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

D1.7 Socio-economic evaluation of innovations

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LIST OF PARTNERS THAT HAVE CONTRIBUTED TO PRODUCE AND REVISE THE DELIVERABLE:

All partners contributed to the deliverable (see detailed list in Chapter 7). We would like to thank Chris Scarr (JHI) for a detailed proofreading of the document; Felicitas Schneider, Kate Parizeau for their thorough revision of the whole document; Christina Strotmann (ISUN) and Mattias Eriksson (SLU) for the internal review of the document as well as their input in Tasks 3.1; 3.2, 3.3, 5,1, 5.3/5.4; Claudia Giordano (LUKE) and Luca Zappi (RER) for their review of Task 2.1; Silvia Scherhaufer for her review of Task 2.2; Clara Cicatiello and Marco Nasso (UNITUS) for reviewing Tasks 2.4 and 3.2; Nina Mesiranta (TAU) for reviewing Task 3.2; Naomi Mackenzie (Kitro) and Katia Lasaridi and Christina Chroni (HUA) for reviewing Task 5.1; Paula Gervin (ISUN) for reviewing Tasks 5.1 and 5.2; Daniel Orth (AIE) and Niina Sundin (SLU) for reviewing Task 5.4; and Mengting Yu (UNITUS) for reviewing Task 5.6.

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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

In the scope of EU LOWINFOOD project, 14 innovations[1] were demonstrated. Innovation ranged broadly in type, from technical to educational, and social to administrative. Some of them were implemented by stakeholders and others were simulations of implementation. The innovations were applied to three supply chains, namely to fruit and vegetable, bakery and fish, as well as to the consumer side in the workplace and school canteens, hotels, restaurants and households. We explore in deliverable D1.7 the socio-economic evaluation of innovations on its users. This deliverable is complementary with deliverables D1.6 and D1.8, dealing with evaluation of the reduction of food loss and waste (FLW) that is achieved through the implementation of innovations, and evaluation of the environmental impacts of innovations. In this deliverable, we do not attempt to compare innovations of a different scale, scope and purpose and the outcome of the project in terms of supporting non-academic partners.

In the assessment of economic and social impact of the innovations, two different surveys and one interview script were used to collect self-declared data. Additionally, waste measurements taken by local partners, and the data collected automatically during the demonstration of several technologies, provided a valuable input for the economic impact analyses.

Several highlights from the socio-economic impact evaluation could be summarised under three main themes. The first one is the need for good quality data and facilitating its collection for demonstration locations. The second one is the innovations of different nature requiring a different approach for assessment, i.e., while our framework functioned comparatively well with evaluating the immediate impact of technological innovations and simulated demonstrations, the potential long-term impact of stakeholder dialogues cannot be captured within the period of the project. Finally, the third result is that both the innovations and the project itself has a wider value beyond the cost savings they enabled or additional income streams they created at demonstration locations.

We discuss these aspects further in the Results and Discussions sections and explore how the outcomes could be improved; both in terms of the socio-economic outcomes and in terms of data collection procedure, so that a more precise evaluation can be made in similar future projects.

[1] While there were 14 innovations, 15 demonstrations took place as one of the innovations, LEROMA platform, was demonstrated in two different value chains.

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1. Introduction to the deliverable

LOWINFOOD is a project committed to co-design: working with actors in the food chain and low-waste value chains, it will support a demonstration of a portfolio of innovations in a set of value chains particularly concerned by food loss and waste. Examples of these value chains include fruits & vegetables, bakery products and fish, as well as at-home and out-of-home consumption. Each of these value chains corresponds to a single Work Package (WP) of the project.

The innovations have been selected from promising solutions that have already been developed and tested by some partners of the consortium, with the aim 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 the innovations' ability to reduce food loss and waste (FLW), and in line with the evaluation framework illustrated in Figure 1. This deliverable (D1.7) investigates the socio-economic impact of innovations tested in the scope of the LOWINFOOD project and explores it from the perspective of multiple stakeholders involved, using both qualitative and quantitative data. This deliverable is complementary to the deliverables D1.1 Report on methodological framework and D1.4 Protocol for collection of social and economic data during demonstrations. It is also complementary to impact assessment deliverables D1.6 and D1.8, evaluating the reduction of FLW achieved through the implementation of environmental innovations and environmental impacts of innovations. The rest of the deliverable is structured as follows Section 2 details the evaluation method utilised in the socio-economic impact assessment task, section 3 presents results for each innovation, and finally a brief discussion (Section 4) and conclusion (Section 5), which will be further expanded 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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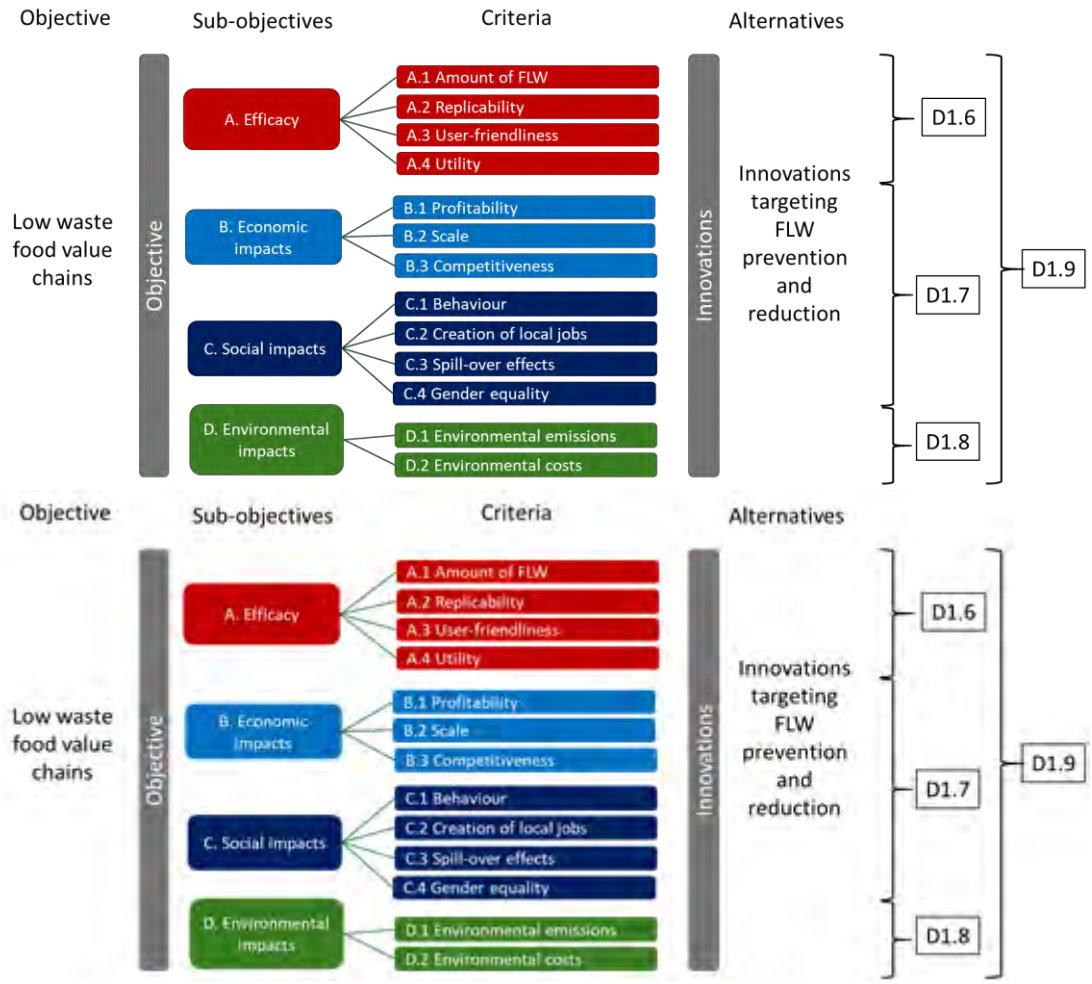
Figure 1: Target hierarchy of the evaluation of LOWINFOOD's innovations and dedicated deliverables presenting the results, the present report D1.7 covers B (light blue) and C (dark blue) sub-objectives



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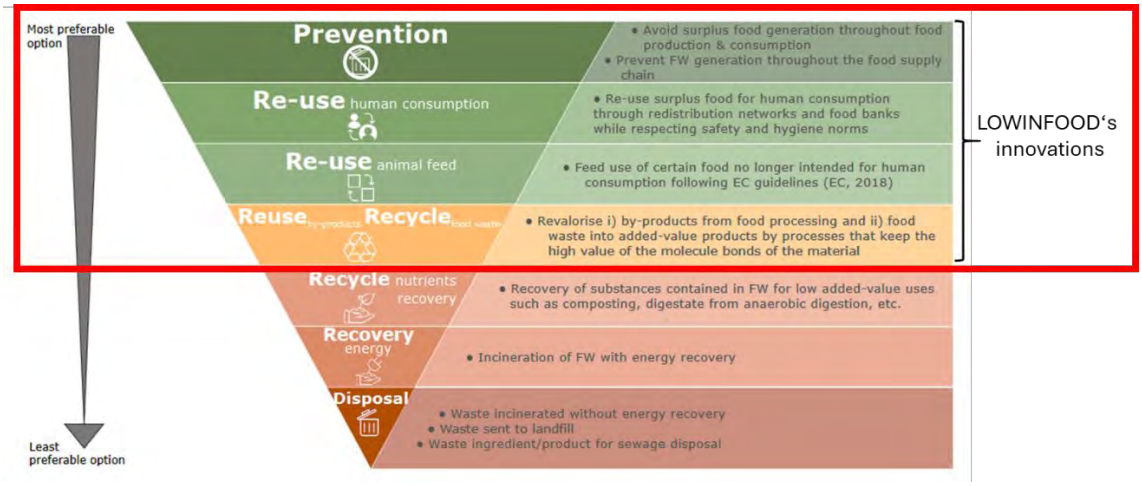
2. Innovations in LOWINFOOD

In line with the hierarchy for prioritisation of food surplus shown in Figure 2, LOWINFOOD's innovations aim to reduce food waste through 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 of the waste hierarchy (European Commision, 2020).

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



Through this evaluation process, 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.

2.1. Overview of innovations

A brief overview of the LOWINFOOD innovations, their geographical scope (country of implementation) and whether they were actually demonstrated, is provided in Table 1 below.

Table 1: Overview of LOWINFOOD's innovations and their status of demonstrations[2]

WP	Task (T) No.*	Geographical scope	Innovation – Short name	Innovation – Status***
WP2	T 2.1	RO	RER Software for F&V**	S

[2] While there were 14 innovations, 15 demonstrations took place as one of the innovations, LEROMA platform, was demonstrated in two different value chains.

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Table 1. Continued

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
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	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. ** F&V= Fruit and vegetable. ***B.... Baseline measured; D... Demonstration measured; S... Baseline and/or demonstration was simulated

2.2. Innovation types and groups

To enable a better understanding of the functionalities of LOWINFOOD's innovations, and the interpretation the results, a higher-level grouping innovation can be adopted. The innovations of LOWINFOOD can be grouped according to the following criteria:

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

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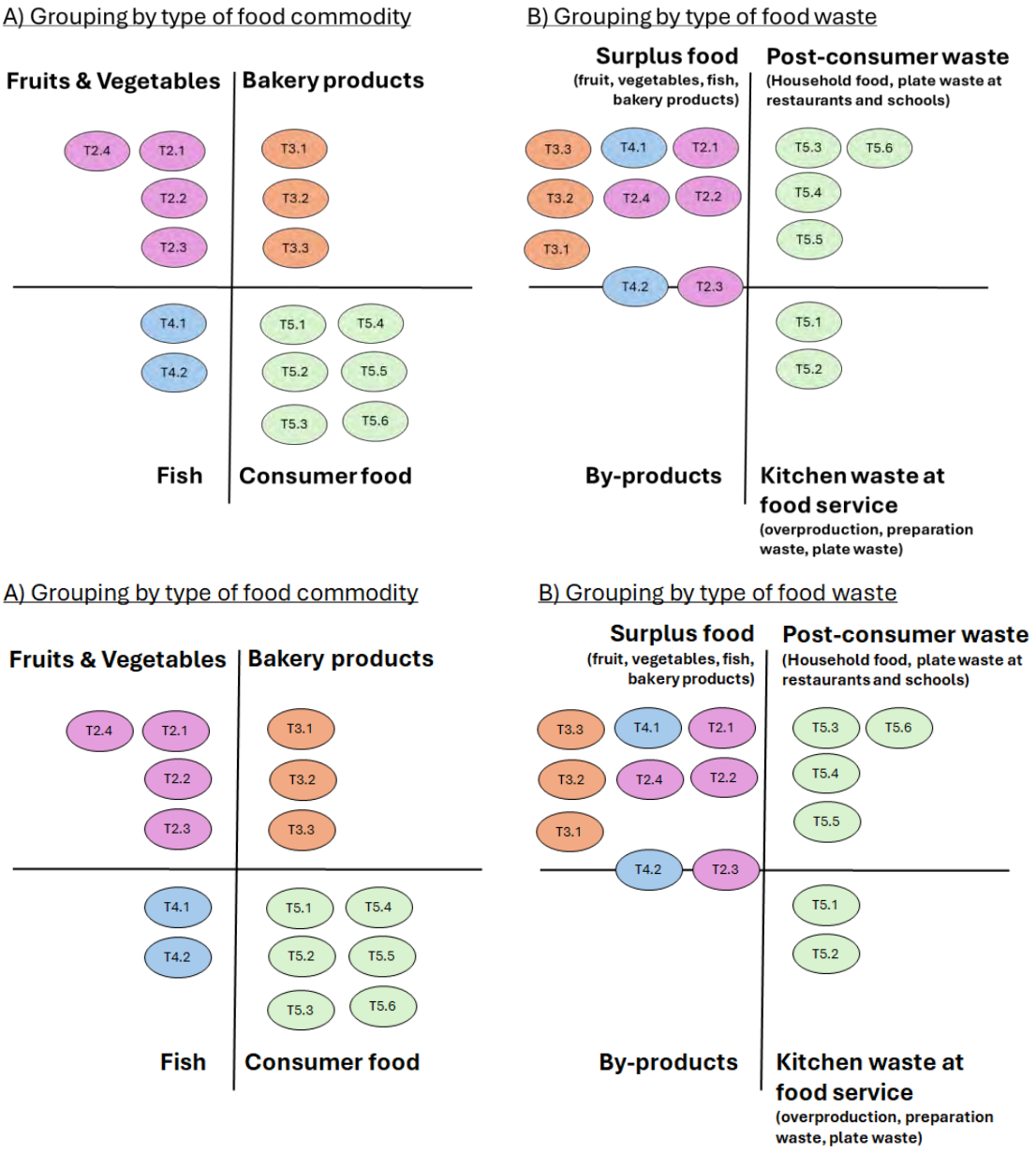
Figure 3: Grouping of LOWINFOOD's innovations by A) type of food commodity, B) type of food waste, C) design of action and D) type of action



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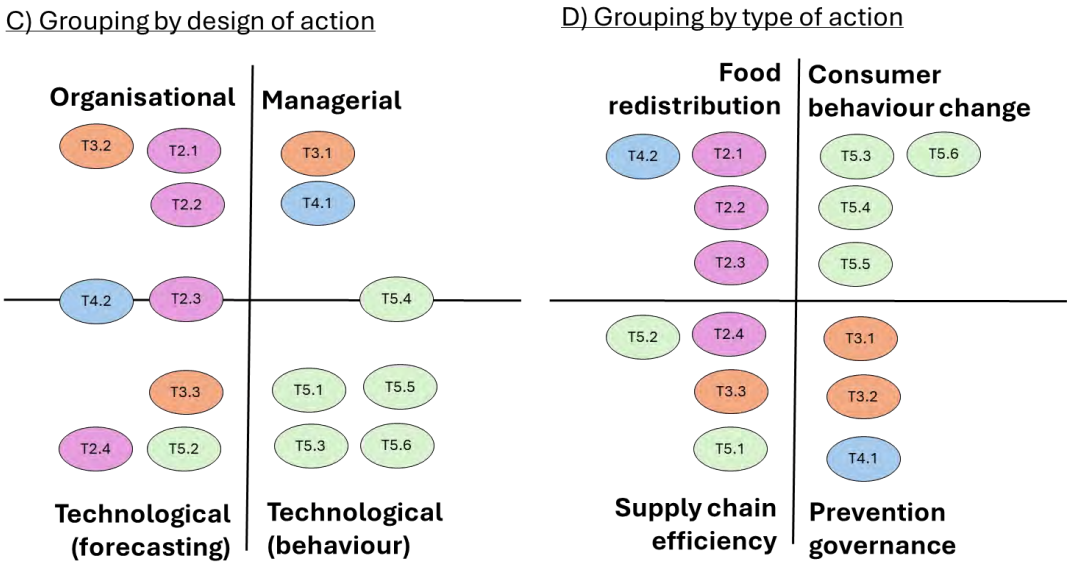

2.3. Food loss and waste (FLW) definition and types

LOWINFOOD uses the term 'food loss and waste' (FLW), which according to the definition developed in the FP7 FUSIONS project, 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). However, differently from the EU regulation (Commission Delegated Decision (EU) 2019/1597), which does not include in the definition the crops which are not harvested because they are not considered 'food' (regulation 178/2000), LOWINFOOD also includes losses at primary production since some of the LOWINFOOD innovations aim at recovering them too (T 2.2, T 4.1, T 4.2).

LOWINFOOD's innovations cover specific parts of FLW, where the general focus is on the avoidable; defined by Quested & Johnson (2009) as "food and drink thrown away that was, at some point prior to disposal, edible (e.g. slice of bread, apples, meat)" or by Lebersorger & 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, i.e., "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), can be covered in some innovations. Table 2 provides further description of FLW types and the associated LOWINFOOD innovations.

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Table 2: Type of food waste handled in LOWINFOOD's innovations

FLW type	Description	Innovations and LOWINFOOD tasks
Surplus food	Arising in the food production and distribution chain for a variety of reasons. and is defined by the European Union Guidelines on Food Donation (2017/C 361/01) (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: T2.1, T 2.2, T2.3, T 2T2.4 Surplus bread: T3.1, T3.2, T3.3 Surplus fish: T4.1,T4.2
Kitchen waste	Typically arising in restaurants, food service, and 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 European waste code covering types of waste which typically include food waste, this is covered in "20 01 08 - biodegradable kitchen and canteen waste".	T5.1, T5.2
Plate waste	Includes food that is served but not eaten. It is a subcategory 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) (Caldeira et al., 2017).	T5.1, T5.3, T5.4, T5.6
By-products	Defined as circular flows of food removed from the food supply chain to produce other products such as animal feed or biomaterials (Caldeira et al., 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 & Sala, 2018).	T2.3, T4.1, T 4 .2
Food waste at household (or post-consumer food waste)	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.).	T5.5
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).	T4.1, T4.2 T2.2

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3. Evaluation method

The socioeconomic evaluation has been carried out in steps, looking at benefits for different types of stakeholders involved in the project and is based on the framework for the data collection and impact analysis provided in D1.4 "LOWINFOOD Socio-Economic Data Collection Protocol" (Koseoglu et al., 2021).

The first part of the analysis is the socioeconomic impact assessment based on the data collected via two separate surveys: the management survey and the participant survey. A generalised template of the management and participant surveys used in data collection can be found in the deliverable D1.4 of the LOWINFOOD project (Koseoglu et al., 2021). This analysis is conducted in two parts: economic impact analysis and social impact analysis.

The economic analysis is conducted at organisation level (i.e., at the level of the entity which has tested the innovation: company, school, or household) and focuses on understanding potential economic gains at organisation level from the use of the innovation, based on the data collected via management surveys from the companies, schools and households that tested the innovation. The analysis looks at various aspects through different categories of indicators, as listed in Table 3 below.

The first group of indicators pertains to the profitability of the innovations. The main measure of profitability is the return on investment (ROI), especially in the case of commercial settings. The second group of indicators measure the changes in the scale of the business in terms of total sales, number of labour hours and the change in its customer and partner base resulting from demonstrating the innovation. Additionally, whether the innovation contributed to the input productivity of the users is measured and while this indicator is categorised under the third category, "competitiveness", it is also applicable to non-commercial establishments such as participating school canteens (in T5.3 and T5.4) and households (in T5.5) in terms of change in the number of meals per kg or per currency unit (EUR) of input, when the information is available for estimations.

Table 3: Indicators for economic impact

Profitability	Change in **direct input costs** (food inputs)
	Change in **fixed costs** due to the innovation (e.g., storage space)
	Change in **variable costs** due to innovation (e.g., energy, water)
	Change in organic **waste management costs**
	Change in the **selling price** of the product(s) involved
	Creation of new **income streams***
	Rate of return on investment
	Change in access to **subsidies** and/or other financial benefits such as tax breaks
Scale	Change in total value of **sales** of the product(s) involved
	Change in total **hours worked**, disaggregated by gender
	New **partnerships** established upstream and horizontally
	Downstream **diversification** (e.g., number and type of buyers)
Competitiveness	Change in the **productivity** of material inputs, or input-output ratio

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The third group of indicators pertains to the benefits for the wider supply chain and local community, are also captured in terms of spillover effects (e.g., whether other organisations took interest in or had already implemented the innovations as a result of recommendation of the companies testing them in the scope of LOWINFOOD project), creation of full time and part time local jobs (Table 4).

Table 4: Indicators for wider supply chain benefits

Creation of local jobs	Change in the number of **jobs**, disaggregated by gender*
Spill-over effects	**Technological change** in other companies*

The second part of the socio-economic analysis is the social impact analysis, which makes use of the data collected via "participant surveys" (see below). This part examines the change in the attitude and behaviour against food waste of those that took part in the implementation of the survey in the participating organisations. This analysis is carried out to understand unaccounted benefits of innovation implementation, and of the public research funding that enables these demonstrations, acting as an intervention in various settings, i.e., workplaces, schools and households, in terms of promoting wider behavioural change, which is critical for reducing food waste.

The **social impact** of the innovations at enterprise level (or, equivalently, at school level for T5.3 "Matomatic" and T5.4 "Holistic Educational Approach" and at household level for T5.5 "CozZo") was meant to be assessed through two indicators: **14**. Change in the awareness of the food waste problem of the staff and management (or participants in the dialogue or educational events or household members) of the food waste problem; and **15**. Change in the attitude towards reduction of food waste of the staff and management (or participants in the dialogue or educational events) towards the reduction of food waste.

According to D1.4 "Socio-economic data collection protocol" (Koseoglu et al., 2021), these had to be measured via "*self-assessment of concerns for, and commitment to, food waste reduction (Likert scale, from "a lot" to "not at all") by the respondent and by each of the employees involved in managing the food product transfer*" (p.21). This took place by means of statements that were meant to be individually assessed by each staff member directly involved in the demonstration of the innovation, including those with managerial roles. Appendix 1 in D1.4 reported a short participant survey with six exemplary statements, prepared by the JHI team, but their number was later expanded, as detailed below.

Hereafter, we will refer to the survey used to assess attitude and awareness as "participant survey". The participant survey was disseminated among employees of the companies, students at the schools, and members of the households implementing the Lowinfood innovations. The same survey was completed before ("baseline") and after the respondents had been involved in the implementation of the innovations ("post-implementation").

To construct the participant survey (in particular, to define the statements to be scored by participants), the JHI team first conducted a literature review of previous studies that had used the Theory of Planned Behaviour (TPB) (Ajzen, 1991) to explore changes in pro-

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environmental behaviour resulting from interventions. Several cycles of review were implemented: with psychologists and sociologists experienced in survey design, followed by three individual test sessions; with the LOWINFOOD partners involved in the evaluation of the innovations; and with the partners involved in specific innovations as data controllers. This allowed the team to simplify and clarify the statements as much as possible before the survey was translated into local languages. The final version of the Likert scale included 33 statements, to be assessed along five levels of agreement, from "strongly agree" to "strongly disagree". No opt-out option was included. however, the intermediate option was "neutral", and the respondents did not have to rank all the statements to proceed.

As a result of the literature review above, the evaluation process was enriched by measuring seven constructs corresponding to an adapted version of the TPB, rather than simply "attitude" and "awareness". The seven constructs, which represent our new **social indicators**, are listed in Table 5.

Table 5: Constructs used as indicators to measure social impact

Attitude	Individuals' positive or negative feelings about performing a specific behaviour, in this case wasting food
Subjective norm	The perceived social pressure to behave or not behave in a certain way that the respondents experience in their social circles (family, friends, colleagues, etc.).
Perceived behavioural control	Proxy for measuring how respondents perceive their ability and the means available to them to behave in a certain way (hereafter, PBC).
Moral concern	An individual's personal beliefs about the moral correctness, or incorrectness, of performing a specific behaviour.
Intention	Proxy for the commitment of the individual to reducing waste In the food waste reduction context.
Situational factors	Access to facilities or resources that may enable or restrict the behaviour in a certain way.

Each of these indicators was measured using at least three statements. When possible, we avoided asking directly about participants' individual food waste, to prevent responses that could be consciously or unconsciously biased due to "social desirability" (Giordano et al., 2018). Additionally, to prevent acquiescence bias, some of the statements were formulated in the opposite direction.

Table 6 below illustrates the statements, their aggregation into the indicators, and the internal consistency of the latter, measured by the Cronbach's alpha.

Conventionally, 0.7 is deemed the minimum acceptable level of this index, but despite several attempts and removal of some statements which showed a lower correlation with the others, it could not be achieved for the indicators "subjective norms" (0.57) and "behaviour" (0.36).

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Table 6: Likert scale statements used in the survey questionnaire, and related indicator

Indicator	Variable name	Statement	Cronbach's alpha	Hypothesis[1]
Attitude	waste_quan	Everyday huge quantities of food are wasted in the world	0.704	+
	planet	The daily amount of food waste is a serious problem for the planet		+
	economic	Food waste is a major economic issue		+
	resources	Wasting food is wasting other resources such as water and energy		+
	waste_inevi	Wasting food at home is inevitable (*reversed item*) (*not used in the indicator*)		-
	waste_impos	It is impossible to avoid food waste at workplace (*reversed item*) (*not used in the indicator*)	n/a	-
Moral concern	worry	The problem of food waste worries me a lot	0.740	+
	waste_irres	Wasting food is irresponsible		+
	guilty	When I waste food, I feel guilty		+
	responsible	Everybody has a responsibility to reduce food waste		+
	principle	Wasting food does not go against my principles (*reversed item*)		-
Subjective norm	socie_care	Many people in our society do not care about their food waste	0.566	+
	hh_support	My household supports my efforts to reduce food waste at home		+
	colleagues	My colleagues support my efforts to reduce food waste at work		+
	pressure	I feel social/peer pressure to avoid wasting food (*not used in the indicator*)	n/a	+
Perceived behavioural control (PBC)	know_hh	I know what to do to reduce food waste at home	0.757	+
	know_eatout	I know what to do to reduce food waste when I eat out		+
	know_restaur	I know what to do to reduce my food waste when eating at a restaurant		+
	know_work	I know what to do to reduce food waste at work		+
	control_wp	I have control over the amount of food waste produced in my workplace		+
	control_hh	I have control over the amount of food waste produced in my household		+
	recycle	I have the ability to recycle my unavoidable food waste such as the inedible peels, pits and stones of fruits and vegetables, bones in meat and fish etc. (*not used in the indicator*)		+
Intention	not_care	I do not care if I waste food (*reversed item*)	0.736	-
	waste_hh	I am committed to reducing food waste in my household		+
	waste_work	I am committed to reducing food waste in my workplace		+
Situational factors	hassle_hh	Reducing food waste in my household is a hassle (*reversed item*)	0.767	-
	waste_time	Reducing food waste requires a lot of time (*reversed item*)		-
	waste_tech	To reduce food waste in my household I need to buy new equipment/new technology (*reversed item*)		?
	council	The local council provides satisfactory resources for recycling food waste (*not used in the indicator*)	n/a	?
	recycle_wp	My workplace provides satisfactory resources to recycle food waste (*not used in the indicator*)		?
Behaviour	food_spoil	I regularly throw away food that I could have consumed due to food spoiling (*reversed item*)	0.364	-
	rarely_waste	I seldom throw away food that could have been eaten because I have bought too much		+
	prepare_waste	I sometimes throw away food that could have been eaten because I have prepared too much food (*reversed item*)		?

Notes: [1] Direction of the hypotheses: **+** indicates an expected increase in the value of the indicator between the baseline and post-implementation surveys; **-** an expected decrease; ? no expected change.

As specified in Table 6 we hypothesise that as a result of being involved in the demonstration of the innovations, the level of agreement with the statements formulated positively increases, while the level of agreement with those formulated negatively decreases; for some statements, we could not formulate a directional hypothesis. Before aggregating them into the indicators, to facilitate the reading of the results, some statements were reversed; consequently, higher values of the indicators always indicate a situation more favourable to food waste reduction (more virtuous behaviours and intentions, higher perceived behavioural

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control (PBC), etc.). As part of the social impact, we also conduct a gender analysis to understand the patterns of representation and inclusion. We use the socio demographic data captured in the management and participant surveys to understand how different genders are represented in the participating organisations, either in decision making or hands-on implementation roles, and if and how their satisfaction with the participation in our research changes by gender.

The data required for this part of the evaluation is also collected via participant surveys in Appendix 1. Besides the 33 statements measuring the impact of innovations on the individuals that were in involved in the demonstrations, the participant survey also included socio-demographic questions (age, gender, education); questions related to the role of the respondents in their organisation (where relevant) and in the management of the innovation; the duration of their involvement in its implementation; and their level of satisfaction with the survey. These are used to generate and assess the change in the **gender-related indicators**. [3] Table 7 lists the indicators used in gender analysis.

Table 7: Indicators used in the gender analysis

Vertical segregation	**Share of genders** involved in implementing the innovation **by job grade**
Horizontal segregation	**Share of genders** involved in implementing the innovation, **by sector**
Share of genders	**Share of genders out of the total** number participants
Survey satisfaction	**Share of genders** among participants who **assess the survey positively**

Two respondents in the baseline survey (all in Holistic Educational Approach) and nine in the post-implementation one (five in Holistic Educational Approach, one in FoodTracks, two in Matomatic and one in Kitro) preferred **not to declare** their gender, and one in each phase (in Holistic Educational Approach) preferred to **self-describe** as "gender queer."[4] These numbers do not allow to implement a meaningful statistical analysis for either the group of non-binary respondents or the group of those who preferred not to declare their gender. Therefore, they are not included as separate groups; however, to avoid ignoring their responses, for the innovation types where they are present, they are aggregated together with the group of male respondents, who is relatively smaller compared to female respondents. Indeed, women as main caregivers traditionally bear most of the burden of food management, and thus represent a sensitive category in the analysis of food related behaviours, including food waste behaviour. Therefore, our main focus here is on whether *women* (self-defined) differ significantly from the rest of the respondents, which will be named "males" if only comprising males, and "others" if including various genders.

The economic impact analysis additionally looks at the impact of public research funding on innovation providers, which within the LOWINFOOD project are exclusively start-ups, except for the Emilia Romania Region, and other non-research organisations that took part either

[3] The question for gathering the respondents' gender was "What is your gender?", and four options were provided: Female / Male / Other (please state in your own words) / Prefer not to say."

[4] Additionally, for four people (two in Holistic Educational Approach and two in Matomatic) who selected "Other" and reported meaningless responses, the gender is recorded as missing.

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as a sectorial support organisation or as compensated users of the innovation (i.e., hotels in Greece). The purpose of this part of the analysis was to account for additional benefits of public funding and how these benefits could be improved in similar projects and consortia in the future. Although the initial aim was to measure the financial benefits quantitatively via online surveys, after the difficulties experienced in data collection via management surveys, we switched to a more qualitative approach by conducting online qualitative interviews to capture benefits that the non-research project partners have received from their involvement in the LOWINFOOD project and public funding they received from the project.

Table 8: Main indicators used to measure the benefits of the project to the non-academic partners

Profitability	Creation of new **income streams**
	Development of **new products and services**
	Improvement in **Technology Readiness Level** of the innovation
	Change in access to **subsidies** and/or other financial benefits
	Change in total value of **sales** of the product(s) involved
Networks	New **partnerships** established upstream and horizontally
	Engaging in **new research consortiums or partnerships**
	Introduction to **new regions and market**
Creation of local jobs	Change in the number of **jobs**, disaggregated by gender
	Change in total **hours worked**, disaggregated by gender

This analysis also aims to explore the potential added benefits of the LOWINFOOD project for the non-academic partners that took part in the consortium and uses several of the economic indicators used in the management survey. Table 8 lists the indicators used. The qualitative interviews were conducted with LOWINFOOD consortium contact people in each organisation. The generalised interview script is included in D1.4 and in Appendix 2.

The rest of the evaluation is structured as below. In Section 3.1, we briefly expand on data collection via surveys and on the results of the participant survey sample data at project level; in Section 3.2, we provide the results of the socio-economic impact analysis by innovations or innovation types. The results of the economic impact analyses will be reported at individual innovation level, while the results of the social impact and gender analysis will be reported at action type category level (as indicated in Figure 3d), as not all innovations had sufficient participants (i.e., data points) to run reliable statistical tests at individual level.

In Sections 3.2, 3.3 and 3.4, the results of the non-research consortium partner interviews will be reported at overall sample level and further discussed based on the type of organisations, i.e., start-up providing innovations; supporting organisations providing sectorial contacts; and users of the innovation, to keep the interview respondents' identities confidential. The evaluation section will finish with section 3.5, which will report the results of the gender analysis, and Section 3.6. with result of the benefits experienced by non-research partners of the consortium. The results will be discussed in Section 4 and further conclusions and recommendations will be made in Section 5.

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4. Evaluation results

4.1. Data collection efforts

The management surveys were implemented by innovation task leaders. Different modes, i.e., online surveys via Lime Survey, in-person interviews or on-paper surveys, were administered to facilitate the management of the test locations to respond the baseline and demonstration phase management surveys at their convenience.

It has to be mentioned that not all the economic indicators identified via literature review and in consultation with T1.3 partners, as listed in Table 3 and Table 4 and further detailed in D1.4 (Koseoglu et al., 2021), were relevant for the purpose of each specific innovation, nor could be captured in the set-up of the specific test location (e.g., not having separate bills by kitchen or canteen prevented the estimation of change in variable production costs in some canteens; food provided by the local administration for reasons different from profit making or cost recovery, thus reduction in cost of the meal provision is not relevant for such test locations). This was mitigated by local research partners tailoring the management surveys implemented at the test location in consultation with the JHI team and innovation providers. As a result, management data sets are not uniform across the innovations.

When available, other secondary data complemented management data responses in the estimation of relevant economic indicators as revealed data. In the absence of regular recording and monitoring, the measurements were more reliable than stated management survey responses. For some innovations, the financial cost of waste was captured automatically (e.g., T5.1 Kitro), or the information automatically captured in the platform were monetised via the efforts of innovation task leaders (e.g., T3.3 FoodTracks). In other instances, some components of food waste were measured as part of the innovation (e.g., plate waste measurements in T5.3 Matomatic) or waste was manually measured and recoded either by the members of the participating organisations/households or by the local academic partners' staff (e.g., artisanal bakeries in Italy taking part in T3.2-bakery supply chain dialogue; T5.4 Austrian school in Holistic Educational Approach and T5.5 Households demonstrating Cozzo) .

Similarly, data captured automatically enabled us to run additional analysis (e.g., information of discounted meals ordered from each participating restaurant on REGUSTO in combination with prices in the menu allowing us to speculate about cost savings for customers and actual amount of additional income created via the app). In some locations, management surveys could not be completed (T5.1 Greece and T5.3 Germany) and the economic impact estimations were entirely based on data captured on devices.

Additionally, not all the time relevant data could be collected by the management of locations testing the innovation due to various reasons, ranging from Covid-19 restrictions during the project, computer literacy, not having enough time for recording data, or having other priorities such as keeping their business afloat during soaring energy costs, interest rates, and increase in cereal prices due to the war in Ukraine (Devadoss & Ridley, 2024), or users' losing interest in the innovations (Strotmann, Gerwin, Eriksson, et al., 2023). In these occasions,

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secondary data was provided by **innovation task leaders** familiar with the local situation; specific supply chain (e.g., bakery) and prices are used when possible.

The social impact analysis, on the other hand, was more structured and uniform across the innovation and participating locations. Indeed, the participant survey was digitised in Qualtrics by the JHI T1.3 team and the questions and statements were modified, and automatic translation was improved with the input of innovation task leaders. The innovation task leaders were provided an individual link to be distributed for the baseline and demonstration phase of the specific innovation they led.

Depending on the innovations, the baseline dissemination took place between the end of March 2022 and the end of June 2024; the post demonstration dissemination, between the end of May 2022 and mid-July 2024. The intensity of response varied depending on the period. Users answered in their local language. In most instances, they were provided a QR code or a link to the survey and assigned an organisational identifier. In some cases (e.g., T5.5 "CozZo" and T2.2 "Unverschwendet"), the task leader used another online data collection tool (e.g., Lime survey), or distributed paper questionnaires.

The uniformity of survey statements across the tasks allowed us to create a large sample and make estimations of social impact on the individuals at project level. The sample characteristics and higher-level estimations are summarised below in Tables 9 and 10.

The data was collected from the users of most of the innovations assessed within the LOWINFOOD project in the fruit and vegetable, bakery, and fish supply chains, as well as with consumers in the households, catering, and tourism sectors. These include T2.1 "Regional online platform", T2.2 "Unverschwendet", T2.4 "Sales forecasting software" (more precisely, Pianeta Cospea), T3.2 "Bakery stakeholder dialogue", T3.3 "FoodTracks", T4.1 "Fish stakeholder dialogue"[5], T5.1 "Kitro", T5.2 "Mitakus", T5.3 "Matomatic", T5.4 "Holistic Educational Approach", T5.5 "CozZo", and T5.6 "REGUSTO". No responses were obtained from T2.3 and T4.2 "Leroma," since no company registered to use the platform to exchange materials in the supply chains of fresh fruit and vegetables or fresh fish, and from T3.1 "Innovative supplier-retailer agreement," since the innovation was not actually demonstration but rather assessed through a simulation.

To ensure confidentiality, no identifier of the individual respondent was included, but rather of their organisations or households. This decision was also due to staff turnover: the respondents to the baseline survey were not necessarily the same as to the post-demonstration survey, although in most instances they likely were, since we dealt with small organisations across a short demonstration period. Additionally, for some innovations it was not possible to obtain a baseline measurement from the demonstrating organisations because they had started using the innovation before the beginning of the project. In these cases, the baseline was obtained by disseminating the survey among users from similar organisations in the same locality, or other departments of the same organisation.

[5] Only baseline data were collected due to the nature of this social innovation, which was not expected to produce a short-term impact, and because it is still being demonstrated as of the date of analysis.

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Table 9 below reports synthetic information about the number of respondents by innovation and phase, while more details are provided in Section 3. The total number of responses is 532, of which belong to 288 baseline, and 244 post-demonstration period. Most responses (388) were obtained in the framework of innovations focused on "consumers' behavioural change", followed by those targeting "supply chain efficiency" (81), those aimed at "food redistribution" (44), and finally, "food waste prevention governance" actions (19). The household respondents are 117 (all those involved in the demonstration of CozZo), the students 179 (150 involved in the Holistic Educational Approach and 29 in Matomatic), the employees of the organisations demonstrating the innovations (including both employees proper, and managers or owners) 236. In terms of countries, Austria is the most represented with 249 responses, followed by Germany with 68, Sweden with 58, Greece with 54, Finland with 43, Italy with 42, Romania with eight, and the United Kingdom (Scotland) and Switzerland with five each. Given the small sample sizes in some instances, the analysis in Section 3 is not demonstrated at the level of the single innovations but for the four innovation categories in turn.

Table 9: Distribution of survey responses by innovation, innovation type, and phase

Innovation category	Innovation	Baseline	Post-impl.	Total
Food waste prevention governance	Bakery stakeholder dialogue	7 (IT)[3]	6 (IT), 1 (FI)	14
	Fish stakeholder dialogue	5 (UK)	0	5
Consumers' behavioural change	Matomatic[1]	8 (AT), 11 (DE), 6 (SW)3	22 (AT), 9 (DE), 14 (SW)	70
	Holistic Educational Approach[1]	99 (AT), 14 (SW)	64 (AT), 24 (SW)	201
	CozZo[2]	23 (AT), 22 (FI), 15 (GR)	22 (AT), 20 (FI), 15 (GR)	117
Supply chain efficiency	Sales forecasting	2 (IT)	2 (IT)	4
	FoodTracks	17 (DE)	6 (DE)	23
	Kitro	5 (CH), 12 (DE), 13 (GR)	5 (DE), 11 (GR)	46
	Mitakus	5 (DE)	3 (DE)	8
Food redistribution actions	Regional online platform	6 (IT)[3], 4 (RO)	7 (IT), 4 (RO)	21
	Unverschwendet	7 (AT)[3]	4 (AT)	11
	REGUSTO	7 (IT)	5 (IT)	12
Total		288	244	532

Notes: [2] Household members; [1] Partly students, partly employees; [3] Baseline obtained from similar organisations or organisational departments not involved in the demonstration of the innovation. AT = Austria, CH = Switzerland, DE = Germany, FI = Finland, GR = Greece, IT = Italy, RO = Romania, SW = Sweden.

Before presenting the results in terms of change in the **indicators** between the baseline and the post-demonstration phases, we provide an overview of their **values**, which represent a normalised average (across the two phases) of the values of the statements contributing to each indicator.[6] Descriptive statistics for the two phases separately and for all the innovations jointly, are provided in Table 10 below. The mean values of the indicators are close to zero, as expected, while their ranges suggest a strong negative skewness, i.e., a small number of respondents characterised by value very unfavourable to FLW prevention and

[6] Although comparing the values across innovation types suggests that the users of specific innovation types started from more favourable values, we suggest that readers focus on the change only.

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reduction, and a large number of respondents characterised by virtuous attitudes and behaviours. These patterns are similar in both phases. Both in Table 10 and in the tables showed in Section 3, the difference is tested statistically using one-tailed or two-tailed *t*-tests, as specified in the notes to the tables. At the whole sample level, only "Moral concern" improves significantly after the demonstration of the innovations. Through their direct involvement, participants probably got more conscious of the food waste problem, which might in turn help the businesses turn their practices against food waste into actual behaviours – although more research would be needed to validate this hypothesis.

Table 10: Values of the indicators across dissemination phases

Indicator	Baseline				Post-demonstration				*p*-value[1]
	Mean	St. dev.	Min.	Max.	Mean	St. dev.	Min.	Max.	
Attitude	-0.02	0.66	-2.86	0.74	0.02	0.69	-2.92	0.74	0.277
Moral concern	-0.04	0.74	-2.49	0.86	0.05	0.66	-2.49	0.86	0.059*
Subjective norm	0.01	0.73	-2.73	1.08	-0.01	0.74	-2.73	1.08	0.616
PBC	0.00	0.63	-1.62	1.11	0.00	0.64	-2.52	1.11	0.470
Intention	-0.01	0.80	-2.83	0.81	0.01	0.82	-2.42	0.81	0.418
Situational factors	0.02	0.82	-2.35	1.09	-0.03	0.83	-2.35	1.09	0.769
Behaviour	-0.03	0.67	-1.84	1.21	0.04	0.66	-1.55	1.21	0.111

Notes: [1] One-tailed *t*-test of the difference in the value of the indicator between phases. Significance level: * 0.10.

4.2. Impact of the 'FW prevention governance' innovations

In this section, first the economic impact analyses of Tasks 3.1, Task 3.2, and Task 4.1 is covered individually, based on management surveys. Then, the social impact analysis is conducted for all the FW prevention governance innovations jointly based on the results of the participant surveys collected from those involved.

4.2.1. Economic impact of 'FW prevention governance' innovations

Task 3.1 Supplier-retailer agreements

Task 3.1 mapped the quantities of baked goods sold at retail level in Sweden and identified the potential pathways for surplus bread sold under "take back agreements" (TBAs). TBA is a common practice in the industrial supplier-retailer interface that leads to surplus in the Swedish baked goods supply chain. Task 3.1 simulated the potential outcomes of different scenarios at national level using company records and secondary data. Therefore, participation of individual companies in the task was not relevant and actual or potential change resulting from the innovation at company level cannot be measured. Therefore, no management and participant surveys were filled in for the analyses of indicators of profitability, competitiveness, wider supply chain benefits or social change.

The data used in the simulation model in T3.1 came from multiple sources, including data disclosed during the Swedish part of stakeholder dialogue detailed in T3.2 and secondary

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sources of information (Bartek. et al., 2024). The quantification of private-label bakery products concerned the same five major retailers (supermarkets), as used in national statistics reported by Statistics Sweden for 2022. These values were extrapolated at national level based on market share, Information on waste rates, sales and annual production of private-label and bake-off bakery products was collected via correspondence with bakeries and private actors and supported (Bartek. et al., 2024) . A second round of stakeholder dialogue was then conducted with relevant industry actors to verify the quantification estimates and to adjust the scenarios according to their input (Bartek. et al., 2024).

Results estimated at national level showed that nearly 180,000 tons of baked goods equivalent to roughly 8.9 billion SEK[7] are wasted every year. 51% of this wastage originate in the supplier-retailer interface. In the supplier retailer interface TBAs play an important role, especially in savoury bread, 76% of which is produced by industrial bakeries and sold under TBAs, where 14% of production, annually corresponding to 27,000 tons of bread. While TBA in itself does not create waste directly, but its potential cascade effects lead to surplus at the supplier-retailer interface.

The simulation exercise explored six different conceptual scenarios identified in the literature and during stakeholder interactions in T3.1, and simulated the impact of different improvements applied either within the current system or without TBA in place (Bartek. et al., 2024). In the socio-economic impact analysis of this task, we focus on the potential cost saving outcomes of the scenarios. We consider the conventional TBAs scenario as the baseline and report the comparative cost saving in each alternative intervention scenario. The potential amount of waste created and the economic value of the potential amount of bakery products that can be saved in each scenario are summarised in Table 11.

Among the simulated scenarios covered in Table 11, sharing data, optimised shelves, and food donations are solutions with TBAs still in place. These also explored that removing the TBA is not very likely to happen. Other simulated scenarios like the retail ownership require the removal of TBA. According to the estimations in Bartek et al. (2024), the most favourable outcomes are achieved in the scenarios of loss rates and best practices. The loss rate scenario simulated the joint benefits at both bakery and retail level by combining the loss rates used in sharing data scenario with the retail loss rates and waste management used in the retail ownership scenario. In the best practices scenario, TBA system was maintained, yet applying the lowest waste rates at bakery and retail level and allowed retaining the high-value pathways for surplus revalorisation (Bartek et al., 2024).

The potential cost saving estimations for the bread producers are based on retail price of bread in Sweden adjusted by the ratio production cost (0.65) to the retail price in the industrial baked good trade in the UK (Jack et al., 2022) as it was not possible to find this figure for Sweden.

[7] For € per ton figures are based on the price of a "*Lingongrova*" loaf (25 SEK per 500 g), marketed as *"Sweden's most purchased bread"* (Bartek. et al., 2024) According to the conversion rate at the time 50 SEK corresponds to 4.40 Euros.

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Table 11: Outcomes of different scenarios simulated in T3.1 in comparison to conventional TBAs scenario

	Sharing data	Optimised shelves	Food donation	Retail owner-ship	Co-logistics	Loss rates	Food hierarchy	Best practice
Reduction in surplus (ton/year)								
Bakery	7,000	0	0	0	0	7,000	0	7,000
Retail	8,000	8,000	6,000	14,000	0	14,000	0	14,000
Total	14,000	9,000	6,000	14,000	0	20,000	0	20,000
Reduction in surplus value (€/year)								
Bakery	12,861,550	0	0	0	0	12,861,550	0	19,787,000
Retail	14,698,914	14,698,914	11,024,185	25,723,099	0	25,723,099	0	25,723,099
Total	25,723,099	16,536,278	11,024,185	25,723,099	0	36,747,285	0	36,747,285

Task 3.2 Stakeholder dialogue in the bread value chain

Stakeholder dialogues in the bakery supply chain explored together with participating industry stakeholders new social and organisational solutions to reduce and prevent the loss and waste of bread products along the whole value chain. The dialogues took place in three EU countries, Italy, Finland and Sweden, between November 2021 and September 2022.

The dialogues included discussions about the current problems and how they could be solved, and these efforts resulted in roadmaps co-created with the supply chain stakeholders involved in the dialogues in each country. The socio-economic impact results are reported for each participating country separately because the creation process of roadmaps, how and what type of data was collected differed depending on the country due to substantial differences in how the bread market functions and the role of different stakeholders (Mesiranta et al., 2022).

In Finland, the dialogue with the bread value chain actors included two types of activities – online workshops organised for bakeries and interviews with bakeries and retailers. Four online workshops with 2-4 bakeries and a representative from the Finnish Bakery Federation were held between January and September 2022. In addition, six interviews were held with other bakeries and four with retailers individually between May and September 2022. The interviews with bakeries focused mostly on large bakeries, whereas the participants in the online workshops were small to medium-sized bakeries (Mesiranta et al., 2022). The retailer interviews included representatives from all of the three major food retailers in Finland and various participants with managerial roles in these organisations (Mesiranta et al., 2022).

The information collected in the stakeholder dialogues was qualitative and not focusing on individual companies involved but on overall experiences in the bakery industry in Finland. The demonstration of any management or participant survey was not possible under the circumstances in which the data collection efforts aimed solely at the co-creation of the bakery industry roadmap. Deliverable D3.2 identifies the common issues leading to surplus in

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the bakery supply chain and comes up with actionable recommendations for the industry to address these issues (Mesiranta et al., 2022). However, the roadmap developed in the Finnish bakery supply chain has not been used during the project.

In Sweden, two rounds of stakeholder dialogue were conducted with five industry actors operating within the Swedish take back agreement (TBA) system. The five partners included two industrial bakeries, retailers and logistic companies (Mesiranta et al., 2022). The qualitative information shared in the first round of these engagements were used in the simulation of alternative scenarios of bakery products sold under TBAs covered above in T3.1. The data disclosed by industry actors on surplus bakery products generated at bakery and retail level were aggregated, and the extrapolation variable used was market share based on sold products per year.

Table 12: TBAs annual effect on the creation of returns and resulting cost to the participating producers

Company code	Production volume (tons/year)	Production losses or production waste (tons/year)	Return volumes from retailers (tons/year)	Average production cost ** (€/kilo)	% of production losses in total production	% of returns in net production ***	Cost of returns to producers (€/year)
C1	116000	2320	8350	3.51	2	7	29309
C2	61000	4470	5330	3.38	7	9	18015
C3*	46000	3700	1700	3.45	8	4	5857

*C1 and C2 production and loss volumes are for year 2020. However, these volumes are 2019 figures for C3. It is assumed that C1's production and losses stayed the same between 2019 and 2020. ** We averaged the retail sale prices of the three main products provided by the bakery production facilities themselves. In the absence of share of production by product, no weights are applied. We assumed the average item to be 0.5 kg to estimate the €/kg price of the bread and assumed 0.65 conversion rate between retail price to production costs based on figures available for the UK in the absence of the same ratio for Sweden (Jack et al., 2022) *** The net production is estimated by deducing production losses from the annual production volume.

The baseline management surveys were filled in by five producers of soft bread products, two of these companies focus only on packed products with fixed shelf life and the other three sell both packed and frozen items. The roadmaps co-created with supply chain stakeholders in Sweden has not been used by the stakeholders during the LOWINFOOD project either, so a second management survey to capture the change resulting from the roadmap was not needed. The lack of demonstration period information prevents any analysis of profitability, competitiveness, and wider supply chain benefits or behavioural change of the potential demonstrated of the roadmap. However, we used the data collected through baseline surveys to comment on the potential economic loss from surplus at these specific producers' end, as a result of the current TBAs in Sweden (Table 12).

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Surplus materials, including returns from TBAs are currently valorised in ethanol production (over 90% of surplus at C2 and C5[8]) and animal feed (60% at C3). It is reported in the baseline management surveys that through these valorisation routes some money is earned, usually ~0,1€/kg (100 €/ton) bread for animal feed and ethanol production. While prioritising cost savings from potential prevention of loss caused by TBAs, higher value valorisation routes (e.g., selling stale bread for crumbs etc.) for unavoidable returns and losses can also contribute to profitability in conditions when returns and surplus are inevitable.

In Italy, the stakeholder dialogue meetings took place in November 2021, March 2022, and May 2022 and ran in coordination with the Swedish and Finnish side of the bakery sector stakeholder dialogues. The structure of the Italian bakery sector is peculiar with around 28 thousand bakeries. In Italy, small craft (e.g., artisanal) bakeries produce 84.1% of the fresh bread marketed in Italy (data referred to the year 2021) and these bakeries typically also sell bread at their own stores, besides supplying supermarkets (Mesiranta et al., 2022). As a result, the stakeholder dialogue in Italy was partially different from the dialogues in Sweden and Finland. Dialogues In Sweden and Finland, included large industry players in various stages of the bakery sector (i.e., production, retail, logistics) and solely focused on craft bakeries when co-creating a roadmap suited to their surplus.

Through collaboration with the Italian Confederation of Craft Trades and Small- and Medium-Sized Enterprises, (CNA), 12 bakeries[9] in Viterbo and Civitavecchia in Central Italy were engaged in waste measurement actives and three moderated meetings, content of which were coordinated with meetings in Sweden and Finland. The meetings were organized with the participating stakeholders to set up the activities and to develop the final roadmap (Mesiranta et al., 2022).

In Italy, the baseline measurements lasted for five months between 1st February 2022 and 30th June 2022; 16 branches from 12 participating bakeries kept a diary provided by the CNA to record their daily production quantity and surplus quantity at the end of the day for the three most popular bakery products[10]. At the end of this process, actions against waste in the bread supply chain were identified as a result of three stakeholder meetings, last of which took place in May 2022 (Pietrangeli et al., 2024).

The demonstration took place exactly one year later in the same period between 1st February 2023 to 30th June 2023 and daily production and surplus amounts were recorded using the same diaries in 10 branches that were still engaged in the task in 2023. During this time some actions identified in the co-created roadmap (as detailed in D3.6) (Pietrangeli et al., 2024) were implemented. The measurements in this second period aimed at monitoring the impact of taking the actions recommended in the Roadmap document on the surplus amount

[8] C4 and C5 not included in Table 12 as components of data on production volume, production losses, return volumes from retailers used in analysis and listed in Table 12 in this was not reported by the C4 and C5

[9] Initially 12 bakeries, running a total of 16 branches, took part in recording their daily production and surplus amount. However, in the demonstration period only 10 branches of 7 companies continued with the recording, therefore the analysis could only be based on these 10 organisations.

[10] Three main categories in which the daily production and surplus records were kept for are common bread, focaccia bread and Italian bread rolls such as *rosette*, *sfilatini*, *panini all'olio*.

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and management. It is useful to indicate here that the production pattern and scale of the bakeries are quite similar to each other, with the exception of IT02 and IT04, which are much smaller in annual production compared to the others (Table 13).

Table 13: The production (or supply) pattern and scale in the participating bakery stores

Bakery store	% of 3 main items considered in company's total production	Total production of the company (kg/year)***	% share in production among participating bakeries ***	Average surplus (kg/day)-baseline	Average surplus (kg/day)-demonstration
IT02	84.24%	30000	4.26	2.63	8.19
IT04*	73.26%	75000	10.64	1.39	3.68
IT05*	73.26%	75000	10.64	1.67	6.75
IT07	74.80%	60000	8.51	2.00	4.23
IT08	86.40%	100000	14.19	0.80	9.45
IT09	74.90%	75000	10.64	4.00	6.08
IT11**	88.61%	88110	12.50	3.00	10.85
IT12**	88.61%	88110	12.50	3.20	9.69
IT13**	88.61%	88110	12.50	1.80	9.40
IT14	83.06%	25450	3.61	1.00	5.53

*IT04 and IT05 are stores that belonged and supplied by the same company. ** IT11, IT12, IT13 are stores that belonged and supplied by the same company. *** total annual production of each participating company and the share of each participating bakery store are included to indicate the differences in scales between participating locations.

The results of measurements and self-declared survey data are discussed jointly. There was no demonstration period management survey, because the cost figures for production and waste disposal in the baseline survey were reported as unchanged during the measurement in 2023. Also 10 branches that continued with measurement did not report any changes linked with the stakeholder dialogue or the "Roadmap – A Hand Against Waste" in the indicators of "competitiveness" and "wider supply chain". Thus, we will focus on potential changes in profitability indicators, namely production and waste disposal costs, based on average surplus amounts measured between 2022 and 2023. The results based on daily measurements are summarised in Table 14.

Based on these figures only the results from IT09 are exactly in line with expectation, i.e., reduction in both the volume and sale value of surplus. If we use the production volumes in Table 13 as weights, the average change in the difference of monetary value of surplus has increased €8.03 a day across 10 bakeries. On average €8 more worth of items were classified as surplus after the innovation compared to before. Without weights, the increase in the average monetary value of surplus across 10 bakeries is 6.77 €/day. The value of surplus in comparison to sales (r€) is as negligible as 0.017% with an average of around 2.5% across the sample, however the surplus increased in all bakeries except one. In one particularly bakery

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(IT13), this increase is significant at 17% and translates into an additional daily cost of €20. The conditions of the specific bakery should be further discussed.

Table 14: Changes in daily waste measurement and value of measured waste between the two measurement periods

Bakery store	Reduction in rq* common bread	Reduction in rq focaccia	Reduction in rq bread rolls	Reduction in surplus (kg/day)	Reduction in average r€**	Reduction in average value of surplus (€/day)
IT02	1.94%	-2.38%	-3.46%	-5.56	-0.07%	-5.11
IT04	2.35%	Not available ***	-0.73%	-2.29	-0.19%	-1.37
IT05	-5.51%	Not available ***	0.59%	-5.08	-2.83%	-7.59
IT07	2.37%	-12.14%	2.77%	-2.23	-0.59%	-0.19
IT08	-4.56%	-4.12%	0.04%	-8.65	-3.39%	-34.71
IT09	1.53%	7.81%	7.37%	-2.08	5.26%	28.61
IT11	-5.38%	-0.48%	-0.46%	-7.85	-3.19%	-5.80
IT12	1.95%	-7.38%	0.25%	-6.49	-2.15%	-10.75
IT13	-13.84%	-13.20%	2.05%	-7.60	-16.71%	-20.06
IT14	-2.44%	-1.68%	-1.86%	-4.53	-2.23%	-10.78

*rq is rate of surplus based on percentage of the daily surplus amount to the daily bread production amount in kgs; **r€ is the monetary value of surplus in comparison to the value of sales; ***Not available is reported for rate of focaccia surplus in IT04 and IT05 because no demonstration measurement averages were reported for these two stores.

We assumed two reasons for this mild, yet unexpected increase in surplus in the demonstration period. Firstly, between baseline and demonstration period measurements the bakery staff are expected to become more aware of waste and to improve the way they measured and recorded the surplus through practice over many daily observations they undertook during the baseline period for 5 months in 2022. Secondly, the year 2022, when the baseline was measured was not a regular year for the industry due to persisting COVID-2019 restrictions and the beginning of the war in Ukraine (Pietrangeli et al., 2024). The combined effect of these events, the first one reducing hospitality demand for bread products and the second one increasing the grain and fuel costs of production, led many bakeries to reduce their production significantly to cut costs. Indeed, the average daily production increased by 21.3% in 2023 with respect to 2022, suggesting that the production recorded in 2022 was not representing their full volume of production. Thus, the surplus to production ratios measured during the baseline period is likely to be much below the baseline situation for the small-scale bakeries under normal circumstances. Moreover, another factor contributing to the surplus observed in 2023 could be the higher number of rainy days recorded compared to previous years in the same period (https://it.climate-data.org/). The adverse weather conditions, such as rain, can discourage customers from visiting stores, thus reducing foot traffic

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and sales volumes. This trend was confirmed during several meetings with the bakery owners, as well as experts from the CNA who noted a decline in customer numbers on rainy days. Therefore, the poor sales during these rainy periods could further explain the observed surplus in 2023.

Further statistical analyses with unaggregated daily measurements were carried out to understand the validity of our assumptions linked with the increase in surplus and surplus/production ratio. To visualise the patterns in data, we plotted the evolution of the change in the ratios of the surplus/production (rq) of three main bakery items in each store and a cumulative value for baseline period across bakeries. Also, the link between the frequency of the disposal routes taken and the interest in reducing surplus/production ratio was explored. We had to use the frequency information because daily quantities disposed via each route were unavailable.

We hypothesised that high-value surplus disposal routes (e.g., reworking surplus into breadcrumbs, discounted sales via apps) may act as an unintentional economic disincentive to prevent in-store surplus. We checked if the bakeries that more frequently used disposal routes such as revalorisation into breadcrumbs or discounted sales on "Too good to go" app had less successful outcomes in reducing their surplus ratio compared to stores often choosing routes with no potential for cost recovery such as donating to charities or giving the surplus to their animals or regular customers. The link between the amount of surplus and the disposal routes indicated for that day and the day after were also explored, to see if there is any relationship with the amount of waste created and the disposal route chosen. The outcomes of these additional statistical analysis are included in Appendix 4. Another possibility is that bakeries already performed quite well in terms of surplus bread prevention compared with other countries and therefore for them it is more challenging to improve their performances.

Task 4.1 Stakeholder dialogue in the fish value chain

The fish supply chain stakeholder dialogue is similar to the supply chain dialogue implemented in the bakery sector in T3.2. It aimed to understand the reasons and hotspots of waste creation, if and how different types of waste could be reduced as well identifying possible connections between stakeholders for material exchanges to add further value to unavoidable surplus and by-product flows such as processing by-products in the seafood supply chain. Task 4.1 took part in Scotland and Germany. The seafood supply chains in these two countries are very different, Scotland being one of the major producers of seafood products and Germany being one of the largest exporters and consumers of seafood products in Europe. Further details could be found in D4.3-*Report on fish supply chain dialogue* (Koseoglu et al., 2024).

In the Scottish side of T4.1, initially five organisations were recruited to the dialogue. The recruited organisations were distributed along the value chain (C1: secondary processor[11] of

[11] Primary processing of fish refers to the process of cutting, filleting, de-boning, peeling, washing, packing, heading and/or gutting and freezing and the secondary processing process of smoking, canning, brining, breading or making ready meals (Wright & Moran-Quintana, 2024).

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fish; C2: primary processor of fish and processing of by-products; C3: user of by-products, C4: secondary processor of fish; C5: primary processing of shellfish) and provided a good representation of the stages of the value chain in Scotland. The management and the participant surveys were filled in by the representatives of these organisations to capture the baseline situation. However, no exchange of waste materials took place between the dialogue members except for five litres of fish oil produced by one of the dialogue participants, for another participant to test its potential use in the production of sustainable cleaning products.

Due to the specifics of the data disclosure agreement the waste type and annual waste amount at individual company cannot be published here. While there are also data gaps and undisclosed parts of information, the limited available data from secondary processors C1 and C4 indicates an opportunity for trading by-products and surplus materials. As a secondary processor, C1 has a food waste mix of fish, crumbs, vegetables, sauce, and takes valorisation routes such as animal feed, anaerobic digestion and composting. For other stakeholder dialogues members, this information was not available. Besides general factors identified in the literature and interviews in T4.1 such as additional costs associated with transport, refrigeration and sorting, a case specific factor that limited material exchange among the dialogue members was the mismatch between the by-products available for exchange and suitable innovative users in Scotland.

Two stakeholders involved in the dialogue, C2 and C3, used seafood materials in their production processes as input. One was a company producing bio-surfactants, which was still operating at lab-scale and used fish oil as the main ingredient. However, they were still at the testing stage and also extracting fish oil from the fish waste was not in their business plan, so they were unable to directly make use of fish waste. The second company was an international market leader in fishmeal and fish oil production and already had a very good logistic network but the scale and the type of offered waste materials (e.g., food waste mix or farmed fish processing by-products) was not suitable for their use.

In the German side of the dialogue, workshops were organised to engage with stakeholders and thus, no management or participant surveys were implemented, and no transfers took place in this part of T4.1 either.

Due to the lack of exchanges and lack of recorded change in waste management practices of the stakeholders resulting from participating in the dialogue, no additional management and participant surveys were distributed to the stakeholders to capture the company level socio-economic impact of the innovation. Instead, an industry level survey was disseminated both in Scotland and Germany to further understand the barriers, opportunities and innovation needs of industry actors and to scope for the industry level situation.

According to the survey responses so far, the most common challenges are the costs of sorting, storing, and transporting surplus, the unwanted catch and the mismatch between available catch and demand. The most common opportunities identified by the survey respondents are expansion of the consumer demand for more species through promotional activities, improvement of the scientific understanding of fishing grounds and exploration of new

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international markets. The most needed interventions by the industry are policy and legislative change to reduce costs for small businesses with irregular flows and innovations for balancing supply and demand and for monitoring and reducing unwanted catch. The further information about dissemination efforts and the findings of the industry survey can be found in D4.3 (Koseoglu et al., 2024).

4.2.2. Social impact of 'FW prevention governance innovations'

The innovation of the type "food waste prevention governance" include social innovations, namely T3.2 "Bakery stakeholder dialogue" and T4.1 "Fish stakeholder dialogue." The former was implemented in Sweden, Finland, and Italy, but no responses were obtained from Sweden, and only one baseline response from Finland, while six post-implementation responses were obtained from the Italian bakeries which took part in the dialogue, followed by seven baseline responses from comparable bakeries which did not. The baseline responses in Italy came from four different bakeries, the post-implementation ones from seven. All respondents were employees. In most instances, they were head cooks, were owning the bakery, and were one of the main people involved in the implementation of the innovation in their organisation. The "Fish stakeholder dialogue" was implemented in Germany and Scotland, but no responses were obtained from Germany, and only five baseline responses from Scotland

Table 15 below reports the change in the indicators as a result of being involved in the implementation of the innovation. The responses from T4.1 "Fish stakeholder dialogue" were excluded from the calculation to avoid distorting the results, since they refer to another innovation for which there are no post-implementation responses to be compared. The innovation of the type "food waste prevention governance" or, more precisely, the "Bakery stakeholder dialogue," resulted in a statistically significant and positive change in the indicators "**Subjective norm**," "**Intention**," and "**Behaviour**," while "Attitude" and "Moral concern" experienced a statistically significant change in the opposite direction. Although the indicator "Perceived behavioural control" did not experience any significant change, many specific statements contributing to it did change in line with our hypotheses (i.e., the level of agreement increased). Overall, most indicators and statements experienced a statistically significant change in the expected direction, suggesting that participating in the innovation had a positive social impact.

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Table 15: Change in social indicators between the baseline and post-implementation phases for innovations of the type "food waste prevention governance", bakeries only (N = 14)

Indicator	Statement	Hypothesis[1]	Baseline	Post-impl.	*p*-value[2]	Baseline	Post-impl.	*p*-value[2]
Attitude	waste_quan	+	5.00	4.71	0.926†	0.641	0.504	0.901†
	planet	+	5.00	5.00	.			
	economic	+	5.00	5.00	.			
	resources	+	5.00	5.00	.			
	waste_inevi	-	1.57	2.00	0.766			
	waste_impos	-	2.43	2.57	0.581			
Moral concern	worry	+	4.57	4.57	0.500	0.588	0.302	0.914†
	waste_irres	+	4.86	4.86	0.500			
	guilty	+	4.57	4.29	0.724			
	responsible	+	4.71	4.86	0.276			
	principle	-	1.00	2.71	0.972††			
Subjective norm	socie_care	+	4.43	4.57	0.384	0.227	0.627	0.064*
	hh_support	+	4.14	4.57	0.109			
	colleagues	+	3.71	4.43	0.032**			
	pressure	+	3.00	3.57	0.221			
Perceived behavioural control (PBC)	know_hh	+	4.00	4.71	0.001***	0.284	0.453	0.171
	know_eatout	+	4.71	4.57	0.695			
	know_restaur	+	4.43	4.14	0.731			
	know_work	+	3.86	4.43	0.020**			
	control_wp	+	4.00	4.29	0.169			
	control_hh	+	3.57	4.43	0.017**			
	recycle	+	4.14	3.00	0.952††			
Intention	not_care	-	1.00	1.14	0.832	0.340	0.657	0.025**
	waste_hh	+	4.43	4.71	0.215			
	waste_work	+	4.14	5.00	0.000***			
Situational factors	hassle_hh	-	1.57	1.43	0.409	0.679	0.802	0.305
	waste_time	-	1.71	1.29	0.116			
	waste_tech	?	1.14	1.29	0.663			
	council	?	1.57	2.43	0.126			
	recycle_wp	?	3.71	4.29	0.119			
Behaviour	food_spoil	-	2.00	1.71	0.169	-0.474	0.080	0.013**
	rarely_waste	+	3.00	2.57	0.719			
	prepare_waste	?	4.14	2.00	0.000***			

Notes: The sample size can vary slightly between statements and indicators because participants were not forced to assess all the statements. [1] Direction of the hypothesis as explained in Table 6. [2] The *p*-values refer to the difference between the baseline and post-implementation responses. For the specific statements, in the case of a "directional" hypothesis the *p*-values refer to a one-tailed *t*-test; in the case of no expected change to a two-tailed *t*-test. For the indicators, the expected change is always positive. Significance levels for changes in line with the hypothesis: *** 0.01, ** 0.05, * 0.10. Significant levels for changes in the opposite direction: ††† 0.01, †† 0.05, † 0.10.

4.3. Impact of the 'consumer behavioural change' innovations

In this section first the economic impact analyses of Tasks 5.3; Task 5.4, Task 5.5 and Task 5.6 is covered individually. Then in the final part, the statistical analyses results of participant surveys collected from those involved in the demonstration of the consumer behavioural change innovations is provided under the social impact evaluation.

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4.3.1. Economic impact of 'consumer behavioural change' innovations

Task 5.3 MATOMATIC Plate Waste Tracker

Matomatic is a software application designed for tablet computers integrated with a scale that is positioned beneath the waste bin where plate waste is disposed. Each time an item is discarded, the tablet records its mass, providing instant and tailored feedback to guests depending on the quantity of the discarded food. In the scope of T5.3, the app was demonstrated in 15 school canteens in Sweden (10), Germany (3), and Austria (2) with the aim of reducing plate waste at schools in an engaging way (Malefors et al., 2023).

A significant percentage (~15%) of reduction was achieved in average plate waste per guest across the schools, moving from 19.7 g to 16.7 g (3 g per guest). The average number of students[12] registered in the participating schools in Sweden and the number of students recorded as having used the school canteen during the demonstration in Austria and in Germany[13] are 355 and 144, respectively. While avoided food waste did not result in change in the cost of meal production in these schools, the process of capturing a baseline has led to accounting and addressing inefficiencies such as surplus lunch orders in schools where the meals are ordered in advance.

There were differences among the participating countries in terms of school types and how the meals were provided. In Sweden, the municipality operates the schools including their canteens where the food is prepared. The organisation is centralised in a way that teachers belong to the education department, and catering staff belongs to the meal service department. Meals were prepared in the school canteen operated by the Uppsala municipality based on the number of students and prioritising affordability of meals. Meal production cost and price per meal figures were similar across all participating schools. Participating schools in Germany were all located in the same region, and were all public secondary schools. Two of them prepared meals in their kitchen (SCH1, SCH3) and one (SCH2) used a catering company and kitchen staff reheated and served the meals on the day. In all schools, the meals were ordered in advance by the students. In Austria, the participating schools were not part of a centralized system. They were of different ownership models (i.e., private schools, public schools) and were based in different regions of the country. Every school had a different way of providing lunch meals for their pupils. For instance, one was a vocational school, and students cooked for themselves. Other schools contracted external companies to provide lunch; and boarding schools had their own chefs for lunch and dinner preparation.

Secondly, disposal cost was based on the size and number of containers and the number of pick-up drives, depending on the region, and the public or private waste disposal company involved. To reduce disposal costs in a significant way, the schools have to reduce not just plate waste but their total food waste significantly. Also, food waste collection is managed by

[12] The number of students using the canteen the Swedish schools is lower in than the registered number of students. Therefore, the innovation's potential might be overestimated in this case.

[13] As we do not have the number of registered students in 3 German schools, the average number of guests served in the canteen of participating the German schools anonymised as SCH1, SCH2 and SCH3 are quoted here.

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the municipality in Sweden and is also commonly undertaken as a public service in Austria and Germany. However, private waste disposal services were available too, and were potentially used by the participating private schools in Austria according to their management survey responses. Therefore, the end-user of disposed food waste (e.g., biogas plants) are identified by the municipality or other service providers collecting the waste, so even if a small profit is made from the valorisation of the food waste from the schools, it concerns the municipality or the waste collection companies, not the schools. In these settings, the economic incentives or disincentives to reduce food waste were low both in the presence and in the absence of innovations.

Table 16: Change in plate waste compared to the baseline in the 10 participating schools in Sweden

Code (code in T5.4)	Baseline (grams / pupil) *	Intervention (grams / pupil)	Change in plate waste (grams / pupil) (% change)
SW1 (SW01)	19.1	13.9	5.2 (27%)
SW2 (SW05)	16.8	11.3	5.5 (33%)
SW3 (SW04)	23.8	26.7	-2.9 (-12%)
SW4 (SW02)	21.8	5.8	16 (73%)
SW5 (SW03)	20.8	19.2	1.6 (8%)
SW6	14.6	10.9	3.7 (-25%)
SW7	22.6	22.7	-0.1 (~0%)
SW8	18.9	16.6	2.3 (12%)
SW9	21.5	22.3	-0.8 (-4%)
SW10	11.8	9.5	2.3 (-19%)
Sweden overall	19.7	16.7	3.0 (15%)

*Baseline figures are captured from the daily records of meals served and food waste at school canteen kept over a decade and do not contain guest number.

In Sweden, the innovation was implemented in 10 schools in partnership with the Uppsala municipality, which provides meals that are served in school canteens (Malefors et al., 2023). The first five schools involved in T5.3 also implemented T5.4, and these were the only locations where serving waste was measured. The schools participating in both innovations are indicated in Table 16 above using information from Malefors et al. (2023) and measurement data provided from the Swedish project partners

According to the management survey responses collected from the 10 participating Swedish schools, no change was detected in sale price, cost of meal production, and food waste management as a result of the innovation, as hypothesised. Using Matomatic did not incur a subscription charge, and the additional gadgets required (e.g., weighing scales, bins, tablets etc.) were one-off costs covered by the LOWINFOOD project. Therefore, no production costs were saved, and no demonstration cost were incurred, and the return on investment (ROI) was not relevant.

However, the innovation had good reception among the participating schools: almost all schools involved declared to be satisfied with the innovation. Eight out of ten schools would

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continue using the device. Four schools shared information about the innovation with other municipalities, and some of those who received a recommendation showed interest, but it was not specified in the management survey responses how many schools were informed and how many among them eventually took the innovation up.

In Austria, the two schools that took part in T5.3 Matomatic (T53AT0002; T53AT0003a-school kitchen; T53AT0003b-school canteen) also participated in T5.4 Holistic Educational Approach. These were both vocational schools: the first one for economics training and the second one for agriculture and nutrition.

We expected the schools that implemented both innovations to achieve higher ratios of reduction than those that only implemented T5.4. The waste categories used in Austria were different from those used in Sweden and Germany, i.e., avoidable food waste and non-avoidable food waste vs. plate or serving waste. In consultation with local partner, we concluded that avoidable food waste corresponds to plate waste defined as everything still on the plate after someone finished eating, and non-avoidable food waste corresponds to kitchen waste defined as peels, bones, and anything not suitable for humans which is wasted while cooking food in kitchens. Only "avoidable" food waste (corresponding to plate waste) was the concern of T5.3.

Table 17: Change in plate waste compared to the baseline period in the two participating schools (three facilities) in Austria

Code	Baseline average (grams / pupil)	Demonstration average (grams / pupil)	Change in plate waste (grams / pupil) (%-change)
T53AT0002	108.3	46.0	-62.4 (-57.6%)
T53AT0003a	16.4	14.5	-1.9 (-13%)
T53AT0003b	409.0	554.0	144.6 (35%)

There were larger fluctuations between the averages in different locations, possibly depending on the specific operation mode of each facility, but we do not have enough information to speculate about this. Table 17 reports plate waste as derived from the Austrian datasets.

The management survey responses will be discussed under T5.4 as these schools were also taking part in that innovation and, as a result, completed a single management survey.

In Germany, three schools participated in T5.3. According to the management survey responses, the kitchen staff of the schools were content with the device, and all reported being very likely to promote the innovation after the end of their use. There were no changes in meal production costs or selling prices that could be linked with Matomatic. In one school (SCH3), not the innovation itself but the measurements in the baseline phase led to the identification of between 10-15 meals that were ordered but not picked up each day. This led to ordering 10 meals less each day and, as a result, to buying less raw materials and more targeted and flexible planning of fresh vegetables and meat use (e.g., more meat is fried at short notice if demand is higher on a specific day). In one other school (SCH2) the meal planning was less flexible: they identified menus being entered 20 weeks in advance as a

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problem. Teachers did not have access to the ordering system to remind the students to collect their meal orders. This also indicated a barrier to reducing overproduction.

The reduction in plate waste achieved in the demonstration period compared to the baseline in the three participating schools is listed in Table 18 below, based on Malefors et al. (2023) and on the measurement amounts provided by the innovation task leaders.

Table 18: Change in plate waste compared to the baseline period in the three participating schools in Germany

Code	Baseline average (grams / pupil) (total waste per day in kg)	Demonstration average (grams / pupil) (total waste per day in kg)	Change in plate waste (grams / pupil) (%-change)
SCH1	26.7 (3.60)	24.5 (4.56)	-2.2 (-8%)
SCH2	42.1 (6.44)	47.5 (7.08)	5.4 (13%)
SCH3	36.2 (4.53)	18.3 (2.38)	-17.9 (-49%)

There are potential economic gains from the reduction of plate waste, which might translate into reduction of production or ordering less meals to feed the same number of students. To illustrate this, an average reduction in plate waste of 17.9 g/pupil (achieved in SCH3) could translate into a potential annual cost saving of €2,350 assuming an average of 144 students per day, 178 school days per year, and €5.12/kg of food input cost for conventional school meals[14].

However, for two reasons stated above, we refrained from calculating these potential cost savings at school or country level. Firstly, due to the heterogeneity of schools and meal provision routes reported by the users in the management surveys, the costs of meal provision vary greatly between three countries[15] and between two of the five schools where the meal production costs were disclosed in Austria. Monetising avoided plate waste based on local prices would underline the price differences rather than the reduction in plate waste amount per pupil. Secondly, it is difficult to assign a realistic timeframe for cost savings with the current amount of data and assume the innovation would retain this level of impact on the students' plate waste behaviour either for an entire school year, semester or month, and if and how its impact on plate waste tails off gradually.

In the absence of the LOWINFOOD project acquiring it, a Matomatic plate tracker would cost approximately €2,000. The service life expectancy of the device is five years, and the tablets that visualise the messages are observed to be the most fragile part of the set-up, needing more frequent replacement than other parts. However, the tablets can be bought separately

[14] Inflation adjusted figures of a study conducted by the German Nutrition Society, available online at: https://www.dge.de/fileadmin/dok/dge/projekte/KuPS-Studie-Abschlussbericht.pdf [accessed 30 October 2024].
[15] The lowest meal production cost is reported in Sweden at €2.90/kg across all the Uppsala Municipality schools, followed by Germany at €5.12/kg, and the highest meal production costs were found among Austrian responses at €12/kg and €16/kg in the two schools that provided this information.

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from the plate waste tracker and be replaced easily. According to the observation of SLU researchers who were leading T5.3 in Sweden, the plate waste-tracker is most effective in the first two weeks of its use in a new location; afterwards, the interest in the device decreases rapidly.

The identification of the most effective intervention period informs a critical cost sharing strategy, especially among the canteens or locations that are part of a network or a larger organisation,[16] which would facilitate the logistics and transport associated with sharing the device. In Sweden, it was recommended that municipalities buy one or two devices and circulate them between their schools during the 40-week school year. In this scenario, a device is based in a school for two-week periods and can be shared by up to 20 schools in a single school year, and up to 100 schools if the device reaches its full life expectancy. This strategy would lower the cost of use to as little as €20 per school excluding logistics and maintenance costs and possible additional expenses of a tablet, bin, bin liners, etc. that need to be incurred separately if not already available in the schools.

Task 5.4 Holistic educational approach

The Holistic Educational Approach engaged pupils and kitchen staff in educational activities, turned school meals into learning occasion (educational meals) and developed a concept around educational meals and other materials to teach pupils, teaching and kitchen staff, about food waste and how it can be reduced (Sundin et al., 2023). While educational meals and teaching materials focusing on food waste were available before, the holistic approach introduced several novelties. For instance, mealtimes were considered part of the setting for the educational meals and the concept was further expanded to classroom teaching activities prior to and after mealtimes (Sundin et al., 2023). Additionally, while previous examples focused on pupils only, in this concept teachers and kitchen staff were also provided with the much-needed education, training, and tools to integrate food waste-reducing measures into their practical work.

While this is one of the most promising innovations to have a longer term impact beyond the demonstration period, we did not expect major changes in the economic indicators as school meals were mostly provided in subsidised way and through the municipality, as least in the Swedish case and daily waste and consumption information has been monitored for more than a decade, indicating that meal production might have already been optimised based on this information (Sundin et al., 2023). However, here we will speculate about the potential impacts of the innovation in terms of reducing production costs, were the changes measured between the baseline and the demonstration period sustained over time and the productions of meals changed in response. The holistic education approach was implemented in Sweden and Austria and varied to some extent between the two countries.

In Sweden, five of ten schools involved in T5.3 implemented T5.4. The Matomatic plate waste tracker was used to measure the plate waste in all participating Swedish schools and there

[16] Examples could be different offices of the same company; different branches of the same government body or schools run by a municipality etc.

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were no schools implementing T5.4 alone. 1,125 pupils participated in total, most participants were primary school pupils aged 6-12 (some between grade 0-6 and in others 0-9). The educational materials that teachers incorporated into their regular teaching curricula and into the educational meals were used in the school canteens for ten consecutive weeks (Sundin et al., 2023). The implementation of the holistic educational concept in Sweden focused on teaching staff (teachers and teaching assistants) as well as pupils. In total, 57 teachers and five teaching assistants were involved and the kitchen staff in the participating schools that were present at the canteens during meals were given a separate workshop. The percentage of participating teaching staff and pupils ranged from 2-100% across the participating schools (Sundin et al., 2023).

The school meals were provided in a non-profit way and the cost information was recorded by the municipality. This confirmed our expectations that the schools that implemented both innovations achieved higher ratios of reduction in their total food waste than those only implementing one (Table 16 in T5.3) except for one school, i.e., SW3. Also, other indicators recovered from the management surveys are included in the T5.3 Sweden section for the five schools that were involved in both innovations. The schools that took part in both innovations performed better than the others as expected.

In Austria, two schools (T53AT0004; T53AT0005) took part in T5.4 "Holistic educational approach" alone, and the rest of the schools were involved in both T5.3 Matomatic and in T5.4 Educational approach tasks. Kitchen workshops were conducted for the kitchen staff and pupils, providing the participants with knowledge and inspiration on how they could reduce their food waste.

T5.4 in Austria used different food waste categories compared to Sweden (avoidable and unavoidable vs. plate and serving waste) and it was not possible to measure non-avoidable waste. In T5.4, there were times that only "unavoidable" waste figures were recorded although the difference between the two categories and how they should be documented was explained at every school. The students taking part in the LOWINFOOD Workshops were around 13 to 16 years old and their cooking skills ranged from very basic to intermediate. Their teachers had already informed them about the problem of food waste and participated in smaller group projects before the workshops (Sundin et al., 2023).

The kitchen staff were involved in all schools and in Sweden, the teachers were also involved. They were the recipients of the participant surveys before and after workshops demonstrating the innovation (Sundin et al., 2023). The average number of teachers involved in the demonstration was 8 across participating schools. On the Austrian side of T5.4, the smart kitchen workshops were the focus of the holistic educational approach. The recipients of the smart kitchen workshops differed in each school (either classes of students or teachers).

While we do not have the data to confirm, we hypothesise that apart from reduction in potential meal orders or preparation, this innovation also has the potential to reduce serving waste (as measured on the Swedish side of the innovation). This results from the training and involvement of the kitchen staff and will have an impact on the overall food waste amount and associated disposal costs. The assumption of potential waste disposal cost

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reduction is based on the two private schools in Austria which indicated significant annual food waste disposal costs in their management survey responses.

The results of T5.3 and T5.4 are further discussed in Appendix 6.

Task 5.5 CozZo Mobile App

CozZo is a mobile app for holistic kitchen management for households. It aims to save households time and money by helping them plan their grocery shopping and manage the food they have at home more efficiently. It helps users to keep an inventory of their fridge and pantry to inform meal prep decisions, keep track of what needs to be bought and what expires when to optimise grocery shopping and helps them monitor their food waste levels.

A major issue with the demonstration was recruiting and retaining participating households in each country. Innovation task leaders managed to recruit a total of 52 households in Finland, Austria and Greece to test the application for a period of 3 to 6 weeks through dedicated efforts further explained in D5.10 (Mesiranta et al., 2023) The recruited households were grouped into the "household approach" and the "student approach", students being recruited among the students of local academic partners (Mesiranta et al., 2023). The number of households in each approach of the final sample is outlined in Table 19 (Mesiranta et al., 2023).

Table 19. The distribution of "household approach" and "student approach" households in the final sample (Mesiranta et al., 2023)

Participating household type	Finland (n=18)	Austria (n=19)	Greece (n=15)	Total (n=52)
Household approach	14	8	11	33
Student approach	4	11	4	19

The main difference between the household approach and the student approach was how the waste audits and the interviews during the baseline and the demonstration period were conducted. In the student approach, the responsible person in the participating households sorted, weighted and self-reported their waste for a week. The categories used for reporting were much broader in the student households compared to regular households in the household approach, as waste was sorted, weighted and recorded by researchers once (in Austria and Finland) or twice (Greece) a week. The management and participant surveys were administered together in both approaches but self-reported online in student approach and were compiled in interview style during a home visit by local researchers in the household approach (Mesiranta et al., 2023). This resulted in disparity in the data quality between household and student approaches. In the latter sample, the results are more contradictory than in the first one.

Task 5.5 provided both management surveys and waste measurements from participating households which enabled vast amount of information in self-assessed and recorded formats, some of which combined with secondary data enabling the cross checking of figures.

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From the perspective of economic impact analysis, we hypothesise that the innovation would lead to cost savings (in terms of food items), reduction of overall food expenditure, and better material productivity (i.e., producing same type of meals at a lower unit cost due to reduced spoilage of food purchases) in the participating households. To understand whether the reduction in the household budget for food purchases resulted from the usage of the app we also checked for the budget for out-of-home food provision to conclude whether the reduction in the household food budget was not caused by eating more meals outside or in the form of take-aways.

While the frequency of app use is not a consideration for the socio-economic impact analysis, it is important as a proxy to understand how much of the change observed between the baseline and the demonstration measurements of waste in the households can actually be attributed to the use of the app. The difference between the pre-demonstration and the demonstration phases was statistically significant in the overall sample. An average reduction of 43% in mass of household food waste between baseline and demonstration period was achieved across all countries (Mesiranta et al., 2023).

Table 20: Economic impact of CozZo app on the household approach households in Finland

LOWINFOOD Code	Change in-HH food shopping (€/week)	% change in weekly HH food shopping	Change in out-of-home food costs (€/week)	% change in weekly out-of-home food costs	Change in total food budget (€/week)	% change in total food budget
T55FI2201	0	0.00	0	0.00	0.00	0.00
T55FI2202	300	150.00	250	150.00	550.00	157.14
T55FI2203	25	16.67	-250	16.67	-225.00	-45.00
T55FI2204	-50	-25.00	120	-25.00	70.00	14.00
T55FI2205	10	6.67	0	6.67	10.00	1.82
T55FI2208	0	0.00	-20	0.00	20.00	-6.25
T55FI2209	-50	-25.00	50	-25.00	0.00	0.00
T55FI2211	-25	-9.09	-30	-9.09	-55.00	-12.94
T55FI2212	-80	-53.33	100	-53.33	20.00	8.00
T55FI2213	0	0.00	130	0.00	130.00	48.15
T55FI2214	0	0.00	0	0.00	0.00	0.00
T55FI2215	-7	-9.33	140	-9.33	133.00	98.52
T55FI2216	5	2.94	-150	2.94	-145.00	-30.85
T55FI2217	5	11.11	-5	0.00	0.00	0.00
Average	8.2		9.2		17.39	

The outcomes of the economic impact assessment presented here are based on the self-provided responses of the participating households, so-called "food managers". Therefore, unless these were derived from a banking app or another automated system, they are not precise and are mainly based on respondents' estimations at the time. It was not possible to derive how the change in household food spending and household waste measurements were linked with change in the productivity of the purchased food materials. Due to the data

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gaps in the management survey in responses related to the number of meals, it was not possible to calculate the material productivity impact of the app directly.

In Finland, the highest frequency of use was achieved among the three countries. 16% of users reported using the app at least once a day (Mesiranta et al., 2023). Therefore, we expect the effect of the CozZo app usage on food consumption behaviour and associated cost savings to be the largest compared to the other countries. Reception of CozZo was positive among household approach participants. Several stated examples of how the CozZo app had saved them money included, e.g., increased awareness via reminders of what they already had on stock as well as items that were about to expire, buying less "unnecessary" things, buying smaller packages avoiding "over-purchasing", planning their purchases/managing their food better etc. However, as one participant highlighted this might not be just due to using CozZo, but to participation in the project in general.

The economic impact of the app is summarised in Table 20 and Table 21 and discussed based on the management survey responses received in the baseline and demonstration periods.

Table 21: Economic impact of CozZo app on the student approach households in Finland

LOWINFOOD Code	Change-in HH food shopping (€/week)	% change-in weekly HH food shopping	Change in out-of-home food costs (€/week)	% change-in weekly out-of-home food costs	Change in total food budget (€/week)	% change in total food budget
T55FI2218	-15	-13.64	-50	33.33	35.00	13.46
T55FI2219	0	0.00	-100	66.67	100.00	45.45
T55FI2220	-50	-66.67	-20	40.00	-30.00	-24.00
T55FI2221	50	50.00	0	0.00	50.00	33.33

The economic outcome was mainly positive: one household (T55FI2211) reduced both their food shopping budget and out-of-home food costs suggesting that the positive effects of the app in household food management did not have negative rebound effects by increasing out-of-home food expenses of these household. In four households, there was change in either one of the two budget components. These either evened each other out (T55FI2209) or their out-of-home food costs increased more than the decrease in the household food shopping budget (T55FI2212; T55FI2215), resulting in an increase in the households' total food budget. Meanwhile there are no changes in two households and significant increase in the total food budget of one household (T55FI2202) and in out-of-home expenses of another household (T55FI2213).

In Finland there was an average increase of 10 €/week in food shopping and 25 €/week for eating outside or for take-aways experienced among household approach households. However, this is only due to the outlying and negative effect of a single household (T55FI2202) with large increase in both of their budgets. Excluding this household, saving of 220 €/week are achieved across remaining household approach households.

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The student households in the sample had smaller households and food shopping budgets, providing less possibility for reducing already low amount of waste and expenditure. Estimated weekly spending for student households on food decreased between the baseline and the demonstration periods for one household, remained the same for one household and increased for two households. The estimated monthly spending for student households on eating out and ordering take-away meals decreased between baseline and demonstration periods for three households and remained the same for one household. Two households achieved positive results, reducing their spending either in one (T55FI2219) or in both (T55FI2220; T55FI2218) budget categories.

In Austria, the frequency of using CozZo was the lowest compared to the other two participating countries, but the largest reduction of waste was achieved in this country. According to their own statements, less than one fifth of the users (18%) had used the app at least once a week; a majority (82%) used it less than once a week and only one user used it daily. When asked if they thought they had saved money by using the CozZo app, 14 households (7 household approach, 7 student approach) out of 19 participants selected 1 or 2 (1: "not at all", 5: "very much"). However, despite the infrequency of use and less favourable perception of its performance in savings, the economic outcomes for the household approach households are mainly in line with expectations and are summarised in Table 22. As mentioned, the largest reduction of waste is achieved in Austria.

Table 22: Economic impact of CozZo app on the household approach households in Austria

LOWINFOOD Code	Change in HH food shopping (€/week)	% change-in weekly HH food shopping	Change in out-of-home food costs (€/week)	% change-in weekly out-of-home food costs	Change in total food budget (€/week)	% change in total food budget
T55AT22012	-100.0	-40.0	0.0	0.0	-100.0	-28.6
T55AT22013	-40.0	-36.4	-40.0	-66.7	-80.0	-38.1
T55AT22014	0.0	0.0	0.0	0.0	0.0	0.0
T55AT22015	-10.0	-16.7	-60.0	-100.0	-70.0	-38.9
T55AT22016	0.0	0.0	0.0	0.0	0.0	0.0
T55AT22017	10.0	6.7	50.0	11.1	60.0	10.9
T55AT22018	20.0	66.7	70.0	58.3	90.0	112.5
T55AT22019	40.0	50.0	-50.0	-50.0	-10.0	-4.4

The estimated weekly food spending for households decreased between the baseline and the demonstration periods for two households, remained the same for three households and increased for six households. The estimated monthly spending for households on eating out and ordering take-away meals decreased between the baseline and the demonstration periods for three households, remained the same for one household and increased in seven households.

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Four households (T55AT22012, T55AT22013, T55AT22015 and T55AT22019) achieved reduction in their overall food budget, without increase in out-of-home food costs. Two households indicated no significant changes (T55AT22014 and T55AT22016). Three households out of eight increased their food budget after the demonstration but for one of the households (T55AT22019), this increase was coupled with decrease in the out-of-home food costs, which halved. The estimated monthly spending on eating out and ordering take-away meals decreased between the baseline and the demonstration periods for three households, remained the same for three households and increased for two households.

We may speculate that as a result of using the CozZo mobile app, some household approach households might have started buying more groceries for preparing meals at home rather than eating out or ordering in. This results in reduction of overall household food budget by 10 €/week, which is a tiny proportion of their overall food budget but is still a change in the hypothesised direction. Considering the steeper increase in consumer prices after COVID-19 pandemic in Europe, the negative results (~11% increase in the overall household food budget) in household T55AT22017 could also be interpreted not as negatively but neutral. Across the household approach households, a total of 110 €/week reduction is achieved.

Table 23: Economic impact of CozZo app on the student approach households in Austria

LOWINFOOD Code	Change in HH food shopping (€/week)	% change-in weekly HH food shopping	Change in out-of-home food costs (€/week)	% change-in weekly out-of-home food costs	Change in total food budget (€/week)	% change in total food budget
T55AT22001	0	0	20	15.4	20	11
T55AT22002	0	0	20	33.3	20	9.6
T55AT22003	-30	-60	50	166	20	25
T55AT22004	10	28.6	45	225	55	100
T55AT22005	-40	-50	-30	-30	-70	-38.9
T55AT22006	2.5	2.7	80	66.7	82.5	38.8
T55AT22007	30	17.6	-10	-20	20	9.0
T55AT22008	7	20	100	66.7	107	57.8
T55AT22009	20	25	-20	-20	0	0
T55AT22010	0	0	0	0	0	0
T55AT22011	10	25	35	140	45	69.2

* 0 grams of waste measured in demonstration period, might be an error due to self-measurement in student approach

In more than half of the households (i.e., T55AT22012, T55AT22013, T55AT22014 and T55AT22016), the change in the measured mass of the household waste and the reported reduction in the household shopping budget were also consistent. However, the cross-checks between waste amounts and change in household shopping expenditure is very preliminary; it does not account for what item has been wasted and does not couple the masses with the actual retail price of wasted food items found in the household waste in each period.

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The student approach households had more modest outcomes as summarised in Table 23. Despite significant reduction in the mass of waste post-demonstration in almost all student households, only one household reduced their total food budget (T55AT22005), and two households recorded no changes (T55AT22009 and T55AT22010). One student household (T55AT22003) managed to decrease their household shopping budget but the increase in their out-of-home food expenditure was higher than the decrease and the total household budget increased as a result.

Again, the result should be interpreted in the context of increasing customer prices during the period and the additional burden of self-measurement in the student approach compared to the household approach, that might lead to short-term change in these households' consumption habits. The large and consistent increase in the out-of-home budgets of the student households compared to the smaller changes in their household food shopping indicates that the students may have shifted to eating outside more than usual to reduce the amount of household food waste they had to sort and weigh.

Table 24: Economic impact of CozZo app on the household approach households in Greece

LOWINFOOD Code	Change in HH food shopping (€/week)	% change-in weekly HH food shopping	Change in out-of-home food costs (€/week)	% change-in weekly out-of-home food costs	Change in total food budget (€/week)	% change in total food budget
T55GR22_0101	-20	-15.4	0	0.0	-20	-11.8
T55GR22_0102	-75	-100.0	-75	-60.0	-150	-75.0
T55GR22_0103	10	11.1	0	0.0	10	11.1
T55GR22_0105	-30	-20.0	-50	-25.0	-80	-22.9
T55GR23_0102	-10	-9.1	-20	-10.0	-30	-9.7
T55GR23_0108	-20	11.1	0	0.0	-20	-2.6
T55GR23_0128	0	0.0	0	0.0	0	0.0
T55GR23_0105	10	9.1	-95	-172.7	-85	-51.5
T55GR23_0107	25	12.5	0	0.0	25	6.3
T55GR23_0106	-40	-44.4	105	60.0	65	24.5
T55GR23_0109	0	0.0	0	0.0	0	0.0
T55GR22_0137	-10	-20.0	-10	-33.3	-20	-25.0
T55GR22_0110	5	9.1	-10	-33.3	-5	5.9
T55GR22_0114	50	33.3	0	0.0	50	16.7
T55GR22_0116	-10	-9.1	20	-4.3	-30	-5.2

Indeed, when compared to the actual self-reported net mass measurement data of the household waste, the changes in the waste measurements and change in budget were consistent in most households. For example, T55AT22003 show both reduction in household shopping budget and reduction in waste weight, T55AT22004 results showed increase in household budget and household waste measurement, and T55AT22005 showed reduction in all food budgets and in household waste measurement. However, these considerations

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are preliminary and future analysis for similar assessments in the future should look to combine waste measurements information with the actual cost of wasted materials found in the household food waste bin in each period.

In Greece, a majority of households (67%) had used the app at least once a week, while, similarly to Austria, no one reported having used the app daily. Household approach households in Greece that participated in the demonstration were sceptical about the app: only 2 out of 11 responded neutrally (score 3) to the question whether they saved money by using the CozZo app, while the scores from the student households were either positive (4) or neutral (3). In Greece, both the household and the student approach resulted in positive economic outcomes, which are summarised in Table 24.

Across the three countries, Greece had the lowest baseline waste measurement figures (Mesiranta et al., 2023), thus lowest potential to reduce household waste across participating households. This also should be considered when interpreting outcomes in waste measurements and budgets. Five households reduced their food purchase budget and in each of these households, the total household food budget including out-of-home and take-away meals decreased as well.[17] Two outlier households (T55GR23_0105 and T55GR22_0102) with large increase affect the averages across the household approach sample.

In the student households, the outcomes were mostly favourable, two households reducing their food shopping bills and two reducing their total food budget out of four. There was only one student household that experienced a steep increase in their food budget in the demonstration period, affecting the sample level average of the student households and the overall gains. But even considering this outlier household in the sample, the overall saving figures were positive for the student households in Greece.

The further statistical analysis of T5.5 data sets in aspects such as demographic distribution, frequency of waste by food categories, reasons for food waste and waste reduction performance of households are included in Appendix 7.

4.3.2. Social impact of 'consumer behavioural change' innovations

The innovations of the type "consumers' behavioural change" include T5.3 "Matomatic" and T5.5 "CozZo," two technological innovations focused on schools and households respectively, as well as T5.4 "Holistic Educational Approach," a social innovation which was also implemented at schools. The prevention governance innovation received the largest number of responses: 388 across the two phases, of which 198 in the baseline and 190 in the post-demonstration phases. Equally, this is the only innovation type where, besides employees (92 across the two phases), also household members (117) and students (179) were involved

[17] The changes in the household budgets and in the weight measurements of waste were not very consistent in multiple household and student approach households (e.g., largest reduction in waste measurement taking place in the household where no budget kind of budget change occurred etc.). However, there might be a lag between buying materials, the lighter in weight yet costlier food items might have spoiled, and also unlike occurrence of waste and budgets are mostly stated based on estimates of the respondents.

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in the demonstration. Matomatic was demonstrated in two schools[18] in Austria (one of which provided all the responses apart from one: eight in the baseline and 21 in the post-demonstration phases), three schools in Germany (all of them represented in both phases), and six out of ten schools in Sweden (four of which provided one single response, others two and eight respectively). In Sweden, Matomatic was already being used before LOWINFOOD; therefore, the baseline was obtained by involving three other schools from Uppsala municipality resulting in a total of six responses.

The Holistic Educational Approach was assessed in 12 schools from Austria: all took part in the baseline (99 responses) but only eight submitted at least one post-demonstration response (for a total of 64); and in three schools from Sweden, which provided 24 responses. Like for Matomatic, also for the Holistic Educational Approach the Swedish baseline was obtained by having the survey completed by teachers from another school from the Uppsala municipality (14 responses). Finally, CozZo was tested by 19 households and student households from Austria (23 baseline and 22 post-demonstration responses), 18 from Finland (22 and 20 responses), and 13 from Greece (15 responses in each phase). These households were the same in both phases; for each household, the questionnaire was filled in by the app manager, and possibly by another household member (other three members in one case). Given these very different types of respondents, in the following the values of the indicators and their change between phases will be discussed separately for employees, household members, and students.

Social impact of consumer behavioural change innovations on employees

Of the 92 employees (mostly teachers and canteen staff) who responded to the participant survey (41 in the baseline and 51 in the post-demonstration phase), 71 provided their role: 12 (five and seven) had managerial positions, 39 (21 and 18) were lower-level staff, and 20 (five and 15) were temporary workers or interns. Almost three quarters had been involved in the innovation since when it was introduced in the school, while the others had been exposed to it during very different periods ranging from less than one week to more than one year.

The changes in the indicators as a result of being involved in the innovation are reported in Table 25 below. We observe a marginally significant ($p < 0.10$) improvement in the "**Intention**" to reduce food waste, probably driven by the large improvement in the statement "*I am committed to reducing food waste in my workplace*".

Instead, "Situational factors" change in a direction opposite to our hypothesis, likely because the respondents increase their level of agreement with the statements "*Reducing food waste in my household is a hassle*" and "*Reducing food waste requires a lot of time*." The statement "*It is impossible to avoid food waste at workplace*," related to "Attitudes," also sees an increased level of agreement, similarly to the statement "*My workplace provides satisfactory resources to recycle food waste*" related to "Situational factors." This result suggests that, despite some improvement in the intention to reduce food waste and in workplace conditions, these

[18] In one vocational school in Austria, the demonstration took place in two different locations within the same school: in the training kitchen for students and in the school canteen.

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innovations have rather created a feeling of food waste reduction being a burden, at least among employees in our sample, who had to manage Matomatic themselves. Whether achieving the same impact in terms of food waste reduction *without* these innovations would have been even more burdensome for participants remains to be assessed. Unfortunately, we lack a counterfactual to answer this question, which is a relevant one for future research on innovations against food waste.

Table 25: Change in social indicators between the baseline and post-demonstration phases among the employees for innovations of the type "consumers' behavioural change" (N = 92)

Indicator	Statement	Hypothesis[1]	Baseline	Post-impl.	*p*-value[2]	Baseline	Post-impl.	*p*-value[2]
Attitude	waste_quan	+	4.63	4.53	0.694	0.131	0.194	0.295
	planet	+	4.61	4.76	0.120			
	economic	+	4.53	4.67	0.171			
	resources	+	4.82	4.71	0.799			
	waste_inevi	-	2.59	2.39	0.190			
	waste_impos	-	2.63	3.33	0.993††			
Moral concern	worry	+	4.24	4.10	0.766	0.209	0.209	0.501
	waste_irres	+	4.41	4.63	0.142			
	guilty	+	4.29	4.31	0.459			
	responsible	+	4.84	4.73	0.863			
	principle	-	2.17	2.24	0.582			
Subjective norm	socie_care	+	4.22	4.00	0.843	0.239	0.236	0.509
	hh_support	+	4.19	4.10	0.662			
	colleagues	+	3.86	4.26	0.028**			
	pressure	+	3.20	3.12	0.620			
Perceived behavioural control (PBC)	know_hh	+	4.68	4.59	0.697	0.262	0.238	0.564
	know_eatout	+	4.30	4.32	0.462			
	know_restaur	+	4.32	4.16	0.750			
	know_work	+	4.22	4.12	0.659			
	control_wp	+	3.11	3.10	0.511			
	control_hh	+	4.19	4.26	0.379			
	recycle	+	3.27	3.45	0.297			
Intention	not_care	-	1.26	1.36	0.716	0.130	0.367	0.070*
	waste_hh	+	4.32	4.53	0.129			
	waste_work	+	3.95	4.53	0.003***			
Situational factors	hassle_hh	-	1.97	2.47	0.980††	0.482	0.101	0.985††
	waste_time	-	1.73	2.22	0.973††			
	waste_tech	?	1.41	1.75	0.129			
	council	?	3.24	3.57	0.219			
	recycle_wp	?	3.08	3.75	0.009***			
Behaviour	food_spoil	-	2.59	2.58	0.479	0.021	0.072	0.349
	rarely_waste	+	3.43	3.86	0.061*			
	prepare_waste	?	2.14	2.38	0.401			

Notes: The sample size can vary slightly between statements and indicators because participants were not forced to assess all the statements. [1] Direction of the hypothesis as explained in Table 6. [2] The *p*-values refer to the difference between the baseline and post-demonstration period responses. For the specific statements, in the case of a "directional" hypothesis the *p*-values refer to a one-tailed *t*-test; in the case of no expected change to a two-tailed *t*-test. For the indicators, the expected change is always positive. Significance levels for changes in line with the hypothesis: *** 0.01, ** 0.05, * 0.10. Significant levels for changes in the opposite direction: ††† 0.01, †† 0.05, † 0.10.

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Social impact of consumer behavioural change innovations on households

Assessing the impact of innovations of the type "consumers' behavioural change" on household respondents is equivalent to assessing the impact of the specific innovation T5.5 "CozZo" (the only one tested by households). Of 117 consumers who responded to our survey (60 in the baseline and 57 in the post-demonstration phase), 79 (68%) belonged to household approach households (including 33 managers in each phase, and eight and five other members in baseline and post-demonstration phases, respectively), 38 (19 in each phase) belonged to student households, mostly from Austria.

Table 26: Change in social indicators between the baseline and post-demonstration phase among regular and student household members for innovations of the type "consumers' behavioural change" (CozZo) (N = 117)

Indicator	Statement	Hypothesis[1]	Baseline	Post-impl.	*p*-value[2]	Baseline	Post-impl.	*p*-value[2]
Attitude	waste_quan	+	4.70	4.89	0.038**	0.084	0.287	0.020**
	planet	+	4.62	4.75	0.128			
	economic	+	4.35	4.57	0.081*			
	resources	+	4.73	4.95	0.013**			
	waste_inevi	-	2.67	2.47	0.197			
	waste_impos	-	2.59	2.20	0.038**			
Moral concern	worry	+	3.76	4.14	0.014**	0.185	0.397	0.018**
	waste_irres	+	4.23	4.58	0.007***			
	guilty	+	4.43	4.61	0.097*			
	responsible	+	4.78	4.79	0.473			
	principle	-	1.65	1.49	0.197			
Subjective norm	socie_care	+	3.97	4.11	0.196	-0.157	-0.169	0.536
	hh_support	+	4.09	4.09	0.491			
	colleagues	+	2.88	2.92	0.427			
	pressure	+	2.80	2.88	0.364			
Perceived behavioural control (PBC)	know_hh	+	4.08	4.40	0.027**	-0.127	-0.033	0.208
	know_eatout	+	3.62	3.88	0.112			
	know_restaur	+	3.82	4.11	0.096*			
	know_work	+	3.83	3.75	0.642			
	control_wp	+	3.10	2.44	0.995†††			
	control_hh	+	4.07	4.21	0.184			
	recycle	+	2.60	3.04	0.067*			
Intention	not_care	-	1.35	1.14	0.039**	-0.040	0.176	0.056*
	waste_hh	+	4.20	4.54	0.011**			
	waste_work	+	3.62	3.69	0.374			
Situational factors	hassle_hh	-	2.43	2.28	0.223	-0.030	0.038	0.330
	waste_time	-	2.55	2.51	0.428			
	waste_tech	?	1.92	1.88	0.870			
	council	?	2.63	2.81	0.505			
	recycle_wp	?	2.36	2.49	0.641			
Behaviour	food_spoil	-	2.75	2.26	0.007***	0.012	0.281	0.029**
	rarely_waste	+	3.68	3.86	0.216			
	prepare_waste	?	2.25	1.95	0.155			

Notes: The sample size can vary slightly between statements and indicators because participants were not forced to assess all the statements. [1] Direction of the hypothesis as explained in Table 6. [2] The *p*-values refer to the difference between the baseline and post-demonstration responses. For the specific statements, in the case of a "directional" hypothesis the *p*-values refer to a one-tailed *t*-test; in the case of no expected change to a two-tailed *t*-test. For the indicators, the expected change is always positive. Significance levels for changes in line with the hypothesis: *** 0.01, ** 0.05, * 0.10. Significant levels for changes in the opposite direction: ††† 0.01, †† 0.05, † 0.10.

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These students are included in this category of respondents because they compiled the survey as regular consumers, not in the context of their school activities, differently from those discussed later. The level of agreement with the statements and the values of the indicators in Table 26 above shows that household members experience a clear improvement in many regards. More precisely, we observe a change in the directions of our hypotheses in "**Attitude**" (p = 0.020), "**Moral concern**" (p = 0.018), "**Intention**" to reduce food waste (p = 0.056), and "**Behaviour**" (p = 0.029). These changes are the result of significant changes in the levels of agreement with several statements contributing to the corresponding constructs.

Noteworthy, the level of agreement with the statement "*I regularly throw away food that I could have consumed due to food spoiling*," which contributes to "Behaviour" and is directly related to the functions of the CozZo app, declines significantly (p = 0.007). Also noteworthy, the only statement that sees a significant change in the direction opposite to our hypotheses ("*I have control over the amount of food waste produced in my workplace*") deals with a context that is not addressed by the CozZo app. This change can be a by-product of the demonstration, as respondent realised that *comparatively*, they have less instruments for reducing food waste in the workplace. Therefore, CozZo seems to have had a **beneficial impact** on many behavioural indicators of waste reduction.

Social impact of consumer behavioural change innovations on students

Finally, across the two phases, the participant survey was completed by 179 students from the Austrian high schools where T5.3 "Matomatic" and T5.4 "Holistic Educational Approach" were being demonstrated: 97 in the baseline and 82 in the post-demonstration phases.[19] All the students are aged 16 or 17. The results in terms of change in the statements and behavioural indicators are provided in Table 27 below. These results are very disappointing for two innovations that are meant to increase students' awareness of the food waste problem and improving related behaviours. Indeed, none of the indicators register a change in the expected direction, while "**Attitude**", "**Intention**" and, noteworthy, even "**Behaviour**" change in the **opposite** direction.[20]

The only statement that registers a significant change in the expected direction (decrease in the level of agreement) is "*Wasting food does not go against my principles*". All the statements related to "Intention" change in a direction opposite to our hypotheses, and after implementation of the innovation, students feel significantly less *guilty* for their food waste, and are less convinced that food waste is a major *economic* issue and that they have the ability to *recycle* their unavoidable food waste. Hence, the innovations dealing with "consumers' behavioural change" did not have **any positive impact** on the students in our sample.

[19] This number also includes a post-demonstration period response from Sweden.

[20] The latter is probably driven by the increase in the level of the agreement with the statement "*I sometimes throw away food that could have been eaten because I have prepared too much food*," on which we do not formulate a directional hypothesis due to the ambiguous nature of the word "sometimes" in this context.

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Table 27: Change in social indicators between the baseline and post-implementation phase among students for innovations of the type "consumers' behavioural change" (Matomatic & Holistic Educational Approach) (N = 179)

Indicator	Statement	Hypothesis[1]	Baseline	Post-impl.	*p*-value[2]	Baseline	Post-impl.	*p*-value[2]
Attitude	waste_quan	+	4.45	4.35	0.731	-0.253	-0.420	0.931†
	planet	+	4.17	4.07	0.734			
	economic	+	4.04	3.72	0.982††			
	resources	+	4.20	4.02	0.896			
	waste_inevi	-	2.56	2.56	0.511			
	waste_impos	-	2.58	2.51	0.348			
Moral concern	worry	+	3.67	3.52	0.836	-0.479	-0.498	0.578
	waste_irres	+	3.74	3.68	0.637			
	guilty	+	3.71	3.50	0.911†			
	responsible	+	4.05	4.10	0.386			
	principle	-	3.18	2.84	0.014**			
Subjective norm	socie_care	+	3.81	3.67	0.801	-0.229	-0.327	0.813
	hh_support	+	3.76	3.62	0.821			
	colleagues	+	3.28	3.26	0.556			
	pressure	+	2.98	2.81	0.848			
Perceived behavioural control (PBC)	know_hh	+	3.75	3.63	0.766	-0.226	-0.295	0.795
	know_eatout	+	3.69	3.64	0.644			
	know_restaur	+	3.76	3.71	0.645			
	know_work	+	3.61	3.53	0.710			
	control_wp	+	3.05	2.92	0.798			
	control_hh	+	3.45	3.45	0.495			
	recycle	+	3.40	3.17	0.913†			
Intention	not_care	-	1.69	1.98	0.976††	-0.372	-0.653	0.993†††
	waste_hh	+	3.71	3.44	0.968††			
	waste_work	+	3.57	3.37	0.938†			
Situational factors	hassle_hh	-	2.68	2.74	0.655	-0.259	-0.356	0.802
	waste_time	-	2.78	2.93	0.840			
	waste_tech	?	2.24	2.35	0.522			
	council	?	2.92	2.89	0.895			
	recycle_wp	?	3.22	3.16	0.705			
Behaviour	food_spoil	-	2.69	2.59	0.273	-0.128	-0.240	0.904†
	rarely_waste	+	3.28	3.10	0.848			
	prepare_waste	?	2.44	2.77	0.060*			

Notes: The sample size can vary slightly between statements and indicators because participants were not forced to assess all the statements. [1] Direction of the hypothesis as explained in Table 6. [2] The *p*-values refer to the difference between the baseline and post-implementation responses. For the specific statements, in the case of a "directional" hypothesis the *p*-values refer to a one-tailed *t*-test; in the case of no expected change to a two-tailed *t*-test. For the indicators, the expected change is always positive. Significance levels for changes in line with the hypothesis: *** 0.01, ** 0.05, * 0.10. Significant levels for changes in the opposite direction: ††† 0.01, †† 0.05, † 0.10.

4.4. Impact of the 'supply chain efficiency' innovations

In this section first the economic impact analyses of Tasks 2.4; Task 3.3, Task 5.1 and Task 5.2 is covered individually. Then in the final part, the statistical analyses results of participant surveys collected from those involved in the demonstration of the supply chain efficiency innovations is provided under the social impact evaluation.

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4.4.1. Economic impact of 'supply chain efficiency' innovations

Task 2.4 Forecasting software to reduce waste of F&V products

The simulation of retail sales aimed to optimise fresh fruit and vegetable orders based on historical data to avoid surplus at store level. The baseline was constructed based on historical sales data of 50 fruit and vegetable items between April and May 2022 and the simulation was conducted between April and May 2024 in 2 stores of the Italian supermarket chain Pianeta Cospea.

As this task was simulation-based and the simulated orders may not have been implemented by the store managers, no actual impact is captured via management surveys and the focus of our impact analysis is the potential cost savings based on the change in different categories of waste between the baseline and the simulated orders. Waste is reported in two categories: recorded waste and total waste, which is sum of recorded and unrecorded waste[21], the inventory gaps for the same products not explained by the recorded waste amount (Malefors et al., 2024). To monetise both recorded and total waste, average unit cost per item figures reported by the retailer were used.

Table 28 below reports the average (mean) change in the percentage ratio of recorded and total waste to the total mass of purchases between the baseline and the implementation (simulation) periods for the two stores and for all products.

Table 28: The change in the % ratio waste to purchase ratio of fresh produce participating stores

Period	Store1 Recorded	Store1 Total	Store2 Recorded	Store Total
Baseline	0.12%	4.05%	0.00%	5.74%
Implementation	0.15%	3.91%	1.92%	5.55%

While the ratio of total waste to purchase mass in both stores decreased modestly, the ratio for recorded waste to purchase mass in both stores increased (by 1.92% in Store 2 and by 0.03% Store1) in the simulations. The majority of the food waste that took place in the two stores was in the form of unrecorded waste. The patterns are similar, with the exception of the total waste of Store1. The value calculations were endogenous to the simulation and was based on the cost of each item to the retailer. While the monetary cost of the total waste in STORE1 increased, the ratio of food wasted to food purchased for STORE1 decreased. It might be worth reflecting on what this means.

The average (mean) change in the value of recorded waste and total waste between the baseline and the simulation scenario for Store1 and Store2 for all products are summarised as Table 29 below.

[21] Recorded waste: all food products recorded as waste by the retailer. Unrecorded waste: food products that are wasted without being recorded. They are measured based on inventory gap.

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*Table 29: Average (mean) change in cost of recorded and total waste in the stores**

Period	Store1 Recorded	Store1 Total	Store2 Recorded	Store2 Total
Baseline	0.43 €	71.50 €	0.08 €	105.80 €
Implementation	1.51 €	104.04 €	34.13 €	107.37 €

*The results reported are based on the change between combination of April and May 2023 for the baseline and combination of April and May 2024 for the simulation scenario. Therefore, they refer to a two-month period. Monthly change in each store can be estimated by halving these.

While the cost figures for all categories increased from baseline to implementation, these increases were small for Store1 recorded waste and STORE2 total waste, and more pronounced (over €30) for Store1 total waste and Store2 recorded waste. The specific conditions in each store can explain the different outcome. Further details of the analysis can be found in Appendix 3.

Task 3.3 FoodTrack Software for bakeries

FoodTracks (FT) aims to improve efficiency of orders in bakeries, where the freshness of the products is critical for the customer. FT was implemented in three bakery companies, each with multiple stores in Germany (Baur et al., 2023). Table 30 shows the indicators that were used for the economic analysis.

Table 30: Indicators for Economic Analysis of FoodTracks

C_{var} lost in EUR / year	Variable cost of returns per year – includes the sum of the variable part of the cost associated with the bakery products that are returned to the production facility without being sold, such as cost of raw materials and production cost. The variable costs are determined using the contribution margin (CM) for bakery products. CM indicates the proportion of the net sales price (NSP) per item that is available to cover fixed costs. The reference values for the CM for the various product groups in German bakeries are assumed as follows: bread 80%, rolls 85%, cake* 45%, pastry 70%, snacks 55% (BWHM GmbH, 2022)
ROI in EUR	Return on investment: The sum of savings through the innovation and the necessary costs. The variable costs saved by using FT are included in the calculation as savings and the annual fees for the bakery stores for FT are taken into account as costs for the innovation.

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

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The measurement periods for the bakeries varied between 7-14 months for the baseline and 10-15 months for the demonstration phase. To make the data from the three bakeries and the two measurement periods comparable, they were each normalised to one year. Based on the order and sales records captured, after starting to use FT, all three companies achieved reductions in their proportion of unsold bakery items returned to the production facility ("returns") to their overall sales, especially DE1 compared to the other two.

We hypotheses that the most relevant economic benefit of optimised orders is the reduction of cost of returns expressed as the variable cost including the raw material input and production cost for the returned items.

While the turnover and the scale of production remained consistent between the baseline and the demonstration periods in companies DE3 and DE4, DE1 increased its production and sales in the demonstration period, which also led to an increase in returns, yet the highest reduction in surplus achieved at this company. The figures interpolated to an annual scale were used to estimate cost-savings at company level and across the three participating companies (Table 31).

Table 31: Variable cost savings related to the use of FoodTracks

Changes in variable cost due to innovation (EUR/year)	**DE1**	**DE3**	**DE4**	**Average***
Total var. cost savings (€/year)	45,673	17,755	25,729	29,719
Reduction in the cost of returned goods	20%	9%	21%	16%

**Average is the arithmetic average of 3 companies and is not weighted by store or production scale.

Apart from the variable cost savings revealed by the analysis, in the management surveys two of three companies reported benefits in terms of reduction in waste management costs, which is another indicator for profitability. On the other hand, there are monthly costs associated with using FT that were stated in the management surveys. These costs were expressed in terms of cost of additional equipment, energy demand reduction and monthly fees paid to the platform by companies for each company based on the charge per store times number of their stores using the platform.

The stated costs of waste management and additional equipment (e.g., computers, tablets etc.) were not robust as they conflicted with each other and were not precise as survey respondents made rough estimates when responding. Also, FT has been in use on various hardware set-ups (e.g., desktops, laptops or tablets) across user sites. This indicates that the equipment already available, not only in company headquarters but also in individual stores (if orders are made in a decentralised manner), will suffice for the implementation of FT without any need for further hardware purchases. The platform did not lead to additional cost in terms of the energy consumption or staff time according to available data. Based on these figures the participating bakeries Returns On Investment (ROI) from implementing FT could be calculated as summarised in Table 32 below.

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The ADB Nord, a training academy for apprentices in the bakery trade, which is also involved as a project partner, can promote the further dissemination of the software in the industry through its spillover effect. They use the training booklet (Strotmann et al., 2023) created as part of the LOWINFOOD project to train employees in the bakery industry in the use of forecasting software as part of their training by apprentices and master bakers.

Table 32: Return on investment (ROI) for users of FoodTracks

Variables	DE1	DE3	DE4	Average
Cost savings from the use of FT (€/year)	45,673	17,755	25,729	29,719
Subscription fees of FT software (€/year) *	8,640	7,560	5,940	7,560
ROI (€)	37,033	10,195	19,789	22,159

*The average subscription cost of FT was 45 EUR per month per store . It was calculated for 16, 14, and 11 stores respectively. The average figures are estimated for a bakery with 14 stores.

Task 5.1 KITRO Innovative food waste solution

Kitro Food Waste Management Solution captures and analyses relevant information about the food being thrown away from commercial kitchens by combining image processing and deep learning technologies with a hardware solution to enable informed decisions and optimized work practices in food service businesses (Strotmann et al., 2023).

Kitro differentiates the food waste measured into edible or inedible. The type of waste measured can be identified based on where the device is put in the food service facility. For instance, plate waste is measured in the dishwashing area, preparation waste in the kitchen, and multiple machines could be used in different locations of the same facility. While both edible and inedible waste categories are measured by mass by the device, only edible waste components (edible overproduction and edible plate waste) are monetised in the system. In the scope of the LOWINFOOD project, Kitro was implemented in two locations in Germany, one location in Switzerland, and two locations in Greece (Strotmann et al., 2023).

We hypothesised that the use of Kitro would reduce food ingredient costs as managers and other staff responsible for the supply of food ingredients will be able to, on the one hand, avoid overproduction in food preparation in kitchens with improved production planning, and on the other hand, adjust portion sizes and content to reduce plate waste with the feedback provided to them by the Kitro dashboard.

Three locations were managed by the German side of T5.1. Each was a different type of Ho.Re.Ca. facility and represented different Kitro user profiles. DE1 was a restaurant in a vacation park in which breakfast, lunch, and dinner were served during the demonstration period captured by Kitro. DE2 was a business canteen that serves only lunch. CH was a restaurant in a hotel in Switzerland (Gerwin & Strotmann, 2024; Strotmann et al., 2023). DE2 has a much larger capacity (800 meals/day) than DE1 (130 meals/day) and CH (300 meals/day) (Strotmann et al., 2023).

Kitro offers two different ingredient pricing options: one is to use industry pricing, and the second one is for the property to provide their personalized costs. When using the industry

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cost, ingredient level costs per kilo are assigned (i.e., over-production waste and plate waste). Kitro provides in-built industry average prices for food ingredients for each country it has users in. The industry averages in each country are not sourced from an open access source but constructed with the entries of past and existing users (e.g., hotels, restaurants etc.) in the same country, and updated based on local inflation information.

New users can enter the price information for the ingredients they use in an Excel template to have their entries as default prices, or use the industry averages available from the most similar country. In either case, the users can edit the price information in the dashboard manually whenever required. For example, in our case studies locations CH, DE1 and DE2, the default prices using industry averages compiled from the entries of Kitro's former customers based in Germany and Switzerland were suitable for use without alterations but had to be replaced manually in the dashboard with local prices in Greece for certain ingredients like fresh fruits and vegetables.

In the German and Swiss sides of the demonstration, we have information in the form of management surveys as well as data captured by Kitro and analysed by ISUN, the research partner involved in the task (Gerwin & Strotmann, 2024). In their management survey responses, based on self-assessment rather than punctual measurements, all three facilities stated that there were no cost savings, reduction in waste disposal costs, or changes in any sale prices as a result of using Kitro. Also, their responses indicated no improvements in other profitability indicators except in the case of CH. CH indicated that Kitro suggested them selling leftovers from brunch buffet on the Too Good To Go app. Following this advice, they started selling 30-40 packages per month at 8 Swiss Francs per package, and after subtracting Too Good To Go's commission of around 20%, this resulted in 200-250 Swiss Francs extra income each month. This could be counted as a new stream of income worth around 190 €/month and 2,280 €/year. This additional income is not created due to the reduction of edible waste production, the explicit goal of Kitro, but is certainly an added benefit of Kitro and the resulting knowledge exchange in CH.

Unlike the two other demonstration locations, CH also mentioned some spillover effects as Kitro was shown to managers of other facilities in their hotel chain. However, the respondents did not specify if this had resulted in any actual adoptions of Kitro by these other facilities. In LOWINFOOD, the fee for Kitro, which depends on the chosen scope of services, were covered by the project. A full-service fee (incl. shipping and setup) of 6620 EUR per year was assumed to calculate the ROI in this deliverable. Even though none of the participating locations in three countries expressed interest in continuing to use the innovation themselves, in two cases the innovation is adopted at wider scale by their parent company after the demonstrations. Kitro is still used in the other facilities of the holiday resort chain that one of demonstration locations is a member of and of the hotel chain that another demonstration location is part of.

Innovation task leaders provided further figures (in addition to the management survey responses) combining user data captured in Kitro, sale prices, the cost of edible waste, the number of meals sold, and the price of different meal ingredients, combined with secondary

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or users' data. These are summarised for Germany in Table 33 below and for Greece later in text, in Table 34. Despite gaps in the data and a number of food items that cannot be covered in the analysis in each location, as detailed above, these analyses provided meaningful insights into the cost of different types of edible food waste and the potential for valorising different types of waste when it cannot be avoided.

Table 33: Change in economic variables between the baseline and demonstration periods in two German (DE1, DE2) and one Swiss (CH) test locations and ROI values for two scenarios

	Change in the cost of edible over-production (€/year) (% change)	**Change in the cost of edible plate waste (€/year) (% change)**	**Total change (€/year) (% change)**	**ROI – Scenario A**	**ROI – Scenario B**
DE1	-6024 (-69%)	-1820 (-15.8%)	-7844 (-39%)	-41%	18%
DE2	-17141 (-48%)	+7447 (+54%)	-9695 (20%)	-27%	46%
CH	+2118 (+6.2%)	+1004 (+5%)	+3122 (+6%)	-147%	-147%

Notes: The percentage ROI is calculated as: (total change + cost of device(s)) / cost of device(s). Scenario A: subscription fee for the actual number of devices deployed. Scenario B: subscription fee for one device deployed.

The monetary figures provided by innovation task leaders are converted to per day values for comparability across locations and between the baseline and demonstration phases. Cost values for the demonstration phase were adjusted in proportion to the average number of guests per day in the baseline across the sample to account for the increase in the average number of guests per day in the demonstration period. The increase was likely to be linked with an overlap between the holiday season and the demonstration period, and was observed in all locations, being particularly significant in the properties located in holiday destinations, i.e., DE1 located in a vacation park in Germany and one of the Greek hotels (G1).

On the German and Swiss sides of the demonstration, each participating location had one device set up in the kitchen area to measure production waste; in DE1 and DE2 there was also another Kitro bin in the dishwashing area to measure plate waste. In CH, one device was targeted to capture both the overproduction and plate waste components.

The ROI was calculated for two scenarios. The users were provided with the devices free of charge as part of the project. This distorts the results of the ROI calculation, as they would probably have made different decisions about the number of devices used if they had had to pay a fee for the devices themselves. In the first scenario (Scenario A), the ROI was calculated for the actual number of devices deployed. In the second scenario (Scenario B), it was assumed that each organisation deployed only one single device. ROI figures were calculated for DE1, DE2 and CH based on the annual change in the cost of food input (change in the cost for edible overproduction and plate waste), and the annual additional income creation

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(only for CH). In Scenario B, we assume that the benefits in terms of cost reduction are not related to the number of devices deployed.

Based on the data measured on the Kitro platform, significant reductions in the net cost of total edible waste were achieved in DE1 and DE2. CH was the only location out of the three where no cost savings were achieved, and a slight increase was observed in the costs of both edible over-production and plate waste[22].

It was assumed that the annual subscription was the only cost linked with using Kitro. Annual subscription costs were estimated based on the number of devices deployed (two in DE1, two for DE2 and one for CH in Scenario A; always one in Scenario B). The return on investment for DE1 is -41% in scenario A, which means, the cost for implementing the innovation cannot be covered by the potential cost savings. In scenario B, on the other hand, the use of the device pays off and leads to a positive ROI of 18%. The situation is similar for the second user. Here, too, if two devices are used, it is not possible to cover the costs of the innovation with the costs saved. If, on the other hand, only one device were used (scenario B), the ROI would have been 46%. CH was the only location out of the three where no cost savings were achieved so that the investment does not pay off at first glance, which is expressed by an ROI of -147%.

In Greece, Kitro smart bins was adopted in two hotels, each receiving five devices. The first hotel, GR1, is an "all inclusive" hotel located on a Greek island. The five KITRO devices were installed in the central kitchen, the cold kitchen where "cold" dishes are being prepared, the restaurant, the terrace left, and the terrace right (Strotmann et al., 2023). The second hotel, GR2, also located on a Greek island, is not an "all-inclusive" hotel. Five KITRO devices were installed in the hotel's à la carte restaurant but in different areas of production: the pastry; close to the bench for the preparation of vegetables; close to the benches for the preparation of meat/fish; the fine dining restaurant; and the main restaurant, where plate waste was measured (Strotmann et al., 2023).

In the Greek side of the demonstration, we analysed the information in the form of management surveys as well as the data captured by Kitro (analysed by HUA, the research partner involved in the task). In the management surveys, both GR1 and GR2 reported no change in the socioeconomic indicators, and both G1 and G2 indicated that there was no potential for reducing waste disposal costs as waste disposal costs are calculated per facility size, thus it is not a relevant indicator for cost saving.

In the management surveys, both hotels expressed interested in continuing to use Kitro, but GR1 stated that they would not continue with the innovation given the cost of Kitro and the additional staff requirement for using the device. Indeed, there was a need to have a member of staff in charge of data input (e.g., number of guests, food cost, etc.), which made

[22] Kitro, the innovation provider in the task, stated that at the time of the survey, CH may not have identified direct cost savings in terms of input costs, disposal costs, or price changes linked with the use of Kitro. However, according to their statements, the savings of food items and food cost was clearly identified and recorded. We were not provided these records during the impact evaluation but the positive outcome during demonstration could be evidenced by CH's continuation of Kitro smart bin use after the end of demonstration period.

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continuation unfeasible in their case. On the other hand, GR2 stated that the innovation was one of the reasons they won a sustainability award, and they had already signed a contract to continue using Kitro after the demonstration. Both hotels recommended the device to others, and indicated that that they would keep recommending it. In the case of GR1, the hotel to which they recommended and provided information about the device would not go forward with adopting the device, stating cost as a barrier. In the case of G2, they promoted it to the members of hotel chain they are part of, and many expressed an interest, but the number of those that started using the device as result of their recommendation was not disclosed.

The results based on data captured by Kitro on overproduction and edible plate waste are summarised in Table 34 below.

Table 34: Change in economic variables between the baseline and demonstration periods in two Greek locations and ROI values for two scenarios

	Change in the cost of edible over-production (€/year) (% change)	**Change in the cost of edible plate waste (€/year) (% change)**	**Total change (€/year) (% change)**	**ROI – Scenario A**	**ROI – Scenario B**
GR1	-4749 (-66.41%)	+4568 (+16%)	-181 (-1%)	-99%	-97%
GR2	-15,471 (-35%)	+3659 (+107%)	-11,812 (-21%)	-64%	78%

Notes: See Table 33.

The results in GR1 and GR2 were similar to the results observed in DE2 in terms of reduction in over-production and increase in plate waste. Major reductions in the cost of edible over-production were achieved in both GR1 and GR2 but these were also coupled with increase in the cost of edible plate waste. Yet this resulted in net reduction in the total cost of edible waste in both locations, much more significant in GR2. In the absence of the LOWINFOOD project demonstration, the hotels were expected to adopt less than five devices (scenario B). In GR2, achieving the same results by using a single device would have led to a positive annual ROI of 78%.

We expected Kitro to reduce over-production in the participating kitchens by allowing for better planning of food production, and to change plate waste on the customer's side through optimisation of portion sizes and contents based on plate waste. The innovation's objective of reducing the cost of edible waste was reached in four of the five participating locations. However, in none of these locations the annual ROI was positive, despite reduction in waste cost. Noteworthy, in DE1, DE2, and GR2 using one single device would have made the balance positive. The current subscription cost limits the economic feasibility of adopting several Kitro devices. This is in line with the recommendation in D5.7 "The Report on Demonstration-Kitro" for launching a lighter model solution with less services (e.g., only measuring

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the categories of waste of higher interest) and targeting smaller businesses at a lower price (Strotmann et al., 2023).

A valuable observation from the data collection process is the mismatch between the stated and observed data, which would also be relevant for other innovations. All respondents of the management surveys were unable to identify and state gains in various indicators linked with food production costs at the time of filling out the management surveys. However, the data captured automatically clearly pointed out to cost savings linked with reduction of over-production and plate waste in most of the participating locations. The reduction of food waste also points to potential unaccounted savings in other aspects of cost (e.g., electricity, gas, water, waste disposal) linked with food production and waste disposal that were covered in the management surveys but were not directly measured.

The demonstration of Kitro also informs where the Kitro device should be placed for most efficient reduction of edible food waste costs. The innovation has been more cost effective across test facilities of different scales in reducing the cost of over-production waste in kitchens, compared to the cost of customers' plate waste in which the influence of kitchen managers' is more limited despite use of innovative solutions like Kitro. Therefore, its deployment in kitchens and particularly in production planning should be prioritised over other locations by prospective users only focused on costs. However, for any property that is looking to have a holistic impact (e.g., environmental benefits), such automated food waste measurement system can lead to higher impact actions and increased resource savings.

Task 5.2 MITAKUS Forecasting software for restaurants

Mitakus is a web-based platform that combines historical sales data from professional kitchens with external factors such as weather, holidays, etc. to calculate a sales forecast. The aim is to help chefs, production and purchasing managers, and operations personnel in planning production quantities based on customer preferences and customer flows and reduce over-production (Strotmann et al., 2024).

In T5.2, Mitakus was tested by DE1 and DE2, two university canteens of different scale, both located in Germany. DE1 serves 2,000 to 3,000 meals a day and DE2 serves 200 to 600 meals a day. Only warm lunch meals were recorded and predicted by Mitakus (Strotmann et al., 2024). We hypothesised that the variable costs of production, particularly the cost of raw food materials, and the productivity of input materials are particularly relevant for the platform.

Similar to the demonstration of Kitro in T5.1, both management surveys and platform-recorded data from two participating canteens during the demonstration were available for the economic impact analysis. The cost information is not automatically embedded in the Mitakus platform, the data captured did not derive financial outcomes of forecast but compared the long-term and short-term forecasts of demand with the current demand in quantities (number of meals) (Strotmann et al., 2024). Both canteens already performed well in terms of mitigating daily changes in customer demand and menu plans and managing overproduction to avoid food waste. Therefore, the reduction potential thanks to Mitakus was limited in

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these specific cases, and these companies might not use Mitakus in their daily business as they concluded that the Mitakus forecasts were not as reliable as their own forecasts (Gerwin & Strotmann, 2024).

In the management surveys, both canteens stated that they recommend Mitakus to others, yet they also indicated that they would not continue using Mitakus after the end of the project, stating low financial benefit and the difficulty to identify additional benefits from the platform. While no subscription costs were charged during the LOWINFOOD project, in the absence of such a subsidy, setting up the Mitakus platform costs € 2,000, and facilities of similar size as DE1 and DE2 were charged monthly fees of € 400 and € 250 for forecasts, excluding desserts and side dishes, resulting in total costs of € 4,800 and € 3,000 annually for basic service at the time.

The manager of DE1 indicated no economic gains or reduction in waste achieved, while DE2 assumed some waste reduction as a result of participating in the project but they did not have the data to provide a specific figure. This can be assumed due to the increased awareness for food waste, a side effect of their participation in the user's participation in LOWINFOOD rather to the use of Mitakus, as these users did not actually use Mitakus.

The lack of economic impact in DE1 and DE2 can be linked to two main reasons. Firstly, the baseline data was collected during the COVID-19 pandemic and as a result, it was not representative of the demonstration period, the predictions not being correct most of the time, and the forecasts were rarely implemented by canteen staff. Secondly, these facilities might not be the ideal settings for the Mitakus platform. The setting in which the canteens operate required high adaptability in the short-term, and their fully equipped kitchens and storage facilities on site allowed for this flexible operation pattern. As a result, both canteens stored and reworked their surplus and were ready to respond quickly if higher than expected customer demand occurred.

Users indicated that the platform would be more beneficial in settings with less possibilities to make use of overproduction; and in locations where menu plans undergo little or no changes, especially in the short-term (Strotmann et al., 2023). A good example of this are satellite kitchens where the possibility to store, rework and reuse surplus food is limited. In these set-ups, the food cooked in a central kitchen is delivered to various satellite kitchens to be reheated and served.

Despite the mismatch between Mitakus platform's capabilities and the operational needs of the participating canteens, DE2 highlighted the benefit of the innovation in terms of making staff avoid food waste and indicated that users with no options to reuse overproduction may benefit the most from the innovation. Indeed, the analysis of social indicators below shows that such innovations generate an impact on employees in terms of improved attitude towards food waste and, possibly, behaviours.

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4.4.2. Social impact of 'supply chain efficiency' innovations

The innovations of the type "supply chain efficiency" include T2.4 "Sales forecasting software", T3.3 "FoodTracks", T5.1 "Kitro", and T5.2 "Mitakus", which are all technological innovations entailing the use of software to improve planning in using food inputs.[23] Our 81 responses, all provided by company employees, are skewed towards the baseline (54) due to the difficulty in obtaining a second response from them. The Sales forecasting software was implemented in a supermarket of the retailer Pianeta Cospea in Italy, obtaining two responses in each phase. FoodTracks was implemented in three German bakeries, of which one provided most of the responses (13 in the baseline and three in the post-implementation phases), and the others one responses in each phase or one in a single phase. Kitro was tested in five organisations: Germany (two), Switzerland (one), and Greece (two), but in the post-implementation phase only one organisation from Germany and two from Greece provided responses. Finally, Mitakus was implemented in two German companies, of which only one provided post-implementation responses.

Among the respondents who provided their role, 28 (14 in each phase) had managerial positions (store, division, bakery, or kitchen managers), 50 (38 in the baseline and only 12 in the post-implementation phases) were lower-level staff. The drop in the number of staff respondents across the two phases highlights to the difficulty in ensuring the commitment to our research of employees without direct management responsibilities. Almost all the respondents were involved in the innovation from the start of its implementation; otherwise, at the post-implementation phase, the period of involvement had been at least two months for everyone. Table 35 reports the change in the indicators as a result of being involved in the implementation of innovations of the type "supply chain efficiency". Noteworthy, differently from other innovation types, we do not observe any statistically significant changes in a direction opposite to our hypotheses, neither in the single statements, nor in the aggregated indicators. A significant positive change is observed in "**Moral concern**" ($p < 0.01$) and "**Intention**" ($p < 0.10$), while other aggregated indicators do not change significantly. Nevertheless, three statements related to "PBC" and one related to "Behaviour" change in line with our hypotheses, in addition to all the statements related to "Moral concern" and one of those related to "Intention." Importantly, a significant positive change ($p < 0.05$) is observed in the statements related to reducing food waste in the workplace ("*I know what to do to reduce food waste at work*" and "*I am committed to reducing food waste in my workplace*"), in line with the type of innovation tested. We could thus conclude that innovations focusing on "supply chain efficiency" are probably the most effective in generating a social impact among employees.

[23] T2.3/T4.2 "Leroma" operates in the areas of food redistribution as well as supply chain efficiency, food valorisation. We discuss it in the section about food redistribution. However, no responses to the participant survey were obtained from its users; therefore, social indicators are not discussed.

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Table 35: Change in social indicators between the baseline and post-implementation phase for innovations of the type "supply chain efficiency" (N = 81)

Indicator	Statement	Hypothesis[1]	Baseline	Post-impl.	*p*-value[2]	Baseline	Post-impl.	*p*-value[2]
Attitude	waste_quan	+	4.57	4.74	0.221	0.094	0.269	0.125
	planet	+	4.53	4.69	0.180			
	economic	+	4.60	4.81	0.104			
	resources	+	4.64	4.81	0.157			
	waste_inevi	-	2.59	2.52	0.410			
	waste_impos	-	2.93	3.22	0.807			
Moral concern	worry	+	4.26	4.67	0.024**	0.058	0.427	0.009***
	waste_irres	+	4.09	4.48	0.052*			
	guilty	+	4.17	4.56	0.042**			
	responsible	+	4.53	4.85	0.037**			
	principle	-	2.33	1.89	0.079*			
Subjective norm	socie_care	+	4.11	4.31	0.212	0.327	0.493	0.146
	hh_support	+	4.29	4.50	0.157			
	colleagues	+	4.19	4.35	0.243			
	pressure	+	2.77	2.96	0.269			
Perceived behavioural control (PBC)	know_hh	+	4.36	4.68	0.056*	0.283	0.399	0.221
	know_eatout	+	4.02	4.44	0.051*			
	know_restaur	+	4.06	4.36	0.114			
	know_work	+	4.26	4.60	0.047**			
	control_wp	+	3.68	3.67	0.519			
	control_hh	+	4.29	4.21	0.640			
	recycle	+	3.66	3.29	0.863			
Intention	not_care	-	1.37	1.19	0.162	0.312	0.581	0.061*
	waste_hh	+	4.49	4.73	0.105			
	waste_work	+	4.42	4.81	0.025**			
Situational factors	hassle_hh	-	2.24	2.29	0.566	0.131	0.120	0.520
	waste_time	-	1.92	2.29	0.889			
	waste_tech	?	2.18	1.79	0.200			
	council	?	3.24	3.33	0.796			
	recycle_wp	?	3.96	3.54	0.165			
Behaviour	food_spoil	-	2.57	2.12	0.073*	0.116	0.235	0.253
	rarely_waste	+	3.82	4.15	0.111			
	prepare_waste	?	2.29	2.52	0.445			

Notes: The sample size can vary slightly between statements and indicators because participants were not forced to assess all the statements. [1] Direction of the hypothesis as explained in Table 6. [2] The *p*-values refer to the difference between the baseline and post-implementation responses. For the specific statements, in the case of a "directional" hypothesis the *p*-values refer to a one-tailed *t*-test; in the case of no expected change to a two-tailed *t*-test. For the indicators, the expected change is always positive. Significance levels for changes in line with the hypothesis: *** 0.01, ** 0.05, * 0.10. Significant levels for changes in the opposite direction: ††† 0.01, †† 0.05, † 0.10.

4.5. Impact of the 'food redistribution action' innovations

In this section first the economic impact analyses of Tasks 2.1; Task 2.2, Task 2.3 (also Task 4.2) is covered individually. Then in the final part, the statistical analyses results of participant surveys collected from those involved in the demonstration of the food redistribution actions is provided under the social impact evaluation.

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4.5.1. Economic impact of 'food redistribution action' innovations

Task 2.1 SIR Software for F&V

The S.I.R. platform (Withdrawal Information System) is an online IT tool created by the Government of the Region of Emilia-Romagna (hereafter RER) in Italy. The aim is to manage and redistribute fresh fruits and vegetables withdrawn from the market as a result of regulations from the Common Agricultural Policy (CAP) of the EU. RER has been using the SIR platform since 2012 to transparently and efficiently monitor donations of withdrawn produce and refunds paid to producers' organisations (POs) in exchange. The surplus produce is redistributed to accredited charities or other venues (e.g., ethanol production, bio-digestors) with refund payments less than donations for human consumption (Callegari et al., 2022).

Task 2.1 of LOWINFOOD replicates the implementation of this tool in Romania, another EU country where CAP mechanisms are also available to refund local POs the expenses associated with withdrawn products and their sorting, packing and transport in case of donation to charities. Romania is a significant producer of agricultural products and yet, unlike many other regions and countries in the EU, a platform for this purpose has not been in use before. The replicators in Romania were kindly supported by the National University of Science and Technology "Politehnica Bucuresti", which is not a partner of the LOWINFOOD consortium.

The demonstration was only theoretical and implemented as a simulation exercise. Three scenarios of use were simulated using historical data of surplus production from a Romanian farmers' cooperative for the period from 2018 to 2022. In the first scenario, it was assumed that all surplus was donated to charities for human consumption. In the second scenario, half of the surplus was assumed to be donated for human consumption and half of the surplus was assumed to be sent to non-human uses. The third scenario assumed all surplus to be sent for non-human consumption uses. In all scenarios, the transport distance is within 750 km, and all transport costs are fully refunded by the CAP (Giordano et al., 2024).

The average cost of (€/kg) of agricultural products fit for human consumption is set nationally in each EU country, and these prices are not available in Romania because the Ministry of Agriculture of Romania is not currently paying out these compensations. In the absence of local figures, the figures used in Table 36 were taken from D2.8 (Giordano et al., 2024). These results were constructed using historical Italian cost averages for reimbursement, which is an overestimation in the case of Romania. The Ministry of Agriculture of Romania were contacted by the local researchers, but the local researchers did not receive any response. Under these conditions, neither a more realistic local rate of compensation could be determined, nor these CAP compensations could be paid through the Ministry of Agriculture of Romania on behalf of the EU Commission at the end of the demo.

After consultation with the task leaders, it was decided to convert these prices using a purchasing power parity (PPP) index of 0.8 between Italy and Romania in 2023 based on the

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European Commission Statistics[24] and to include the converted figures in parentheses in Table 36 below.

Table 36: Scenarios of surplus reimbursement from CAP mechanism to the partnering Romanian producer Organisation if SIR were in place (Giordano et al., 2024)

Description	Strawberries	Plums	Apples	Pears	Sum
Product (Tons)	200	200	100	100	600
Unharvested (Tons)	2	2	1	2.2	7.2
Harvested but not sold* (Tons)	0	10	20	3	33
Total amount of surplus (Tons/year)	2	12	21	5.2	40.2
Free of charge distribution for human consumption (€/kg)	1.105 (0.884)	0.376 (0.300)	0.241 (0.193)	0.181 (0.145)	-
Other uses (€/kg)	0.829 (0.663)	0.282 (0.226)	0.181 (0.115)	0.254 (0.203)	-
Sorting and packaging (€/ton)**[25]	201.1 (160.9)	159.6 (127.7)	201.1 (160.9)	187.7 (150.2)	-
Scenario 1 (€/ton- average per year)***	2613.6 (2090.9)	1071.2 (857.0)	442.7 (354.2)	1160.0 (928)	5287.5 (4230)
Scenario 2 (€/ton-average per year)***	1721.4 (1377.1)	676.6 (541.2)	266.6 (213.2)	720.1 (576.1)	3384.7 (2707.8)
Scenario 3 (€/average per year)***	829.3 (663.4)	282 (225.6)	90.5 (72.4)	280.1 (224.08)	1481.9 (1185.6)

*out of the scope of EU Regulation. Only "Unharvested products" have been considered for the estimation of the reimbursement. The costs for sorting and packaging for Romanian products are defined by the Commission Implementing Regulation (EU) 2017/892 Annex V. Strawberries in a certain €/ton for each category and cherries strawberries come under the definition "Other Products" for which the refund is €201,10 ton, apples, for example, are priced differently at €187,70/ton. For transport, the formula is similar: depending on the food category, a certain amount of €/ton is set for Romanian products, depending on the distance, a certain amount of €/ton is established (for example: €18.2 per ton for distances under 25 km, €41.4 for distances under 200 km, etc.). For the transport cost used in the simulation scenarios were directly provided by the Romanian POz. ** the PPP conversion rate between Italy and Romania is 0.8 and this rate has been applied to the figures provided in Giordano et al. (2024) to construct the figures in parentheses for Italy .

While no management survey was distributed due to the theoretical nature of the simulation, it is possible to discuss the potential wider supply chain impact of T2.1 in Romania. First of all, the simulated demonstration has informed farmers, POs, and other interested stakeholders of the CAP payments that they could claim in the future. During engagement

[24] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Purchasing_power_parities_and_GDP_per_capita_-_flash_estimate

[25] There are two formulas based on predefined parameters in the EU implementing regulation used in the calculation of packing and transport costs. For transport, depending on the distance, a certain amount of euros per ton is established. For packaging, the formula is similar: depending on the food category, a certain amount of euros per ton is set for packing and sorting. For Romanian products, it's €201.1 per ton as used for strawberries and plums in the simulations. The transport cost used in the simulations does not come from the formula based on predefined parameters in the EU implementing regulation but was provided by the Romanian producer organization involved in the task and included directly in the estimated yearly final figure in each scenario.

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activities, two more farmer cooperatives and three charities expressed interest in getting to learn about the SIR platform, which could be considered a spill-over effect. A capacity-building workshop in Bologna was held with the interested stakeholders in October 2023, which signals the establishment of potential new contacts through this task.

Task 2.2 Unverschwendet Cooperation system for fruit and vegetables

Unverschwendet GmbH in Austria (UNV business concept) enables business-to-business surplus food transfers. UNV acts as an intermediary in a network of surplus food providers and surplus receivers. They buy surplus food, transport, store, and potentially process it to sell it to suitable buyers (Scherhaufer et al., 2024). UNV manages this network of surplus providers and surplus users and organises services to enable transfers between supply and demand of surplus food for profit. The surplus food that is offered to UNV GmbH by the surplus providers in their network is categorised in 9 main groups: fruits (fresh), fruits (semi-processed), fruits (processed), vegetables (fresh), vegetables (semi-processed); vegetables (processed), oils and pulses (fresh), oils and pulses (semi-processed), and other (Scherhaufer et al., 2024).

Based on the transfers made within the network during the demonstration period, the following examples are provided for each category by the task leaders. Categories of "Fruits (fresh)" and "Vegetables (fresh)" contain different kinds of unprocessed fresh fruits (e.g., apple, pears, plumps etc.) and vegetables (e.g., cucumber, pepper, tomato, etc.), respectively. Categories of "Fruits (semi-processed)" and "Vegetables (semi-processed)" refer to items such as apricot puree concentrate, watermelon syrup and pumpkin cubes. Category of "Vegetables (processed)" indicate items like canned corn. While no amounts classified as "Fruits (processed)" were transferred during demonstration period, based on example provided for "Vegetables (processed)" category, canned fruits can be considered as an example of "Fruits (processed)". Category of "Oils and pulses (fresh)" include raw items like beans and chickpeas. Category of "Oils and pulses (semi-processed)" contain items like cooked beans, chickpeas and "Other" category puts together transfers of miscellaneous items like fennel, caraway seeds, popcorn maize etc. that cannot be put in any of the other categories.

UNV was already operating at the start of the LOWINFOOD project and the aim of T2.2 was to scale up their on-going business activities by expanding the number of network partners and increase the volume of annual surplus transfers it facilitated in the two-year demonstration period from February 2022 to January 2024. We hypothesised that the direct economic benefits of the task's aim will be the expansion of UNV's cost saving in provision of food ingredients for UNV and additional income creation for surplus providers.

In the interview conducted with UNV in 2022, at the start of WP1, they stated that their network consisted of 50 to 100 farmers and 15 food processors and aimed to expand the network to include around 500 farmers by 2023. They further stated plans for resuscitating relationships with restaurants to potentially involve them in the network. According to the feedback of UNV colleagues leading Task 2.2, the number of businesses that UNV was offered surplus food and actually bought surplus food from were 45 and 33 at the end the two years of demonstration period and in this period, they had to change their strategy due to the changing market conditions.

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The food service sector faced difficult times during the pandemic. Also, restaurants turned out to be complex partners for surplus food transfers (e.g., restaurant kitchens: only small quantities, canteen kitchens: high standards). For these reasons, UNV has decided in the course of the project to switch to the acquisition of fewer but bigger clients on the demand side like wholesalers or processing facilities. As a result, their annual volume of transfers increased from 57 tons of surplus food (largely used to produce watermelon syrup; about 25 tons) between July 2019 to July 2020 and from around 28 tons between July 2020 to July 2021[26] to 370 tons for the two-year demonstration period (i.e., 185 tons/year). Therefore, the initial aims of increasing the volume of surplus transfers have been met with a lot of success according to the input by UNV (Scherhaufer et al., 2024).

On the other hand, it has not been possible to estimate how proportional the economic gains from achieving the aimed increase in annual trade volume have been with the available data. Raw data was collected in the demonstration period for the surplus food quantities that was bought by UNV including 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.

While this data may be fit for use in other impact analyses, its formatting was not suitable for the purposes of economic impact analysis. First of all, the scale and the monetary value of transfers before the start of their involvement were not known, a single data set was provided without dates. Hence, a baseline to compare with the figures achieved between February 2022 and January 2024 could not be constructed. Secondly, raw data collected was aggregated to nine food categories (fresh fruit, processed fruit etc. as detailed above) before sharing to LOWINFOOD partners and no average price per category was available and each surplus transfer was recorded without disclosing the content only referring to the category. This formatting disabled the construction of prices based on national statistics for Austria in the demonstration period. As a result, we were unable to estimate the scale of the additional income for the surplus providers and the cost savings for UNV using the average discount range of 20-40% UNV applies to full market prices when offering prices for its transfers.

Additionally, four interviews with companies providing surplus food were conducted in August 2023 using management and participant surveys[27] to obtain more specific information at individual network member level. The economic data collected via management surveys did not allow for estimation of additional income generation by the four companies during demonstration and is summarised in Table 37.

[26]Task leader indicated that the UNV recorded surplus transfer using a different logic before 1 January 2022 and that this difference may complicate comparing total amounts of transfer during two-year demonstration period and those occurred in years prior to the demonstration period. However, without knowing about the nature of the change in the logic of records and if and how the reported weights of total surplus transfers in each period are affected from this change, we accept the figures expressed in tonnes/year provided for these periods comparable for the purpose of the evaluation made in this report.

[27] Participant survey responses are included in the social impact analysis for the food redistribution action group of innovations at the end of the section as number of responses from most innovations are too few (e.g., 4) to run a standalone analysis.

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On the other hand, the four companies' responses provided valuable qualitative insights. Based on the management surveys filled in by four stakeholders, the fixed and variable costs of one company increased and for other three, the costs stayed the same as a result of their involvement. Three out four respondents indicated that they were not creating revenues with their surplus through other valorisation routes, prior to their collaboration with UNV, which partially confirms our initial hypothesis about additional income creation for surplus food providers. One of the responding companies further exemplified that through cooperation with UNV, excess vegetables can be processed and sold, and do not have to be disposed of. Two of the four participating companies indicated that they informed others about the UNV business concept, one of these two recommending it to approximately five other businesses. All four companies stated that they would continue their cooperation with UNV, and that they had had a better experience than they had expected.

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Table 37: Summary of transfers from the management surveys

Company code	Food 1	Total annual surplus product quantity	Frequency of surplus*	% of surplus in total production on avg.	Other buyers of your surplus goods besides UNV?	% of the surplus can be used by working with UNV?	Food 2	Total annual surplus quantity	Frequency of surplus*	% of surplus in total production on avg.	other buyers of surplus goods besides UNV?	% of the surplus can be used by working with UNV?
C1	No info	No info	No info	1-5%	No	20%	It is assumed that the three of the four companies only had one type of surplus sold to UNV.					
C2	pumpkin	20ha*	1=daily	10-50%	Food bank Vienna	5%						
C3	apricot	10ha*	6=several times a year or other specification	10%	Food bank	90%						
C4	pumpkin frozen	No info	6=several times a year or other specification	>10%	Social markets Austria	>1%	bell pepper frozen	No info	6=several times a year or other specification	>10%	social markets Austria	No info

* In the production period

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Task 5.6 REGUSTO Mobile App

The REGUSTO mobile app has been in use in Italy between 2019 and 2023[28] (Rellini et al., 2023; Rellini & Secondi, 2022). Before it became unavailable in the app market in 2023, the REGUSTO app allowed its users to collect take-away meals at reduced prices from restaurants. For restaurants the app provided the opportunity to make a profit from meals prepared in surplus on the day by selling them while they are still fit for human consumption, rather than disposing these meals which might potentially incur additional costs (Rellini et al., 2023; Rellini & Secondi, 2022). We expected change in the indicators of additional income streams and possible reduction in food waste disposal costs due to the set-up and the purpose of this innovation.

The meals purchased are stored in boxes called REGUSTO Bag, that aimed to innovate the concept of take-out and "doggy" bags, aiming to reduce plate waste. Sit-in customers in restaurants were encouraged to use these bags to take along their leftovers and they were also used to pack surplus food orders on the app. Each restaurant participating in T5.6 received 300 REGUSTO Bags, some posters and other materials for raising awareness. In the present report, the impact of the innovation related to the sale of surplus meal sales on the app is covered. The use of these bags is more relevant from the perspective of environmental impact covered in D1.8 and is only considered as a cost aspect for the restaurants in the absence of the project in the socio-economic impact assessment.

Table 38: The summary of responses from the restaurants testing REGUSTO app

Restaurant code	BP* kitchen FW** (kg/month)	BP client FW** (kg/month)	BP cost of food waste disposal (€/month)	DP kitchen FW (kg/month)	DP client FW (kg/month)	DP cost of disposing of food waste (€/month)	New income created	New income (€/month)	Cost avoided (€) (due to waste reduction)	# of meals sold on the app
R1	300	8%	300	290	7%	300	No	0	0	1
R2	160	6%	200	140	5%	180	Yes	150	30	144
R3	150	10%	200	100	6%	180	Yes	200	20-30	280
R4	200	10%	300	150	7%	280	Yes	180	50	185
R5	600	10%	1000	600	10%	280	0	0	50	1

*BP refers to baseline period and DP refers to demonstration period **In consultation with innovation task leaders, we confirmed that client food waste (FW) corresponds to plate waste left over by the customers on the table, which is more relevant to the doggy bags and environmental impact analysis, and the kitchen related to the surplus meals sold as takeaway on the app.

[28] In 2023, the business transformed itself into an online business-to-business platform for redistributing surplus food from retail to charitable organisations due to increased competition from similar apps and changing market in the Italian Ho.Re.Ca sector

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The baseline and demonstration activities of the REGUSTO app in the scope of Task 5.6 took place in five restaurants (anonymised as R1, R2, R3, R4, R5) in the province of Lazio and Umbria (Italy) between May 2022 and July 2023. The participating restaurants filled in the management and participant surveys. The changes in economic indicators with regards to management survey responses from the five restaurants are summarised in Table 38 above.

The management survey responses jointly with data on orders made on the app indicated that two of the participating restaurants had negligible sales (i.e., R1 and R5 each sold one meal only). Three out of these five received orders and sold meals on the app. For a more representative assessment of the economic impacts, the rest of this section focuses only on outcomes in the three restaurants R2, R3 and R4 (Table 39).

Table 39: Economic outcomes of using REGUSTO app on R2, R3 and R4

Indicator	**R2**	**R3**	**R4**
Change in food waste management cost (€/month)	20	20	20
Cost avoided in € (due to waste reduction) (€/month)	30	25	50
Cost resulted from implementation of REGUSTO (€/month)	100	0	100
Additional income creation through orders on REGUSTO (€/month)	150	200	180
Fixed cost of waste disposal associated with meals sold on REGUSTO (€/month)	30	-	10
Variable cost of waste disposal associated with meals sold on REGUSTO (€/month)	20	-	10
Number of new users	10	30	50
Number of orders on REGUSTO (average number of orders on REGUSTO per user)	144 (14-15)	280 (9)	185 (3-4)

The management survey responses from the restaurants are in contradiction with each other's responses, and with the reality in the region and with what was recorded in the app. This required a lot of input from REGUSTO and local research partner for meaningful interpretation. Firstly, the local partners clarified that the trade waste in the region is charged at a monthly fix rate and is based on the floor area of the establishment rather than being proportional to the amount of food waste or other waste disposed. This input also falsified the initial hypothesis that selling meals on the app to reduce participating restaurants' food waste disposal costs. Therefore, the change in monthly food waste management costs and cost avoided due to waste reduction reported in the management surveys are not relevant.

Secondly, it was indicated by the task leaders and in the management survey response of one restaurant that advertising meals on the app was free of charge for restaurants. Therefore, the cost resulted from the use of REGUSTO was not relevant either. The management survey responses reported components of fixed and variable costs of meals sold on the REGUSTO mobile app. Considering no additional staff hours, no additional gadgets or items were specifically bought for advertising on the app were reported in the survey responses or by the academic partners, restaurants facing additional costs for selling discounted meals seemed unlikely. In consultation with the task leaders, it was suggested that the survey

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respondents might have confused these with the changes in actual fixed costs (e.g., taxes, permanent staff, rent, utilities, cleaning costs, insurance policies, and equipment maintenance costs) and variable costs (e.g., raw materials and seasonal staff) of running restaurants that are not linked with advertising and selling meals on the app. Therefore, these entries were also deemed not relevant and not considered in the calculations in consultation with REGUSTO and UNITUS, the local academic partner in the task,

Using the information in Table 38 and inputs from REGUSTO and UNITUS teams, we considered indicators relevant to this innovation are additional income creation resulting from the sale of discounted meals and new streams of business, accessing new type of customers through the app and no additional expenses (e.g., purchase of devices etc.) were made for demonstration. We derived additional income creation for the demonstration period[29] based on the monthly figures reported and in the absence of costs arising from the use of app, the return on investment (ROI) during demonstration in three locations could be estimated at €450, €600 and €540 in R2, R3 and R4 respectively. However, from this amount, the commission of REGUSTO must be deducted to calculate the net additional income for the restaurants. In the absence of commission rate, we applied the 20% commission charged from restaurants by Too Good To Go[30], a similar app for selling unsold meals at a discounted price, for each order made and estimated €1440, €1920 and €1728 net annual additional income for R2, R3 and R4 respectively. If we consider the standard price of a REGUSTO bag reported at €1 assuming one bag was used for each online order[31], still significant additional incomes of €1008, €840 and €1038 can be achieved at R2, R3 and R4 respectively.

The data captured in the app for the sale of each food category were combined with the secondary information about the sale prices of meals in the restaurants and further statistically analysed to understand the scope for additional cost saving for the customers buying discounted meals on the app, as well as for cross-checking the figures for additional income generation and the number of meals sold that were declared by the restaurants in the management surveys (Table 38). The analyses found that the largest consumer savings were achieved by pizza orders made to R2, followed by main dish orders to R3. The further results of this analysis can be found in Appendix 3.

[29] I have made the addition about the demonstration period you suggested and wrote this footnote (The data was reported in monthly figures in all management surveys and the total demonstration period was planned as 3-months in 2022. However, for some restaurants, due to their seasonal operations, i.e., R1 is a restaurant at the beach only open in summer, and Covid restrictions, longer demonstration period in total due to these breaks in their demonstration. In the three restaurants (R2, R3, R4) where discounted sales on app occurred and thus results can be considered here, the demonstration period dates were 14 May 2022 – 7 August 2022 (continuous) for R2; 12 May 2022 – 20 Jan 2023 for R3 and 14 May 2022 – 24 Jan 2023 for R4).

[30] We took this rate of commission charged a similar app, which also operates in Italy, the management survey filled in by one of locations demonstrating Kitro in Task 5.1.

[31]. It was indicated by UNITUS that the cost of the bags can change with the quantity ordered but using the standard price would be more suitable in these calculations. We assumed the potential number of orders made annually will be proportional to the number of orders made during the demonstration period in each participating location.

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4.5.2. Social impact of 'food redistribution action' innovations

The innovations of the type "food redistribution actions" include T2.1 "Regional online platform" and T2.2 "Unverschwendet," which are organisational innovations, as well as T5.6 "REGUSTO," which is a technological one. Our 44 responses were all provided by employees and are evenly distributed between the baseline (24 responses) and the post-demonstration phases (20 responses). The regional online platform was demonstrated in Italy, with the involvement of the employees of the Government of the Region of Emilia-Romagna (13 responses between the two phases), and replicated in Romania, where we obtained responses from a university, a producers' organisation, and (only in the baseline) a food redistribution NGO. Unverschwendet was demonstrated in Austria, where 11 organisations including farms, processors and wholesales responded between the two phases. REGUSTO was demonstrated in Italy, involving five restaurants where up to two employees per unit filled in the survey.

Table 40. Change in social indicators between the baseline and post-demonstrated phase for innovations of the type "food redistribution action" (N = 44)

Indicator	Statement	Hypothesis[1]	Baseline	Post-impl.	*p*-value[2]	Baseline	Post-impl.	*p*-value[2]
Attitude	waste_quan	+	4.42	4.50	0.400	0.095	0.102	0.485
	planet	+	4.63	4.55	0.652			
	economic	+	4.29	4.40	0.361			
	resources	+	4.58	4.45	0.701			
	waste_inevi	-	2.00	1.90	0.349			
	waste_impos	-	2.08	1.85	0.206			
Moral concern	worry	+	4.33	4.05	0.822	0.346	0.333	0.530
	waste_irres	+	4.46	4.40	0.579			
	guilty	+	4.38	4.40	0.457			
	responsible	+	4.58	4.58	0.507			
	principle	-	1.29	1.60	0.900			
Subjective norm	socie_care	+	4.25	4.05	0.775	0.201	0.161	0.567
	hh_support	+	4.21	4.11	0.629			
	colleagues	+	3.75	3.95	0.264			
	pressure	+	3.08	2.75	0.881			
Perceived behavioural control (PBC)	know_hh	+	4.29	4.15	0.693	0.188	0.025	0.788
	know_eatout	+	4.04	3.70	0.831			
	know_restaur	+	3.67	3.75	0.416			
	know_work	+	4.29	4.10	0.749			
	control_wp	+	3.54	3.00	0.908†			
	control_hh	+	4.21	4.20	0.512			
	recycle	+	3.63	3.45	0.652			
Intention	not_care	-	1.17	1.25	0.747	0.443	0.412	0.574
	waste_hh	+	4.67	4.60	0.647			
	waste_work	+	4.42	4.50	0.366			
Situational factors	hassle_hh	-	1.83	1.95	0.645	0.174	0.203	0.450
	waste_time	-	2.38	2.05	0.192			
	waste_tech	?	2.00	2.10	0.772			
	council	?	2.82	2.90	0.859			
	recycle_wp	?	3.63	3.35	0.530			
Behaviour	food_spoil	-	2.25	2.30	0.553	0.072	0.132	0.376
	rarely_waste	+	3.42	3.65	0.293			
	prepare_waste	?	2.29	2.25	0.911			

Notes: The sample size can vary slightly between statements and indicators because participants were not forced to assess all the statements. [1] Direction of the hypothesis as explained in Table 6. [2] The *p*-values refer to the difference between the baseline and

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post-demonstration n responses. For the specific statements, in the case of a "directional" hypothesis the *p*-values refer to a one-tailed *t*-test; in the case of no expected change to a two-tailed *t*-test. For the indicators, the expected change is always positive. Significance levels for changes in line with the hypothesis: *** 0.01, ** 0.05, * 0.10. Significant levels for changes in the opposite direction: ††† 0.01, †† 0.05, † 0.10.

The regional online platform in Italy, and Unverschwendet was already in operation before the LOWINFOOD project; therefore, the baseline responses come from organisations comparable to those involved. Among the 33 respondents who specified their role in the organisation, 18 (nine in each phase) had managerial positions, including six who were the owners, while 15 (eight in the baseline and seven in the post-demonstrated phase) were lower-level staff. Around half of the respondents had been involved in the innovation since it was introduced; otherwise, the period of involvement had been at least three months for everyone at the moment of the post-demonstration survey.

Table 40 above reports the changes in the value of the statements and indicators as a result of being involved in the demonstration of innovations of the type "food redistribution actions". Noteworthy, **none of the statements or indicators** register a statistically significant change in any direction, apart from one statement related to PBC ("*I have control over the amount of food waste produced in my workplace*") which registers a marginally significant change ($p < 0.10$) in a direction opposite to our hypothesis. Therefore, we can conclude that at least within our small sample, the innovations of the type "food redistribution actions" generate **no significant behavioural impact**. This is probably due to the fact that these innovations do not aim at *preventing* the waste of food resources, but rather at making the most from food which has already been produced and is at risk of being wasted, thus focusing on the possibility of generating a profit from it.

4.6. Evaluation of gender and representation

LOWINFOOD included a gender perspective and aimed to ensure **gender equality** throughout the demonstration and evaluation of all the innovations. Therefore, the data were disaggregated by sex, accounting for multiple inequalities and for women's needs. As explained in Section 2, gender data was collected via participant surveys and disaggregated by sex using the categories *female, male, other* and *prefer not to say* to account for different gender identities; however, due to sample size issues and the focus on women's needs, here we discuss the results based on two categories: women *respondents* vs *others* (named "males" if the group only includes males, "others" otherwise).

Besides the 33 statements, the participant survey also included socio-demographic questions (age, gender, education); questions related to the role of the respondents in their organisation (where relevant) and in the management of the innovation; the duration of their involvement in its demonstration; and their level of satisfaction with the survey.

These questions were used to generate and assess the change in the **gender-related indicators**, which according to D1.4, are the following: share of genders interviewed before and after the demonstration of the innovations; vertical segregation, i.e., whether the people who contributed to different tasks related to the innovation had significantly different job grades

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depending on their gender;[32] and survey satisfaction by gender, before and after the demonstrated of the innovations.[33] Unfortunately, we could not measure horizontal segregation, because the innovations were mostly demonstrated in small companies or anyway in a single department of a company or organisation. In the following, the indicators are presented starting from the share of genders, and then going more into detail with the indicators of vertical segregation and survey satisfaction.

4.6.1. Food waste prevention governance innovations' gender analysis

In terms of **share of genders** interviewed, in both the "baseline" and "post-demonstration" phases, five respondents (71%) were male, two (29%) females. In terms of **vertical segregation**, a chi-square test across both phases [$\chi^2(2) = 5.833$, $p = 0.054$] suggests that the role (job grade) of the participants is associated with their gender; indeed' all the male respondents were the owners of the bakery, compared to half of the female respondents. Finally, the average **survey satisfaction** (Table 41), is slightly higher for male respondents in the baseline, but the ranking is reversed in the post-demonstration phase; however, these figures do not differ significantly across genders and phases.

Table 41. Average survey satisfaction by gender and phase for "FW prevention governance" innovations (N = 14)

Gender \ Phase	Total	Baseline	Post-impl	*p*-value[2]
Total	14	7	7	
Female	4	4.00	5.00	n/a
Male[3]	10	4.20	3.80	0.471
p-value[1]		0.576	0.203	

Notes: [1] Two-tailed *t*-test of difference across genders in the same phase; [2] Two-tailed *t*-test of difference across phases for the same gender; [3] No non-binary respondents or respondents who did not report their gender are present for this innovation type.

4.6.2. Consumers' behavioural change innovations' gender analysis

The gender-related indicators relative to this type of innovations are discussed for different types of participants separately.

The first category of participants are **employees** (schoolteachers). In terms of **share of genders**, female employees dominate the sample, accounting for 75% of the total, a percentage which does not change between the "baseline" and the "post-demonstration" phases. In terms of **vertical segregation**, a chi-square test across the two phases [$\chi^2(5) = 9.856$, $p = 0.079$] suggests that the role (job grade) might be associated with the gender, and indeed the share of other-gender respondents occupying managerial position is 39%, compared to

[32] The question asked was adapted to the specific innovations, but the generic format reviewed by the Research Ethics Committee of the JHI was: What is your role in the organisation? Student placement or trainee / Contract or temporary worker / Permanent contact staff without managerial duties / Sector or department manager / Executive level manager / Owner / Other (please specify).

[33] The question was: Are you satisfied with this survey? Not at all satisfied / Somewhat satisfied / Neither satisfied nor dissatisfied / Somewhat satisfied / Very satisfied.

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9% among females [$t(69) = 3.022$, $p = 0.004$], confirming a situation of vertical segregation within our sample. Finally, the mean **survey satisfaction** is in Table 42 below. It is almost the same regardless of gender in the baseline, and slightly lower for females in the post-demonstration phase; again, these figures do not differ significantly across genders and phases.

Table 42. Average survey satisfaction by phase and gender among employees, for "consumers' behavioural change" innovations (N = 92)

Gender \ Phase	Total	Baseline	Post-impl	*p*-value[2]
Total	92	41	51	
Female	69	3.25	3.24	0.961
Others[3]	23	3.22	3.33	0.826
p-value[1]		0.939	0.807	

Notes: [1] Two-tailed *t*-test of difference across genders in the same phase; [2] Two-tailed *t*-test of difference across phases for the same gender; [3] Includes non-binary respondents and respondents who did not report their gender (two for this innovation and participant type).

As for the **share of genders in households**, across the two phases we received 82 responses from females (70%), with an increase between baseline (68%) and post-demonstration (72%), driven by a reduction in the number of male respondents. **Vertical segregation** cannot be assessed, but the large share of female respondents [which differs at 10% from the share in the rest of the sample in a two-tailed *t*-test, $t(530) = -1.714$, $p = 0.087$] might suggest that women acted as app managers in most instances because they borne the burden of food management. Finally, concerning **survey satisfaction** (in Table 43 below), we observe very limited change across phases for both genders, and although male respondents tend to declare higher satisfaction, neither of these differences is statistically significant.

Table 43: Average survey satisfaction by phase and gender among household members, for "consumers' behavioural change" innovations (CozZo) (N = 117)

Gender \ Phase	Total	Baseline	Post-impl	*p*-value[2]
Total	117	60	57	
Female	82	4.41	4.37	0.784
Male[3]	35	4.63	4.56	0.688
p-value[1]		0.251	0.350	

Notes: [1] Two-tailed *t*-test of difference across genders in the same phase; [2] Two-tailed *t*-test of difference across phases for the same gender; [3] No non-binary respondents or respondents who did not report their gender are present for this innovation and participant type.

To conclude the gender overview, the **share of genders among students** reveals a large prevalence of female respondents (120 or 67% across the two phases), although they see a decline in both absolute and relative terms, from 69 (71%) in the baseline to 51 (62%) in the post demonstration phase, while the number of other-gender respondents increase by three. Similarly to household respondents, **vertical segregation** cannot be assessed. In terms of **survey satisfaction** (Table 44), female students declare a marginally significantly

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(p = 0.094) higher value on average in the baseline phase, although the difference becomes non-significant after demonstration. Equally, no change is observed across phases.

Table 44: Average survey satisfaction by phase and gender among students, for "consumers' behavioural change" innovations (N = 179)

Gender \ Phase	Total	Baseline	Post-impl	*p*-value[2]
Total	179	97	82	
Female	120	3.35	3.51	0.368
Others[3]	59	2.93	3.23	0.326
p-value[1]		0.094*	0.207	

Notes: [1] Two-tailed *t*-test of difference across genders in the same phase; [2] Two-tailed *t*-test of difference across phases for the same gender; [3] Includes non-binary respondents (two for this innovation and participant type) and respondents who did not report their gender or whose gender was marked as missing (nine).

4.6.3. Supply chain efficiency innovations' gender analysis

In terms of **share of genders** interviewed, across the two phases there was an equilibrium, with 51% of the responses coming from females and 49% from other genders. However, this changed between the two phases, as women dropped from 30 (6%) in the baseline to 11 (41%) in the post-demonstration phases, resulting in an increased share of other genders, from 24 (44%) to 16 (59%). In terms of **vertical segregation**, a chi-squared test implemented across the two phases [$\chi^2(6) = 14.390$, $p = 0.026$] suggests that there is a significant association between the role (job grade) and the gender when all the roles are considered separately. A further *t*-test reveals that this might be driven by the share of people in managerial roles being significantly higher among other-gender (non-female) respondents [65% *vs* 32%, $t(79) = 3.14$, $p = 0.002$], providing evidence of vertical segregation. This might also explain the drop in the share of female respondents between phases, as they do not occupy managerial roles and therefore feel less committed to delivering a good quality evaluation.

Finally, as for **survey satisfaction** (Table 45), we observe an increase among females and a decline among other-gender respondents across phases, with the latter declaring higher satisfaction in the baseline, and lower after demonstration; however, none of the differences is statistically significant.

Table 45: Average survey satisfaction by phase and gender, for "supply chain efficiency" innovations (N = 81)

Gender \ Phase	Total	Baseline	Post-impl	*p*-value[2]
Total	81	54	27	
Female	41	3.75	4.10	0.212
Others[3]	40	3.95	3.81	0.703
p-value[1]		0.448	0.477	

Notes: [1] Two-tailed *t*-test of difference across genders in the same phase; [2] Two-tailed *t*-test of difference across phases for the same gender; [3] Includes non-binary respondents and respondents who did not report their gender (two for this innovation type).

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4.6.4. Food redistribution actions' gender analysis

In terms of **share of genders** interviewed, 48% of the respondents across the two phases were female, 52% males, which is an exception to the overall dominance of women in the sample. The share of male respondents increases from 50% to 55% between the two phases. As for **vertical segregation**, we detect no significant association between the job grade and the gender when all the roles are considered separately [$\chi^2(4) = 2.262$, $p = 0.688$]. Equally, the share of people in managerial roles (60% among males, and 56% among females) does not differ significantly depending on the gender [$t(31) = 0.25$, $p = 0.805$]. Finally, as for **survey satisfaction**, we observe a slight increase among females, and a slight decline among male respondents across the two phases, with males declaring lower satisfaction in both phases. However, none of these differences is statistically significant, as reported in Table 46.

Table 46: Average survey satisfaction by phase and gender, for "food redistribution" innovations (N = 44)

Gender \ Phase	Total	Baseline	Post-impl	*p*-value[2]
Total	44	24	20	
Female	21	4.42	4.56	0.655
Male[3]	23	4.25	4.09	0.708
p-value[1]		0.666	0.205	

Notes: [1] Two-tailed *t*-test of difference across genders in the same phase; [2] Two-tailed *t*-test of difference across phases for the same gender; [3] No non-binary respondents or respondents who did not report their gender are present for this innovation type.

4.7. Evaluation of the project's benefits to its non-research partners

In addition to the socio-economic evaluation based on the protocol framework, we conducted online interviews with 15 of the 16 non-research partners of the LOWINFOOD consortium. Aim was to assess their experience being part of an H2020 consortium, the benefits they think it provided them, and how these could be improved in future projects. The interviewees included 7 start-ups, 3 sectorial organisations, 2 local administrations and 2 companies (two hotels belonging to separate hotel chains). We collected primary data using the interview script in Appendix 2.

The contact persons of the non-research organisations in the consortium were recruited as interviewees. All except one stated that they were involved in the project from proposal stage to the time when the interviews were conducted. While the representatives of the innovation providers and hotels interviewed had top management roles in their organisations (i.e., they defined their roles as "CEO", "COO" or "managing director", etc., as well as being one of or sole founder), for sectorial organisations and local authorities the role of the interviewees varied such as quality manager, operations manager, policy or project officer, or sectorial supervisor. Most interviewees were educated at bachelor or master level, with three people having PhD degrees. Half of the respondents (8 out of 16) identified as female, the others as male, and the average age was between 35 and 40.

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First, we collected information on **profitability** and **networks**. This category of indicators mainly concerns the start-ups that contributed to the project as **innovation providers**. These two class of indicators explored whether participation in the research project had led to development of additional income streams; new products and services; subsidies and tax breaks; improvement of the Technological Readiness Level (TRL) of the innovations they offered in the project; and expansion of networks leading to further contacts, partnerships, and access to more regions and different market.

Out of seven innovation providing SMEs, only one had developed a new product (e.g., a business-to-business platform for exchanging overstock to respond to the changing hospitality market after COVID-19 in the country they operate in). Another SME had started a new service of selling data to companies. However, it was difficult to link these achievements with their involvement in the consortium. Another one had created, with the help of a research partner in the consortium, a tool for external use to check sustainability of business operations., Meanwhile five out of seven enterprises improved their existing product significantly and added new features, thus achieving higher TRL levels, usually reporting having moved from initial TRL 2-3 to TRL 8-9 at the time of the interviews. By that time, all the tasks involving demonstration of the innovations had already been concluded.

In terms of **facilities that were testing the innovations**, both hotels involved stated that they indirectly saved money as their involvement increased the efficiency of food material use and reduced food waste in their kitchens. The scale of savings was not disclosed but indeed cost savings, though minor, can be traced back in the economic analysis of T5.1 (see chapter 3.4).

Almost all innovators reported that involvement in LOWINFOOD had helped them accelerate the process of **network building** and mentioned introduction to further contacts through other research and non-research partners in the consortium. In the case of two innovation providers, the connections in the project led to five and seven new customers, respectively, and they planned to continue doing business with them after the end of the project. Each of two further innovation providers established continuous business collaboration with another non-research partner from the consortium and explored the potential for collaborations with several other partners from the consortium.

It has been reported in the interviews that the project had not only led to new business connections but also to introduction to **new markets** and regions that would not have been explored in the absence of the consortium and the financial support that came from the project. In the case of three innovation providers, the project funds enabled them to translate their product into different languages and have it tested in different countries. In the case of supporting organisations, the funding received from the project allowed one non-research partner to expand its operations to another European Union member country that they have not operated in before and recruit members there as an organisation that operates at EU level. For another one, it allowed them to test locally an approach which had been proposed for demonstration at national level after its local success.

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As for **creation of local jobs**, the funding received by the SMEs mostly went towards staff time, which was critical for improving, supporting and promoting their innovations. In the case of three enterprises, the improvement of their innovations was directly linked with the ability to employ additional technical staff, fully or partially funded by the project. Moreover, in four companies, additional staff was employed for customer relations as well as marketing and social media management with the help of project funds.[34] It was also openly stated that LOWINFOOD was an important revenue stream during the COVID-19 pandemic, helping bridge their financial gap in this difficult period for the hospitality and catering sector.

In addition to above mentioned issues, benefits such as involvement in the consortium making the innovation providers more visible and more credible to prospective collaborators, as well as customers and knowledge exchange with researchers and other partners were also mentioned in these interviews.

[34] However, the gender and hours of these contractors could not be provided to us during the interview and were not provided later despite our follow-up emails.

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5. Discussion

The socio-economic impact evaluation framework was set out in D1.4 (Koseoglu et al., 2021) for the purpose of evaluating the socio-economic impact of the innovations tested in the scope of the LOWINFOOD project. The implementation of this framework, which was carried out for the first time in this project, provided us with insights both about the outcomes of the innovations and the context of the evaluation framework, and how the framework can be improved for future applications in similar projects. Here, we will discuss the insights about the socio-economic impact of the innovations; the performance of the socio-economic evaluation framework in delivering this assessment, and the limitations experienced overall.

Firstly, it is important to differentiate between the purpose and the design of different innovations when considering their socio-economic or other types of impacts assessed in the scope of WP1. While most technical innovations like platforms and applications have visible and immediate impacts on current or potential profitability, the impacts of social innovations and educational interventions are not immediate and could not be fully measured in the timeline of the project. However, unlike technical innovations, their impact is expected to go beyond the period of demonstration. Furthermore, it is difficult to estimate the conclusive impact of conversations initiated and connections established as part of the seafood (T4.1) and bakery (T3.2) stakeholder dialogues, or the overall impact of the training provided to teaching and kitchen staff as well as pupils as part of T5.4 Holistic Educational Approach. Therefore, the framework was not efficient in estimating the longer-term potential value of such innovations. Unfortunately, the research team was constrained by the project's duration and funding window.

Additionally, not all innovations were targeting commercial gains directly and were tested in commercial settings (e.g., Matomatic Plate waste tracker in T5.3. While we cannot exclude that such innovations have a potential for creating economic benefits for the provider in other settings/framework than the tested ones, other aspects of the evaluation such as social impact or behavioural change are more relevant to their target users and contexts. Similarly, some innovations that had suboptimal outcomes in the scope of their demonstration in LOWINFOOD had already built a paying (and growing) customer base in other settings (e.g., T5.5 CozZo) or were being successful in the transfers of other types of food products (T2.3 and T4.2 Leroma).

Apart from the diversity of innovations that limited comparability, the collected data also did not allow for comparison. The economic impact evaluation of some innovations were mainly based on revealed data – either captured by the technical innovations (e.g., T5.1 Kitro in its application in Greece) or through waste measurements (e.g., in artisanal bakeries in T3.2 in Italy, and in schools participating in T5.3 Matomatic and T5.4 Holistic Educational Approach).However, in the rest of the tasks the economic impact had to be evaluated based exclusively on self-assessed figures provided in the management surveys (e.g., T2.2 UNV, T3.2 Bakery supply chain stakeholder dialogue in Sweden) or on simulations made by academic partners (e.g., T3.1 Simulation of take-back agreements, T2.4 Forecasting retail demand, T2.1 replication of SIR platform in Romania). There were also innovations in which it

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was possible to collect both real (observed) and self-assessed data (e.g., T3.3 FoodTracks, T5.5 CozZo mobile app; T3.2 Bakery supply chain stakeholder dialogue in Italy) allowing us to check findings from different data sources against each other, and to run statistical analyses.

Participant survey results generally showed a neutral or positive impact of being involved in testing the innovations, stronger for some indicators such as "moral concern" and "intention". The effectiveness was related to the type of innovation: "supply chain efficiency" and "food waste prevention governance" interventions seemed to be more effective than others. Equally, certain socio-demographic profiles and typology of participants were found to be more receptive to the message entailed in the innovations. Women and highly educated people were the most influenced. Also, household members from the household approach category experienced stronger change as a result of being involved in the demonstration of innovations, compared to student household members.

Regarding the representation of different genders, female participants constituted around 65% of the participant survey sample. This percentage was even higher for the innovations of the type "consumers' behavioural change" (71%) that also included household members using the CozZo app for household food management and students involved in the innovations demonstrated at schools. Despite their smaller share, male participants were more represented in managerial positions in the sample of innovations demonstrated at workplaces. We detected no significant change in the survey satisfaction between different genders or phases.

As well as the socio-economic benefits of the innovations to their users, we also evaluated potential financial benefits of being part of an H2020 research project consortium and of receiving public research funding to non-research partners, particularly the innovation providers. Most of the participants (~75%) stated that they had had a positive experience with the LOWINFOOD project, and were interested in taking part in similar projects in the future. Various types of benefits were mentioned, the two most common being the ability to fund additional staff or contractors' time to improve or market the innovation, and to access new test locations, market and contacts through the consortium. This final step of the evaluation enabled us to account for the additional benefits of public funds for research and of international consortia bringing scientists and other type of partners together.

Our study presents some limitations, mostly due to the quality of data collected despite the efforts of the research partners. First, we used questionnaires, thus the self-declared nature of the data may not exactly reflect real intentions and behaviours. However, our focus on change rather than on absolute levels mitigates this risk. Second, ours is not a panel dataset, and we lack a control group to apply a difference-in-differences approach. Hence, we cannot control for the impacts of confounding factors, such as the COVID-19 pandemic or the war in Ukraine, which both happened during the data collection. Third, the small sample and the high dropout rates in some instances raise concerns in terms of self-selection. In the future, the inclusion of a control group and, where possible, the integration of survey data with actual FLW quantification, could provide better insights into the impact of demonstration of innovations against food loss and waste or pursuing different sustainability goals.

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6. Conclusions

As the official website of the European Commission explains, Innovation Action (IA) projects aim to produce plans or designs for new or improved products, processes or services including prototyping, testing, demonstrating, piloting, large-scale product validation and market replication. The LOWINFOOD project is an IA, and in its scope, it addressed multiple of these aims: during the course the project, all innovations were demonstrated, some innovations were planned and designed (e.g., stakeholder dialogues in seafood and bakery supply chain, SLU/AEI Holistic Educational Approach in schools), existing products and services improved (e.g., the UNV business concept expanding its customer base and transfer volume) or moved into new markets (e.g., REGUSTO moving from the business-to-customer market into business-to-business operations). Based on this, we can conclude that the project has achieved its aims.

However, it is difficult to state the same for the economic impact of the innovations demonstrated in the project. Except few innovations, it was not possible to come up with tangible economic benefits across test places, or estimate return on investment values for most innovations due to the reasons explained above in the Discussion section. Our conclusions will cover how the socio-economic evaluation process and evaluation outcomes could be improved in future IA projects.

First of all, the quality and availability of quantitative data must be improved. The locations that used the innovations could be better incentivised through compensation of their staff time and by better highlighting the potential benefits of the innovations for their businesses or households. The main responsibility of user organisations is to record cost data during the baseline and demonstration periods of project: rather than providing rough estimates in management surveys, relevant parts of the companies' accounts should also be disclosed. Both test locations and innovation providers must agree more in detail upon their responsibilities regarding data collection and provision before becoming part of the project.

Secondly, we observed that the innovations provided by more involved partners provided better data sets and had better economic impact outcomes. Therefore, innovation providers should be engaged more in the recruitment of the users, data collection, and evaluation processes to get more business insights from the demonstration activities, which can benefit their future food management and profitability in turn. Also, by being involved in these processes, they can recruit locations that fit their target customer profile and that will continuously use their innovation during the demonstration period, monitor their user experience, and gain potential customers as observed in some tasks in the project.

Thirdly, the burden of data collection must be reduced for those using the innovations. It should be explored if and how the data required for a socio-economic evaluation can be collected automatically, especially in technical innovations. Based on management survey responses, we realised that several indicators (e.g., change in jobs and employment, change in sale prices and number of units sold, etc.) recorded zero change across all locations, demonstrating different innovations in the scope of LOWINFOOD project and can thus be removed from the protocol, allowing for shorter management surveys to be prepared for its

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future impact assessments. Additionally, participant survey data can be integrated with FW quantification measurements to enable checking self-reported survey responses against actual behaviours.

Fourthly, as well as the TRL of the innovations, subscription costs are also important for their market uptake. While users were not charged subscription fees during the project, these costs were stated as a reason why they would not continue using certain innovations. For this reason, future projects should also look into how to reduce the costs of the innovations to enable uptake by a wider customer base.

Finally, despite the limitations mentioned above, the funds provided to EU H2020 Innovation Action projects generate indirect social benefits. In the evaluation framework, we captured two main aspects of these additional benefits that have not been captured in previous project evaluations and in the relevant scientific literature on innovation. The first additional benefit is the social impact of the innovations on the individuals that were involved in their demonstrations, namely how the attitude and behaviour of these individuals changed as a result. To achieve wider impact through demonstrations, more diverse demographic groups should be targeted (e.g., employees, lowly educated people, young people), and venues like workplace canteens could be chosen to test innovations. Equally, interventions that entail concrete experience with food, like handling of leftovers, rather than simply information provision, are likely to generate higher impact.

The second additional benefit is supporting non-research partners through public funds. Funding, both public and private, is critical for the survival of innovative start-ups till they reach profitability, and these organisations are central to the innovation ecosystem in Europe. However, the benefits of the LOWINFOOD consortium and research funds were found to go beyond the financial support, providing other advantages to the innovative start-ups, such as new customers, new markets and expanded networks. Sectorial organisations also played a crucial role in reaching out and establishing trust and connections with industry stakeholders in the project. Future IA projects should thus involve more collaborations between sectorial organisations and academia. Projects like LOWINFOOD can play an instrumental role in establishing trust and better understanding of each other's priorities among the partners from different industries and lead to long term inter-sectorial collaborations.

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Credit authorship contribution statement

Table 47: Credit authorship contribution statement of D1.7

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					
Canaj, E.	ARE				T21					
Contrino, L.	ARE				T21					
	BLU				T51					
Brunnhuber, N.	BOKU									
Gollnow, S.	BOKU									
Ladurner, T.	BOKU				T55		T55			
Münch, S.	BOKU									
Obersteiner, G.	BOKU									
Scherhaufer, S.	BOKU				T22 T55					
Schmied, E.	BOKU				T22					
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	CNA				T31 T32					
Lakar, O.	ELH									
Olazar, E.	ELH									
Urruzola, M.	ELH									
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				T42					

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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
Gerwin, P.	ISUN				T51 T52 T53	T51 T52 T53				
Strotmann, C.	ISUN				T23 T33 T41 T42 T51 T52 T53	T23 T33 T41 T42 T51 T52 T53				
Williams, I.	JHI					T24	T24			T33 T51 T52 T53 T54 T55 T56
Martinez, G.	JHI	T22 T32 T33 T53 T54 T55 T56	T22 T32 T33 T53 T54 T55 T56	T22 T32 T33 T53 T54 T55 T56	T22 T32 T33 T53 T54 T55 T56		T22 T32 T33 T53 T54 T55 T56			
Koseoglu, N.	JHI	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL[11] ALL[12] ALL[13]
Piras, S.	JHI	ALL	ALL	ALL (par-tici-pant sur-vey)	T41 T42	T41 T42	ALL	ALL	ALL	ALL[11] ALL[13]
Hofmann, A.	KITRO				T51					
Billinger, M.	LER			T23 T42	T23, T42					
Casalino, F.	LER			T23 T42	T23 T41 T42					
Giordano, C.	LUKE				T21	T21				
Malefors, C.	MATO			T53 T54	T53 T54					
Wolkow, R.	MITA			T52	T52					

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Bruschini, P.	PICO				T24					
Valeri, C.	PICO				T24					
Rellini, P.	REG				T56	T56				
Pinghini, 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			ALL	
Sjölund, A.	SLU									
Sundin, N.	SLU				T53 T54	T53 T54				
Mesiranta, N.	TAU				T32 T55	T32 T55	T55		T55	
Närvänen, E.	TAU				T32 T55	T32 T55			T55	
Sutinen, U.-M.	TAU				T32 T55					
Mattila, M.	TAU				T32					
	THA				T51					
Falasconi, L.	UNIBO				T21					
Blasi, E.	UNITUS				T32 T24	T32 T24			ALL	
Cicatiello, C.	UNITUS				T24 T32	T24 T32				ALL[13]
Yu, M.	UNITUS				T56	T56				
Nasso, M.	UNITUS				T32 T24	T32 T24				
Pietrangeli, R.	UNITUS				T32 T24	T32 T24				
Secondi, L.	UNITUS				T56	T56				
Diesenreiter, C.	UNV				T22	T22				
Nygardh, S.	UPP				T53 T54					

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

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

[5]**Formal analysis**: Application of statistical, mathematical, computational, or other formal techniques to analyse or synthesise 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 post-publication 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

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

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Appendix 1. Management and participant survey templates

The set of questions in the **management survey** were prepared by each task team using the template in D1.4 and in consultation with the James Hutton team, innovation providers and the implementation locations (users) of the innovation. The management surveys were intended to be answered by a management representative involved in demonstration. These surveys were created to ideally be filled in using the data recorded before demonstration (for baseline) and during the demonstration (to understand the effect of the innovation). However, this was not always the case, and, in some cases, responses were likely to have been estimated on the spot at the time of responding the management survey.

Some of the general characteristic or questions were not be applicable to all innovation partners or innovations and these were either removed from the list of question in these specific innovations or advised to be filled as "Not applicable" or "NA" by specific type of organisations (e.g., households, schools etc.) in D1.4. Below a full list of indicators and exemplary questions provided to the task teams to develop the economic impact part of their management surveys can be found.

Management survey template

Profitability

1. Change in direct input costs of food inputs (applicable for innovations used in enterprises using food as raw ingredient (e.g. restaurants, canteens, food processors, charities) or, in general, for the main input (e.g. ethanol producers).

Option 1 (preferable): total amount of food (or ingredient) inputs during a measurement period (kg, tons) * average unitary price of food inputs during the measurement period

Option 2: total expenditure on food or ingredient inputs during the measurement period[35]

Exemplary question format from the questionnaires: *What is the cost (unitary market price x number of unit used) for each of your food related inputs in the absence of the innovation?*

What is the cost (unitary price during the innovation x number of unit used) for each of your food related inputs as a result of the innovation?

2. Change in indirect fixed costs due to the innovation (e.g. storage space, equipment purchase, rent, or insurance etc.) – any relevant cost that does not change directly with the size of production depending on the product and the supply chain.

[35] The demonstration partners do not need to categorise the costs as fixed or variable if they can tell us about the cost structure in their supply chains and provide the company accounts.

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Option 1 (preferable): The cost of each classified item of (fixed) cost that occurs in the operations over the measurement period * frequency of the cost

Option 2[36]: The list of relevant fixed cost items that occur in the operations over the measurement period and the unitary change in each of these fixed cost items between the measurement periods before and after the innovation[37]. If any prices are missing, at worst we can estimate listed items' cost based on the average market prices for the material or the service in the case study location.

Exemplary question format from the questionnaires: *What are the relevant fixed costs before the implementation of the innovation (e.g. additional/new capital investment, storage space etc.)?* – any relevant cost that change with the size of production depending on the product and the supply chain.

What are the relevant fixed costs after the implementation of the innovation (e.g. additional/new capital investment, storage space etc.)?

3. Change in variable costs due to innovation (e.g. energy, water, refrigeration depending on the product and the supply chain).

Option 1 (preferable): The cost of each classified item of (variable) cost that occurs in the operations over the measurement period * frequency of the cost

Option 2: The types of variable costs that occur in the operations of the innovator over the baseline period and the total cost of each over measurement period.

Exemplary question format from the questionnaires: *What are the variable costs before the implementation of the innovation?*

What are the variable costs after the implementation of the innovation?

4. Change in organic waste management costs

Option 1 (preferable): The type and the amount of organic waste[38] * organic waste collection[39] related charges for the specific disposal type (if relevant disintegrated by different options of disposal) + qualitative specification of the nature (on-off, proportional, fixed) of the cost

Option 2: If the amount and type of waste, disintegrated as organic and inorganic, is already collected and provided for the environmental impact assessment in LOWINFOOD, we can use this amount and ask additionally whether organic waste has a unit or average economic

[36] From here onwards in the text, I create Option 2 as the less preferable/ more compromised option in each case.
[37] Most of the fixed costs, unlike variable ones, might be one-off payments anyways.
[38] Organic waste entails only food related waste, e.g., leftovers, scraps etc. in the context of this analyses
[39] Waste collection charges might be fixed costs or might have tiered system like commercial wastewater collection service in each the location. and this pricing structure can be indicated accordingly in the blocks.

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value or disposal charge in the relevant local administration, and how much that value or cost would be.

Exemplary question format from the questionnaires: *In the absence of the innovation, in what ways do you dispose of the wasted or lost food materials (e.g. livestock feed, ethanol producers, waste collection)? Do you make a profit from this disposal route? If yes, how much €s per unit in each alternative?*

If you dispose it without making any profit, what is the average cost of organic waste disposal for your organisation per month? Is it a fixed cost independent of the amount or does it vary with the quantity of waste disposed? How much is the unit/ fixed cost?

Alternatively for innovations that already provide the unitary change in the output before and after the innovation in other assessments, only the change in the market price of the product (or produce) sold[40] can be measured.

Exemplary question format from the questionnaires: *What are the prices of the products addressed by the innovation before the innovation over the baseline period?*

5. Change in the total value of sales of the product(s) involved

Option 1: Total number of the units sold x unitary price

Exemplary question format from the questionnaires: *What are the prices of the products before the innovation during the baseline period? How many units of each product are sold on average per month before the innovation?*

What are the average prices of the products addressed by the innovation after the innovation? How many units of each product are sold on average per month after the innovation?

6. Rate of return on investment

Option 1 (preferable): Net value gained from time and financial investment in the innovation (increase in the profits because the innovation reduced variable/fixed/waste disposal costs, increased sales or increased product prices) and total cost of implementing the innovation.

Option 2: Our estimation of the net value they gained based on (Indicator 1,2,3,4,5)/ (30% of the "estimated eligible costs" for the organisation in the LOWINFOOD grant agreement) *100

Exemplary question format from the questionnaires: *What is the total cost (e.g. labour, technology, energy etc.) of implementing the innovation for your organisation?*

Then we will divide this figure by the overall financial benefit of the project (sum of the changes in the input, variable and fixed costs, change in sales, change in prices, new income streams, new financial subsidies) based on the data for the indicators above. [otherwise: *What is the total net gain of implementing the innovation for your organisation?*]

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7. Change in total hours worked, disaggregated by gender

Option 1: The number of hours worked by each employee[41] (disaggregated by gender and position in the company)

Exemplary question format from the questionnaires: *Please indicate, disaggregated by gender and position, the number of Full-Time Equivalent jobs in the organisation before the innovation (if this is only a share of time of one or more employees, please indicate the change in total hours worked).*

Please indicate, disaggregated by gender and position, the number of Full-Time Equivalent jobs in the organisation after the innovation resulting from the implementation of the innovation (if this is only a share of time of one or more employees, please indicate the change in total hours worked).

Or we can ask one time at the end of the innovation:

Please indicate, disaggregated by gender, the type of position/job title, the number of Full-Time Equivalent jobs in the organisation that were created (or lost) as a result of the implementation of the innovation (if this is only a share of time of one or more employees, please indicate the change in total hours worked. Please specify how many hours is a Full-Time Equivalent[42].

	Number of FTE jobs created	Number of FTE jobs lost	Change in tot. hours worked
Female			
Male			
Other			

8. Change in the productivity of material inputs or input-output ratio

Option 1: Amount (kg/tons/pieces per week) of input / Amount of output (e.g. kg/tons/pieces per week) – either consumed at home or school or sold in the market depending on the innovation (kg/tons/pieces/final products[41] per week)

Exemplary question format from the questionnaires: *What is the amount of each input items purchased in an average week? What is the amount of the same items thrown away in an average week (including unavoidable waste) are provided, we can derive the amount consumed?*

This question does not need to be answered if the amounts of inputs to productions, the amount of organic waste and the resulting output from production is already detailed before and after the innovation in the previous questions.

[41] Only employees that are using the innovation. For instance, fruit and vegetable producers.

[42] The number of full-time equivalent hours changes in different European countries and different employment types (e.g. employees, freelance/own account workers, employers, contributors to family business etc.) according to Eurostat statistics. We will use the country and job type average but also consider the difference between different employment types and hours typically worked in a full-time position in Europe.[41]A dish in a restaurant or canteen, a batch of bakery products, a meal at home or at a charity are examples of a final product sold or consumed by piece.

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9. Change in the number of jobs, disaggregated by gender

Option 1: Number of people employed in the company, the type of contracts and hours, disaggregated by gender, and the role in the company

10. Creation of new income streams

The names of new food products to be sold on the market (including food products which were already sold before but were re-branded, or whose packaging was changed to reflect the use of the innovation, e.g. a sustainability label) created during the duration of LOWINFOOD as a result of participating in the innovation.

Exemplary question format from the questionnaires: *Are there new income streams resulting from the innovation?*

If you answered yes to the previous question, please indicate the type of new income streams and how much is gained.

11. Change in access to subsidies and/or other financial benefits

Subsidies and/or other monetary benefits (in Euros) received due to waste reduction (specifying if these are one-time, periodical, fixed or proportional to the amount of waste).

Exemplary question format from the questionnaires: *Are there new subsidies and/or other monetary benefits received as results of food waste reduction after the innovation? If you answered yes to the previous question, please indicate their value in Euros.*

If you received any subsidies and/or other monetary benefits as results of waste reduction, please specify whether these are (multiple choices possible):

- *One-off*
- *Periodic*
- *Fixed*
- *Proportional to the quantity of waste*
- *Other (please specify)*

In scale:

12. Downstream diversification (e.g., number and type of buyers)

The number and type of new buyers and sellers with which the respondent company came into contact with as a result of their involvement in the innovation + willingness to continue the relationship (assessed on a Likert scale from “very likely” to “very unlikely”).

Exemplary question format from the questionnaires: (covering both diversification and new partnerships)

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Did you establish new contacts or agreements with other actors of the chain as a result of your involvement in the innovation? What type of contacts (e.g. downstream actors like suppliers; other retailers, others) are these?

If yes, how likely is that you continue these relationships on a 1 (very unlikely) to 5 (very likely) scale? Please use the table below to indicate and use as many lines as necessary to indicate a new contact.

Progressive number	*Type of relationship (buyer, seller, etc.)*	*Formal contractual agreement (yes/no)*	*Likelihood of continuing relationships*				
			Very unlikely	*Somewhat likely*	*Neither likely nor unlikely*	*Somewhat likely*	*Very likely*
1							
2							
3							
4							
…							

In community and supply chain:

13. Spill-over effect in terms of technological change in other companies:

Exemplary question format from the questionnaires: *Please indicate if you have informed other companies of the innovation. If yes, what is the number of other companies you have informed of the innovation you have taken part in (e.g. dialogue, platform, software etc.)? How many of these companies declared to be interested in it? How many of them have already started using the innovation?*

14. Vertical segregation

List of people who have contributed to different tasks related to the innovation (e.g. transferring the product, from making contacts to the delivery of the product) (for each person, specify the gender + job grade)

Exemplary question format from the questionnaires: *Please indicate the list of staff members who have contributed at different tasks related to the innovation in your organisation (e.g. transferring the product, from making contacts to the delivery of the product) and for each person please indicate their gender, company sector, and job grade.*

The horizontal segregation is only asked in social and stakeholder innovations that bring users from different organisations in their implementation.

The indicators to capture changes in awareness and attitude of staff members resulting from taking part in the innovation were initially included in the management survey which focuses on the economic gains of the locations testing the innovations. In consultation, we prepared a separate survey to be answered individually by students, staff and household members directly involved in the innovations.

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The second survey, participant surveys[43], were more standardised than management surveys and minimally edited by the innovation task leaders to include place specific aspects such as company roles and length of demonstration period etc. The standard surveys implemented in the local language allowed for the creation of a project level data sample and collection of data relevant for gender analysis at project level. The template for the participant survey is included in the following.

Participant survey template for the innovations end-users

LOWINFOOD is an EU-funded multi-actor project which aims to design sustainable food supply chains through the demonstration of innovative solutions to **reduce food loss and waste**. The project implements different types of innovations, evaluating their potential to solve the food waste problem in the EU. [Name of the relevant innovation] is one such innovation, and we want to evaluate its impact on sustainability. We also want to assess any changes in the awareness, attitudes, and behaviours towards food waste of those involved in the implementation of [name of the relevant innovation]. To determine these factors, we kindly request your participation in this survey since your organisation will be involved or you have been actively involved in the implementation of [name of the relevant innovation]. We would appreciate your responses to the questions below that will be used in the social impact analysis of the innovations and for providing further insights to the European Commission.

CONFIDENTIALITY/PERSONAL DATA

Once the survey is finalised, the answers will be stored initially with Qualtrics in a password protected electronic format in an institute drive dedicated to the project. Data will later be downloaded and stored on a secure server of the James Hutton Institute. In this survey we do not collect names or other information that may directly identify you. However, we have to capture some demographics (age range, gender, level of education) which will help us produce summary statistics, but these will not be used in any attempt to reveal your identity. Furthermore, if you choose to share in open text entries any information that may directly or indirectly identify you, this information will be processed in line with data protection legislation and all reasonable steps will be taken to ensure confidentiality. No names or other identifying information would be included in any publications or presentations based on this questionnaire, and your responses will remain confidential.

The James Hutton Institute ('we,' 'us,' 'our') is the data controller with respect to how your participatory data will be used in this study. The James Hutton Institute will process the data for the purposes of the research outlined above. Research is a task that we perform in the public interest. Further information about how we process the data we collect as well as your rights with respect to your participation is available at our full privacy notice -

[43] These surveys were initially called "staff surveys" in D1.4 but later they were renamed as "participant surveys" to be more inclusive of the household members and students involved in the demonstration of the innovations.

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https://www.hutton.ac.uk/terms. If you have any queries about your participation in this data collection, you can contact our Data Protection Officer on dpo@hutton.ac.uk.

CONTACT: For any inquiries, you can contact Dr Nazli Koseoglu Nazli.Koseoglu@hutton.ac.uk.

ELECTRONIC CONSENT: Please select your choice below.

By clicking on the 'agree' button, you acknowledge that:
- You have read and understood the above information.
- You voluntarily agree to participate.
- You are 16 years of age or older.

If you do not wish to participate in the research study, please decline participation by clicking on the 'disagree' button

- o agree
- o disagree

Q1. What sector is your company in? [only for innovations dealing with different companies] [single choice between-innovation specific options]

Q2. What is your role in the company?

- o doing a traineeship or a student placement
- o Contract or temporary worker
- o Permanent contact staff without managerial duties
- o Sector or department manager
- o Executive level manager
- o Owner
- o Other (please specify) _____

Q3. What is your responsibility in the innovation?

- o I have never used the innovation and/or I have never heard about it → go to Q6
- o I am the only person in charge of implementing the innovation
- o I am one of the main people involved in the innovation
- o I use or help with the innovation without a decision-making role
- o I am distantly/indirectly involved in the use or support of the innovation
- o Other (please specify) _____

Q4. Have you been involved in this innovation since it was introduced in your company?

- o Yes, I started using it since it was introduced in my company → go to Q6
- o No, when I started using it had already been introduced

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Q5. If you have started using the innovation after it had already been introduced, could you please specify how long you have been using it?

[single choice between-innovation specific options]

Q6. What is your age?

- o 16-17 [only for Holistic Educational Approach]
- o 18-24
- o 25-34
- o 35-44
- o 45-54
- o 55-64
- o 65 or more

Q7. What is your gender?

- o Female
- o Male
- o Please state in your own words _____
- o Prefer not to say

Q8. What is your current level of education?

- o No qualifications
- o High school or equivalent qualification
- o Trade/technical/vocational training
- o University or college undergraduate degree
- o Post graduate education (Master's or PhD degree)

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Q9. To what extent do you agree to the following statements?

	Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
Everyday huge quantities of food are wasted in the world	0	0	0	0	0
Wasting food at home is inevitable	0	0	0	0	0
It is impossible to avoid food waste at workplace	0	0	0	0	0
The problem of food waste worries me a lot	0	0	0	0	0
Wasting food is irresponsible	0	0	0	0	0
When I waste food, I feel guilty	0	0	0	0	0
Wasting food does not go against my principles	0	0	0	0	0

Q10. To what extent do you agree to the following statements?

	Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Some-what Agree	Strongly Agree
Everybody has a responsibility to reduce food waste	0	0	0	0	0
I do not care if I waste food	0	0	0	0	0
I am committed to reducing food waste in my household	0	0	0	0	0
I am committed to reducing food waste in my workplace	0	0	0	0	0
The daily amount of food waste is a serious problem for the planet	0	0	0	0	0
Food waste is a major economic issue	0	0	0	0	0
Wasting food is wasting other resources such as water and energy	0	0	0	0	0

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Q11. To what extent do you agree to the following statements?

	Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
Many people in our society do not care about their food waste	O	O	O	O	O
My household supports my efforts to reduce food waste at home	O	O	O	O	O
My colleagues support my efforts to reduce food waste at work	O	O	O	O	O
I feel social/peer pressure to avoid wasting food	O	O	O	O	O
I regularly throw away food that I could have consumed due to food spoiling	O	O	O	O	O
I seldom throw away food that could have been eaten because I have bought too much	O	O	O	O	O
I sometimes throw away food that could have been eaten because I have prepared too much food	O	O	O	O	O

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Q12. To what extent do you agree to the following statements?

	Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
I know what to do to reduce food waste at home	O	O	O	O	O
I know what to do to reduce food waste when I eat out	O	O	O	O	O
I know what to do to reduce my food waste when eating at a restaurant	O	O	O	O	O
I know what to do to reduce food waste at work	O	O	O	O	O
I have the ability to recycle my unavoidable food waste such as the inedible peels, pits and stones of fruits and vegetables, bones in meat and fish etc.	O	O	O	O	O
I have control over the amount of food waste produced in my workplace	O	O	O	O	O
I have control over the amount of food waste produced in my household	O	O	O	O	O

Q13. To what extent do you agree to the following statements?

	Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
Reducing food waste in my household is a hassle	O	O	O	O	O
Reducing my food waste requires a lot of time	O	O	O	O	O
To reduce the food waste in my household I need to buy new equipment/new technology	O	O	O	O	O
The local council provides satisfactory resources for recycling food waste	O	O	O	O	O
My workplace provides satisfactory resources for recycling food waste	O	O	O	O	O

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Q14. Are you satisfied with this survey?

- o Not at all satisfied
- o Somewhat dissatisfied
- o Neither satisfied nor dissatisfied
- o Somewhat satisfied
- o Very satisfied

Q15. If you have any additional comments, please write them here:

_____

Thank you for participating in the staff survey.

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Appendix 2. Non-academic partner interview script

[Name of organisation] – [Innovation Partner or Supporting Organisation]

Could you tell us a bit about the operations and the scale of your organisation?

Are there new income streams such as new products or services resulting from being part of the consortium?

(If you answered yes to the previous question) Please indicate the type of new product, service, or other streams and how much has approximately been gained from it so far.

Any changes in TRL level of your innovation between the start and the end of the project?

*Did you establish new commercial contacts or agreements with other actors as a result of your involvement in the LOWINFOOD consortium?

(If you answered yes to the previous question) How likely is that you continue these new relationships?

Are there new subsidies and/or other monetary benefits received as results of your involvement in the LOWINFOOD consortium?

(If you answered yes to the previous question), Please indicate their value in Euros, and whether these were one-off or are recurring.

Has taking part in this project led to change (either loss or increase) in the hours worked by the staff or the employment/unemployment of additional people?

(If you answered yes to the previous question) Please indicate, how many hours per week is a Full-Time Equivalent job in your jurisdiction.

Please, indicate disaggregated by gender, the type of position/job title, the number of Full-Time Equivalent jobs in the organisation that were created (or lost) as a result of the implementation of the innovation (if this is only a share of time of one or more employees, please indicate the change in total hours worked). Please specify how many hours is a Full-Time Equivalent.

	Number of FTE jobs created	**Number of FTE jobs lost**	**Position**	**Change in total hours worked**
Female				
Male				
Others				

What is the total cost in Euros (e.g. labour, technology, energy etc.) of taking part in the LOWINFOOD project for your organisation? Have you gone over budget or spent over your budget allocation in a certain aspect?

What was your initial motivation to take part in the LOWINFOOD project? Were you satisfied with your decision to take part in the LOWINFOOD project?

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(If you answered yes to the latter question), what have you found particularly beneficial for your organisation? / (If you answered no to the latter question), what are the reasons for this?

Will you be interested in taking part in the other EU projects in the future? In either case, why? (similar projects here refers to multi-member consortiums and/or projects are partly/fully funded with national or EU research funds)

Participant demographics.

Person	**Were you directly involved in the LOWINFOOD project? (If yes, what is your role?)**	**How long have you been involved in the LOWINFOOD project?**	**Position in the organisation**	**Education Level**	**Age**	**Gender**

** = Only applicable to innovation partners*

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Appendix 3. Supplementary statistical analyses

Introduction

This Appendix presents some supplementary statistical analyses to the socio-economic evaluation of the innovations that has been carried out in the scope of LOWINFOOD project. When the data enabled us, we explored wider socio-economic impacts beyond those set out in D1.4 "Socio-economic data collection protocol", as well as the reasons for different levels of socio-economic outcomes for the same innovation across its demonstration locations. The section is structured by innovation.

Task 2.4 Retail demand forecasting simulation

Statistical analysis of recorded and total waste values reported in participating stores

In Store1 there was very little difference between the periods of baseline and demonstration[44] in terms of the cost of recorded waste, as most of the costs at baseline and demonstration periods worked out to be € 0.00. There were more non-zero values for the same measure for total waste, with one extreme value indicating that the cost of banana waste had risen by € 3,443.56 between the baseline and demonstration periods. When comparing these, it is clear that there is a significant amount of unrecorded waste for Store1, and that there is no clear trend toward either an increase or decrease in cost of waste in this store as a result of demonstration of the forecasted values. The total waste must include a lot of unrecorded waste, and there is no clear trend towards an increase or decrease in this figure as a result of the demonstration of the innovation. The change in the food wasted as a percentage ratio of the food purchased by Store 1 between the baseline and demonstration periods is presented below in Figure 1A.

Store 2 had more non-zero values than Store1, and also trended more towards an increase in the cost of waste between baseline and demonstration periods. The change in the food wasted as a percentage ratio of the food purchased by Store 2 between the baseline and demonstration periods is presented below in Figure 2A.

The costs of recorded waste are almost exclusively positive, meaning that there is an increase in the cost of recorded waste for the majority of the products. The change in the food wasted as a percentage ratio of the food purchased by Store 2 between the baseline and demonstration periods is presented in Figure 2A below. The graph shows that the total waste must include a lot of unrecorded waste (although again, less than that of Store1), and that there a trend towards an increase in this figure as a result of the demonstration of the innovation. demonstration periods were also previously found.

One extreme value indicates that there was a 53.71% decrease in the ratio of total Salad Iceberg" gr 400 wasted to those purchased for Store 2, which is likely linked to the earlier

[44] The demonstration of Task 2.4 was simulation like in Tasks 2.1 and Task 3.1 which are not featured here.

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finding that there was an extreme decrease in the cost of waste for “Salad “Iceberg” gr 400”, between the baseline and demonstration periods in the Store2 store. Notably, the same level of extreme decrease is not seen for the “Strawberries gr 500” product, where an extreme decrease in the cost of waste between the baseline and increase in cost of waste in this store as a result of demonstration of the innovation.

Figure 1A: Change in the cost of recorded and total waste by product in Store1

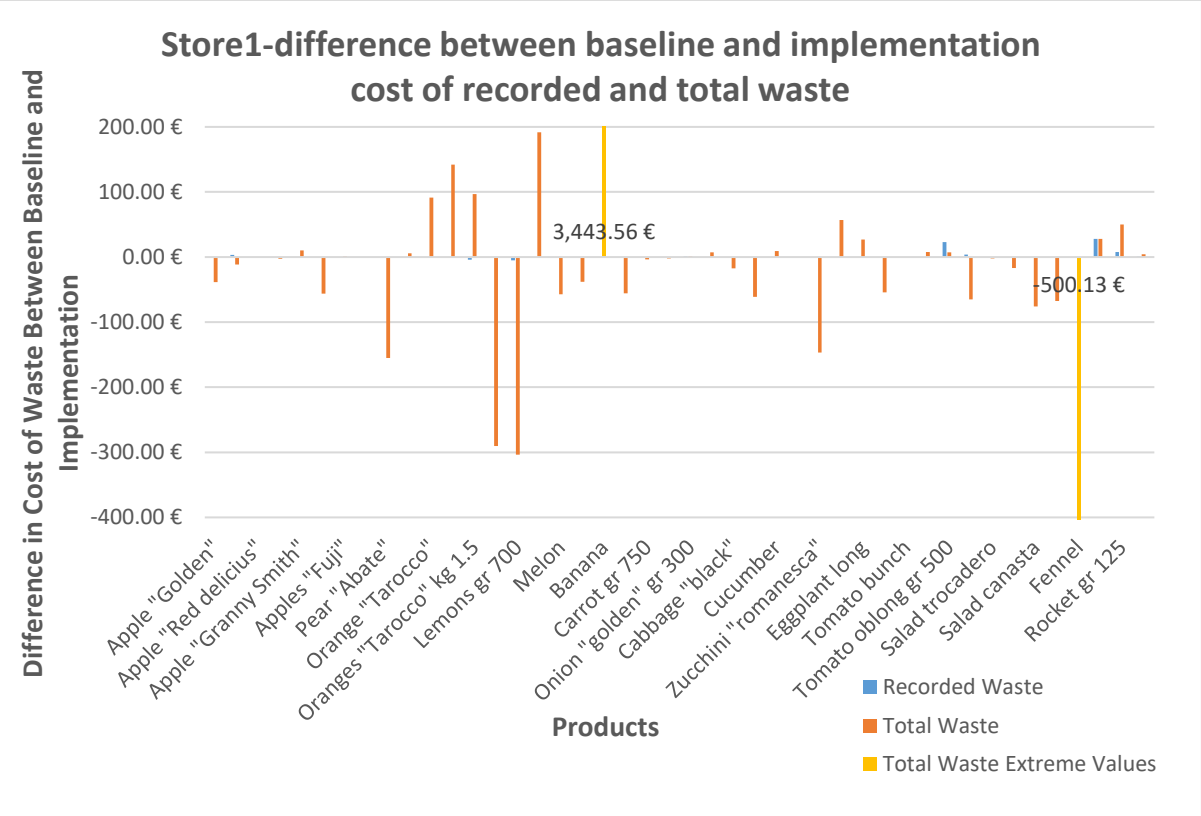

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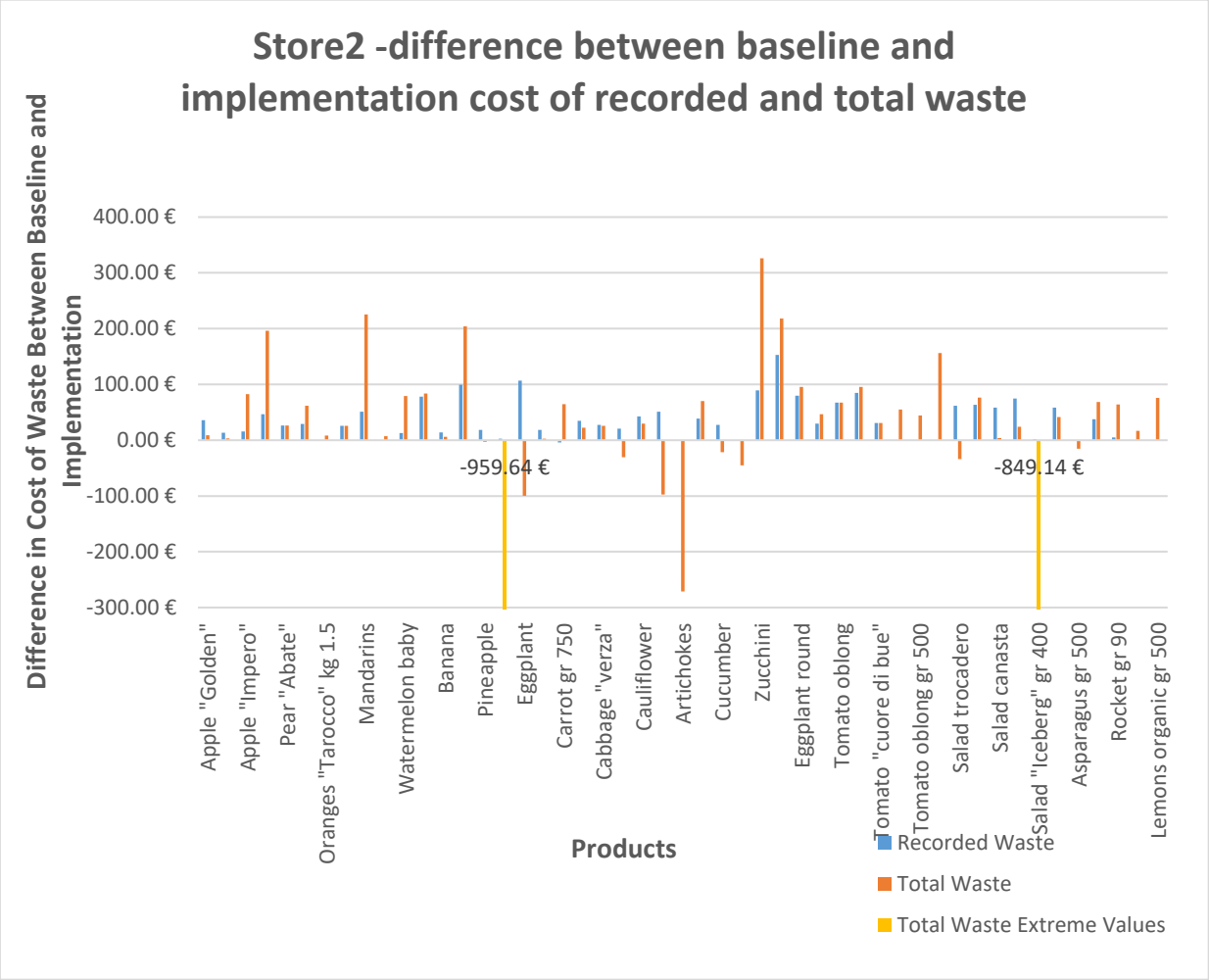
Figure 2A: Change in the cost of recorded and total waste by product in Store 2



Task 3.2 Stakeholder dialogue in the bread value chain

Statistical analysis of daily surplus measurements taken at the artisanal bakeries in Italy

Accounting for the income achieved through surplus is essential to understand whether there is an economic incentive to produce in surplus for the bakeries. Unfortunately, the disposal routes chosen for the surplus at the end of each day was reported without any percentage of share information about amounts allocated to each chosen disposal route.

For this reason, we looked into the frequency of disposal routes reported by the participating bakeries. We checked if there is a link between the frequently used waste disposal route (and whether it made bakeries any additional income) and the potential interest in reducing surplus/production ratio.

We can hypothesize that bakeries that more frequently use money-making disposal routes (such as revalorisation in breadcrumbs or discounted sales on Too good to go app) would

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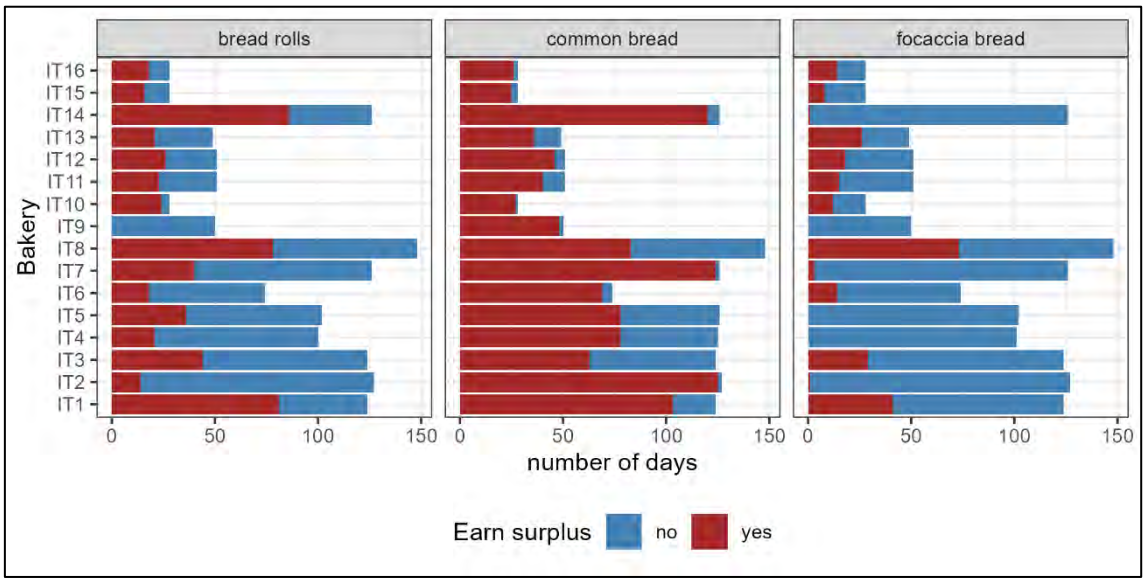
be less interested to reduce their surplus compared to others (such as those more often donating to charities or giving it to as feed for animals), due to lack of economic incentive to reduce their surplus. We checked if there is a link between the amount of surplus generated each day and the disposal route taken on that day and the day after, to assess if there is any relationship with the amount of waste and the route.

To answer this question, we create a new variable called '*earn_surplus*' which takes values 1 if the destination of surplus included reuse, *sold_animals* and *app2good2go*. Figure 3A shows that common bread is the type of bread which is more likely to make bakeries money from its surplus.

Figure 3A: Additional income creation from three main bakery products used in reporting.



We calculate the mean ratio of quantity produced bread and surplus by the type of bread, bakery, and *earn_surplus*. As we can see in Figure 4A, it seems that ratio of surplus was greater in those days where surplus was used in routes where it is possible to create additional income.

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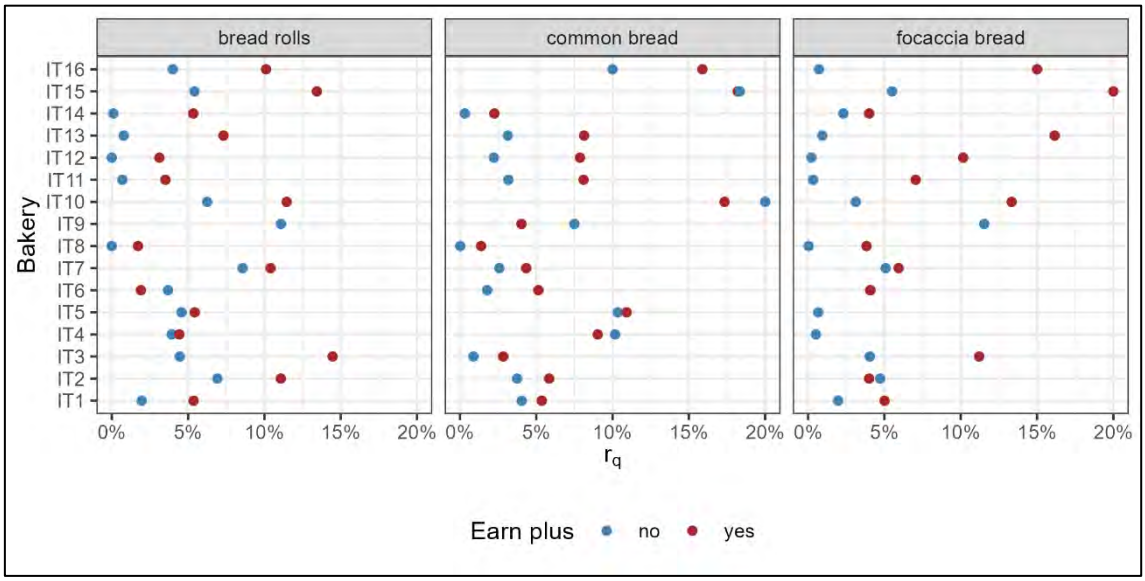
Figure 4A: The relationship between surplus amount and the disposal route



To test the hypothesis that the surplus tends to increase on days where surplus was used in disposal routes in which it is possible to make money, we fit a linear mixed model on the ratio of surplus. We include as covariates the type of bread, use of surplus to make money and the interaction between type of bread and use of surplus, with bakery as random effect (Table 1A). Based on the p-values, we conclude that surplus tends to increase on days when the disposal route is used to revalue surplus bread.

Table 1A: Results of the linear mixed model

	Estimate	St. err.	t value	Pr(>|t|)
(Intercept)	0.0508	0.0081	6.2781	0.0000
earn_surplus	0.0285	0.0032	8.8356	0.0000
type_bread common bread	0.0114	0.0039	2.9061	0.0037
type_bread focaccia bread	-0.0137	0.0026	-5.1693	0.0000
earn_surplusyes: type_bread common bread	-0.0210	0.0050	-4.2019	0.0000
earn_surplusyes: type_bread focaccia bread	0.0368	0.0051	7.2098	0.0000

Figure 5A below depicts the changes in the ratio of bread surplus quantity (BSQ) and bread produced quantity (BQP) for each bakery and type of bread. Horizontal lines represent the mean ratio of surplus for each period, accompanied by their respective confidence intervals. To determine which bakeries have significantly reduced their surplus ratios, we examined the overlap of confidence intervals before and after the demonstration. Bakeries IT1, IT3, IT6, IT10, IT15, IT16 left the study before the demonstration period so they were excluded from the analysis. The below analyses only include IT02, IT04, IT05, IT07, IT08, IT09, IT11, IT12, IT13 and IT14 which took part in both the baseline and demonstration periods and their surplus measurement data from both periods are available for analysis.

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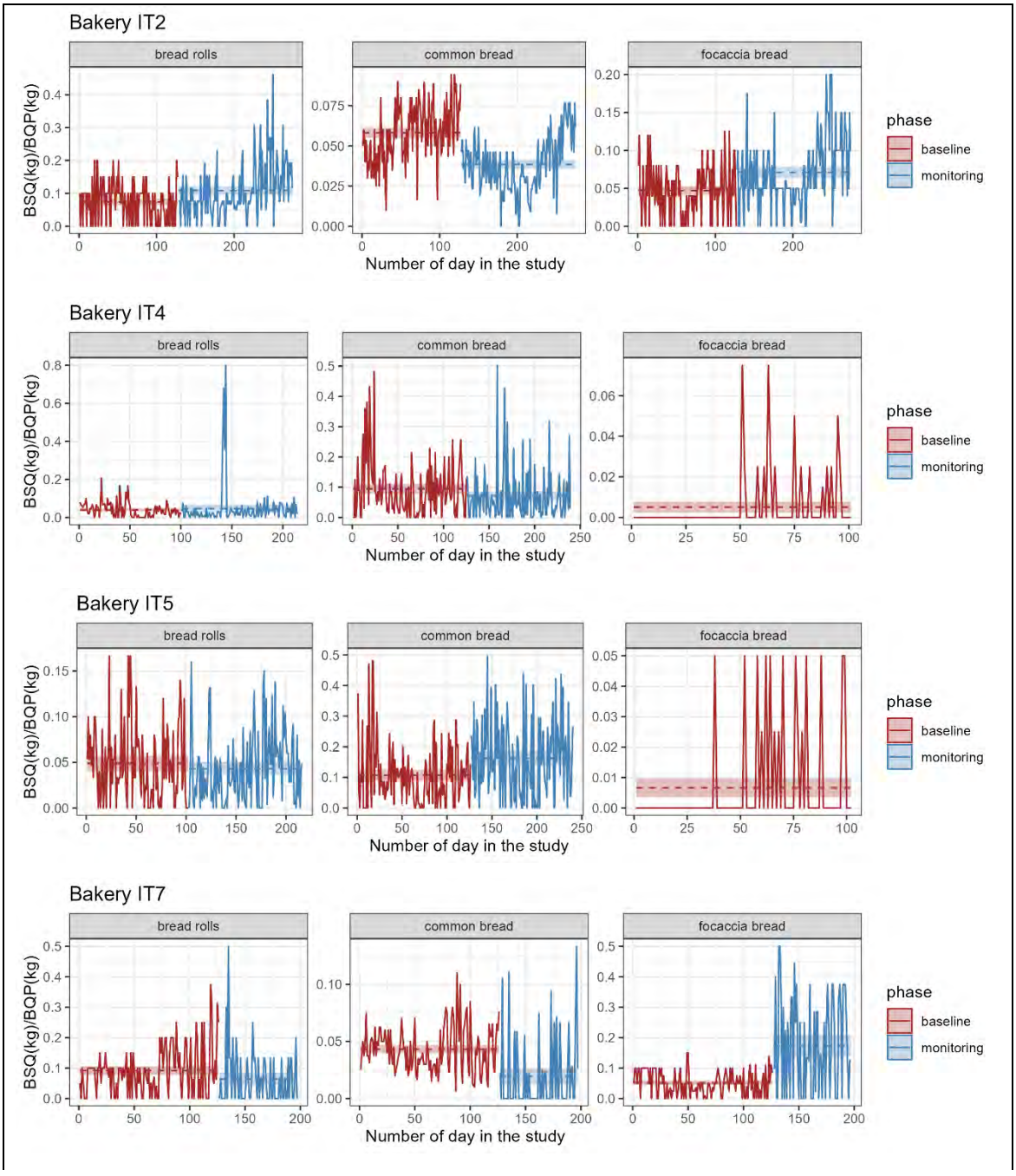
Figure 5A: Evolution of surplus quantity to production quantity ratio in the baseline and demonstration periods[45]



[45] The bakeries that left the task after the baseline period and for which we did not have the demonstration period measurements are not included.

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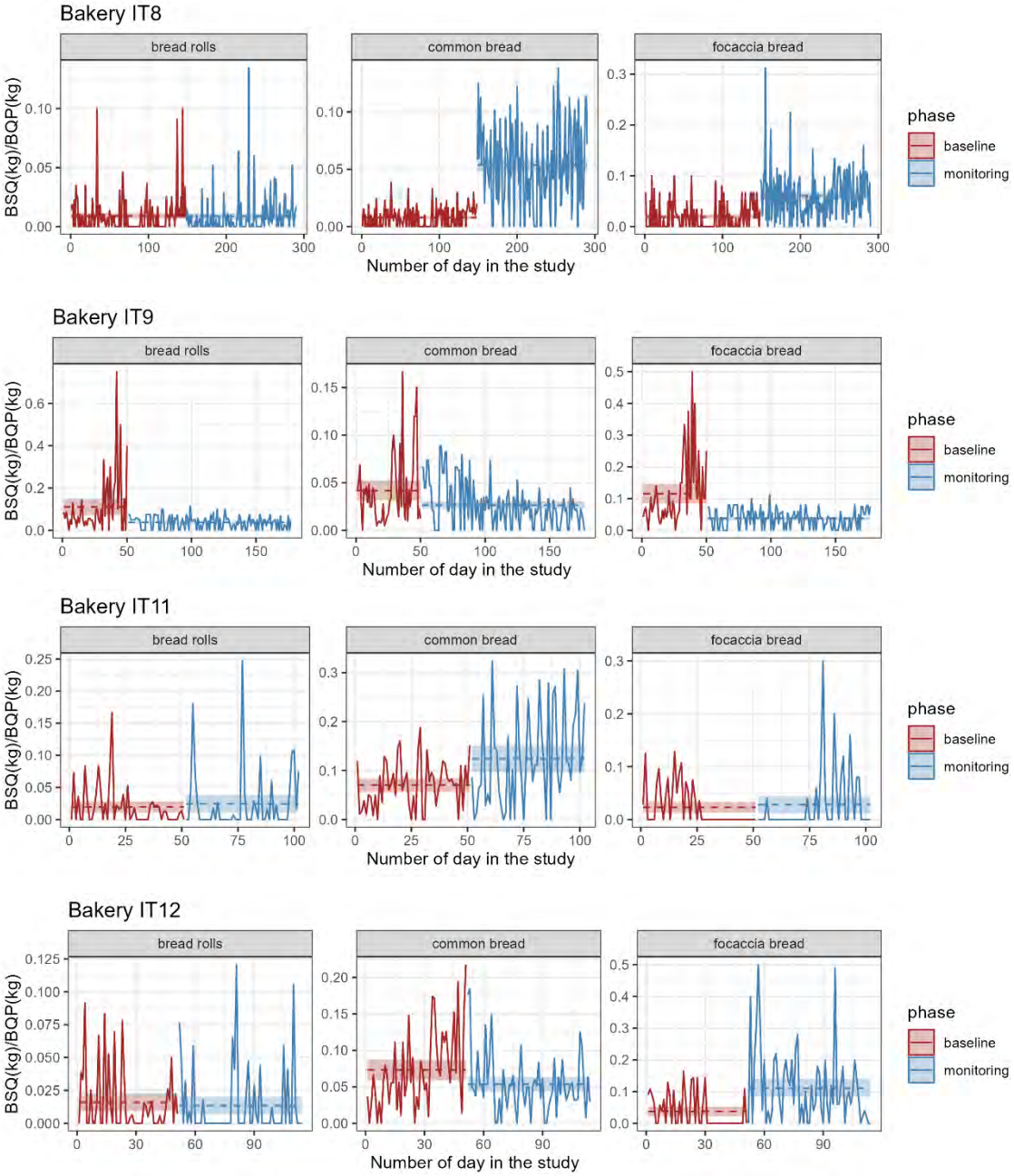

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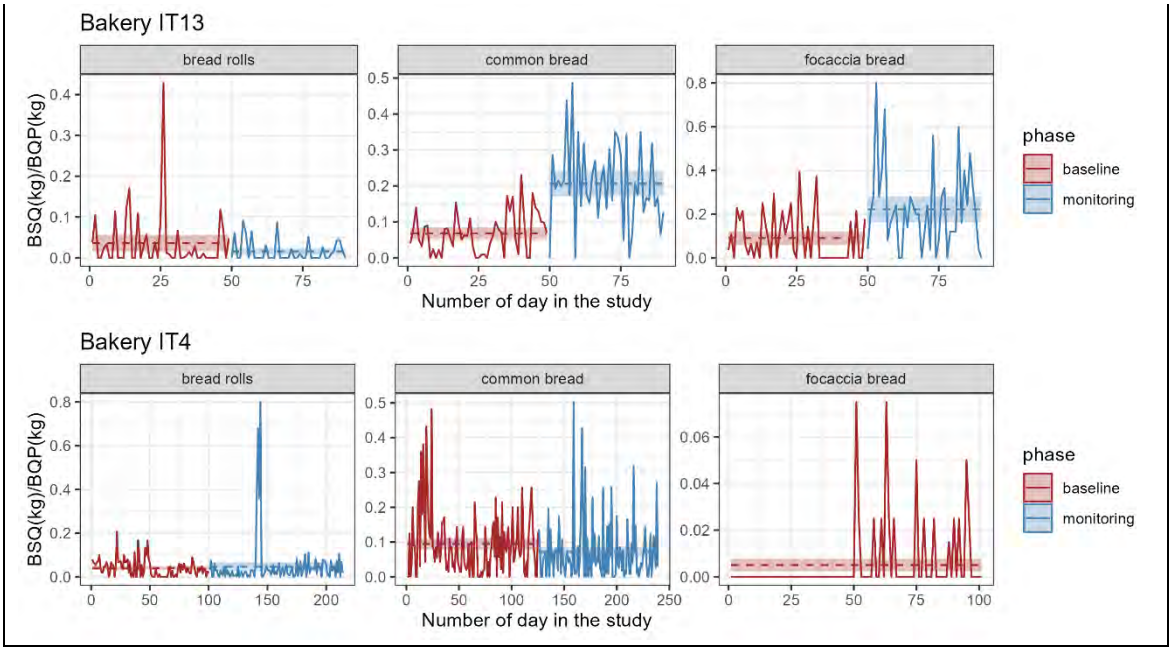
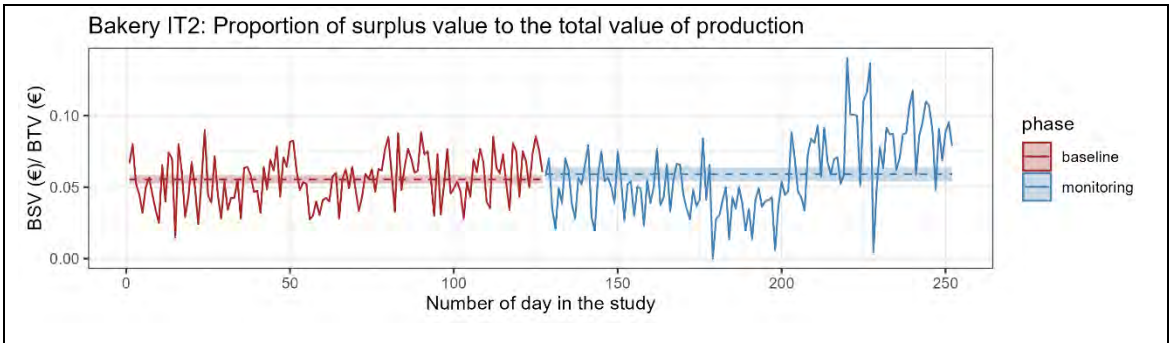


To assess the changes in value of bread surplus, the ratio between bread surplus value (BSV) and bread turnover value (BTV) was obtained. These indicators consolidate the surplus value across all bread varieties. In Figure 6A below, the tracking of this indicator across the period of study is shown. Horizontal lines indicate the mean value, along with the confidence interval al 95%. Notably, only bakery (T9) showed a significant reduction in the value of surplus bread. Figure 6A shows the evaluation of the surplus value proportional to the total value of production between baseline and demonstration periods.

Figure 6A: Evolution of the bakery surplus value to bakery total production value ratio in the baseline and demonstration periods in each participating bakery



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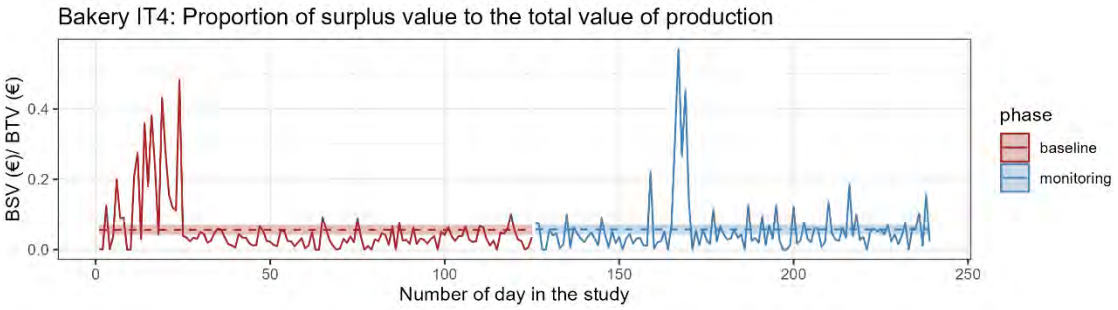

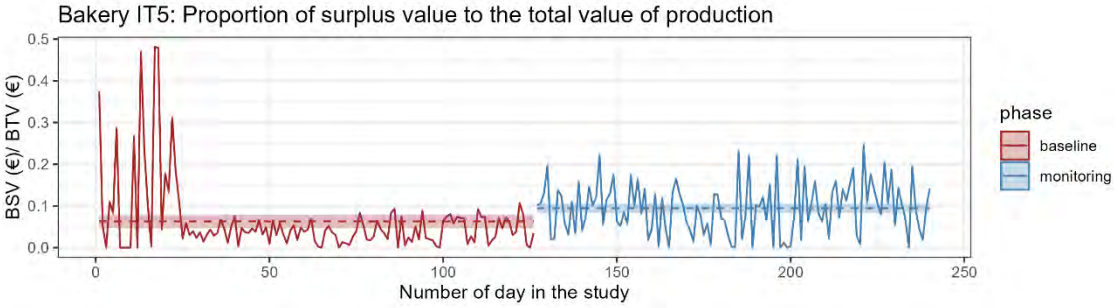

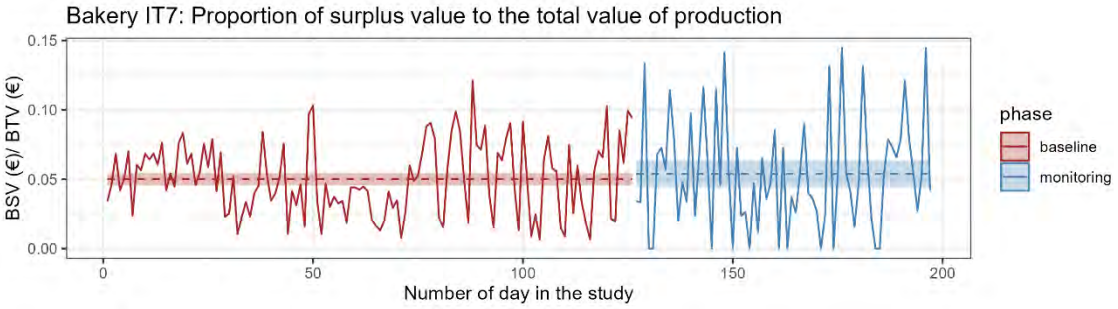

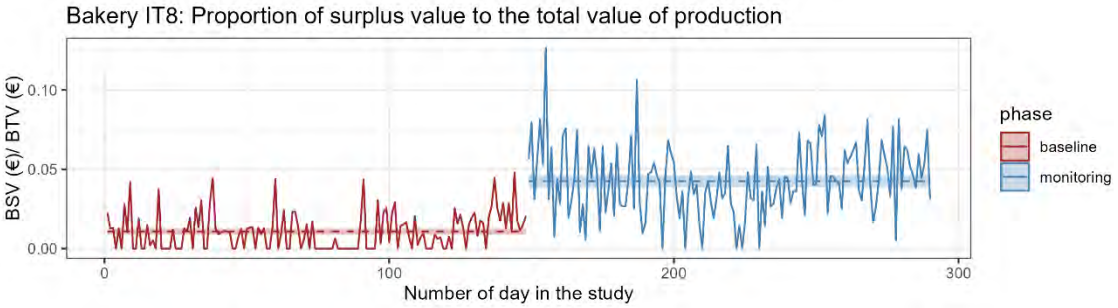

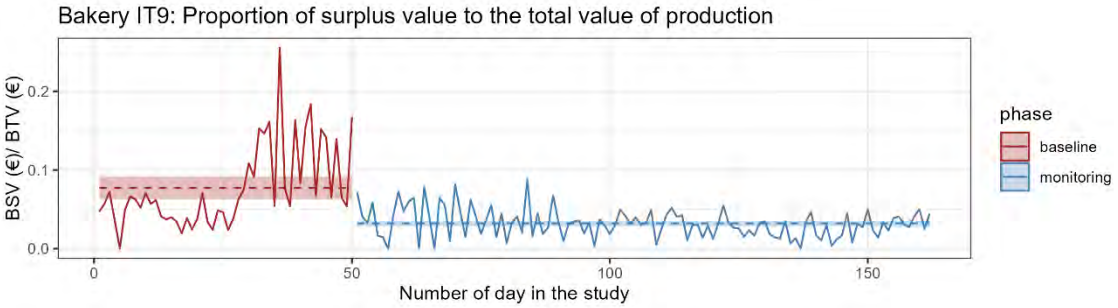

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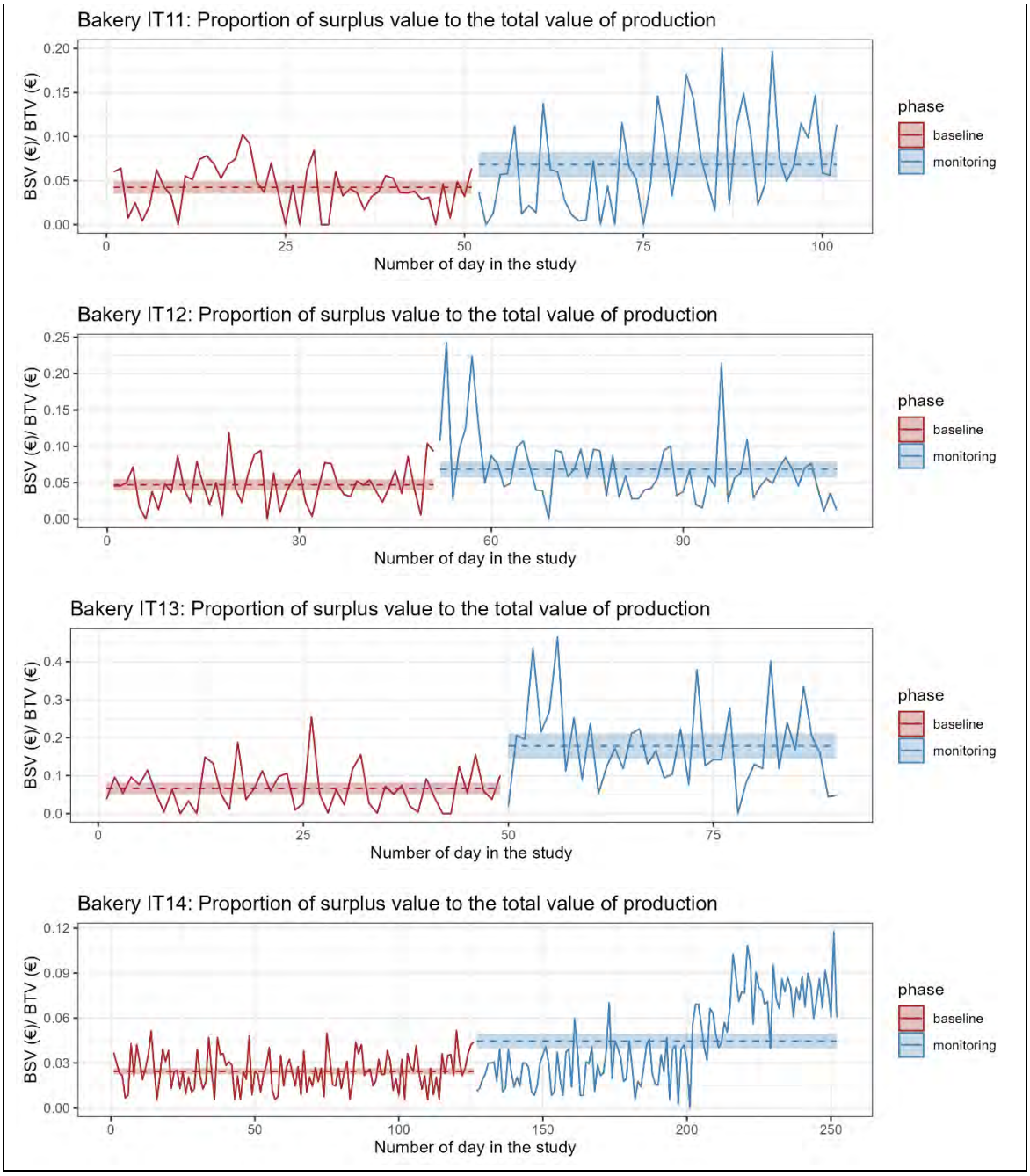

Figure 7A shows the evaluation of the daily surplus value between baseline and demonstration periods. Horizontal lines indicate the mean value, along with the confidence interval al 95%. Among the participating locations, bakery (T9) achieved the best daily surplus reduction outcome.

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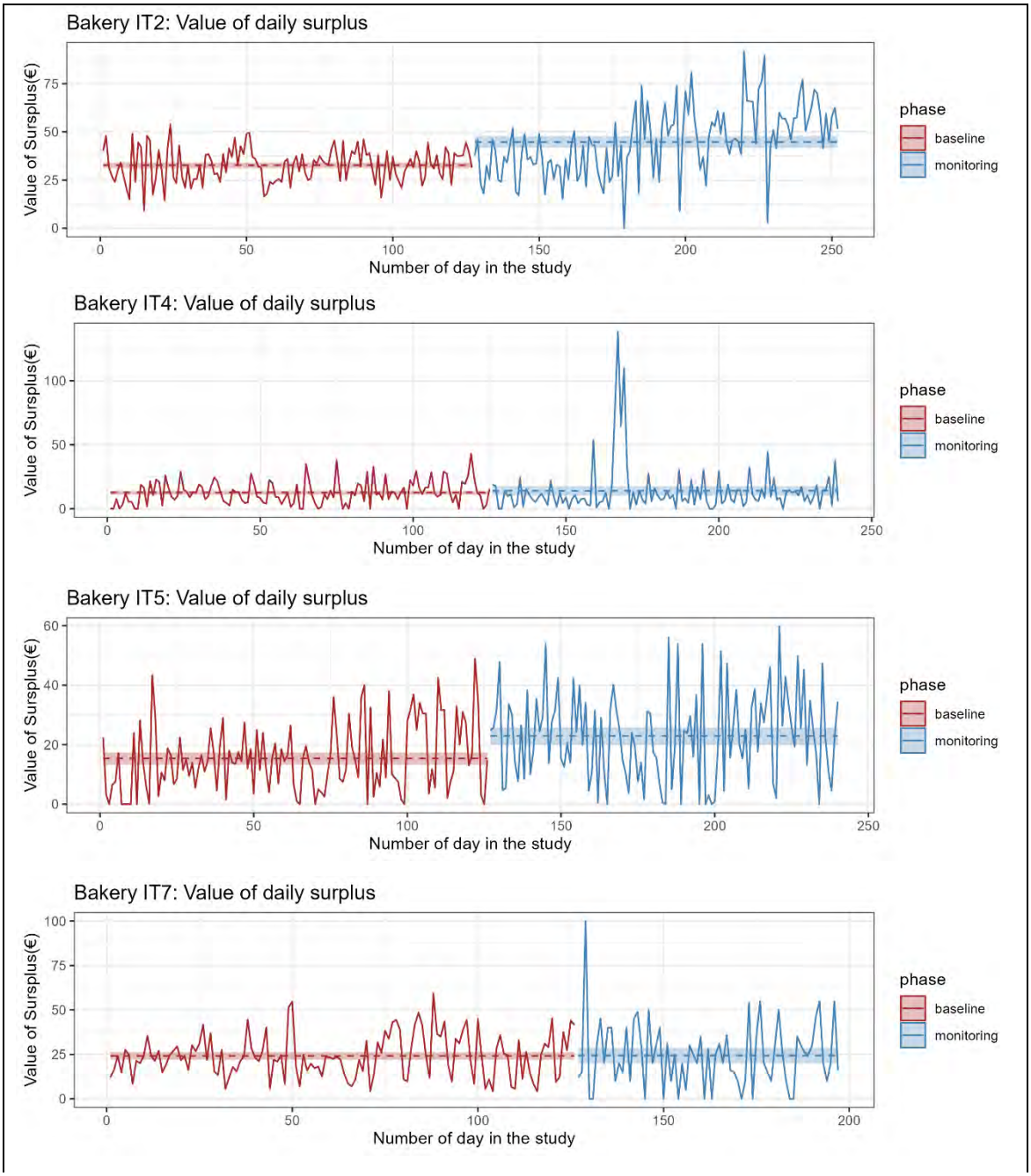
Figure 7A: Evolution of the daily surplus value over baseline and demonstration periods in each participating bakery



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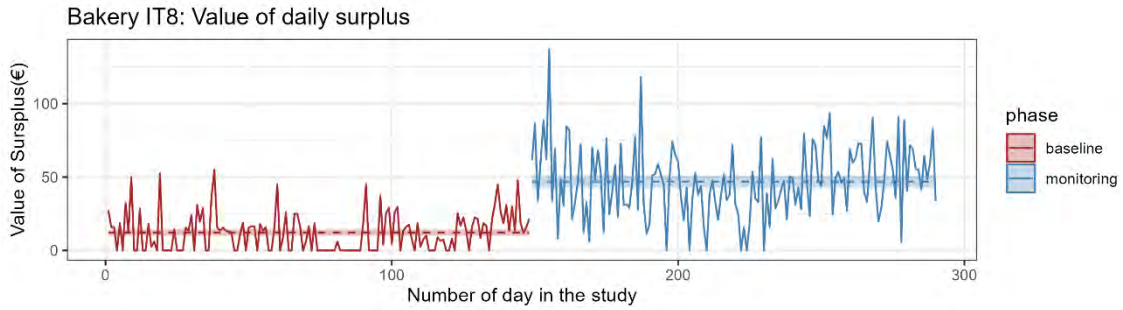

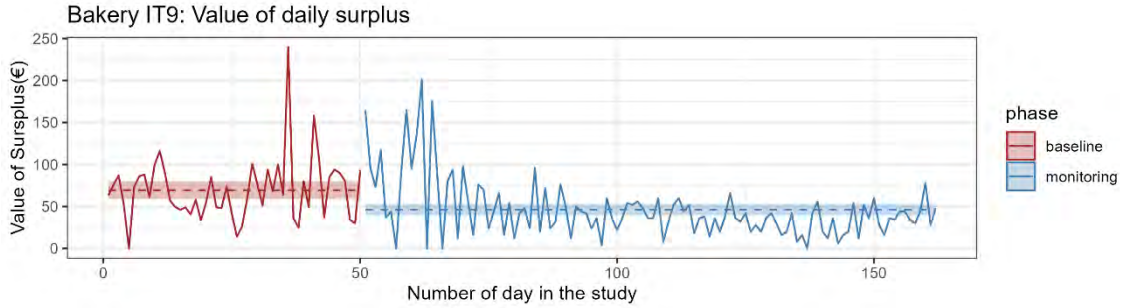

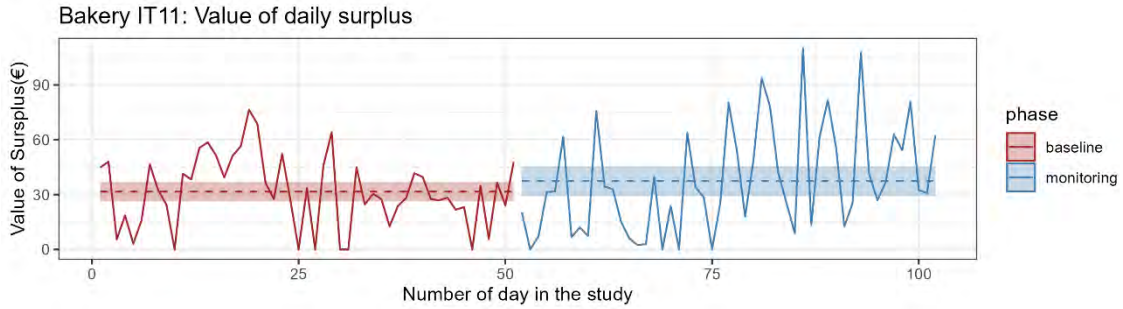

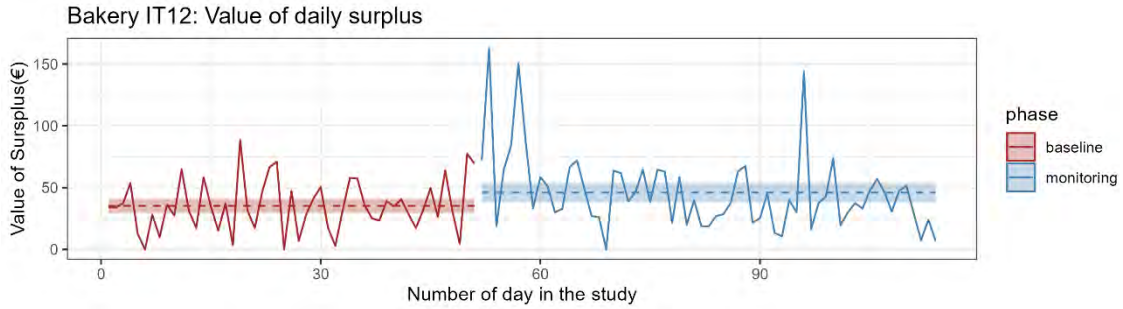

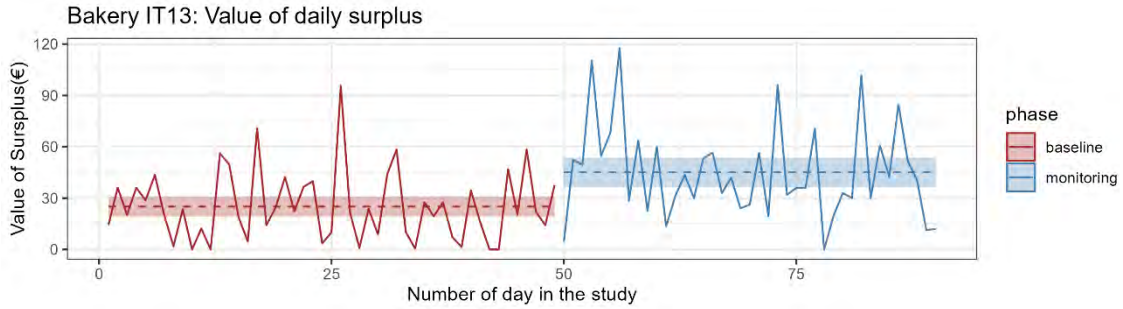

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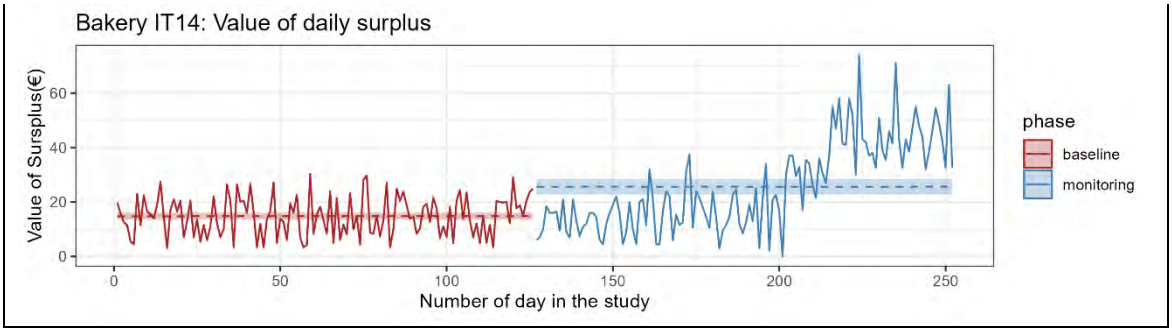


Task 3.3 FoodTrack Software for bakeries

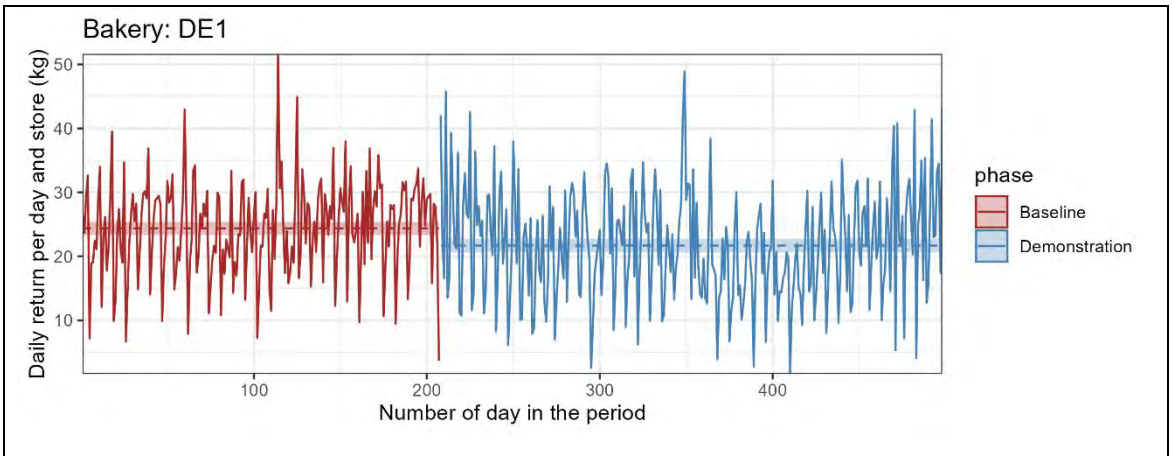
Statistical analysis of bakery goods return data set

For data analysis, the rate of return was used as the primary indicator to filter the data. This indicator is calculated as the ratio of product returns to the difference between production and depreciated products. Only data with return rates between 0 and 1 were considered.

To assess the performance of the innovation, two indicators were tracked throughout the study period. The first indicator is the daily quantity of returns per bakery store, as shown in Figure 8A. Horizontal lines indicate the average quantity of returns per day and bakery store, along with a 95% confidence interval. Overall, average quantities of returns reported by the participating bakeries are smaller in the demonstration. Whilst confidence intervals do not overlap between baseline and demonstration periods of the study, providing evidence that each bakery experienced a significant reduction in return volume.

It is important to note that the reduction trend among the bakeries is not smooth, but instead fluctuates. However, bakery DE1 exhibits an increasing trend towards the end of the demonstration period.

Figure 8A: The reduction trend in bakeries DE1, DE3 and DE4



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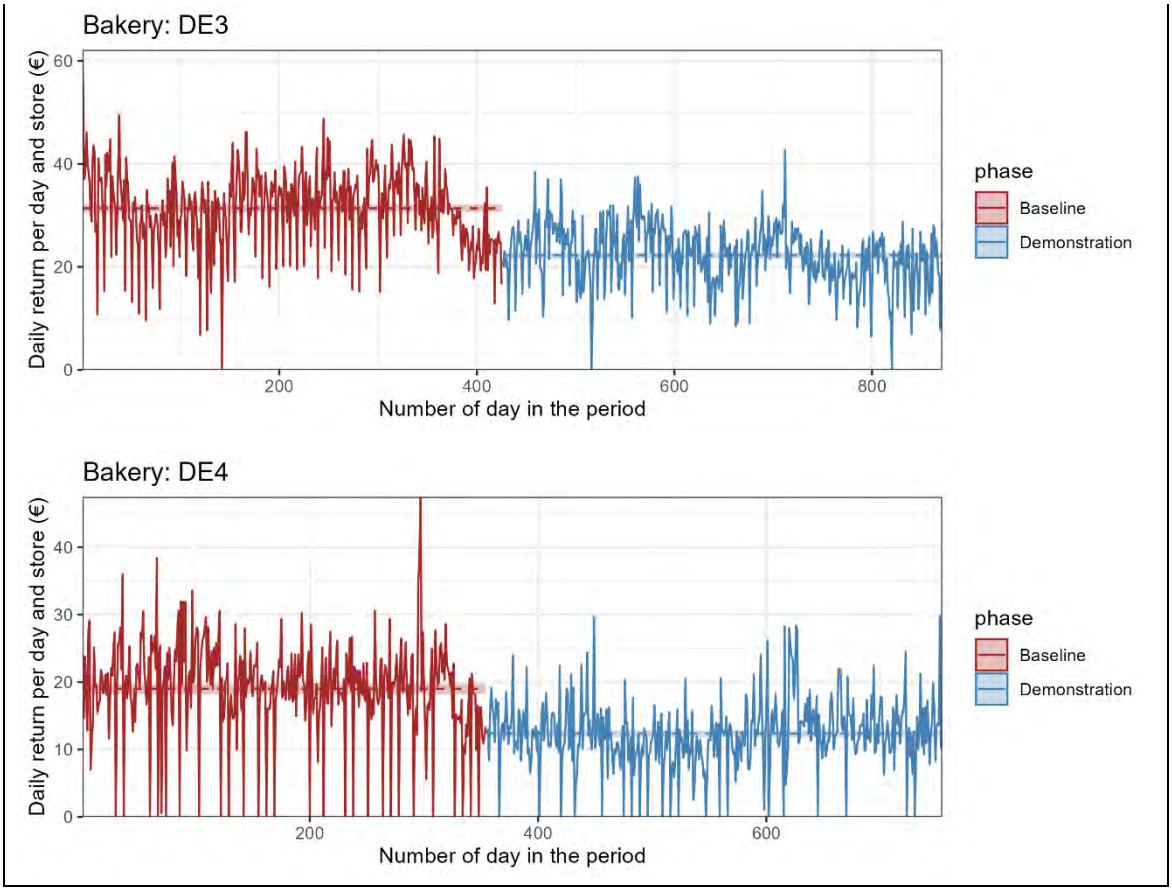
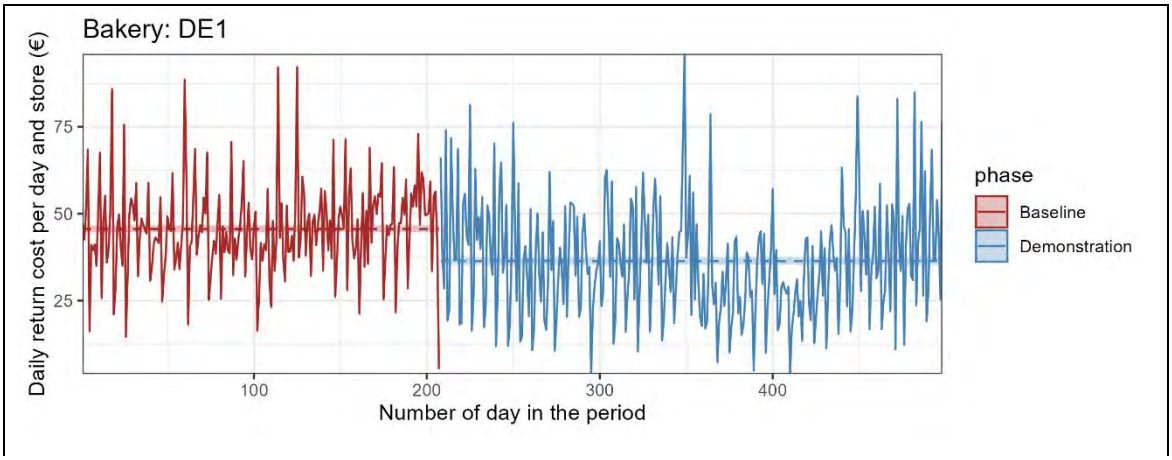


The second indicator is the daily cost of returns, as shown Figure 9A. All bakeries have experienced a reduction in value, based on the magnitude of difference. Bakery DE1 has the largest reduction, resulting in the most significant savings. Conversely, bakery DE2 has the smallest reduction, despite having a greater reduction in volume compared to the other bakeries.

Figure 9A: Daily cost of returns in bakeries DE1, DE3 and DE4



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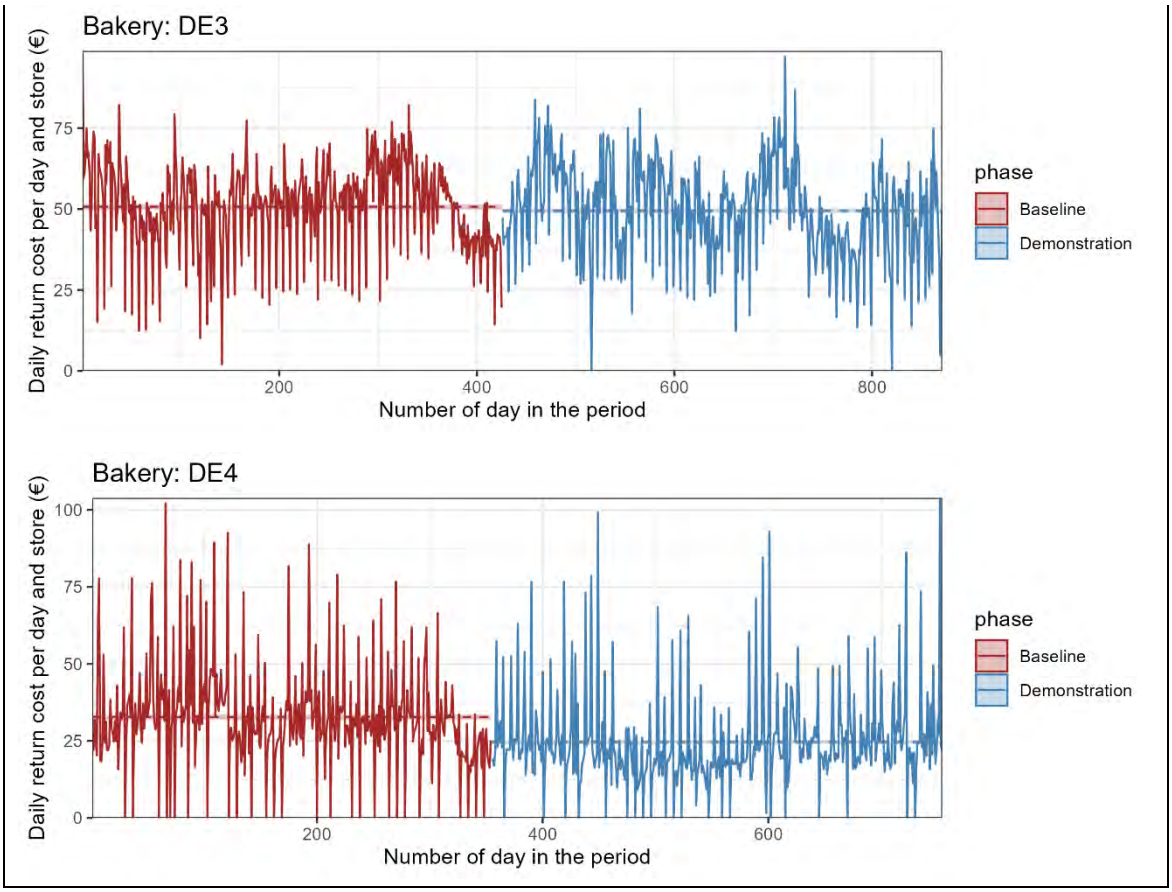

Tasks 5.3 Matomatic Plate Waste Tracker and Task 5.4 Holistic educational approach

Statistical analysis of plate waste measurement data in schools

Data analysis was carried out at country level. Schools from 3 countries (Sweden, Germany and Austria) participated in T5.3 and 2 countries (Sweden and Austria) in T5.4. 5 of 10 Schools that participated in T5.3 in Sweden also participated in T5.4 and 3 of 5 schools that participated in T5.4 in Austria also participated in T5.3. For this reason, all Swedish schools are included in Figure 10A for T5.3, while 5 school implementing both T5.3 and T5.4 are included in Figure 12A for T5.4 . All five Austrian schools are included in Figure 13A for T5.4 but not in T5.3 section as there are no schools in the Austrian sample that only implemented T5.3.

T5.3 Sweden

The data analysed were from 10 school units. In the data set instances with date 28-01-2021 were identified due to bug in the software for unit SW1 & SW6 based on local partner's email. Four duplicates were most likely corrections or updates made in the system where the previous observation have not been removed. In such cases, the first instance was removed from the analysis.

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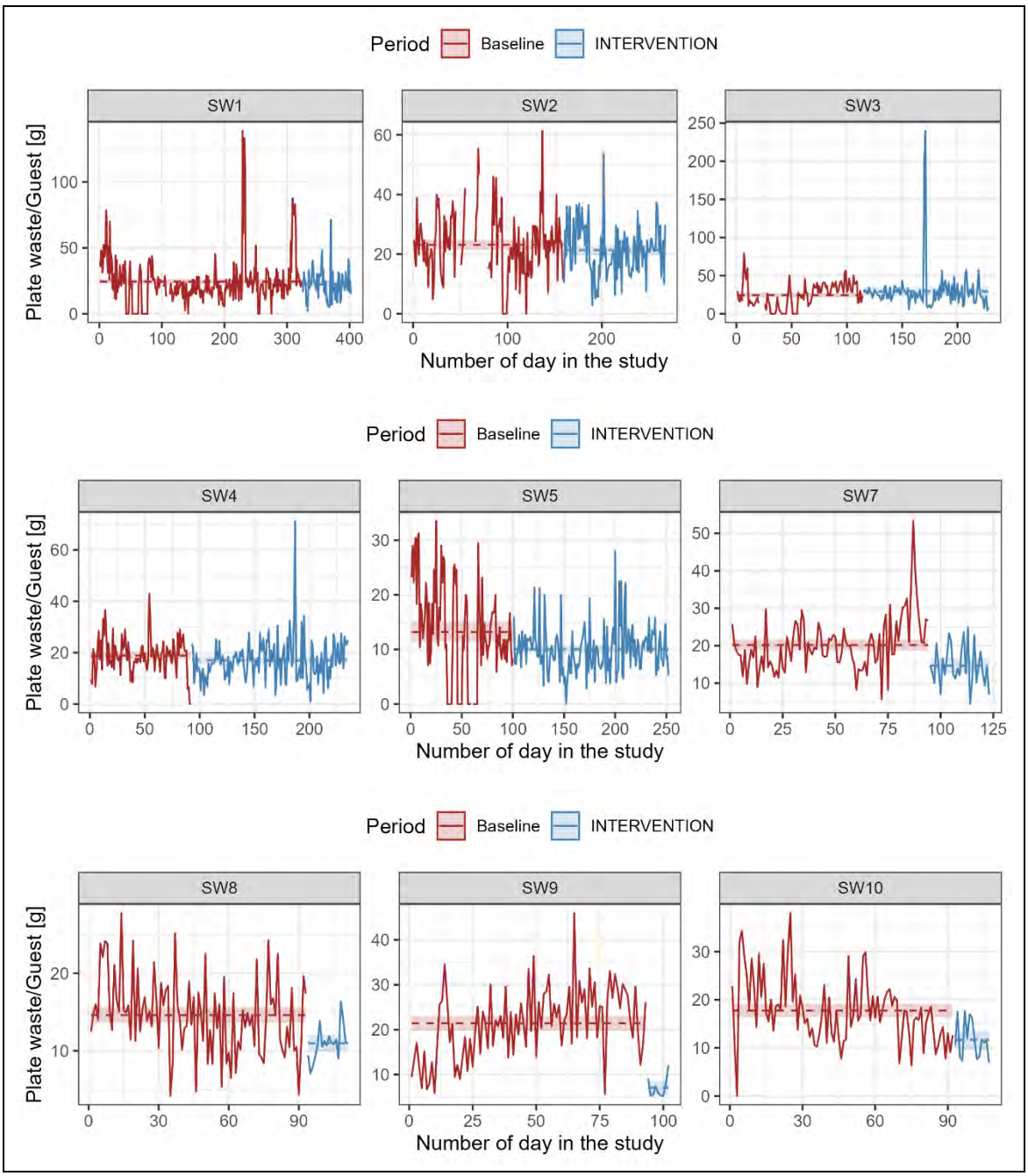
Additionally, Unit SW6 was excluded from the analysis due to lack of information during the demonstration period. After cleaning the data, the tracking of plate waste per guest was obtained for each school and reported in Figure 10A. The horizontal lines denote the mean plate waste per guest along with their respective confidence interval at 95%.

Figure 10A: Daily plate waste measured in schools participated in T5.3 – Sweden



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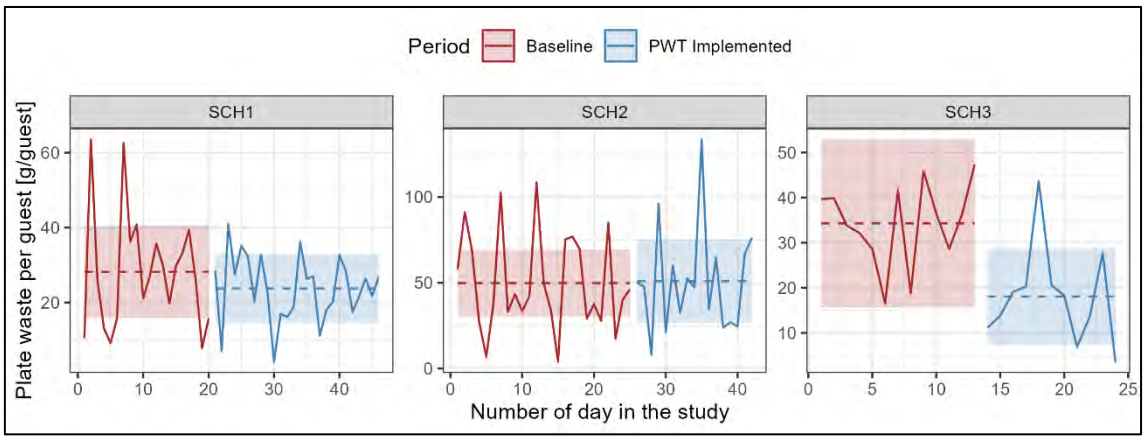
From the above Figure 10A, no strong pattern in the tracking of food waste across the units can be identified. The duration of the study varied from 100 to 400 days, influencing the length of confidence intervals, which were larger in units with shorter study periods. Most baseline means were higher than those during the intervention period, suggesting a reduction in food waste, except in unit SW3. This can be explained by days where food waste was unusually larger. It is important to mention that reduction in units SW8, SW9 and SW10 needs to be analysed with cautious due to few data in the intervention period.

T5.3 Germany

Three school units were analysed. The tracking of plate waste per guest is shown in Figure 11A. Horizontal lines represent the mean plate waste per guest over the study period, along with their respective 95% confidence intervals. Only units SHC1 and SCH3 observed reductions in food waste; however, these reductions were not significant due to overlapping confidence intervals. Note that the size of the confidence intervals is larger because of the short study period, indicating that any conclusions about the reduction in food waste are subject to uncertainty due to the lack of data.

Figure 11A: Daily plate waste measured in schools participated in T5.3 – Germany



T5.4 Sweden

Five schools were analysed, with duration of study varying from 50 days to 200 days. Tracking of food waste per guest is illustrated in Figure 12A. Horizontal lines represent the average of food waste per guest across the period of study, along with respective confidence intervals at 95%. According to the data, school SW05 showed a consistent decrease in food waste towards the end of the demonstration period. All schools exhibited peaks of unusually high food waste, likely due to data entry errors or festive days when pupils were more likely to stay at home. Overall, no significant reduction in food waste was observed, except at school SW05.

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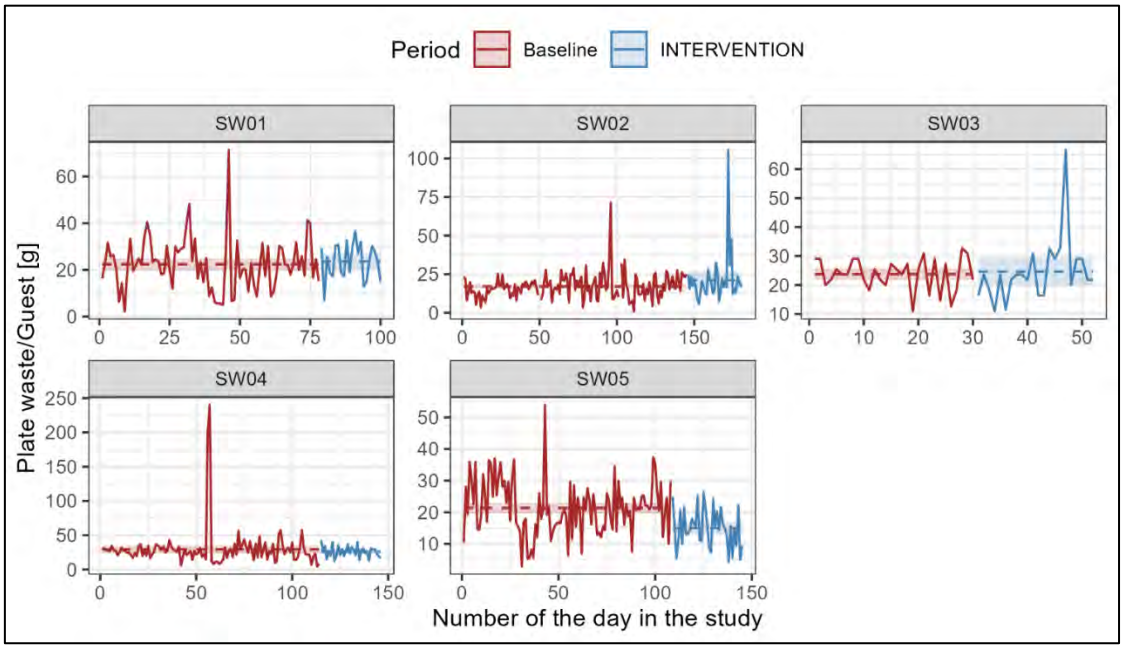
Figure 12A: Daily plate waste measured in schools participated in T5.4 – Sweden



T5.3 and T5.4 Austria

Eleven schools were analysed. Innovations T5.3 and T5.4 were implemented in 3 schools. No results can be estimated for T5.3 in Austria because there are no schools that only implemented T5.3. The analysis for the schools which implemented both T5.3 and T5.4 will be made in T5.4. In the Figure 13A is reported the tracking of the food waste per guest for schools in Austria. Horizontal lines represent the average of food waste per guest during the period of study, along with confidence intervals at 95%. There were mixture results in the reduction of food waste, being schools AUT2 and AUT5 the only schools with a significant reduction in food waste. Due to the duration of study, there is a lack of information to estimate confidence intervals with precision.

For data analysis, the average food waste per guest was calculated at the school level for each study period. To assess differences between the schools, a linear regression model was fitted, with the average food waste per guest during the demonstration period as the dependent variable. The predictors included the average food waste during the baseline period, type of innovation, study duration, and the average number of pupils at the school.

The scatterplot in Figure 14A shows the average plate waste per guest in the baseline and demonstration periods. The dotted line represents a line with a slope of 1 and an intercept of 0. Points below this line indicate a reduction in plate waste.

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Figure 13A: Daily plate waste measured in schools participated in T5.4- Austria

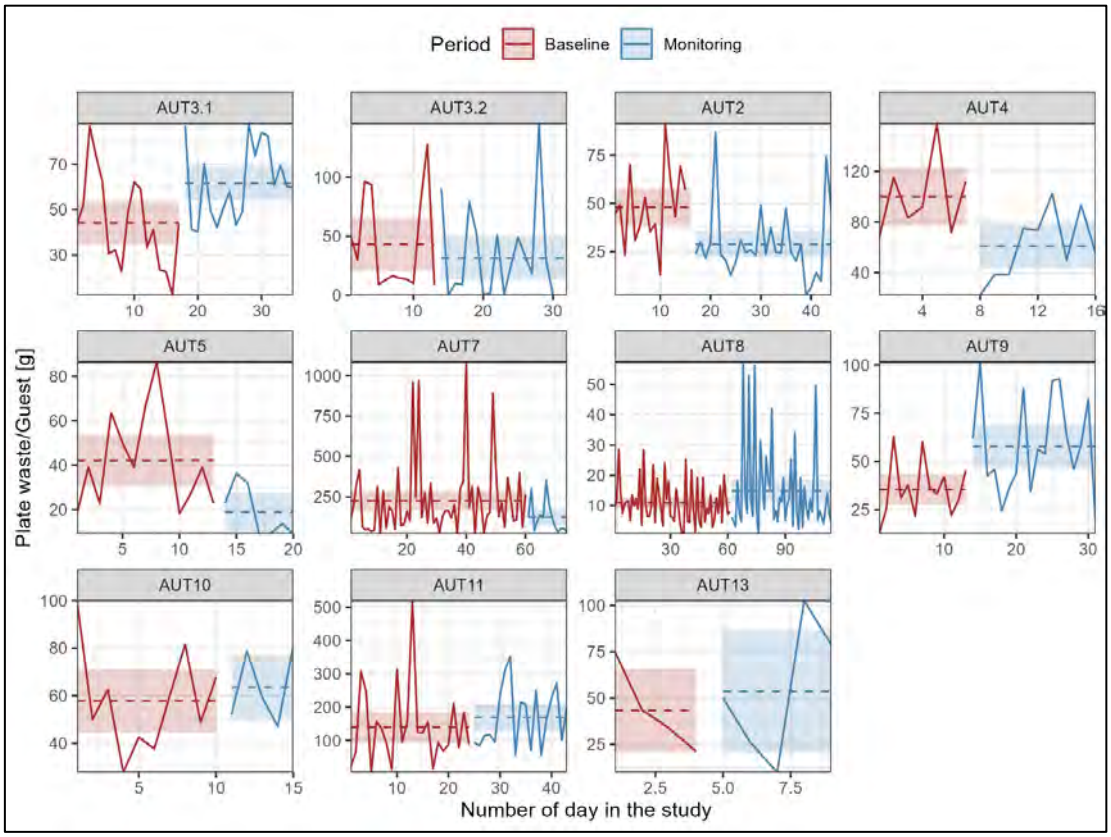
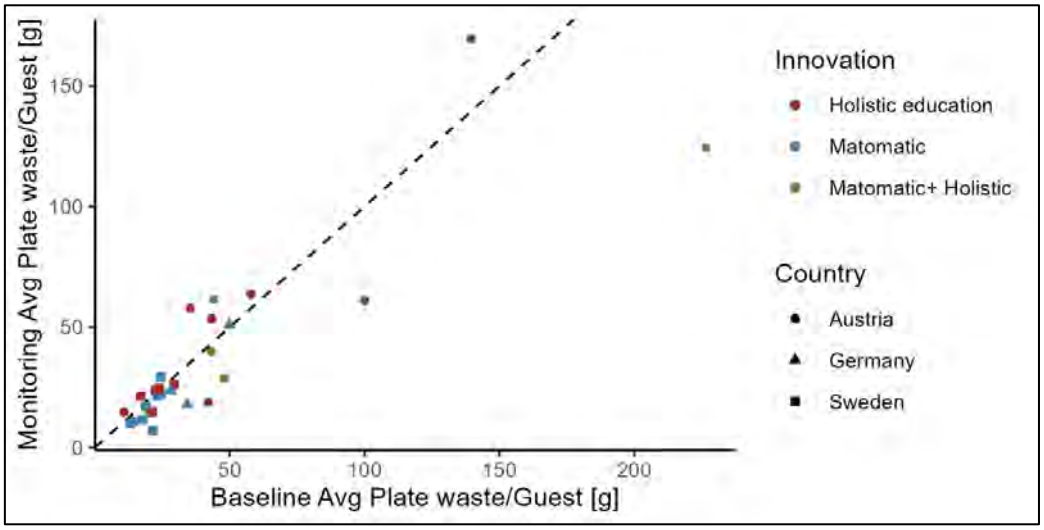


Figure 14A: Association between reducing food waste and type of innovation



Estimated coefficients are given in Table 2A below, the average plate waste in the baseline is the only significant predictor. According to the magnitude of the coefficient, for each gram

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of food waste produced in the baseline, it is estimated that 0.637g would be produced in the demonstration, which represents a reduction of 36.3%.

Table 2A: Estimates of coefficients when using the average amount of baseline waste as a predictor for average waste measurements in the demonstration period

	Estimate	St. err.	t value	p-value	Significance
(Intercept)	23.726	9.103	2.606	0.0161	*
plate_waste_guest_Baseline	0.637	0.096	6.635	0.0000	***
innovationMatomatic	-4.164	10.257	-0.406	0.6887	
innovationMatomatic+ Holistic	-17.620	11.855	-1.486	0.1514	
countryGermany	-12.457	16.433	-0.758	0.4565	
countrySweden	-16.098	11.381	-1.415	0.1712	

Significance codes: 0 <= '***' < 0.001 < '**' < 0.01 < '*' < 0.05; Residual standard error: 18.38 on 22 degrees of freedom; Multiple R-squared: 0.7874, Adjusted R-squared: 0.7391; F-statistic: 16.3 on 22 and 5 DF, p-value: 0.0000

Task 5.5 CozZo mobile app

The statistical analysis of waste measurements from participant households

Regular households, i.e., household approach households, were the original focus, but the difficulties recruiting them led to recruitment of students attending the three universities in the task to complement the sample (and to reach the sample size we had agreed in Grant Agreement (which was set at 50-80 households). As a result, most of participants households consisted of students (i.e., student household approach households).

While the balance between the number of student and normal/regular households could not be aimed in the recruitment due to the reasons explained above, the Austria sample had the most balanced data with respect to the representation of households from both household and student approach as shown in Figure 15A.

Figure 15A: Distribution of participating household in term of different household categories across 3 participating countries

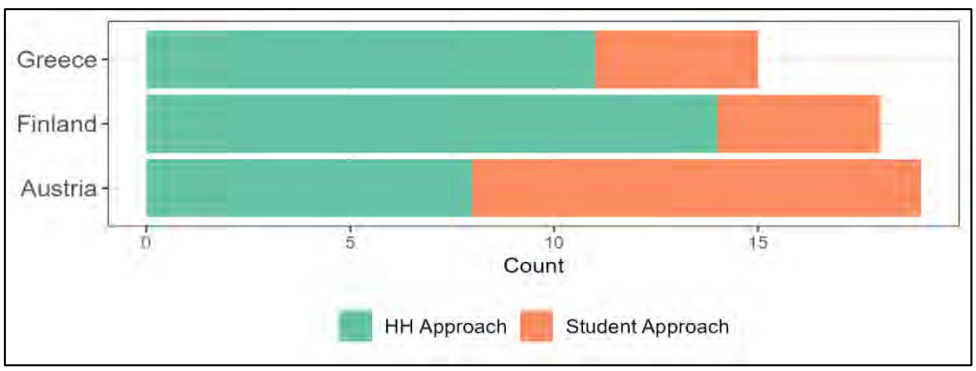

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Figure 16A: Distribution of participating households according to role and responsibility in the household in terms of using the CozZo app across 3 participating countries

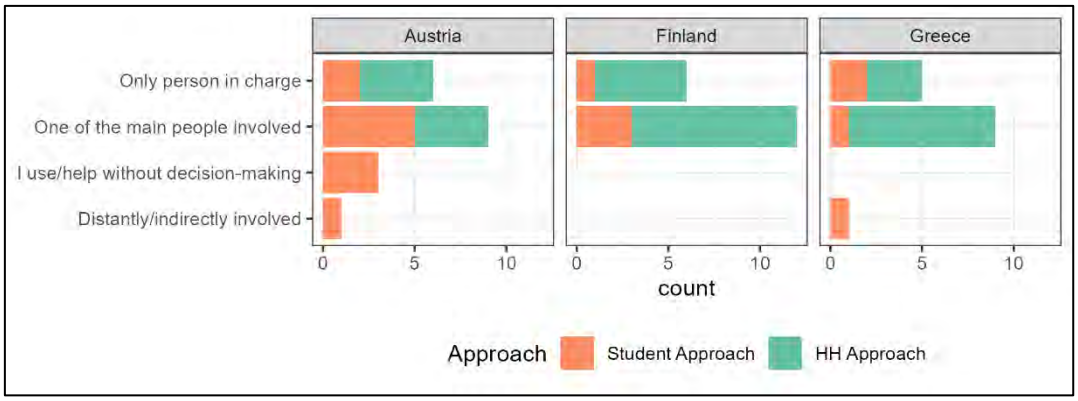

Figure 17A: Distribution of participating households according to ages of the household members CozZo app across 3 participating countries

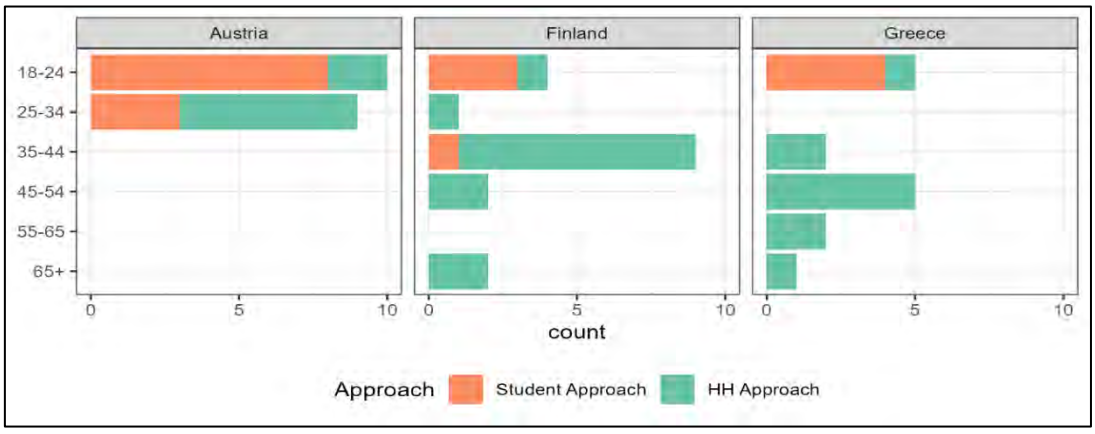

Figure 18A: Distribution of participating households according to education level of the household members using CozZo app across 3 participating countries

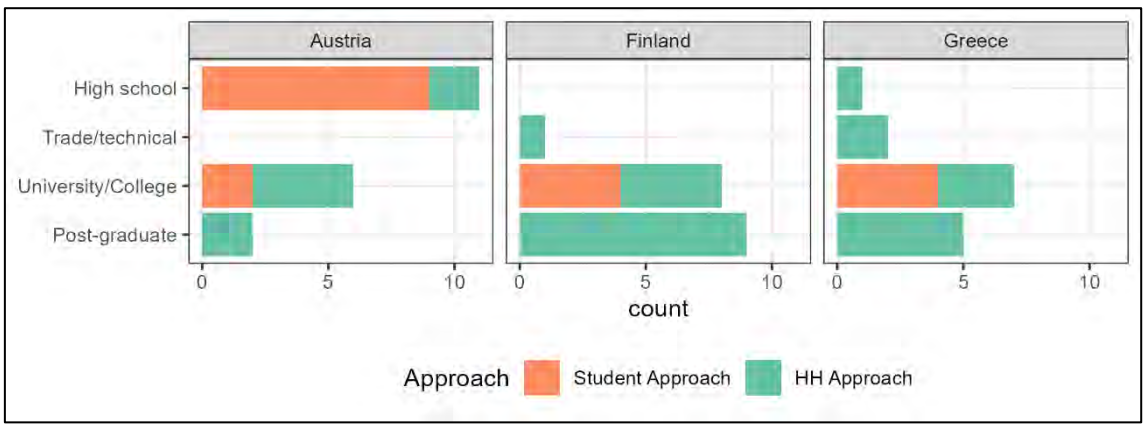

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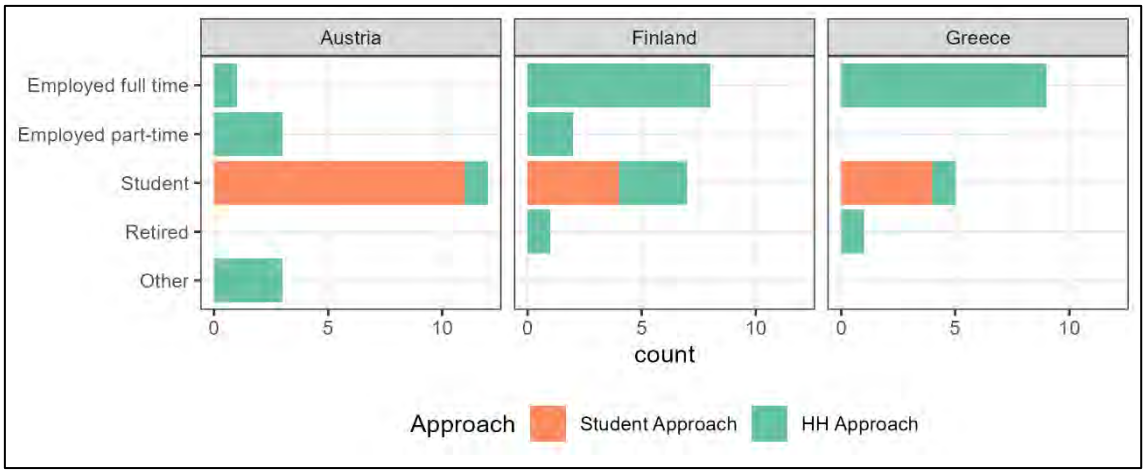
Figure 19A: Distribution of participating households according to work-life situation of the household members using CozZo app across 3 participating countries



The graphs in Figures 16A, 17A, 18A and 19A show the distribution of different attributes among the participating household sample.

Figure 20A: Frequency in waste groups based on categories used in measurement data

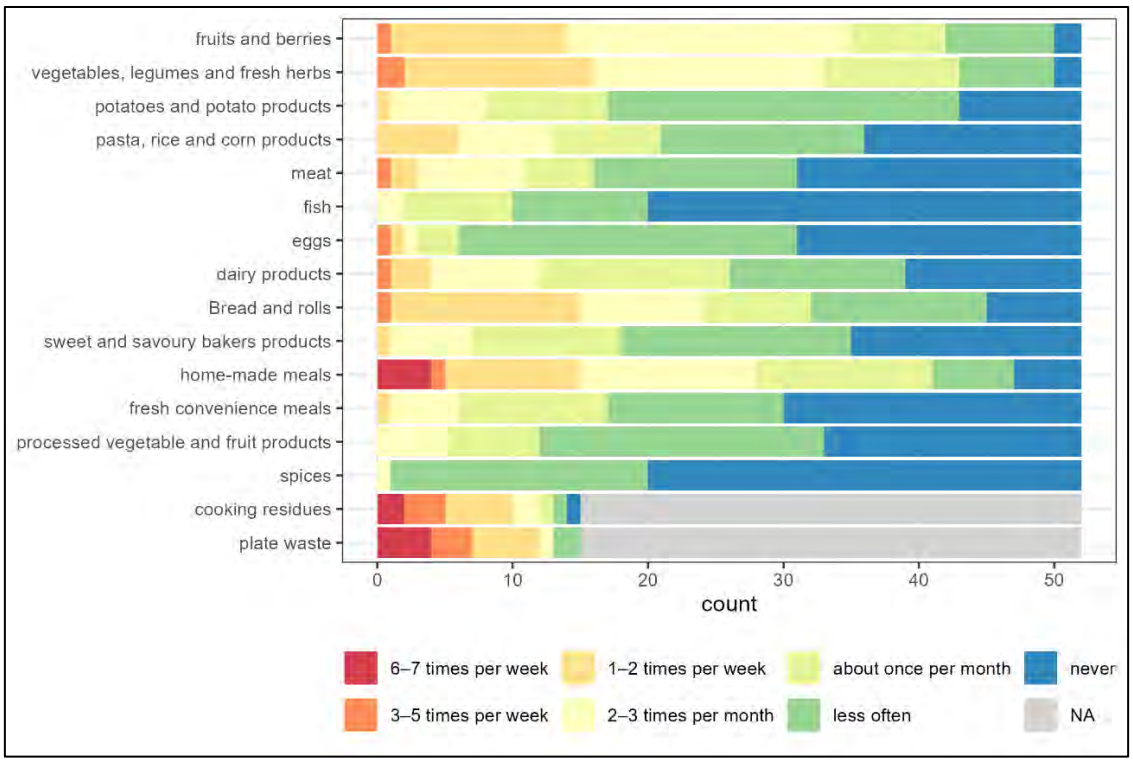


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Figure 21A: Distribution of participating households according to household composition across 3 participating countries

In the household surveys, participants were also asked how frequently they waste 17 types of food. The frequency was measured using a 7-point Likert scale, ranging from 1 (6-7 times per week) to 7 (never). We calculated the average category level to determine which types of food are most likely to be wasted.

Table 3A: Mean frequency of each food type being found in the household bin

Label	**Mean frequency***
spices	6.58
fish	6.38
eggs	6.17
processed vegetable and fruit products	6.04
fresh convenience meals	5.96
sweet and savory bakery products	5.83
meat	5.81
potatoes and potato products	5.67
pasta, rice, and corn products	5.54
dairy products	5.42
Bread and rolls	4.75
home-made meals	4.31
fruits and berries	4.27
vegetables, legumes, and fresh herbs	4.23
cooking residues	3.27
plate waste	2.73

*Mean of score frequency of food waste sorted from never to very often

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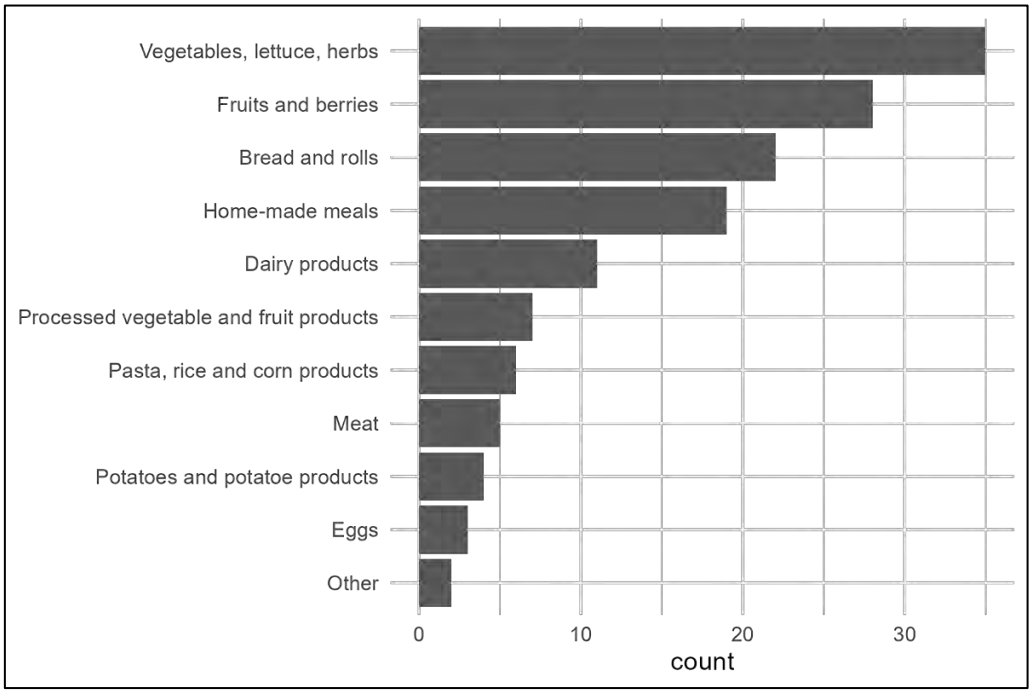
As shown in Table 3A, spices are the least likely to be wasted. Cooking residues and plate waste were the most frequently wasted categories. However, these categories were not considered in the overall analysis because they were only surveyed in Austria. Therefore, vegetables and fruits are the categories most likely to be wasted.

In addition, participants were asked to select up to three types of food that produce the highest amount of waste in their households. As shown in the Figure 22A below, not only do vegetables and fruits produce food waste more frequently, but they also generate the largest amount of food waste.

Figure 22A: Food groups constituting the highest amount of waste in household



In another section of the questionnaire, participants were asked about their motivations to produce food waste in their household trough 11 statements measured on a five-point Likert scale. Distribution of the responses are reported in Figure 23A below.

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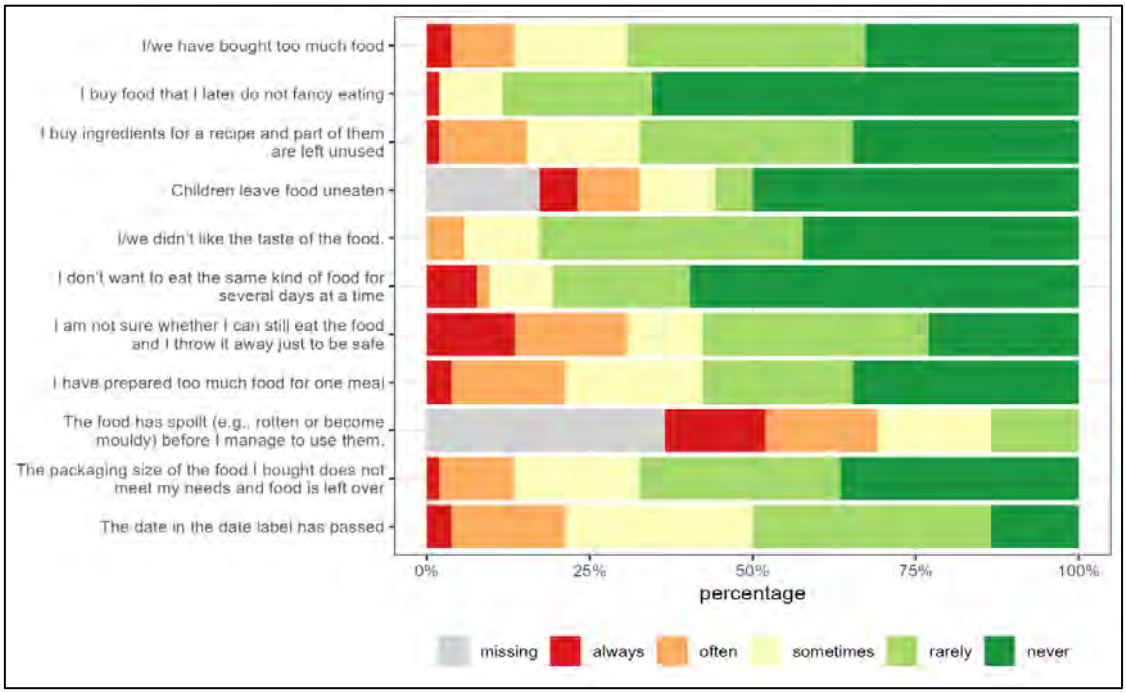
Figure 23A: Reasons for wasting food



Missing values in the statement "The food has spoilt (e.g., rotten or become mouldy) before I manage to use them" are from Austria, where the statement was not asked. Consequently, this statement was excluded from the analysis. Additionally, the statement "Children leave food uneaten" was not considered in the analysis because the majority of respondents were students.

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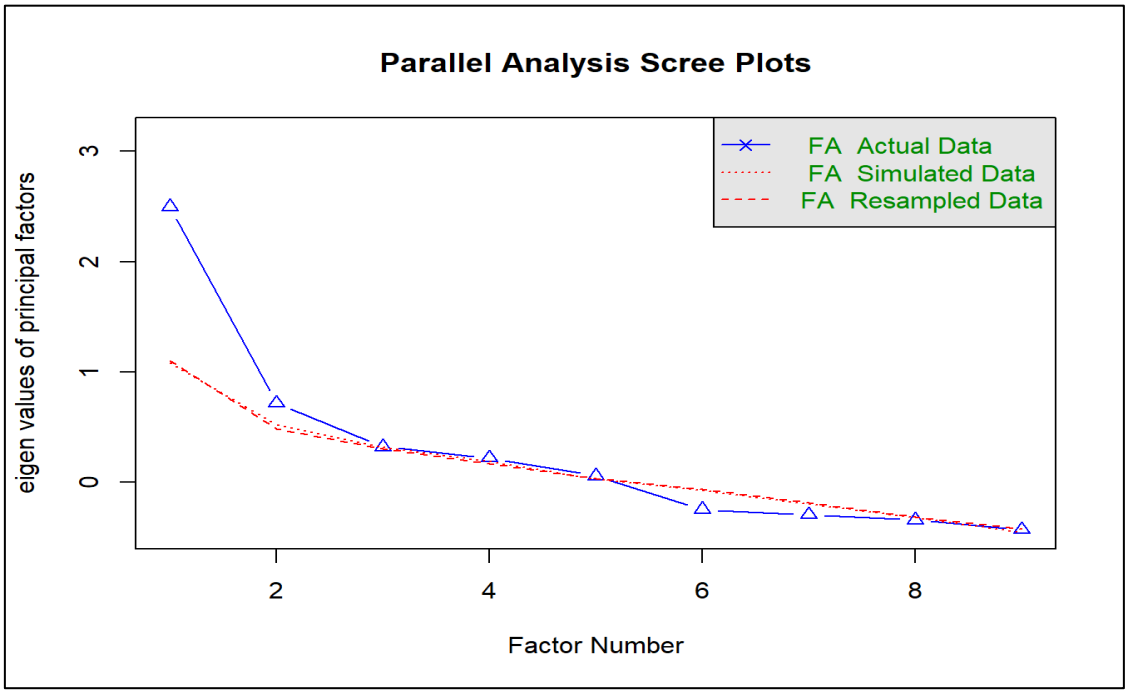
Figure 24A: Exploratory Factor Analysis (EFA) to explore the reasons of food waste



We run an Exploratory Factor Analysis (EFA) to determine the number of factors that could explain the reason to waste food. Using *fa.parallel* analysis, it suggested to use 2 factors. To name these factors, we assess the loading weights.

Table 4A: Statements used in EFA and how their relationship with two different factors

Statements from the survey	MR2	MR1
The date in the date label has passed	0.50	0.05
The packaging size of the food I bought does not meet my needs and food is left over	0.63	-0.05
I have prepared too much food for one meal	0.43	0.38
I am not sure whether I can still eat the food, and I throw it away just to be safe	0.26	0.36
I do not want to eat the same kind of food for several days at a time	0.15	0.70
I/we did not like the taste of the food.	-0.20	0.72
I buy ingredients for a recipe and part of them are left unused	0.41	0.42
I buy food that I later do not fancy eating	-0.09	0.43
I/we have bought too much food	0.73	-0.06

In this case, the first factor is related to the statements "The date on the label has passed," "The packaging size of the food I bought does not meet my needs and food is left over," and "I/we have bought too much food." We can name this factor "recognition of quantity wasted"

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On the other hand, the statements "I don't want to eat the same kind of food for several days at a time," "I/we didn't like the taste of the food," and "I buy food that I later do not fancy eating" are related to the second factor. It is clear that this factor reflects the appeal of the food. We can name this factor "preferences that led to waste"

Due to small sample size and lack of normality distribution in the data, we conducted a rank test to determine which categories experienced the greatest reduction before and after innovation. Specifically, we only consider those categories with more than 20 cases. As we can see in Table 5A below, only bread pastry and total amount of food waste have a statistically significant reduction.

Table 5A: Changes in food waste weights measured in baseline and demonstration periods

type of food	statistic	p-value
Fruits	0.09	0.76
Vegetables	1.78	0.18
Bread and Pastry	3.92*	0.05
Dairy products	0.63	0.43
Side dishes	0.54	0.46
Other	1.80	0.18
TOTAL	7.53*	0.01

*Statistically significant at level of 5%

Finally, we calculated number of men and women within household. However, there were a lack of information about the gender of the member in the household. Thus, we focus on the gender of participant responding the management survey in each participating household.

We reshape the dataset to fit a linear regression model, where the amount of food waste in the baseline helps us to predict the amount of food waste in the demonstration period. In Figure 25A below, we can see the scatterplot of the food waste in the baseline and demonstration periods. The dotted line indicates the straight line with slope 1 and intercept 0. Those points underneath the straight line have a reduction of food waste.

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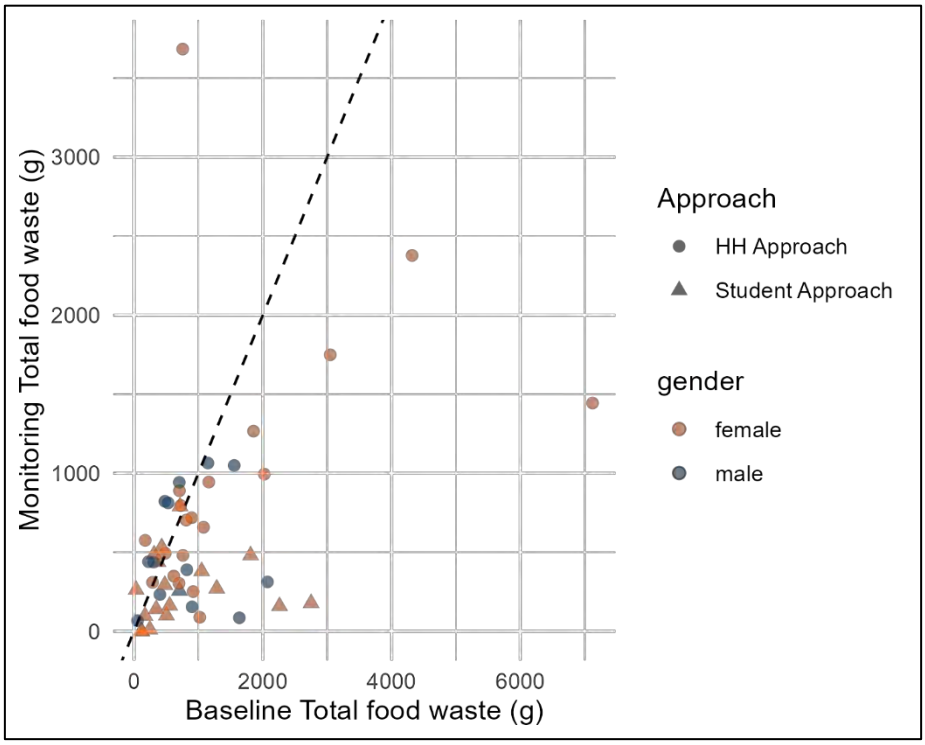
Figure 25A: Change in measured waste amount with relation to the gender of survey respondent



In order to assess whether the gender has a significant effect on the reduction of food waste, a linear regression model was fitted using the equation below.

$$monitoring = \beta_0 + \beta_1 \cdot baseline + \beta_2 \cdot gender + \beta_3 \cdot Approach + \beta_4 \cdot baseline \cdot Approach + error$$

Table 6A: The result of the linear regression analysis looking at effect of gender

	Estimate	St. err.	t value	Pr(>|t|)	
(Intercept)	171.389	55.038	3.114	0.0020	**
Baseline	0.296	0.027	10.853	0.0000	***
Gender	-42.587	37.241	-1.144	0.2536	
Approach: Student Approach	-59.011	40.031	-1.474	0.1414	
baseline: Approach Student Approach	-0.199	0.067	-2.986	0.0030	**

Significance codes: 0 <= '***' < 0.001 < '**' < 0.01 < '*' < 0.05; Residual standard error: 291.1 on 348 degrees of freedom; Multiple R-squared: 0.2821, Adjusted R-squared: 0.2739; F-statistic: 34.19 on 348 and 4 DF, p-value: 0.0000

Based on the Wald statistical test, we conclude that gender does not have statistically significant effect on the reduction of food waste. On the other hand, the food waste in the baseline period is a statistically significant predictor of food waste in the demonstration period. For every gram of food waste produced in the baseline, it is likely that 0.30 grams of food waste

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will be produced in the demonstration period. This represents a 70% reduction. Finally, we can see that approach is statistically significant, which indicates that student had a better performance in the reduction of food of waste.

Task 5.6 REGUSTO mobile app

Statistical analysis of discounted meal orders made on the REGUSTO app

For the analysis, three restaurants with more than single order on the app were considered. To estimate the potential gains of orders made through the app, average price for each category used in the categorisation of orders in the output data was constructed using the menu prices for each location. Then, the total savings by customers were calculated using the discount range applied to the menu prices for the orders on app reported by each restaurant in their survey responses. The total cost of dishes was estimated as shown in the Table 7A to estimate average cost savings for customers using the app.

Table 7A: Total customer savings made from the discounted orders on the app

Restaurant name	Food type	Total Customer Savings (€)	Estimate of total cost (€)	Weight (kg)	Number of orders
R2	Side dish	121	200	11.3	25
R2	Second main dish	464	3525	46.1	94
R2	First main dish	111	687.5	11.8	25
R3	Pizza	651	1343.9	79.5	151
R3	Side dish	264	634	29.5	64
R3	Sandwich	5	15.8	0.8	2
R3	Salty dish	5	9.9	0.5	1
R4	Others	59	127.5	4.5	15
R4	Sandwich	269	586.5	30	69
R4	Side dish	240	476	22.2	56
R4	Second main dish	219	407	21.1	44
R4	Salty dish	3	8.5	0.4	1

To visualize the differences of type and cost savings from orders on the app across the restaurants, refer to the scatterplot in Figure 26A below.

This chart clearly shows that the orders of simple dishes yield the largest savings for customers while incurring the least cost for the restaurants. And the largest customer savings are achieved in pizza orders. At the other hand, second main dish was the highest value dish for the restaurant, with lower saving rates compared to other dishes. Due to lack of information, no further statistical analysis was conducted.

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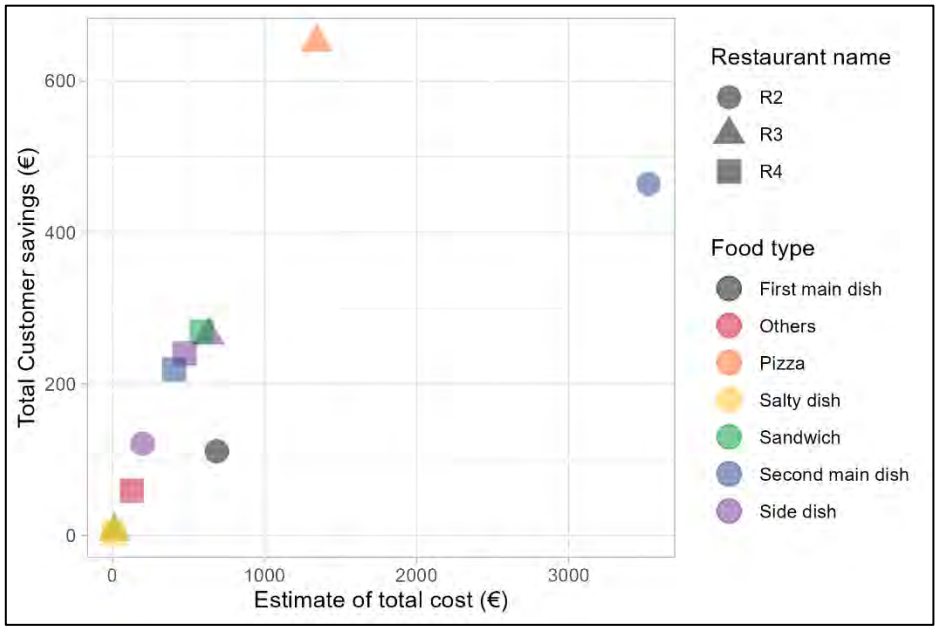
Figure 26A: The type of orders made and saving achieved from orders made on the app



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