidies, incentives and support programmes for farmers and livestock farmers.

6. Challenges in the Agriculture and Livestock Activity

Climate Risks: Impact of adverse weather events on crops and livestock (drought, frost, floods).

Soil problems: Erosion, compaction, degradation of grasslands affecting both agricultural and livestock production.

Animal Health and Pests: Livestock health problems, pests and diseases affecting crops and animals.

7. Agricultural and Livestock Potential
Expansion Zones: Identification of areas with potential to expand crops or improve pastures.

Innovation: Possibilities to improve production through new technologies, improved livestock breeds, or new adapted crops.

Diversification: Opportunities to diversify production by incorporating new agricultural or livestock products.

8. Development Projects and Plans

Ongoing initiatives: Agricultural and livestock infrastructure improvement projects, rural development programs, sustainability initiatives.

Future Planning: Long-term strategies for integration of crop and livestock activities, development of new areas, improvement of existing practices.

2.3 Enumeration of nearby companies

To find and create a list of companies classified by type of product related to the agricultural world, the following steps are recommended:

1. **Defining the Typology of Agro-industrial Products**

Before starting the search, it is important to define what types of agro-industrial products you are interested in classifying. Some examples include:

- Primary agricultural products: fruits, vegetables, cereals, pulses.

- Processed products: oils, preserves, processed foods.

- Agricultural inputs: fertilisers, seeds, pesticides, agricultural machinery.

- Related services: agronomic consultancy, agricultural technology, irrigation systems.

2. **Using Company Databases**

Use specialized databases that allow you to search for companies by sector and product. Some of the most useful include:

- Kompass database: global database classifying companies by activity and product.

- Infoempresa.com: provides detailed information on companies in Spain, including the agricultural sector.

- Europages: European platform that allows you to search for suppliers and manufacturers by product type.

- AgroPages: a specific source for the agricultural sector with listings of companies in agrochemicals, fertilisers, machinery etc.

3. **Search Sector Directories and Associations**

Associations and federations of farmers and agribusinesses often have directories of their members classified by type of activity. Some examples:

- FEPEX (Spanish Federation of Fruit, Vegetable, Flowers and Live Plants Exporting Producers Associations).
- ASAJA (Asociación Agraria Jóvenes Agricultores): directories of agricultural services companies.
- AEPLA (Asociación Empresarial para la Protección de las Plantas): companies related to phytosanitary products.

4. **Using Advanced Google Search Tools**

Perform targeted Google searches using advanced search operators to filter by company type and product:

- Example search: site:.com "fertiliser company" AND "agriculture".
- Use keywords such as "suppliers", "manufacturers", "distributors" and product type to refine the results.

5. **Browse Agricultural Fairs and Events**

Trade fairs are an excellent source of contact with specialised companies. Check catalogues and participant listings for events such as:

- FIMA (International Fair of Agricultural Machinery)
- Fruit Attraction: list of fruit, vegetables and related technologies exhibitors.
- Agroexpo: an event that brings together suppliers of all kinds in the agricultural sector.

6. Organising the Information Collected

- Create a Spreadsheet: e.g. Excel or Google Sheets to list the companies. Sort by:
- Name of the company.
- Product Typology.
- Location.
- Contact (web, email, telephone).
- Remarks (services, specialities).
- Categorise by typology: Create specific columns for the typology of product and sector of activity, facilitating the segmentation of the data.

7. Verify Information

Check reliability: Ensure that the data collected is accurate by updating the list regularly and removing inactive companies.

8. Updating and Expanding the List

- Update regularly: Review the information at least once a year to keep the list relevant.
- Expand through referrals: Contact the listed companies to ask for referrals from other companies or related sectors.

2.4 Enterprise Inputs/outputs

The organization of company information in the agribusiness sector is essential to optimize operations, improve decision making and facilitate supply chain management. Properly classifying and managing the inputs (inputs) and outputs (outputs) of each company allows for better integration of processes, promotes efficiency and helps to identify opportunities for improvement. The following are the key steps to organize the information of agro-industrial companies considering their inputs and outputs.

1. Identification of Inputs and Outputs

The first step is to identify the main inputs and outputs of each company. In the agro context, these may vary according to the typology of the enterprise:

- Inputs: Resources and materials that the company uses for its production. Examples:

- Raw materials: seeds, fertilizers, pesticides, water, energy.

- Machinery and technology: tractors, irrigation systems, farm management software.

- Manpower and services: field staff, technicians, consultancy and maintenance services.

- Outputs: Products or services that the company generates. Examples:

Agricultural products: fruit, vegetables, cereals, dairy products.

- By-products and waste: manure, organic waste, recyclable materials.
- Services: agricultural consultancy, product transport, food processing.

2. Classification and Categorization of Information

Once the inputs and outputs have been identified, it is important to categorize the information to facilitate access and analysis. This categorisation can be done by:

- Product type: Agricultural (fruits, vegetables), Inputs (fertilizers, machinery), Services (logistics, consultancy).
- Production process: Cultivation, processing, storage, distribution.
- Value chain sector: Primary production, processing, distribution, marketing.

- This structure provides a clear overview of each stage of the production chain and facilitates the connection between suppliers, producers and consumers.

3. Creation of a Centralized Database

The information must be centralized in an accessible and well-organized database. For this purpose, data management software such as ERP (Enterprise Resource Planning) or CRM (Customer Relationship Management) adapted to the agribusiness sector can be used. The database should include:

- Company details: Name, location, type of activity.
- Inputs details: Type, quantity, supplier, cost.
- Details of Outputs: Type of product, production volume, customers, destination.
- Performance Indicators: Input use efficiency, productivity, waste generation.

4. Inputs and Outputs Relationship Matrix

To facilitate decision-making, it is useful to create a matrix relating inputs to outputs. This matrix allows visualizing how different resources influence production and the generation of products and by-products. It also helps to identify areas for improvement, such as waste reduction or optimization of resource use.

5. Sustainability and Life Cycle Analysis

It is essential to analyze the environmental impact of inputs and outputs. This analysis allows companies to identify opportunities to reduce their ecological footprint, such as the implementation of regenerative agriculture techniques, waste recycling or the reuse of by-products.

- Life Cycle Assessment (LCA): Analyses the environmental impact of products from the production of inputs to the final disposal of outputs.
- Sustainability measures: Use of renewable energy, reduction of chemical inputs, efficient water management.

6. Updating and Maintaining Information

Information must be constantly updated to reflect changes in production, changes in input prices or the emergence of new markets for products. Establishing processes for regular review and updating of data is crucial to maintain the relevance and accuracy of the database.

7. Data Visualisation and Reporting

Implementing data visualisation tools (dashboards, graphs) facilitates the analysis and presentation of information to teams and management. This improves responsiveness and enables continuous monitoring of key performance indicators.

2.5 Waste types, collection and transport

Organic waste in the agri-food industry is very varied and depends on the type of agricultural or livestock activity. The following cases can be distinguished by their abundance and typology:

1. **Crop residues**

- Crop residues: This is one of the most abundant residues in the agricultural industry. They include the stalks, leaves, husks and roots that remain after harvesting crops such as maize, wheat, rice, among others. They are highly bulky and are mainly used for composting or as feedstock for biofuels.
- Non-marketable fruits and vegetables: This type of waste comes from fruits and vegetables that do not meet the quality standards for sale. They are rich in nutrients and can be used in biogas production or as animal feed.

2. **Waste from Agro-industrial Processes**

- Beer bagasse: This is the fibrous residue left over after beer production. It is one of the most important wastes in countries with high beer production and is mainly used as feed for ruminants or for biogas production.
- Fruit peels and pulps: Derived from fruit processing for juices, jams, or preserves. They are abundant in the citrus, apples, grape, etc. industries, and are used for the production of organic compounds, biogas or as compost.
- Grain milling by-products: Residues such as bran, rice husks, and other by-products are used in animal feed, biofuel production, or composting.

3. **Livestock Waste**

- Manure and slurry: Manure and slurry are the most abundant waste from livestock farming. Manure comes mainly from cattle, pigs and poultry, and is widely used in soil fertilization, biogas production, and composting.
- Slaughterhouse waste: Includes bones, fat, blood and other by-products of animal slaughter. Used in the production of meat and bone meal, biodiesel, or for composting.

4. **Fishery and aquaculture wastes**

Fish and shellfish waste: These wastes include heads, bones, guts and skin. They are very common in the fishing industries and are used in the production of fishmeal, oils and organic fertilizers.

Ranking by Importance:

1. Crop residues: These are crucial because of their quantity and their potential to be used in biofuels.
2. Manure and slurry: Important for its use in fertilization and biogas production.
3. Beer bagasse: Significant in energy and material production.
4. ~~Beet bagasse: important because it is used in ruminant feed.~~

5. Slaughterhouse waste: Importance in the animal feed and biodiesel industry.
6. Fruit peels and pulps: Vital to produce organic compounds.

Classification by Quantity:

1. Harvest residues: These are the most abundant.
2. Manure and slurry: Produced in large quantities, especially in areas with high livestock activity.
3. Fruit peels and pulps: Highly generated in food processing industries.
4. Beer cane bagasse: Abundant in sugar-producing regions.
5. Slaughterhouse waste: Although not as abundant, it is significant in the production of by-products.

Typology:

- Solid waste: Crop residues, bagasse, husks, solid manure.
- Liquid waste: slurry, liquid waste from the agri-food industry.
- Semi-solid waste: Fruit pulp, fish waste.

Each of these wastes has a significant environmental and economic impact, and their proper management is crucial for the sustainability of the agri-food industry.

1. **Waste Identification and Classification**

- Agricultural waste: This includes crop residues (leaves, stems, roots), pruning residues, non-merchantable fruits and vegetables, among others.
- Restaurant waste: Composed of food leftovers, used oils, fruit and vegetable peels, leftovers from unserved food, among others.

Sorting: At each origin (agricultural farm, restaurant), waste should be pre-sorted into specific containers: organic (for composting/biogas) and non-organic (which could include packaging and recyclable materials).

2. **Collection Scheduling**

- Efficient Collection Routes: Routes are designed to minimize travel between different waste sources (farms, restaurants) and treatment or recycling centers. Routes should be planned considering the geographical proximity of the sources, thus reducing the distances traveled.
- Collection Frequency: An optimal collection frequency is established based on the amount of waste generated and the needs of the generators. For example, collection may be carried out on alternate days or at night to reduce traffic and fuel consumption.

3. **Efficient Vehicle Use**

- Low Emission Vehicles: Collection trucks running on alternative fuels (biofuels, electric, hybrid) are used to minimize the consumption of fossil fuels and the emission of polluting gases.
- Optimal Load Capacities: Vehicles should be designed to maximize load capacity, minimizing the number of trips required.

4. **Consolidation and Reverse Logistics**

- Consolidation Centers: Collected waste is taken to nearby consolidation centers, where it is bulked and prepared for processing. These centers act as intermediate points, reducing the need for long journeys from waste sources to treatment plants.
- Reverse logistics: Instead of returning empty, collection vehicles can take recycled products or compost back to farmers or distributors. This maximises the use of transport and reduces the need for additional trips.

5. **Waste Processing**

- Composting: Organic agricultural and restaurant waste is taken to composting plants, where it is decomposed to produce compost, which can be used as organic fertilizer in agriculture.
- Biogas production: Organic waste can also be treated in biogas plants, where it decomposes anaerobically to produce biogas (a renewable energy source) and digestate, which can also be used as fertilizer.
- By-product recycling: Used oils and other by-products (such as cardboard or plastics) are sent to recycling centres for processing and reuse in new applications.

6. **Continuous Monitoring and Optimisation**

- Fuel Consumption Monitoring: Monitoring systems are implemented in vehicles to track fuel consumption and optimize routes based on the data collected.
- Route Optimization: With the help of geographic information systems (GIS) and data analysis, collection routes can be continuously adjusted to further reduce resource consumption.
- Education and Training: Ongoing training of employees and sensitization of waste generators (farmers and restaurants) on the importance of proper waste segregation and collection efficiency.

7. **Expected results**

- Reduced Fuel Consumption: By optimizing routes and using efficient vehicles, fuel consumption is reduced.
- Resource savings: Waste consolidation and reverse logistics allow for better use of resources, both in transport and processing.
- Waste Valorization: Through composting, biogas production and recycling, what would be waste is transformed into useful resources, closing the life cycle of products and reducing environmental impact.

2.6 Logistics evaluation

Assessing the logistics of a process is crucial to optimize operations and reduce costs, but nowadays, it is equally important to minimize the environmental impact, especially the carbon footprint. Efficient logistics focuses not only on the movement of products, but also on the sustainability of each stage of the process, from the sourcing of raw materials to the final delivery to the customer. Below are the steps to assess and optimize the logistics of a process with a special focus on reducing the carbon footprint.

1. Mapping the Logistics Process

The first step is to map the entire logistics process to identify all stages that generate carbon emissions. This includes:

- Transport of raw materials.
- Storage and handling.
- Intermediate transport between production or distribution plants.
- Final delivery to the client.

It uses flow charts and process maps to visualise all logistical movements and activities involved.

2. Measuring the Carbon Footprint of Each Stage

For each identified step, calculate the carbon footprint using recognised tools and methodologies, such as the GHG Protocol (Greenhouse Gas Protocol) or specific tools such as the transport carbon footprint calculator. Key factors to measure include:

- Fuel consumption: in transport vehicles, loading and unloading machinery.
- Emissions from storage: energy consumption in storage facilities (lighting, air conditioning).
- Distance travelled and mode of transport: assess emissions associated with trucks, trains, ships, or aircraft.

3. Route and Mode Optimisation

Reducing distances and optimizing routes is one of the most effective methods to reduce carbon footprint. Consider the following strategies:

- Use of shorter and more efficient routes: use route optimization software to minimize transport distance and time.
- Shift to more sustainable modes of transport: prioritize the use of trains and ships over road and air transport, which generate higher emissions.
- Implementation of collaborative transport: sharing vehicles and loads with other companies to maximize capacity and reduce empty trips.

4. Use of Low Emission Vehicles and Technologies

The adoption of more efficient vehicles and clean technologies is crucial:

- Electric or hybrid vehicles: replacing diesel or petrol vehicles with cleaner options.
- Use of biofuels: integrating renewable fuels that generate lower CO_2 emissions.
- Regular maintenance and optimization of vehicles: proper maintenance reduces fuel consumption and emissions.

5. Storage and Handling Efficiency

Operations within warehouses also contribute to the carbon footprint. To minimize them:

- Storage space optimization: reduces the need for multiple installations and minimizes internal movements.
- Use of renewable energy: install solar panels, use LED lighting and energy management systems.
- Electric equipment: electric forklift trucks instead of internal combustion models.

6. Packaging Assessment and Reduction

The type and quantity of packaging significantly influences the weight and volume of shipments, affecting fuel consumption:

- Reduce unnecessary packaging: eliminate non-essential materials and use recycled and recyclable options.
- Lighter and more compact packaging reduces the weight of shipments, reducing fuel consumption.

7. Real-Time Monitoring Technology Implementation

It uses real-time monitoring systems and data analysis tools to continuously assess the efficiency and impact of logistics:

- Telemetry and GPS: to monitor fuel consumption and vehicle emissions in real time.
- Fleet management systems: optimize the planning and operation of logistics.
- Data analysis for demand forecasting reduces the need for express transport, which is often less efficient.

8. Carbon Offsetting

Where emission reductions are not possible, consider carbon offsetting:

- Purchase of carbon credits: to offset emissions generated by logistics activities.
- Reforestation and conservation projects: invest in initiatives that help absorb CO_2 .

9. Audits and Continuous Review

conducts regular logistics audits to assess compliance with carbon footprint reduction targets and adjusts strategies as necessary:

- Performance indicators (KPIs): tracking emissions per tonne transported, fuel efficiency, and percentage of sustainable transport use.
- Sustainability reporting: documents and communicates progress to stakeholders to reinforce the company's environmental commitment.

2.7 Selecting the interconnections and material flows

In the agro-industrial sector, focusing production on sustainability is particularly relevant, as it allows transforming organic waste into valuable inputs for new stages of the production cycle, reducing dependency on external resources and reducing environmental impact. The following is a guide to create a circular economic model considering the inputs and outputs of companies, logistics and the use of organic matter from crops, processing with the black soldier fly (Hermetia illucens), and poultry feed.

To make it easier to decide which companies participate in the model and to be able to create the model, we have chosen to use a selection matrix system, which is a very useful tool for comparing different resources, evaluating their characteristics and weighting each of them according to their relative importance, such as distance, quality of the goods to be transported, cost, etc. To carry it out:

1º) The evaluation criteria are chosen, such as: a) Distance; b) Cost; c) Quality; d) Availability; e) Environmental impact.

2º) These criteria are then assigned weights, which determine the importance of each criterion in the evaluation. For example, if distance is the most important factor, you can assign it a higher weight than the others. The sum of all weights must be 100%. In our case: a) quality 40%; b) cost 30%; c) distance 20%; d) availability 10%.

3º) the companies to be compared are ordered in the matrix with each of the resources they possess.

4º) Each resource is evaluated based on the criteria by assigning a score to each resource according to each criterion. For example, distance can be evaluated in kilometres and scored according to a range (e.g. 1-5 points, where 1 is far and 5 is near).

5º) Multiply scores by the weights assigned to each resource and each criterion, multiplying the score obtained by the weight assigned to the criterion. This will allow weighting the influence of each criterion, highlighting the most important ones, such as cost.

6º) Add the weighted scores of each resource. The resource with the highest total score will be the most suitable according to the defined criteria and weights.

7º) Analysis of matrix results to make informed decisions. If distance is a critical factor, ensure that its weight reflects this priority appropriately.

This method helps you select the resource that best suits CEBM, optimizing decision-making in an objective and structured way (see figure 3)

Example of a Selection Matrix:

Resource	Quality (40%)	Cost (30%)	Distance (20%)	Availability (10%)	Total Score
Resource A	4 (1.6)	3 (0.9)	5 (1.0)	2 (0.2)	3.7
Resource B	5 (2.0)	2 (0.6)	4 (0.8)	4 (0.4)	3.8
Resource C	3 (1.2)	5 (1.5)	3 (0.6)	5 (0.5)	3.8

Figure 7. Example of matrix evaluating/comparing different resources to feed the process.

1. Definition of the Inputs and Outputs of the Circular Model

The first step is to identify and classify the inputs and outputs of each stage of the agro-industrial process:

Inputs:

- Agricultural raw material: crops (fruit, vegetables, cereals).
- Energy: electricity, biogas.
- Water: for irrigation and cleaning processes.
- Black soldier fly larvae: as intermediate process for residues.

Outputs:

- Agricultural products: processed food, animal feed.
- Organic waste: crop residues, processing residues.
- By-products: organic fertilizers, larval frass, biofuels.

2. Circular Economy Cycle Mapping

The next step is to map the cycle of the economic model, visualizing how the outputs of one stage become inputs for another. The proposed cycle includes:

1. Agricultural Production:

- Cultivation of fruit, vegetables and cereals.

- Collection of agricultural products and generation of organic waste.

2. Organic Waste Management:

- Collection of agricultural residues (leaves, husks, plant remains).

- Transport of waste to a black soldier fly larvae processing plant.

3. Processed with Black Soldier Fly (Hermetia illucens):

- Organic waste is used as food for the larvae.

- Production of frass (organic fertiliser) and protein from larvae.

4. Poultry Feed Production and Feeding:

- The larvae are processed to produce protein-rich feed.

- Feeding hens and other poultry with the feed produced.

5. Recovery of poultry manure:

- The manure produced is collected and processed.

- Use of manure as organic fertilizer for crops.

3. Logistics Optimization to Minimize the Carbon Footprint

Logistics is a key element in the circular economy. For the model to be sustainable, the movement of materials and products must be optimized:

- Short and efficient routes: Design optimized routes to minimize waste and product transport distances.
- Use of sustainable transport: Adopt electric, biogas or shared vehicles to reduce emissions.
- Nearby logistics centers: Locate waste collection centers and processing plants close to the points of generation.

4. Economic Valuation of By-products

The generation of valuable by-products is a pillar of the circular model. Properly valuing these products is essential for economic viability:

- Larval frass: Can be marketed as an organic fertilizer, with a high added value in organic farming.
- Larval proteins: Used in the production of poultry and fish feed, reducing the need for more expensive protein sources such as soya or fish.

- Organic manure fertilizers: Reducing costs of chemical fertilizers, improving soil health and agricultural production.

5. Economic Modelling of the Process

The economic model should consider the costs and benefits of each stage of the circular cycle:

Costs:

- Crop production and processing.
- Transport and logistics of waste and products.
- Infrastructure and operation of the larval plant.
- Feed processing and manure management.

Benefits:

- Sale of agricultural products.
- Income from the sale of frass and larval proteins.
- Savings in fertiliser and animal feed costs.
- Improving sustainability and reducing the carbon footprint.

6. Technology Implementation and Monitoring

The use of advanced technology can optimize the circular model:

- Real-time data monitoring: Use of sensors and software to track waste production, efficiency of the larval process and quality of manure as fertilizer.
- Process automation: Minimizes operating costs in processing plants and improves efficiency.

- Blockchain and traceability: Ensures transparency in the value chain, especially for organic

products.

Figure 8. flowchart of the process to formulate of the CEBM

2.8 Creation of the model

There is a diversity of tools to create a CEBM, but one of the most useful tools is the use of the Triple Layered Business Model Canvas (TLBMC) in the Design of a Circular Economy Business Model (CEBM)

The Triple Layered Business Model Canvas (TLBMC) is an advanced strategic design tool that extends the traditional business model by incorporating three levels of analysis: economic, environmental, and social. This three-dimensional structure enables a holistic assessment of an organisation's value proposition, aligning business objectives with the sustainability principles of Circular Economy Business Models (CEBM).

The economic layer retains the elements of the original Business Model Canvas (Osterwalder & Pigneur, 2010), focusing on value creation, delivery, and capture. It supports the structuring of key activities, strategic partnerships, cost and revenue structures, and customer relationships.

The environmental layer introduces variables related to the ecological impact of the business model, such as material and energy use, emissions, waste, and processes for recycling and reuse. This analysis helps identify opportunities for improvement in resource efficiency, circular design, and the reduction of the ecological footprint.

The social layer addresses aspects such as employee wellbeing, working conditions, community impact, diversity and inclusion, and stakeholder value creation. This dimension reinforces the alignment with the Sustainable Development Goals (SDGs) and corporate social responsibility.

The use of the TLBMC in designing a CEBM facilitates the transition towards regenerative, resilient, and responsible business models. It offers a robust methodological framework to integrate sustainability into the core strategy of organisations. Its application is especially relevant in the context of the European Green Deal and the EU Circular Economy Action Plan.

How to Apply the Triple Layered Business Model Canvas (TLBMC)

The TLBMC is applied as a strategic analysis and design tool that enables the visualization, questioning, and redesign of business models by incorporating three key dimensions: economic, environmental, and social. Below is a step-by-step guide(see figure)

Figure 9. Step by step guide for TLCEBM

1. Define Purpose and Scope

Before starting, it is essential to clearly define what is the objective of the analysis (e.g., redesigning a business model towards circular economy principles), the product or service being analysed. And who are the main stakeholders involved.

2. Economic Layer

This layer follows the traditional Business Model Canvas by Osterwalder and Pigneur (2010), focusing on how the company creates, delivers, and captures economic value through nine core elements (see Figure 9)

- Customer Segments
- Value Proposition
- Channels
- Customer Relationships
- Revenue Streams
- Key Resources
- Key Activities
- Key Partnerships
- Cost Structure

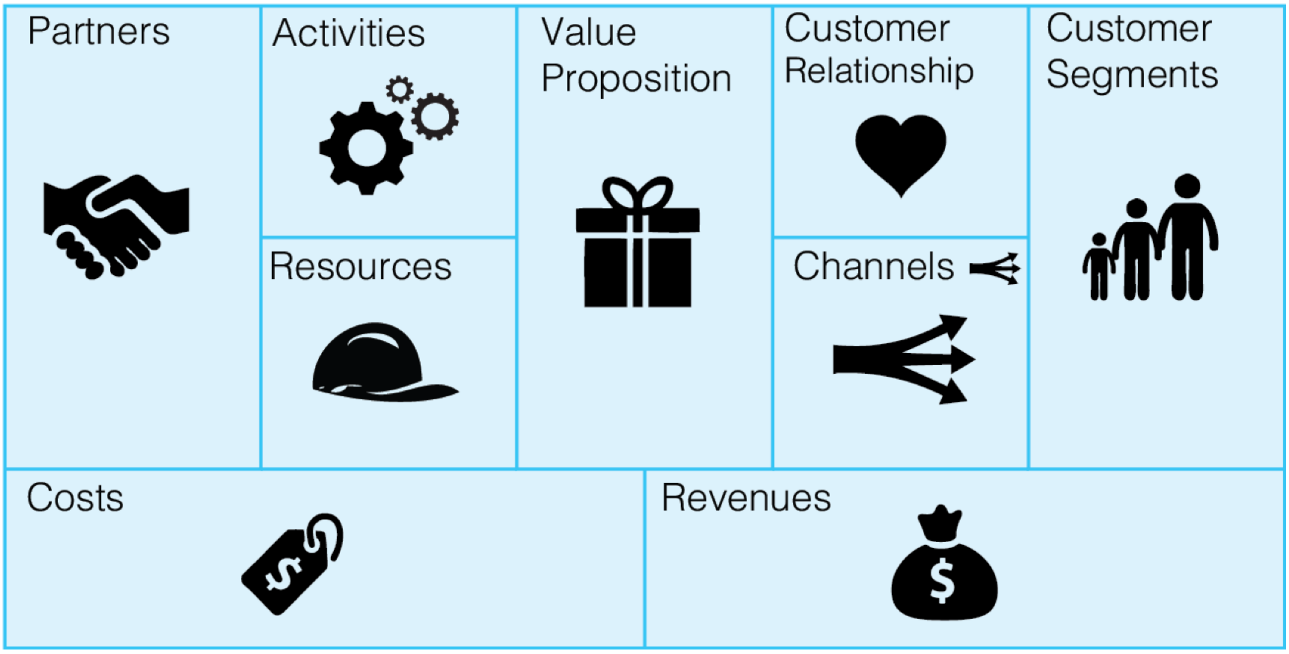

Figure 10: Economic layer of the TLCEBM (Pigneur et al. 2015)

3. Environmental Layer

This layer evaluates the environmental impact of the business model:

- Materials: use of raw materials (fossil, recycled, renewable, etc.).
- Energy: energy consumption and sources.
- Emissions: waste, CO_2 emissions, and other outputs.
- Distribution: logistics and transportation impacts.
- Product Use: efficiency, durability, and end-of-life.
- Infrastructure: sustainability of physical assets.
- Environmental Practices: actions to minimize environmental impact.

The goal is to identify opportunities for material loops, waste reduction, and circular design (see Figure 10)

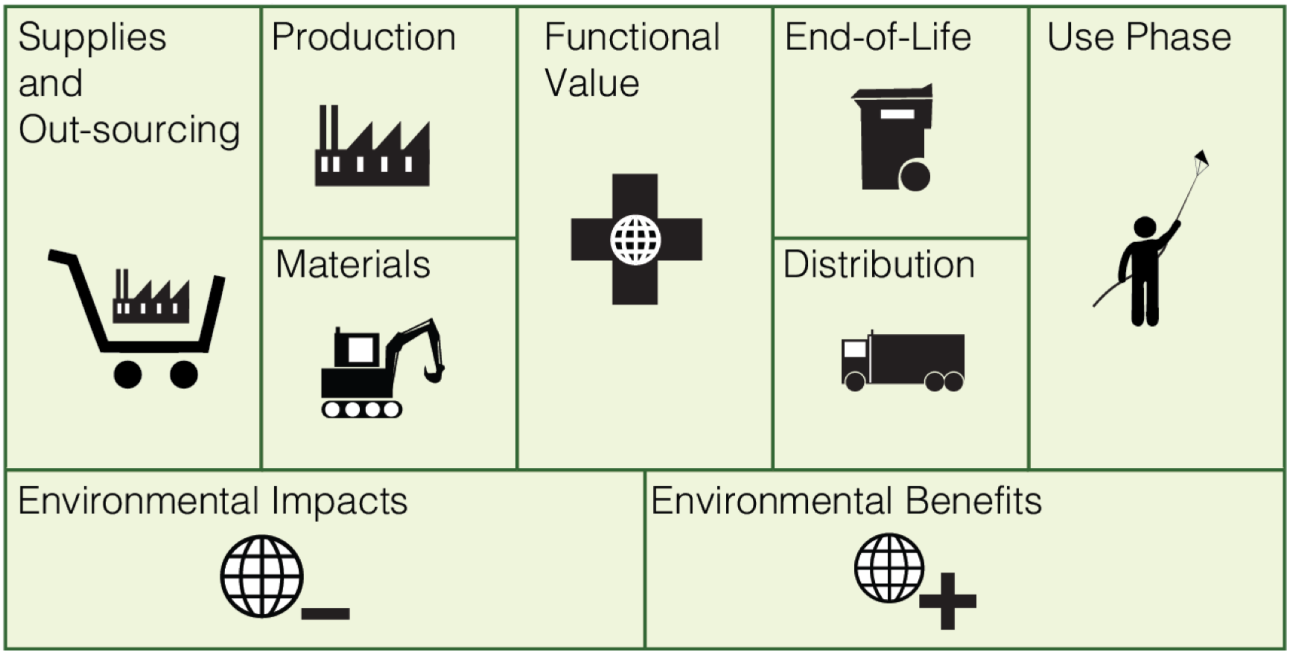

Figure 11. Environmental layer of the TLCEBM (Pigneur et al. 2015)

4. Social Layer

This layer analyses the social impact of the business model:

- Social Stakeholders: communities, employees, suppliers, etc.
- Social Value: non-economic benefits created for society.
- Working Conditions: job quality, equity, diversity.
- Human Relations: ethical interaction with employees and customers.
- Social Costs: negative impacts on society or communities.
- Human Capital and Networks: talent development and collaboration.

It helps align the business with the Sustainable Development Goals (SDGs) and corporate social responsibility (see Figure 11).

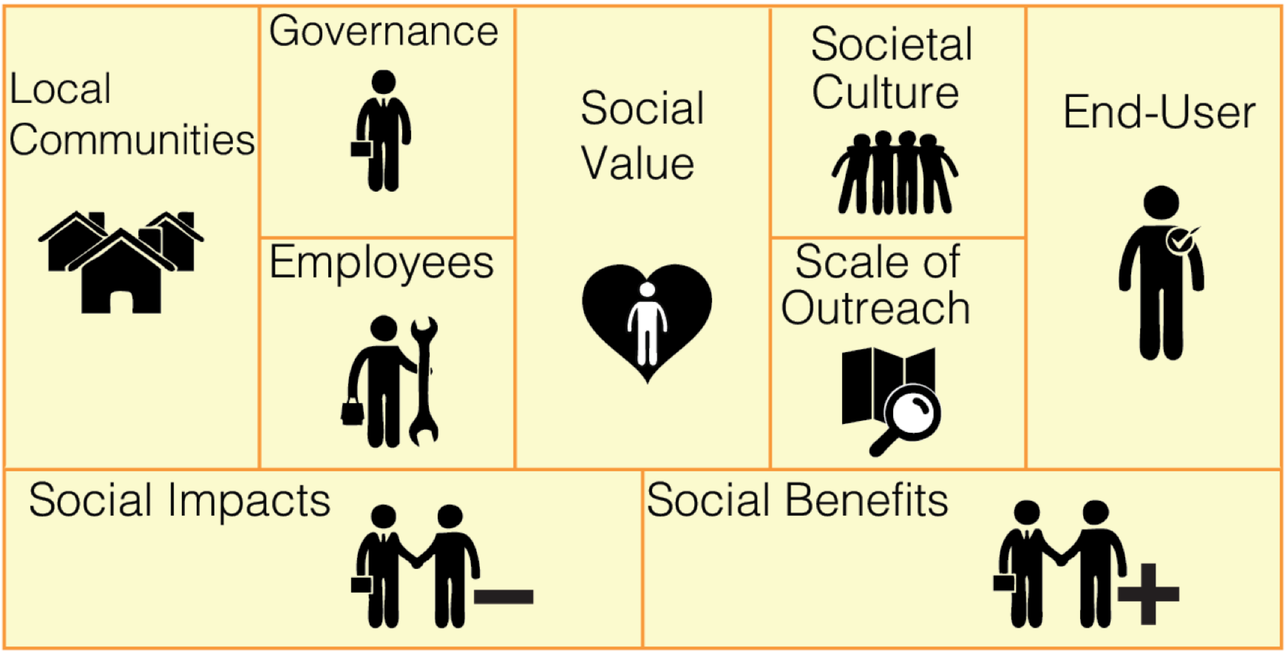

Figure 12: Social layer of the TLCEBM (Pigneur et al. 2015)

5. Integrated Analysis

Once all three layers are completed the next step is to compare the blocks across layers (e.g., how the economic value proposition aligns with environmental and social value), then Identify tensions, contradictions, or synergies and finally prioritize areas for improvement or innovation, guided by sustainability and circularity principles.

6. Business Model Redesign

Based on the analysis, the model is redesigned to enhance circularity (closing loops, reuse, regenerative design), were there is an inclusion (value for more stakeholders), producing a resilience (reduced social and environmental risks).

2.9 Evaluation of the model

Evaluating a business model based on the circular economy requires a multidimensional approach that considers not only financial performance, but also the benefits in terms of sustainability and the social impact generated. A circular economy model seeks to close production cycles, minimising waste and maximising the use of resources, which implies a more complex assessment than traditional models. The main ways to evaluate a circular business model from a financial, sustainability and social impact point of view are described below.

1. Financial Assessment of the Circular Business Model

The financial evaluation focuses on the profitability and economic viability of the model. Key aspects include:

1.1 Cost Benefit Analysis

- Reduced operating costs: Evaluates the savings generated by reducing the use of virgin raw materials, energy and water. For example, the use of waste as an input significantly reduces production costs.
- Income from by-products: Identifies new sources of income from the sale of by-products, such as organic fertilisers or animal feed, derived from agro-industrial waste.
- Waste management savings: Recycling and reuse of materials reduces the costs associated with waste disposal.

1.2 Return on Investment (ROI) analysis

Calculate the ROI by considering the initial investments in recycling technologies, logistics and waste processing. It is important to compare this return with traditional metrics to validate the economic viability of the circular model.

1.3 Cash Flow and Cash Conversion Cycle

- Operating cash flow: Assesses how circular operations impact cash generation. Positive cash flow is essential to maintain the viability of the business.
- Cash conversion cycle: A circular model can reduce the cycle by reusing internal resources, improving liquidity.

1.4 Financial Risk Analysis

- Market risks: Assesses the sensitivity of the model to price fluctuations in the markets for recycled inputs and by-products.
- Regulatory risks: Consider dependence on government incentives or environmental regulations that may affect the financial model.

2. Sustainability Assessment of the Circular Model

Sustainability is a central pillar in circular models and is measured through the positive environmental impact generated by the business. Key indicators include:

2.1 Carbon Footprint Analysis and Emission Reductions

- Measuring CO_2 emissions: Evaluates the number of emissions avoided by using recycled materials or implementing renewable energies. Compares the emissions of the circular model with those of a traditional linear model.
- Ecological footprint reduction: Calculates the reduction in the use of natural resources such as water, land and fossil fuels.

2.2 Resource Efficiency

- Materials reuse index: Measures the proportion of reused materials compared to virgin materials.
- Water and energy efficiency: Evaluates the reduction in consumption of these key resources along the entire value chain.

2.3 Waste Management and Zero Waste Economy

- Recycling and recovery rate: Calculates the percentage of waste that is recycled or reused in the production process.
- Hazardous waste avoidance: Measures the reduction in the generation of toxic waste or waste that is difficult to treat.

2.4 Regulatory Compliance and Environmental Certifications

- Sustainability certifications: Consider certifications such as ISO 14001, EMAS, or eco-labels that validate the company's sustainable processes.
- Compliance with circular economy policies: Assesses alignment with local and international sustainability regulations.

3. Social Impact Assessment of the Circular Model

Social impact measures how the circular model contributes to the well-being of communities and employees, and is analysed through the following factors:

3.1 Job Creation and Working Conditions

- New job opportunities: Evaluates the number of jobs created in areas such as recycling, logistics, and waste recovery processes.
- Quality of employment: Consider whether the jobs generated are secure, well paid and offer opportunities for career development.

3.2 Local Community Impact

- Improved quality of life: Measures how waste reduction and improved agricultural practices impact on the health and well-being of the community.
- Education and awareness-raising: Evaluates training and awareness-raising initiatives on sustainable practices aimed at employees, suppliers and consumers.

3.3 Inclusion and Equity

- Participation of vulnerable groups: Analyse whether the model includes opportunities for women, youth and other vulnerable groups.
- Inclusive value chain development: Assesses whether the circular economy benefits small businesses and local farmers.

3.4 Contribution to Food Security

Contribution to sustainable food production: Assesses whether the use of by-products, such as poultry feed or organic fertilisers, improves the sustainability of the food system.

2.10 Robustness check

Robustness analysis (or robustness testing) is a technique used in research and data analysis to assess the reliability and stability of the results obtained in a statistical or econometric model. Its main objective is to determine whether the results are consistent and valid under different conditions or assumptions, which increases the credibility and confidence in the conclusions of the study.

What is a Robustness Check?

The Robustness Check consists of verifying whether the results of an analysis remain stable and significant when changes are made to assumptions, variables, methodologies or data sets. It is a way of assessing the sensitivity of the model to different variations and checking that the findings are not the product of arbitrary specifications or modelling errors.

In simple terms, it is like "testing" the results under different scenarios to make sure that they do not change drastically, which would indicate that the initial results are robust and do not depend on a single set of assumptions.

When is a Robustness Check used?

Robustness Checks are especially important in economic, financial, scientific and public policy studies, where decisions must be based on robust conclusions. They are used in:

- Econometric models: to validate the relationship between variables.
- Regression analysis: to check the stability of the coefficients.
- Financial forecasting: to ensure the reliability of predictive models.
- Experimental and quasi-experimental research: to verify that the results are not sensitive to changes in the study design.

Conducting a robustness analysis

To carry out a Robustness Check, several steps are followed that involve modifying or adjusting the original model and observing how the results behave. The key steps are detailed below:

1. Identifying Key Model Assumptions and Specifications

The first step is to identify which aspects of the original model might be influencing the results. This includes:

- Variables included in the model.
- Statistical assumptions (linearity, homoscedasticity, normality).
- Estimation methods used (Least Squares, OLS, etc.).
- Definitions of dependent and independent variables.

2. Modification of Model Assumptions and finding the stress factors

Stress factors are those one than could affect the model in a negative way in the future. Example of that factors are petrol or electricity pricing, economical changes, global warming, water scarcity and so on. Also, changes can be made to the model to observe which things could affect the model.

- Changes in model specifications: Test with different combinations of independent variables or excluding variables that could be generating biases.
- Use of different estimation methods: Use alternative methods to check whether the coefficients remain stable (e.g. use linear regression instead of logistic regression).

- Transformations of variables: Test with logarithmic, quadratic or other transformations that may affect the interpretation of the results.

3. Create a matrix to compare which changes will affect the model more

Creating a matrix to compare how different factors affect the model and which one will have a deeper effect on the model. Then, if the factor changing forecast a model collapses, it the saying factor could be considered a threat for the model. Comparing different models and how do they behave for the same stress factor helps to decide which model is more robust.

4. Use of Alternative Data or Different Time Series

If possible, use alternative data sources to check if the results are replicated with different data sets. This is especially useful in timing and prediction studies.

- Data from different periods: Evaluates whether results are consistent at different points in time.
- Data from independent sources: Compares results using data from different surveys or databases.

5. Parameter Sensitivity Analysis

Modify the values of key parameters to assess the sensitivity of the model:

- Sensitivity test: Slightly change the values of the model parameters and see if the results change significantly.
- Confidence intervals: Widen the confidence intervals of the coefficients and check whether the results remain within acceptable ranges.

3 Resources and tools

For the implementation of circular economy business models, various technological tools, databases and contacts of interest are essential. At the moment the following are available.

3.1 Technological tools

1. Circularity Assessment Tool (CAT): A tool for assessing the circularity of a company or product. (https://cat.ganbatte.world/)
2. Circulytics: Developed by the Ellen MacArthur Foundation, it assesses the circularity of companies by providing detailed data for improvement (https://www.thecircularlab.com/).
3. EcoChain: Platform for measuring and managing environmental impact and carbon footprint, optimising circular product design (https://ecochain.com/)
4. ReSOLVE Framework: Strategic tool that helps to design circular business models (Regenerate, Share, Optimise, Loop, Virtualize, Exchange).
5. SimaPro: Life Cycle Assessment (LCA) software that helps companies measure the sustainability of their products and services.
6. GaBi: Another LCA tool to model and analyse the environmental impact of products throughout their life cycle.

3.2 Databases

The following databases may be useful in helping to create the CEBM:

1. European Circular Economy Stakeholder Platform (ECESP): Repository of case studies, policies, and good practices on circular economy in Europe (https://circulareconomy.europa.eu/platform/en)
2. Material Circularity Indicator (MCI): Database that helps to measure the circularity of materials in products and services (https://www.ellenmacarthurfoundation.org/material-circularity-indicator).
3. The Circular Economy Database (CEDb): Database compiling global circular business models, products and services (https://ec.europa.eu/eurostat/web/circular-economy/database)
4. PRODCOM: European industrial production database that can be useful to understand material flows.
5. Ecoinvent: Global database providing Life Cycle Inventory (LCI) data for environmental analysis (https://ecoinvent.org/)

3.3 Contacts of interest

1. Circular Economy Club (CEC): International network of circular economy professionals with presence in more than 140 countries (https://www.circulareconomyclub.com/)

2. European Circular Economy Stakeholder Platform (ECESP): Contact point for relevant actors in the circular economy in Europe (https://circulareconomy.europa.eu/platform/en)
3. Circular Economy Hotspot: Annual event bringing together experts and companies interested in the circular economy (https //circulareconomyhotspot.com)

4. ICLEI - Local Governments for Sustainability: Global network of over 1,750 local governments committed to sustainability and the circular economy.
5. Ellen MacArthur Foundation: A world leader in promoting the circular economy, offering educational networks and resources.(https://www.ellenmacarthurfoundation.org/)

4 Success stories

The circular economy is increasingly being applied in the agri-food industry to reduce waste, improve sustainability and increase efficiency. Some of the most relevant success stories are shown below and can serve as inspiration.

4.1 Adnams Brewing Process

A UK company based in Southwold, Adnams Brewery has integrated circular economy principles by reusing waste from beer production as livestock feed or to generate biogas, which is then used to power the brewery. This approach not only reduces waste but also saves costs and reduces carbon emissions. The changes it has made to its production system include

1. Use of waste*: Adnams uses spent grains (a by-product of the brewing process) to generate biogas, which is injected into the national gas grid. This anaerobic digestion process transforms organic waste into clean energy, reducing dependence on fossil fuels and significantly reducing its carbon emissions.
2. Cask reuse and water recycling: The brewery reclaims casks from pubs to reduce the waste and carbon impact associated with making new casks. It is also exploring options to recycle water used in the brewing process, which helps minimise the use of water resources.
3. Sustainable distribution centres: Adnams has built a distribution centre designed to maximise energy efficiency and reduce emissions, including green roofs that help mitigate water consumption. These roofs also house rescued bees that encourage local biodiversity, an innovative example of integrating sustainability into infrastructure.
4. Measured impact: Thanks to these practices, Adnams has managed to reduce its carbon emissions by 48% since 2008, cut water use by one million litres per year, and operate a zero waste to landfill policy. These results show how adopting a circular approach not only improves environmental sustainability but can also be economically beneficial for the company.

4.2 Naranjas del Carmen

This Spanish company based in Valencia produces citrus fruit and has implemented a circular economy model by transforming pruning and other agricultural waste into compost, which is used to fertilize its own crops. This not only reduces waste but also improves soil health and reduces dependence on chemical fertilizers. Naranjas del Carmen is a leading example of circular economy in the agri-food industry in Spain. Founded by the Úrculo brothers in Bétera, Valencia, this company has implemented sustainable and innovative practices that have revolutionized the way its products are grown and marketed by taking the following steps:

1. Crowdfarming and Direct Sales: Naranjas del Carmen introduced the concept of crowd farming, a model where customers "sponsor" trees and receive the fruit directly at their homes. This system ensures that only what is to be consumed is grown, reducing food waste and optimizing resources. Most sales are made through its online platform, which eliminates intermediaries and allows direct contact with consumers, especially in markets such as Germany, where the freshness and traceability of products are highly valued.
2. Use of Waste and Ecological Production*: On their farm, they use ecological practices such as natural pollination with bees and the production of orange blossom honey, a by-product that maximizes the use of their natural resources. In addition, surplus fruit is transformed into

jams and juices, avoiding waste and generating new products that expand their offer throughout the year.

3. Innovation in Sustainability: The company distinguishes itself through its commitment to sustainability at the operational and design level. Even in their offices, they recycle and reuse materials to create a work environment that reflects their green values. They use recycled wooden crates and leftover materials for decoration, promoting a low-impact environment with high environmental commitment.
4. Economic and Social Impact: Naranjas del Carmen has managed to triple its revenues in recent years, thanks to its sustainable model and the attractiveness of its products in international markets. Its focus on selling fresh fruit, picked only to order, has revolutionized consumer perceptions of freshness and quality, moving away from traditional, less sustainable practices such as premature harvesting and the use of chemicals to preserve fruit.

This approach has not only made Naranjas del Carmen a commercial success story, but also a model of circular economy applicable to other companies in the agri-food sector.

4.3 Nestlé and Carrefour's Loop Project in Spain

An outstanding example of circular economy implementation involving several companies in the value chain is the Loop Project of Nestlé and Carrefour in Spain, in collaboration with other companies in the packaging and logistics sector. This project represents a multi-stakeholder alliance (Nestlé, Mars Petcare, Mondelez, Danone, Proctor & Gamble, Coca-Cola, PepsiCo and TerraCycle) to reduce the use of single-use plastics through the implementation of reusable packaging. The project is characterized by a Multi-Sector Collaboration that brings together major brands from the food industry, together with the Loop platform, which specializes in reusable packaging. These companies work together to offer products in packaging designed to be returned, washed and reused rather than discarded after first use. This creates a circular value chain in which each actor in the value chain has a specific role. On the one hand, there are the manufacturers (Nestlé, Unilever, etc.) who produce the food and beverages in reusable packaging, on the other hand the retail chain (Carrefour) who takes care of the distribution and sale of these products in their shops, promoting the circular economy directly with consumers and finally Loop who manages the return of used packaging, washes it and puts it back into circulation. This creates a closed loop where packaging circulates continuously between manufacturers, retailers and consumers.

As Impact and results, this model has led to a significant reduction in the use of single-use packaging and increased consumer awareness of the importance of reuse. It also fosters innovation in the design of durable and easily washable packaging, driving new solutions within the sustainable packaging sector.
In terms of the scale and replicability of the model, the success of this project in Spain has served as an example for replication in other countries and sectors, demonstrating that collaboration between companies can create a significant impact on waste reduction and the promotion of sustainable practices on a large scale.

This case is a clear example of how the circular economy can be effective when several companies collaborate along the entire value chain, from production to recycling and reuse of products.

4.4 La Fageda Group

A Spanish company located in Catalonia, which produces yoghurt and other dairy products, has implemented a circular economy system in its production process. They use livestock by-products to generate energy through biogas and compost, which reduces waste and energy costs. In addition, they reuse water in their production process, which contributes to a more sustainable management of water resources.

4.5 Barilla

Italian multinational company has embraced the circular economy by reusing the by-products of wheat milling. This waste is turned into animal feed, reducing the need for new resources. In addition, they have optimized their supply chain to minimize food waste and use recyclable packaging for their products, reducing their environmental impact.

4.6 Closing the Loop

The Closing the Loop in Tomatoes project in the Netherlands, based in the tomato growing sector, has adopted circular economy practices by reusing water and nutrients in closed greenhouses. These systems allow almost total reuse of resources, minimizing the use of water and fertilizers and reducing waste as much as possible.

5 Circular Economy business model Murcia Region

5.1 Introduction to CEBM in Murcia

Murcia, as part of the SUSTAvianFEED regions, has been identified as the location for the main development of the CEBM. As will be seen later in the document, Murcia is a region with a large agricultural, livestock and food processing activity. This allows for great potential in terms of the development of CEBM, as it allows for the closing of the economic and resource circle in a given location. Although circular economy models can be applied to a single company, we have sought to develop a model in which several entities participate, thus seeking a greater benefit for the entities involved and thus increase the impact of the model in the region.

This section aims to apply the systematic process of creating the CEBM presented in section "2. Implementation" but for ease of reading, sections have been grouped together to allow a better understanding of the process. Also to simplify the process, the process is shown once the conclusions have been finalised, although if you wish to find more details, you can look for more information in the annexes.

In the first instance, the companies of interest in the area are listed, the outputs and inputs resulting from their activity are listed, an evaluation is made of the logistics and intrinsic productivity of each substrate and finally a model is created to be evaluated. With the model already created, a robustness study is carried out to help see how durable the model can be over time and what the risks of applying the model are.

5.2 Location description

1. *Geographical Location*

   - Coordinates: The Region of Murcia is located in the south-east of the Iberian Peninsula, between latitudes 37°23' and 38°45' N and longitudes 0°39' and 2°21' W.
   - Proximity to Markets: Murcia is strategically located close to important national and international markets, especially due to its proximity to the Mediterranean coast. This facilitates the export of agricultural and livestock products to other parts of Spain and Europe.
   - Transport: The region has a dense network of roads and motorways, such as the A-7 and the AP-7, which connect Murcia with other autonomous communities and with the rest of Europe. The International Airport of the Region of Murcia and the Port of Cartagena are essential for the transport and export of agricultural and livestock products.

2. *Physical Aspects of the Territory*

   - Topography: Murcia has a diverse topography, with plains on the coastal strip and mountain ranges inland, such as the Sierra de Espuña and the Sierra de Carrascoy. The flat areas, such as the Guadalentín Valley, are suitable for intensive agriculture, while the mountainous areas are mainly used for extensive grazing.
   - Climate: Murcia enjoys a semi-arid Mediterranean climate, characterised by hot, dry summers and mild winters. Rainfall is scarce, ranging between 300 and 350 mm per year, which influences the need for irrigation and livestock farming practices.

- Soil: Soils in Murcia vary, being mostly calcareous, with fertile areas in the meadows of the Segura River and its tributaries. These soils are ideal for intensive agriculture, although their management requires efficient water use.
- Water Resources: The Segura River is the main water source in the region, essential for crop irrigation. In addition, groundwater and technician irrigation systems, such as drip irrigation, are used to optimise water use in a region with low rainfall.

3. *Agronomic and Livestock Aspects*

- Types of crops: Murcia is a leader in the production of fruit, vegetables and citrus fruits. Among the most important crops are lettuce, tomatoes, peppers, melons, lemons and table grapes. In addition, fodder crops such as alfalfa, essential for livestock feed, are grown.
- Agricultural yields: Agriculture in Murcia is highly productive thanks to advanced technology and efficient irrigation. The region is known as "the market garden of Europe" due to its great capacity to export fresh produce.
- Livestock: Livestock farming in Murcia focuses on sheep, goats, pigs and, to a lesser extent, cattle. Extensive livestock farming is common in mountainous areas, where the terrain is not suitable for agriculture. Lamb and goat production is traditional, and pig production is well developed, with a significant processing industry.
- Feeding and forage: The production of forages such as alfalfa is essential for livestock feeding. However, limited water availability in the region makes it necessary to optimize production and rely on feed supplements for livestock during the drier seasons.

5. *Agricultural and Livestock Infrastructure*

- Irrigation Systems: Murcia is a pioneer in the use of irrigation technologies, especially drip irrigation, which maximizes water efficiency in an arid region. This system is essential to maintain agricultural productivity in the region.
- Livestock infrastructure: The region has modern livestock handling facilities, including stables, corrals and automated feeding systems. In addition, there are slaughterhouses and meat processing plants, which add value to local livestock production.
- Agricultural and Livestock Technology: The use of advanced technology is common in Murcia, both in agriculture and livestock farming. Sensors, water management systems and modern agricultural machinery are used to optimise production and ensure sustainability.

6. *Socio-economic Aspects Related to Agriculture and Animal Husbandry*

- Rural Population: A significant part of the population of Murcia is involved in agricultural and livestock activities. The region has a rich agricultural tradition, with a deep knowledge passed down from generation to generation.
- Land Ownership and Tenure: The structure of land ownership in Murcia includes both large farms and small family farms, especially in rural areas.
- Markets and Trade: Murcia is one of the main agricultural exporting regions in Spain. The region's products are traded both domestically and internationally, with a particular focus on exports to Europe.
- Government Policies and Support: Farmers in Murcia benefit from various policies and subsidies, both at regional and national level, which support farm modernisation, water management and sustainability.

7. *Challenges in the Agriculture and Livestock Activity*

- Climate Risks: The Region of Murcia faces significant challenges due to water scarcity, drought and climate change. These factors affect both agricultural and livestock production, making it essential to adapt to new techniques and technologies.
- Soil problems: Soil erosion and salinisation are critical problems affecting agricultural productivity in some areas of Murcia. Sustainable soil management is vital for the continuity of production.
- Animal Health and Pests: Livestock farming in Murcia faces challenges related to animal health, such as disease prevention, as well as the management of pests that can affect both crops and pastures.

8. *Agricultural and Livestock Potential*

- Expansion Zones: The region has areas with potential for the development of new agricultural and livestock activities, especially in the improvement of pastures and the introduction of crops and livestock breeds more adapted to the arid climate.
- Innovation: Murcia is well positioned to lead in agricultural and livestock innovation, with opportunities to integrate new technologies and sustainable practices that improve efficiency and profitability.
- Diversification: There are opportunities to diversify production, including organic farming and the production of livestock products with designation of origin, which can add value and attract new markets.

9. *Development Projects and Plans*

- Ongoing initiatives: Murcia has several projects focused on improving agricultural and livestock infrastructure, such as the modernisation of irrigation systems, the development of new and more resistant crop varieties and the strengthening of the livestock value chain.
- Future Planning: The region has long-term plans to ensure the sustainability of its water resources, promote precision agriculture and expand the production of high-quality food for premium markets.

As can be seen in the description of the territory, the region of Murcia is a territory where a large part of the population lives in rural areas and with a very dynamic and productive agriculture, ranging from planting to the processing of vegetables for their commercialisation. Livestock farming is also an important economic driving force. On the other hand, one of the major constraints is the scarcity of water and the evolution of the land towards desertification. Intuitively, any circular business idea that includes the collection of agricultural and livestock waste, its transformation into products that can later be used in animal feed and fertilisers, and consequent savings in water consumption, will make good economic and environmental sense.

5.3 Enumeration of nearby companies

To start with the process of creating a CEBM in Murcia, we first proceeded to list the companies of interest that exist in the region. Using company directories, we searched for: (a) primary producers of fruit and vegetables, as this is one of the major resources available and because it is necessary in the following links; (b) fruit and vegetable processing companies because they generate waste that can be incorporated into the system; (c) dairy and brewing companies that can also provide resources; d) companies producing animal feed that can absorb the production of larvae; e) companies producing pickles to absorb the waste from larvae production; f) oil mills producing oil, which is a very abundant product in the Mediterranean basin; g) other companies that improve the model.

Fruit and vegetable companies:

Fruit and vegetable companies generally produce a large amount of waste associated with products that do not comply with market quality such as size, weight or colour, but also because they are damaged by pests or broken during harvesting (in the case of fruit). In another type of product, vegetable production companies generate a lot of waste that is left in the field as a by-product of production. For the sake of convenience, companies that produce and process for marketing fresh produce have been introduced, which also generate many by-products in the process. Table 1 lists the agricultural companies that were initially selected.

Table 1. List of companies producing vegetables in Murcia

Fruits and vegetables producers	Location
Grupo Hortofrutícola Paloma	- La Palma
Frutas Esther S.A.	- Abarán
El Dulze Growers S.L.	- San Javier
SAT Perichán	- Mazarrón
Surinver	- Pilar de la Horadada
El Ciruelo	- Alhama de Murcia
Agrícola Santa Eulalia S.L.	- Totana
SAT Hortiberia	- San Javier
SAT Agrimur	- Lorca
Agromurgi S.L.	- San Javier

Fruit and vegetable processing companies:

This group includes companies in the canning industry that make various preparations, including producers of juices and juice purées, porridges, canned tomatoes and preserves in syrup. These companies generate many by-products in the form of peelings, pulps, damaged fruits and products that do not meet the required quality. A table showing the companies in this sector is shown in Table 2.

Table 2. Companies manufacturing preserved foods in Murcia

Preserved foods	Location
Hero España S.A.	- Alcantarilla
Jufer S.A.	- Molina de Segura
Cofrusa (Conservas de Frutas S.A.)	- Alguazas
Conservas Ybarra Murcia S.L.	- Murcia.
Conservas Caravaca S.A.	- Caravaca de la Cruz

Preserved foods	Location
La Pastora S.A.	- Murcia.
Conservas Vega Alta S.L.	- Cieza
Conservas Hida Alimentación S.A.	- Mula
Conservas Helios S.A.	- Murcia.
Conservas Caparrós S.A.	- Murcia.
Conservas Vega Mayor S.A.	- Lorca
Conservas Bonny S.L.	- Murcia.

Dairy and brewing companies

The list includes companies involved in the production of dairy products, as they can be used in insect rearing. In most cases, for example, cheese dairies can provide whey, dairies can provide milk that has been acidified, and dessert producers can provide poorly made desserts and other products. Table 3 shows the companies in the dairy sector.

Table 3. Companies Producing dairy products in Murcia

Dairy production	Location
Central Lechera Murciana (CELMUR)	- Murcia.
Lácteos del Segura S.L.	- Cieza
Postres Reina S.A.	- Caravaca de la Cruz
Quesería El Roano	- Bullas
Lácteos La Ermita	- Molina de Segura
Quesos La Yerbera S.L.	- Murcia.
Quesería Alimer	- Lorca.
Quesería El Roano	- Bullas
Estrella de levante	- Murcia.

Feed companies

Due to the nature of the project, Alia is considered as a relevant company in the manufacture of poultry feed and no other company in this sector is included in this section. Alia has a great experience in the manufacture of poultry feed and especially considering sustainable ingredients.

Companies producing pickles and olives

These companies are added to the list because they have a dual function, on the one hand because they produce by-products when making pickles such as vegetable pieces and trimmings, and on the other hand because they consume a by-product of chitosan production such as NaOH, which is used for the curing of olives. The companies in this sector are listed in Table 4.

Table 4. Companies producing olives a pickle in Murcia

Companies producing pickles and olives	Location

Grupo Ybarra Alimentación S.L.	- Alcantarilla
Encusa S.A. (Encurtidos del Sureste)	- Murcia.
Agridemur S.L.	- Murcia.
El Faro S.A. (Aceitunas y Encurtidos)	- Alcantarilla
Aceitunas y Encurtidos El Gallo S.L.	- Murcia.
Aceitunas y Encurtidos Ballester S.L.	- Murcia.
Aceitunas y Encurtidos La Española S.L.	- Murcia.
Aceitunas y Encurtidos Montes S.L.	- Murcia.
Aceitunas La Torre S.L.	- Torre-Pacheco
Aceitunas Periche S.L.	- Murcia.
Aceitunas Bética S.L.	- Murcia.

Olive oil mills producing olive oil

The olive tree is one of the products that are present throughout the Mediterranean basin. Normally, olives are processed in olive oil mills, where various waste products such as pomace and alpechín (Spanish word for vegetative water) are generated, which in fact cause a great environmental problem. Fortunately, alpechín and pomace can be ensiled and used throughout the year and serve as food for the larvae. This reduces the environmental problem of waste while generating a new product. Table 5 shows companies in this sector.

Table 5. Olive mills located in Murcia

Olive oil mills producing olive oil	Location
Almazara La Rambla	Puerto Lumbreras
Almazara San Nicolás	Cieza
Almazara Deortegas	Yecla.
Almazara Valdelaparra	Molina de Segura
Almazara García Armero	Algezares
Aceites Cazorla y Parra S.L.	Caravaca de la Cruz
Almazara del Río Mula	Mula
Almazara Virgen de la Salud	Mazarrón
Almazara El Tendre	Alcantarilla
Aceites Lorquimur S.L.	Lorca

Other companies

To make the model more rounded, a few companies have been selected that help to understand the CEBM and give the system greater sustainability. On the one hand, biodiesel production companies have been included, which can take advantage of the oils extracted from the larvae and on the other hand, companies that produce fertilisers locally that can absorb the production of larvae. With the addition of these companies, no substantial waste would be generated in the implementation of the CEBM

To start with the process of creating a CEBM in Murcia, we first proceeded to list the companies of interest

5.4 Inputs/outputs of enterprises

To continue with the creation of the model, we proceeded to list the type of input or output that the companies have. To facilitate the model, only the inputs and outputs that are of interest to the model have been considered, either because their outputs are needed in the form of waste or because they need some output. Also to facilitate the model, a quality factor has been added to the quantities of inputs obtained, which would be the quality contributed to the system, since, for example, a tonne of lettuce (practically water) does not have the same nutritional value as a concentrated fruit pulp. These quality values have been assigned based on previous experiences in Entomo. Also to make the model more comprehensible, it has been chosen to divide the waste production by weeks, although the waste is often unevenly distributed throughout the year. In table x6

5.5 Logistics evaluation

Distance is a major factor in the creation of the CEBM, transporting waste, especially if it is plant waste with a high proportion of water, can place a heavy burden not only on the cost of production but also on the sustainability of the system.

As indicated in section 2, logistics has a great influence on the creation of the model, in order to better select the companies that can become part of the model, a row has been added to the selection matrix that takes into account the distance that exists between Entomo (which will receive the waste) and the waste giver. In order to facilitate the development of the model, the main site has been taken into account and no other sub-sites that it may have. Table x7 shows the results.

5.6 Creating the connection

Once it was decided which companies could participate in the model, they were contacted to better understand their willingness to participate in the model, as well as the details of disposing of their waste or purchasing the products, in order to ensure the long-term development of the model.

Interviews (LL) were conducted to help gather the information and a summary is given in table x8. For more details, please refer to the Annexes.

5.7 Creation of the model

After the analysis carried out, a model has been created that complies with the principles of circularity. The model includes the business partners of the SUSTAvianFEED project in the region of Murcia such as Alia as a feed producer and Entomo as a producer of black soldier fly. To start describing the model the by-product producers will be taken.

Waste production:

After having considered all the nearby options as waste suppliers, the following have been considered, due to their proximity, availability of products throughout the year and the suitability of these products:

- **Estrella de Levante**: a brewery located in Murcia (71 km), produces beer and in the process generates around 20 tonnes of beer bagasse per day. The residue is rich in protein and fibre. The substrate tends to decompose quickly so it either must be kept refrigerated or consumed frequently.
- **Almazara Llano & Monte:** a company dedicated to the production of wine and oil, produces around 20,000 tonnes per year of alperujo (Spanish name for dry olive pomace) or the equivalent of 50 tonnes/day. The company is in Mula (33 km). The alperujo is characterised by a relatively high fat and protein content, but low in carbohydrates.
- **Alimer:** Cooperative society located in Lorca (65km) with 1800 members including farmers and stockbreeders. It stands out for its agricultural production of fruit and vegetables, which produces an approximate waste of around 20 tonnes per day throughout the year but divided into different seasonal products. It also produces goat's cheese, which produces approximately 2 tonnes of whey per day. Both products are interesting to produce larvae. In the case of the fruit because of its sugar content, which facilitates the growth of the larvae, and in the case of the whey because of its sugar and whey protein content, which are of high quality.

In addition to the companies that are highlighted to form part of the model, waste will be taken from other companies, such as Hida, Postres Reina, Patatas Rubio and other companies, which may form part of the model more sporadically due to seasonality or the exceptional nature of the waste.

BSF Farm (Entomo):

All residues are collected as often as necessary to remove them from the source and to create a necessary feed formulation. In the case of alperujo, it will be collected during the oil production season and stored in ponds and covered so that it can be ensiled and used throughout the year. For the formulation of larval feed, 33% beer bagasse, 33% alperujo, 25% fruit and 9% goat whey will be mixed. This gives a total of 60 tonnes of larval food per day. From these 60 tonnes of food, about 10 tonnes of fresh larvae will be obtained which, when processed, will result in 1600 kg of protein-rich meal, 1600 kg of oils and 50 kg of chitosan. The use of the products will go to the following industries

- Protein: it will go to animal feed production, due to its good animal protein content of approximately 60%. Its easily digestible proteins are particularly suitable for feeding chicks.
- Hydrolysed proteins from the production of chitosan (200kg/day) will go to agriculture as a biostimulant for plant growth.
- Fats: 1300 kg/day of the total will be sold for animal feed. Very interesting for its qualities in the fattening of small animals and for its antibiotic properties.
- Chitosan: produced for its antibiotic properties and to prevent intestinal disorders in small animals, production is low.

As a result of the production of these raw materials, two main residues are obtained:

- Frass: which is the equivalent of manure. It is the result of larval feeding, where they leave undigested lignin and cellulose, and this is mixed with the excreta and microorganisms inoculated by the insects, giving a mixture which, depending on the feed provided, can be a good source of nitrogen, phosphorus and potassium as well as organic carbon. The frass will be consumed by Alimer in its crops. To make the system circular.

- 50% soluble NaOH. This could be considered a highly hazardous waste because of its caustic power, but it is also used for the production of soaps and for curing olives.

Feed mill (Alia):

This company produces about 12,000 tons of feed per month for various types of livestock. It is located in Lorca (65km). This company will receive the protein from the larvae at a level of 60%. The meal will be integrated into their feed as one of the ingredients.

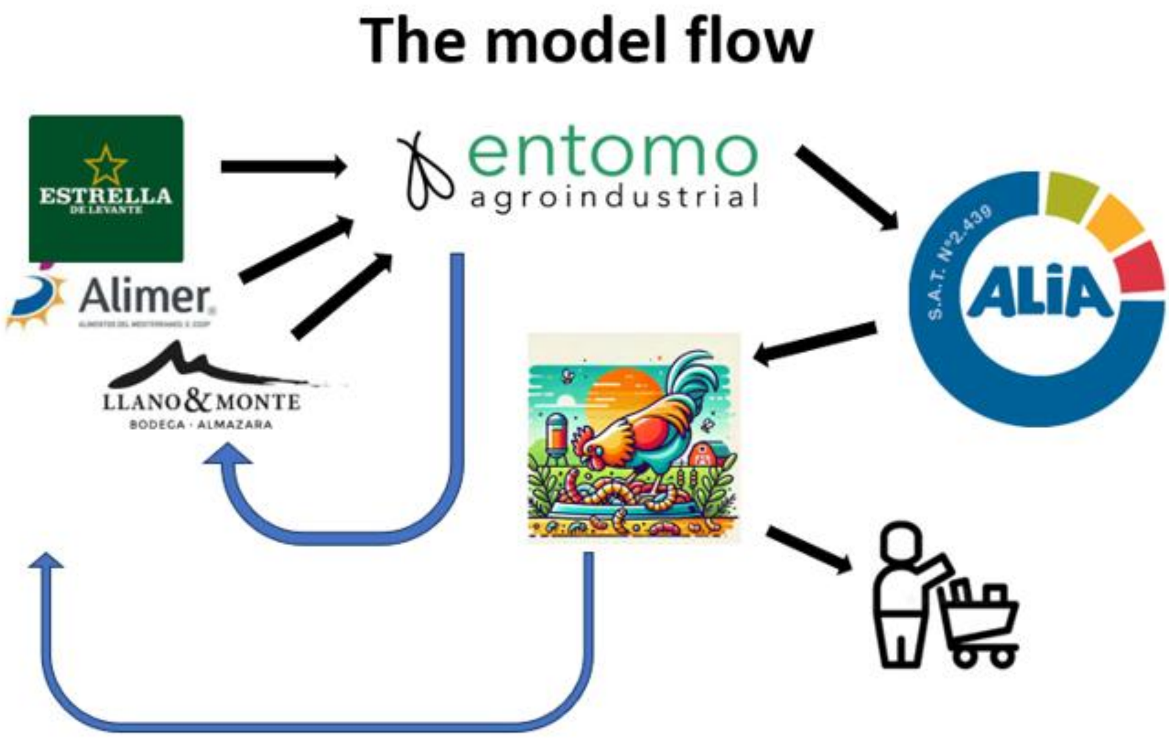

Figure 13. Material flow in the Murcia CEBM

Olive production company (Fruyper): This company is located in Murcia and is dedicated to the production of canned olives. The olive curing process requires the use of soda to carry it out.

These companies would complete the model, but some alternatives are proposed to make it more appropriate.

Biodiesel production company (TSK Biodiesel): Company located in Cartagena (106km) that produces biodiesel from used oils and other fats. The biodiesel produced can be used to move the lorries that transport goods from one place to another.

Fertiliser producing companies (Fervalle): company located in Lorquí (59km) that produces and markets a variety of fertilisers and can use frass as an ingredient in its formulations, especially for the organic line.

The TLCEBM for Murcia region was elaborated by the SUSTAvianFEED partners during the different CEBM workshops. And the result is shown below (see figure 14, 15 and 16)

<table>
<tr>
<td rowspan="2">Partners
- Alia
- Entomo
- Alimer
- Estrella de levante
- Almazara Llano&Monte</td>
<td>Ativities
- Plant waste production
- Waste treatment with BSF
- Protein production
- Sustainable Poultry
- Fertilizer production</td>
<td rowspan="2">Value proposition
- Sustainable organic waste treatment
- Sustainable poultry feed production</td>
<td>Customers relationship
- Direct sales
- Technical assistance</td>
<td rowspan="2">Customers segment
- Poultry producers preferably organic, free raise, slow growing species</td>
</tr>
<tr>
<td>Resources
- Pultry feed mil
- Insect farm
- Olive mil
- Vegetable production
- Waste</td>
<td>Channels
Cooperative distribution</td>
</tr>
<tr>
<td colspan="3">Cost
Feed=90; Growing=210; Drying= 98
Total 398€/ton
Total cost for 1170 tons/year 465660€</td>
<td colspan="2">Revenue
For the selling of 1170 tons a year
At a selling cost of 650€/ton
Totals 759200€/year; 293540€</td>
</tr>
</table>

Figure 14: Economic layer of the TLCEBM in Murcia

Supplies and outsourcing	Production	Functional value	End of life	Use phase
- Organic waste - Water - Electricity	- Short life cycles - Sustainable feeds - Frass for fertilizer	- Reduction and transformation of organic waste - Production of alternative feeds - Especial nutritional profile - Eco and sustainable meat and eggs production	100% cyclical	- Poultry farms the product is used as normal feed
	Materials - Organic waste - Alternative feed ingredients		**Distribution** Cooperative distribution short distribution	

Environmental impact	Environmental benefits
- Energy consumption during production, although solar panels could reduce the demand - Water consumption, lower than other farm animals but water need to be used	- Lower competition for resources - Lower carbon footprint - Waste reduction - Lower use of land

Figure 15. Environmental layer for the TLCEBM in Murcia

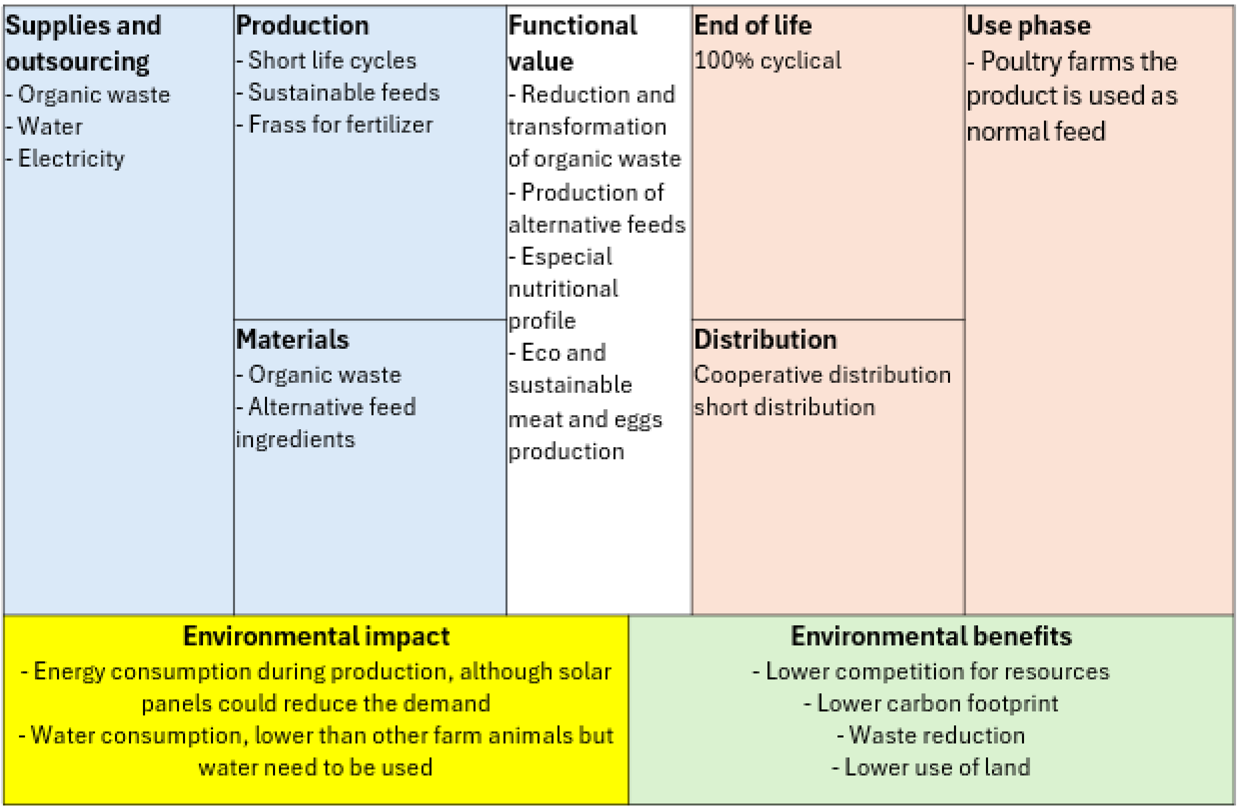

Figure 16: Social layer of the TLCEBM in Murcia

5.8 Evaluation of the model

To evaluate the model and for simplicity, it has been evaluated just economically. To carry it out, interviews were carried out with different representatives of the companies involved in the model and other stakeholders with certain involved in the sector and which could affect the model. They were asked information such as the price at which they would sell the waste, the price at which they would buy the products, as well as if they would be willing to make contracts to stably supply the products, by-products, or waste. All the companies present in the model would supply waste to facilitate the model.

As a result of the interviews:

Estrella de Levante, which is a brewery located in Murcia, the main subproduct that could contribute to the model is the beer bagasse. This company could contribute about 40 tons a day of this product. The beer bagasse has economical value right now and thus it is sold at 26€ per ton.

In the case of Alimer, it would be enough to be able to contribute approximately another 20 tons of fruits and vegetables of different types. The ton of vegetables would not have any cost, only the transport, which from the location where it is found to the factory is approximately 3 euros per ton.

In the case of the olive pomace, Llano del Monte, could provide approximately 40 tons a day as far as it is storage to be used after season. the price would be 6 euros per ton when collected fresh, and 0,5 € cost for storage and handling.

With all this in mind and considering the mixture created with different subproducts, Entomo would be able to make a production of larvae that with an approximate produce 21 tons of dry larvae per day. The production cost at this scale could be as low as 0.65€ per kg of dry larvae. However, if CAPEX is included in the economical balance and for an amortization period of 15 years, a product cost of about 0.95€ per kg could be considered. And to create interesting profits, a price of 1.3 € would be the most recommended.

Alimer could create feed with the insect larvae although it would be too expensive because it would be more expensive than what the soy costs in 2024 (350€ per ton). So it doesn't seem reasonable to use BSF meals as a simple protein source. Anyway, under these conditions the company Entomo Consulting would not have benefits and therefore the model would fail if a profound change is not proposed. The model would make more sense for Entomo if it reached a sales price of about 1,300 euros per ton, but this selling price is simply out of range. With this, in the end, the model would be very difficult to be executed if it had to be evaluated from an economic point of view, but it would make sense if it is evaluated from an environmental point of view, since there is a certain amount of waste that is eliminated from the environment while there is a series of products that are produced. It should also be noted that when larvae are raised with the olive pomace, they accumulate polyphenols, giving them antioxidant and antimicrobial properties that could provide an extra value. as an ingredient, not as a source of protein, but due to the medicinal effect it can have e positive on chickens. In any case, still now this contribution on animal health is not yet economically evaluated and still BSF meal is considered more as a protein source than as an additive to improve chicken health. Thus, price is still a handicap. To offset price issues, considering than one of the most important factors for insects' production is energy cost due to acclimatation of the rearing chambers, the production cost could be sharply decreased if the location has more favourable climate conditions or if only seasonally production is carried out. If insects' production is done in favourable climate conditions, production cost could be cut to 0,45 and profits could be seen at 0.75 €/kg. This price would be still expensive as protein source but more suitable to be incorporated in chicken feeds.

5.9 Robustness check

The study of robustness is a part of the process to be able to evaluate how stable our business model would be when faced with a series of cases that could affect it in the future. There are many ways to do a robustness study of the model, but for this guideline it is going to be used a simple study identifying possible risk (stress factors) and giving a score to check which one of the stress factors could be a risk in the system and decide how each of them will affect the system in general. It helps us to be able to predict future failures of the model and apply corrections in other to make it more robust.

Identification of the stress factors and analysis

Stress factors are those one who could affect the model at a certain point. To simplify the model to each factor a score from 0 to 3 will be applied to each factor being 0, a very negative effect in the model and 4 a very positive effect on the model. and the main one identified for the study are:

Increase the price of raw materials for feeds (grains): it is understood that the increase in the price of raw materials could have an effect that could be positive or negative but considering that by increasing the price of raw materials used to produce feeds, possibly will produce an increase in the value of agriculture by-products. If grains increase the value, more by-products will be included on the feeds and then the price of this raw material will also increase. This, for example, would be clear in with the use of beer bagasse for the feeding of ruminants, if the price of the grain or the hey increases in price, also the cattle producers would consume more beer bagasse and therefore this would increase in value. However, the beer bagasse could be substituted for other byproducts like the olive pomace and field vegetables, and it could be considered that the increase in the price of raw materials would affect less the production of larvae than would do the livestock. Therefore, it would be considered that the risk is relatively low. Giving a score of **3 (favourable risk)**

Electricity price increase: In the case of increasing the prices of electricity, the production of larvae would be highly affected because the price of production depends enormously on the energy needed to acclimatize the chambers. Therefore, in the case of an increase in the prices of energy, the price of production of larvae would greatly increase and, consequently, its production would be commercially unfeasible. Giving the score to this stress factor of 0 (very considerable risk)

Increase price of fuels: In the case of an increase in the price of fuels, it could be considered that fuel prices will naturally increase. Therefore, the price of raw materials that are used in the production of larvae would increase. However, the price of by-products transport, considering that it is close, is less affected by the price of oil than those raw materials that come from far away. Therefore, it would be less affected than other raw materials that are imported. It gives a score of **2 (some risk)**

Geopolitical changes: Geopolitical changes could be considered to affect the price of raw materials. In any case, those geopolitical changes, as they affect more the relations between the countries, it is very possible that those relations between the countries would affect the price of raw materials. This could mean that the importation of raw materials would be difficult, as the production of larvae would not depend so much on these imports, it would mean that it would be less affected or even be benefited by geopolitical changes, since the proximity of the production of larvae would make it a resource to take into account in substitution of other raw material resources. It gives an score of 4(very positive)

Water scarcity: In the case of water scarcity, the model would not be as affected as it is seen in other productions. For example, grain production is extremely dependent on rain, and water scarcity and drought directly affect it. In the case of the production of BSF, residues usually used already have a moisture and do not need to consume so much water. Therefore, it would be less affected or benefited by the scarcity of water. In any case, there are small details to consider. For example, in years of scarcity of water, less olive oil is produced and, therefore, there is less alperujo available. This means that part of the available alperujo is lost, or its price is raised. The beer bagasse production is not affected by draught, because although the value of barley increases due to poor harvest, the total cost of production is mainly paid by the one who consumes the beer and does not affect the sub-product so much, which would be the bagasse. It gives an score of 3 (favourable risk)

Periodical climatic stress (El Niño): Phenomena such as El Niño), of deep drought during a certain period, since we have already mentioned that the lack of water does not affect the production of BSF while it affects other sectors. In the case of El Niño, normally the fisheries in Chile, Ecuador and Peru, decrease the production of fishmeals. This produces a great shortage of resources that increases the price of fishmeal and that therefore increases the price of BSF meal simply as substitute those sources of animal proteins that would no longer be available. It is a score of 4 (very positive)

As it can be seen, the biggest risk than challenge the model is the increase of electricity, so to create a more robust business model, it would be recommended to create a system with more independence of the conventional electricity grid and using more renewable energy sources like solar. In this way the increase of electricity process will affect the model in a lower extension. In addition to that, if BSF are produced seasonally, when the climate is more favourable, less electricity is needed, and the model will be more robust. In the case of Murcia region, weather is favourable for 9 months a year, so the production would recommend being done during this period and it will make the CEBM more robust. Thus, a system to store by-product during resting period would be a recommendation to give more robustness to the system

6 Conclusions

As a conclusion, it has been possible to create a circular economy business model adapted to Murcia region in which, fortunately, there is a large quantity of agricultural resources that can be used.

For the business model created the by-products to produce the BSF procced from three different industries. The production of beer bagasse is done in Estrella de Levante, which allows to have a stable source to make the BSF larvae providing proteins. It is also interesting the production of Alperujo, which can be used to provide energy, organic acids and preservative for the diet, and this can be used for the complementation of beer bagasse from Estrella de Levante, it can be complemented with the production of goat cheese whey and the production of vegetables by Alimer, which would complement the larvae diet. All these by-products would be used for the production of larvae in industrial entomology. From there, two main products would come out. On the one hand, the frass, or fertilizer after the digestion of organic elements, which can be fertilized in agricultural companies. And on the other hand, dried larvae, which can be used by Alia to be one of the ingredients in the production of sustainable feed in the emulsion region.

After doing an analysis of the model, it can be seen that if the established model is based on high technology and a high level of climate control, there is a problem because the production of larvae is highly affected by energy cost and then the larvae will have higher cost than what the market could really pay for an ingredient for the production of feeds. Of course, if these larvae use were analyzed from an environmental or sustainability point of view, they could be very interesting, but that would not support the model from an economic point of view. However, the recommendation made, is to make the production of larvae seasonally skipping deep winter to decrease energy cost. In this case, the production cost would be low enough to be considered competitive, although it would not yet compete with the normal prices of other raw materials that are relatively low (soy and corn). In any case, considering that it is possible that the value of raw materials to produce feed increases in the coming years, it is also possible that the prices of BSF becomes more competitive. In addition, the fact that insect flours have a few properties that could be considered medicinal in chicken production could make them interesting, although not as primary ingredient, but as an additive to improve the quality of life of chickens or to improve their productivity.

The study of robustness of the model concludes that for many of the stress factor that affects the BSF production in a future scenario, most of them will favourably affect and will make more competitive it source than other raw materials. In other words, the risk factors that could happen in the future would affect other elements more than the production of BSF, due to the nature of being produced locally, not being severely affected by drought, nor by the increase in the price of oil, or even being improved by some other factors like geopolitical issues. However, there is a factor that produces a very high risk, which is the increase in the price of electricity, since the production of BSF is strongly affected by the prices of energy. This energy is used to climate the chambers. However, this risk could be greatly reduced if sustainable sources of energy were used, such as solar, which would decrease the dependence on the external electricity supply and, therefore, on the prices. This risk could also be reduced by simply produce during the time of the year when the climate is more favourable to carry it out, which in the case of the Murcia Region could be up to 9 months a year, leaving 3 months to clean the facilities and prepare them for use in the next season.

With all this, it could be said that this model of circular economy is robust if independence is sought with respect to electricity supply and the production cost of BSF is reduced.

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ANNEX I

Handbook: Guide to build a circular economy business in the agri-food sector

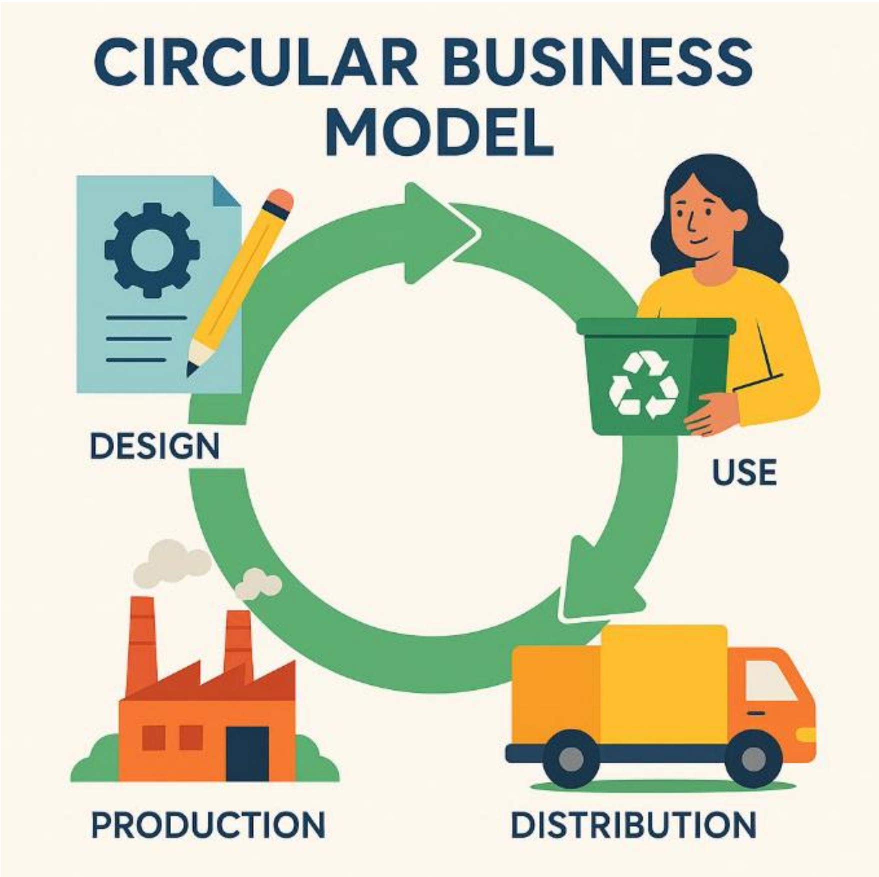
This guide is intended for entrepreneurs, farmers, livestock producers and agri-food professionals who want to transform their activities toward a more sustainable model. It is based on the approach of the SUSTAvianFEED project and clearly presents how to apply circular economy principles step-by-step.

1. What is the Circular Economy and Why is it Important?

The circular economy is a model of production and consumption that promotes reusing, repairing, refurbishing and recycling existing materials and products for as long as possible. Unlike the traditional linear model ('take-make-use-dispose'), the circular economy transforms waste into resources.
In the agri-food sector, this model allows agricultural and livestock by-products to be turned into fertilizers, energy, or new products. It also promotes efficient use of water and energy, helping reduce environmental impact and increase profitability.
For example, pruning residues can become compost, manure can generate biogas, and fruit and vegetable waste can feed insects later used as animal feed.

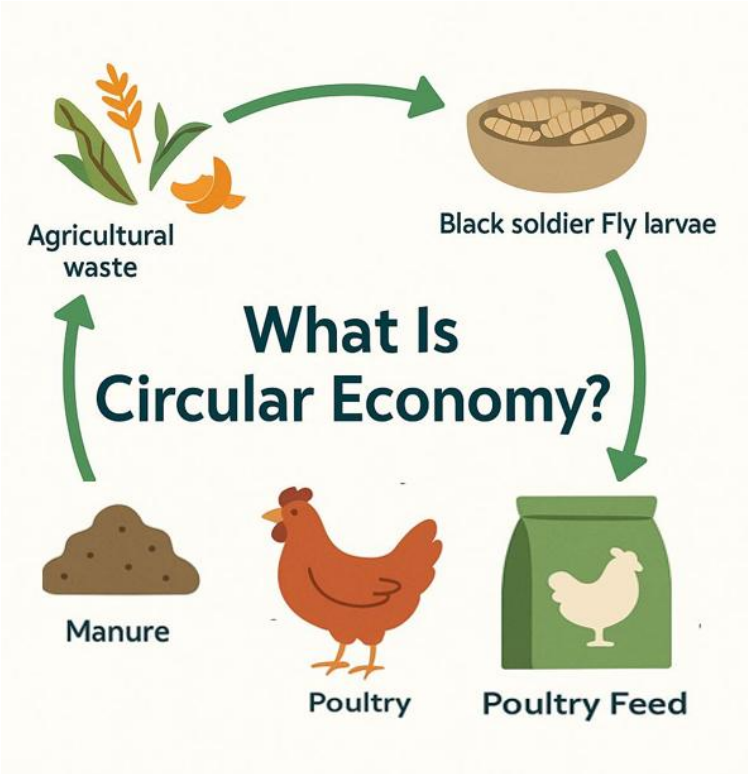
2. Step-by-Step: Designing Your Circular Business Model

To transform an agri-food business toward circularity, it's key to follow a series of structured stages.
Step 1: Initial Diagnosis
Identify your inputs (water, fertilizers, feed, energy) and outputs (organic waste, manure, by-products). List the most consumed resources and the types of waste you generate, and explore which could be reused or recovered.
Step 2: Identify Circular Opportunities
Explore how to modify your processes to close resource loops. Can you reuse manure as fertilizer? Feed animals with by-products? Use crop residues for compost or energy generation?
Step 3: Design Your Model
Use tools like the Circular Economy Business Model Canvas (CEBM Canvas) to define your circular value proposition, key partners, revenue streams and how to deliver sustainable value.



3. Practical Case Study: The Murcia Circular Model

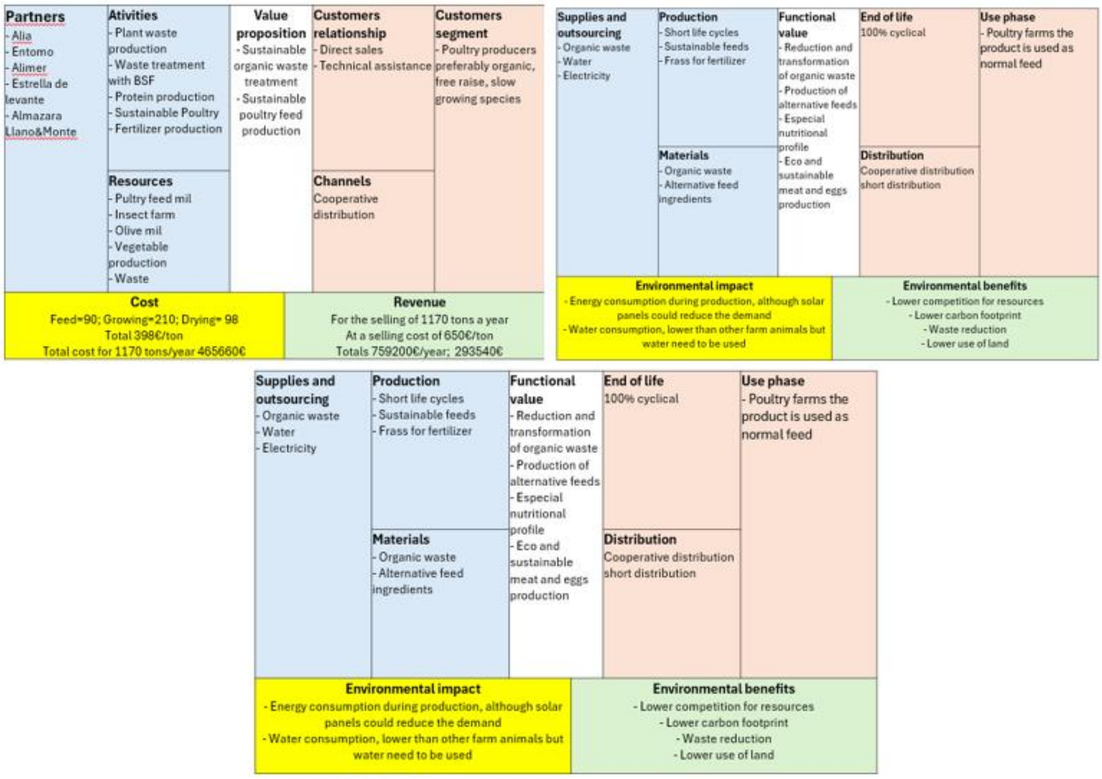
Murcia (Spain) is a region with strong agricultural and livestock production, making it ideal for circular approaches. The SUSTAvianFEED project showed how agricultural waste (like vegetable residues) can be used to feed Black Soldier Fly larvae, which are later processed into protein-rich animal feed. Poultry manure is then composted and used as organic fertilizer for crops.
This model closes multiple loops: reduces waste, replaces imported soy-based feed, improves soil health, and lowers greenhouse gas emissions.
Such integration requires cooperation between producers, processors and technology partners but can begin on a small scale by a single farmer or entrepreneur.



4. Tools and Resources for Circular Business Design

Designing a circular model is easier with digital tools and structured methodologies.
- Circular Canvas: Visual tool for designing sustainable business models.
- Triple Layered Canvas (TLBMC): Integrates economic, environmental and social layers.
- Circulytics (Ellen MacArthur Foundation): Measures your business circularity.
- Ecochain, SimaPro: Software for measuring environmental impact and carbon footprint.

Explore databases like ECESP or CEDb to find real-life circular examples and join networks like the Circular Economy Club for peer learning and support.



Triple Layered Business Model Canvas (TLBMC)

Partners

5. Inspiring Success Stories

Adnams (UK): Uses brewery waste to produce biogas for factory energy.
Naranjas del Carmen (Spain): Reuses pruning waste for compost, reduces food waste, and sells directly to consumers.
Nestlé + Carrefour (Spain): Reusable packaging system (Loop) to reduce plastic waste.
La Fageda (Catalonia): Generates energy and fertilizer from livestock manure.
Barilla (Italy): Turns wheat by-products into animal feed and uses recyclable packaging.
These examples show that circular economy is not only possible, but profitable and scalable in diverse contexts.

6. Final Checklist and Next Steps

How to know if you're ready to transform your business:
- Have you identified your main resources and waste?
- Can you recover or reuse some of that waste?
- Have you explored technologies or partnerships to support the transition?
- Have you defined your circular value proposition?
- Can you measure and communicate your positive impact?

If you answered 'yes' to several of these questions, you're on the right track. Start with a pilot, measure outcomes, and expand. The circular economy is not only an environmental commitment—it's an opportunity for innovation, efficiency and leadership.