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Towards a new zero food waste mindset based on holistic assessment

D1.1 Related Accounting methods and databases for SBF design

Deliverable Nº	D1.1	Work Package Nº	1	Task/s Nº	1.3 & 1.4
Work Package Title	Collaborative investigation of new decision-making framework				
Linked Task/s Title	Task 1.3: Co-design and co-creation of the FWPR actions database Task 1.4: Detailed discussion with JRC about the accounting methodologies based on the database results				
Status	Final			(Draft/Draft Final/Final)	
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Authors	UJI: Responsible of the Deliverable, review of the accounting methodologies in EU projects and Databases analysis; DEU: Scientific literature review; STRA: Databases review. ALL PARTNERS: final review.				

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1. Introduction and scope

ToNoWaste is a project funded by the European Union under the program Horizon Europe in the topic HORIZON-CL6-2021-FARM2FORK-01-13.

The project starts 01/09/2022 with a project duration of 48 months.

The mission of ToNoWaste is to encourage actors in European food systems, using evidence-based tools and lessons learned, to make better decisions towards more sustainable food production and consumption patterns.

ToNoWaste main objective is to provide farmers, supply chain companies as well as consumers and policymakers with more objective, integrated, and standardized information about the impacts and global co-benefits of their daily actions in terms of food waste. ToNoWaste will inspire them to co-create a portfolio of positively assessed pathways to shift Europe towards a healthier, more resilient, inclusive, and sustainable food production and consumption.

1.1 Specific objectives of the project

(O1) To Design an open innovation ecosystem that engages European researchers, municipalities, farmers, supply chains and citizens to share open access scientific knowledge about FLWPR (Food Losses and Waste Prevention and Reduction) and its assessment. (WP1)

ToNoWaste seeks to create synergies with other ongoing actions related to FLWPR at EU level keeping in touch with four H2020 sister projects to reuse data and collaborate in the actions assessment for avoiding duplication.

(O2) To unveil what better decision means in the fresh food value chain (FFVC), supporting the FLWPR actions with the best impacts for the food system sustainability. (WP1)

ToNoWaste has selected FFVC because the Milan urban food policy pact prioritized to make fresh food accessible for all due to its potential to solve dietary-related illnesses (e.g., diabetes, heart disease and cancer). Therefore, O2 will investigate how to make FLWPR compatible with FFVC sustainable development with a cost-benefit approach (RO1).

(O3) To co-create a new science-based framework (SBF) for evidence-based decision making in food systems. (WP2)

O3 will look for synergies with H2020 sister projects, city councils and JRC to define logical steps for environmental/social/economic holistic impact FLWPR assessment (RO2).

(O4) To transform the SBF into Quantitative Decision-Making Methods (QDMM) that supports researchers and professionals in decisions related to FLWPR in the FFVC. (WP2)

O4 requires the SBF decomposition into specific workflows for the fresh products under study, considering its origin and business processes involved to establish the limits of acceptance/significance for each decision maker (R03).

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(O5) To engage more and more FSC actors in the mindset and Behavioral shift offering open access to: i) consumer perception of the FLWPR problem in fresh food value chain (FFVC) and potential solutions; ii) learning contents, technical guidelines to implement the best practices available - including date marking and smart food packaging, as well as iii) apps that automate the participation and monitoring process for facilitating decision making for supply chain actors (WP4 and WP5).

The Behavioral change will be prompt by results of social research (RO4) focused on understanding the consumers' and producers' perception of the problem and the solutions proposed by decision-makers. ToNoWaste will facilitate the co-creation of FLWPR guidelines to identify hotspots of problems, plan actions, assess corrective solutions and document improvements. During Multi-actor workshops and other networking events, we will validate the tools (PR, DEM) by discussing the practical learnings (KH1) and quantitative data from actions assessment (KH2).

(O6) To take advantage of synergies among R&I projects and local/national FLWPR actions to co-create specific accounting tools and an integrated platform for assessing the root causes behind FW along the value chain as well as fostering the most beneficial FLWPR actions. (WP2 and WP3)

O6 will require the creation of accounting tools for professionals and its integration into an open platform for non-expert users (DEM) to facilitate the decision-making process to all the actors involved in the value chain. DEM will maximize the impact at EU level using open-source technologies as FIWARE. The previous/current FLWPR actions in sister H2020 projects will be compared to detect the best practices that maximize the overall positive impacts.

(O7) To foster the organizational change with new coaching services and best practices in FSC. (WP6)

O7 is based on the creation of learning contents, training actions and a business coaching service oriented to support entrepreneurs. ToNoWaste will take advantage from current innovation HUBs related to urban FFVC where food companies (mainly SMEs) can co-create more sustainable business models.

(O8) To co-create new EU policies considering the diversity on regulatory ecology about FLWPR. (WP6)

O8 will consider the new accounting and reporting methodology developed for ensuring a deeper integration of sustainability into the corporate governance and regulation of public supporting schemes for innovative businesses (KH4). The project will investigate how to transform the best FLWPR actions in terms of KPIs into new standards and labels for fostering the organizational change. The project will use the Covenant of Majors and Milan Urban Food POLICY Pact for the open discussion of the white paper where other agencies like DG AGRI and JRC will be invited.

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1.2 Scope of the deliverable

This deliverable D1.1 is part of the Work Package one (WP1) of the ToNoWaste project, which has a twofold objective. On the one hand, it aims to design an open innovation ecosystem that engages European researchers, municipalities, fresh food value chains (FFVC) and citizens into the creation of open access scientific knowledge about Food Losses and Waste Prevention and Reduction (FLWPR) actions. On the other hand, it attempts to jointly unveil what "best" decision means for supporting the best FLWPR actions in the Fresh Food Value Chain (FFVC) considering impacts on the sustainability of the food system.

More specifically and to contribute to the achievement of the WP1 objectives, this deliverable (D1.1) aims to provide a detailed review of the current and previous FLWPR actions implemented in the European Union to study their specifications and get objective data about the results obtained. This will ensure their systematic registration and classification considering their potential heterogeneity and will allow an accurate selection of the portfolio of solutions in subsequent deliverables (D1.3; D2.1; D3.2; D5.1).

In this context, the review of FLWPR actions presented in this deliverable focus on compiling information about the accounting methodologies and assessment tools that are being used to measure and manage environmental, social, and economic issues related to the studied actions and the links between them.

Section 2 contains the glossary agreed upon by the ToNoWaste partners, while section 3 is devoted to explaining the accounting methodologies and assessment tools theoretical background and two subsequent subsections deal with the different sources of information analyzed: EU-funded projects and scientific literature. Section 4 presents different available impact assessment databases that can be used to assess the environmental, social and economic aspects of food losses and food waste. Finally, section 5 lists the references used.

2. Glossary

The ToNoWaste Glossary has been discussed and agreed upon partners and is available on our website (http://ToNoWaste.eu).

ACTION/ INTERVENTION	Any activity designed to reduce the amounts of food waste generated at any point of the food supply chain (Caldeira, C. et al, 2019).
BIO-WASTE	Biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants (European Union, 2008).
CIRCULARITY	Economic system whereby the value of products, materials and other resources in the economy is maintained for as long as possible, enhancing their efficient use in production and consumption, thereby reducing the environmental impact of their use, minimizing waste, and the release of hazardous substances at all stages of their life cycle, including through the application of the waste hierarchy (European Union, 2020).
EDIBLE PARTS OF FOOD WASTE	"Food" (see definition, including drink) that is removed from the human supply chain (i.e., to end up at the following destinations: landfill, controlled

	combustion, sewer, co/anaerobic digestion, compost/aerobic digestion, or land application) (United Nations ENVIRONMENT PROGRAMME, UNEP, 2021).
FINAL CONSUMER	The ultimate consumer of a food-stuff who will not use the food as part of any food business operation or activity (European Union, 2008).
FOOD	Any substance or product, whether processed, partially processed, or unprocessed, intended to be, or reasonably expected to be ingested by humans. Includes drink, chewing gum and any substance, including water, intentionally incorporated into the food during its manufacture, preparation, or treatment. It includes water after the point of compliance as defines in article 6 of Directive 98/83/EC and without prejudice to the requirements of Directives 80/778/EEC and 98/83/EC (European Union, 2002). Shall not include: a) Feed b) Live animals unless they are prepared for placing on the market for human consumption c) Plants prior to harvesting d) Medicinal products within the meaning of Council Directives 65/65/EEC and 92/73/EEC e) Cosmetics within the meaning of Council Directive 76/768/EEC f) Tobacco and tobacco products within the meaning of Council Directive 89/622/EEC g) Narcotic or psychotropic substances within the meaning of the United Nations Single Convention on Narcotic Drugs, 1961, and the United Nations Convention on Psychotropic Substances, 1971 h) Residues and contaminants
FOOD BUSINESS	Any undertaking, whether for profit or not, and whether public or private, carrying out any of the activities related to any stage of production, processing, and distribution of food (European Union, 2002).
FOOD LOSS	The decrease in the quantity or quality of food resulting from decisions and actions by food suppliers in the chain, excluding retailers, food service providers and consumers. Empirically, the term refers to any food that is discarded, incinerated, or otherwise disposed of along the food supply chain, which starts with harvest/slaughter/catch up to but excluding the retail level, and the food does not re-enter the supply chain for any other productive use, such as for feed or seed (Food and Agriculture Organization, FAO, 2019).
FOOD SURPLUS	For the purposes of the Food Waste Index, food surplus refers to food that is redistributed for consumption by people, used for animal feed or used for bio-based materials/biochemical processing (UNEP, 2021).
FOOD WASTE	Refers to the decrease in the quantity or quality of food resulting from decisions and actions by retailers, food service providers and consumers (FAO, 2019).
FOOD SYSTEM SUSTAINABILITY	A system that provides and promotes safe, nutritious, and healthy food of low environmental impact for all current and future EU citizens in a manner that itself also protects and restores the natural environment and its ecosystem services, is robust and resilient, economically dynamic, just and fair, and socially acceptable and inclusive. It does so without compromising the availability of nutritious and healthy food for people living outside the EU, nor impairing their natural environment (SAPEA, 2020).

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INEDIBLE (OR NON-EDIBLE) PARTS	Components associated with food that, in a particular food supply chain, are not intended to be consumed by humans. Examples of inedible parts associated with food could include bones, rinds, and pits/stones. "Inedible parts" do not include packaging and what is considered inedible varies amongst users (e.g., chicken feet are consumed in some food supply chains, but not in others), changes over time, and is influenced by a range of variables including culture, socio-economic factors, availability, price, technological advances, international trade and geography (UNEP ENVIRONMENT PROGRAME, 2021).
PERISHABLE FRESH FOOD	Natural or prepared products, within the categories of vegetables, meat, fish, and cooked dishes (ToNoWaste Grant Agreement), that need to be stored under controlled temperature conditions or that have a maximum shelf life of no more than 30 days (Ministry of Industry, Tourism and Commerce, Spain, 2005).
PREVENTION	Measures taken before a substance, material or product becomes waste and that reduce (European Union, 2008): a) the quantity of waste, including through the re-use of products or the extension of the life span of products; b) the adverse impacts of the generated waste on the environment and human health, or; c) the content of harmful substances in materials and products.
RESILIENCE	The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management (United Nations Office for Disaster Risk Reduction, 2009; UNEP ENVIRONMENT PROGRAME, 2017).
SUSTAINABILITY PRINCIPLES	There are four principles that should be addressed: • The sustainability dimensions (financial-economic, environmental, and social) • Inter-generational perspective (time perspective) • Stakeholder approach • Life cycle thinking (Muñoz-Torres et al., 2018).
VALORIZATION AND CONVERSION	Fractions of food and inedible parts of food removed from the food supply chain to be reused or recycled (animal feed, bio-based materials, and biochemical processing (Gustavsson et al., 2014).
WASTE	Any substance or object which the holder discards or intends or is required to discard (European Union, 2008).

3. Food losses and Waste accounting methodologies

This deliverable outlines the accounting methodologies and assessment tools used in Food Losses and Waste Prevention and Reduction (FLWPR actions currently and previously implemented along the supply chain, with emphasis on those developed in the European Union. To achieve this, different methodologies of knowledge extraction were used to guide the process of extraction and analysis of information from previous EU projects and scientific literature. The use of these information sources provides the study with a multidisciplinary approach that guarantees the expansion of the scope of the information extraction process.

3.1 Theoretical background

This deliverable uses different methodologies to extract knowledge from a variety of sources and databases. To do that, the deliverable reviews EU projects and scientific literature. To review EU projects, we have followed a systematic methodology that ensures that all relevant EU-funded projects are reviewed and that the different FLW accounting methodologies are characterized (see epigraph 2.2). This will support the analysis of the degree of development of current assessment methodologies to tackle sustainability issues. Although these documents do not belong to what is called scientific literature (scientific books and journals), they are very relevant for the ToNoWaste project background analysis and can be classified as relevant grey literature. The concept of "grey" refers to its uncertain status as technical literature, which is not produced by commercial publishing and that it is difficult to catalogue, but that has become more accessible due to its publication on the world wide web and the availability of online resources. For the scope of this deliverable, we are not conducting a systematic grey literature review but have conducted our research in relevant online databases to capture those documents that speak to the scope of this deliverable.

To review scientific literature this deliverable follows an approach that allows to shed some light on the accounting methodologies employed in quantifying FLW, while emphasizing the importance of reliable and standardized key performance indicators (KPIs) for accurate measurement. As is thoroughly explained in section 3.3.2, the analysis process is divided into two stages, a general search to identify the most important scientific publications about the topic and specific searches to expand upon the main aspects detected during the first stage.

3.2 EU funded projects review

3.2.1 Aim and scope

With the aim of contributing to the broadening of knowledge and moving a step forward, a systematic review of FLWPR actions related projects previously funded by the EU was carried out. This review contributes to setting a solid science-based foundation to develop the future activities of this project and aligning them with previous research funded by the European Union.

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In this line, CORDIS and BBI JU databases were used to conduct the systematic review, and to compile information related to accounting methodologies and assessment tools used in previous projects funded by the EU. The time scope for the review was established for the period between 2013 and 2023. This decision is justified by the earlier FUSIONS H2020 project, whose literature revision time scope finished in the year 2013and whose overall aim was to contribute to the harmonization of food waste monitoring, the feasibility of social innovative measures for optimized food use in the food chain and the development of a Common Food Waste Policy. In line with this harmonization, starting the analysis of the present deliverable in 2013 provides a time scope wide enough to compile the highest quantity of knowledge generated, but tight enough to avoid overlapping.

CORDIS stands for Community Research and Development Information Service. It is the primary public repository and information source for research and development (R&D) projects funded by the European Union (EU). CORDIS provides access to a vast database of EU-funded projects, including those funded under the EU's Framework Programs for Research and Technological Development. BBI JU stands for the Bio-based Industries Joint Undertaking. It is a public-private partnership established between the EU and the Bio-based Industries Consortium (BIC).

This compilation is organized on project sheets and exposes the general aim of the projects studied; their specific objectives linked to the ToNoWaste project; the system studied during the project; the scope of the study; the presence and location of pilot sites and; a keyword section. Furthermore, it exposes more specific aspects related to D1.1 presenting, on the one hand, which sustainability dimensions are assessed during the project and how they are assessed and, on the other hand, which accounting methodologies are applied along the development of the project and how they are applied.

3.2.2 Method of review

Aiming to ensure the relevance of the selected projects, the research methodology carried out by García-Holgado et al. (2019) was taken as a foundation to conduct the project selection process. The authors describe a four-stage methodology to select the most suitable European research projects within a specific area of knowledge – the health sector in their case- with the aim of extracting information for further research. Based on the mentioned study, the search methodology for the present deliverable is designed to adapt the area-specific inclusion and quality criteria to the field of food losses and waste accounting methodologies and assessment tools, as the main subject of this research.

CORDIS and BBU JU databases were used to perform this research. CORDIS is the main European projects database and contains international projects and BBU JU is also a European database but focuses on bio-economy. Using "food loss" or "food waste" as a search engine on the CORDIS database, 333 projects were obtained. The BBU JU database does not have the possibility of inserting filtering criteria available so that all the projects stored on this database were initially considered, a total of 124 projects. Both searches were done in December 2022.

The **first stage** of the search methodology applied by García-Holgado et al. (2019) consisted of listing the projects obtained from the databases on an Excel sheet. The

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second and third stages corresponded to the screening process, during which inclusion and quality criteria were applied to define the projects that would form part of the final list to be analyzed, as shown in Figure 1.

Adapting this methodology to these deliverables' objectives includes defining three mapping questions: (i) What methodological approaches are being used to characterize and quantify food loss and waste?; (ii) What food loss and waste reduction measures are being implemented? and; (iii) What methodological approaches are being used to assess the performance of food loss and waste reduction measures?

Once the mapping was clearly designed, a search strategy was structured, which was conducted using the CORDIS and BBI JU databases, with the search period covering projects funded from 2013 to March 2023, since 2013 is the last year considered in the analysis of accounting methodologies carried out by the FUSIONS Horizon 2020 Project. Finally, keywords considered for the search were “food loss” or “food waste”.

The following step consisted of defining six inclusion criteria due to the general nature of the first search. One example of such criteria is connected to the following question: Is the project classified in a call related to food? After filtering all the projects whose objectives are aligned with the objectives of this study, they were included.

However, it is important to ensure that the quality and quantity of the publicly available information of the projects is sufficient for further study. For this reason, eight quality criteria were defined. One example of such criteria is connected to the following question: Are there public deliverables associated to the project? For more information on the scientific basis of the methodology and discussion of the inclusion and quality criteria, see (Domingo, Escrig and Muñoz; 2023). This methodology allowed for the creation of a list of suitable projects to be analyzed by extracting information on their accounting methodologies.

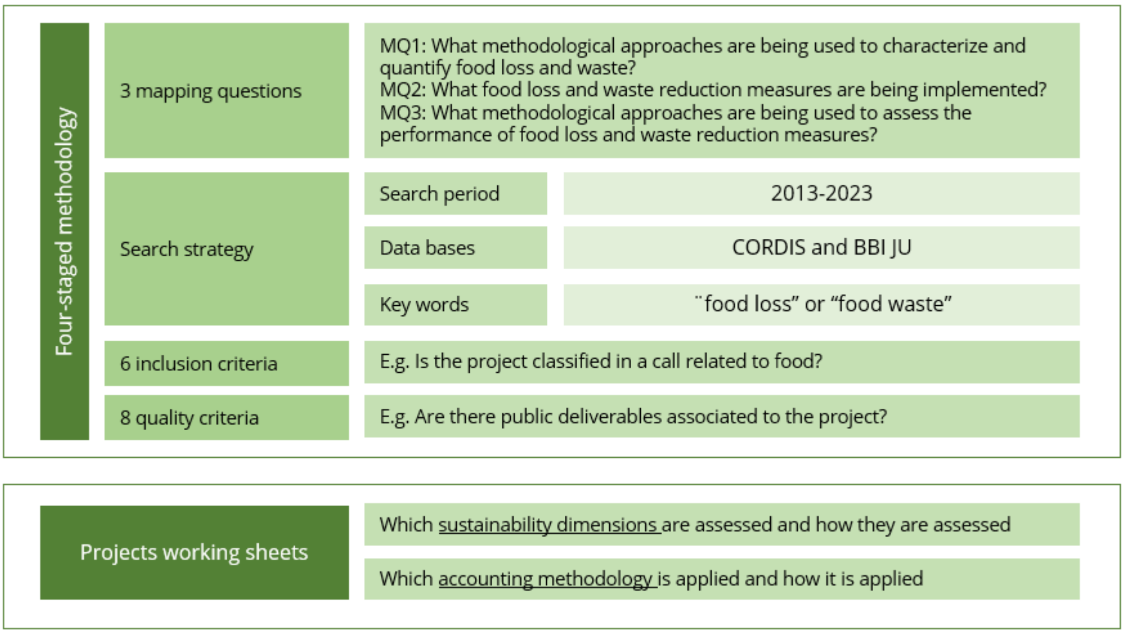

Figure 1. Screening methodology to select projects

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The PRISMA flow diagram (Figure 2) shows the number of projects initially obtained from databases, those that were excluded during the screening process and the number of projects included in the final list for review. The mentioned list consists of 21 projects related to FLWPR measures, which provide enough quantitative and qualitative public information to be analyzed in detail.

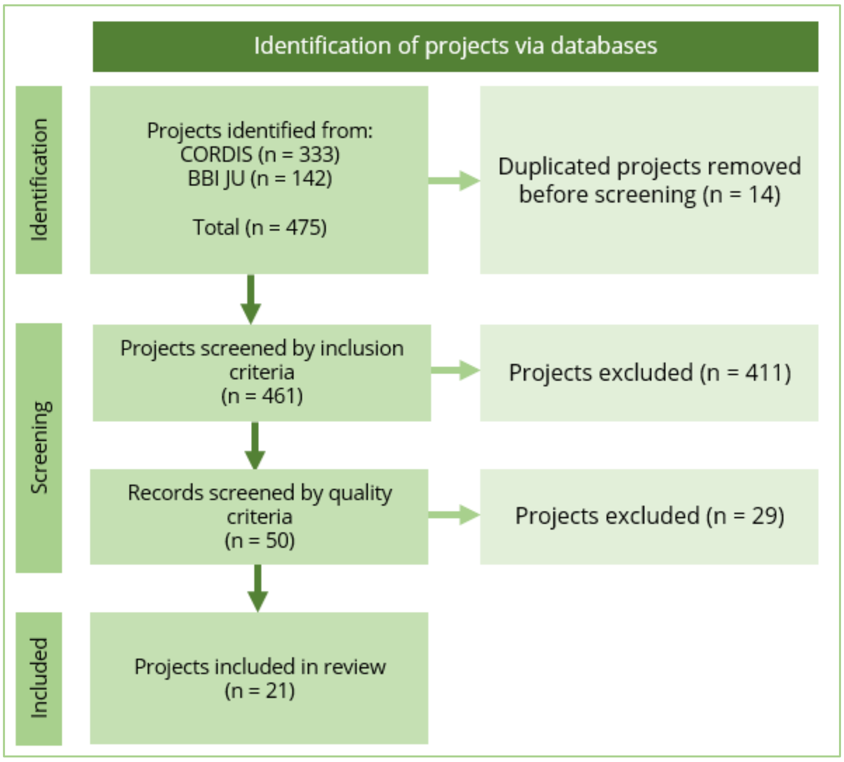

Figure 2. Adapted PRISMA flow diagram for projects systematic review

The fourth and last stage of the searching methodology consisted of a compilation of the relevant information for the study on an Excel sheet. To extract the information on the selected projects, a review of projects' deliverables was carried out. During this review, deliverables associated with administrative working packages were considered as irrelevant, since the focus of the study is to analyze the use of accounting methodologies and assessment tools within projects funded by the EU. The information extracted from this final list of projects was organized on working sheets.

These sheets compile relevant general information about projects. They also reflect the core information for the analysis, that is: which sustainability dimensions are assessed on each project and how they are assessed; and which sustainability accounting methodologies are applied and how. The next section offers the result of the projects' review. It is organized in sheets with relevant information about projects' objectives, scope of the projects and boundaries, sustainability dimensions and impact categories under analysis, projects' sustainability accounting method(s) and piloting process (if any).

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3.2.3 Projects Review

This section provides a compilation of the project sheets obtained as a result of the EU-funded project analysis. The studied projects were classified to carry out a proper analysis considering the specific particularities of each kind of project. This classification was made attending to the nature of the solutions to the problem of food losses and waste provided by each project.

The three categories defined for this classification were: solutions based on social aspects (S), solutions based on organizational aspects (O) and solutions based on technological aspects (T). This classification is also aligned with the objectives of the FUSIONS project aiming to harmonize the methods. The first group looks at aspects such us social behavior analysis and change or social cooperation. The second group focuses on enabling a more sustainable and efficient management of the food supply chain through activities such as food redistribution, multi-approach prevention strategies and the integration of circular business models. The last group includes projects, which focus on developing technologies to prevent and reduce FLW such us smart packaging or valorization processes.

Attending to this classification, the first group of project sheets presented relates to solutions presented based on social aspects. Within this group, the project with the earliest end date is presented in the first place, followed by more and more recent projects, ending with the project with the latest end date. Then, the group of projects classified as solutions based on organizational aspects is presented, following the same ordering structure as the previously defined group. Finally, the group of projects belonging to the category of solutions based on technological aspects is organized considering their end date once again.

Furthermore, and to facilitate their tracking, each project was assigned a code which can be consulted on the upper right corner of the sheets. The initial letter of the code refers to the category, to which the project was assigned and the three numbers that compose the second part of the code were assigned to the projects during the search process. This number facilitated the project tracking during the process and is useful to find projects in the Excel sheets, on which the screening process is reflected.

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	FUSIONS Food Use for Social Innovation by Optimizing waste prevention Strategies	Start date: 01/08/2012 End date: 31/07/2016	Code S-193
		Framework program: Seventh Framework Program Topic: KBBE.2012.2.5-02	

General aim of the project	Specific objectives linked to ToNoWaste
To promote food waste prevention contributing to the harmonization of food waste monitoring; feasibility of social innovative measures for optimized food use and prevention strategies in the food supply chain and the development of a Common Food Waste Policy for EU-28.	To assess the environmental and socio-economic impacts of food waste and to provide a common methodology for the environmental assessment of food waste along the value chain in Europe. To provide recommendations on standard approaches on quantitative techniques to estimate the level of wasted food at different stages of the supply chain. To identify the main causes of food waste generation along the food supply chain and how technology development, food supply chain management, and consumers' behaviors and lifestyles may lead to an increase or reduction in food waste in the future. To identify existing social innovation solutions that reduce food waste; to test new social innovation ideas that reduce food waste; to evaluate their impact on reducing food waste and to explore how policies could be improved to stimulate this social innovation activities.

System under study	Scope of the study
A literature review carried out in February 2013, performed for each step of the food supply chain. The relevant areas reviewed linked to ToNoWaste objectives were: - Socio-economic and environmental impact of food waste; - Quantitative methods to estimate the level of wasted food and data sources; - Environmental impact of food waste assessment methods; - Primary causes of food waste and aspects that suggests possibilities for reduction in food waste; - Food waste prevention and food waste management activities; - EU legislation and policies with implications on food waste; - Market-based instruments and policy measures to promote behavioral change and social innovation; - Previous most relevant food waste studies. Social innovation belonging to five sectors: environment, health, workplace innovation, regional strategies, social economy/social entrepreneurship. Seven new social innovation projects were implemented and evaluated***. Food products considered for the environmental assessment were apples, tomatoes, potatoes, bread, milk, pork, beef, chicken, white fish.	Primary production, processing of agricultural staples, food processing and packaging, wholesale and logistics, retail and markets, food services, and household consumption.

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Social organizations considered for the impacts of food banks and other initiatives assessment were food banks, food pantries, soup kitchens, shelters, and combinations of them.	

The project assesses some sustainability dimension	☒Environmental ☒Social	☒Economic ☐Non
What it is assessed		Deliverable
(i) Socio-economic impacts of food waste including: - (ia)Impacts on health and nutritional issues; - (ib)Impacts of food loss and waste reduction; - (ic)Impacts of food redistribution organizations, such as food banks or social supermarkets. (ii) Environmental impacts of food waste.		* **
How it is assessed		Deliverable
A quantification of food waste levels was performed, proposing a methodology for the replicability of this quantification process. Then the impact of these food waste was calculated following the structure shown below: (ia) Impact on health and nutritional factors. Nutrient losses in terms of human nutrient requirements were analyzed and nutrient degradation was investigated based on a literature review. A short overview of anti-nutritional factors for mycotoxins, glycoalkaloids, pesticide residues and other examples was included. (ib) Socio-economic impacts of reducing food waste. A comparative qualitative analysis of studies was undertaken. The reviewed studies were classified into two categories: - Studies that sought to develop a theoretical framework for the economics of food losses and waste and a description of how the framework can be implemented in a quantitative model; - Studies that applied economic modeling, primarily to analyze and to quantify the impacts of reducing global food losses and waste on production, trade, prices and incomes. Empirically, Computable General Equilibrium (CGE) models and Partial Equilibrium (PE) models were found in the literature review performed by this project to quantify the potential socio-economic impacts of FLW. (ic) Impacts of food banks and other initiatives. The methodology of social capital was applied. The outcome of the literature review and the consultation rounds during project meetings was a list of social impacts from various stakeholders and steps of the food supply chain. Out of this list only indicators for food redistribution organizations were selected to test the methodology. (ii) Environmental impacts of food waste. The methodology of the Life Cycle Assessment (LCA) was used, which accounts for emissions from cradle to grave, covering most of the steps of the food supply chain.		D1.4 * **

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The project uses accounting method(s) ☒Yes ☐No	
Application of the method(s)	Deliverable
(ib) Socio-economic impacts of reducing food waste. Bringing together all the FLW socio-economic impacts studies with the aim of synthesizing and comparing knowledge. (ic) Impacts of food banks and other initiatives. Methodology of social capital: the networks of social relations based on social norms of trust and reciprocity. A pilot study was carried out to assess the applicability of the concept of social capital aimed at evaluating the social impact of food redistribution initiatives. (ii) Environmental impacts of food waste. The project presents an assessment of the quality and robustness of environmental attribute data of each impact category (mostly from LCA) Combination of two LCA methods: - Top-down: uses material flow analysis (leaving out input-output analysis) in combination with coefficients to derive the impact of an average impact per unit of food and drink in the EU-28. This study is based on GWP values. - Bottom-up: starting on a product level to calculate the environmental impact of each selected indicator product. This study is based on GWP, EP and AP values. The results of both approaches, top-down and bottom-up, are extrapolated to show the contribution of environmental impacts of food waste on the entire food supply chain and to then compare them.	* ** ***
Aspects and impact categories	Deliverable
(ii) Environmental - Global warming potential (GWP) - Eutrophication potential (EP) - Acidification potential (AP) - Photochemical ozone creation potential - Ozone depletion potential - Human toxicity potential - Ecotoxicity potential - Abiotic resource depletion - Biotic resource depletion - Reported energy - Land use - Biodiversity - Water use (i) Social capital dimensions - Groups and networks - Trust and solidarity - Collective action and cooperation - Social cohesion and inclusion - Information and communication - Food safety - Food security	**

The project has pilot sites ☐Yes ☒No

Key words
Common Food Waste Policy, Environmental impacts, Socio-economic impacts, Social innovation, Food waste quantification, Social capital methodology, Life Cycle Assessment (LCA)

* FUSIONS Definitional Framework for Food Waste
** Criteria for and baseline assessment of environmental and socio-economic impacts of food waste
*** Social innovation projects to reduce food waste: key recommendations for policy makers and for the private sector

Table 1. FUSIONS working sheet

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	REFRESH Resource Efficient Food and dRink for the Entire Supply cHain	Start date: 01/07/2015 End date: 30/06/2019	Code S-347
		Framework program: Horizon 2020 Topic: WASTE-2-2014	

General aim of the project	Specific objectives linked to ToNoWaste
To develop a 'Framework for Action' (FA) (food industry voluntary agreements) to tackle food waste, taking into consideration consumer understanding to reduce food losses along production and supply chains, reducing waste management costs, and valorizing un-avoidable food waste and packaging materials.	To understand consumer behavior with food and food waste and consumer understanding in relation to waste generation, handling, reuse, and by-product valorization. To assess the success of FAs and help lead organizations responsible for them to set baselines and work with business participants to measure and report their food waste data. To provide an overview of the existing EU policies and instruments with an impact on food waste generation and/or prevention and develop a model that can assess their impact on reducing food waste at the consumer level. To support the development of a harmonized approach to EU food waste legislation by addressing environmental impacts and LCC of possible policy and consumption. To review measures and methodologies for evaluating the environmental sustainability and life cycle costing dimensions of food waste and food valorization. To supply LCA and LCC data for selected cases of valorization routes to be used for the identification of the most sustainable and economically viable solution. To develop and test a prototype monitoring tool focused to facilitate effective decision-making leading to actions that will prevent and valorize waste.

System under study	Scope of the study
Consumer food management in two areas: - In-home: planning, provisioning, storing, preparing, consuming, and disposal; - Out-of-home: ordering/serving and consuming. The same harmonized method for assessing environmental impacts and cost developed by the project was tested in practice in two selected case studies: - Valorization of manufacturing, retail, and catering food surplus as pig feed; - Prevention of surplus up to wholesale in the peach and nectarine supply chain. Integration of LCC and LCA valorization results to higher system levels was performed on two food products: - Meat: beef, pork, and poultry;	The whole chain paying special attention to consumer food management stages. FORKLIFT (FOod side flow Recovery LIFe cycle Tool) has a cradle-to-factory gate perspective

- Tomato: tomato juice, tomato whole or in pieces, tomato sauces, or tomato other than whole or in pieces. Scaling up models and processes were presented on the practical case of producing food ingredients from a chicory processing by-product.	

The project assesses some sustainability dimension	☒Environmental ☐Social	☒Economic ☐Non

What it is assessed	Deliverable
The process of setting up and running an FA in each of the piloted countries. The potential environmental and economic feasibility and benefit of valorization routes of a given-side-flow and other mitigation strategies. The mass flows of meat supply chain and tomato supply chain at country levels. The comparison between side flow valorization, valorization as a part of waste management and end of life treatment.	D2.8 D5.4 D5.5 D5.6 D6.5

How it is assessed	Deliverable
Mitigation strategies were grouped into five categories: production efficiency, process optimization, food waste reduction, trade pattern change, diet structure change. As far as cost modeling is concerned, the following type of costs were assessed along the supply chain: internal, avoided, and external. Furthermore, costs were categorized by stage and, when possible, by specific typology: material, energy, labor, transport. No evaluation of net present value or added value was carried out. The study provides a clear guidance on cost-benefits of valorization to identify their economic feasibility. The methodology of techno-economic analysis gives quantitative notion of expected food valorized product cost price and effects of technological alternatives and market development. The environmental impacts have been assessed using the ILCD impact assessment methodology recommended by the European Commission (EC, 2012). Data was extracted from Ecoinvent. Mass, energy, and GHG emissions along the entire supply chain were considered. A mapping of the mass flows of meat and tomato supply chains was performed. This mapping was matched with LCA results to explore GHG emissions mitigation potentials of measures from production side to consumption side. FORKLIFT (https://eu-refresh.org/forklift.html) was developed based on the Life Cycle Impact Assessment methodology to help stakeholders gain a general understanding on and to highlight the environmental impacts in terms of GHG emissions and costs for selected valorization routes of a given side flow (for the comparison analysis of valorization activities). Specifically, this was done for energy production and waste management, as these are common processes for the different side flows. A consequential approach was selected to analyze the change produced when valorization is allowed. Average nutritional value was calculated and multiplied by the volume of food surplus in tons previously gathered. The study applied the stepwise procedure for LCA/LCC studies on food surplus in Davis et al. (2017).	D5.4 D5.5 D5.6 D6.5

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The project uses accounting method(s) ☒Yes	☐No
Application of the method(s)	Deliverable
(i) Life Cycle Costing – LCC. E-LCC (environmental-LCC), was the method applied in REFRESH and the FORKLIFT tool. The costs are related to real money flows. Externalities that were expected to be internalized were also included. With the aim of simplifying and providing reliable resources, this tool only included, in its default version, costs directly related to LCA inventory items. (ii) Life Cycle Assessment - LCA (ISO 14044). Distinguishes between two different types of modelling: - Attributional LCA (ALCA): assesses the impact of a functional unit using data (footprint). - Consequential LCA (CLCA): assesses the effect on one system due to changes (interventions). Economic allocation was chosen as the appropriate method, allowing the user to include the relative value of side flow with respect to the product portfolio of the given product being processed. No cut-off criteria are defined for this study. Only processes contributing significantly to the GWP are considered. Two types of emission accounting approaches are considered, depending on how the international trade was considered: - Territory-based: includes emissions occurring within the national boundary. - Consumption-based: takes into account the emissions from domestic final consumption of the studied product, as well as emissions caused by the production of its imports elsewhere. GHG accounting differentiated between positive values are GHG emissions, negative values are GHG savings. There were some particularities regarding the analysis of each food product: - Meat: the dry matter balance and related energy and emissions of the whole system were calculated based on the Material Flow Analysis (MFA) principles. The energy within the mass was calculated based on their corresponding energy coefficients. GHG emissions accounting was performed along the meat supply chain, which includes all emissions from animal production and related to process energy use in other stages. - Tomatoes: GHG emissions accounting is based on the process energy (PE) used to process the goods. (iii) FORKLIFT tool. GHG emissions from the upstream processes, before the side flow was generated, are allocated between the main product and side flow, based on their actual or estimated economic value for the generator of the side flow (economic allocation).	D5.2 D5.3 D5.4 D5.5 D5.6
Aspects and impact categories	Deliverable
Environmental - Climate Change according to IPCC 2013 GWP 100a characterization factors; - Climate change according to ILCD (IPCC 2007 GWP 100a characterization factors); - Water resource depletion; - Mineral, fossil, and resource depletion; - Freshwater eutrophication;	D5.1 D5.2 D5.4 D5.5

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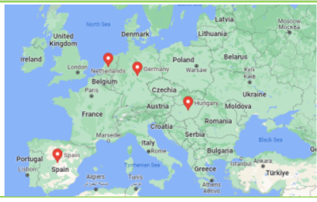
- Marine eutrophication; - Terrestrial eutrophication; - Acidification; - Land use (expressed as kg C deficit in ILCD method); - Land use as LCI result has also been included (m2 land occupation). Economic - Initial investment costs; - Financing costs; - Recurring operating and maintenance costs and capital replacement costs; - Resale value or salvage/disposal costs.	

The project has pilot sites ☒Yes ☐No	
Spain Hungary Germany Netherlands	

Key words
Food valorization, Ecoinvent, Cost-benefit, Life Cycle Costing, Life Cycle Assessment, Economic Assessment, Environmental Assessment

Table 2. REFRESH working sheet

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cities 2030	**CITIES2023** Co-creating resillient and sustainable food systEms towards FOOD2023	Start date: 01/10/2020 End date: 30/09/2024	Code S-090
		Framework program: Horizon 2020 Topic: CE-FNR-07-2020	

General aim of the project	Specific objectives linked to ToNoWaste
To bring together researchers, entrepreneurs, civil society leaders, cities and all agents of Urban Food Systems and Ecosystems (UFSE) to create a structure focused on the transformation of the way systems produce, transport, supply, recycle and reuse food.	To provide a participatory production of outlines, developments (joint activities), pilots (small-scale on specific thematic), and validation of cost-effective Impact Monitoring and Assessment (IMA) methods taken from identified good practices, in particular cutting-edge approaches and mechanisms from the rural development arena, sustainable land management, and evidently food security and nutrition programmes, all related to Cities and Regions Food Systems (CRFS). To generate a category of indicators to assess impacts of cooperation between the different actors of the CRFS: cooperation mechanisms efficiency. Cities2030 develops beyond the 6 categories enhancing the Milan Urban Food Policy Pact (MUFPP) framework (outcomes, impact, indicators, recommendations, etc.) with two key pathways: nature-based solutions (NBS) and urbanization as such. To assists and empower cities and regions to implement sustainable Cities and Regions Food Systems (CRFS) and achieve five specific objectives: secure healthy and sustainable food, stop food poverty and insecurity, protect, and preserve natural resources, enhance circularity and local food belts, and develop food culture and skills. To explore and map the novel trends in all applicable sphere of the food system identifying emerging digital and technological solutions, start-ups, practices of local communities, findings of international research projects and other initiatives that promote positive transformation in CRFS (D3.7).

System under study	Scope of the study
Cities2030 practices a multi-actor approach at 'macro', 'meso' and 'micro' levels, exploring, testing, scoring, and validating local and regional supply and value chains, introducing the concept of 'food environment' e.g., supply and value chains ecosystems. - 'Macro' level: it connects with production quantities which are adjusted on a "right amount of the right source" basis. - 'Meso' level: it links with sustainability, resources' use efficiency, productivity, quality, profitability, and the social	Project focus areas: production, processing, distribution, markets, consumption, waste, security, ecosystem services, livelihood and growth, inclusion, and equity.

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environment (e.g., employment and livelihood) of the comprehensive value chain production system. - 'Micro' level: it relates with innovative nutraceutical frameworks supported by 'omic' technologies e.g., proteins (proteomics) and metabolites (metabolomics), characterization of functionalities, community data examination (diet habits, regional and local food belts, circularity, etc.) and combines information with other sources of data. More than 140 innovations and good practices that have already demonstrated positive impact on food systems and have potential for transfer to other territorial areas were obtained (D3.7). All collected innovations were clustered into 10 thematic categories: food production, processing, distribution, markets, consumption, waste, food security, social inclusion & equality, ecosystem services, and livelihood & growth. 15 cities piloted policy and innovation experiments in living lab type environments.	

The project assesses some sustainability dimension	☐Environmental ☐Social	☐Economic ☒Non
What it is assessed		Deliverable
A cost-effective Impact Monitoring and Assessment (IMA). The definition of priorities for interventions per identified cities' needs via a structured assessment with the measurable indicators from the monitoring framework.		D1.1
How it is assessed		Deliverable
The project delivered a digitally enhanced "Impact Monitoring and Assessment Tool" (IMAT), to facilitate and accelerate the identification, monitoring, assessment, and characterization of the project's overall impact, considering a precise framework detailed in the miscellaneous outputs produced in the scope of the project. The characterizations of cities engaged in the project were done considering a set of indicators and into what stent these indicators are reflected and covered by current municipal initiatives.		D1.1

The project uses accounting method(s)	☐Yes ☒No
Application of the method(s)	Deliverable
Aspects and impact categories	Deliverable

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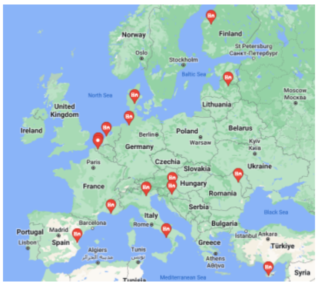
The project has pilot sites ☒Yes ☐No

CRFS Labs:
Germany: Bremerhaven
Belgium: Bruges, Agrotopia
Netherlands: Haarlem
Romania: Iași
Slovenia: Murska Sobota
Spain: Quart de Poblet
Finland: Seinäjoki
Cyprus: Troodos

Denmark: Vejle

Croatia: Velika Gorica
Italy: Vicenza
Latvia: Vidzeme

France: Marseille
Italy: Pollica



Key words

Impact Monitoring and Assessment (IMA), Urban Food Systems and Ecosystems (UFSE), Cities and Regions Food Systems (CRFS), Milan Urban Food Policy Pact (MUFPP), Living Lab

Table 3. CITIES2023 working sheet

	FOOD TRAILS Building pathways towards FOOD 2023-led urban food policies	Start date: 16/10/2020 End date: 15/10/2024	Code S-161
		Framework program: Horizon 2020 Topic: CE-FNR-07-2020	

General aim of the project	Specific objectives linked to ToNoWaste
It aims to translate the worldwide Milan Urban Food Policy Pact's shared vision and collective commitment to integrated urban food policies into measurable and long-term progress towards sustainable food systems in Europe and building pathways towards FOOD 2030-led urban policies.	To enhance theoretical understanding of food innovations as related to the FOOD 2030 framework and the potential opportunities and barriers for food system transformation. To identify the mechanisms that have been deployed to overcome the barriers to the development of an urban food policy and support project pilot cities in the development of their Living Lab. To illustrate the food policy priority goals identified as the most relevant by partner cities for their Living Lab and in relation to the four key priorities of FOOD 2030. To provide a map of existing urban good practices and innovations in the realm of food that contribute to the four pillars of the EU's FOOD 2030 Framework.

System under study	Scope of the study
European cities that developed case studies relating to food-based participatory policy making initiatives. Fifteen of them were highlighted for their participation to the MPA and their good practices on developing food policies. Cities where the assessment of food policy priority goals was performed as a focus of their Living Lab and the overall assessment process.	Cities with high participation in Milan Pact Awards (MPA)

The project assesses some sustainability dimension	☒Environmental ☒Social	☒Economic ☐Non
What it is assessed		**Deliverable**
The social, economic, and environmental benefits of urban food practices with more innovative features for systems transformation in Europe. The quality of food polices and food actions to help researchers to better understand the innovative trends in Europe on food policies. How cities can work overtime and how this could impact the approach to different fields of action of the food system.		D1.1 D1.2 D1.3
How it is assessed		**Deliverable**
Analyzing a selection 42 innovative food practices from European case study cities to understand their real and potential fit with the four priorities of FOOD 2030 and their actual or potential contribution to food system transformation, making use of the new CLIC conceptual framework methodology. Analyzing the innovations in the Milan Urban Food Policy Pact (MUFPP) cities, based on the database of the Milan Pact Awards of 159 urban food policy practices formally supported by mayors. Focusing on cities that were more active and with		D1.1 D1.2 D1.3 D2.1

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the highest scores, the project gives an overview on the quality of food polices and food actions. Applying a Food Policy Action Canvas (FPAC) framework to help policy makers identify food issues-related policy priorities and guide their policy actions in a step-by-step process. Urban food practices reviewed were spurred by particular concerns – be these health, social empowerment of vulnerable communities, or environmental concerns. However, all have delivered more than one benefit in the context of aiming to contribute to sustainable food systems. The report is based on empirical data for the study of the Living Labs collected through two different methodologies: interviews and a structured survey.	

The project uses accounting method(s) ☒Yes	☐No
Application of the method(s)	Deliverable
(i) CLIC framework. Has 4 pillars for a sustainable (economic, social and environmental) transformation of food system: - <u>Co-benefits</u>: the acknowledgment that oftentimes activities that realize benefits in one sustainability dimension impact other parts of the food system (or other connected systems) in a positive or negative way, leading respectively to synergies (co-benefits) or trade-offs. - <u>Linkages:</u> systemic innovations, by their very nature, break spatial fixes (i.e., the urban-rural divide); they create hybrid places where urban and rural actors exchange knowledge, resources, goods and services. In the food system, place-making strategies should be sustained by systemic innovations that create alternative food distribution channels. - <u>Inclusion</u> of all food system actors in the innovation process, while ensuring also a fairer distribution of its outcomes. - <u>Connectivity</u> is about policy integration and the adoption of a coherent "place-based" approach around it. The CLIC offers a prism to facilitate, at the same time, the analysis of systemic innovation processes, their implementation and their evaluation. (i) City Region Food System assessment. The City Region Food System (CRFS) assessment is a theoretical and analytical tool developed by RUAF and FAO to understand and improve the city region food system dynamics. The final goal of the CRFS assessment is to advance the CFRS policy design or strategy planning. To do so, the CFRS assessment builds upon 9 overarching objectives, 29 desired outcomes, 29 impact areas and 210 indicators.	D1.1
Aspects and impact categories	Deliverable
Milan Urban Food Policy Pact categories: - Governance; - Sustainable Diets and Nutrition; - Social and Economic Equity; - Food Production; - Food Supply and Distribution; - Food Waste. FOOD 2023 framework pillars: - Nutrition; - Climate; - Circularity; - Innovation.	D2.1

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<table>
<tr><th colspan="2">The project has pilot sites ☒Yes ☐No</th><th>Key words</th></tr>
<tr>
<td>Case study cities
Netherlands: Almere, Amsterdam, Ede
Spain: Barcelona, Slow Food Barcelona, Madrid, Valencia
Germany: Berlin, Cologne
Belgium: Bruges, Ghent
Slovenia: Ljubljana

France: Nantes, Paris

Latvia: Riga

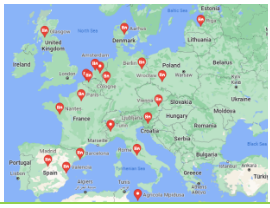
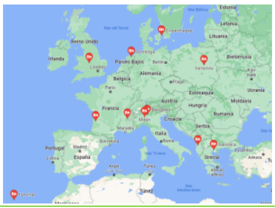
Italy: Turin, Agricola Mpidusa, Slow Food Rome
Austria: Vienna
Denmark: Aarhus
Scotland: Glasgow
Poland: Wroclaw
</td>
<td>Living labs
Poland: Warsaw
Albania: Tirana
Greece: Thessaloniki
Netherlands: Groningen
France: Grenoble-Alpes Metropole, Bordeaux Metropole
Portugal: Funchal
Denmark: Copenhagen
United Kindom: Birmingham
Italy: Bergamo, Milan
</td>
<td>Milan Urban Food Policy Pact, FOOD 2030, Milan Pact Awards (MPA), Environmental assessment, Social assessment, Economic assessment, CLIC framework, City Region Food System (CRFS) assessment</td>
</tr>
</table>

Table 4. FOOD TRAILS working sheet

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	CHORIZO Changing practices and Habits through Open, Responsible, and social Innovation towards ZerO food waste	Start date: 01/10/2022 End date: 30/09/2025	Code S-084
		Framework program:	Horizon Europe
		Topic:	HORIZON-CL6-2021-FARM2FORK-01-13

General aim of the project	Specific objectives linked to ToNoWaste
To improve the understanding between social norms, consumer behaviors and economic actor decisions and Food Loss and Waste (FLW) generation and use this knowledge to improve the effectiveness of decision-making and engagement of food chain actors, towards zero food waste.	To address existing research gaps and use its outcomes to deliver and advance innovations helping actors to engage more effectively in food waste prevention and reduction activities. To integrate EU and food chain actors to enhance contingency knowledge and produce new effective instruments for facilitating successful transitions towards minimizing FLW. To undertake a comprehensive evidence-based analysis of previous/ongoing FLW prevention/reduction actions and tools, including a cost/benefit analysis and an impact assessment. To provide evidence on the role of existing social norms in actors' FLW behaviors through translating results from previous FLW actions into evidence and generate new evidence on social norms & FLW behaviors. To develop an FLW Datahub (Chorizo FLW Insighter), which will incorporate the results of the evidence-based analysis of previous/ongoing FLW actions, new empirical case study evidence on social norms, consumer behavior, economic actor behavior and charity behavior in relation to FLW. To develop a modelling & predictive analytics backbone based on data from the Case Studies (CSs) and use it to discover and explain the correlations between social norms, business practices, consumer behavior and food waste. To manage the project's innovation upscaling effectively, by a strategy for the exploitation of the project results and implementing responsible innovation management practices that guide the project to exploitable and sustainable outcomes. To utilize advanced modelling techniques to produce solutions that integrate behavioral and economic theories and integrate gender and intersectional analysis to interpret social norm and behavioral data and to effectively engineer innovation processes and outputs.

System under study	Scope of the study
Six Case Studies to overcome shortcomings of the evidence-based analysis associated to the use of secondary data:	Food Chain Actors

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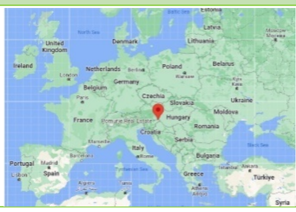
- Household food waste in and off crisis periods; - Hospitality food waste; - Food services food waste (Pomurje, Slovenia); - School food waste and relation with obesity and malnutrition; - Food waste in a food banks' mediated supply chain; - Food waste in relation to date marking and sustainable and smart food packaging.	

The project assesses some sustainability dimension*	☐Environmental ☐Social	☐Economic ☐Non
What it is assessed		Deliverable
How it is assessed		Deliverable

The project uses accounting method(s)*	☐Yes	☐No
Application of the method(s)		Deliverable
Aspects and impact categories		Deliverable

The project has pilot sites	☒Yes	☐No
Slovenia: Pomurje		

Key words
Social norms, FLW Datahub, Food Loss and Waste (FLW), Case Studies (CSs), Food Chain Actors, Evidence-Based analysis

*More results related with sustainability assessment and accounting methodologies are expected in next deliverables.

Table 5. CHORIZO working sheet

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	SavingFood An innovative solution to tackle food waste through the collaborative power of ICT networks	Start date: 01/01/2016 End date: 30/04/2018	Code O-369
		Framework program:	Horizon 2020
		Topic:	ICT-10-2015

General aim of the project	Specific objectives linked to ToNoWaste
To offer a novel approach to tackle food waste by turning the environmental issue into an innovative solution to fight hunger. The project builds on the collaborative power of Information and Communication Technology (ICT) networks and creates an online community of citizens, food waste stakeholders and policy makers that through knowledge creation and sharing they are empowered to take direct action and become part of the suggested food waste solution.	To facilitate the redistribution of surplus food to those in need, ensure that no food is wasted through lack of communication, support the participation of people in organized as well as ad hoc events around food saving and encourage wide debate. To create a social movement around food redistribution to reduce food waste and fight hunger. To offer a complete, sustainable, and flexible platform that allows and encourages all stakeholders in the food chain -farmers, big food companies, retailers, small shops, civil society organizations, charities, and citizens –to interact and connect with each other and to deliver food surplus to the most needed in society. To design a pilot implementation plan to prepare the ground for testing the SavingFood platform in the four pilot locations by engaging existing and new communities of organizations (food donors and food recipients), farmers and individuals (volunteers, gleaners, and citizens) in a co-creating manner by means of an iterative process. To empower communities to take action and to become part of the SavingFood food waste solution, whilst raising awareness and promoting collaboration.

System under study	Scope of the study
By means of an online platform to foster large scale collaboration the project aims to help four key groups: - Donors; - Intermediaries; - Recipient organizations; - Volunteers. The platform should support three different food redistribution scenarios: - Big and small donations (general food rescue); - Gleaning (food saving events); - Farmers markets (food saving events). Key target groups are: - Foodbank; - Grassroot Food surplus; - Redistribution initiatives;	The redistribution practice includes all activities from the gate of the donor to the end user: collecting, transportation, storage, distributing and usage.

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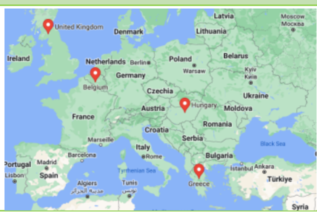
- Gleaning Group; - Charity; - Donor (retail, shops, supermarkets, restaurants); - Citizen/volunteer.	

The project assesses some sustainability dimension	☐Environmental ☒Social	☒Economic ☐Non
What it is assessed		Deliverable
An overview of behavioral change models that were used in the context of food waste reduction in the domestic context and the psychological drivers towards such behaviors. The progress made in the current status of the platform prototype and to give guidance towards further development of the platform according to the specifications set out in the previous deliverables. The successful implementation of the four pilot cases and its social and economic impact for the communities involved in the SavingFood pilots. The usability and technology acceptance of the platform and services and their effectiveness in changing behavior towards participation in food waste reduction.		D2.1 D2.5 D3.4 D5.1 D6.8
How it is assessed		Deliverable
The IA4SI FP7 project methodological framework for measuring the impact of social innovation was investigated. The identification of some crucial aspects of food surplus redistribution and SavingFood was kept in mind when trying to work out a Behavioral change campaign. The methodology to be followed for the technical evaluation of the platform prototype is the (i) "Product Quality Model". A set of characteristics are presented and defined, as well as the internal and external measures of software quality are described. To ensure SavingFood continuation after project completion there are two significant categories of cost that should be covered: - Maintenance costs to cover some basic server and personnel costs and sustain the platform and service to its current instances. - Expansion costs, to cover the replication of the platform by additional organizations and meet their special requirements and needs.		D2.5 D3.4 D5.1 D6.8

The project uses accounting method(s)	☒Yes	☐No
Application of the method(s)		Deliverable
"Product Quality Model" follows ISO/IEC 25010:2011 guidelines. The IA4SI FP7 project methodological framework (Passani et al., 2016) is a self-assessment methodology for evaluating projects in the field of social innovation through a mix of qualitative and quantitative methodologies. The IA4SI methodology uses eight synthetic indices: four of them are related to key areas of impact (social impact, economic impact, environmental impact and political impact), and four are related to attributes of the innovation developed (efficiency, effectiveness, fairness, sustainability). The (ii)social, (iii)economic and (iv)environmental impact areas of IA4SI are the most relevant for the SavingFood project since these are also the core areas of the project.		D3.4 D5.1

Aspects and impact categories		Deliverable
(i) Characteristics to evaluate software quality: - Functional suitability; - Performance efficiency; - Compatibility; - Operability; - Reliability; - Security; - Maintainability; - Profitability.	(ii) IA4Si social impacts: - Community building and empowerment; - Information; - Ways of thinking, values and behavior; - Education and human capital; - Science and academia; - Employment. (iii) IA4Si economic impacts: - Users economic empowerment; - Economic value generation by the project; - ICT driven innovation. (iv) IA4Si environmental impacts: - Greenhouse gasses emissions; - Air pollution related to transport; - Solid waste; Sustainable consumption of goods and services.	D3.4

The project has pilot sites	☒Yes ☐No
Greece Hungary United Kingdom Belgium	

Key words
Behavioral change, Redistribution of surplus food, Social impacts, Economic impacts, Software quality evaluation, Product Quality Model, IA4SI FP7 project

Table 6. SavingFood working sheet

	FOODRUS AN INNOVATIVE COLLABORATIVE CIRCULAR FOOD SYSTEM TO REDUCE FOOD WASTE AND LOSSES IN THE AGRI-FOOD CHAIN	Start date: 01/11/2020 End date: 30/04/2024	Code O-171
		Framework program: Horizon 2020 Topic: RUR-07-2020	

General aim of the project	Specific objectives linked to ToNoWaste
To enhance the resilience and sustainability of European food systems by deploying and demonstrating the value of 12 innovate solutions that will promote sustainable and cooperative models for prevention, reutilization, recovery and valorization of food losses and waste with a special focus on perishable food.	To reduce the FL and the generation of food waste through the implementation of effective multi-approach prevention strategies (social, ethical, financial, managerial, organizational, and technological) without compromising on food quality, including safety, and sustainability. To provide precise reliable and long-term quantification and monitoring of generated FW in the selected FVCs based on the implementation of different ICT tools (IoT, IoH, Blockchain, Fiware, etc.). To combine quantitative information with different qualitative citizen-science based approaches to learn about the intricate direct and indirect causes of inefficiency and identify potential drivers for innovative circular approaches along the FVC. To promote and foster long term behavioral changes to increase resilience and sustainability of local/regional food ecosystems based on the empowerment and engagement of all the actors involved through specific Social Pilot's Programs and the use of educational materials, legal instruments and collaborative approaches, citizen science activities, sustainable and ethical finance, bio-economy, and last mile logistics. To apply a multi-criteria assessment methodology to evaluate the impact and feasibility of the implemented strategies in terms of food loss/waste reduction, economic costs saved and environmental and social impacts. To build up a solid multi-actor alliance towards food sovereignty based on new sustainable and cooperative models for prevention, reutilization, recovery and valorization of food losses and food waste. To implement living labs in the regions of Navarre-Basque Country (Spain), Copenhagen (Denmark) and Nitra and Bratislava (Slovakia) aimed at testing and demonstrating the strategies and solutions deployed under real conditions for their pre-market approval in specific value chains regarding vegetables (V), meat & fish (MF) and bread (B).

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System under study	Scope of the study
The 3 systems that are being studied in the pilots of the project are: – Cross-regional Spanish pilot (SPP) focused on vegetables and IV range salads and localize in the region of in Navarre-Basque Country and involving 8 relevant stakeholders as partners, third parties and subcontracted. – Danish pilot (DP) that will analyze the value chain for meat and fish in the region of Copenhagen and involving 5 relevant stakeholders as partners, third parties and subcontracted entities. – Slovak pilot (SLP) localized in 5 locations analyzing the bread value chain and involving 11 relevant stakeholders as partners, third parties and subcontracted entities.	All the stages in the FSC: Primary production, processing and manufacturing, retail and other distribution of food, restaurants and food services, and household consumption.

The project assesses some sustainability dimension	☒Environmental ☒Social	☒Economic ☐Non
What it is assessed		Deliverable
The sustainability impact of 12 sets of solutions that will be designed, deployed, and tested in the 3 pilots. To assess this impact, a set of KPIs have been defined in the project, encompassing the 3 pillars of sustainability.		D1.1 D1.2 D1.3 D1.4 D1.5
How it is assessed		Deliverable
The sustainability impact is assessed by calculating and comparing the results of the KPIs in the baseline (before the implementation of the solutions) and in the prevention scenarios (after the implementation of the solutions). In order to define the KPIs and how the overall sustainability performance of the FLW prevention strategies is calculated, a comprehensive methodology was built. It includes several phases: - Literature review and pre-selection of KPIs; - Consultation with experts; - Consultation with FSC stakeholders; - Analytic Hierarchy Process; - Creation of the sustainability index.		D1.1 D1.3 D4.1 D4.3

The project uses accounting method(s)	☒Yes ☐No
Application of the method(s)	Deliverable
The quantification KPIs follow the guidelines set by the Commission Delegated Decision (EU) 2019/1597. The impacts measured through the LCA KPIs of the project are being calculated considering: - The ISO standards 14040 and 14044. - The International Reference Life Cycle Data (ILCD) System handbook. - The Product Environmental Footprint Category Rules (PEFCR) guidance. - The "Assessment of food waste prevention actions" technical report developed by the Joint Research Centre. The rest of the 69 KPIs follow different calculation approaches depending on the KPI source, characteristics of the pilots, etc. They are defined in Annex III of the deliverable D1.1.	D1.1

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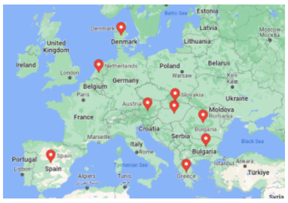
Aspects and impact categories		Deliverable
The KPIs of the project are classified within 15 latent variables, called: - Cooperation; - Economic performance; - Involvement performance; - Quantification; - Environmental footprint; - Implementation impact; - Lack of awareness; - Logistics and reverse logistics; - Packaging; - Process operation efficiency; - Product quality; - Redesigning the product or the production processes; - Social performance; - Social outcomes; - Technical performance;	Two environmental LCA impact categories were considered, both taken from the EF method: - Climate change; - Water use.	

The project has pilot sites ☒Yes ☐No	
Spain Denmark Slovakia Hungary Austria Netherlands Greece Bulgaria Romania	

Key words
Food loss, Food waste, Food loss and waste, Food supply chain, Food value chain, Food waste prevention, Circular food strategies, Circular economy, Sustainability, Waste management, Digital technologies

Table 7. FOODRUS working sheet

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	HOOP HUB OF CIRCULAR CITIES BOOSTING PLATFORM TO FOSTER INVESTMENTS FOR THE VALORIZATION OF URBAN BIOWASTE AND WASTEWATER	Start date: 01/10/2020 End date: 30/09/2024	Code O-215
		Framework program:	Horizon 2020
		Topic:	CE-FNR-17-2020

General aim of the project	Specific objectives linked to ToNoWaste
To foster urban circular bio-economy (UCBE) across Europe by unlocking bio-based investments through a systemic and cross-cutting approach. The project action is deployed by offering Project Development Assistance (PDA) to a group of 8 Lighthouse Cities and Regions and, in later stages, the project will feature the HOOP Urban Circular Bio-Economy Hub (UCBH), an online platform that will provide opportunities to replicate the PDAs of the Lighthouses to other cities and regions across Europe.	To support selected European cities to implement the most appropriate technologies for recycling bio-waste and to help unlock bio-based investments and deploy local bio-economies in Europe. To develop an integrated Circular Business Model (CBM) typology focused on bio-waste as well as a new circular valuation method. To screen the existing innovative circular business models for Urban Circular Bio-Economy focusing on the identification of CBMs for bio-waste valorization and the development of a CBM typology which will be able to incorporate also other business cases of bio-waste valorization in the future. To foster investment and implementation of urban bio-waste and wastewater valorization projects. To establish a European network to facilitate the exchange of good practices related to urban bioeconomy among cities and regions and to promote the replication of HOOP outcomes across Europe. The HOOP Network of Cities and Regions will be materialized in the Urban Circular Bioeconomy Hub (UCBH), an online platform to foster knowledge exchange and replication in cities across Europe.

System under study	Scope of the study
The analysis of the CBMs behind 15 successful solutions for bio-waste valorization (D4.1) and a template business canvas for bio-waste valorization is proposed.	Circular Business Models (CBM)

The project assesses some sustainability dimension	☐Environmental ☐Social	☐Economic ☒Non
What it is assessed		**Deliverable**
The aim of the analysis is the identification of CBMs focused on bio-waste valorization and the presentation of a typology which will be able to incorporate also other business cases of bio-waste valorization in the future.		D4.1
How it is assessed		**Deliverable**
The methodology consists of 4 levels: - 1st level of analysis: Literature review; - 2nd level of analysis: Development of the HOOP CBMs; - 3rd level of analysis: CBM identification for bio-waste; - 4th level of analysis: Investigation of drivers and barriers.		D4.1

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The project uses accounting method(s) ☐Yes ☒No	
Application of the method(s)	Deliverable
Aspects and impact categories	Deliverable

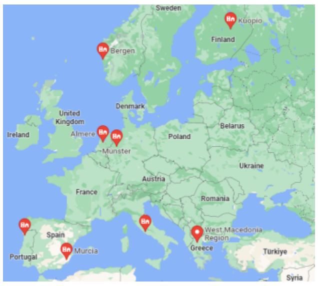
The project has pilot sites ☒Yes ☐No	Key words
Lighthouse cities: Italy: Albano-Laziale The Netherlands: Almere Norway: Bergen Finland: Kuopio Germany: Münster Spain: Murcia Portugal: Greater Porto Greece: Western Macedonia 	Urban circular bio-economy, Circular Business Model (CBM), Bio-waste valorization.

Table 8. HOOP working sheet

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	LOWINFOOD Multi-actor design of low-waste food value chains through the demonstration of innovative solutions to reduce food loss and waste	Start date: 01/11/2020 End date: 28/02/2025	Code O-258
		Framework program: Horizon 2020 Topic: RUR-07-2020	

General aim of the project	Specific objectives linked to ToNoWaste
To co-design low-waste value chains by supporting the demonstration of a portfolio of innovations in a set of value chains particularly concerned by food loss and waste, as well as in at-home and out-of-home consumption.	To set a methodology for the evaluation of LOWINFOOD's innovations and the roadmap for data collection. To quantify potential environmental benefits of low-waste food supply chains. To presents the indicators to be used for the socio-economic evaluation of the LOWINFOOD innovations. To compare the behavior of food system before and after the implementation of the innovations.

System under study	Scope of the study
Innovations that potentially impact three levels: - Directly, on the implementing organizations; - Indirectly, on the supply chain and the community; - At the project level, fostering product and market development. Two food systems: - Conventional Food Supply Chain (baseline); the system before implementation of innovation; - Low-waste Food Supply Chain (innovation); the system after the implementation of innovation. The value chains studied are fruits and vegetables; bakery products; and fish. The type of innovation studied is institutional, social, organizational, technological and managerial.	Primary Production, food processing, retail and distribution, food service, and household consumption.

The project assesses some sustainability dimension	☒Environmental ☒Social	☒Economic ☐Non
What it is assessed		**Deliverable**
Three aspects of a group of 15 innovations against FLW have already been developed and tested by some partners of the consortium. (i) Socio-economic aspects: - The extent to which innovations affect the economy and society. (ii) Environmental impacts: - (A) Linked to producing the food no longer purchased; - (B) Linked to the waste treatment operations; - (C)The environmental impacts caused by implementing the action. (iii) Efficacy of the innovations.		D1.1 D1.2 D1.4
How it is assessed*		**Deliverable**
(i) Socio-economic impacts: Isolating whether the changes resulted solely from an intervention, and to accounting for impacts only attributable to the innovation. As well as the baseline measurements, external factors such as local policies and price structures will be analyzed and considered in the interpretation of the outcomes. (ii) Environmental impacts through a life cycle inventory model adapted to each impact:		D1.1 D1.2

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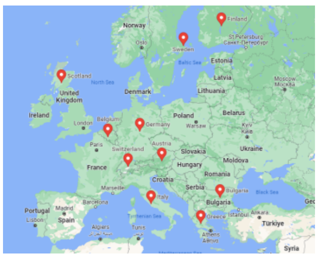
- Type (A): data covers food products diverted from being wasted and is assumed to replace food production elsewhere; - Type (B): data covers FLW management practices and were taken from Ecoinvent 3 database; - Type (C): data covers all activities related to the innovation action and were provided by user and combined with data from suitable Life Cycle Inventory (LCI) database. (iii) Efficacy: Delphi consultation.	

The project uses accounting method(s)	☒Yes ☐No
Application of the method(s)	Deliverable
(i) Socio-economic impacts The analysis was carried out calculating a set of indicators. The results and their implications were interpreted considering the local policy context and supply chain conditions. (ii) Environmental impacts accounting follows the rules of: - LCA based on ISO 14044 (ISO, 2006a, 2006b); - The handbook and guidelines from the International Reference Life Cycle Data (ILCD) System; - Product Environmental Footprint (PEF); - FLW related impact assessment approaches developed by the JRC technical report 'Assessment of food waste prevention actions'; - H2020 project REFRESH; - Interreg Central Europe STREFOWA. (iii) Efficacy defined as: - The amount of Food Loss and Waste (FLW) prevented thanks to the innovations.	D1.1
Aspects and impact categories	Deliverable
(i) Economic: - Profitability - Scale - Competitiveness (ii) Environmental: - Climate change - Acidification - Eutrophication - Land use - Water use - Resource use (i) Social: - Behavior - Creation of local jobs - Spill-over effects - Vertical segregation - Horizontal segregation - Share of genders interviewed - Survey satisfaction	D1.1

The project has pilot sites ☒Yes ☐No	Key words
Germany Austria Sweden Finland Italy Belgium Bulgaria Scotland Switzerland Greece	Low-waste value chains, Socio-economic assessment, Environmental assessment, Efficacy assessment, Ecoinvent, Life Cycle Assessment (LCA).



*The impact assessment will be conducted in the upcoming years and published in D1.7 and D1.8

Table 9. LOWINFOOD working sheet

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	ZeroW Systemic Innovation Towards a Zero Food Waste Supply Chain	Start date: 01/01/2022 End date: 31/12/2025	Code O-459
		Framework programme: Horizon 2020 Topic: LC-GD-6-1-2020	

General aim of the project	Specific objectives linked to ToNoWaste
To reduce Food Loss and Waste by employing systemic innovations with the approach of developing a core demonstrative environment supporting in nine Systematic Innovation Living Labs (SILLs) along the value chain, complemented by assessment activities to ensure a long term environmental and economic sustainability of zero-FLW (0FLW) solutions and a just transition towards a near-zero FLW system.	To provide a conceptual framework for food loss and waste (FLW) starting from the EU definition of FLW but proposing several refinements that enrich the conceptual framework. To assess the FLW reduction potential of the nine SILLs that are part of the project. To design, develop, and deploy an overarching methodology to assess the SILLs. To provide a methodological guide to perform the innovation assessment of the ZeroW Systemic Innovations Living Labs (SILLs). To pave the way for developing an economic model that can process meso- and macro-economic scenarios for FLW, both top-down at EU level and bottom-up based on upscaling scenarios of the nine ZEROW Systemic Innovations Living Labs (SILLs). To summarize, the main findings from recent literature studies are focused on identifying the sources and drivers behind food waste.

System under study	Scope of the study
Nine specific Systematic Innovations (ISs) providing solution to a FLW problem proposed by the SILLs: - SILL 1: FLW monitoring and assessment. Focused on fruits and vegetables and located in Slovenia. - SILL 2: Innovative sustainable and smart packaging for fresh food. Focused on protein foods (oily fish) and located in Spain. - SILL 3: wasteless greenhouse solutions for (pre)harvesting aligned with short-term demand. Focused on fruits and vegetables and located in Lithuania. - SILL 4: mobile food valorization as services. Focused on fruits and vegetables and located in Flanders. - SILL 5: Ugly food identification, shelf-life assessment and alternative valorization. Focused on fruits and vegetables and located in Andalusia (Spain). - SILL 6: reduction through advanced data-drive production process control and optimization. Focused on protein foods (processed poultry) and located at local scale. - SILL 7: reduction through efficient food bank networks. Focused on fruits, vegetables, grains, protein foods and dairy and located at local, regional and national scales. - SILL 8: retail food waste valorization through algae production for high-value applications.	The whole Food Supply Chain (FSC) from pre-harvest to consumption.

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Presumably focused on a mix of all kinds of food categories and located in Portugal. - SILL 9: Fork to Farm to Fork: informing and nudging consumers to make better dietary choices. Focused on all food categories and located in the Netherlands. The project uses the EU definition of food waste, as provided in the amendment to Directive 2008/98/EC on Waste. This allows the SILLs to better clarify to what extent they can contribute to the reduction targets (to be defined in future EU legislation) within the context of the EU and its Member States. At the end it will provide recommendations with regards to changes to the EU definition of FW. Food loss and waste (FLW) was modelled from three points of view: - FLW conceptual model - FLW economic model development & SILL-based validation - Modelling the impact of FLW operational & policy interventions at the micro- (Supply Chain - SC), meso- (food sector) and macro- (EU) levels. The Systemic Innovation Readiness Level (SIRL) proposes five main innovation dimensions: technology dimension, behavioral dimension, policy and governance dimension, business dimension and value chain dimension.	

The project assesses some sustainability dimension	☒Environmental ☒Social	☒Economic ☐Non
What it is assessed		Deliverable
Existing interventions to reduce FLW and therefore present all nine SILLs of the ZEROW project. The FLW reduction potential of the nine SILLs that are part of the project. The extent that the SILL innovations are improving during the project. Environmental, social, and economic impacts of the SILLs throughout their duration. The just transition elements of the innovations demonstrated. The economic viability of the SILL products and services and the long-term financial planning for economic sustainability for SI scale up for all SILLs.		D1.1 D5.1
How it is assessed		Deliverable
Optimal allocation of available funds to such scale up and operational sustainability activities will be further analyzed during the cost-benefit analysis leading to JTM for all SILLs. Performing interviews with the leaders of each SILL to ensure that the conceptual model that underlies the economic model can capture the results of the efforts made in each of the nine SILLs. This model will assess the actual impact of the SILLs and estimate the potential impact when the SILL interventions are scaled up across the whole European Union. The project reports three high level tools which correspond to the above three assessment viewpoints: (i) Systemic innovation readiness levels (SIRL) (defined in Deliverable 4.1) exploited to assess to the extent the SILL innovations are improving during the project lifetime (ii) Life Cycle Sustainability Assessment (LCSA) utilized to derive a holistic view of the social (Social-LCA), economic (Life Cycle Costing), and environmental (Life Cycle Assessment) impacts of the SILLs.		D1.1 D5.1

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(iii) Cost benefit analysis utilized as a means to evaluate just transition elements. The methodology to assess the systemic innovation living labs is employed four times during the project life cycle (first round for baseline data collection from SILLs and three subsequent rounds of assessment), therefore it is dynamic and customizable in nature. The methodology is highly adaptive, and it is possible to implement it in different SILLs. Each SILL has unique objectives inside the FLW supply chain, and the methodology can be adapted to each SILL's specific conditions.	

The project uses accounting method(s) ☒Yes	☐No
Application of the method(s)	Deliverable
Having numerous novel technologies in each SILL and a broad array of sustainability in the food supply chain, uncertainty of inventory data and unavoidable errors in the data collection process are current issues during the SILL life cycle. To solve the issue of uncertainty it is recommended that to use the Monte Carlo analysis. The project has three assessment viewpoints: (i) Systemic Innovation Readiness Level (SIRL): Maturity scales were used to evaluate the readiness level of each SILL. These scales can be developed based on the general innovation readiness level. To exploit the SIRL assessment, the SILLs must agree on the key innovation dimensions of their systemic innovations are to be assessed. Each SILL will use the SIRL as a continuous and iterative assessment tool to evaluate the readiness levels of all dimensions of the systemic innovations and express concrete readiness progress ambitions and action plans. (ii) Life Cycle Sustainability Assessment (LCSA): Performs the assessment from a life cycle perspective in the three dimensions of sustainability: social, economic and environmental. (iia) Social Life Cycle Assessment (S-LCA): A schematic methodological approach based on the UNEP/SETAC (UNEP 2020 Guidelines) methodology was used to measure the social impacts. The assessment takes a stakeholder driven approach where the potential impacts on different stakeholder categories are considered and studied. (iib) Life Cycle Costing (LCC) (iic) Life Cycle Assessment (LCA): Assessment methodology: Environmental Footprint (EF) 3.0 The methodology follows ISO standards 140401, 14044 and is interoperable during use in different SILLs. A combination of two LCA approaches were incorporated in the assessment methodology: - Conventional LCA: to assess mature and commercially scaled technologies generating detailed inventory data. - Prospective LCA: has been recently introduced to perform LCA in emerging technologies. Multiple functional units should be included. Multiple functional units can be tested in a sensitivity analysis in order to analyze the sensitivity that relies on the definition of the functional unit. The first stage of the assessment is to select the impact categories and functional units which are relevant for each SILL. SETAC gives a common methodological framework and guidance to hotspot analysis which will be further illustrated under ZeroW assessment framework.	D5.1

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(iii) Cost-benefit analysis (CBA): The analytical framework of performing the CBA incorporates characteristics and requirements in line with the "Guide to Cost-Benefit Analysis of Investment Projects" published by the EC34. The CBA methodology is based upon the steps reported by AEOLIX project and has been further adopted for the systemic innovation and SILL perspectives. For each SILL, end users are identified. End user identification cluster them into specific groups followed by identification of costs and benefits through scouting business cases for each SILL, each group, and type of transactions. The costs and benefits are then categorized by user, SILL category, and year followed by their financial valuation as it is the most crucial aspect of the entire CBA.	
Aspects and impact categories	Deliverable

(iia) S-LCA Stakeholders categories
- Worker
- Local community
- Value chain actors
- Consumer
- Society
- Children
(iib) Cost profiles for LCC
- Fixed costs
  - Investment and interest
  - Maintenance
  - Cost of staff
  - Other: cost of permits, contracted costs and overhead
- Variable costs
  - Energy
  - Raw materials
  - Auxiliaries
  - Waste management
  - Transportation
  - Revenue from by-products (income)
(iic) LCA
- Climate change
- Ozone depletion
- Human toxicity, non-cancer effects
- Human toxicity, cancer effects
- Particulate matter
- Ionizing radiation, human health
- Photochemical ozone formation, human health
- Acidification
- Terrestrial eutrophication
- Freshwater eutrophication
- Marine eutrophication
- Freshwater ecotoxicity
- Land use
- Water use
- Resource use, fossil
- Resource use, mineral and metals
(iii) Cost-benefit analysis indicators
- Internal Return Rate (IRR)
- Net Present Value (NPV)
- Benefit to cost ratio
	D5.1

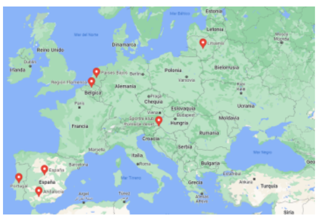
The project has pilot sites ☒Yes ☐No	Key words
Slovenia: Pomurje Spain (national) Spain (regional): Andalusia Lithuania Flanders Portugal Netherlands 	Systematic Innovation Living Labs (SILLs), Zero Food Loss and Waste (0FLW), Social assessment, Economic assessment, Environmental assessment, Life Cycle, Sustainability Assessment (LCSA), Social Life Cycle Assessment (S-LCA), Life Cycle Costing (LCC), Life Cycle Assessment (LCA), Conventional LCA, Prospective LCA, Cost-benefit analysis (CBA), Monte Carlo analysis

Table 10. ZeroW working sheet

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SISTERS	**SISTERS** Systemic Innovations for a SusTainable reduction of the EuRopean food waStage	Start date: 01/11/2021 End date: 30/04/2026	Code O-385
		Framework program: Horizon 2020 Topic: LC-GD-6-1-2020	

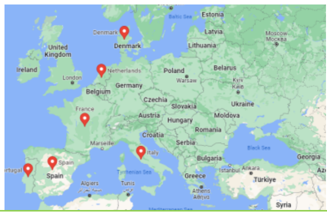
General aim of the project	Specific objectives linked to ToNoWaste
To reduce food loss and waste in the main stages of the Food Value Chain in Europe that will result in a consistent reduction of the environmental & economic impact of the current dynamics in the food system, as well as achieving optimal shelf-life of widely consumed food products. This will be achieved through innovations targeted to each stage of the chain: new tools for primary producers for promoting direct and Short Chain sales (farmers); new technological innovations in packaging for processors and retailers; and awareness campaigns for retailers and consumers on food loss and waste.	To carry out case-studies for testing the effectiveness of the Short Chain Platform (App) (WP1). To demonstrate an improved shelf life and verify food safety of the SISTERS food packaging (WP3). To study the economic feasibility of the developed packaging solutions (WP3). To formulate good practice guidelines to diminish food loss & waste, to be implemented by wholesalers/retailers (WP4). To get feedback from wholesalers/retailers in order to assess the impact of the actions implemented (WP4). To evaluate the replicability of SISTERS through a business and simulation model. To carry out a Life-Cycle Assessment (LCA), Social Life-Cycle Assessment (S-LCA) and Life-Cycle Cost (LCC) (WP6). To push SISTERS solutions to TRL 7-8.

System under study	Scope of the study
Five developed solutions: - Short chain platform for farmers to sell their discarded products. - Smart and reusable food containers to diminish food losses during transportation. - Bio-based and home-compostable food packaging (PLA as one of its major components) to improve the preservation and quality of food. - Seal of excellence - QR dynamic labelling SISTERS is currently working together with the AGROBRIDGES, COCOREADO, COACH, FOOD'R'US and LOWINFOOD projects.	The stages of food chain connected with each of the five solutions: Production, logistics, processing, marketing and consumption.

The project assesses some sustainability dimension*	☒Environmental ☒Social	☒Economic ☐Non
What it is assessed		**Deliverable**
Financial projections performed to facilitate any decision-making relevant for determining future business performance. Social and environmental impacts of the actions.		D6.3
How it is assessed		**Deliverable**
Performing and assessment of the Technology and Market maturities to evaluate the financial feasibility. EBITDA was selected as parameter for the economic evaluation. The financial estimation takes into consideration revenues as the result of the sum of the products in the sales forecast and the individual prices established. The Gross Margin is revenue minus the Cost of Goods Sold.		D6.3

The impacts described in the Description of Action are social and environmental, declared with the appropriate KPIs. These must be expressed in economic and market impacts KPIs that remain to be solidly justified and evaluated, and only if the latter KPIs are achieved will the former be achieved. Life-Cycle Assessment (LCA), Social Life-Cycle Assessment (S-LCA) and Life-Cycle Cost (LCC) will be performed.	

The project uses accounting method(s)*	☒Yes ☐No
Application of the method(s)	Deliverable
Aspects and impact categories	Deliverable

The project has pilot sites	☒Yes ☐No	Key words
Engaged in dissemination events: Spain Italy France Portugal The Netherlands Denmark 	Engaged in dissemination events (abroad): Egypt South Africa Morocco Chile Costa Rica Ecuador Brazil	Environmental assessment, Social assessment, Economic assessment, Life-Cycle Assessment (LCA), Social Life-Cycle Assessment (S-LCA), Life-Cycle Cost (LCC)

*More results related with sustainability assessment and accounting methodologies are expected in next WP6 and WP7 deliverables.

Table 11. SISTERS working sheet

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	FRESH-DEMO Waste reduction and quality improvement of fruits and vegetables via an innovative and energy-efficient humidification/disinfection technology	Start date: 01/03/2015 End date: 28/02/2017	Code T-180
		Framework programme: Horizon 2020 Topic: SFS-17-2014	

General aim of the project	Specific objectives linked to ToNoWaste
To reduce post-harvest waste and improve the quality of fruits and vegetables via an innovative and energy-efficient humidification technology with the support of a natural processing aid.	To assess the environmental performance of the humidification systems as a potential technology to reduce post-harvest losses of fruits and vegetables taking the life cycle perspective. To determine whether humidification systems are sound investment in the fruit and vegetable sector. To compare performance of humidification-based systems with that of conventional supply chains. To quantify the trade-offs between potential benefits and burdens of the use of humidifiers.

System under study	Scope of the study
Two systems were considered: **humidification-based systems and conventional supply chains** Supply chain of strawberries, peaches, table grapes and asparagus were considered for the (i) process-based LCA and average generic fruit and vegetable for the (ii) EIO-LCA and (iii) CBA.	Storage, transport, and retailing.

The project assesses some sustainability dimension	☒Environmental ☐Social	☒Economic ☐Non

What it is assessed	Deliverable
Environmental performance of humidification technology. Economic performance of the humidification technology relative to the baseline system with conventional cooling without humidification system, quantifying trade-offs between costs and benefits to identify whether humidification systems are sound investment in the fruit and vegetable sector. Trade-offs between environmental and economic impacts.	D5.1 D5.2

How it is assessed	Deliverable
- Environmental performance: Performing a LCA from two different perspectives. The results from (i) process-based LCA gives an overview of the performance of the technology when applied in demonstration case studies, whereas results from (ii) hybrid LCA extends the assessment to the fruit and vegetables sector at European scale. - Economic performance: Carrying out a (iii) cost-benefit analysis (CBA) to determine whether humidification systems are sound investment in the fruit and vegetable sector. To incorporate the trade-offs assessment between environmental and economic impacts, the environmental impacts were monetized within the CBA.	D5.1 D5.2

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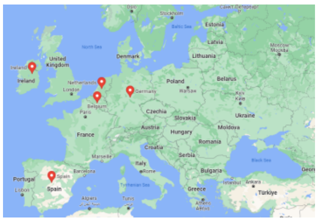
<table>
<tr><td>The project uses accounting method(s)</td><td>☒Yes ☐No</td></tr>
<tr><td>Application of the method(s)</td><td>Deliverable</td></tr>
<tr><td>(i) Process-based LCA
- Environmental LCA methodology was applied in accordance with the requirements of the EU's International Reference Life Cycle Data System (ILCD) guidelines and the ISO standard (ISO 14044).
- Environmental impact scores were calculated using characterization factors according to ILCD's recommended methods at midpoint (ILCD 2011 Midpoint+, version 1.08), as implemented in SimaPro.
- Normalization references are based on domestic inventory calculations for the EU 27, version 4.0, in the reference year 2010 (Benini et al., 2014).

(ii) Hybrid LCA:
Process-based LCA presents the problem of the omission of certain parts of the product system. To overcome this problem the economic input-output life cycle assessment (EIO-LCA) is considered. In this line, hybrid LCA presents the combination of these two methods:
- (i) Process-based LCA: data is used for foreground systems;
- EIO-LCA: data is used to capture all the missing flows (EU27 Input Output Database 2003).

(iii) Cost-benefit analysis (CBA):
Benefits or burdens from monetized externalities were calculated monetizing in EURO (€) the environmental impacts calculated by the LCA approach, considering each endpoint impact category contributing to the LCA areas of protection: resource use, ecosystem quality, and human health. Monetization process followed this structure:
- Environmental impacts scores calculated using ILCD's recommended methods at midpoint were recalculated using endpoint method ReCiPe 2008 with hierarchical (H) perspective. This recalculation was needed because modelling impacts at midpoint levels is sufficient for comparison between systems but is insufficient for monetization, which requires that the impacts can be expressed in terms to which monetary preferences can be attributed.
- Monetary valuation from Stepwise2006 was done using conversion factors between the endpoint indicators from Stepwise2006 and those of ReCiPe2008. This was necessary as although the different impact assessment methods use the same endpoint categories, they deviate slightly in the definitions and units of the endpoint category indicators.
Data for the CBA come from three main sources:
- Measurements performed during the project in the retail using two Dutch supermarkets.
- Calculations of LCA performed along the project where systems boundaries were defined, and life cycle inventoried modelled and documented.
- Other data, being either retrieved from literature, calculated, or assumed based on reasonable expectations.</td><td>D5.1
D5.2</td></tr>
<tr><td>Aspects and impact categories</td><td>Deliverable</td></tr>
<tr><td>(i) Process-based LCA
- Climate change
- Ozone depletion
- Human toxicity, non-cancer effects
- Human toxicity, cancer effects
- Particulate matter
- Ionizing radiation HH

(ii) Hybrid LCA
- Climate change
- Particulate matter
- Photochemical ozone formation
- Acidification
- Terrestrial eutrophication
- Marine eutrophication</td><td>D5.1
D5.2</td></tr>
</table>

- Photochemical ozone formation - Acidification - Terrestrial eutrophication - Freshwater eutrophication - Marine eutrophication - Freshwater ecotoxicity - Land use - Water resource depletion - Mineral, fossil & ren resource depletion	- Mineral, fossil and renewable resource depletion (iii) CBA - Net present value - Total present value of costs (capital expenditures and operational expenditures) - Total present value of benefits (increasing sales, avoided disposal of biowaste, avoided energy consumption, avoided labour, increase in weight during transport, monetized externalities)	

The project has pilot sites ☒Yes ☐No	
Spain Ireland Netherlands Germany Belgium	

Key words
Economic Input-Output Life Cycle Assessment (EIO-LCA), Life Cycle Assessment (LCA), Cost-benefit analysis (CBA), environmental assessment, economic assessment, environmental impacts monetization, International Reference Life Cycle Data System (ILCD), ReCiPe 2008

Table 12. FRESH-DEMO working sheet

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WASTE2FUELS	WASTE2FUELS Sustainable production of next generation bio-fuels from waste streams	Start date: 01/01/2016 End date: 31/12/2018	Code T-446
		Framework programme:	Horizon 2020
		Topic:	LCE-11-2015

General aim of the project	Specific objectives linked to ToNoWaste
To develop next generation bio-fuel technologies capable of converting agro-food waste (AFW) streams into high quality bio-butanol.	To use the suitable fractions of food waste for fuel production. To perform a research work towards making next generation bio-fuel common-sense vision commercially viable in practice and analyzing the successful potential exploitation pathways. To perform an environmental assessment, social assessment, and life cycle cost analysis of bio-butanol production route from agro-food wastes.

System under study	Scope of the study
Three agro-food wastes were analyzed as feedstock: - Apple pomace - Potato peel - Brewer spent grain - The social installation of a second generation biorefinery in Europe.	Cradle-to-gate

The project assesses some sustainability dimension	☒Environmental ☒Social	☒Economic ☐Non
What it is assessed		**Deliverable**
Social economic and environmental sustainability of bio-butanol production route from agro-food wastes. The comparison between the environmental burdens associated with the butanol production routes from agro-food wastes and different separation options. The public's opinion and knowledge about the use of bio-fuels, and in particular bio-butanol, in transportation.		D7.3 D7.4
How it is assessed		**Deliverable**
To be able to give a more comprehensive assessment of the sustainability of products, an expansion of the LCA framework to also include these product impacts on people, known as social impacts. Together with the environmental burdens, also a life cost analysis and preliminary consideration related to social life cycle analysis was presented.		D7.3 D7.4

The project uses accounting method(s)	☒Yes	☐No
Application of the method(s)		**Deliverable**
(i) Social Life Cycle Assessment (SLCA): The approach proposed by Macombe et al. (2013) was followed to qualitatively discuss the social concerns related to the installation of a second generation bio-refinery in Europe. The "Guidelines to SLCA" (Benoît et al., 2010) were also considered. (ii) Life cycle costing (LCC): Environmental LCC was chosen for this analysis.		D7.3 D7.4

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The conceptual framework of environmental LCC is based on the physical product life cycle of LCA. Cost-of-magnitude estimation seems to be the appropriate cost estimation technique at this stage. The overall LCC against the Global Warming Potential as one of the LCA result was plotted. (iii) Life Cycle Assessment (LCA): Follows the environmental LCA standards of ISO 14040 (2006) and ISO 14044 (2006). Life cycle inventory of pre-treatment, fermentation and separation is based on process modelling outputs from AspenPlus. The methodology of impact assessment used for the study is the “ILCD” (The International Reference Life Cycle Data System).	
Aspects and impact categories	Deliverable
(i) Social impacts - Working conditions - Migration, resource access, resource competition - Lanc occupation - Distribution of the profit - Social tension - Human health and safety issue - Living cost (ii) Economic assessment - Capital costs - Variable operating costs - Fixed operating costs (iii) Environmental midpoint impacts - Global Warming potential - Acidification - Freshwater eutrophication - Marine eutrophication - Terrestrial eutrophication - Ozone depletion - Photochemical ozone formation - Resource depletion water - Resource depletion, mineral, fossils, and renewables	D7.3 D7.4

The project has pilot sites	☐Yes	☒No

Key words
Bio-fuel, Agro-food waste (AFW), Social assessment, Economic assessment, Environmental assessment, Social Life Cycle Assessment (SLCA), Life cycle costing (LCC), Life Cycle Assessment (LCA), AspenPlus, The International Reference Life Cycle, Data System (ILCD)

Table 13. WASTE2FUELS working sheet

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AGROCYCLE for a circular economy	**AgroCycle** Sustainable techno-economic solutions for the agricultural value chain	Start date: 01/06/2016 End date: 31/05/2019	Code T-017
		Framework programme: Horizon 2020 Topic: WASTE-7-2015	

General aim of the project	Specific objectives linked to ToNoWaste
To improve the economic, environmental, and social sustainability of agricultural production systems through the sustainable utilization of agricultural wastes, co-products and by-products (AWCB).	To convert low value agricultural waste into highly valuable products developing an understanding of the waste streams and piloting a key number of waste utilization/valorization pathways. To develop a framework to help identify the pathways most sustainable for AWCB material streams. To provide AgroCycle Protocol Rules (APR) for an assessment framework for the sustainability performance of agri-food waste and by-product valorization.

System under study	Scope of the study
A total of 18 identified unavoidable and available for valorization AWCB streams of commodities from the main agricultural groups. This groups are animal products (milk and meat), cereals including rice, oil seeds, fruits including tomatoes and olives, vegetables, tuber (potato) and root crop (sugar beet). Four case studies were analyzed: - Micro anaerobic digestion of animal manure/slurry - Fertilizer from rice by-products - Valorization of fruit processing wastewater - Bio-plastic from potato pulp The AGROCYCLE-LCA calculations was divided into three different life cycle stages: - Upstream processes (from cradle-to-valorization processor gate). - Core processes (from valorization processor entry gate-to-exit gate). - Downstream processes (from valorization processor exit gate-to-grave/cradle).	Cradle-to-grave/cradle

The project assesses some sustainability dimension	☒Environmental ☒Social	☒Economic ☐Non

What it is assessed	Deliverable
Circular economy practices to make sure that they do not cause an economic and social stress before implementing them and do not represent inefficiencies. The comparison of the sustainability of a linear agricultural system verses a circular agricultural system through the assessment of: - The use of resources - Potential environmental impacts (D6.3) - Potential social impacts (D6.5) - Potential economic impacts (D6.4)	D1.3 D6.1 D6.2 D6.6
How it is assessed	**Deliverable**

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The framework for analyzing AWCB efficiency was composed by four quadrants (avoidable-unavailable; unavoidable-unavailable; avoidable-available; unavoidable-available). Use of natural resources was divided into upstream and downstream. Resources considered for the assessment are non-renewable resources, renewable resources, secondary resources, recovered energy flows (MJ), water use. A tiered life cycle sustainability assessment (LCSA) framework was proposed for AWCB valorization systems. The tiered LCSA framework has three tiers, and each tier has different impact categories, specified characterizations for life cycle inventory assessment and input data requirement. Environmental, social, and economic impacts were divided into upstream and downstream. Impacts were grouped into three tiers, based on global importance or impact relevance, practicality, and complexity. - Tier I: most important due to global relevance. - Tier II: important indicators for circular economy. - Tier III: optional indicators for a comprehensive sustainability assessment. Sustainability of the novel circular agriculture pathways was considered by describing the impacts of substituting conventional linear products with novel AgroCycle pathways.	D1.3 D6.1 D6.2 D6.6

The project uses accounting method(s) ☒Yes	☐No
Application of the method(s)	Deliverable
The LCA methods encompassed impacts in the (i)social (sLCA), (ii)economic (LCC) and (iii)environmental (eLCA) domains that were eventually integrated into a (iv)Life Cycle Sustainability Assessment (LCSA). (i) Hybrid social LCA Follows the UNEP-SETAC Social LCA Guideline. Data was obtained from a multi-regional input-output database. To provide a comprehensive estimate of the social-economic upstream and downstream impacts of implementing and using AgroCycle technologies, the hybrid analysis was performed combining two approaches: - Economic input-output LCA - Process-based LCA (ii) LCC A specific cost inventory for the assessment of four AgroCycle case studies was built due to the lack of default cost entries available in the most common databases used for LCA. (iii) Environmental LCA It follows ISO 14040 standard (ISO 2006), UNEP/SETAC methodologies, PEF guidelines and the AgroCycle protocol (AgroCycle 2017). Furthermore, the Centrum voor Milieuwetenschappen (CML) 2001 baseline methodology was used without normalization or weighting, and included the environmental impact climate change (CC, kg CO2-e). Both emissions to the atmosphere and removals from the atmosphere were accounted for the assessment of the overall GHG emissions of the product. Where some or all removed carbon will not be emitted to the atmosphere within the 100-year assessment period, the portion of carbon not emitted to the atmosphere during that period was treated as stored carbon.	D6.1 D6.5 D6.3 D6.4 D6.6

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<table>
<tr><td colspan="2">
LCA modelling was performed with GaBi v.8 software. Background data was taken from Ecoinvent and GaBi 6.

Cut-off rules: LCI data for a minimum of 95 % of total inflows to the core module shall be included.
Allocation rules: defined for individual products when the manufacturing processes result in many kinds of products and where there is only aggregate information available about the total activity and emissions.

(iv) LCSA
This framework has three tiers:
- Tier I: designed for carrying out a streamlined LCA. It provides a fundamental profile of the sustainability performance of the system as an accessible and entry level LCSA. It is focused on impacts of greatest public and policy concern (e.g., climate change, employment, production cost). It has low demand for data quality.
- Tier II: is a ‘business-as-usual’ LCSA. It aims to reduce uncertainty by increasing the specification of data quality and includes more impact indicators with a greater data demand.
- Tier III: has a high temporal and spatial resolution for LCA results.
</td><td></td></tr>
<tr><td colspan="2">Aspects and impact categories</td><td>Deliverable</td></tr>
<tr><td>
(i) Mid-point level social issues (ranked by importance) and stakeholder category.
- Fair wage (worker)
- Health and safety (worker)
- Working time (worker)
- Public living condition (local community)
- Provision of employment (local community)
- Child labour (worker)
- Forced labour (worker)
- Contribution to economy (society)
- Technology development (society)
- Promoting social responsibility (value chain)
- Resource and energy security (local community)
</td><td>
(ii) Economic issues
- Production cost
- Initial costs
- Periodical maintenance costs
- Operational costs
- End of life disposal costs or residual value of the goods
- Profitability
- Efficiency of value creation from valorization

(iii) Mid-point level environmental issues (ranked by importance)
- Global warming
- Acidification
- Eutrophication
- Water use
- Land use
- Mineral resource depletion
- Human toxicity
- Ozone layer depletion
- Eco-toxicity
- Photochemical smog
</td><td>D6.1</td></tr>
</table>

The project has pilot sites ☒Yes ☐No	Key words
Greece Italy Germany United Kingdom	Cradle-to-grave/cradle, Agricultural wastes, co-products and by-products (AWCB), Environmental assessment, Social assessment, Economic assessment, UNEP/SETAC, PEF, CML 2001.

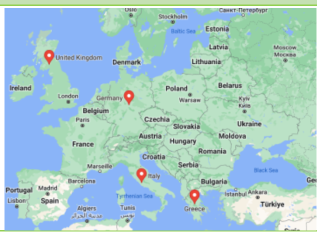

Table 14. AgroCycle working sheet

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	NanoPack Pilot line production of functional polymer nanocomposites from natural halloysite nanotubes: demonstrating controlled release of active antimicrobials in food packaging applications	Start date: 01/01/2017 End date: 31/12/2019	Code T-289
		Framework programme: Horizon 2020 Topic: PILOTS-02-2016	

General aim of the project	Specific objectives linked to ToNoWaste
To demonstrate a solution for extending food shelf life by using novel smart antimicrobial surfaces, applied in active food packaging products.	To perform a LCA for the NanoPack food packaging. To apply the Social LCA and social acceptance tools to NanoPack technology. To minimize the amount of preservatives required to maintain freshness, add value and assure safety to the entire supply chain. To run pilot lines in operational industrial environments to manufacture commercially feasible antimicrobial polymer films, accepted by consumers and bring the innovation to an industrial validation level (TRL7).

System under study	Scope of the study
Packaging material with three primary features: flexible, active, and antimicrobial This packaging is initially designed for: - Meat products - Fish products - Bread and bakery products - Dairy products	Cradle-to-grave

The project assesses some sustainability dimension	☒Environmental ☒Social	☐Economic ☐Non
What it is assessed		**Deliverable**
The environmental performance of the treatment and recovery system of each NanoPack stream to understand if the benefits arising from the material and energy recovery are offsetting the burdens. Quantitative and Qualitative information of social dimension of sustainability. The social acceptance of NanoPack technology and its final products. Comparison of the NanoPack concept with the conventional recycling and valorization processes for these flows.		D7.1 D7.3
How it is assessed		**Deliverable**
Throughout the LCA process, the general environmental impact of the proposed system will be assessed. Quantitative targets that could also be applied as performance indicators of the environmental assessment were established. Social acceptance was assessed performing the social sustainability assessment from a social acceptance point of view. Indicators for social sustainability of technical systems were evaluated using semi-structured questionnaire (mix of qualitative and quantitative information).		D7.1 D7.3

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The project uses accounting method(s) ☒Yes ☐No	
Application of the method(s)	Deliverable
(i) Social Life Cycle Assessment (S-LCA) - Performed according to ISO 14040 standards (ISO, 2006) and the UNEP Guidelines for Social Life Cycle Assessment of Products a methodology to develop life cycle inventories and using the Social Hotspot Database. - The impact categories preferably reflected internationally recognized categorizations/standards (like the UN declaration on economic, social, and cultural rights -ECOSOC, standards for multinationals). - Semi-quantitative and qualitative data that matches the ISO 14040 standard were integrated, according to the Guidelines (UNEP, 2009). (ii) Life Cycle Assessment (LCA) - Performed according to the ISO 14040 standards (ISO, 2006) and using Ecoinvent v3.3 database in Simapro 8. - The 'cut-off' methodology used was defined by Ekvall &Tillman (1997). - Environmental profiles of the processes involved were determined applying the Centre for Environmental Studies (CML) 2000 method, due to its uses of multiple indicators at midpoint level.	D7.1 D7.3
Aspects and impact categories	Deliverable
Social and its associated stakeholders - Human rights (worker) - Working conditions (consumer) - Health and safety (local community) - Cultural heritage (society) - Governance (value chain actors) - Socio-economic repercussions (value chain actors) Environmental - Global warming potential - Acidification - Eutrophication - Eco-toxicity - Human toxicity - Abiotic - Energy and raw materials consumption Indicators for social sustainability of technical systems (Assefa and Frostell, 2007) - Knowledge - Perception - Fear	D7.1 D7.3

The project has pilot sites ☐Yes ☒No

Key words
Active packaging, Environmental assessment, social assessment, ISO 14040 standards, UNEP Guidelines for Social Life Cycle Assessment of Products, Social Hotspot Database, Ecoinvent, Centre for Environmental Studies 2000 method

Table 15. NanoPack working sheet

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them

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	RES URBIS REsources from Urban Bio-waSte	Start date: 01/01/2017 End date: 31/12/2019	Code T-352
		Framework programme: Horizon 2020 Topic: CIRC-05-2016	

General aim of the project	Specific objectives linked to ToNoWaste
To make it possible to convert several types of urban bio-waste into valuable bio-based products, in an integrated single bio-waste bio-refinery and by using one main technology chain.	To collect and analyze the data on urban bio-waste production and present management systems in five territorial clusters that were selected in different countries and have different characteristics. To perform a well-targeted experimental activity to solve a number of open technical issues (both process- and product-related), by using the appropriate combination of innovative and catalogue-proven technologies. To perform a market analysis within several economic scenarios and business models for full exploitation of bio-based products (including a path forward to fill regulatory gaps). To compare the environmental performance of different urban organic waste treatment options in the five territorial clusters of the project.

System under study	Scope of the study
A portfolio of PHA-based bio-plastics, produced at pilot scale and tested for applications: - Biodegradable commodity film - Packaging interlayer film - Specialty durables (such as electronics) - Premium slow C-release material for ground water remediation Six organic waste management scenarios: - Current treatment (baseline) - Maximization of the organic waste incineration (WtE) - Maximization of the anaerobic digestion (AD) - Maximization of the anaerobic digestion with upgrading of the biogas and optimizing the treatment of the residues from the AD pre-treatment (AD+) - Application of the RES URBIS bio-refinery to the cluster (RES URBIS) - Application of the RES URBIS biorefinery to the cluster with upgrading of the biogas and optimizing the treatment of the residues from the AD pre-treatment (RES URBIS+) The waste management technologies covered are: - The RES URBIS bio-refinery - Waste-to-Energy plant - Anaerobic digestion plant - Dewatering plant and reject water treatment - Composting plant - Use-On-Land - Land filling	All the activities related to the management of urban organic waste, which enters the system were included without considering the upstream impacts related to the biomass production. All the capital goods, transportation, treatments processes and residues management are included without considering the bio-waste collection and logistic.

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Urban bio-waste includes the organic fraction of municipal solid waste (from households, restaurants, caterers and retail premises), excess sludge from urban wastewater treatment, garden and parks waste, selected waste from food-processing (if better recycling options in the food chain are not available), and other selected waste streams.	

The project assesses some sustainability dimension	☒Environmental ☐Social	☒Economic ☐Non
What it is assessed		Deliverable
The comparison between the environmental performance of existing waste management systems with novel bio-refinery approaches developed within RES URBIS. The Hotspots and key parameters in the system to orient further research activities and/or improved data collection. The framework conditions that potentially affect the decision-making process at the local scale. The quantitative economic performances in terms of Costs and Benefits of RES URBIS technology applied in a projected full-scale environment. Whether the direct or the extended supply chain is the best option.		D1.3 D5.4
How it is assessed		Deliverable
A consolidated LCA was performed and recommendations on the RES URBIS bio-refinery were drawn. The results were supported with sensitivity and uncertainty analyzes, as well as with scenario analysis to identify important aspects that should be taken into consideration during future decision-making. The modelling of six waste management scenarios was carried out to perform the comparison using LCA. Specific models were developed and applied in order to assess both costs and benefits deriving from the utilization of the technology. The analysis performed was based on the RES URBIS Territorial Clusters. To assess whether the direct or the extended supply chain is the best option, a break-even analysis of PHA production via RES URBIS processing technology versus Biogas via AD has been performed. After the definition of the target value chain and linkage with biogas, an economic model to simulate performances of RES URBIS was built and used for comparing projected scenarios with current state of the art. Benchmarks from Anaerobic Digestion for Biogas production were studied and progresses for OPEX and CAPEX modelling.		D1.3 D5.4

The project uses accounting method(s)	☒Yes	☐No
Application of the method(s)		Deliverable
(i) Cost-benefit analysis (CBA): The costs and benefits considered were those that would be in the first line bear from a potential investor for realizing RES URBIS at full scale. EBITDA was selected as main parameter for the evaluation. The design of the CBA model took into account the impact of economic figures relevant for the assessment of economic performances of the operations platform for PHA production, such as CAPEX and OPEX, projected at a full scale. Benchmarks from Anaerobic Digestion for Biogas production have been studied and progresses for OPEX and CAPEX modelling.		D1.3 D5.4

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Levelized cost analysis: To assess whether the direct or the extended supply chain is the best option, a break-even analysis of PHA production via RES URBIS processing technology versus Biogas via AD has been performed. Two figures were used: - Levelized Cost of Energy (LCOE): to evaluate the performance of renewable energy. - Levelized Cost of PHA (LCOP): defined as analogous figure of LCOE to enable the comparison. (ii) Life Cycle Assessment (LCA): The study was carried using the software EASETECH that is a mass balance-based waste-LCA model that allows linking impacts and emissions to the waste composition or to the single substance. The emissions for the mass-balanced LCA modelling were related to the input material. The modelling approach chosen was consequential, which allowed to analyze potential future scenario for the treatment of organic waste that would induce changes in the waste sectors and other interconnected sectors. Multi-functionality was addressed by system expansion and co-products were also credited the avoided emissions that would have been produced by the marginal production. Assessment considerations: - Environmental Footprint (EF) categories calculated at midpoint level - Normalization following a global normalization reference, so that all impact categories have the same unit (i.e. Person Equivalent PE). - Aggregation of the normalized impact categories into one single environmental score using the weighting system calculated by the JRC - Results of a range of impact categories (Climate Change, Photochemical Ozone Formation, Terrestrial Acidification, Terrestrial Eutrophication, Freshwater Eutrophication, Marine Eutrophication and Depletion of fossil resources) were aggregated single-scores and presented disaggregated by waste flows and by contributing processes. - The results for the three toxic impact categories (i.e. freshwater ecotoxicity, human toxicity cancer, human toxicity, non-cancer) were not included in the weighted single indicator because as the characterization factors for heavy metals are associated with large uncertainty in the current method, they are not robust enough. Two types of data were collected: - Foreground data: mainly from the partners of the project or from literature describing similar context. - Background data: mainly based on the Ecoinvent v 3.5, consequential system model. Due to the uncertainty associated to data, all parameters covering emissions (air, water, soil) and consumptions (energy and ancillary materials), transport (km) were modelled using probabilistic uncertainty distributions rather than as a discrete number. Two analyzes related with these uncertainties were performed: - Monte-Carlo analysis: to propagate these uncertainties. - Global sensitivity analysis (GSA): to identify the parameters that contributed the most to the uncertainty.	

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Aspects and impact categories	Deliverable
(i) Economic: - OPEX - CAPEX (ii) Environmental midpoint indicators and their characterization methods: - Climate change (Baseline model of 100 years of the IPCC2013) - Ozone depletion (World Meteorological Organization) - Particulate matter (Disease incidences) - Ionizing radiation, human health (Human health effect model as developed by Dreicer et al. (1995)) - Photochemical ozone formation (ReCiPe, 2008) - Terrestrial acidification (Accumulated exceedance) - Eutrophication, terrestrial (Accumulated exceedance) - Eutrophication, freshwater (EUTREND model as implemented in ReCiPe 2008) - Eutrophication, marine (EUTREND model as implemented in ReCiPe 2008) - Land use (Soil quality index (based on LANCA)) - Water depletion (AWARE 100) - Depletion of fossil resources (CML 2002) - Depletion of mineral resources (CML 2002 (ultimate reserve)) - Freshwater ecotoxicity (USEtox model v.1.01) - Human toxicity, cancer (USEtox model v.1.01) - Human toxicity, non-cancer (USEtox model v.1.01)	D1.3

The project has pilot sites ☒Yes ☐No	Key words
Territorial clusters: Spain: Barcelona Denmark: Copenhagen Portugal: Lisbon Wales: South Wales Italy: Trento	Software EASETECH, EBITDA, OPEX CAPEX, Environmental assessment, Economic assessment, Anaerobic digestion, Cost-benefit analysis (CBA), Life Cycle Assessment (LCA), Monte-Carlo analysis, Global sensitivity analysis (GSA)

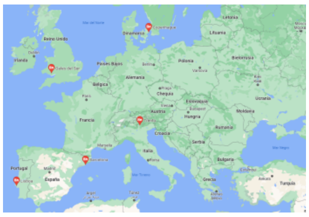

Table 16. RES URBIS working sheet

NOAW	NoWA Innovative approaches to turn agricultural waste into ecological and economic assets	Start date: 01/10/2016 End date: 31/01/2021	Code T-300
		Framework programme: Horizon 2020 Topic: WASTE-07-2015	

General aim of the project	Specific objectives linked to ToNoWaste
To contribute to a 'near zero-waste society' by promoting a circular economy in which agricultural waste, by-and co-products are turned into eco-efficient bio-based products with direct benefits for the environment, economy and society.	To evaluate the technical-economical performances of innovative wastes management conversion processes, it is of prime interest to assess also the environmental and human sustainability of the various processes. To develop innovative eco-design and hybrid assessment tools of circular agro-waste management strategies and address related gap of knowledge and data via extensive exchange through the Knowledge exchange Stakeholders Platform. To create a framework for how several evaluation methods can be applied on one case study and how methods can be combined into hybrid tools. To apply environmental assessment methods on selected technologies, in order to facilitate decision making. To develop and validate the economical and energetic feasibility of the processes at lab-scale (TRL3-4) but also pilot-scale (TRL6-8) for the most promising valorization routes (WP3 and WP4). To implement software that provides a decision-making mechanism which relies on the fair aggregation of the individual preferences of the stakeholders. To develop innovative and robust approaches and tools adapted to the assessment and determination of optimal agro-wastes management strategies.

System under study	Scope of the study
The wastes management conversion processes investigated were: - Anaerobic digestion (benchmark process) - Two stages anaerobic digestion for hythane and carboxylates production - Integration of value-added molecules/products generation upstream of the AD bio-refinery process - Integration of value-added molecules/products generation downstream of the AD bio-refinery process: VFA valorization - Integration of AD process in a bio-refinery concept through downstream innovative valorization routes for the solid anaerobic digestate.	All steps that could have an impact due to the new management waste system developed are included.

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Two scenarios were assessed: - Production of biogas - Combined production of biogas and Polyhydroxyalkanoates (PHA). The conversion through Anaerobic Digestion (AD) was focused on a set of solid agricultural wastes: - Crop residue: wheat straw (WS) - Agro-food waste: winery wastes (WW) - Animal husbandry waste: animal manures (AM) Impacts on four areas were assessed: - Soil impact - Air impact - Water impact - Human impact/safety. The decision support informs decision makers on three levels: - Product - Farm - Region Case studies performed within the project framework: - Life cycle assessment of bio-composite packaging materials introducing vine shoots as fillers. - Lessons from combining techno-economic and life-cycle assessment -a case study of polyphenol extraction from waste resources. - Incorporating Relative Importance: selecting a polyphenol production method for agro-waste treatment in an environmental and economic multi-criteria decision-making context	

The project assesses some sustainability dimension	☒Environmental ☒Social	☒Economic ☐Non
What it is assessed		Deliverable
The economical, human and environmental sustainability of the innovative wastes management conversion processes. The maximum potential environmental impact savings from the implementation of innovative bio-refinery alternatives with a comparative approach. The introduction of a new technology for the treatment of agricultural residues. The territorial impacts of the Agro-Waste Management Plan (AWMP) on the environment in the strategic planning of agro-waste management. The economic and environmental information of the selected technologies. Intercontinental differences in the background systems and socio-political context.		D1.1 D1.3 D2.2 D2.3 D2.5
How it is assessed		Deliverable
Techno-economic assessment (TEA) was applied for process flow design optimization at an early stage in combination with Life Cycle Assessment which is capable of providing holistic information on the potential environmental impacts of a choice and determine the best suitable bio-refinery scheme under which wastes uses are sustainable. Besides, to evaluate the technical-economical performances of these innovative wastes management conversion processes, it is of prime interest to assess also the environmental and human sustainability of the various processes. The evaluation		D1.1 D1.3 D2.1 D2.3 D2.5

of both the environmental and human impacts of the agricultural waste management routes require the development of appropriate sustainability indicators and methodologies to evaluate these indicators. By analyzing the existing and the planned agro-waste management concept, possible trends and impacts on space and the environment were identified, serving as a basis for decision-making by stakeholders. The assessment of spatial/territorial impacts on the environment through Strategic Environmental Assessment (SEA) for the purpose of strategic planning (AWMP) is one of the starting and most important phases in creating a sustainable waste management policy in the particular area. The Territorial Metabolism-Life Cycle Assessment (TM-LCA) approach was used to assess the introduction of a new technology for the treatment of agricultural residues. A scenario of biogas production was compared to a scenario of combined biogas and PHA production, developed at pilot scale. The two scenarios were modelled with dynamics built into both foreground and background systems. The scenarios were then tested at a territorial scale, in two geographically dissimilar producing territories (Languedoc-Roussillon region in southeast France, and the Willamette, Umpqua, Rogue and Columbia valleys of Oregon State in the USA.), to observe the effects of regional differences on territorial performance. Finally, multi-criteria assessment (MCDA) was applied in the interpretation phase to prevent drawing incorrect conclusions from the use of global warming potential (GWP) as a single indicator and to help ease interpretation of results. By applying the Multi-Criteria Evaluation method (MCE) method in SEA accompanied by Geographic Information System (GIS) tools, the process of evaluation became more objective, especially if compared to the group of criteria for the assessment of spatial dispersion of impacts. By using the spatial data based on GIS presentation, it is possible to reliable determine the spatial dispersion of impacts of the AWMP planning propositions, which is done in this case.	

The project uses accounting method(s) ☒Yes	☐No
Application of the method(s)	Deliverable
The two baseline scenarios were assessed with the **OpenLCA** (GreenDelta, 2019) software and the **Ecoinvent 3.4** database with the Cut-off system model. The **ReCiPe 2016 Hierarchist method** was used for impact assessment. Impacts were assessed at the midpoint level with a time horizon of 100 years from the time of emission. All midpoint impact categories were included in the assessment of the dynamic system model and in all scenarios to obtain temporally specific results for each year of the time horizon. Territorial scale impacts are assessed using both midpoint impacts and single score indicators. In order to give a measure of scale to the potential savings induced by the implementation of the two scenarios, the GWP impacts were normalized using carrying capacity-based normalization factors. Deliverable D2.1 provides an overview of the methods applied in the study with their advantages and disadvantages. These methods and the important documents to describe them are presented below: **(i) Life Cycle Assessment (LCA)**: ISO 14040, ISO 14044 **(ii) Territorial Metabolism–LCA (TM-LCA)**: Sohn et al 2018 **(iii) Computational social choice**: Brandt et al. 2016 **(iv) Argumentation**: Phan Minh Dung (1995) **(v) Multi Criteria Decision Analysis (MCDA) - TOPSIS**: Hwang and Yoon (1981), Yoon (1987), Hwang, Lai, and Liu (1993).	D2.1 D2.2 D2.3

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(vi) Multi Criteria Evaluation (MCE) in **Strategic Environmental Assessment (SEA)** of Waste Management Plan (WMP): Josimović et. al (2015) (ii) Combining Territorial Metabolism-Life Cycle Assessment (TM-LCA) Because LCA is a product focused method, it also has global perspective and thus local and regional issues are not always considered. One way to come around this issue is to combine LCA with other methods such as territorial metabolism (TM). (v) Multi Criteria Decision Analysis (MCDA) The added layers of information to the TM-LCA, mean that the interpretation phase becomes more resource intensive. This can be eased by the use of extra tools, such as MCDA. (v) Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS): Out of the many MCDA methods that exist, one that has shown great capability in dealing with LCA results is TOPSIS. The output from TOPSIS is given in the form of a single score performance index, which is used to derive preference between the scenarios being assessed. In order to check for burden shifting when using GWP as an indicator impact, TOPSIS was applied with equal weighting to all impact categories. Ranking was then performed in a pairwise fashion i.e., within each energy mix future, for the two scenarios, Biogas-only and PHA-biogas using both GWP as a single score indicator and TOPSIS. (vi) Multi Criteria decision analysis (MCE): The MCE method used was originally defined in IAUS in a scientific research project themed "Method for Strategic Environmental Assessment in Planning" (2005–2007), and later developed through several still ongoing scientific research projects, all of which have been funded by the Ministry of Education and Science of the Republic of Serbia. MCE for SEA is a method developed to be suitable for the assessment of agro-waste management strategies from a planning perspective and a regional perspective. Depending on how problems are formulated, a more product-focused method, such as LCA, can be used and give valuable information. (vi) Strategic Environmental Assessment (SEA): SEA Directive 2001/42/EC prescribes the obligation to undertake SEA for plans, programs and framework documents in different fields, thus also in the field of waste management. (vi) Geographic Information System (GIS): The GIS combines spatial data (maps, ortho-im-ages, satellite images) with qualitative and quantitative data, as well as descriptive databases helping in MCE, which is necessary in elaboration and implementation of AWMP. Having this in mind, MCE is the support instrument for developing the SEA. Several opportunities for combining these methods into hybrid tools were identified: - Combining **Territorial Metabolism and Life Cycle Assessment (TM-LCA)** allows for process-based environmental impact modelling at a regional scale - Several add-on elements are possible for the TM-LCA method e.g. approaches to dynamic systems and **Multi Criteria Decision Analysis (MCDA)**. These combined TM-LCA methods are dubbed **TM-LCA+**.	

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- A combination of **Computational social choice** and **Argumentation** permits to support decision based on validated preferences.	
Aspects and impact categories	Deliverable
Midpoint environmental impacts (ReCiPe) - Fine particulate matter formation - Fossil resource scarcity - Freshwater ecotoxicity - Freshwater eutrophication - Global warming - Human carcinogenic toxicity - Human non-carcinogenic toxicity - Ionizing radiation - Land use - Marine ecotoxicity - Marine eutrophication - Mineral resource scarcity - Ozone formation. Human health - Ozone formation. Terrestrial ecosystems - Stratospheric ozone depletion - Terrestrial acidification - Terrestrial ecotoxicity - Water consumption (vi) SEA indicators - Cause indicators represent human activities, processes and relations influencing the environment - Consequence indicators showed the state of the environment - Response indicators defined political and other actions aimed at changing the consequences to the environment	D1.1 D2.2 D2.3

The project has pilot sites ☒Yes ☐No	Key words
Serbia France Italy USA: Oregon State	Wastes management conversion processes, Agro-Waste Management Plan (AWMP), Environmental assessment, Techno-economic assessment (TEA), ReCiPe 2016 Hierarchist method, Life Cycle Assessment (LCA), Territorial Metabolism–LCA (TM-LCA), Computational social choice, Argumentation, Multi, Criteria Decision Analysis (MCDA) – TOPSIS, Multi Criteria Evaluation (MCE), Strategic Environmental Assessment (SEA), Waste Management Plan (WMP), Geographic Information System (GIS)

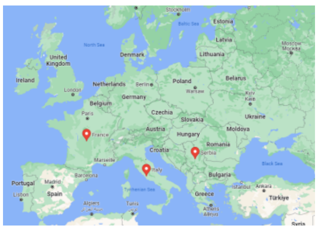

Table 17. NoWA working sheet

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NewPack New BioBased Film for Packaging	NEWPACK Development of new Competitive and Sustainable Bio-Based Plastics	Start date: 01/06/2018 End date: 31/08/2021	Code T-297
		Framework program:	Horizon 2020
		Topic:	BBI.2017.R6

General aim of the project	Specific objectives linked to ToNoWaste
To develop and validate novel biodegradable plastic packaging films, able to replace conventional plastic films used for food packaging applications and aiming at prolonging the shelf lifetime of packaged food products leading to achieve the decrease of food waste and the reduction of carbon footprint of packaging film solutions. The packaging film is produced from agro-waste feedstock contributing to a circular economy production model. It is biodegradable and compostable at their end-of-life.	To assess the economic viability for each of the product streams through the realization of a technical and economic evaluation to guide the important decision points throughout the project and also study the environmental suitability of the processes and associated bio-based plastics by means of an environmental Life Cycle Assessment (LCA). To evaluate ex-ante the economic feasibility of the preliminary NEWPACK process design at a commercial scale. To identify the best candidate food products and the best scenarios for maximum benefit from the sustainable packaging developed in NEWPACK, compared to conventional plastic materials. To monitor the performance of the product in key environmental indicators, guide the design towards a sustainable pathway of the bio-based film and compare it with the environmental performance of reference technologies. To calculate and understand the environmental impacts over the life cycle of the new developed value chain for the most relevant indicators in view of integrated eco-design. To compare the environmental performance of PHB and PLA bio-based polymers to the conventional reference technologies (European bio-plastics). To generate new packaging with a higher success rate, which would satisfy the population interested in differentiating, high added value, and more environmentally friendly packaging. To find out the consumer's opinion and perception to verify that these new developments are adapted to the market. To reach a Technology Readiness Level (TRL) of 5 or 6 at the end of the project in pilot scale production.

System under study	Scope of the study
Three scenarios were defined: - Scenario 1: Baseline - Scenario 2: Consequential scenario for 1 m^2 food packaging film, and - Scenario 3: Consequential scenario for a food package (tray and film)	Cradle-to-grave Life stages considered are extraction and transformation of raw materials, their transport to the

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Four bio-based materials that comprise the bio-based blend were outlined (NEWPACK film): - PHB - PLA - OLA plasticizer - CNWs The feedstock of the NEWPACK product is agro-food waste: - Potato peels for PHB - Wheat straw for cellulose nanowhiskers - Shrimp shells for chitin nanoparticles - Maize for PLA Four plastic films were outlined as reference products for the comparison: - Polyvinyl Chloride (PVC) 14 μm - Polyethylene terephthalate (PET) 27 μm - Polyethylene terephthalate (PET) 94 μm - Polystyrene (PS)/ Polyethylene terephthalate (PET) 94 μm) Three end-of-life scenarios to describe the film waste management were examined: - 100% composting - 100% incineration - 100% land filling. Four food products were aimed as final application for the developed bio-based film: - Whole mushroom - Mixed vegetables - Sliced cured ham - Sliced vegan sausages	processing plant in Europe as well as all transport activities between manufacturing processes, and the end-of-life treatment of the compostable film. The use stage is excluded as it is estimated by project partners to be identical among all assessed film products.

The project assesses some sustainability dimension	☒Environmental ☐Social ☒Economic ☐Non
What it is assessed	Deliverable
The economic feasibility of the NEWPACK packaging films. The sustainability performance of the PHB-PLA blend bio-plastic packaging film value chain. The environmental performance of these novel materials, as well as to evaluate the benefits of the bio-based feedstock in the value chain and identify critical points in the feedstock acquisition and the end-of-life treatment of these materials. The shelf-life extension of the packaged products which allowed for the evaluation of avoided emissions from food waste prevention. Aspects like the avoidance of wheat straw as bedding material in animal farms, or potato peels as animal feed will be addressed. The comparison of the environmental impacts of the two conventional plastic film materials in relation to the NEWPACK film's impacts (NEWPACK film, PET film and PVC film) The environmental impacts related to the full share of activities that are expected to change when producing and disposing of the Newpack film in an industrial scale context.	D6.1 D6.2 D6.3

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How it is assessed	Deliverable
A large-scale commercial production was modelled to economically evaluate NEWPACK packaging films. Due to the uncertainty surrounding the economic assumptions in the baseline, a sensitivity analysis on the main modelled economic parameters using Monte Carlo simulations was performed. This simulation allowed to explore in detail what most influences the profitability of the investment. A techno-economic analysis of the bio-based packaging film production was performed considering major investment and operating costs, discounted cash flows, and the minimum selling price of the products. A cost-benefit analysis (CBA) was performed to study the profitability of the processes in terms of investments and operating costs. To assess and quantify the environmental performance of NEWPACK materials, the benefits of bio-based feedstock and the critical points of its acquisition and end of life, the Life Cycle Assessment (LCA) methodology was applied. Consequential LCA principles were applied to assess: - The shelf-life extension of the packaged products - The environmental impacts related to the activities that are expected to change Sankey diagram was performed to show the material, energy, water, and waste flows.	D6.1 D6.2 D6.3

The project uses accounting method(s)	☒Yes ☐No
Application of the method(s)	Deliverable
(i) Cost-benefit analysis (CBA) The threshold price for the bio-based packaging film was calculated assuming a pay-back period of 20 years. Due to the lack of information, several assumptions about the project financials were made. These assumptions entailed uncertainty which was addressed performing a sensitivity analysis using Monte Carlo simulations. The PERT distribution was used to represent the uncertainty of each variable. Three values (i.e., minimum, mode, and maximum) define each distribution. (ii) Life Cycle Assessment (LCA) Following the standards by the International Organization for Standardization (ISO) 14040-14044 standards (ISO 14040 (2006), ISO 14044 (2006)). Background data was taken from the Ecoinvent database version 3.4 and 3.5. Consequential system model database was not used since cut-off system model was preferred both for the attributional and consequential LCA. The consequential questions were solved by applying a system expansion approach. Two levels were considered when applying impact assessment methods: - Midpoint analysis: Environmental Footprint (EF) version 3.0 - Endpoint analysis: IMPACT 2002+ Two modelling principles were used: - <u>Attributional with allocation</u> (intermediary phase of the project): describes actual or forecasted specific or average supply-chains together with their use and end-of-life stage, in a static environment. It was used to identify the environmental hotspots in the production of the NEWPACK product in the different environmental indicators.	D6.1 D6.2 D6.3

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- Consequential (final phase): considers a generic supply-chain, and the system depicts an interaction with the market and reflects the consequences that the decisions of the analyzed system may have on the market, in a dynamic technosphere (ILCD, 2010). It was used to estimate the potential risks or benefits of introducing the novel bio-based film on the market. Market mechanisms were integrated in the assessment when possible. The End-of-life (EoL) model is based on the Circular Footprint Formula (CFF) of the Product Environmental footprint (PEF) recommendations for recycling, collection and trashing rates in European counties. Cut-off criteria: The aspects that were globally excluded from the perimeter of the study concern were packaging of raw materials and intermediate products; chemicals and trace elements that were used in amounts smaller than 1% in of final product (in mass); and building infrastructure of the research and pilot plants. Allocation: Was applied based on the economic value of the main product and co-product for potato peels, as a co-product from the potato production, and which have a certain economic value; and wheat straw (cellulose source), with an economic price on the market, as a co-product of the wheat market. No allocation rule was applied to the shrimp shells, as they were considered to be mainly a waste rather than co-product in this study.	
Aspects and impact categories	Deliverable
(i) Economic: - Investment costs (fixed-capital investment (FCI), working capital and start-up expenses) - Operating costs - Net Present Value (NPV) and threshold price for NEWPACK film. (ii) Environmental midpoint indicators - Climate Change (carbon footprint) - Water use (water footprint) - Land use - Resource use, energy carriers (energy footprint) (ii) Environmental endpoint indicators - Ecosystems Quality - Human health	D6.1

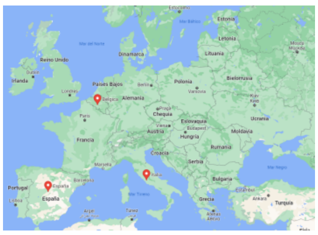
The project has pilot sites ☒Yes ☐No	Key words
Belgium Spain Italy 	Monte-Carlo simulation, Biodegradable plastic packaging films, Techno-economic analysis, Cost-benefit analysis, Life Cycle Assessment (LCA), Environmental assessment, Economic assessment, Sankey diagram, Ecoinvent, Attributional LCA, Consequential LCA, Environmental Footprint (EF), Circular Footprint Formula (CFF), IMPACT 2002+

Table 18. NEWPACK working sheet

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	MyPack Best markets for the exploitation of innovative sustainable food packaging solutions	Start date: 01/11/2017 End date: 31/10/2021	Code T-286
		Framework program:	Horizon 2020
		Topic:	SFS-35-2017

General aim of the project	Specific objectives linked to ToNoWaste
To help sustainable food packaging technologies to reach or extend their market to reduce waste, both in food and packaging materials, and its negative impacts on the environment.	To study the role of packaging in relation to consumer food waste. To apply LCA and LCC to identify sustainable packaging solutions, reducing food waste and packaging itself to the minimum and find a balance between under- and over-packaging. To determine the optimum environmental performance of packaging overcoming different consumers perceives about sustainability. To study innovative packaging technologies in order to develop fit for purpose packaging solutions that reduce food waste and packaging materials, improving the environmental and eco-efficiency performance. To understand European consumers' preferences and willingness to buy sustainable packaging alternatives.

System under study	Scope of the study
Comparative study of **105 packaging combinations**, which were classified in three categories attending to the ratio between packaging and food impact: - Under-packaging: low packaging Food environmental effect ratios: priority is a reduction of food waste through an increase of packaging performance. - Over-packaging: high packaging Food environmental effect ratios: priority is a reduction of packaging waste, either through mass reduction, or through the choice of alternative packaging technologies. - Unclear situation Intermediate ratios can profit from strategies of both under-packaging and over-packaging. Then, 7 innovative sustainable food packaging solutions were considered of which 5 were developed and exploited. Based on the selected innovative technologies three markets were identified: - Market 1: Bio-based and biodegradable film for fresh and processed food; - Market 2: Inert, heat resistant and barrier packaging for processed food; - Market 3: Micro-technological insertion for fresh product. Packaging technologies promoted: biodegradable and compostable packaging; packaging from renewable resources; and elaborated (high barrier and active) packaging technologies.	Cradle-to-grave Raw materials, transport, production processes, packaging, distribution and storage processes and product end-of-life (Exclusion of the use phase and transport processes to retail and from retail to consumer)

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Type of food considered: fresh pre-cut salad; organic biscuits; and baby food.	

The project assesses some sustainability dimension	☒Environmental ☐Social	☒Economic ☐Non
What it is assessed		Deliverable
(i) The costs involved over the entire life cycle of the food and packaging solution; (ii) Environmental and technical performance of innovative packaging technologies; (iii) Eco-efficiency; (iv) The balance between direct packaging impact (negative) and functional packaging impact (positive due to food waste reduction); (v) Packaging efficacy for consumer products.		D3.5 D3.3
How it is assessed		Deliverable
(i) LCC was performed in parallel to the LCA study to quantify the Life Cycle Costs of food and packaging solutions. (ii) Scenario analyzes are performed to interpret the environmental performances of the food packaging combinations. - Food type and food waste: in the end-of-life scenarios a food waste rate of 20% is applied as a default value. - Trade-off between packaging alternatives: the extra environmental burden of the packaging can be compensated by the reduced food waste. - Packaging reuse: it was investigated what happens if glass packaging is taken back and reused as packaging - Consumption and shelf life: shelf life of pre-packed food has been evaluated based on technical sheets, while the shelf life of loose food is based on common habits. (iii) Eco-efficiency is assessed through the combination of LCA y LCC (v) Packaging efficacy was assessed through a consumers survey methodology developed within the EU funded H2020 project REFRESH.		D3.5 D3.3

The project uses accounting method(s)	☒Yes ☐No
Application of the method(s)	Deliverable
(i) The basis for the LCC analysis is the same system boundaries, data inventory and the same scenarios of the LCA, in order to be able to put in parallel environmental and economic aspects, providing an eco-efficiency ratio as an important performance indicator. LCC impact assessment is relatively simple since all costs will be aggregated in the same currency unit (Euro). (ii) Life Cycle Impact Assessment (LCIA) was performed with the Climate Change indicator of the EF method and the Recipe Endpoint H/A method. (iii) The eco-efficiency analysis requires the use of a single score, therefore LCA results are expressed in the single score of the ReCiPe method. LCC results are automatically represented by a single score, since they are expressed in euro. (i)(ii) LCA and LCC are applied at three levels: - State of the art level: many cases of under-packaging and over-packaging are identified.	D3.5

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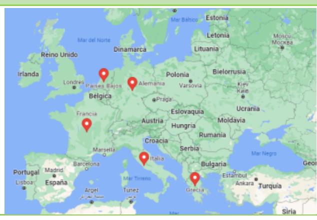
- Technology level: novel technologies are proposed. - End-user level: suitable technologies will be tested at three end-users: salads, baby food and organic products.	
Aspects and impact categories	Deliverable
Environmental: - Climate Change indicator of the EF method - Recipe Endpoint H/A method. Consumer perception: - Packaging material - Food handling - Packaging disposal Economic: - €/kg consumed	D3.5 D3.3

The project has pilot sites	☒Yes ☐No
France Germany Italy Netherlands Greece	

Key words
Life Cycle Assessment (LCA), Life Cycle Costing (LCC), Eco-efficiency, Environmental assessment, Economic assessment, Consumer perception.

Table 19. MyPack working sheet

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GLOPACK	GLOPACK Granting society with LOw environmental impact innovative PACKaging	Start date: 01/06/2018 End date: 30/11/2021	Code T-197
		Framework program: Horizon 2020 Topic: SFS-35-2017	

General aim of the project	Specific objectives linked to ToNoWaste
To facilitate access to innovative food packaging for both companies and consumers enabling the reduction and circular management of food, including packaging and wastes. To develop a new biodegradable packaging, with active and/or intelligent functionalities.	To compare the environmental performance of the production of GLOPACK packaging with that of the production of conventional plastic packaging. To evaluate the environmental performance over the entire food supply chain of three food products packed in GLOPACK packaging and to compare it to the case where the products are packed in the benchmark reference packaging.

System under study	Scope of the study
Three packaged food products are under study: falafel, cheese and beef meat. The packaging areas studied are (1) biodegradable packaging materials made from agro-food residues, (2) active packaging to improve the shelf life of food without additives, and (3) radio-frequency identification (RFID) labels to indicate food spoilage wirelessly.	Cradle-to-grave

The project assesses some sustainability dimension	☒Environmental ☐Social	☐Economic ☐Non
What it is assessed		**Deliverable**
Five aspects to obtain a broad analysis of the environmental sustainability of plastic packaging: -Direct impacts of packaging through production and disposal; -Direct impacts of packed food by production and consumption; -Indirect impacts of packed food due to food loss and waste influenced by the packaging material; -Direct impacts of packed food by improper management; -Circularity of packaging.		D4.4
How it is assessed		**Deliverable**
Kinetic equations are used to build scenarios for the change in food loss and waste (FLW) due to the use of GLOPACK packaging that could affect the shelf life and hence influences the amount of FLW through the food supply chain. The environmental impact of an increased amount of FLW is calculated by LCA. An assessment of resource usage and environmental burdens related to emissions, effluents and waste is performed.		D2.3 D4.4

The project uses accounting method(s)	☒Yes	☐No
Application of the method(s)		**Deliverable**
Life cycle assessment (LCA) according to the ISO standards is applied. Two LCA databases are employed: Ecoinvent v3.6 (with cut-off modelling) and agri-footprint, both embedded in the software SimaPro, version 9.1. The environmental impacts assessed are divided on three levels: PHBV pellet production; packaging production and packaged food product life cycle. The environmental impacts considered on this project are: - Resource footprint, calculated with the Cumulative Exergy Extraction from the Natural Environment (CEENE) method.		D4.4 D1.4

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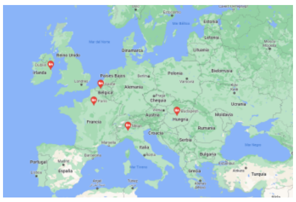
- Global warming impact, calculated with the European Environmental Footprint 3.0 (EFv3.0). - Single score of EFv3.0 to provide a picture of the global environmental impact of the packaging. - Impact on marine ecosystem services. - Circularity. The cumulative degree of perfection (CDP), calculated as the ratio of the exergy content of a product to the total resource footprint (by CEENE) of its production chain is also assessed. The PREI (%) LCIA-based indicator is assessed to capture the relative importance of packaging in the packed food system. This indicator is calculated as the percentage ratio of the environmental impact of packaging to the environmental impact of packed food. Decision Support System (DSS) is developed to efficiently support the selection process for packaging solutions including indicators on environmental sustainability.	
Impact categories	Deliverable
(i) Standardized LCA Evaluation at midpoint: - Resource footprint (MJ_{ex}): a-biotic renewable resources; nuclear energy; minerals (and mineral aggregates); land and biotic resources; fossil fuels; metal ores; water resources. - The cumulative degree of perfection (no units). - Environmental Footprint 3.0: Climate change (kg CO2 -eq). Evaluation at endpoint: - Single score of EFv3.0 (μPt) (ii) Additional inventory flow compared to traditional LCA To evaluate the impact on marine ecosystem services caused by an addition of a fixed amount of plastic waste to the marine environment an additional inventory flow compared to traditional LCA is used. Ecosystem services are measured at the endpoint level in monetary terms (Euros) according to the framework for their evaluation. The impact assessment relies on the methodology proposed by Beaumont et al. (2019) and further adapted by World Wide Fund for Nature (WWF) (2021). Impact categories covered are "plastic leakage to the marine environment" and; "impact on marine ecosystem services". (iii) Methodology to measure circularity: - Circularity based on the composition and characteristics of the packaging: secondary sourcing degree and; recoverability degree.	D4.4

The project has pilot sites ☒Yes ☐No	
France (Paris) Italy (Milan) Belgium (Ghent) Ireland (Dublin) Hungary (Budapest)	

Key words
Food packaging, Life Cycle Assessment (LCA), Environmental Footprint (EF), Cumulative Exergy Extraction from the Natural Environment (CEENE), Decision Support System (DSS), Cradle-to-grave, Intelligent packaging

Table 20.GLOPACK working sheet

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	WASTE2FUNC	Start date: 01/06/2021 End date: 30/11/2024	Code T-447
	Lactic acid and biosurfactants sourced from sustainable agricultural and industrial (food) WASTE feedstocks as novel FUNCtional ingredients for consumer products	Framework program: Horizon 2020 Topic: BBI-2020_SO1-D1	

General aim of the project	Specific objectives linked to ToNoWaste
To convert food and crop waste into bio-based functional molecules, lactic acid and microbial biosurfactants for the household and healthcare products industries.	To establish a sustainable biomass waste supply chain in close collaboration with the primary sector by developing an appropriate registration and collection system for erratic agricultural biomass waste and integrating this new biomass supply chain into the existing industrial one, which is currently converting this biomass into biogas. To analyze greenhouse gas (GHG) savings for different end of life waste measures.

System under study	Scope of the study
The efficient conversion of food (crop) waste into two types of bio-based functional molecules for use in home-and personal care applications: lactic acid and microbial biosurfactants, Available feedstock is waste from: fruit and vegetable processing, oil seed processing, cereal crop processing, slaughterhouse, dairy processing, breweries, sugar-processing industry, meat-alternative production, supermarket food, bakery, used cooking oil and mixed food waste prom catering units. The key feedstocks identified by a Multi Criteria Analysis (MCA) were: - Food waste from local catering outlets (if the material was source separated) - Used cooking oil from local catering outlets - Sugar waste from the sugar-processing industry (molasses and pulp)	The value chains will be set up by (interaction with) all relevant key stakeholders: farmers and their representatives, primary crop-/food processors, food processors and -retailers, food waste collectors, technology owners for bio-based process, scale up facilities, product developers and -retailers in the respective sectors of application (home-and personal care) (B2B and B2C), regulators and the consumer.

The project assesses some sustainability dimension*	☒Environmental ☐Social	☒Economic ☐Non
What it is assessed		**Deliverable**
Environmental, economic, social and regulatory aspects and constant optimization.		D2.2
How it is assessed		**Deliverable**
To identify the most eligible and feasible feedstocks, an Multi Criteria Analysis (MCA) was used based on factors that impact on the security of the supply chain. Risk minimization was considered and the sensitivity to geopolitical and climate problems. A basic assessment of the potential carbon savings or improvements in sustainable practices was conducted qualitatively. This is also a method of highlighting the most promising feedstocks.		D2.2

For each of the feedstocks, the current scenario was compared on a carbon-emissions and sustainability basis, to the case of sending this feedstock for production in either of the WASTE2FUNC processes. A table was created to analyze if there is a carbon saving by sending a feedstock to WASTE2FUNC compared to its current purpose, if this destination agrees with the waste hierarchy (reduce, reuse, recycle, recover, landfill) and what other impacts this destination will have.	

The project uses accounting method(s)*	☒Yes ☐No
Application of the method(s)	Deliverable
Techno-economic analysis (TEA) Life Cycle Assessment (LCA)	WP5
Aspects and impact categories	Deliverable

The project has pilot sites ☐Yes ☒No	Key words
	Conversion of food waste, Multi Criteria Analysis (MCA), Techno-economic analysis (TEA), Life Cycle Assessment (LCA), Economic assessment, Environmental assessment

*Environmental and regulatory analysis information is expected on WP5 deliverables.

Table 21. WASTE2FUNC working sheet

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Summarizing, Table 22 presents a description of the most frequently used sustainability accounting methodologies according to the analysis of projects funded by the EU conducted in this deliverable, together with the main scientific references to deepen our understanding on them.

Accounting methodology	Description	Main references
Environmental Life Cycle Assessment (E-LCA)	Environmental Life Cycle Assessment (E-LCA), also referred to as Life Cycle Assessment (LCA), is a technique that aims at addressing the environmental aspects of a product and their potential environmental impacts throughout that product's life cycle. The extraction and consumption of resources (including energy), as well as their releases into the air, water, and soil, are quantified throughout all stages. Their potential contribution to environmental impact categories is then assessed. The ISO 14040 and 14044 standards provide general guidance to implement an LCA. According to ISO 14040, the four phases of LCA are: • Goal and scope definition • Inventory analysis: Life cycle inventory (LCI) • Impact assessment: Life cycle impact assessment (LCIA) • Interpretation of the results	International Organization for Standardization. (2006). Environmental management. Life cycle assessment. Principles and framework (ISO 14040) SMART DELIVERABLE D5.4 Sustainability Assessment Guide
Life Cycle Inventory (LCI)	The life cycle inventory analysis phase (LCI phase) is the second phase of LCA. It is an inventory of input/output data regarding the system being studied. It involves collection of the data necessary to meet the goals of the defined study.	International Organization for Standardization. (2006). Environmental management. Life cycle assessment. Principles and framework (ISO 14040)
Life Cycle Impact Assessment (LCIA)	The life cycle impact assessment (LCIA) phase is the third phase of the LCA. The purpose of LCIA is to provide additional information to help assess a product system's LCI results so as to better understand their environmental significance.	International Organization for Standardization. (2006). Environmental management. Life cycle assessment. Principles and framework (ISO 14040)

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Life Cycle Interpretation	Life cycle interpretation is the final phase of the LCA procedure, in which the results of an LCI or an LCIA, or both, are summarized and discussed as a basis for conclusions, recommendations and decision-making in accordance with the goal and scope definition.	International Organization for Standardization (2006). Environmental management. Life cycle assessment. Principles and framework (ISO 14040)
Social Life Cycle Assessment (S-LCA)	The Social Life Cycle Assessment (S-LCA) is a technique that aims to assess the social and socio-economic impacts (and potential impacts) of products along their life cycle. In the S-LCA, the starting point is to define the goal and scope, as well as to determine the functional unit of analysis. It is important to note that S-LCA often works with semi-quantitative or qualitative data from characteristics of processes, which cannot be provided per process or unit of output.	UNEP-SETAC (2013). The Methodological Sheets for Subcategories in Social Life Cycle Assessment (S-LCA). SMART DELIVERABLE D5.4 Sustainability Assessment Guide
Life Cycle Costing (LCC)	Life cycle costing (LCC) is an assessment of all costs associated with the life cycle of a product that are directly covered by any one or more of the actors in the product life cycle (e.g., supplier, manufacturer, user or consumer, or End of Life actor) with the complementary inclusion of externalities that are anticipated to be internalized in the decision-relevant future.	Hunkeler et al. (2008) Environmental Life Cycle Costing. SETAC-CRC.
Life Cycle Sustainability Assessment (LCSA)	The Life cycle sustainability assessment LCSA can be accomplished by including environmental, social and economic aspects and enlarging the system boundary from a micro-level (process-based) to macro-level (economy-wide) analysis. Practical application of LCSA requires integration of various methods, tools, and disciplines. Muñoz et al. (2018) propose a Sustainability Assessment Framework to measure the environmental, social and economic impacts of organizations along the life cycle.	Muñoz-Torres, M.J., Fernández-Izquierdo, M.Á., Rivera-Lirio, J.M., Ferrero-Ferrero, I., Escrig-Olmedo, E., Gisbert-Navarro, J.V., & Marullo, M. C. (2018). An assessment tool to integrate sustainability principles into the global supply chain. Sustainability 1 0 (2), 535. Onat et al. (2017). Systems thinking for life cycle sustainability assessment: A review of recent developments, applications, and future perspectives. Sustainabi lity 9(5), 706.

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Cost-benefit analysis (CBA)	Cost-benefit analysis (CBA) is the most commonly used technique in appraising public investment. CBA is an analytical tool for judging the economic advantages or disadvantages of an investment decision by assessing its costs and benefits in order to assess the welfare change attributable to it. The main project performance indicators for CBA are: net present value, internal rate of return (IRR) and the benefit-cost (B/C) ratio.	European Commission. Directorate-General for Regional and Urban policy. (2014). Guide to Cost-Benefit Analysis of Investment Projects. Economic appraisal tool for Cohesion Policy 2014-2020.

Table 22. Accounting methodologies description

3.3 Scientific literature review

3.3.1 Aim and scope

The aim of this scientific literature review is to provide an in-depth exploration of the crucial topic of FLWPR within the context of sustainability. Throughout this section, we will delve into the multiple aspects of FLW, examining the causes that contribute to its occurrence, exploring a wide range of solutions and strategies aimed at mitigating FLW, and highlighting the evolving landscape of FLW-related terminology. We will also explore the intricate relationship between consumer behavior and FLW, acknowledging the role of digitalization and innovative technologies in facilitating FLW prevention efforts.

This section sheds light on the accounting methodologies employed in quantifying FLW, emphasizing the importance of reliable and standardized key performance indicators (KPIs) for accurate measurement. We will also discuss the various methodologies used for the decision-making process, enabling stakeholders to make informed choices in the field of FLWPR. By addressing these key areas, this section aims to provide a comprehensive understanding of FLW, its underlying causes, and the diverse range of strategies and methodologies available to fight this pressing global challenge.

3.3.2 Method of review

With the aim of analyzing the state of the art, a search for scientific articles was conducted on the Web of Science search engine. The main mapping questions for this search were:

-What kind of approaches are taken in the literature to reduce FLW?

-Where are the main gaps to address the FLW problem?

-Which are the main methodologies used to evaluate the performance of FLW activities? Which other methodologies are used in similar multi-criteria decision making processes?

The analysis process was divided into two steps:

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- A general search to identify the main publications related to the topic and identification of main aspects subjected to study in the literature;
- Specific searches to go deeper into the different aspects previously identified, as in some cases no specific papers about FLW were identified and a wider scope for the search was needed.

In the first step, only papers published from the year 2019 onwards were considered. This decision was made since the Commission Delegated Decision (EU) 2019/1597 was published in that year, and it forms a cornerstone in the field of FLW quantification. The following keywords were used to filter the papers:

" (fresh AND food) OR (food AND waste) OR (fresh AND food AND waste) OR (fresh AND food AND loss) OR (food AND waste AND loss)
AND
(prevention OR reduction)
AND
(assessment OR appraisal OR evaluation OR monitoring OR metrics OR analysis)
AND
(environ* OR social OR econom* OR sustain*) "

A list of 5,135 papers was finally accepted as the input for the next step. Then, these papers were analyzed in order to rule out those that were not relevant for this review. Among the publications that were found, some just mentioned the keywords, others lightly touched upon this topic as they deal with a related subject, and others deal with the topic from a different approach that is not applicable. So, only the studies that addressed FLWPR as it is done in ToNoWaste passed the filter. This resulted in the selection of a total of 655 papers, which represents 12.7% of the sample obtained from the search.

The main issues addressed in the literature are:

a. Context (sustainability, circular economy opportunities, regulatory framework, SDGs);
b. Terminology (definitions, connection with waste hierarchy principles);
c. Causes and factors that influence over the behavior patterns;
d. Accounting methodologies:
    i. Environmental, technical, social and economic dimensions;
    ii. FLW quantification methodologies;
    iii. Multicriteria decision making tools;
e. Solutions, strategies, tools and actions to reduce and prevent? FLW:
    i. Policies and financial instruments;
    ii. Food technologies;
    iii. Food waste valorization technologies;
    iv. Business expansion opportunities.
f. The role of digitalization as a driver to improve FSC and in particular FLW reduction and prevention.

For the objective of this deliverable, we will only focus on those aspects related to accounting methodologies, understood as the dimensions and methods that may be used to measure the impact of FLW prevention actions. Due to the complexity and multidimensionality of the problem a deeper analysis has been carried out for all these aspects that will serve as a framework for the different issues that will be addressed in the ToNoWaste project. Next, the main outcomes are explained.

3.3.3 Analysis and interpretation

I. FLW prevention and reduction

When assessing FLW prevention and reduction strategies it is very important to understand what these concepts mean. Waste hierarchy is a priority tool to manage waste according to 4 levels (prevention, recycling, recovery, and disposal), taking the Waste Framework Directive (Directive 2008/98/EC) as a reference. However, the application of this concept to FLW management has generated some controversies and different pyramid schemes can be found.

Teigiserova et al (2020) proposed a pyramid with different levels of application. In a nutshell, surplus food is prevented first, followed by reuse for human consumption (reuse - H), while food waste is considered for reuse for animal feed (reuse -A), to be prioritized over the material recycling, followed by the nutrient recovery, and finally use for energy recovery, with the disposal avoided (Figure 3).

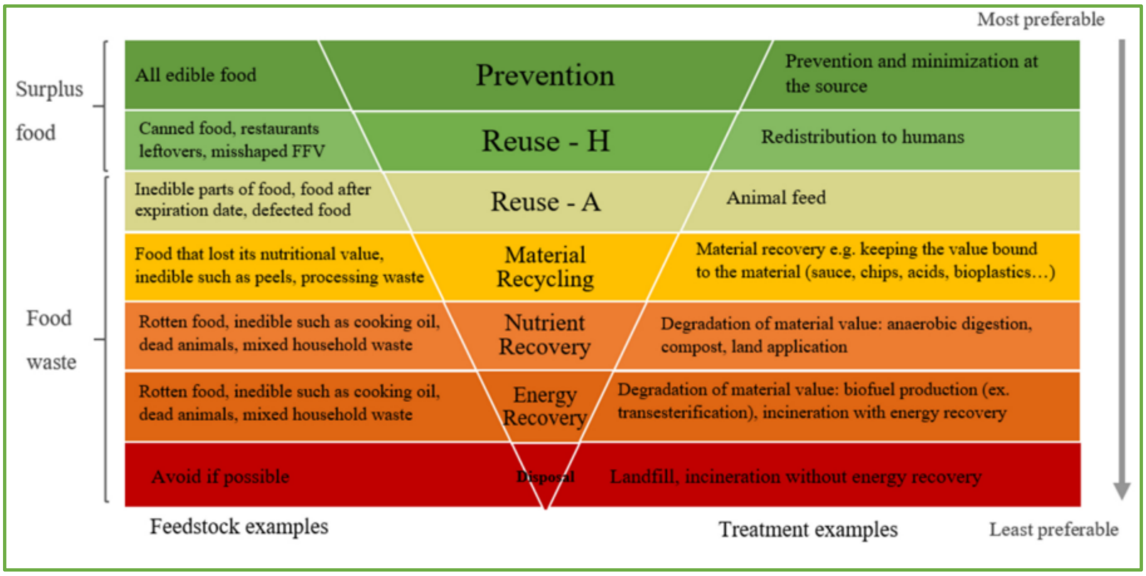

Figure 3. Updated hierarchy for food surplus and waste proposed by Teigiserova et al., 2020

The European Commission's Knowledge Centre for Bioeconomy presents an alternative waste hierarchy (Figure 4), suggesting a different approach based on the framework established by Teigiserova et al. (2020) and two additional sources. In contrast to the aforementioned hierarchy, this proposed structure retains the first three levels with minor variations, while renaming the fourth one as "Reuse by products/Recycle food waste." This version created by the Joint Research Centre incorporates nutrient recovery within the recycling level and introduces a new disposal option at the last level: the discharge of food waste through sewage.

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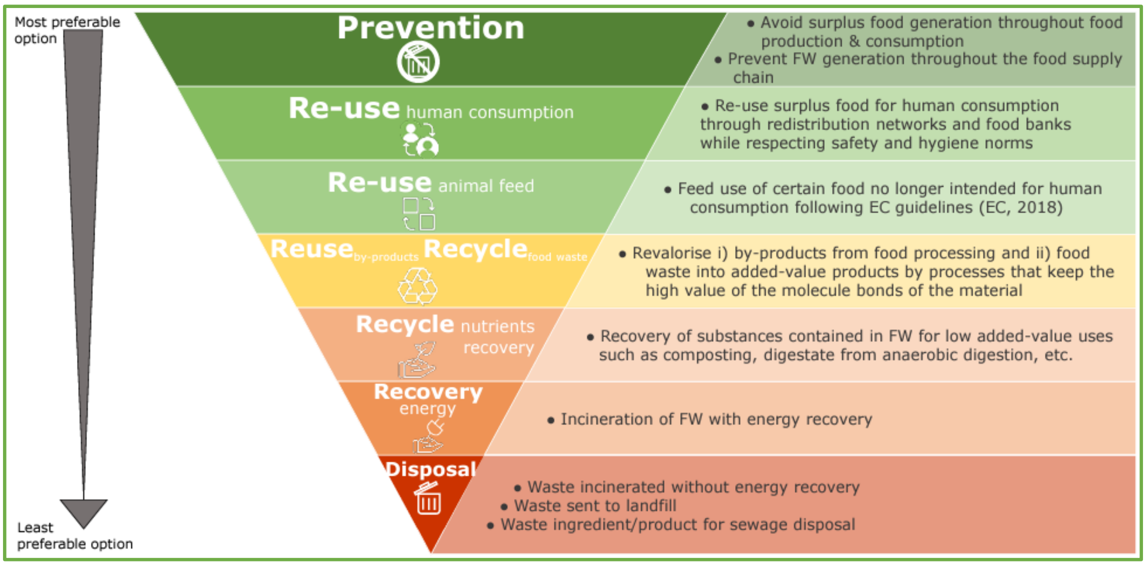

Figure 4. Food waste hierarchy proposed by Sánchez López et al., 2020

Nevertheless, according to the Waste Directive reuse implicitly assumes that the product has been already used (i.e. consumed in the case of food) so it seems that the employment of the reuse concept couldn't be deemed as an alternative in the food waste hierarchy. This classification is in accordance with the food waste hierarchy established by WRAP (Figure 5).

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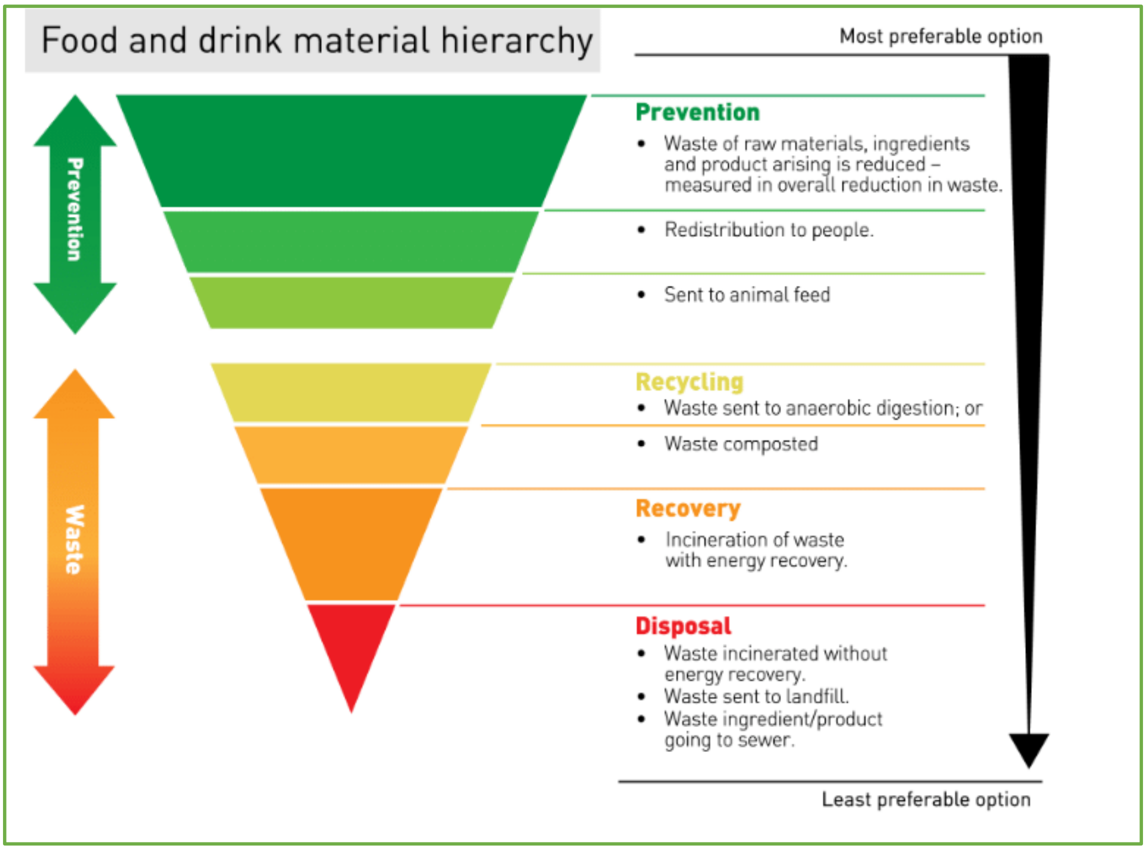

Figure 5. Food Waste Hierarchy (WRAP, 2018)

The ToNoWaste project will focus on those actions directly related to the green part (prevention at origin and reuse), which will have a direct impact on the reduction of FLW generation. Some authors even divide prevention into two streams (upstream and downstream) to differentiate between those actions that avoid producing surplus and those actions that manage surplus, respectively. This is especially interesting because the FLW not generated cannot be measured and their quantification must follow other approaches different from direct measurement.

Regarding the possible solutions that can be found in the literature to prevent FLW, the following can be highlighted:

- Demand forecasting. Such systems are able to better predict the number of customers in a restaurant for example, and thus the amount of food required to meet the demand and avoid overproduction (Harshini et al., 2021).
- Cold chain monitoring. By maintaining optimal temperature conditions throughout the food supply chain, these IoT solutions extend the shelf life of perishable food products and prevent FLW generation (Gillespie et al., 2023).
- Improved traceability with blockchain. The potential of the blockchain technology to prevent FLW is endorsed by the transparency, effectiveness, security, and reliability in the data it provides to food supply chain stakeholders (Kör and Krawczyk, 2021).
- Social actions. Social innovations and campaigns are instrumental in preventing FLW by raising awareness and fostering a supportive legislative and policy

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framework (Al-Obadi et al., 2022), analyzing the peculiarities for households (Chengqin et al., 2022) or HORECA sector (Alsuwaidi et al., 2022), identifying the role of young people (Ghine and Ghiuta, 2019), cultural aspects (Pelau et al., 2020), the impact of date marking on their choices (Secondi, 2019), or, as pointed out in more recent publications, in analyzing the influence of emotions on the decisions made by consumers when it comes to reducing FLW (Jabeen et al., 2023)

- Stocks management. Proper storage ensures the preservation of food and creates an appropriate environment for its optimal shelf life, which leveraging the prevention of FLW (Valmorbida Moraes et al., 2021).

II. Accounting methodologies

Effective measurement and management of FLW requires robust accounting methodologies that provide accurate insights into the magnitude and patterns of FLW across the food supply chain. In this subsection, we will delve into the various accounting methodologies employed for FLW quantification, key performance indicators (KPIs) for measurement, and methodologies for decision-making processes. Thus, this subsection aims to provide a comprehensive overview of the tools and frameworks available for effective FLW measurement and management. By adopting standardized approaches and leveraging data-driven insights, stakeholders can enhance their ability to make informed decisions, allocate resources strategically, and drive meaningful progress towards reducing FLW within the context of sustainable food systems.

a. Quantification

Accurate quantification of FLW is essential to understand the scale of the problem and identify areas where interventions can be most effective. Accounting methodologies for FLW measurement encompass a range of approaches, including waste composition analysis, direct weighing, and indirect estimation methods. Each methodology offers distinct advantages and considerations, depending on the stage of the supply chain, available data, and desired level of detail. By exploring these methodologies, we can gain a comprehensive understanding of how FLW is measured and develop insights into the causes and patterns of FLW occurrence.

Food waste is generated not only at the municipal level, but also in the previous stages of the chain and can be measured in different ways. Therefore, in order to get an overview of practices in this area in Europe, a review of the methodologies used according to the literature has been carried out. In Table 23, we can find the methods of measurements in direct access to food waste, in function of the stage of the food supply chain, proposed by the Delegated Decision (EU) 2019/1597. We can see the waste composition analysis and diaries methods, two of the three main methodologies found in the literature. The third one mentioned is the “direct measurement”, close to the waste composition analysis in its definition but more suitable for the other stages of the supply chain. Another methodology, widely used by studies, is the survey, not mentioned in the Delegated Decision because it does not require direct contact with the wastage managers.

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However, it is mentioned for the other stages of the supply chain (questionnaires and interviews).

<table>
<tr><th>Stage of the food supply chain</th><th colspan="5">Methods of measurement</th></tr>
<tr><td>Primary production</td><td rowspan="5">— Direct measurement</td><td rowspan="3">— Mass balance</td><td rowspan="2"></td><td colspan="2" rowspan="2">— Questionnaires and interviews
— Coefficients and production statistics.
— Waste composition analysis</td></tr>
<tr><td>Processing and manufacturing</td></tr>
<tr><td>Retail and other distribution of food</td><td rowspan="3">— Waste composition analysis</td><td rowspan="2">— Counting/scanning</td><td></td></tr>
<tr><td>Restaurants and food services</td><td rowspan="2"></td><td rowspan="2">— Diaries</td></tr>
<tr><td>Households</td><td></td></tr>
</table>

Table 23. Methodologies based on direct access to food waste/direct measurement, from the Delegated Decision (EU) 2019/1597

In this case, a specific revision of the literature was made from 2004 onwards, as Delegated Decision is quite recent and not many related papers can be found.

A total number of 25 scientific publications were analyzed. Other papers were not selected, either because they were not within the geographical area (European Union) or because the stage of the supply chain was not fitting our research criteria.

Since the scope used in each source considerably conditions the results of the quantification, these are indicated in Table 24, which shows a summary of the definitions of FLW used, the stage of the FSC measured and the method used.

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Reference	Year	Definitions	FSC stage(s)	Method(s)
Ioannou, A., Georgali, P.-Z., & Fokaides, P. A. (2022). Quantification of food waste in an insular island state for all stages of the food supply chain. Resources, Conservation, and Recycling, 185(106486), 106486.https://doi.org/10.1016/j.resconrec.2022.106486https://doi.org/10.1016/j.resconrec.2022.106486	2022	Not mentioned. It only refers to the Delegated Decision.	Primary production	Questionnaires and interviews Coefficients and production statistics
			Processing and manufacturing	Questionnaires and interviews Coefficients and production statistics Mass balance
			Retail and other distribution of food	Questionnaires and interviews Coefficients and production statistics Mass balance
			Restaurants and food services	Questionnaires and interviews Mass balance
			Households	Diaries
Thanomnim, B., Papong, S., & Onbhuddha, R. (2022). The Methodology to Evaluate Food Waste Generation with Existing Data in Thailand. Thai Environmental Engineering Journal, 36(1), 1-9.	2022	**Food loss:** "Any substance, drink that is intended for human consumption includes edible parts and inedible parts measures along production and supply chains, including post-harvest losses." **Food waste:** "Any substance, drink that is intended for human consumption includes edible parts and inedible parts measures at retail, food service, and households."	Retail and other distribution of food Restaurants and food services Households	Waste composition analysis

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Fernandez-Zamudio, M.-A., Barco, H., & Schneider, F. (2020). Direct measurement of mass and economic harvest and post-harvest losses in Spanish persimmon primary production. Agriculture, 10(12), 581.https://doi.org/10.3390/agriculture10120581https://doi.org/10.3390/agriculture10120581	2020	**Food loss:** FUSIONS' concept.	Primary production	Counting/scanning Questionnaires and interviews
Amicarelli, V., Roe, B. E., & Bux, C. (2022). Measuring food loss and waste costs in the Italian potato chip industry using material flow cost accounting. Agriculture, 12(4), 523.https://doi.org/10.3390/agriculture12040523https://doi.org/10.3390/agriculture12040523	2022	**Food loss:** "Decrease in the quantity or quality of food resulting from decisions and actions by food suppliers in the chain, excluding retailers, food service providers and consumers…" (FAO) **Food waste:** "Decrease in the quantity or quality of food resulting from decisions and actions by retailers, food service providers and consumers." (FAO)	Primary production Processing and manufacturing Retail and other distribution of food Household	Mass balance
Afzal, N., Basit, A., Daniel, A., Ilyas, N., Imran, A., Awan, Z. A., Papargyropoulou, E., Stringer, L. C., Hashem, M., Alamri, S., Bashir, M. A., Li, Y., & Roy, N. (2022). Quantifying food waste in the hospitality sector and exploring its underlying reasons—A case study of	2022	**Food waste:** "Decrease in the quantity or quality of food resulting from decisions and actions by retailers, food service providers and consumers." (FAO)	Restaurants and food services	Questionnaires and interviews Diaries

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Lahore, Pakistan. Sustainability, 14(11), 6914.https://doi.org/10.3390/su14116914https://doi.org/10.3390/su14116914				
Amicarelli, V., Rana, R., Lombardi, M., & Bux, C. (2021). Material flow analysis and sustainability of the Italian meat industry. Journal of Cleaner Production, 299(126902), 126902.https://doi.org/10.1016/j.jclepro.2021.12690https://doi.org/10.1016/j.jclepro.2021.12690	2021	**Food loss and waste:** "Intending food (including inedible parts) discharged, lost, degraded, consumed by pets or utilized in non-food or energy fields. Donation of food surpluses is not accounted in the present paper."	Primary production Processing and manufacturing Retail and other distribution of food Restaurants and food services Household	Mass balance
Herrera-Quinteros, G., & Jara-Rojas, R. (2023). Food losses perceived by family farms: Challenges and policy implications from a micro-approach quantification. Frontiers in Sustainable Food Systems, 6.https://doi.org/10.3389/fsufs.2022.961120https://doi.org/10.3389/fsufs.2022.961120	2023	**Food loss:** "A decrease in the mass of edible food originally intended for human consumption. Food losses occur at the production, postharvest, processing, and storage stages."	Primary production	Questionnaires and interviews

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Alshabanat, Z., Alkhorayef, A., Ben Haddad, H., Mezghani, I., Gouider, A., Tlili, A., Allouche, M. A., & Gannouni, K. A. (2021). Quantifying food loss and waste in Saudi Arabia. Sustainability, 13(16), 9444.https://doi.org/10.3390/su13169444https://doi.org/10.3390/su13169444	2021	Not clear.	Primary production Processing and manufacturing Retail and other distribution of food Restaurants and food services Household	Mass balance Questionnaires and interviews
Bedoya-Perales, N. S., & Dal' Magro, G. P. (2021). Quantification of food losses and waste in Peru: A mass flow analysis along the food supply chain. Sustainability, 13(5), 2807.https://doi.org/10.3390/su13052807https://doi.org/10.3390/su13052807	2021	**Food loss:** "Decrease in the quantity or quality of food resulting from food suppliers' decisions and actions in the chain." **Food waste:** "Decreases the quantity or quality of food at the end of the food chain, resulting from decisions and actions by retailers, food services, and consumers."	Primary production Processing and manufacturing Retail and other distribution of food Restaurants and food services Household	Mass balance
Tóth, K., Borbély, C., Nagy, B., Szabó-Szentgróti, G., & Szabó-Szentgróti, E. (2021). Measurement of food losses in a Hungarian dairy processing plant. Foods (Basel, Switzerland), 10(2), 229.https://doi.org/10.3390/foods10020229https://doi.org/10.3390/foods10020229	2021	**Food loss:** A reduction in the weight or quality of food at the beginning of the FSC (production, harvesting, processing). It is caused by logistical and infrastructural barriers.	Processing and manufacturing	Direct measurement (Volumetric assessment) Direct measurement (Weighing assessment) Mass balance Coefficients and production statistics Questionnaires and interviews

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Kohan, R. (2022). Quantification of food waste in retail operations: A fruit and vegetables wastage case in Paraguay. SSRN Electronic Journal.https://doi.org/10.2139/ssrn.4239473https://doi.org/10.2139/ssrn.4239473	2022	**Food Waste Ratio** (FWR) = Total mass of waste/Total mass of delivered or sold items	Retail	Mass balance
Tóffano Pereira, R. P., Galo, N. R., & Filimonau, V. (2022). Food loss and waste from farm to gate in Brazilian soybean production. Journal of Agriculture and Food Research, 10(100431), 100431.https://doi.org/10.1016/j.jafr.2022.100431https://doi.org/10.1016/j.jafr.2022.100431	2022	**Food loss**: Food loss describes the situations whereby edible food leaves the food supply chain because of unintentional events, such as extreme weather, an unexpected technical failure or limited storage capacity **Food waste:** In contrast, food waste arises due to intentional human actions whereby the food suitable for human consumption is not consumed because of negligence or due to a conscious decision to dispose of it. The food is intended for human consumption. which does not serve this purpose, for whatever reason, is considered lost or wasted.	Primary production	-Continuous monitoring of a crop to collect data (collecting soybeans on precise acres and then multiplying the result to obtain real estimations). -then interviews with stakeholders and use of secondary data to triangulate the first results.

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Joensuu, K., Hartikainen, H., Karppinen, S., Jaakkonen, A.-K., & Kuoppa-Aho, M. (2021). Developing the collection of statistical food waste data on the primary production of fruit and vegetables. Environmental Science and Pollution Research International, 28(19), 24618–24627.https://doi.org/10.1007/s11356-020-09908-5https://doi.org/10.1007/s11356-020-09908-5	2021	**Side flow:** everything but food use: feed use, energy use, other use, composting/bio-waste & left on field. **Food loss and waste:** Food losses occur at the first stages of the food supply chain: primary production and food industry, whereas losses occurring at the retail and consumption stages are referred to as food waste	Primary production	Surveys to farms stakeholders (to know the amount of waste).
Zhang, H., Li, S., Wei, D., He, J., Chen, J., Sun, C., Vuppaladadiyam, A. K., & Duan, H. (2021). Characteristics, environmental impact, and reduction strategies of food waste generated by young adults: Case study on university canteens in Wuhan, China. Journal of Cleaner Production, 321(128877), 128877.https://doi.org/10.1016/j.jclepro.2021.128877https://doi.org/10.1016/j.jclepro.2021.128877	2021	No clear definition	Restaurants and food services	Combined direct weighing, questionnaires, statistical analysis. +environmental impact evaluated with LCA

Leverenz, D., Hafner, G., Moussawel, S., Kranert, M., Goossens, Y., & Schmidt, T. (2021). Reducing food waste in hotel kitchens based on self-reported data. Industrial Marketing Management, 93, 617–627.https://doi.org/10.1016/j.indmarman.2020.08.008https://doi.org/10.1016/j.indmarman.2020.08.008	2021	No clear definition	Restaurants and food services	food waste tracking
Kasavan, S., Ali, N. I. B. M., Ali, S. S. B. S., Masarudin, N. A. B., & Yusoff, S. B. (2021). Quantification of food waste in school canteens: A mass flow analysis. Resources, Conservation, and Recycling, 164(105176), 105176.https://doi.org/10.1016/j.resconrec.2020.105176https://doi.org/10.1016/j.resconrec.2020.105176	2020	No clear definition	Canteens "Food waste is measured during two stages: the 'pre-consumer' and the 'post-consumer" stage	mass flow analysis direct weighing

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Eriksson, M., Malefors, C., Callewaert, P., Hartikainen, H., Pietiläinen, O., & Strid, I. (2019). What gets measured gets managed – Or does it? Connection between food waste quantification and food waste reduction in the hospitality sector. Resources, Conservation & Recycling: X, 4(100021), 100021.https://doi.org/10.1016/j.rcrx.2019.100021https://doi.org/10.1016/j.rcrx.2019.100021	2019	No clear definition	Restaurants and food services	
van Dooren, C., Janmaat, O., Snoek, J., & Schrijnen, M. (2019). Measuring food waste in Dutch households: A synthesis of three studies. Waste Management (New York, N.Y.), 94, 153–164.https://doi.org/10.1016/j.wasman.2019.05.025https://doi.org/10.1016/j.wasman.2019.05.025	2019	**Food waste** = edible part includes liquids but not as food waste	Households	
Jörissen, J., Priefer, C., & Bräutigam, K.-R. (2015). Food waste generation at household level: Results of a survey among employees of two European	2015	**Avoidable food waste**; Not? unavoidable or liquids.	Households	

research centers in Italy and Germany. Sustainability, 7(3), 2695–2715.https://doi.org/10.3390/su7032695https://doi.org/10.3390/su7032695				
Engström, R., & Carlsson-Kanyama, A. (2004). Food losses in food service institutions Examples from Sweden. Food Policy, 29(3), 203–213.https://doi.org/10.1016/j.foodpol.2004.03.004https://doi.org/10.1016/j.foodpol.2004.03.004	2004	Storage, preparation and serving losses, leftovers and plate waste.	Food service institutions (kitchens)	
Langley, J., Yoxall, A., Heppell, G., Rodriguez, E. M., Bradbury, S., Lewis, R., Luxmoore, J., Hodzic, A., & Rowson, J. (2010). Food for thought?--A UK pilot study testing a methodology for compositional domestic food waste analysis. Waste Management & Research: The Journal of the International Solid Wastes and Public Cleansing Association, ISWA, 28(3), 220–227.https://doi.org/10.1177/0734242X08095348https://doi.	2010	No clear definition	Households	

org/10.1177/0734242X0809534 8				
Lebersorger, S., & Schneider, F. (2011). Discussion on the methodology for determining food waste in household waste composition studies. Waste Management (New York, N.Y.), 31(9–10), 1924–1933.https://doi.org/10.1016/j.wasman.2011.05.023https://doi.org/10.1016/j.wasman.2011.05.023	2010	Differentiation between garden waste and food waste	Households and commercial stores	
Lebersorger, S., & Schneider, F. (2011). Discussion on the methodology for determining food waste in household waste composition studies. Waste Management (New York, N.Y.), 31(9–10), 1924–1933.https://doi.org/10.1016/j.wasman.2011.05.023https://doi.org/10.1016/j.wasman.2011.05.023	2014	Packed and unpacked food, packaging considered in FLW	Households	

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Tua, C., Grosso, M., & Nessi, S. (2018). The “REDUCE” project: definition of a methodology for quantifying food waste by means of targeted waste composition analysis. Rivista Di Economia Agraria, 72(3), 289–301.https://doi.org/10.13128/REA-22804https://doi.org/10.13128/REA-22804	2017	Definitions from FUSION	Public administration, Households and businesses	
Rispo, A., Williams, I. D., & Shaw, P. J. (2015). Source segregation and food waste prevention activities in high-density households in a deprived urban area. Waste Management (New York, N.Y.), 44, 15–27.https://doi.org/10.1016/j.wasman.2015.04.010https://doi.org/10.1016/j.wasman.2015.04.010	2015	Following Lebersorger and Schneider (2011)	1034 households	

Table 24. FLW quantification studies

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As can be observed, transparency regarding the definitions followed is not always a given and when provided, it is evident that there is no consensus concerning these, which makes the comparability of results difficult. FAO definitions for food are the most extensively used in literature and projects; this is probably due to the dates of the studies, as most of them are prior to the Delegated Decision.

As a result, the first gap identified is the lack of standardized terminology to ensure the appropriate use of the terms thereby avoiding misinterpretation or confusion and to make the results comparable. The FOODRUS project analyzes these discrepancies in terminology thoroughly in its public deliverable D1.1 Circular food strategies documentation (FOODRUS project, 2022), and includes a description of the process carried out to come up with this framework. Next a summary of the main concepts is explained.

First, it is essential to define the key definitions to be used so that the quantification methodology's basis is established. The following are the most relevant terms that have to be considered:

- Food: Before defining food loss and waste it is important to establish what we understand by 'food'.
- Edible food and inedible food parts: It is considered vital to determine these terms, but there is room for improvement
- Food loss and food waste: It is considered of relevance to study the intentionality of the causes and thus potential solutions.

The definition of food is not always a given, which may lead to confusion or the differentiation among edible and inedible or food loss and waste, depending on the source.

Next, we list the most used definitions, corresponding to the ones used in the FOODRUS project:

- Food: "Any substance or product intended or reasonably expected to be ingested by humans, whether processed, partially processed or unprocessed." (European Union, 2002).
- Edible food: "Components associated with a food, in its fresh state, which are customarily consumed by humans in the member states, whether consumed raw, or after processing or cooking. The definition of edible parts of food may differ from country to country or from region to region, depending on local habits and culture"(European Commission, 2021). Other definitions refer only to the product being in demand or set by the person/company.
- Inedible food: "Parts of the food that have not been separated as co-products from the edible parts when the food has been produced (including all stages of production, processing and distribution)" (European Commission, 2021).
- Food loss (FL): "Food loss is the decrease in the quantity or quality of food as a result of the decisions and actions of suppliers in the food chain, excluding retailers, food service providers and consumers." (FAO, 2019). In the case of food loss, it seems that literature agrees that it only refers to the food chain.

- Food waste (FW): There are currents excluding inedible parts or the food supply chain. The following definition is selected: "Any food that has become waste under these circumstances:
    - It has entered the food supply chain.
    - It has been removed or discarded either from the food supply chain or at the consumption stage.
    - Finally, it has been destined to be processed as waste". (Eurostat, 2021).

In addition to these fundamental concepts the concept “eatable food” has to be considered so that it is not mistaken for “edible food”. Eatable food stands for the food which retains the necessary properties to be placed on the market for human consumption (Garcia-Garcia et al., 2017).

Therefore, to quantify food waste, the specifications set out in the Delegated Decision (EU) 2019/1597 (European Commission, 2019) will be followed, although with the addition of some modifications in line with the FOODRUS framework. They showcase the distinction made between edible food and eatable food, or between digitalization and digitization, as well as other specifications that are necessary for the food waste characterization such as whether it was cooked or not.

b. Key Performance Indicators (KPIs)

Quantifying food loss and waste (FLW) generation is crucial for understanding its magnitude, but it is equally important to examine its impact on the three sustainability pillars: environment, society, and economy. This analysis aligns with one of the key objectives of the European Green Deal (European Commission, 2019) and the Circular Economy Action Plan (European Commission, 2020) of the European Union, which aim to promote sustainable practices and minimize waste throughout the entire food system. In this regard, there are reference studies like the one performed by Yontar and Ersöz (2020), who focused on finding out which parameters define the sustainability level of a food supply chain. But it is worth mentioning the study carried out by the Joint Research Centre (Caldeira et al., 2019), which assesses the sustainability performance of FLW prevention actions. This study puts forward a series of efficiency and effectiveness indicators and methodologies to measure performance in a standardized way. Standardizing KPIs is crucial for consistent and meaningful measurement of the FLW impact. KPIs provide a set of metrics that enable stakeholders to track progress, benchmark performance, and evaluate the effectiveness of FLW reduction initiatives. By employing standardized KPIs, stakeholders can align their efforts, facilitate comparisons, and drive collective action towards FLW reduction targets. Here, we analyze these KPIs and their significance in assessing the sustainability performance of FLW prevention and reduction strategies. Finally, the Joint Research Centre also developed a free-to-use calculator for assessing the impacts of food waste prevention actions, which is presented in the paper written by De Laurentiis et al. (2020).

Life Cycle Assessment (LCA) methodology stands out as one of the most commonly used to measure the aforementioned sustainability impact whit the use of different KPIs. Several authors employ this methodology in the FLW generation context. For example: Winans et al. (2020), who assessed the carbon footprint of food losses in primary production in California; De Menna et al. (2020), who provide knowledge on how to develop both E-LCA and LCC of FLW in school canteens; or Bergström et al. (2020), who studied the three dimensions by conducting a LCSA of food redistribution in Sweden. On top of it, this methodology is also used to include the possible rebound effects that may arise as a consequence of preventing FLW generation. Which was thoroughly explored by Albizzati et al. (2022).

c. Decision-making methods

Methodologies for the decision-making process play a pivotal role in identifying appropriate interventions and resource allocation to address FLW. These methodologies involve considering multiple factors, such as cost-effectiveness, environmental impacts, and social considerations, to inform strategic decisions. By understanding and applying these methodologies, stakeholders can make informed choices regarding FLW prevention and reduction, maximizing the impact of their efforts.

A preliminary search was made to identify the multi-criteria tools used in FLW problem. However, no previous studies related to FLW were found with the same objective as the ToNoWaste project and because of this the scope has been opened up to identify similar decision-making problems. For this purpose, different multi-criteria decision-making tools were identified and a classification of the problem was made classifying the nature of the problem between qualitative and quantitative problems.

Based on this, the most commonly used methods to face problems similar to the ones addressed in ToNoWaste are:

Method	Description	Main references
Step-wise weight assessment ratio analysis (SWARA)	In this method, which uses the weighting method, the relative importance and the initial prioritization of alternatives for each attribute are determined by the opinion of the decision maker, and then, the relative weight of each attribute is determined.	Hosseini Dehsiri et al., 2023; Mishra et. al, 2023
Analytic hierarchy process (AHP)	In the theory of decision-making, the analytic hierarchy process (AHP) is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology.	Fan et al, 2023; Rai et al., 2022; Han et al., 2023; Shadmaan et al., 2023; de Paula Vidal et al., 2022; Dagtekin et al., 2022; Mathew et al., 2020; Bakioglu et al., 2021
Fuzzy Logic	Neural network-based artificial intelligence and fuzzy logic, when analyzed, are the same thing—the underlying logic of neural networks is fuzzy. A neural network will take a variety of valued inputs, give them different weights in relation to each other, and arrive at a decision, which normally also has a value. Nowhere in that process is there anything like the sequences of	Rai et al, 2022; Aryanfar et al, 2020; Wu et al., 2020; de Paula Vidal et al., 2022; Shojaeimehr et al., 2022

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	either-or decisions which characterize non-fuzzy mathematics, almost all computer programming, and digital electronics. In the 1980s, researchers were divided about the most effective approach to machine learning: deductive models or neural networks. The former approach requires large decision trees and uses binary logic, matching the hardware on which it runs. The physical devices might be limited to binary logic, but AI can use software for its calculations. Neural networks take this approach, which results in more accurate models of complex situations. Neural networks soon found their way onto a multitude of electronic devices.	
Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)	It is a method of compensatory aggregation that compares a set of alternatives, normalizing scores for each criterion and calculating the geometric distance between each alternative and the ideal alternative, which is the best score in each criterion. The weights of the criteria in TOPSIS method can be calculated using Ordinal Priority Approach, Analytic hierarchy process, etc. An assumption of TOPSIS is that the criteria are monotonically increasing or decreasing. Normalization is usually required as the parameters or criteria are often of incongruous dimensions in multi-criteria problems. Compensatory methods such as TOPSIS allow trade-offs between criteria, where a poor result in one criterion can be negated by a good result in another criterion. This provides a more realistic form of modelling than non-compensatory methods, which include or exclude alternative solutions based on hard cut-offs.	Zhou et al., 2023; Huang et al., 2023; Dagtekin et al., 2022; Aljaghoub et al., 2023; Shojaeimehr et al., 2022; Lin et al., 2023; Mathew et al., 2020; Bakioglu et al., 2021; Singaravel et al., 2023
System dynamics	System dynamics is a methodology and mathematical modelling technique to frame, understand, and discuss complex issues and problems. Originally developed in the 1950s to help corporate managers improve their understanding of industrial processes, SD is currently being used throughout the public and private sector for policy analysis and design.	Manuel et al., 2023; Che et al., 2023; Bilal Yildiz et al., 2023; Karimi-Arpanahi et al., 2023; Lee et al, 2019, Galli et al., 2019
K-means	K-means clustering is a method of vector quantization, originally from signal processing, that aims to partition n observations into k clusters in which each observation belongs to the cluster with the nearest mean (cluster centers or cluster centric?), serving as a prototype of the cluster.	Fan et al., 2023
Game Theory	One of game theory's important advantages in this regard is its ability to consider a hierarchical and sequential decision-making process using the Stackelberg or Leader-Follower model. In this model, a leader's decision is influenced by the reaction of his or her followers. The leader's decisions can be affected when followers who	Motlaghzadeh et al., 2023

	have shared decision variables, objectives, and constraints are involved in a multi-level decision problem.	
Imperfect Complete Information Game (ICIG)	Imperfect because it takes nature into account, making the outcome unpredictable.	Motlaghzadeh et al., 2023

Table 25. Multi-criteria decision tools description

For qualitative problems the most used methods are: AHP, Fuzzy logic, k-means, ICIGG, cognitive mapping. It is also noteworthy that these methods normally are not used independently and combinations of methods are used. For example, when AHP is used, Fuzzy logic is used in 63% of the papers studied. When TOPSIS is used, AHP or another 'criteria weighting method' is used because TOPSIS alone cannot tell which criteria is more important.

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4. Impact assessment databases to assess food losses and waste

Databases are necessary for the correct understanding of the environmental aspects and impacts associated with the food life cycle to collect enough, adequate and reliable information regarding inventories of inputs and outputs of resources and emissions throughout the different stages of products' life. They are secondary data sources.

Secondary data sources refer to existing data that has been collected by others. These sources provide information that has already been gathered, processed, and made available for public use. For the purpose of this deliverable, defining secondary data sources involves understanding their characteristics and identifying the types of data they provide. Key aspects to consider include the nature of secondary data, the primary purpose of the database, the methods used in the collection, the accessibility, relevance, reliability and granularity of the data.

Secondary data can be either quantitative or qualitative. Quantitative data consists of numerical or statistical information, such as survey results, sales figures, or census data. Qualitative data includes non-numerical information, such as interviews, case studies, or observations.

Secondary data sources are originally collected for different purposes. Some data sources are developed by government agencies and others are collected by market research firms that gather data for commercial purposes. There are also databases that were constructed by previous academic research studies.

When focusing on data collection methods, secondary data can be collected through various methods, such as surveys, experiments, observations, administrative records, databases, or published reports. Understanding the methods used in data collection is essential for evaluating the quality and reliability of secondary data. Regarding the accessibility of data, this depends on factors like availability, cost, permissions, and legal restrictions.

An important issue is data relevance and reliability. When assessing these aspects in secondary databases, we need to consider factors such as the timeframe of data collection, geographical coverage and sample size. It is also important to evaluate the reliability and validity of the data source and any potential biases or limitations.

4.1 Environmental databases

For the purposes of assessing environmental impacts, databases must collect, at least in a well-ordered manner, all relevant information for the identification and quantification of the energy and materials consumed, the water used, and the environmental emissions caused.

The main applications are:

- The identification of key environmental performance indicators.
- Hotspot analysis.

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- To support applications to take micro-level decisions and develop accounting processes.
- Development of life cycle assessments.

In this regard, Table 26 presents a list compiling some of the most important databases used to assess environmental impacts at academic research and professional level. This list presents databases used for a wide range of sectors as well as databases specifically focused on the environmental impacts associated with the agri-food sector.

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Name	Description	Country	Developer	Access	Web
ECOINVENT	The Ecoinvent database contains more than 18,000 datasets covering a wide range of sectors. It includes among others, agriculture, waste treatment and recycling. It provides detailed data on material and energy flows, emissions and other environmental impacts associated with products and processes.	Switzerland	Non-profit association – Swiss Federal Institute of Technology (Zurich) – Swiss Federal Institute of Technology (Lausanne) – Paul Scherrer Institute – The Swiss Federal Laboratories for Materials and Technology – Agroscope	Licenses: commercial, educational, developer, enterprise	www.ecoinvent.org
AGRIFOOTPRINT	Agri-footprint is a comprehensive database focused on the agriculture and food sectors. It contains 4800 processes and products and provides specific data for products such as crops, processed foods, feed and other agricultural inputs. It is based on an attributional approach. Three allocations options can be applied: mass, energy, and economic.	Netherlands	– Blonk is a corporation expert in food system sustainability, offering advice and developing tailored software tools and data.	Licenses: research, commercial, developer	www.bloncksustainability.nl
AGRIBALYSE	It is a specific database for the agri-food sector in France. It contains life cycle inventories of a wide range of agricultural and food products, such as cereals, meat, dairy, fruits, vegetables, among others. Provided by ADEME, the database includes LCIs for 2517 agricultural and food products produced and/or consumed in France.	France	– ADEME: The French Agency for Ecological Transition – INRDE: Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnment	Open. ETALAB's licence	www.agribalyse.fr
USLCI DATABASE	The United States Life Cycle Inventory database provides individual gate-to-gate, cradle-to-gate and cradle-to-grave accounting of the energy and material flows into and out the environment, including agriculture and agribusiness. That are associated with producing a material, component, or assembly in the United States.	USA	– National Renewable Energy Laboratory and ITS Products. US Department of Energy, Office of Energy, Efficiency and Renewable Energy – Alliance for Sustainable Energy	Open	www.nrel.gov/lci/
WFLCA	The World Food LCA Database provides stakeholders across the agri-food value chain with high-quality	Switzerland France	– Quantis is a sustainability consultancy company	Exclusively available for	www.quantis.com

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	emissions factors and environmental footprint data (including carbon, water, and land) to help them understand the impacts of their products. The main aim of the WFLDB is to create a database that represents agricultural primary products and processed food products.	Germany Italy USA		SIMAPro users	
EF DATABASE	The environmental footprint database is designed to support the practice of product environmental footprint category rules (PEFCR) and organization environmental footprint category rules (OEFCR).	Europe	– European Platform Life Cycle Assessment (EPLCA)	Designed to support the use of PEFCR and OEFCR	www.eplca.jrc.ec.europa.eu
GaBi	GaBi databases offer 15,000 process datasets including 1000 models from primary sources.	USA	Sphera is a private provider of Environmental, Social and Governance (ESG) performance and risk management software, data and consulting services	Licensed	www.sphera.com/life-cycle-assessment-lca-database/

Table 26. Databases to assess food losses and waste environmental impacts

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4.2 Social aspects databases

Social life cycle inventories related to agribusiness involve the collection of data on social aspects and human impacts throughout the entire life cycle of a product or business process. Moreover, it is important to highlight that, to our knowledge, there are fewer specific databases for social assessment purposes compared to environmental life cycle inventory databases.

It is also important to note that calculating social life cycle inventories can be challenging due to the complex and subjective nature of social aspects. In addition, the availability of specific data may be difficult in some cases, and it may be necessary to conduct primary studies or collect data from local and specific sources to address the social aspects connected to agribusiness.

In this sense, Table 27 presents a description of the two main external databases used to assess social impacts.

Name	Description	Web
SHDB	The Social Hotspot Database provides information about social risks and opportunities to help supply chain stakeholders to improve their management of social responsibility. The database includes an extensive list of indicators around labor rights, health and safety, human rights, governance, and community infrastructure.	www.socialhotspot.org
PSILCA	The Product Social Impact Life Cycle Assessment Database allows calculation and assessment of social impacts and assist to detect social hotspots providing information on social aspects of products over their life cycles for almost 15,000 industry and commodities and for 69 qualitative and quantitative indicators connected to four stakeholders: workers, value chain actors, local community, and society.	www.psilca.net

Table 27. Databases to assess food losses and waste social impacts

4.3 Economic databases

When assessing the economic impact of a product or a process throughout its life cycle, there are several databases that can provide valuable information. These databases typically contain data on factors such as production costs, employment and value-added contributions. Tor the purposes of this deliverable, it is necessary to focus on Sector-Specific Databases. These databases often focus on key economic indicators and trends within a particular industry. For the agriculture sector data, there is some information at country level. As an example, the Spanish Food chain watchdog published by the Spanish Agriculture Ministry that offers prices at origin and wholesalers. At the EU level, we can find the AGRIDATA database from EUROSTAT that offers price information for representative products per Member State. At world level is possible to find the Food and Agriculture Organization (FAO) databases

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Name	Description	Web
AGRIDATA-EUROSTAT	Price information for representative products per EU Member State in all sectors, going back 30 years. Recent monthly market prices are calculated as weighted averages of the weekly prices that Member States communicate. A separate Data Explorer sheet provides bulk downloads for 5 groups of sectors as well as a bundle for all agricultural markets.	https://agridata.ec.europa.eu/extensions/DataPortal/prices.html
FAO	The FAO Food Price Index (FFPI) monitors price changes in international markets for key basic foodstuffs. There is also information at producer level.	https://www.fao.org/worldfoodsituation/foodpricesindex/en/
Spanish Food chain watchdog	The objective of this national initiative is to achieve balance in the food chain and to be able to guarantee fair, loyal and effective competition while maintaining an adequate level of prices and informing consumers in an appropriate manner. This watchdog provides the prices recorded at origin-wholesaler for a list of 34 of the most significant fresh food products.	www.mapa.gob.es/en/alimentacion/temas/observatorio-cadena/

Table 28. Databases to assess food losses and waste economic impacts

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