LOWINFOOD

Multi-actor design of low-waste food value chains through the demonstration of innovative solutions to reduce food loss and waste

GA No. 101000439

D1.6 Evaluation of the efficacy of innovations

WP1 - Type of deliverable: R - Dissemination level: PU - Due date: 31st October 2024

HISTORY OF CHANGES after the first submission of the deliverable on 31/10/2024		
Date	***Change description***	***Reference to the EC request***
16/06/2025	*Results section for task 4.1 amended*	*The results of task 4.1 are improved by adding insights on the stakeholder dialogue implemented in Germany (p.28)*

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ALL PARTNERS CONTRIBUTED TO THE DELIVERABLE (SEE DETAILED LIST IN CHAPTER 7)

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LOWINFOOD Consortium

N.	Full name of the organisation	Short name	Country
1	Università degli Studi della Tuscia	UNITUS	Italy
2	Alma Mater Studiorum Università di Bologna	UNIBO	Italy
3	Sveriges Lantbruksuniversitet	SLU	Sweden
4	FH Münster University of Applied Sciences	ISUN	Germany
5	The James Hutton Institute	JHI	United Kingdom
6	Universitaet Fuer Bodenkultur Wien	BOKU	Austria
7	Tampereen Korkeakoulusaatio SR	TAU	Finland
8	Charokopeio Panepistimio	HUA	Greece
9	Osterreichisches Okologieinstitut	AIE	Austria
10	Elhuyar Fundazioa	ELH	Spain
11	Matomatic AB	MATO	Sweden
12	Unverschwendet GmbH	UNV	Austria
13	Akademie Deutsches Baeckerhandwerknord GGmbH	ADB	Germany
14	Foresightee (terminated on 30/01/2023)	FOR	Belgium
15	Leroma GmbH	LER	Germany
16	Mitakus Analytics UG	MITA	Germany
17	Kitro SA	KITRO	Switzerland
18	Regione Emilia Romagna	RER	Italy
19	Pianeta Cospea srl	PICO	Italy
20	Cogzum Bulgaria OOD	COZ	Bulgaria
21	Uppsala Kommun	UPP	Sweden
22	Recuperiamo srl	REG	Italy
23	Antegon GmbH	FT	Germany
24	Confederazione Nazionale dell'Artigianato e della piccola e media impresa Associazione di Viterbo e Civitavecchia	CNA	Italy
25	Assemblee des Regions Europeennes Fruitieres Legumieres et Horticoles	ARE	France
26	L.V.L Anonymi Emporiki Toyristiki Kksenodoxeiaki Kataskevastiki Etaireia	BLU	Greece
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Summary

The efficacy report presents the results of 14 innovations and 15 demonstrations carried out throughout the project.
The initial, overarching goal was to advance all of them to a high Technology Readiness Level (TRL), ideally reaching 8 or 9, in various operating environments to assess their capacity for reducing food waste in these new settings.
Not all trials succeeded in reaching a TRL of 8 or 9, as some challenges arose during testing. These challenges were either context-related, which affected testing opportunities, or due to the innovation's inability to perform well in the specific environment where it was tested. The testing environment included factors like the type of canteen, food supply chain stage, or business type selected. At times, the context changed during the project; for instance, organizational leadership changes impacted the availability for testing the innovations.
In twelve (12) cases, the innovations produced results based on demonstrations. One innovation did not produce any data, as it was unsuitable for the selected value chains (this affected two demonstrations). Another did not intend to produce results based on a demonstration but a simulation. In the other cases, the demonstration was either fully operational (8), or implemented alongside an existing system for comparison (2); in two (2) cases, it was partially simulated, based on collected data. A common issue across tests was detecting units, with significant challenges at the production/processing stage, where companies were especially reluctant to share data.
The second goal of the efficacy task was to assess each innovation's capacity to reduce food waste by measuring waste quantities (in mass) before, during, or after the demonstration, with statistical evaluations when possible.
Overall, some innovations performed better than others in reducing food waste. Eight (8) out of 14 innovations either reduced food waste or partially reduced it (for instance, the demonstration showed positive results in one country but negative in another). In cases where the innovation did not produce measurable reductions in food waste—either due to its limitations or because the task was to simulate scenarios rather than conduct a full-scale test—these conditions are thoroughly explained.
All innovations have potential for food waste reduction if improved, and some were operational in real settings well before the project began, with exceptions primarily at the processing stage. So, even if the LOWINFOOD project did not yield robust or positive results, it is known that the same innovation may perform better in other contexts. Therefore, conditions necessary to optimize their performance are outlined to ensure each innovation can be adopted under favorable conditions for success.

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The following table anticipates results:

Geographical scope	Innovation	FLW type	FLW reduction (Yes = Y / No = N)
RO	Software for F&V	Food losses	Simulated scenario based on real data
AT	Cooperation system for F&V	By-products	Y
DE	B2B digital marketplace for F&V	Food losses	No data
IT	Forecasting software to reduce waste of F&V products	Surplus food	Y/N
SE, FI, IT	Supplier-retailer agreements	Surplus food	No testing was foreseen in this task, but simulated scenarios
SE, FI, IT	Stakeholder dialogue in the bread value chain	Surplus food	N
DE	Software for bakeries	Surplus food	Y
DE, UK	Stakeholder dialogue in the fish value chain	Food losses	No data
DE, UK	B2B digital marketplace for fish	Food losses	No data
DE, CH, GR	Smart bin	Plate waste	Y
DE, SE	Forecasting software for restaurants	Kitchen waste	Y/N
DE, SE, AT	Plate Waste Tracker	Plate waste	Y
SE, AT	Holistic educational approach	Plate waste	N
FI, AT, GR	Mobile App for management of food at home	Food waste at household (or post-consumer food waste)	Y/N
IT	Mobile App connecting restaurants leftovers with consumers	Food waste at household (or post-consumer food waste)	Y

This report is linked to reports D 1.7 (Koseolgu et al., 2024) and D 1.8 (Scherhaufer et al., 2024), which assess the socio-economic impacts of the innovations, and the environmental impacts based on LCA methodology, respectively.

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Introduction to the deliverable

LOWINFOOD is a project committed to co-design, together with actors of the food chain, 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 (fruits & vegetables, bakery products and fish), as well as in at-home and out-of-home consumption. Each of these value chains corresponds to a single Work Package (WP) of the project.

The innovations are selected among promising solutions that have already been developed and tested by some partners of the consortium, with the aim of providing the necessary demonstration and upscale to allow market replication.

The LOWINFOOD consortium comprises 28 entities, located in 13 different countries, and ranging from universities and research institutes to start-ups, foundations, associations, and companies working in the food sector. During the 52 months of the project, the partners are committed to complete 30 tasks and to deliver 60 outputs (deliverables).

WP1 is focused on the evaluation of the efficacy, the economic and social impacts as well as the environmental impacts of the innovations, based on the results achieved and data gathered in WP2-5 about their ability to reduce FLW. This deliverable (D1.6) examines the capacity of the innovations to reduce food waste within their testing environments. It highlights the key operational conditions that support the effective functioning of these innovations, such as user engagement and friendliness, compatibility with existing processes, perceived utility and replicability potential. By illustrating these conditions, the report provides insights into how these innovations can be successfully implemented and scaled in different markets. It ends with a discussion and conclusion section, which will be further examined in the concluding deliverable of WP1 (D1.9). As all LOWINFOOD partners have contributed to the elaboration of this evaluation a detailed credit authorship statement is added in the last chapter.

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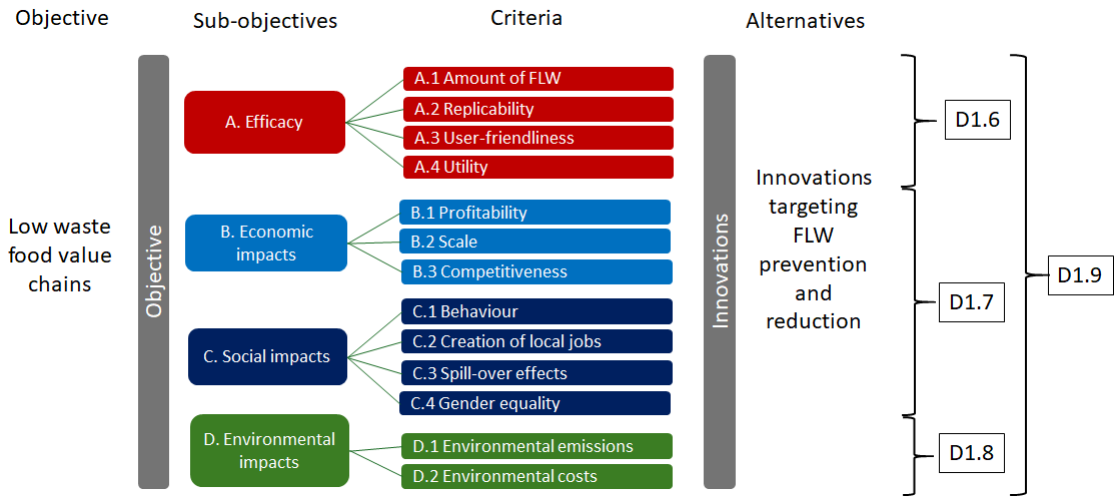

Figure 1: Target hierarchy of *the evaluation of LOWINFOOD's innovations and dedicated deliverables* presenting the results. *The present report (D1.6) covers A (red) sub-objectives.*

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1. Innovations in LOWINFOOD

LOWINFOOD's innovations aim to reduce food waste by prevention (e.g. prevention of surplus food at source), re-use (e.g. through food redistribution, food donation) and reprocessing (e.g. reprocessing of surplus food for human consumption), and are therefore situated in the upper halve of the waste hierarchy.

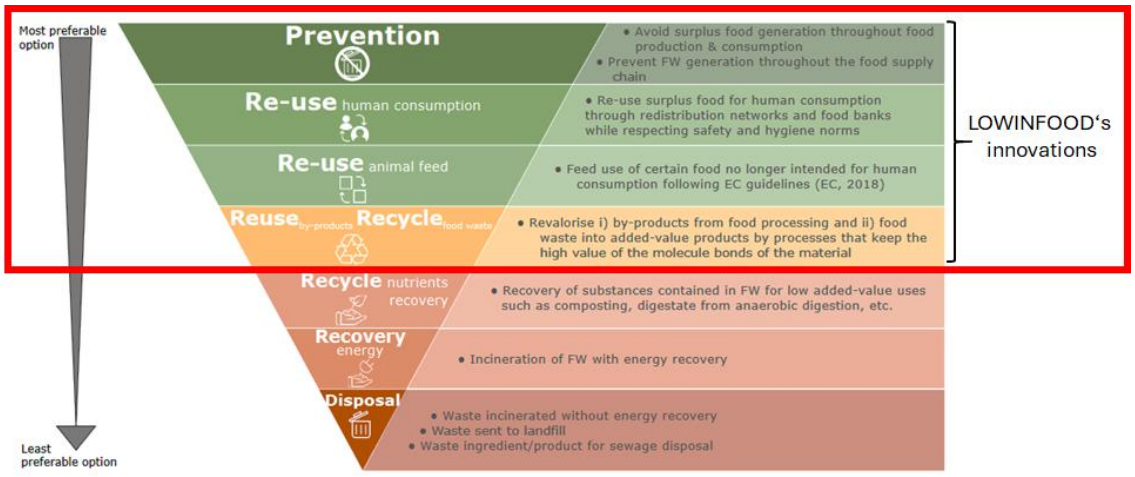

Figure 2: Hierarchy for prioritisation of food surplus, by-products and food waste (FW) prevention (European Commission, 2020) and corresponding LOWINFOOD innovations

Two scenarios are compared:

- BASELINE "no action scenario", the system without the innovation/before the innovation was introduced.
- DEMONSTRATION "Prevention/Redistribution action scenario", the system when the innovation was introduced.

Overview of demonstrations

Table 1: Overview of LOWINFOOD's demonstrations

WP	Task (T) No.*	Geo-graphical scope	Innovation - Short name	Innovation – Status**
WP2	T 2.1	RO	RER Software for F&V	S
WP2	T 2.2	AT	UNV Cooperation system for F&V	B, D
WP2	T 2.3	DE	Leroma B2B digital marketplace for F&V	S

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WP	Task (T) No.*	Geo-graphical scope	Innovation - Short name	Innovation – Status**
WP2	T 2.4	IT	Forecasting software to reduce waste of F&V products	B, S
WP3	T 3.1	SE, FI, IT	Supplier-retailer agreements	S
WP3	T 3.2	SE, FI, IT	Stakeholder dialogue in the bread value chain	B, S
WP3	T 3.3	DE	FT Software for bakeries	B, D
WP4	T 4.1	DE, UK	Stakeholder dialogue in the fish value chain	S
WP4	T 4.2	DE, UK	Leroma B2B digital marketplace for fish	S
WP5	T 5.1	DE, CH, GR	KITRO Innovative food waste solution	B, D
WP5	T 5.2	DE, SE	MITAKUS Forecasting software for restaurants	B, S
WP5	T 5.3	DE, SE, AT	MATOMATIC Plate Waste Tracker	B, D
WP5	T 5.4	SE, AT	SLU/AIE Holistic educational approach	B, D
WP5	T 5.5	FI, AT, GR	CozZo Mobile App	B, D
WP5	T 5.6	IT	REGUSTO Mobile App	B, D

*AT = Austria, CH = Switzerland, DE = Germany, FI = Finland, GR = Greece, IT = Italy, RO = Romania, SE = Sweden.
**B.... Baseline measured; D... Demonstration measured; S... Baseline and/or demonstration was simulated

Innovation types and groups

For a better understanding of the functionalities and for the interpretation of results a grouping of LOWINFOOD's innovations is of relevance. LOWINFOOD's innovations can be grouped by the following categories:

A. Type of food (fruit & vegetables, bakery products, fish, consumer food)
B. Type of food waste (surplus food, post-consumer waste, food by-products, kitchen waste at food service),

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C. Design of action (organisational, managerial, technological that is forecasting related, technological that is behaviour related)
D. Type of action (according to Caldeira et al. (2019): food redistribution, consumer behaviour change, supply chain efficiency, food waste prevention governance)

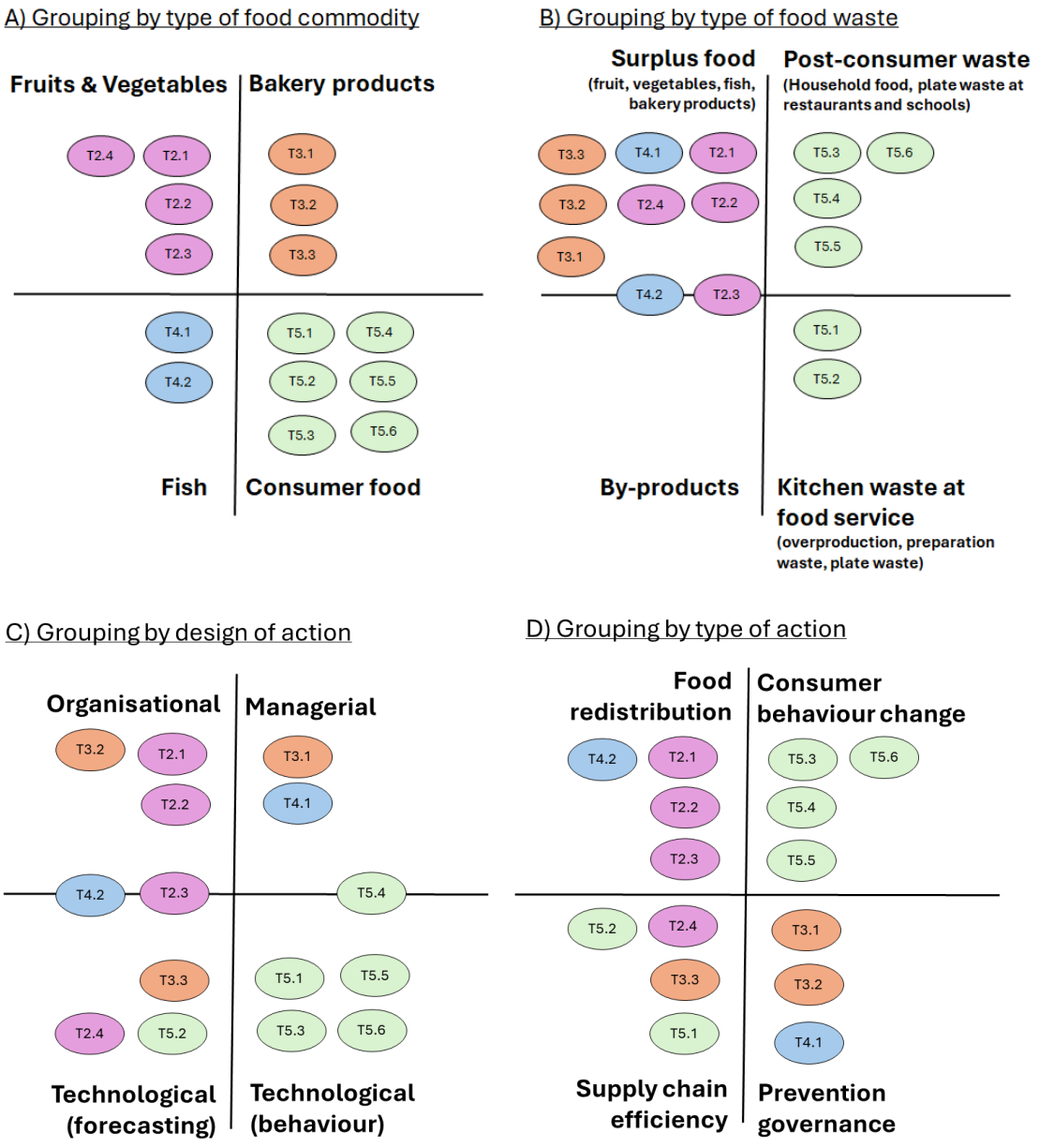

Figure 3: Grouping of LOWINFOOD's innovations by A) type of food commodity, B) type of food waste, C) design of action and D) type of action

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Food loss and waste (FLW) definition and types

LOWINFOOD uses the term 'food loss and waste' (FLW), which refers to "any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed (including composted, crops ploughed in/not harvested, anaerobic digestion, bio-energy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea)" (Östergren et al., 2014). This term reflects the EU definition of 'food waste' but also the definitions by the FAO of 'food losses' and 'food waste' (FAO, 2021). LOWINFOOD's innovations cover specific parts of FLW, whereby the general focus is on the avoidable part that is by definition of Quested and Johnson (2009) "food and drink thrown away that was, at some point prior to disposal, edible (e.g., slice of bread, apples, meat)." or by definition of Lebersorger and Schneider (2011) "which are still unrestrictedly edible at the time of their disposal or which would have been edible if used in time". However, also unavoidable FLW can be covered in some innovations that is "waste arising from food or drink preparation that is not, and has not been, edible in normal circumstances (e.g., meat bones, eggshells, pineapple skin, tea bags)" (Quested & Johnson, 2009).

In the description of LOWINFOOD's innovations a further classification of FLW is necessary:

Table 1: Type of food waste handled in LOWINFOOD's innovations

FLW type	Description	Innovations and LOWINFOOD tasks
Surplus food	is arising in food production and distribution chain for a variety of reasons and is by definition of European Commission (2017) "consisting of finished food products (including fresh meat, fruit and vegetables), partly formulated products or food ingredients". "Foods which do not meet manufacturer and/or customer specifications (e.g. variations in product colour, size, shape, etc.) as well as production and labelling errors can generate surplus in the agricultural and manufacturing sectors for instance. Difficulties in managing supply and demand can lead to over-ordering and/or cancelled orders."	Surplus fruits & vegetables: T 2.1, T 2.2, T 2.3, T 2.4) Surplus bread: T 3.1, T 3.2, T 3.3 Surplus fish: T 4.1, T 4.2
Kitchen waste	is typically arising in restaurants and food service as well as households, but also in retail and other distribution sectors. Kitchen waste covers waste from overproduction, preparation waste and serving as well as plate waste. According to the waste code included in the European list of waste for types of waste which typically includes food waste, this fraction is covered in "20 01 08 - biodegradable kitchen and canteen waste".	T 5.1, T 5.2

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FLW type	Description	Innovations and LOWINFOOD tasks
Plate waste	This includes food that is served but not eaten. It is a sub-category of kitchen and canteen waste. Generally, food waste in restaurants and canteens can be categorized by its receiving point (e.g. storage, preparation, dishwasher sieve, serving and plate) (C. Caldeira, Sara, & Serenella, 2017).	T 5.1, T 5.3, T 5.4, T 5.6
By-products	are defined as circular flows of food removed from the FSC to be used to produce other products such as animal feed or biomaterials (Carla Caldeira, De Laurentiis, Corrado, van Holsteijn, & Sala, 2019). Although by-products are according to the EU definition not included in food waste, it is often classed and reported as waste in industrial context (Corrado et al., 2019).	T 2.3, T 4.1, T 4.2
Food waste at household (or post-consumer food waste)	This includes food damaged due to lack of cooling/storage facilities; food not eaten e.g. due to excess, elapsed expiration date, low consumer appeal, and plate waste; and inedible food waste (fruit kernels, bones, etc.)	T 5.5
Food losses	pre-harvest losses, i.e. losses that occur before the raw material is ready for harvest or slaughter, such as weather-related damage to crops (which is accounted for as agricultural waste)	T 4.1, T 4.2 T 2.2

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2. Evaluation method

The aim of this specific report is to present the results of testing 14 innovations designed to reduce FLW, specifically the innovations' capacity to reduce FLW (in mass, volume, number of items). These innovations cover a wide range of approaches and include various sub-objectives. For instance, a specific sub-goal was to expand the scope of the innovations by incorporating new products, different stages of the food supply chain, and targeting new groups. Alternatively, some innovations were tested in new EU countries, or some innovations at Technology Readiness Levels (TRL) 4/5 (developed by startups and previously tested on a small scale) were applied to a broader panel (scaled up to TRL 7-8).

A key initial objective was to assess whether replicating these innovations under different conditions could be effective and whether they would be accepted by new stakeholders involved in the replication process. The main goal was to evaluate if, in this expanded context, these innovations could effectively reduce FLW.

The fact that a given innovation has not reduced FLW during the Lowinfood test does not necessarily mean that the innovation is incapable of achieving this goal.

In many cases, an innovation demonstrates effectiveness in certain contexts but not in others. Moreover, the range of innovations of LOWINFOOD includes different types of innovative solutions, ranging from technological to social and organizational, meaning that also the timeframe in which these innovations are expected to provide a change of the status quo may be different. These results should be openly discussed, allowing future adopters to understand from the outset the specific conditions required for the innovation to succeed — or the conditions which could have an influence on failure. By sharing these insights, stakeholders can make informed decisions and implement innovation in environments where it is most likely to deliver its intended impact.

Methodology

Data has been collected based on the methodological protocol developed as a result of the T 1.1 (Scherhaufer et la., 2021). The entire protocol for the efficacy is based on the delegated decision 2019/1597, Annex III; thus, data collection methods were inspired to those listed in table 3:

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Table 2- Methodology for the in-depth food waste management. Source: Delegated Decision (EU) 2019/1597 of 3 May 2019, Annex III

<table>
<tr><th>Stage of the FSC</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></td><td colspan="2">Questionnaires and interviews
▪ Coefficient and production statistics
▪ Waste composition analysis</td></tr>
<tr><td>Processing and manufacturing</td><td rowspan="4">Waste composition analysis</td><td rowspan="3">Counting and scanning</td><td></td></tr>
<tr><td>Retail and other distribution of food</td><td rowspan="3">Diaries</td></tr>
<tr><td>Restaurants and food services</td><td rowspan="2"></td></tr>
<tr><td>Households</td><td></td></tr>
</table>

Table 2 reflects the most advanced knowledge about food waste accounting methods. For instance, it is not a coincidence that the use of questionnaires and interviews is available only for quantifying food waste at primary production and processing: in these stages, the access to data is relatively difficult, and third-party accounting method are unlikely to be accepted from companies. For the other stages, most reliable and effective methods exist, such as scanning, diaries and waste audits; questionnaires are used only to assess qualitative information.

As from Scherhaufer et al. (2021), the major indicator for evaluating the efficacy is the amount of FLW prevented thanks to LOWINFOOD's innovations. An 'absolute' indicator addresses the amount of FLW avoided – calculated using the same reference unit, *tons of food saved from being wasted* - thanks to the innovation by looking at FLW before and during or after the innovation. Furthermore, each innovation has been evaluated according to 'relative' indicators aiming at assessing the FLW rate over the amount of food processed. The 'relative' indicator shows the improvements in the specific settings in which the innovation is implemented (i.e., when considering the food handled/cooked/managed/served).

A further list of indicators then addresses the innovation performance in terms of:

Utility: It describes the usefulness of the innovation, conceived as the state of being useful, profitable, or beneficial.

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Replicability: Replicability, which is also defined as transferability and scalability, refers to the potential of the innovation or pilot test to be replicated, scaled up, expanded or adapted to other contexts. It aims to understand the innovation features that enable or constrain replicability. Some questions that the indicator addresses are:

- *Is it easy to assess the results (monitoring, evaluating processes)?*
- *Does it generate direct or indirect economic resources and benefits itself or is it sustainable only through external funding?*
- *If yes, how long after the adoption of the innovation to see the results?*
- *Is it easy to access and start innovation?*

User-Friendliness: It consists of usability and satisfaction, both from the innovator and final user perspective. The indicator addresses the following questions:

- *Is the application of the innovation easy to perform?*
- *Can all relevant staff members operate the innovation easily?*
- *Is the innovation easy to maintain or does it require the help of the innovation providers?*
- *Does the innovation require specific training or know-how to be implemented?*

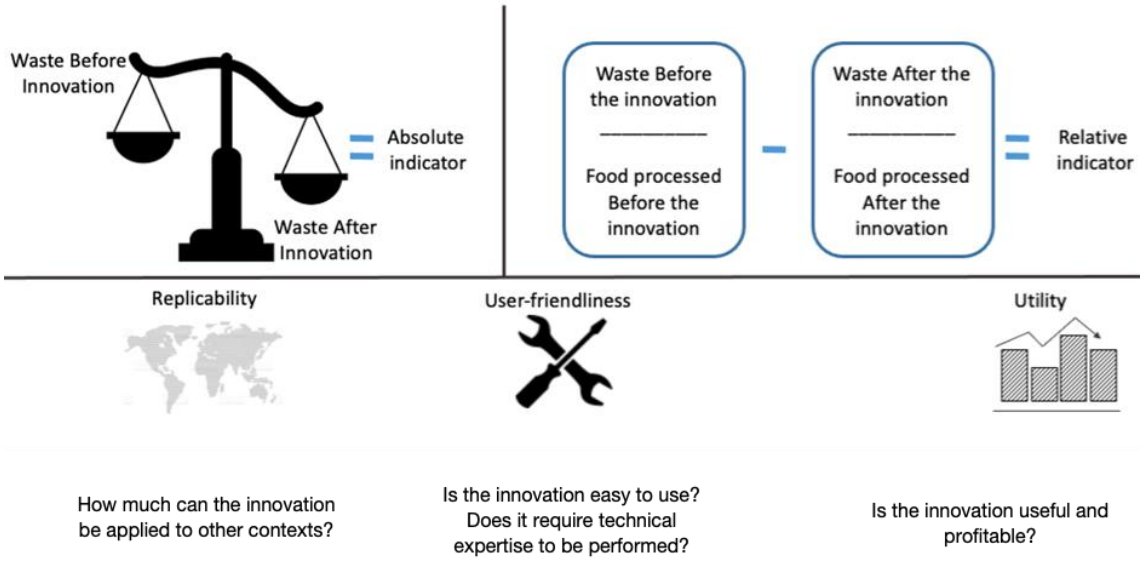

Figure 4- Methodological framework to evaluate the efficacy of LOWINFOOD innovations (Scherhaufer et al., 2021, fig. 3, p. 18)

While absolute and relative indicators have been calculated based on direct measurement methods, the three dimensions of utility, replicability and user-friendliness were assessed through questionnaires addressed to the innovation adopters.

This assessment encountered some challenges in relation to specific innovations, such as a limited number of adopters, low user engagement, a higher rate of discontinuation during

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the test, and incomplete responses to the final questionnaire. However, these aspects provide valuable insights into the innovation itself, revealing something on its perceived utility, user-friendliness, and potential for replication. Rather than being seen as shortcomings, these challenges are opportunities for reflection and analysis about the innovation itself and about the potential of FLW reduction measurement with robust methods. Literature recognizes that difficulties in adopting innovations are a common and expected part of the process (Vanclay, 1992; Douthwaite, Keatinge, and Park, 2001) and FLW measurement through reliable methods is always challenging, as it is a resource-demanding process. yet, the LOWINFOOD evaluation methodology aimed at high quality data first, as according to the authors, this is the priority in the field.

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3. Evaluation of results

In Table 3, the capacity of the innovation to reduce food waste with certainty is highlighted (column FLW reduction). Some innovations reduced food waste with certainty in our tests and they are indicated with a Y (yes) or N (no). Some didn't fully work in our tests, namely they worked only in some countries and not others, or they did not work at all perhaps due to conditions in the settings that have been identified (Y/N). Some innovations did not work as they were thought and planned and did not produce data.

Table 3- Innovations' capacity of reducing food waste during Lowinfood demonstration.

Geographical scope	Innovation	FLW type	FLW reduction (Yes = Y / No = N)
RO	Software for F&V	Food losses	Simulated scenario based on real data
AT	Cooperation system for F&V	By-products	Y
DE	B2B digital marketplace for F&V	Food losses	No data
IT	Forecasting software to reduce waste of F&V products	Surplus food	Y/N
SE, FI, IT	Supplier-retailer agreements	Surplus food	No testing was foreseen in this task, but simulated scenarios
SE, FI, IT	Stakeholder dialogue in the bread value chain	Surplus food	N
DE	Software for bakeries	Surplus food	Y
DE, UK	Stakeholder dialogue in the fish value chain	Food losses	No data
DE, UK	B2B digital marketplace for fish	Food losses	No data
DE, CH, GR	Smart bin	Plate waste	Y
DE, SE	Forecasting software for restaurants	Kitchen waste	Y/N
DE, SE, AT	Plate Waste Tracker	Plate waste	Y
SE, AT	Holistic educational approach	Plate waste	N
FI, AT, GR	Mobile App for management of food at home	Food waste at household (or post-consumer food waste)	Y/N

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Geographical scope	Innovation	FLW type	FLW reduction (Yes = Y / No = N)
IT	Mobile App connecting restaurants leftovers with consumers	Food waste at household (or post-consumer food waste)	Y

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3.1 Evaluation of efficacy for FW governance innovations

T3.1 'Supplier-retailer agreements'

Goal and scope

The objective is to demonstrate the effectiveness of new business models for bread supply aimed at reducing waste at the supplier-retailer interface. This work builds on previous outputs from Task 3.2, where stakeholder dialogues were conducted in Sweden, Finland, and Italy. During these discussions, a panel of bakeries developed and endorsed a roadmap to reduce bread waste, as detailed in D3.2 (Mesiranta et al., 2022) for each country. Based on the insights from these dialogues, Task 3.1 focused on mapping and modeling current bread flows and exploring new solutions that could help minimize bread waste, with a particular focus on the Swedish bread supply chain and the Take-Back Agreement (TBA) system.

As outlined by Sjölund et al. (2023), the Swedish bread market is highly concentrated, with three bakeries holding 80% of the market share, and similarly, three retail chains control nearly 90% of retail distribution. These key players operate under a take-back agreement (TBA), which requires bakeries to handle bread production, forecasting, delivery, and unsold bread management, illustrating an uneven power dynamic between suppliers and retailers.

Methodological note

Surplus bread refers to bread that has been baked, delivered to stores, and put on sale but remains unsold by the end of the day (Garrone et al., 2014).

The approach used to evaluate the potential effects of the proposed solutions involved creating a model of the current bread supply chain and simulating the outcomes of various suggested interventions as conceptual scenarios.

The data utilized in the T3.1 simulation model was sourced from multiple channels, including insights shared during the Swedish stage of the stakeholder dialogue in T3.2, as well as from secondary sources (Bartek et al., 2024). The calculation of private-label bakery products involved the same five major supermarket retailers referenced in national statistics reported by Statistics Sweden for 2022. These figures were scaled up to a national level based on market share. Information on waste rates, sales, and yearly production of private-label and bake-off bakery items was obtained through communication with bakeries and private companies, as accurately described by Bartek et al. (2024). A second stakeholder dialogue was conducted with industry representatives to validate the estimates and refine the scenarios according to their feedback.

Based on the insights from stakeholder dialogues and suggestions for reducing bread waste, one baseline and six alternative bread management scenarios were developed: three within the system applying the TBA, and three where the TBA was removed (Table 4). The

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simulation of the scenarios with the TBA still in place, i.e. the Shared data, Optimised shelves and Food donation scenarios, revealed a potential reduction of bread waste of about 10 500, 2400 and 600 tonnes for each scenario respectively (Table 5).

Table 4 - Scenarios on bread waste reduction in Sweden. *Source: Sjölund et al. (2023), table 1 p. 11.*

Scenario	**System**	**Change in current practices**
Baseline	Current practices included TBA	No change, Business As Usual (BAU)
Shared data	TBA still in place	Increased sharing of sales and point of sales data between suppliers and retailers
Optimized shelves	TBA still in place	Optimization of shelving management in store by reducing assortments/volumes, using mirrors and angles shelves
Food donation	TBA still in place	Decentralized donation of surplus bread removed from shelves
Retail ownership	TBA removed	Transferred ownership of bread from bakeries to retailers to allow for alternative prevention measures, no change in waste management pathways
Co-logistic	TBA removed	Alternative transportation model inferring co-transport for bread suppliers
Reduced price	TBA removed	Reducing prices at surplus bread and sell at retail

Table 5- Bread waste quantities at bakery and retail levels from each scenario. Source: Sjölund et al. (2023), table 2, p. 12.

Scenario	**Bread waste quantity (Tonnes/year)**			**Waste rate (%)**	
	Total	**Retail**	**Bakery**	**Retail**	**Bakery**
Baseline	32500	19700	12800	9.2	6.2
Shared data	22000	13900	8100	6.5	3.8
Optimized shelves	30100	17300	12800	8.1	6.2
Food donation	31900	19100	12800	8.9	6.2
Retail ownership	22400	9600	12800	4.5	6.2

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Scenario	Bread waste quantity (Tonnes/year)			Waste rate (%)	
Co-logistic	31700	19700	12000	9.2	5.6
Reduced Price	26200	13400	12800	6.2	6.2

Utility, user-friendliness and replicability

No management survey was received for this innovation as the result was based on the simulation of scenarios created by researchers, fed by the interviews and focus group meetings with relevant actors.

Interpretation and review

The "Shared Data" scenario was identified as the most beneficial for reducing bread waste, with a potential reduction of approximately 10,500 tons of bread per year.

This scenario improves the flow of bread throughout the supply chain, allowing bakeries to restock shelves only when necessary, thereby preventing overproduction and overstocking.

Other scenarios showed waste reduction potential at only one stage —- either at the bakery or retail level. However, the Retail Ownership scenario had the most significant impact on the retail side, reducing waste from 9.2% to 4.5%. Meanwhile, the Shared Data scenario had the greatest impact on the bakery side.

It's notable that only two scenarios reduced waste at the bakery level, primarily because most actions targeted the retail stage, without directly affecting production. While other potential actions for bakeries were discussed in a previous report (Mesiranta et al., 2022), they were not evaluated in this deliverable.

Limitation of the accounting and monitoring stage

These estimates are based on assumptions and stakeholder input, meaning their real-world impact is uncertain. Since all scenarios were developed with industry expertise, it's reasonable to expect that implementing them would reduce bread waste, though the degree of reduction may vary between interventions.

Last, each scenario focuses on different stages of the bread supply chain and is presented with individual implications. However, they are not mutually exclusive, meaning combined implementation of multiple scenarios could result in even greater waste reduction than the individual scenarios suggest.

T3.2 'Stakeholder dialogue in the bread value chain'

Goal and scope

T3.2 explores how engaging stakeholders through dialogue can lead to more effective strategies for minimizing food waste in craft bakeries. The demonstration of how these

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strategies can lead to an actual reduction of food waste was run in Italy, despite the stakeholders' dialogue took place also in Sweden and Finland. In Italy, it involved a panel of bakeries that usually sell their product directly, through their own stores. Data about surplus bread and its management was collected before and during the implementation of some actions that resulted from the stakeholder's dialogue.

Methodological note

Surplus bread refers to bread that has been baked, delivered to stores, and put on sale but remains unsold by the end of the day (Garrone et al., 2014).

The test timeline is February 1, 2022, to June 30, 2023. The baseline measurements were conducted over five months, from February to June 2022. The evaluation includes 12 craft bakeries affiliated with CNA (a leading Italian association of craft businesses) situated in various municipalities within the province of Viterbo, Italy. These bakeries distribute their products directly through 16 stores. Three stakeholder meetings, with the final one in May 2022 (Pietrangeli et al., 2024), identified actions to address waste in the bread supply chain. The demonstration began one year later, from February 1, 2023, to June 30, 2023.

During this period, some actions outlined in the co-created roadmap (detailed in Pietrangeli et al., 2024) were executed. Daily production and surplus quantities were recorded using the same diaries in 10 stores that continued participation in 2023. The aim of this second phase was to assess the impact of the roadmap actions on surplus quantities and management.

The focus of the test is on fresh bread, which is baked and sold within 24 hours, according to the Italian law. The evaluation primarily considers three key products that account for 70 to 80% of the total production volume: 1. Common bread; 2. Focaccia bread; 3. Bread rolls.

Baseline Quantification Methodology
Each bakery staff member is required to maintain a daily diary detailing:
- The quantity of bread produced
- The amount of surplus bread
- The sales price of the bread
- The destination of any surplus bread

Baseline

Legend

BSQ = the daily quantity of bread surplus in kg;
BPQ = the daily quantity of bread produced in kg;
i = the i types of bread considered (ranging from 1 to 3 and corresponding to common bread, focaccia bread and bread rolls respectively);
j = the j bakery branch considered (ranging from 1 to 16 and reflecting the bakery branches included in the panel).

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The rate of surplus in quantity is calculated, for each observation, as:

$$r_q = \frac{BSQ_{ij}}{BPQ_{ij}}$$

Table 6 - Summary of baseline data collection for bakeries

	Common bread	Focaccia bread	Bread rolls
No. observations	1386	1337	1336
Average Rq (rate of bread surplus in quantity)	5.9%	4.0%	5.3%
Standard deviation rq	10.00%	5.00%	5.00%
Min rq	0.00%	0.00%	0.00%
Max rq	48.00%	50.00%	75.00%
Average kg of surplus per day	3.40	0.70	0.78
Min kg of surplus per day	0	0	0
Max kg of surplus per day	30	15	15
Std.dev. of kg of surplus per day	3.26	1.02	0.93

Demonstration

Common bread

Table 7- Common bread - Ratio BSQ/BPQ (Rq %) -Average difference baseline-demonstration

Bakeries	No. Observations Base	No. Observations Demo	Avg Base (SD)	Avg Demo (SD)	Median base	Median Demo
14	979	997	5.59 *(6.40)*	6.89 *(8.31)*	4.00	4.33

Common.bread - Ratio BSQ/BPQ (Rq) - Kruskal-Wallis test baseline-demonstration P value= 0.0086**

The Rq (ratio BSQ/BPQ) shows the daily quantity of bread surplus in kg/ the daily quantity of bread produced in kg; this means that, during the baseline data collection, the average daily waste for bread was 5.59%, while during the demonstration it was 6.89%. The difference is statistically significant (P-value= 0.0086).

Focaccia bread

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Table 8 - Focaccia Bread- Ratio BSQ/BPQ (Rq %) - Average difference baseline and demonstration

No. Observations Base	No. Observations Demo	Avg base	Avg Demo	St dev base	St dev Demo	Median base	Median demo
728	769	4.32	7.60	5.70	9.66	3.33	5.00

*Focaccia.bread - Ratio BSQ/BPQ (Rq) - Kruskal-Wallis test baseline-demonstration P-value= 6.4e-16****

The Rq (ratio BSQ/BPQ) shows the daily quantity of focaccia bread surplus in kg/ the daily quantity of bread produced in kg; this means that, during the baseline data collection, the average daily waste for focaccia bread was 4.32 %, while during the demonstration it was 7.60%. The difference is statistically significant (P-value= 6.4e-16).

Bread rolls

Table 9- Bread.rolls - Ratio BSQ/BPQ (Rq %) - Average difference baseline and demonstration

No. Observations Base	No. Observations Demo	Avg base	Avg Demo	St dev base	St dev Demo	Median base	Median demo
930	997	4.84	4.68	6.45	6.78	2.86	2.61

Bread.rolls - Ratio BSQ/BPQ (Rq) - Kruskal-Wallis test baseline-demonstration p-value= 0.3833

The Rq (ratio BSQ/BPQ) shows the daily quantity of bread rolls surplus in kg/ the daily quantity of bread produced in kg; this means that, during the baseline data collection, the average daily waste for bread rolls was 4.84%, while during the demonstration it was 4.68%. The difference is not statistically significant (P-value= 0.3833).

Utility, user-friendliness and replicability

The primary aim of this innovation was to use a participatory approach to co-design, together with bakeries in different countries, a set of actions to prevent the generation of surplus bread, and to avoid the waste of any surplus that may be produced. In Italy, this process led to a significant involvement of the bakeries of the panel, which defined a set of five actions against bread waste and implemented a diary study to actually measure the quantity of surplus bread they produce every day.

The **utility** of these actions did not provide conclusive results, but the monitoring phase revealed that the daily measurement of bread surplus – which is the first action suggested by the roadmap – is feasible at the bakery level, and likely increases the attention of owners towards the issue of bread waste, especially in a period of huge rise in production costs.

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The **user-friendliness** of this innovation derives from the participatory process used to design actions that are feasible at craft businesses, which represent the majority of bakeries in Italy.

The role of CNA as facilitator in this process was crucial and is expected to push the **replicability** of the innovation after LOWINFOOD. Indeed, while the demonstration was conducted at the local level, CNA showed interest in upscaling the roadmap against bread waste at the national level, for example by making available to craft bakeries tools to report their best practices to reduce surplus bread and waste (see D3.6, Pietrangeli et al. 2024).

Interpretation and review

For common bread, the difference in surplus rate (Rq) between the baseline and demonstration phases is significant across all bakeries and at the overall level. Granular results (per single bakery), even if nor presented in this report, showed a great variability, whereas half of the bakeries experienced a reduction in Rq and the other half saw an increase. For focaccia bread, the differences are significant and there is a general trend across bakeries (except for one) toward an increase in Rq. Regarding bread rolls, only 1/4 of the bakeries showed significant differences in Rq: among these, half experienced an increase in Rq, and the other half experienced a decrease. So, either at granular and aggregated level, it is hard to say that this innovation worked, but limitations in data collection played an important role in affecting the testing phase (both at baseline and demonstration).

Limitation of the accounting and monitoring stage

The baseline data was collected during the first year of the Russia-Ukraine war, when wheat cost was higher, and consumption of wheat products decreased. This resulted in lower sales and reduced production rates, which gradually increased in the following years and saw a significant rise during the demonstration stage. This is a possible explanation for the data emerged from this test.

Additionally, between the baseline and monitoring phases, it was expected that bakery staff would become more aware of waste and possibly improve their accuracy in measuring and recording surplus. This improvement could be a result of the daily observations and practice they gained during the baseline period of five months in 2022.

T4.1 'Stakeholder dialogue in the fish value chain'

Goal and scope

Task 4.1 implemented a social innovation consisting of a dialogue among stakeholders of the whole seafood (i.e., fish and shellfish) supply chain, similarly to what was done in the bakery sector (T3.2). It aimed to identify waste generation hotspots, explore reduction strategies, and find opportunities for material exchanges to enhance value from surplus

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materials and by-products, such as those from seafood processing. The dialogue took place in Scotland and Germany, with Scotland being a major seafood producer, and Germany a leading import and consumption market. Given the high value of seafood material, the value chain is very efficient in ensuring that all edible parts are used for human consumption; therefore, valorizing seafood by-products, including for non-human uses (which is not the primary goal of the LOWINFOOD project) was considered more interesting for companies than exploring further recovery routes. Furthermore, the dialogue highlighted that industry stakeholders, and primarily fish companies, are traditionally a very close-knit group, and are unwilling to disclose data that could damage their reputation or lead to requests for change in practices.

Methodological note

The stakeholder dialogue followed the protocol defined in D4.1 (Piras et al., 2022), with some adaptations based on the lessons learned along the process. In both countries, key industry (individual companies or associations) and policy stakeholders were identified and invited to first take part in a semi-structured interview, generally held online based on a script tailored to the sector of the interviewee. Afterwards, participatory events (workshops and focus groups) were meant to be organized. However, only in Germany it was possible to organize a stakeholder workshop, which took place in Bremen in June 2023, while in Scotland the JHI team attended several industry and research events, primarily the Scottish Skipper Expos in 2023 and 2024, where a stand was set up to facilitate networking. Based on the qualitative information collected during the interviews, a survey on revalorization of seafood materials was set up and disseminated among industry and policy stakeholders to rank challenges, opportunities, and potential interventions.

In Scotland a total of 22 stakeholder organizations were interviewed (including two individuals from different departments in one case, for a total of 23 interviewees): 13 from companies operating at various stages of the seafood value chain (one fishing company, three processors, one fishmonger, four retailers, two users of waste materials, two trading apps and platforms), and nine from trade and industry associations, policy, government bodies, and networking and support organizations. In Germany, the number of interviews was nine, including three from companies operating at various stages of the value chain (wholesale, gastronomy and retail), and six of other types (two industry associations, two research and non-profit organizations, one financial lender, and one technical supplier).

Results

It is not possible to comment on food waste quantities as neither industry stakeholders provided access to data, nor the dialogue was meant to produce an impact in the short-term besides transactions of products; therefore, no before-after comparison is possible. Nevertheless, a baseline management survey was completed by five stakeholders who joined the Scottish dialogue and consented to complete it. These included two primary processors (one of fish; one of fish and by-products and/or waste), and three secondary

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processors (two of fish, and one of by-products and/or waste). These ranged from small, young companies with a turnover of under £ 30,000, to large ones with a turnover of over £50M and over 100 years of activity. Given the small and diverse sample size, we cannot present aggregated data for confidentiality and comparability reasons. However, we report some exemplary figures. Stakeholders were asked to report the mass of fish materials removed from the value chain for human consumption (i.e., during processing) for up to three final products. This figure was nil or <0.02% for most products, also due to the nature of the companies, but in one case it amounted to 18.5% of the quantity of fish inputs, suggesting that there is a significant scope for valorization. A single, exploratory transaction took place thanks to the dialogue, between a company using by-products to make fishmeal and fish oil, and one start-up company planning to use fish oil for producing biosurfactants (sustainable cleaning products), for a total of five liters; this relationship is still in place at the time of report submission.

The stakeholder dialogue in Germany revealed an initial consensus that fish loss and waste (FLW) along the national value chain—particularly in processing, trade, distribution, and catering—is minimal (Koseoglu et al., 2024). This perception is attributed to the high cost and increasing scarcity of fish, which incentivize careful resource use. However, upon closer examination, stakeholders acknowledged that certain losses do occur, especially in relation to consumer behavior and logistical challenges. One key issue identified was that while FLW in the domestic value chain is relatively low, significant losses are observed at the consumer level, as supported by existing literature. Moreover, consumer preferences for fresh over frozen fish can indirectly contribute to spoilage further upstream.

Stakeholders also reflected on the links between the German market and fishing activities in developing countries. Some argued that losses prior to processing are not officially considered FLW and that the influence of the German value chain is limited. Others stressed that weak infrastructure—such as lack of local processing capacity—leads to spoilage and resource overexploitation. Certifications were seen as potential tools to professionalize upstream value chains and reduce losses before import.

Regarding regulation, stakeholders had diverging views. While some supported stricter rules and recognized the value of certifications and landing obligations, others were concerned that excessive regulation could generate new sources of FLW. A common position was the need to reform EU regulations related to the use of side streams for human consumption and to promote harmonized reporting, possibly through voluntary guidelines or alignment with initiatives like the EU directive on green claims.

Technical and educational solutions were also discussed, such as super-chilling technologies and early-stage consumer education. Cold chain management emerged as a critical point, particularly at interfaces between stages, and while generally reliable in Germany, it can be vulnerable during heat waves or staff shortages.

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Finally, the economic viability of side-stream utilization was debated. While most stakeholders acknowledged that by-products are already used extensively, the full nutritional potential is often unrealized due to logistical and workforce constraints. External shocks like Brexit, COVID-19, and the war in Ukraine were not considered major contributors to FLW, though some isolated impacts were reported.

Limitation of the accounting and monitoring stage

As mentioned above, initial surveys captured the baseline situation, but no significant byproduct/waste material exchanges occurred, except for a small trial involving fish oil, which anyway was not aimed at recovering seafood material for human nutrition. Data confidentiality, comparability issues due to the diversity of the sample, and completeness, limit disclosure of specific waste types and quantities.

Interpretation and review

In Scotland, secondary processors showed potential for trading seafood by-products, as this could reduce their waste management costs and potentially increase profitability. However, logistical (e.g., geographical distance) and mismatches between supply and demand hindered exchanges. Further details can be found in D4.3 (Koseoglu et al., 2024) and in D1.7 (Koseoglu et al., 2024b). The overall lack of collaboration from industry stakeholders when it comes to talking about food waste and trying to reduce it is a result in itself, which highlights that not all the actors of the food supply chain are ready to challenge the problem, and many still feel it bears reputational as well as financial risks (e.g., fishing companies being asked to adopt new practices and costly innovations). For instance, retailers were keen to speak about the actions they were taking for preventing or reducing food waste, as they address this issue in terms or corporate social responsibility and probably saw the interviews as an opportunity to achieve further visibility, but still were unwilling to share quantitative data. This also points out the huge data gaps in certain stages of the food supply chain at scientific level, and the strong imbalance between food waste research at consumer stage and all the other stages (Giordano & Franco, 2022). In Germany, stakeholders generally perceived food loss and waste (FLW) in their value chain as limited, though they acknowledged that losses occur at each stage. They highlighted that primary processing often takes place abroad or on board vessels, limiting domestic control. A key concern raised was the shortage of skilled labour, which may lead to interruptions in cold chains and delays in retail and catering operations, potentially resulting in product spoilage. Profitability and technical challenges were also noted as barriers to further reducing FLW, particularly in the use of by-products.

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3.2 Evaluation of efficacy for innovations promoting consumer behavior change

T5.3 'MATOMATIC Plate Waste Tracker'

Goal and Scope

The goal of this evaluation is to assess the impacts of innovations for food waste prevention and reduction. The MATOMATIC plate waste tracker (T53) is a technical innovation to increase students' awareness about food waste in school canteens.

The MATOMATIC plate waste tracker includes a smart scale giving primary school students feedback on how much plate waste they generate. It reports to children advice and tips on how to reduce their food waste and information about its impacts. It also allows the students to provide feedback to the canteen staff on why they wasted food in order to not just nudge the students to waste less, but also inform the staff of what could be improved according to the students. Despite being an "independent" innovation, which can be just used during the mealtime with no additional efforts, better performances have been reported when the educational staff (teachers, canteens employees) have a good attitude and supervise its use by children.

Methodological note

The sampling strategy for this study focuses on schools across three countries: Germany, Sweden, and Austria. In total, 17 schools were involved in the analysis, distributed as follows: 3 schools in Germany (DE), 10 schools in Sweden (SW), and 4 schools in Austria (AUT). One of the Swedish schools was excluded from the final analysis due to difficulties in using the MATOMATIC system during the pandemic. This resulted in 9 schools being considered from Sweden. The selection of schools in these countries provides a diverse sample across different regions, with special attention to any external challenges affecting data quality, such as those caused by the pandemic.

In some cases, as in the case of Sweden, the Municipality of Uppsala (5 schools) had already implemented a manual monitoring strategy of food waste for schools before the innovation started, so this is how baseline was collected. In the case of Germany and Austria, the baseline was collected manually and on purpose before the test started.

Results

Table 10: Aggregated results for MATOMATIC plate waste tracker in three countries

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Country	Average amount of food waste at BASELINE	Average amount of food waste at DEMONSTRATION
Austria	148.80 g per student and day	53.90 g per student and day
Germany	38.90 g per student and day	24.80 g per student and day
Sweden	23.40 g per student and day	17.50 g per student and day

Kruskal-Wallis rank sum test Sweden P-value= 1.90e-14 ***
*Kruskal-Wallis rank sum test Germany p-value= 1.00e-05****
*Kruskal-Wallis rank sum test Austria p-value= 3.50e-06****

The plate waste tracker reduced food waste in all the testing countries.

Utility, user-friendliness and replicability

Based on the management survey delivered by 5 schools in Sweden (the same 5 schools that tested also the educational approach T54), the **utility and replicability** of the innovation appears to be generally positive, though there are a few concerns regarding its long-term sustainability within school curriculums. Several staff members expressed willingness to continue using the innovation and even promote it to other schools. Specifically, two schools have already recommended or would promote the innovation to other institutions, highlighting its usefulness in educating pupils about food waste. The involvement of staff members was positive, with participation rates ranging from a few individuals to larger groups, showing engagement from both teachers and assistants, regardless of gender. However, challenges related to time and curriculum integration were raised. One respondent indicated that while food waste is an important issue, it is difficult to find room for such projects within the existing curriculum, suggesting that the innovation might be more successful if integrated into the regular school program. Another noted that while the innovation was a good tool for educating younger pupils, it required extra effort outside of the standard work. Despite these concerns, the overall feedback was that the innovation was rewarding and useful, with the potential to be promoted and replicated, provided that it is embedded into the school routine rather than treated as an external or additional project. Therefore, while replicability is good, it may depend on how well the innovation can be incorporated into the daily structure of school activities.

Based on the provided data, the **user-friendliness** of the innovation across different Swedish schools seems relatively high, but with a few challenges. The innovation was reported as being generally easy to use for the staff across all schools, with all respondents indicating that it was manageable. However, one noted that the main challenge was finding time for planning. In terms of features to improve, suggestions included running the innovation for a full semester to better integrate the subject into the curriculum and allow more time to address other responsibilities. Another recommendation was to create a bank of brief lessons rather than just providing material suggestions to explain the impact of food waste, as in the current version of the innovation. Some participants felt that more information should be provided to parents and guardians, ideally in multiple languages. One

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specific, additional suggestion related to the plate waste tracker tool was to simplify the options on the tablet, while one participant indicated no changes were needed.

When it came to starting the innovation, the difficulty ratings ranged from 1 to 4, with two schools finding the process very easy (rated 1), while three schools found it moderately difficult (rated 4). This suggests that while many schools could implement the innovation with relative ease, a few faced challenges related to planning and setup. The weekly time commitment varied, with most schools dedicating around 1 hour per week, though one school spent about 3 hours per class/group across multiple groups. Despite this, no additional personnel were needed to implement the innovation, indicating that it could be implemented within existing resources.

Overall, the innovation was well received in Sweden, particularly by the pupils, who found it engaging and interesting. Younger students especially enjoyed the multimedia aspects, such as film clips, and were curious about learning how to manage food waste. The feedback highlights the user-friendliness of the innovation, although improvements related to planning resources, parent involvement, and simplifying tools were suggested to further enhance its integration and ease of use.

Utility in Germany showed mixed results. While MATOMATIC raised awareness among pupils and helped them understand the quantities of food waste, its direct impact on reducing food waste was less clear. In some schools, students responded positively to the system and began considering smaller portions. However, the expected reduction in food waste was lower than anticipated, with one school reporting no significant improvement. Another school noted that although leftovers were placed in the waste bin on the scales rather than on the tray trolley, reducing the effort required for kitchen staff, fewer students consistently used the scales after initial engagement. Additionally, MATOMATIC did not lead to significant skill development for staff. Kitchen staff in one school did not engage with the system at all, and while some teachers and research partners staff participated in managing the system, they did not report any new skills gained. This suggests that, while MATOMATIC was useful in raising awareness about food waste for pupils, its utility in reducing waste and providing professional development for staff was limited. Some operational improvements, such as reduced effort for kitchen staff, were noted, but these gains were not widespread. Ultimately, although MATOMATIC succeeded in its educational goals to some extent, its long-term effectiveness in reducing food waste and enhancing skills was more modest.

In Germany, **replicability** showed positive results as well. The feedback from three schools indicates that MATOMATIC was tested in the schools with some success, but there is no clear intention to continue its regular use after the project concludes. While the potential of the innovation was recognized, none of the respondents explicitly stated plans for its regular adoption. However, one school expressed interest in using MATOMATIC occasionally to raise awareness among pupils about food waste, highlighting that while the system may not be integrated into daily operations, it still holds educational value. During the implementation

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some challenges arose, particularly in the second school, where kitchen staff were reluctant to engage with the plate waste tracker. This reluctance stemmed from the additional workload associated with using and maintaining the equipment, which created a barrier to its effective use. Initially, teachers attempted to take over these responsibilities, but this was not sustainable due to their unavailability during critical times. In contrast, the first and third school conducted the activities without significant operational issues, suggesting that the innovation can be managed more easily under certain conditions or with more cooperative staff.

The **user-friendliness** of MATOMATIC in Germany varied across different aspects of its implementation, but overall, it was regarded as easy to use once introduced. Most staff required minimal training, with no extensive sessions necessary. In most cases, a brief explanation or a simple 5-minute instruction was enough for kitchen staff and teachers to understand and operate the system. In fact, staff found it less demanding than expected, with some only needing around 5 minutes per day for tasks like carrying the device to and from the tray rack, cleaning it, and maintaining it. However, while the system was technically simple, there were some operational challenges. In one school, teachers initially took responsibility for managing MATOMATIC but weren't always available at lunch. As a result, external staff (student assistants hired by the research partner) had to step in to collect the data during the demonstration period. This highlights a reliance on external assistance in one school, as kitchen staff showed reluctance to fully engage with the operational tasks required by the system, such as turning the device on, supervising its use, and cleaning it. Some reported technical issues further complicated user-friendliness. Problems with tablets and cables, such as broken tablets, loose cable contacts, and repeated error messages, have been reported. Despite these challenges, users rated the system's features positively. The dashboard, functionality, and ease of use for managers received high scores, indicating that the interface and the overall system design were effective and user-friendly. Feedback on ease of use for kitchen staff was mixed, with some giving high marks while others encountered difficulties, likely due to technical issues with hardware. Overall, MATOMATIC was considered user-friendly, requiring minimal time commitment and no additional staffing. However, technical issues and occasional reliance on external assistance highlighted areas where improvements could be made to ensure smoother operations and less dependence on external support.

In Austria, four schools took part in the survey on the Plate Waste Tracker, sharing insights into its utility, replicability, and user-friendliness. For **utility**, two schools noted that the device helped raise awareness of food waste and its impact on the environment, especially among students. This awareness had a positive effect on group behavior, with students in two schools encouraging each other to avoid leaving leftovers. Regarding **user-friendliness**, the schools reported only minor adjustments were needed. Three schools said the device required no extra workload, while one mentioned a small additional task of 15 minutes per day. All four schools found it easy to set up, and three would recommend it to other

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institutions, showing a generally positive experience with the device and a positive degree of **replicability** of the innovation.

Interpretation and review

Based on the results obtained, the innovation can be considered successful in several key aspects, especially regarding its impact on reducing food waste, ease of use, and potential for replication. The data shows a significant reduction in food waste during the demonstration phase across all three countries (Table 10).

As detailed in the user feedback, the innovation was generally considered easy to use by the staff across all participating schools. The primary challenge reported was related to planning and time management, but the overall implementation was manageable without the need for additional personnel. Four schools found the setup process very easy, while one in Sweden rated it as moderately difficult, reflecting some initial challenges but nothing insurmountable and 1 in Germany refused to run the test by itself, as the kitchen staff saw it as a waste of time. Once implemented, both teachers and students found the innovation engaging, especially younger pupils, who were reported to have enjoyed the interactive components such as film clips.

The feedback suggests strong potential for replication. All schools were able to integrate the innovation without requiring additional resources, indicating that it can fit within existing school infrastructures. There were also suggestions for improvements, such as extending the program to a full semester and providing more lesson planning resources, which would likely make the innovation even more effective and easier to implement in the future. The innovation's success in reducing food waste and its positive reception by both staff and students indicate that it has significant potential for replication in other educational settings. With some improvements to planning resources, this innovation could be scaled up to achieve a greater impact in reducing food waste and in supporting a third-party, objective evaluation of food waste quantities and characterization in school canteens, as requested by Waste Directive 2018/851.

Limitation of the accounting and monitoring stage

Nothing to be reported.

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T5.4 'SLU/AIE Holistic educational approach'

Goal and scope

Holistic educational concepts (T5.4) were tested in Austria and Sweden to reduce food waste at schools (Sundin et al., 2023).

The goal of the demonstration is to explore how school meals can be used as a learning tool to raise awareness of food waste and promote sustainable habits. By adapting existing educational materials to fit meal settings, and by providing training for teachers and kitchen staff, the initiative aims to encourage food waste reduction among students and support more sustainable practices in meal preparation.

Methodological note

In Sweden, five schools in Uppsala participated, all of which had previously been involved in the MATOMATIC plate waste monitoring initiative. The schools were monitored using a combination of baseline, monitoring, and post-questionnaire (POST Q) data gathered after the educational intervention. The intervention focused on engaging pupils in activities both within and outside the classroom. Data have been analyzed as such and then aggregated (monitoring + post Q= demonstration).

The percentage of pupil/class engagement across the five schools varied. In two schools, 100% of the pupils/classes participated in the educational intervention, reflecting full school-wide involvement. In one school, 45% of the pupils were engaged, while 35% and 19% of the pupils participated in the two other schools.

In Austria, the focus was on kitchen workshops, which were specifically designed for school canteen kitchen workers. These workshops provided practical training on food waste reduction techniques, targeting those directly involved in food preparation and service.

Results

Table 11: Food waste

Country	Average amount of plate waste at BASELINE	Average amount of plate waste at DEMONSTRATION
Austria	49.0 g per student and day	54.5 g per student and day
Sweden	22.2 g per student and day	22.0g per student and day

Kruskal-Wallis test on Plate waste Guest (g). difference between periods, Sweden. P-value: 0.1297
Kruskal-Wallis test on Plate waste Guest (g). difference between periods, Austria. P-value: 0.4029

Utility, user-friendliness and replicability

No management survey was delivered for this innovation.

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Interpretation and review

The educational approach did not seem to perform well anywhere, in line with findings from background literature (Piras et al., 2023). However, an important limitation in the demonstration phase may have influenced the result for Sweden, so this result should not be considered as definitive.

Limitations of the accounting and monitoring stage

The level of pupil/class engagement in the educational intervention varied across the five schools in Sweden. In two schools, 100% of the pupils participated, indicating full engagement. However, in the other three schools, participation was lower, with 45%, 35%, and 19% of pupils/classes involved in the educational activities. The food waste was still measured for more classes than those engaged in the demonstration. This was because isolating food waste measurements for only the treated classes created logistical challenges. In school canteens, where multiple classes eat together, it was difficult to segregate the food waste data for specific groups. So, the educational approach should be tested again along with MATOMATIC but measuring only the food waste of units under observation.

T5.5 'CozZo: Mobile application to manage household food provisions and avoid kitchen waste'

Goal and Scope

This innovation (T5.5) is a mobile application for consumers that aims to reduce food waste at home. The mobile App named CozZo combines a digital shopping planner with automated food and home supplies catalogues. It is not dependent on store choice and provides different features to help plan food shopping and manage food at home. During grocery shopping, the food needs to be added to the user's "home catalogue" with calculated expiry dates and reminders. This reduces user's product management efforts with suggestions and helps users to buy products in the right quantity, to know what expires today or tomorrow and to see their actual food waste level.

CozZo was tested in Austria, Finland and Greece, among households and students. The goal of this evaluation is to assess the efficacy of the innovation in reducing food thrown in the bin. A detailed report with outputs and analysis has been produced by Mesiranta et al., (2023).

Methodological note

The total number of participants in this demonstration was 52, split into three countries. In Austria and Finland, in the student approach (where participants were recruited from university students) was that they used the App only for 3 weeks (versus 6 weeks for other households). In Greece, the student approach used the mobile App for 6 weeks like the other

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households.

The composition of the household food waste was determined through two sorting analyses (one before and one during the demonstration phase), run by researchers, for the length of one week during each phase for the case of households. In the case of students, the waste sorting analysis was run by themselves and then reported to researchers in an Excel file.

Results

The reported values concern both students and households, they have been summed only because few units were engaged in this test, but we need to be aware that usually students and households do not have similar behaviors in food consumption and waste and waste sorting analysis were conducted differently, so they should not be merged in the same calculations.

The FLW values (average, Min, Max, median) are reported in Kg / week, with reference to the week of observation.

Table 12- FW difference between baseline and demonstration in the three countries, Cozzo App for food waste reduction at home

Food waste data	Austria		Finland		Greece	
	Baseline	Dem	Baseline	Dem	Baseline	Dem
Total number of participating HHs	19	19	18	18	15	15
Average HH food waste [kg/week]	1.0	0.4	1.3	0.8	0.7	0.6
Min HH food waste [kg/week]	0.1	0.0	0.0	0.0	0.0	0.0
Max HH food waste [kg/week]	3.0	2.0	7.1	3.6	1.5	1.0
Median HH food waste [kg/week]	0.7	0.3	0.8	0.4	0.7	0.7

*Kruskal-Wallis test on Austria FW data: p-value 0.0265**
Kruskal-Wallis test on Finland FW data: p-value 0.1946
Kruskal-Wallis test on Greece FW data: p-value 0.7557

Utility, replicability and user-friendliness

In the case of Greece, 11 users answered to the questionnaire to gather the three dimensions. In the case of Finland, 18 users answered to the questionnaire while in Austria, 17 replied. In all the cases, answers have been analyzed combining students' and households', since the sample is too small otherwise.

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A final interview with data controllers, supporting with the interpretation of the users' insights, has been run.

Finland

The **utility** of the CozZo app, as evaluated through the questionnaire, revealed mixed perceptions among users. The most positively rated feature was the "Cook Expiring Products" recipe list, which received an average score of 5.06, showing that users valued practical, actionable support for reducing food waste. Other features like the expiry date-sorted inventory list and summary notifications on expiring items were also appreciated (average >4), indicating that users found these tools helpful in managing their inventory. However, features like the automatic estimation of product shelf life according to storage conditions received a lower average score of 2.94, suggesting this functionality did not align well with user needs, possibly due to perceived inaccuracies. In terms of the app's influence on purchasing habits, the average score was 2.67, suggesting limited impact. While some respondents noted improvements in planning and checking inventory, many did not feel the App significantly enhanced their purchasing routines. Similarly, 7 out of 18 participants reported changes in purchasing habits unrelated to the app, such as shopping less frequently or focusing on minimizing waste, which may indicate an underlying interest in food waste reduction independent of the app's functionality. For perceived financial savings, users gave an average score of 2.07, indicating limited monetary impact. While 5 respondents noted minor savings due to less reduced overpurchasing and increased awareness of their stock, the consensus was that the App provided little direct financial benefit.

The app's **replicability** was assessed through users' willingness to recommend it to other people, their satisfaction with the App meeting their expectations, and its adoption within households. Respondents rated how well the App met their personal expectations on a scale from 1 to 10, with an average of 6.14, indicating moderate satisfaction. In terms of recommending the App to others, the average score was 5.85, reflecting some hesitation to promote it widely. Household adoption was limited, with 12 out of 14 respondents reporting that only one person in their household had downloaded the app, and just one household having two users. These results indicate a moderate level of personal acceptance but limited household expansion.

The CozZo app's **user-friendliness** was evaluated through questions about frequency of use, ease of starting and engagement with specific features like shopping lists and recipes. Respondents reported varied usage frequencies on a scale from 1 to 5, with an average score of 2.57, indicating occasional rather than regular use. Users rated the ease of starting the app, with an average score of 2.5, suggesting moderate difficulty in getting started, as no one found it "very easy." Engagement with features like shopping lists and recipes was low. Most respondents (10 out of 18) did not create any shopping lists, and only three respondents created more than one list. Similarly, 14 out of 18 respondents did not create any recipes, with only one user creating a significant number (10 recipes).

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When openly asked about strengths and weaknesses of the app, users agreed on the positive side of features that improved awareness of their food inventory, such as reminders for expiring items and the shopping list function. These features helped users track items in their fridge or pantry, making it easier to focus on ingredients that needed to be used soon. However, the app's weaknesses often outweighed its strengths for many users. Common issues included the time-consuming process of keeping the inventory updated, manual data entry, and challenges with the barcode scanner. Language inconsistencies (English, Finnish) and too many features also made the interface difficult to navigate.

Greece

Based on the feedback provided, the CozZo App has demonstrated mixed results in terms of perceived utility, replicability, and user-friendliness. In terms of **utility**, while certain features like the "8 o'clock summary notifications" and "individual expiry notifications" were highly valued (scoring above 4.0), the App as a whole was seen as moderately useful for reducing food waste and improving purchasing habits, with overall average ratings of 2.64 and 2.55, respectively. Users appreciated specific functions like expiration reminders, but other features such as the "Cook Expiring Products" recipe list were less utilized.

When it comes to **replicability**, many users expressed uncertainty about continuing to use the app, with only a small number affirming they would keep it in their routine. The moderate likelihood of recommendation (5.09 out of 10) suggests that while some users see its potential, many are hesitant to fully adopt it in their daily kitchen management. **User-friendliness** was rated moderately (3.27), with initial challenges related to setup, language barriers, and learning the various features. However, once these obstacles were overcome, users found the App easier to navigate, although some aspects like manual data input were seen as time-consuming.

Austria

In Austria, the **utility** of the CozZo App was perceived in both positive and negative terms. Out of the respondents, 5 users found the push notifications and best-before date reminders helpful for preventing food waste, particularly for forgotten items. However, 4 users who already had efficient food management practices reported little improvement in their routines. Regarding **user-friendliness**, 6 users found the App difficult to use due to the time required for setup and maintaining the inventory, especially when entering pantry or freezer items. While 3 users appreciated features like the shopping list and chat function in shared households for coordinating purchases, less reliable elements like the barcode scanner and recipe suggestions reduced the app's ease of use. In terms of **replicability**, the App showed potential for larger households (mentioned by 2 users) in avoiding unnecessary purchases, but it had limited impact in smaller or well-organized households, where existing habits worked well, as reported by 4 users.

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Interpretation and review

The t-tests suggest that we cannot state that the innovation is able to reduce food waste, but not even the opposite (p-value: >0.05), unless in the case of Austria. This is mostly imputed to the sample size, which is too small in this demonstration. Average food waste in Austria and Finland encourages us to be optimistic about the App performances, but this cannot be confirmed from a scientific standpoint (see next paragraph about limitations).

Overall, the CozZo App seems to offer valuable assistance for shopping, storage, and meal planning. Features like the receipt scanner and integration with market products are appreciated, and many users find it easy to use for family food planning. However, the App faces some challenges, specific to different types of users. For instance, for older individuals or those who are experienced in managing food supplies, the App might feel redundant or too time-consuming. The input process for food supplies is often described as slow. There is also a barrier for Android users, as the App is unavailable on that platform. Language is another obstacle, with users requesting translations for features, product listings, notifications, and newsletters. Finally, some users report that unless food products are logged immediately after purchase, it's easy to lose track, and improvements are needed for the barcode scanning feature.

In an interview with the creator and owner of the App, we discussed these results, that are ambivalent: for some features the App seems to be useful and appreciated, but there are limitations that hinder its replicability.

According to the owner, the success of a digital App designed to reduce food waste is heavily influenced by cultural factors and lifestyle changes, as evidenced by its different performance across different regions. In countries like Greece, Italy and Bulgaria, for instance, cultural attitudes pose a challenge: while many people download apps on the phone, they tend to use only basic features, such as chatting or sharing pictures, rather than engaging with its core functionality aimed at reducing food waste. It is, indeed, true that the digital literacy rate in these countries is mostly below the EU average or just at the average, which means they are not benchmark for other countries (EU Data, 2023). With its many features, the App is most effective for users who already have experience with similar applications, highlighting the importance of good digital skills to maximize its impact. However, also in Finland and Austria the App was not labelled as fully user-friendliness, in the Lowinfood test.

Additionally, the societal emphasis on food waste reduction in the country, or the perception of being a person who does not waste food, might lead to a lack of motivation among users. Also in this case, scientific evidence (Sigala et al., 2024; Giordano et al., 2018, 2020), highlights that Greece and Italy are countries where people think to be virtuous on food waste, but then they are proven wrong by waste statistics or direct food waste measurements (diary and waste compositional analysis).

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Finland, on the opposite, reports a more frequent use of the App (see Mesiranta et al., 2023; D 1.7, Koseoglu et al., 2024), even though the rating of the App seems to report difficulties as well.

There is also another reason that could explain the performance of this App during our demonstration. According to the owner, the app's primary benefit - helping users track what they have in their fridge - may have been influenced by the rise of remote working, as people can easily check their fridge in person. The App works better where all adult members of a family work in the office, so it is less useful if one of the adults' members of the family is at home and has more control over food planning. Furthermore, the growing trend of online shopping has also impacted the app's effectiveness: the App would work best in partnership with retail companies, but without a budget, retailers have been reluctant to participate in such demonstrations.

Based on our conversation and on the owner reporting, the App seems to work better in the United States, where it has seen a resurgence in usage over the past two years (after lockdown ended), with reported downloads ten times higher than in Europe. This increase correlates with more people returning to office work, where the app's functionality becomes more relevant. Also, the owner reports that, since American households tend to have larger shopping plans and storage capacities, the App becomes more useful, particularly for those with separate fridges or multiple homes, such as summer houses.

Limitation of the accounting and monitoring stage

The t-tests show inconclusive results regarding the effectiveness of the innovation, with p-values greater than 0.05 in almost all cases. This outcome is likely due to the small sample size - 19 units in Austria, 19 in Finland, and 15 in Greece. Although average food waste reductions in Austria and Finland suggest potential positive effects, from a scientific perspective, a larger sample size is needed for more robust conclusions. Additionally, the possibility of behavioral reactivity, where participants alter their actions because they know they are being observed, may have impacted the results. It is advisable to conduct waste audits without participants' awareness to mitigate this effect (D 5.10, Mesiranta et al. 2023).

T5.6 'REGUSTO Mobile App: Mobile application to sell restaurants' surplus food and track the delivered products up to the bin

Goal and Scope

REGUSTO is a mobile application that allows consumers to buy meals from restaurants at a reduced price and thus helps prevent food waste at the same time. Restaurants use REGUSTO to sell fresh meals prepared in surplus. The App enables users (consumers) to find the closest offers, thanks to geo-location and proximity marketing. Once the food has been selected, the quantities and the time to collect are decided. At the time of collection, the meals purchased are stored in the REGUSTO Bag.

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REGUSTO is the first in Italy to introduce the innovative concept of "dynamic pricing" in against-waste food sharing: it offers restaurants the opportunity to sell their food with variable and timed discounts. This task aims at using this application to improve the mission of avoiding food waste up to the bin, by tracking the food waste deriving from the food brought home through the REGUSTO Bag, whether they consist of complete meals to be consumed at home (take-out food) whether they are leftover meals taken home via the (REGUSTO) doggy-bag.

The App was improved during COVID19, to improve user-friendliness and then the demonstration started.

Further info about the innovation can be found in D 5.11, Rellini et al., (2023).

Methodological note

The initial number of restaurants testing the new version of the App was 6, then 5 after a dropout, all located in the center of Italy. Approximately 300 REGUSTO bags per restaurant were delivered.

A total of 580 survey responses and 58 client-submitted photographs were collected from residents across 23 cities in 7 regions of Italy. After performing data cleaning and corrections, observations lacking key data necessary for analysis were removed. As a result, 574 valid observations were retained for the final analysis. All data was collected through a survey. Further details can be found in LOWINFOOD D 5.11 (Rellini, Secondi, Yu, 2023).

Table 13: FW difference between baseline and demonstration during the test for Regusto App

Country	Type of food waste	Average amount of food waste at BASELINE	Average amount of food waste at DEMONSTRATION
Italy	Kitchen food waste*	282.00 kg per restaurant / month	256.00 kg per restaurant / month
	Consumer food waste**	230.60 kg per restaurant / month	160.00 kg per restaurant / month

**Kitchen food waste: the reduction of this type of waste is mainly caused by the surplus redistribution via the App.*
*** Consumer food waste: due to the use of Regusto bag, plate waste left in restaurants by consumers (and treated/handled/disposed by the restaurants as waste management) was reduced.*

Utility, user-friendliness and replicability

The **utility** of the REGUSTO App appears to be moderate to high based on the responses from restaurants. The number of new buyers during the demonstration period varied across restaurants, with 10, 30, 50, and 30 reported. Despite this variability, there is a strong willingness to maintain relationships with existing buyers, with most respondents indicating they would "probably" or "very probably" continue these connections. The time required to place an order through REGUSTO is efficient, ranging between 5 to 7 minutes per order, with

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one user completing orders in less than 5 minutes. This suggests that the App provides a practical and efficient tool for managing food waste and surplus sales. In terms of its impact on reducing food waste, most users agreed that REGUSTO plays an important role in their operations, highlighting its success in contributing to food waste reduction, which aligns with its primary goal.

The **replicability** of the App is promising, as most users did not need to purchase additional devices to implement it, relying instead on existing technology like smartphones, tablets, or computers. This low barrier to entry enhances its potential for widespread adoption. Furthermore, respondents indicated a strong willingness to continue using the App in the future, with most answering "probably" or "very probably." Additionally, the likelihood of recommending REGUSTO to other businesses was consistently positive. While some users suggested the addition of features such as a delivery option, the overall functionality was well-received, indicating that the App can be replicated in similar settings without the need for extensive adjustments.

When it comes to **user-friendliness**, the feedback was also positive. Users found the App easy to implement, with no reported challenges in getting started. The dashboard received good reviews, with most users satisfied or very satisfied with its design and usability. Minimal interaction with customer support was reported, suggesting that the App operates smoothly without the need for frequent troubleshooting. Moreover, the App requires only a minimal time commitment, with most users dedicating less than five hours a week to using REGUSTO. These factors contribute to the overall impression that REGUSTO is highly user-friendly, easy to integrate into daily operations, and efficient in its execution. Also, feedback from the restaurants' staff highlights its strong user-friendliness: most users found it easy to start using the app, with the majority rating the ease of use as 4 or 5 out of 5. Only a very small portion encountered difficulties, suggesting that the learning curve is minimal. Additionally, customers expressed a generally positive experience with the app, as 183 rated it "very satisfied" and 299 "satisfied", indicating that the App met expectations in terms of functionality.

Interpretation and review

On the whole, REGUSTO seems to be a successful App to promote the use of doggy-bag and discounted purchases of restaurants surplus food. It would be interesting to observe the widespread of the App also in other restaurants in Italy and its dynamics to challenge competing Apps.

Limitation of the accounting and monitoring stage

Nothing to be reported.

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3.3 Evaluation of efficacy for supply chain efficiency innovations

T2.3 'Leroma B2B digital marketplace for F&V'

Leroma is a B2B online platform to connect producers with surplus food and processors watching out for input materials for their usual food production. The idea was to connect F&V producers with processors and other food chain actors through an online platform. The demonstration revealed that the mediation of highly perishable products, such as fruits and vegetables, is extremely hard.

Similar to the fish value chain (see chapter T4.2), efforts were made to convince companies to use Leroma for exchanging F&V products, and to engage these potential users of Leroma in completing the surveys designed to evaluate the baseline situation of the companies and the impact of Leroma in terms of waste reduction, efficiency, and socio-economic and environmental effects. Regarding the use of the surplus exchange platform, some companies were persuaded to offer surplus products, all from Germany. F&V products were advertised, and many transactions have taken place in this product segment, but only for F&V derivates with long shelf life like powders, juice etc. The start-up contacted personally many companies via emails and phone calls.

No perishable products could be transferred (on the fundamental problem of perishable products for a platform like Leroma see chapter T4.2). Due to the lack of users in this specific market segment, regrettably no questionnaires have been completed and it is possible to conclude that Leroma failed in reducing F&V food waste through connecting farmers and producers with other actors of the FSC. This conclusion, however, is only true for the specific test and scope proposed initially, meaning that the same platform could work with other products and in different contexts, but this was out of the scope of our demonstration.

The demonstration conducted within the LOWINFOOD project somehow helped the start up to focus more clearly their business on non-perishable products that are more suitable to be traded via the Leroma digital platform.

T2.4 'Forecasting software to reduce waste of F&V products'

Goal and scope

Innovation T2.4 outlines the development and demonstration of forecasting software designed to predict future sales of F&V in supermarkets. The software leverages neural networks and machine learning techniques to create forecasts based on store-specific historical data. Trained to predict daily or weekly sales for individual products in the F&V department, the technology aims to provide accurate sales forecasts that help food category managers reduce over-ordering and minimize food surplus, thereby decreasing waste at supermarkets. To better frame the scope of this demonstration, it is useful to recall the

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ordering process, occurring every morning, under the responsibility of the food category manager of the store, for every product of the F&V department:

1. Estimate sales of the next day: in the baseline situation, this is done with a naïve approach that considers the sales of the previous day, the sales of the previous year on the same day, the day of the week, including holidays
2. Check of the quantity of product in stock
3. Consider weather conditions and seasonality
4. Adjust the order to cope with the risk of having a surplus.

The forecasting software provides the food category manager with more accurate sales predictions for the next day, improving the reliability of the information he/she considers at point 1 of the process. This means that, even when the forecasting software is used, the quantity that is ordered is a human-based evaluation, considering all the factors mentioned.

During the final phase of the test, the model achieved an absolute error of 32% in predicting sales quantities across all forecasted products, measured by monetary sales value. This marks a significant improvement over the baseline model previously used, which had a 55% error for the same products during the same period (Malefors et al., 2024). Additionally, the demonstration generated positive interest from food category managers, who appreciated the software's ability to provide reliable insights that support the ordering process.

Methodological note

The software was initially tested in a pilot run at a single supermarket, for one month, and then fully demonstrated over two months in two Italian supermarkets. The demonstration specifically focused on providing food category managers with more accurate information on future sales to support their decision about the quantity of products to be ordered. This means that, even if the reliability of the forecasts provided by the software is better than the pre-existing approach (called “naïve”), this does not necessarily result in a decrease of the quantity of food surplus and, therefore, food waste. Moreover, the naïve approach to estimate the sales of the next day was kept as a benchmark, meaning that in case of big differences between the software forecasting and the naïve approach, it is likely that the food category managers opted for the traditional approach, to be “on the safe side”.

The baseline was measured during April-May 2023 at two Italian supermarkets. Data on purchases, sales, prices and waste were collected from stores’ records, by individual product. Both in the baseline and in the demonstration, the focus was kept on a list of key products, that were selected in accordance with the stores’ staff because they are particularly subject to waste, and at the same time they are relevant in terms of sales, during the season considered. The quantity of waste is calculated by adding up, for each item, the quantity recorded as waste and the quantity wasted without recording (the so-called unrecorded retail food waste: Cicatiello et al. 2017; Eriksson et al. 2012), estimated by considering the inventory gaps recorded at the end of each month.

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Table 14- FW difference between baseline and demonstration during the test for the innovation 'Forecasting software to reduce waste of F&V products'

	N. of items	Purchase tot (kg/month)	Purchase avg (kg/month)	Waste tot (kg/month)	Waste avg (kg/month)	Waste on purchase avg %/month*
Baseline	206	168 202.1	816.5	5,680.4	27.7	5.1
Demonstration	206	199 902.3	970.4	9,202.0	44.7	5.1

Legenda
AVG= Average
TOT= Total
Purchase: purchase in mass store KG
Sales: sales in mass store KG
Waste: Total mass food waste store KG
N.: F&V item types
**Waste on purchase avg %/month: average waste of individual product in each of the 2 months*
*Purchase in mass store KG p-value = 0.0051***
*Total mass food waste store KG p-value = 0.0013***
Percentage (%) of waste on purchase p-value = 0.2019

Utility, user-friendliness and replicability

No management survey was delivered in this case, due to the unavailability of store managers (upper management level with respect to food category managers) to disclose sensitive data about the stores involved in the demonstration However, in the final focus groups with food category managers – the actual users of the forecasts provided by the software - a positive perception of the innovation emerged. The food category managers demonstrated openness towards the innovation, contributing to a successful testing phase and appreciating the reliability of the forecasts it can give (Malefors et al., 2024).

Interpretation and review

The software consistently improves the stores' sales forecasting accuracy, reducing the average error from 55% with the naïve forecasting approach to 32%, with the forecasting software. There is reason to believe that, if used exclusively or systematically integrated into the daily ordering routine, the error rate could be further reduced. Lowering the error translates to ordering less surplus food, thereby reducing food waste. This innovation holds promise, particularly in a context where sales forecasting is still fully human-driven, and it would be worthwhile for additional stores to test and implement it.

Food waste reduction was not achieved at this stage, probably due to a longer time needed by the food category managers to integrate the forecasts provided by the software in the ordering decision process. An interesting aspect is that the test allowed to improve the forecasting software, for example by defining a list of key products – for which the forecasts

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are provided on a daily basis - which change with the store and the season, and that is therefore tailored to the needs of each specific store.

Limitation of the accounting and monitoring stage

Despite the promising results, the innovation should be tested on a larger sample of supermarkets, as in this case the demonstration phase involved only 2 stores in Italy, from the same supermarket chain. Another key aspect emerging from the test is that the innovation needs to be used for a longer time to be well integrated into the daily ordering decision routing. For sure, it is a promising innovation for the specific context, such as stores where forecasting is mostly based on human experience. Additionally, in many places in Italy and globally, forecasting software are already available for supermarkets, so an idea could be comparing the results of this software with existing ones.

T3.3 'FoodTracks Software for bakeries'

Goal and scope

FoodTracks (https://www.foodtracks.de/) is a Software as a Service (SaaS) solution designed to enhance order management and maximize revenue opportunities within the bakery sector. By utilizing an AI algorithm, it analyzes both historical and real-time data from the bakery's IT system, to which FoodTracks is integrated. This data includes ordered, sold, and returned quantities of specific bakery products, along with key master data such as order units and shelf life. Using these insights, FoodTracks identifies revenue opportunities and generates more accurate order recommendations. The algorithm also factors in external elements, such as weather conditions and public holidays, ensuring more precise order suggestions for individual bakery products at specific stores, while reducing the risk of sell-outs (Baur et al., 2023).

Methodological note

The bakery forecasting software, based on AI, aims at connecting the production stage of a bakery with the retail stage and tries to reduce food waste quantities due to an improvement in forecasting capacities of the bakeries' sales stores.

The forecasting software FoodTracks was tested in three German bakeries, for a total of 38 sales stores during the demonstration period. The implementation of FoodTracks took place over a period of up to 15 months, from March 2022 to May 2023, as part of the LOWINFOOD project. Throughout this time, improvements were made to enhance the software's user-friendliness, functionality, and overall acceptance. Initially, FoodTracks was assessed at Technology Readiness Level (TRL) 6, and by the end of the demonstration phase, it had achieved TRL 9, demonstrating its successful application in an operational environment.

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The dataset available for the efficacy analysis of the three bakeries comprised 1,291,883 observations for the baseline and demonstration phases. Each observation represents an order for an item placed in a store on a particular day with the corresponding return data and the respective mass per item.

Indicators

RR in %	Return rate: relative indicator that represents a measure of the proportion of returned products – Quantity of products returned to the central production site (not sold at end of day) divided by the quantity of products delivered and available for sale in the bakery stores (calculated as the mean value of all observations)
QR_{ds} in kg/(day*store)	Returned products per day and store – absolute indicator that represents a measure for the quantity of products not sold: Average of the three bakeries for total quantity of returned products divided by number of opening days and number of stores

Results

Table 15- Return rates (%) per product category for all three bakeries

Category	Baseline	Demonstration	P-value (KW)	Signif.
Bread	19.1	14.7	< 2.2e-16	***
Cake	9.5	7.9	< 2.2e-16	***
Pastries	15.6	11.6	< 2.2e-16	***
Rolls	20.5	17.6	< 2.2e-16	***
Snacks	10.4	12.9	< 2.2e-16	***
Total (average)	16.5	13.4	< 2.2e-16	***

Table 16 - Returned products per day and store, average for all three bakeries

Food waste data				
	Baseline	Demonstration	P-value (KW)	Signif.
QR_{ds} (kg/(day*store)	26.2	19.1	< 2.2e-16	***
Number of participating stores [no.]	38	41		
Total days measured	1029	1207		

On average 7.1 kg of returned products could be prevented daily per store by the use of FoodTracks. This results in an annual reduction for the three bakeries with 41 sales stores of

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106 tons of returned products. The average is statistically significant (Kruskal- Wallis p-value > 0.001).

Utility, replicability and user-friendliness

The implementation of FoodTracks in German bakeries demonstrates different levels of replicability, user-friendliness, and utility. In terms of **utility**, on average, FoodTracks suggested an average of 259.939 order proposals, with companies implementing an average of 39% of these suggestions. The software's functionality received high satisfaction ratings (4 or 5 out of 5) from all respondents. Two out of three companies rated their personal expectations with the software being met at 4 out of 5, while one rated it 2 out of 5. Expected benefits included time and cost savings (3 companies), with two companies also anticipating a reduction in food loss and waste, and one expecting cost-savings. All three companies expressed full satisfaction with FoodTracks' software support, functionality, and intuitive use. However, none of the companies reported the development of new competencies (such as technological, social, or technical skills) through the use of FoodTracks.

In terms of **replicability**, the resources needed to implement the innovation varied among companies. Personnel deployment ranged from 1 to 2 employees, with weekly working hours spanning from 4-6 hours (2 respondents) to 20 hours (1 respondent) for demonstration. All three respondents expressed full willingness (5 out of 5) to promote the innovation, indicating a high potential for replication.

Regarding **user-friendliness**: while two companies found starting with FoodTracks very easy, one reported it as very difficult. All companies reported the need for specific training, particularly in software usage. Competencies beneficial for using FoodTracks included technical know-how (1 company), numerical skills (1 company), understanding procurement (1 company), and one company reporting *"general bakery knowledge about assortment, ordering process, cash register system, merchandise management, baking slips dough"* as typologies of competences beneficial to use the software. Looking at new routines needed to adopt the innovation, all interviewed reported that the ordering process became easier, with *"order suggestion"* being present, *"95% of the order suggestions made by FoodTracks are correct and corresponding to our needs",* and *"the handling and ordering process is very clear"*. One company reported changes in their manufacturing process, as the company indicated *"We've changed from a decentral order system to a central order system"* and *"Due to the centralization of procurement, the ordering process was quickened"*. Interestingly, no changes were reported in internal (i.e., between management and sales staff) or external communication (i.e., with suppliers), work motivation, or trust in employees. Finally, an average of 90 mails have been sent by the three companies (min 12, max 194) for issues with the software.

Interpretation and review

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Without any doubt, FoodTracks demonstrated a clear ability to reduce food waste for all products under the demonstration phase. Moreover, the innovation showed positive outcomes across the three key dimensions: utility, replicability, and user-friendliness.

Limitation of the accounting and monitoring stage

The data sets of the bakeries had to be cleansed first. In the process, it turned out that there were incorrect entries. For example, there were implausible values, such as negative values for delivered products or unrealistically high values for returned products resulting from input errors. As part of the implementation of FT, the bakeries are required to enter their data cleanly into the system. Since this was not always the case in the past and also during the use of FT, these observations could not be used for the analysis.

T4.2 'Leroma B2B digital marketplace for fish'

Leroma is a B2B digital platform for food materials that creates a digital bridge between suppliers and food producers. It features a database of raw materials which can be filtered by specific criteria, as well as a surplus exchange that provides the industry with a marketplace for their leftover stock. Efforts were made to convince companies to use Leroma for exchanging seafood products. Surveys were designed to evaluate the baseline situation of these potential users of the platform as well as the efficacy of Leroma in reducing food waste, and the resulting socio-economic and environmental impacts. Two seafood companies from the UK (one from Scotland) registered on the platform but were not active. Some companies were persuaded to offer surplus products on the exchange platform, all from Germany. Eight fish products were advertised; however, no transaction took place in this product segment.

Regarding the surveys, only two questionnaires were partially completed. The collected data reflect the baseline conditions of these companies, but do not reflect outcomes from utilizing Leroma. To mitigate this issue, qualitative feedback regarding Leroma's potential impact on the seafood value chain was gathered during the stakeholder dialogue as well as through a revalorization survey in Task 4.1.

In the framework of the T4.1 stakeholder dialogue, participants generally expressed themselves favorably about Leroma and its possible use in the seafood value chain; but they also stated that the Leroma platform may not yet align well with the needs of highly perishable commodities, such as seafood products. On the other hand, the stakeholders pointed out that there are often well-established functioning structures in the value chain for further distribution of seafood materials and (by)products. This is justified by the high (economic) value of the fish commodity, which results in an efficient use of resources, meaning that little goes unused, or used below its potential anyway. This makes it difficult for innovations like Leroma to enter the market. Additionally, the networks of users from the sector (potential sellers and buyers) are still limited, which can delay the finalization of a

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matching – a significant challenge in the presence of high perishability and the need for sellers to store the material until then. This discovery is considered an important finding of the LOWINFOOD project.

To achieve a more objective assessment of the potential of the platform for the seafood industry, the "development of digital marketplaces to match buyers and sellers of surpluses" was included among potential innovations, identified through the dialogue interviews, that stakeholders were asked to rank (more details about the survey can be found in D4.3 [Koseoglu et al., 2024]). This type of innovation ranked fifth out of 11, with 41 out of 79 respondents (52%) selecting it, and an average ranking of 3.12 out of 5 (respondents could select and rank up to five innovations, 1 being the most promising). While it did not rank very high, it did not rank very low either. The ranking differed between Scottish and German respondents, with the latter ranking it second, but the difference was not statistically significant.

T5.1 ' KITRO Innovative food waste solution'

Goal and Scope

KITRO (T5.1) is a technological innovation aiming at quantifying and classifying food waste at food service stage by using artificial intelligence (AI). The classification of food waste is useful to discuss kitchen organizational changes in cooking and serving food. The innovation was tested in Germany, Greece and Switzerland during the project.

KITRO provides restaurants, canteens and hotels with a fully automated food waste management solution. By combining image processing and deep learning technologies with a hardware solution, relevant information on the food being thrown away is captured and analyzed. Food services receive detailed insights into their food waste via an online dashboard, empowering them to make informed decisions and optimize work practices leading to a reduction in food waste, food cost and their negative environmental impact.

The hardware comprises a scale that is placed underneath the waste bin of the kitchens, where serving losses and plate waste is discarded and an Internet of Things device with a camera on top. Through image recognition, the kind and quantity of food that is wasted is recorded.

A full report on demonstration can be found in Strotmann et al. (2023).

Methodological note

Three canteens, one resort and one hotel were engaged in the test.

KITRO provided the data used in the following analysis. For each picture taken and therefore, for every time something was thrown away by the users, Kitro recorded the mass of the waste, food category, waste source type, and cost among other variables.

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Anytime waste was labelled non-food, liquid or as an error by Kitro, the data was excluded. Users recorded their guest numbers on the online dashboard, which were also sent to the research partners for the analysis. This way, waste per guest and day could be calculated.
For the baseline measurements, Kitro was installed for about a month (see table 7 and table 10) before seamlessly going into the demonstration phase for about one year (DE1, DE2 and CH) or two summer vacation seasons (GR1 and GR2).
Switzerland (CH) and Germany (DE1 and DE2) demonstrations were under control of the same scientific partner (ISUN), so data is reported jointly.

Results

Table 17- Aggregated results for KITRO in two countries

Country	Average amount of food waste at BASELINE	Average amount of food waste at DEMONSTRATION
Germany and Switzerland	136.6 g per guest / day (edible)	133.0 g per guest / day (edible)
Greece	102.0 g per guest / day	49.5 g per guest / day

*GR: Mann-Whitney test on Total food waste per guest (g) by Phase (Baseline-Demo) p value= 2.5e-15****
DE, CH: Mann-Whitney test on Edible food waste per guest (g) by Phase (Baseline-Demo) p-value = 0.4085

Germany and Switzerland

Table 18-Number of observations and guests recorded during the test in German and Swiss food services

DE	No. Observations (days) Base	No. Observations (days) Demo	Average guests per day (Sd) Base	Average guests per day (Sd) Demo	Median guests per day (Iqr) Base	Median guests per day (Iqr) Demo
DE1	29	233	93.6 (69.6)	132.4 (72.8)	76.0 (123.0)	148.0 (102.0)
DE2	32	217	336.4 (120.7)	342.8 (168.9)	371.0 (148.0)	360.0 (281.0)
CH	28	307	232.8 (61.8)	300.8 (68.5)	225.0 (41.5)	291.0 (91.0)
Total	89	757	224.7 (134.4)	261.0 (139.0)	212.0 (171.0)	253.0 (184.0)

Mann-Whitney test on guest count by phase (baseline-demostration)
*DE1: p-value= 0.0116 **
DE2: p-value= 0.7276
*CH: p-value= 1.7e-07 ****
*Total: p-value= 0.0193 **

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Table 19- Average Food Waste per guest during the test in Germany and Switzerland (g)

DE	Mean (sd) Base	Mean (sd) Demo	Median (iqr) Base	Median (iqr) Demo
DE1	202.8 (350.9)	91.2 (70.6)	111.9 (167.2)	90.8 (73.4)
DE2	113.8 (58.3)	86.6 (71.2)	97.5 (85.2)	71.3 (70.2)
CH	127.9 (40.2)	141.6 (40.3)	116.9 (28.1)	138.5 (54.8)
Average (Total)	147.2 (205.9)	110.3 (65.6)	111.9 (78.2)	109.4 (78.5)

Mann-Whitney test on waste per guest (g) by Phase (Baseline-Demonstration)
DE1 p-value= 0.0691
*DE2 p-value= 0.0048***
*CH p-value= 0.0371**
Total p-value= 0.2102

Table 20-Edible food waste per guest (g) during the test in Germany and Switzerland

DE	Mean (sd) Base	Mean (sd) Demo	Median (Iqr) Base	Median (Iqr) Demo
DE1	115.9 (139.4)	52.7 (45.0)	79.4 (134.5)	52.3 (52.2)
DE2	194.2 (337.5)	264.1 (342.2)	0.0 (217.6)	144.7 (354.5)
CH	92.4 (25.2)	101.3 (31.8)	87.7 (30.4)	98.9 (39.0)
Total	136.6 (220.2)	133.0 (204.5)	84.4 (126.4)	83.8 (77.3)

Mann-Whitney test on Edible waste per guest (g) by Phase (Baseline-Demonstration)
*DE1 p-value= 0.0097***
*DE2 p-value= 0.0085***
CH p-value= 0.1498
Total p-value= 0.4085

Greece

In Greece, the innovation was tested in two hotels in two touristic islands. The number of observations per baseline (1) and demonstration (2) are listed in the following Table 10.

Table 21- Number of observations and guests recorded during the test in Greece

GR	No. Observations (days) Base	No. Observations (days) Demo	Average guests per day (Sd) Base	Average guests per day (Sd) Demo	Median guests per day (Iqr) Base	Median guests per day (Iqr) Demo
GR 1	30	314	571.6 (267.5)	818.1 (269.5)	645.0 (467.2)	903.0 (227.2)
GR 2	30	305	336.9 (97.5)	384.0 (87.9)	370.0 (20.8)	392.0 (26.0)

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Total	60	619	454.2 (232.1)	604.2 (296.2)	380.5 (276.2)	463.0 (517.0)

Mann-Whitney test on Guests per day by Phase (Baseline-Demonstration)
*Hotel 1 p-value= 1.2e-07****
*Hotel 2 p-value= 2.9e-07 ****
*Total p-value= 1.6e-06 ****

Table 22- Average food waste per guest (g) during the test in Greece

GR	Mean (Sd) Base	Mean (Sd) Demo	Median (Iqr) Base	Median (Iqr) Demo
GR 1	99.2 (80.0)	57.7 (28.4)	72.9 (29.9)	52.2 (26.9)
GR 2	104.8 (156.3)	41.1 (35.3)	77.8 (37.3)	32.0 (38.7)
Total	102.0 (123.1)	49.5 (33.0)	75.6 (33.4)	45.2 (34.9)

Mann-Whitney test on Total food waste per guest (g) by Phase (Baseline-Demonstration)
*GR1 p-value= 2.5e-08****
*GR 2 p-value= 2.1e-09****
*Total p-value= 2.5e-15****

Table 23-Edible food waste per guest (g) during the test in Greece

GR	*Mean (Sd) Base*	*Mean (Sd) Demo*	*Median (Iqr) Base*	*Median (Iqr) Demo*
GR 1	*41.0 (29.4)*	*38.9 (21.1)*	*33.0 (11.5)*	*35.0 (27.5)*
GR 2	*51.9 (42.8)*	*33.2 (30.1)*	*48.1 (30.6)*	*26.9 (33.1)*
Total	*46.4 (36.8)*	*36.1 (26.0)*	*37.9 (22.4)*	*30.4 (30.4)*

Mann-Whitney test on Edible waste per guest (g) by Phase (Baseline-Demonstration)
GR1 p-value= 0.5734
GR 2 p-value= 0.0025**
Total p-value= 0.0077 **

Utility, user-friendliness and replicability

Germany

In terms of **utility**, the indicator on the number of pictures taken ranged from 4,273 to 36,175, with an average of 18,033. All three companies stated that Kitro helped them reduce food waste and met their expectations, which included increased awareness and actual reduction of waste. In terms of skill development, minimal new skills were reported. No new technological skills were developed. One company noted improvements in technical skills (i.e., a better understanding of handling food items), with improvement in six men and two women, and in social/relational skills related to food waste awareness among staff, with 15 staff in service, 22 staff in the kitchen.

User-friendliness indicators highlight that Kitro received high marks for ease of use and satisfaction. All three companies found it easy to implement and use, with minimal resources required. The dashboard and features were well received, with ratings mostly at 5 (very

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satisfied). There were no reported issues or inquiries about the innovation. Some suggestions for improvement included making successes more visible and adding a real-time waste display in the kitchen. When asked about additional resources needed in terms of training, one company reported that the kitchen staff did not require training, while people from management participated in a 4-hour training (two hours for a meeting with Kitro to explain the dashboard and two hours to test the software). Another company reported that, while no extra time is needed for the kitchen and service staff, extra time is required to enter the number of guests and evaluate data from waste. Finally, in terms of perceived non-financial improvements, two companies indicated that Kitro had positive effects on PR, one reported increased communication in the team, and one higher motivation in employees.

Looking at **replicability** indicators, two companies plan to continue using Kitro after the project. One company does not intend to keep using it, citing that it has served its purpose, providing analysis of FLW which allowed the company to change the portion sizes and menu. Despite this, two out of three companies would recommend Kitro, rating it 8 out of 10 for likelihood of recommendation. However, concerns were raised about its cost-effectiveness and practicability for smaller businesses. One company mentioned that Kitro is more useful in bigger establishments with 600+ customers per meal.

Interpretation and review

Kitro was tested in hotels across Germany and Greece, where it delivered positive results. By utilizing artificial intelligence, image processing, and deep learning, Kitro automates the process of quantifying and classifying food waste, offering a significant upgrade over traditional manual methods like waste sorting. The system's hardware, including a scale beneath the kitchen bin and a camera to capture waste data, provided food services with detailed insights via an online dashboard. This enabled hotels to make informed decisions, leading to a significant reduction in food waste quantities.

However, while Kitro's efficiency and ability to streamline waste tracking proved highly effective, its cost emerged as a barrier in certain markets. In Greece, for instance, the high cost of the system was flagged as a significant limitation, potentially challenging its wider adoption. On the other hand, the cost was less of an issue in Germany, suggesting that in wealthier countries or regions with higher budgets, Kitro could be implemented more readily. The innovation holds great promise for HORECA businesses globally, especially in affluent markets, where the investment in Kitro could easily be justified by the long-term savings and sustainability benefits it delivers.

Moreover, Kitro offers a clear advantage when it comes to quantifying and accounting for food waste, aligning directly with the targets of SDG 12.3 of the United Nations and the European Commission's mandatory food waste reporting requirements for member states. With the right adoption strategies and potential cost reductions, Kitro could also be highly beneficial at the household level. It would support the every-four-year accounting mandate imposed by the EU, offering a solution that is far more efficient and standardized than the

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current methods - such as paper diaries and manual waste sorting analyses. Kitro's automated, data-driven approach would significantly reduce the effort required to meet these regulations while providing highly accurate and reliable data, helping countries achieve their sustainability goals with less administrative burden and higher accuracy.

Limitation of the accounting and monitoring stage

Despite the success of this testing phase, it would be beneficial to replicate the testing in other countries and over more units, also to feed Kitro with new information. Motivation loss on-site during the measurement has been reported and this might have influenced the results.

T5.2 'MITAKUS Forecasting software for restaurants'

Goal and scope

Mitakus is a web-based platform that integrates historical sales data from professional kitchens with external factors like weather and holidays to predict sales on a per dish basis and optimize menu design. It assists chefs, production, and purchasing managers in determining customer preferences and estimating ingredient quantities (Wolkow et al., 2023). The intervention aims at reducing the overproduction in canteens kitchens.

Methodological note

Mitakus was tested in two German canteens (DE1 and DE2). A third user who had agreed to test Mitakus shortly before the end of the work package also dropped out after a few weeks, so no further data could be collected. The users (DE1 and DE2) worked with Mitakus to fit a forecasting model to their facilities and compared Mitakus with their traditional long-term planning tools.

DE1 serves around 4000 meals per day, and DE2 around 350-600 with each offering four to five different dishes per day. Only warm lunch meals were recorded and forecasted using the system (Strotmann et al., 2024).

Mitakus is supposed to be used by kitchen managers viewing the forecast and then taking the forecast into consideration while planning or even relying on the forecast completely for planning quantities. Both users informed the data controller (ISUN) that they did not trust the forecast enough to solely rely on it and did not take it into consideration for planning in some cases, especially during stressful times. Also in the case of this innovation, the engagement of workers and companies to run the test was highly influential of the results.

Mitakus calculated both a long-term forecast with first predictions six weeks in advance and a short-term forecast with daily changes to reflect the recent situation the best. Those two forecasts were compared to the users' own long-term predictions based on their experience

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which they use for planning. Real sales were recorded to show if Mitakus could improve accuracy of planning numbers compared to the system already in use.

The theoretical approach makes use of the indicators "Mean absolute percentage error" (MAPE). MAPE is defined as the mean value of the relative differences between forecasted and actual sales numbers.

Data used to assess the quality of the Mitakus forecast

- MAPE long-term (compares the Mitakus long-term forecast and the actual sales)
- MAPE short-term (compares the Mitakus short-term forecast and the actual sales)
- MAPE target-value (compares the target quantity projected by the user and the actual sales)

$$\text{MAPE} = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{forecasted\ value - actual\ value}{Actual\ value}\right|$$

With MAPE: Mean absolute percentage error of forecasted values (percentage mean value of the absolute difference between forecasted and true values, divided by the true value, where the true value indicates the actual sales)

In the MAPE equation "n" refers to the number of forecasts made.

DE1: *Period Analyzed:* February 2023 - November 2023
Number of Dishes (n) forecasted: 1337 (about 4 dishes per day over 10 months)
DE2: *Period Analyzed:* February 2023 - October 2023
Number of Dishes (n) forecasted: 982 (about 4 dishes per day over 9 months)

Results

DE1: *Forecast Performance*

- Mitakus Long-Term Forecast: Average deviation of 26% from actual sales
- Mitakus Short-Term Forecast: Average deviation of 20% from actual sales
- User's Own long-term planning quantity: Average deviation of 57% from actual sales (MAPE business own forecast)

In the case of DE1, Mitakus short-term forecasts were the most accurate, followed by the long-term forecasts, while the user's own planning quantity had the highest deviation.

DE2: Forecast Performance

- Mitakus Long-Term Forecast: Average deviation of 73% from actual sales
- Mitakus Short-Term Forecast: Average deviation of 30% from actual sales
- User's Own long-term planning quantity: Average deviation of 34% from actual sales (MAPE business own forecast)

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In the case of the DE2, the short-term forecasts were again the most accurate, but both long-term and user's own forecasts had higher deviations compared to DE1. The long-term forecasts showed a significantly higher deviation in DE2 than DE1. The two companies engaged opted not to follow up with the use of Mitakus after the test ended.

Table 24- Mitakus test results in two canteens

User	No. of dishes forecasted	MAPE (Mitakus long-term forecast)	MAPE (Mitakus short-term forecast)	MAPE (user's own planning quantity)
DE1	1337	28% *(SD 34%)*	20% *(SD 27%)*	57% *(SD 94%)*
DE2	982	73% *(SD 48%)*	30% *(SD 36%)*	34% *(SD 80%)*

Utility, user-friendliness and replicability

The companies had differing experiences with Mitakus' **utility**. One company reported no reduction in food waste and unmet expectations for improved long-term planning, while the other believed participating in the project helped reduce food waste. Non-monetary benefits were perceived differently, with one company rating them low (1 out of 5) and the other rating them rather high (4 out of 5), citing Mitakus as proof of professionalism in food waste avoidance. Neither company reported the development of new skills as a result of implementing Mitakus. Looking at the results, the short-term forecasting is always more accurate with Mitakus rather than the previous forecasting method; however, the forecasting may not reflect the reality of the two kitchens selected, which declared to use/re-use surplus food quite easily, so they can deviate from forecasting and established menus at the moment.

Mitakus received mixed reviews for ease of use and satisfaction (**user-friendliness**). While the dashboard was highly rated, with both companies giving it 5 out of 5, the companies reported several inquiries (7 in total) about issues, mainly concerning login problems and data display. Implementation required minimal technological resources, primarily using existing PCs and staff training time. The difficulty in starting to use the innovation ranged from "rather difficult" to "neither easy nor difficult." Suggestions for improvement included more accurate long-term forecasts and the need for more time to engage with the system.

With regard to the **replicability** potential of the innovation, the adoption of Mitakus among the two German companies shows limited long-term commitment, as neither plans to continue using it after the project. However, both companies would recommend Mitakus to others, suggesting its potential value for smaller facilities less aware of food waste or those with less volatile menu plans- especially those who do not adapt menus quickly, on the basis of kitchen leftovers/surplus.

Interpretation and review

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The users required a forecast 6 weeks in advance to effectively plan for ordering and procuring raw materials. To meet this need, the forecasting process was extended progressively to cover a 6-week period, resulting in the development of a long-term forecast. However, this extended timespan introduced challenges in accuracy, as the further out the predictions were made, the more potential there was for deviations from actual sales. To address this limitation, a short-term forecast was introduced alongside the long-term forecast. This short-term forecast leveraged recent sales data, enabling it to produce more precise and timely predictions. While it offered improved accuracy for the nearer term, it was not available in time for the critical 6-week advance ordering window. Consequently, the dual-forecast approach aimed to balance the need for advanced procurement planning with the benefits of more accurate near-term sales predictions. Mitakus, which requires about two weeks of planning to optimize forecasting, struggled to adapt to this more flexible, day-to-day approach- the canteens know a couple of days in advance how many guests they will have and adapt to this immediately, but Mitakus cannot adapt to this quick change. Users suggested that Mitakus would be better suited for environments like satellite kitchens, where surplus storage is limited, and menu plans are more structured (Strotmann et al., 2024). However, with further work on the forecasting, Mitakus can become more suitable also to different situations. Moreover, in one kitchen both the long term and short-term forecasting was still more accurate than those provided by the previous forecasting method, so the innovation is reducing food waste if used in the appropriate context (kitchen where menus don't deviate quickly from plans and kitchen staff is willing to use it).

Limitation of the accounting and monitoring stage

In the beginning, all available historical data sets were used to calculate the forecast by Mitakus. But because of the changes during and after the pandemic, all data from 2021 and before could not be used. This issue limited data availability to create an accurate forecast, as new post-pandemic costumer habits needed to be considered. Additionally, it took some time to calculate a more accurate forecast because of the data adjustments.

It is also important to remind that Mitakus was never fully adopted by itself, but it was used in addition to traditional production planning tools and data were compared in the end.

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3.4 Evaluation of efficacy for food redistribution innovations

T2.1 'RER Software for F&V'

Goal and scope

This paragraph summarizes the results of Task 2.1 of LOWINFOOD, which aimed to scale up the use of the S.I.R platform, a software from the Emilia-Romagna Region (RER) in Italy, for facilitating surplus food donations and refunds to farmers via the Common Agricultural Policy (CAP) crisis management fund (Giordano et al., 2024). While attempts to replicate the system in other EU countries faced challenges, Romania was identified as a potential partner. A theoretical demonstration (simulation) and capacity-building workshop to potential replicators were conducted to show the platform's benefits, with hopes for its official adoption by Romania's Ministry of Agriculture in the future.

1. Absolute indicator: kg of food waste avoided
2. Relative indicators: kg of food waste avoided over company/cooperative/P production
3. Kg/euros of food waste diverted to human donation over company/cooperative/PO production
4. Kg/euros of food waste diverted to animal feed/ethanol production over company/cooperative/PO production

Methodological note

Since the Ministry of Agriculture of Romania, which manages the CAP funding, was not reached (lack of answer), the demonstration phase was a simulation. This means that the data about FLW shared by the Valea Topologului Agricultural Cooperative were treated in the platform by the RER as they belong to the platform. The aim was to simulate the financial benefit for the participating cooperative resulting in successful implementation of the platform. Despite the Cooperative and Romanian food banks becoming aware of the CAP program's functioning mechanism and technological platform between the baseline and demonstration stages—thanks to a capacity-building session in Bologna in 2023—the platform has not been tested in Romania. This is because the data input and control depend on regional and national authorities, and the recipients of CAP funding are Producer Organizations (POs), which were either absent or not identified during the testing phase. As a result, the outcomes are entirely simulated, as the Cooperative did not handle any data in Romania.

Three types of scenarios are generated: H1 (all unharvested product is destined to human consumption); H2 (half of the unharvested product goes for human consumption); H3 (all unharvested product is destined to different utilization than human consumption).

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The three scenarios produce different economic values, as the destination for human consumption is the most valued in the CAP regulation and provides the highest compensation to farmers, followed by ethanol production and other uses (see Giordano et al., 2024 for further details).

The indicator is the economic return that the agricultural cooperative would have had if the innovation was fully in place, expressed in Euros/ton.

Results

Saved amounts and revenue

Since the Ministry of Agriculture was not involved in the replication phase, a real-time demonstration could not be developed. To address this, we assumed that the Agricultural Cooperative was an Italian PO receiving the same reimbursements from CAP funding, and we simulated the results in the three listed cases to showcase the potential benefits for farmers if the platform were fully adopted. We assume that the reimbursement from CAP could be lower in the case of Romania (the funding is related to the average production cost assumed from the Ministry in a dialogue with the POs).

The baseline concerned the following products: strawberries, plums, apples and pears (see Giordano et al., 2024). In the timeframe 2018-2022, assuming that Valea Topologului Agricultural Cooperative was a PO, it would have received 5287.5 Euros per year if all the unsold food was given to donation for human consumption (H1). In H2 namely, if half of the unsold quantity was donated for human consumption and half for other purposes, the revenue would have been 3384.7 Euros per year. In the third scenario, where all the unsold products go for other purposes (no human consumption), the reimbursement would have been 1482 Euros per year.

Table 25- Food waste at baseline and demonstration. simulated scenarios of payment to farmers based on CAP regulation.

Scenario	Cherries (Euros)	Strawberries (Euros)	Total (Euros)
Baseline (2018-2022) *			
H1		2613.60	
H2		1721.40	
H3		829.30	
Demonstration (2024)			
H1	639.00	4047.50	4686.50
H2	479.25	3035.25	3514.50

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Scenario	Cherries (Euros)	Strawberries (Euros)	Total (Euros)
H3	319.50	2023.75	2342.25

**baseline provided also data about Strawberries/ Plums/ Apples/ Pears, which are not comparable with the demonstration phase as only strawberries and cherries data were collected in 2024. To see all the data for the baseline, see Giordano et al., 2024.*

In 2024 with the full implementation of the platform, the PO would have recovered 4000 kg of fruits (500 kg of cherries, 3500 kg of strawberries) and would have earned back 4686.50 Euros only for the donation of surplus strawberries and cherries for human consumption (H1); donation for human consumption but without compensation is what actually occurred in reality. About 3514.50 Euros in case of H2 (half donated for human consumption, half for other uses); 2342.25 Euros in H3 (all unsold products for other purposes than human consumption).

Utility, user-friendliness and replicability

The indicators for this innovation are not available, as the results were produced based on a simulated demonstration, namely the test was run by RER based on data collected from the Agricultural Cooperative. During the capacity building workshop held in Bologna on 18-19 of October 2023, enthusiasm in pushing the innovation forward with governmental authorities was recorded. Both farmers and charities found the system easy to use and highly beneficial. The challenge of replicability remains, as the necessary prerequisites slow down adoption in countries where the system is technically available but not yet implemented in practice.

Interpretation and review

The adoption of the S.I.R. platform in Romania would undoubtedly benefit farmers and help reduce food waste from unsold fruits and vegetables. However, three key requirements make the process less easy than it could be: 1) the implementation of the regulation for the CAP emergency crisis funding: some countries, like Italy, France, Spain and Greece opt for this choice, while others, such as Austria, opt for farmers' insurance. 2) The involvement of the Ministry of Agriculture or any agency in charge of managing CAP funding at national/regional level. 3) the presence of recognized POs that can request CAP repayments. These prerequisites demand significant organizational changes, which must occur well before implementing the S.I.R. platform, as it is primarily a technological solution. Additionally, strong commitment from the CAP payment agency (either ministerial or regional, according to the Member State governance) is essential, as proper monitoring of the trucks—both at loading and delivery to food charities—requires active control at both points.

In the case of Romania, two out of three requirements described above where not met, as it was impossible to reach out the ministerial authority and there are no recognized POs in Romania.

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The cooperative joining the testing phase expressed their willingness to lobby in favor of the adoption of this CAP regulation and declared from the beginning of the testing phase that they already made a formal request to the Ministry to be recognized as a PO. Also, the Food banks expressed their willingness in pushing the adoption of this platform after the capacity building.

As for the key requirement 1, many countries were contacted in the partner replication search but did not agree to participate in the test phase. The primary challenge included the existence of similar, or alternative IT platforms to manage this regulation. In fact, while this platform was innovative in 2011, different IT systems have been set in place in the meanwhile (i.e., France and Spain). Other issues arose, such as the fear of the potential need for software adaptation and additional administrative burdens. Additionally, in countries like Greece, there have been significant difficulties in contacting key stakeholders, such as ministry officials and farmers' organizations (no answer or no direct contact).

Such difficulties required flexibility in the approach to allow for replicability. The innovation holds significant potential that should be explored and fully utilized in Romania and in places where this mechanism is not fully in place.

Limitation of the accounting and monitoring stage

Due to the lack of a real-time demonstration, we assumed the Cooperative operated as an Italian PO with CAP funding reimbursements and simulated outcomes in three cases to show potential benefits for farmers if the platform were fully adopted. It is important to note that the reimbursement from CAP could be lower in Romania, as funding is tied to the average production costs determined by the Ministry in consultation with POs at national level.

Another limitation is that the Cooperative participating in our demonstration is not currently a PO, so they lack full-time administrative staff for monitoring and reporting. This made it difficult to obtain data on production and losses, as the farmers are constantly busy with harvesting and fieldwork. As a result, a practical demonstration of the platform, where the OP/Cooperative would report their own food losses for donation in the IT system, was not feasible. Instead, the simulation used data provided by the Cooperative to the Emilia Romagna region, which was then input into the S.I.R. platform. This process was only to estimate the amount of funding the Cooperative would have been eligible for and the quantity of products that charities would have received if the system had been fully operational.

It is worth underlining that this Operative program from CAP needs to be based on the PO work and existence, which should be also officially recognized from the national Ministry of Agriculture- for further details, see Giordano et al., 2024.

However, the present results should be followed up with outreach activities and lobbying efforts, as there is clear potential for farmers to benefit from adopting this system—they are

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incentivized to recover unsold agricultural products and donate them in exchange for an economic reward.

T2.2 'UNV Cooperation system for F&V'

Goal and scope

Innovation T2.2, Unverschwendet (UNV), started as a cooperation system between farmers and restaurants to redistribute unharvested agricultural products in Austria. These products are thus made available for human consumption instead of ending up as food waste. UNV started as an association and became an LTD company in 2016, before LOWINFOOD started. Due to COVID-19 lockdown, UNV was not able to develop the initial idea of connecting farmers with restaurants. Also, it was not easy to allocate the surplus food products (sometimes huge quantities) to restaurants. For this reason, UNV redirected the surplus food to processors.

The traded food products between farmers and processors increased from 50 tons in 2019 and 370 tons in 2022, due to the engagement of two large-scale processors. There is a notable gap between the supply side (27 actors) and the demand side (7 actors). During the LOWINFOOD project, UNV expanded its geographical focus to Hungary, Slovakia and the Czech Republic and created its own brands, such as No-Gin.

Methodological note

The baseline data consists of the recording of surplus food that was redistributed/transferred in the years 2016-2021. The demonstration phase records the food surplus that was redistributed/transferred in the period between Feb 2022 and Jan 2024, when new actors (food processors) were engaged thanks to the activity run in the project.

Prevention and redistribution actions were not only implemented in the demonstration but were already taking place in the baseline. In the baseline, food surplus was redistributed but to a lesser extent than during the demonstration. The aim of the demonstration was to enlarge the network with cooperating partners and to increase the volume of annual transfers.

Raw data was collected in the demonstration period including the surplus food quantities that was offered and bought by UNV, the price, the origin, the reasons for the generation of surplus food, the cultivation type as well as the type of processing conducted by UNV in order to sell the processed food. Additionally, four interviews with companies providing surplus food were conducted in August 2023 to obtain more specific data and information (combined management and participant survey). Raw data was aggregated into nine food categories (fresh fruit, processed fruit etc.) to guarantee confidentiality of companies before sharing with LOWINFOOD partners.

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Results

Table 26: Food surplus quantities for the Unverschwendet cooperation system

Food waste data	Austria	
	Baseline	Demonstration
Total food surplus transferred per year[kg]	2 200 (2016) 5 188 (2017) 25 373 (2018) 55 700 (2019/20)* 25 300 (2020/21)* * deviating financial years	28 300 (2022) 370 000 (2023)
Duration of demonstration phase [years]		2
Food surplus on average per year [kg/year]	22 752	326 500

Due to the lack of detailed data records at baseline, a direct comparison of the before and after situation of certain key performance indicators was not possible. Therefore, only the data of the demonstration period can be shown (Table 26).

The Table below (Table 27) shows the amount of surplus food that was offered to UNV. The main food category that is offered to UNV are fresh vegetables with 1.9 tons, followed by fresh fruit with nearly 600 tons and semi-processed vegetables with about 450 tons. Yet only a small part of the food offered can also be used and transferred by UNV. Only 19% of the surplus food that was offered to UNV could be transferred.

The amount of surplus food per transaction is 7 582 kg on average (see Figure below). This amount can fluctuate considerably. One transfer included a total amount of even 85 tons of surplus food at once. The majority of transfers range from 600 kg to 10 000 kg per transaction.

Table 27- Amount of surplus food offered to UNV and transferred by UNV for the period 02/2022 to 01/2024 (demonstration period)

Food Category	Total offered surplus food [kg]	Transferred surplus food [kg]	Share of offered food to transferred food	No. of actions surplus food offered	No. of surplus food transactions	Amount of surplus food in kg/No. of transactions*
1) Fruits (fresh)	582,565	277,328	48%	24	17	16,313
2) Fruits (semi-finished)	348,906	116,766	33%	31	12	9,731
3) Fruits (processed)	-	-		0		
4) Vegetables (fresh)	1,926,278	171,009	9%	51	35	4,886
5) Vegetables (semi-finished)	448,397	74,315	17%	29	17	4,371

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Food Category	Total offered surplus food [kg]	Transferred surplus food [kg]	Share of offered food to transferred food	No. of actions surplus food offered	No. of surplus food transactions	Amount of surplus food in kg/No. of transactions*
6) Vegetables (processed)	23700	9085.44		2	1	
7) Oils and pulses (fresh)	23,400	2,501	11%	2	1	
8) Oils and pulses (semi-finished)	55,568	4,168	8%	5	3	1,389
9) Other	314,428	57,568	18%	24	8	7,196
TOTAL	3,723,242	712,741	19%	168	94	7,582

**Average amount of surplus food in kg per number of transaction ('Transferred surplus food [kg]: 'No. of surplus food transactions')*

The numbers of partners at baseline and demonstration are not meaningful to compare due to the involvement of fewer large-scale partners at demonstration instead of many small restaurants or other partners at baseline. The number of businesses that received surplus food from UNV reached 33 in the two years of demonstration.

Utility, user-friendliness and replicability

In terms of **utility**, two out of the four companies that answered the questionnaire reported that participation in the cooperation system led to new skills development among their staff, in particular, they have noted improvements in communication and relationship skills for both male and female employees. Looking at expectations, the cooperation has generally met participants expectations, two participants indicated full satisfaction (rating it 5 out of 5), one participant rated it 4 out of 5 and one 3 out 5.

Regarding **user-friendliness**, two out of four companies answering the questionnaire found the UNV cooperation system very easy to use (rating it 5 out of 5), two companies find it quite difficult (rating it 2 out of 5 and 3 out of 5 respectively), explaining that UNV standards and requirements were initially difficult to implement. All companies expressed high satisfaction with the cooperation, unanimously rating it 5 out of 5. While none of the companies needed to recruit new personnel for this collaboration, two companies reported an increase in the number of hours worked (2 hours more and 3 to 6 hours more per week) due to the cooperation with UNV. The increase in hours worked has been registered in the activities of logistics, production and organization.

Interpretation and review

Initially, the innovation aimed to connect farmers with restaurants, but the COVID-19 lockdown rendered this model impractical as most restaurants were closed for nearly two years. Moreover, the supply-demand imbalance was clearly highlighted: the suppliers

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offered tons of food products at the time, amounts that could not have been handled by restaurants.

In response, UNV demonstrated a good adaptability by shifting focus to food processors. This pivot involved collecting surplus produce and redirecting it to processors for the creation of new products from fruits and vegetables. Attempts to include products of animal origin were abandoned, as they implied strict food safety rules that were not economically efficient and they were out of scope of this demonstration.

The potential for growth is clear, given that only 19% of the surplus food offered to UNV can currently be redistributed. This limited transfer is partly due to the scarcity and difficulty of acquiring businesses on the demand side, but also because much of the surplus, such as lettuce and radishes, is unsuitable for further processing. Additionally, the remaining shelf life of the surplus is often too short for product development, which typically requires 6–12 months, while surplus items often last only 2–3 months. Irregular quantities and changing types of surplus food often hinder finding more partners on the demand side.

The results of the innovation test and additional interviews with data controllers suggest that the marketing/persuasive capacity of UNV was essential to build a network capable of providing and receiving surplus food at short notice. So, probably an essential winning feature of this initiative is direct contact between people, in this case UNV and FSC actors. Also, results indicate that the surplus food must be specifically tailored to meet industry requirements, as businesses are unlikely to adjust their processes. Consequently, significant efforts in persuasion and persistence were necessary to build support among industry partners, many of whom initially displayed limited awareness of surplus redistribution.

Overall, the innovation test underscores the foundational role of trust-based partnerships and adaptability in addressing surplus redistribution barriers within the food industry, especially with reference to perishable products.

This adjustment highlights the innovation's success in addressing food surplus, even in the face of a crisis. Moreover, it shows the effectiveness of a cooperation system based on personal agreements rather than technological platforms, suggesting that such a system can be more responsive and effective; the owner reports that such agreements worked also through remote contacts (Video and phone calls), so geographical proximity and face-to-face contacts are not necessary.

Limitation of the accounting and monitoring stage

Due to the aggregation level of data at demonstration and the lack of disaggregated data records at baseline, a statistical analysis was not possible.

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Discussion

The testing process provided interesting results, revealing significant potential across all 14 food waste reduction innovations. The results highlighted the strengths of the highest-performing solutions, while also offering important lessons from those with comparatively lower performance, all of which contribute to informing future refinement and application.

The first challenge encountered in most of the tasks was engaging the people and organizations involved in adopting the innovations. The results of some demonstrations were less significant or representative (for example, simulated or tested on a limited number of units) because participants showed resistance to adopting changes, an issue especially observed with companies. In few cases, this led to the lack of sufficient data to test the innovation.

Promising innovations should be further tested on a larger scale and adapted better to specific contexts, but many companies perceive experimentation as a 'waste of time' and prefer to focus on daily tasks. This resistance is common when different organizational levels have contrasting views on innovation: for example, management may be supportive, while operators see it as an additional burden that takes time away from routine activities, or vice versa (Cicatiello et al., 2020). This issue is not limited to companies; public bodies, such as ministries and local administrations, have also shown fragmented engagement in some cases. Fragmentation or internal disagreements limit an innovation's ability to achieve its goals.

The **first lesson learned** is thus clear: innovation works best when it is fully embraced by the adopting organization.

Also, fear of sharing data and information from companies harms the success of the testing phase. This problem has been reported for more than a decade now and keeps being a problem despite the important efforts that the UN, the government and civil society have put over the topic. Probably, instead of inspiring action to reduce food waste, in some cases it increases the feeling of shame associated with food waste, which equates to fear for the reputation of the company. It has been largely observed over years, however, that the food waste reduction has been embraced as a cause from bigger companies (Tesco, IKEA, etc) more than smaller ones, both for a social responsibility component and for availability of resources that bigger companies have.

The **second lesson** is that often, even when initial resistance is strong, innovation can generate enthusiasm among participants during the demonstration. This was the case with various software and technological innovations, where initial hesitation turned into growing interest as the concrete benefits of the innovation became evident. Therefore, even when an innovation is met with a reluctant initial response, it can still be adopted and, over time, inspire engagement and approval.

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A second challenge was related to the methodology. The methodological framework, developed as an initial step of the project and based on the Delegated Decision, met EU requirements and provided high reliability in some cases. However, it was resource-intensive and presented significant limitations. For example, conducting waste audits if subjects know they are being observed can lead to altered behaviors, both consciously (due to social desirability bias) and unconsciously (behavioral reactivity). The ideal way to avoid this is to conduct waste audits without subjects' knowledge (the optimal solution) or to extend the observation period to at least one month. Otherwise, it is difficult to ensure high-quality data on food waste.

Therefore, **the third lesson learned** is that while it is essential to adhere to the Delegated Decision, it is equally important to maintain data quality standards. This was a key aim of the project; however, the more ambitious the methodology, the more resources are required.

Collecting enough data to measure each innovation's impact was difficult, but the project Lowinfood succeeded in 11 out of 15 demonstrations. Some innovations clearly reduced food waste, while others provided useful insights that help developers understand what stops ideas from working in real-life situations- another main goal of the project. Even when innovations did not reduce food waste as much as hoped, the results were still helpful. For example, the innovators used the information to improve their market strategies.

This process supports the main idea of LOWINFOOD: although there are many ways to reduce perishable food waste, testing these ideas in real settings is essential to ensure they work effectively and make a meaningful impact across the food supply chain.

The **fourth** and main lesson learned is that, despite challenges, food waste must be measured as accurately as possible. Accurate measurement is essential not only to assess the effectiveness of an innovation and improve it but also to provide evidence-based guidance for policymakers. While precise measurement and reporting require time and resources, the cost of funding or promoting ineffective solutions can be even higher. We keep seeing educational measures and campaigns whose impacts are often only measured through questionnaires -if measured at all- sometimes backed by public funding. This approach is no longer viable; we now have sufficient knowledge to establish better methodological frameworks. Furthermore, an innovation that succeeds in one setting may deliver disappointing results in another slightly different context, making rigorous testing crucial.

Conclusion

Within the field of sustainable development, there is a spectrum of readiness among stakeholders to adopt innovations aimed at reducing environmental resource pressures. For instance, strategies to minimize food waste are intended not only to decrease waste but to contribute to a rebalanced food system characterized by more rational and efficient

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production processes. Different institutions have demonstrated their commitment to these goals, as evidenced by the establishment of SDG 12.3 and the 2018 amendment to the Waste Directive. These entities (the UN and the EU) have invested and will likely continue to invest resources in alignment with these objectives.

To achieve the targets set by the European Commission, it is crucial to keep testing and refining innovations while actively encouraging economic actors across the spectrum- from farmers to consumers- to embrace these changes, especially at production and processing stages. However, persuasion alone may still be insufficient; social influence through peer behavior and the provision of adequate funding play equally important roles in facilitating this transition.

The European Union, as a global leader in food waste reduction, has undertaken scientific and standardized approaches to measure and analyze food waste. Such efforts can be fed by the results of relevant projects. One of the central insights from this project is that the urgency of reducing food waste is still not universally acknowledged, which may represent an obstacle to the adoption of innovations.

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5. Credit authorship contribution statement

Table 28: Credit authorship contribution statement of D1.6

Name	Organisation	Conceptualization[1]	Methodology[2]	Software[3]	Investigation/data collection[7]	Resources[7]	Data curation[8]	Writing – original draft[9]	Writing – review & editing[10]	Other
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Rothe, M.	ADB				T33					
Kaltenbrunner, K.	AIE				T53 T54					
Orth, D.	AIE				T53 T54		T53 T54			
Canaj, E.	ARE				T21					
Contrino, L.	ARE				T21					
	BLU				T51					
Brunnhuber, N.	BOKU	ALL					ALL	ALL	ALL	
Ladurner, T.	BOKU				T55					
Scherhaufer, S.	BOKU	ALL			T22 T55		T22 T55		ALL	
Schmied, E.	BOKU				T22					
Dimitrov, I.	COZ			T55		T55				
	CNA				T31 T32					
Pfaff, T.	FT				T33					
Abeliotis, K.	HUA				T51 T55					
Chroni, C.	HUA				T51 T55		T51 T55			
Lasaridi, K.	HUA				T51 T55					
Baur, V.	ISUN									
Engelmann, T.	ISUN				T23 T42		T23 T42		T23 T42	
Gerwin, P.	ISUN				T51 T52 T53	T51 T52 T53	T51 T52 T53		T51 T52 T53	
Strotmann, C.	ISUN				T23 T33 T41 T42 T51 T52	T23 T33 T41 T42 T51 T52	T23 T33 T41 T42 T51 T52		T23 T33 T41 T42 T51 T52	

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Name	Organisation	Conceptualization[1]	Methodology[2]	Software[3]	Investigation/data collection[7]	Resources[7]	Data curation[8]	Writing – original draft[9]	Writing – review & editing[10]	Other
					T53	T53	T53		T53	
Mzek, T.	JHI				T41 T42	T41 T42				
Koseoglu, N.	JHI				T41 T42	T41 T42				
Piras, S.	JHI				T41 T42	T41 T42		T41 T42		
Hofmann, A.	KITRO				T51					
Billinger, M.	LER			T23 T42	T23, T42					
Casalino, F.	LER			T23 T42	T23 T41 T42					
Giordano, C.	LUKE	ALL	ALL	ALL	ALL	T21	ALL	ALL	ALL	ALL[11, 12]
Malefors, C.	MATO			T53 T54	T53 T54					
Wolkow, R.	MITA			T52	T52					
Bruschini, P.	PICO				T24					
Valeri, C.	PICO				T24					
Rellini, P.	REG				T56					
Pinhgini, R.	RER				T21					
Ziosi, C.	RER				T21					
Bartek, L.	SLU				T31 T32	T31 T32				
Eriksson, M.	SLU				T24 T31 T32 T52 T53 T54	T24 T31 T32 T52 T53 T54			T24 T31 T32 T52 T53 T54	
Sundin, N.	SLU				T53 T54	T53 T54				
Mesiranta, N.	TAU				T32 T55	T32 T55			T55	
Närvänen, E.	TAU				T32 T55	T32 T55				
Sutinen, U.-M.	TAU				T32 T55	T32 T55				

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Name	Organisation	Conceptualization[1]	Methodology[2]	Software[3]	Investigation/data collection[7]	Resources[7]	Data curation[8]	Writing – original draft[9]	Writing – review & editing[10]	Other
Mattila, M.	TAU				T32	T32				
Falasconi, L.	UNIBO				T21				T21	
Alboni, F.	UNIBO						ALL	ALL	ALL	
Carloni, E.	UNIBO*	ALL	ALL					T53 T54	ALL	
Di Fiore, G.	UNIBO*	ALL	ALL						ALL	
Blasi, E.	UNITUS				T24 T32	T24 T32				
Cicatiello, C.	UNITUS				T24 T32	T24 T32			ALL	ALL[13]
Yu, M.	UNITUS				T56	T56			T56	
Nasso, M.	UNITUS				T24 T32	T24 T32				
Pietrangeli, R.	UNITUS				T24 T32	T24 T32				
Secondi, L.	UNITUS				T56					
Diesenreiter, C.	UNV				T22	T22				
Nygardh, S.	UPP				T53 T54					

**Moved to a new institution in the meantime but contributed during the whole project duration*

Terms and definitions (according to the Contributor Roles Taxonomy of Elsevier):

[1]**Conceptualization**: Ideas; formulation or evolution of overarching research goals and aims

[2]**Methodology**: Development or design of methodology; creation of models

[3]**Software**: Programming, software development; designing computer programs; implementation of the computer code and supporting algorithms; testing of existing code components

[4]**Validation**: Verification, whether as a part of the activity or separate, of the overall replication/ reproducibility of results/experiments and other research outputs

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[5]**Formal analysis**: Application of statistical, mathematical, computational, or other formal techniques to analyze or synthesize study data

[6]**Investigation**: Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection

[7]**Resources**: Provision of study materials, reagents, materials, patients, laboratory samples, animals, instrumentation, computing resources, or other analysis tools

[8]**Data Curation**: Management activities to annotate (produce metadata), scrub data and maintain research data (including software code, where it is necessary for interpreting the data itself) for initial use and later reuse

[9]**Writing - Original Draft**: Preparation, creation and/or presentation of the published work, specifically writing the initial draft (including substantive translation)

[10]**Writing - Review & Editing**: Preparation, creation and/or presentation of the published work by those from the original research group, specifically critical review, commentary or revision – including pre-or postpublication stages

[11]**Visualization**: Preparation, creation and/or presentation of the published work, specifically visualization/ data presentation

[12]**Supervision**: Oversight and leadership responsibility for the research activity planning and execution, including mentorship external to the core team

[13]**Project administration**: Management and coordination responsibility for the research activity planning and execution

(Funding acquisition: Acquisition of the financial support for the project leading to this publication) excluded from the table

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