

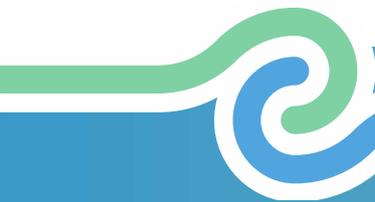
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Italy – Croatia

 **ECOFOODCYCLE**



INTERREG ITALY-CROATIA PROGRAMME 2021-2027 PROJECT ECOFOODCYCLE

D1.1.2 FOOD WASTE AUDIT

Version 3.0 – 12/2025



ECOFOODCYCLE

Reducing Food Waste and its Environmental Footprint through Sustainable Food Systems

D1.1.2 Food waste audit

WP1 – Act. 1.1

Document information

Project name	ECOFOODCYCLE - Reducing Food Waste and its Environmental Footprint through Sustainable Food Systems
Project ID	ITHR0200316
LP	Public Institution Development Agency of Lika-Senj County - LIRA
PP	Public institution Regional development agency of Karlovac county – JURRA – PP2 Zadar County Development Agency ZADRA NOVA – PP3 University of Rijeka, Faculty of Economics and Business – PP4 ECAMRICERT S.R.L. – PP6 University of Foggia – PP7 National Confederation of the craft sector and small and medium enterprises Abruzzo – PP8
Responsible PP	PP6 - ECAMRICERT S.R.L.





Length	140 pages
Version	3.0
Distribution Level	Public

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EXECUTIVE SUMMARY

The **ECOFOODCYCLE Food Waste Audit** aimed to:

- Quantify food waste along the agri-food supply chain in selected Italian and Croatian regions.
- Assess its environmental impacts through Life Cycle Assessment (LCA).

Methodology

- Data collected through 186 questionnaires (123 in Italy, 63 in Croatia) targeting producers, processors, retailers, consumers, and hospitality operators.
- Two complementary approaches applied:
 - **Bibliographic approach** (Mediterranean diet benchmarks, Waste Watcher & FAO data).
 - **Questionnaire-based approach** (primary data from stakeholders).

Key Findings

- Consumers: \approx 4.3 kg/week per person, mainly fruit & vegetables (1.6 kg) and bread (0.5 kg).
- Production & processing: fruit & vegetables dominate by volume, but meat waste is the main environmental hotspot.
- Retail sector: bread waste $>97\%$ in large enterprises; meat waste dominates impacts in medium and small enterprises.
- Food Service sector: large operators waste mainly dairy ($\approx 81\%$); medium enterprises are dominated by meat waste ($\approx 41\%$).
- Environmental impacts: agriculture is the main hotspot; meat waste exceeds 2,000 mPt/kg, confirming the high intensity of animal-based products.



Limitations

- Results are an indicative baseline, not a statistically normalized dataset.
- Variability in enterprise data and consumer subjectivity affect robustness.

Recommendations

- Broaden and diversify the stakeholder sample to increase representativeness.
- Prioritize prevention in high-volume categories (fruit, vegetables, bread) and high-impact categories (meat, fish, dairy).
- Adopt a multi-indicator perspective to design effective prevention, recovery, and valorization strategies.



1. INTRODUCTION

The Interreg Italy–Croatia ECOFOODCYCLE project was established to address the challenge of food waste in cross-border territorial contexts through a systemic approach. Its main objectives are to collect and analyze primary data directly from food supply chain stakeholders, to quantify the environmental impacts associated with food waste by applying Life Cycle Assessment (LCA) methodologies, and to define strategies and operational solutions for the prevention, recovery, and valorization of surplus food.

By involving pilot regions in Italy (Veneto, Abruzzo, Puglia) and selected areas of Croatia (Primorje–Gorski Kotar, Karlovac, Zadar, Lika–Senj), the project aims to improve knowledge of the phenomenon, identify environmental hotspots along the agri-food value chain, and propose practical measures that can be replicated at both regional and national level.

This Food Waste Audit was carried out as part of the project’s planned actions for the quantitative and qualitative analysis of food losses. The audit builds upon the methodological framework and recommendations outlined in the document *“Guidelines to Conduct Food Waste Audit”*, prepared in the initial phases of the project to ensure consistency and harmonization across the data collection process. The study is structured in two phases. The first focuses on the collection of data on food waste across the main supply chain stages, namely primary production, processing, distribution, household consumption and collective catering. The second phase applies a life cycle perspective to calculate the environmental burden of wasted food, thus translating quantitative evidence into environmental impact profiles.



The results presented here therefore provide a dual contribution: on the one hand, they offer a factual overview of food waste quantities in the Italian and Croatian pilot regions; on the other hand, they highlight the associated environmental implications, offering a robust knowledge base for the design of prevention and mitigation strategies grounded in scientific evidence.

1.1. CONTEXT

Food waste is recognized as one of the main environmental, economic, and social challenges at the global level. According to FAO (2013), approximately one third of all food produced annually for human consumption is lost or wasted, amounting to around 1.3 billion tonnes per year. This phenomenon leads to the unnecessary exploitation of natural resources (water, soil, energy) and contributes significantly to greenhouse gas (GHG) emissions, estimated at over 3.3 Gt CO₂eq per year worldwide. In addition to the climate dimension, food waste generates pressure on ecosystems, accelerates land degradation, and exacerbates water scarcity, while also representing a missed opportunity in terms of nutrition and food security.

In Europe, the Farm to Fork Strategy of the European Commission, as part of the broader European Green Deal, identifies the prevention and reduction of food losses as a key driver for the transition towards a more sustainable agri-food system. The Joint Research Centre (JRC, 2020) estimates that the European Union generates approximately 88 million tonnes of food waste each year, equivalent to 173 kg per capita, with an overall environmental footprint exceeding 170 million tonnes of CO₂eq. The impacts are not limited to climate change: food waste in Europe also contributes



to eutrophication, acidification, and biodiversity loss, while undermining the efficiency of resource use across the entire supply chain.

From a socio-economic perspective, food waste entails considerable costs. Eurostat and related EU studies have highlighted that food waste translates into billions of euros lost annually in production, logistics, and disposal, placing additional burdens on companies, public administrations, and households. At the same time, the ethical implications are evident: while large amounts of food are discarded, a significant share of the global population still suffers from hunger or malnutrition, highlighting a critical imbalance in the global food system.

Addressing food waste has therefore become a strategic priority at both national and international levels. The United Nations Sustainable Development Goal (SDG) 12.3 explicitly calls for halving per capita global food waste at the retail and consumer level, as well as reducing food losses along production and supply chains by 2030. To achieve this, robust data collection, life cycle-based methodologies, and systemic approaches are essential to quantify impacts, identify hotspots, and implement effective prevention, recovery, and valorization measures.

1.2. ITALIAN AND CROATIAN CONTEXT

In Italy, according to the Waste Watcher report (2025), household food waste averages approximately 88 grams per person per day, equivalent to about 27 kg/year per capita, with a predominance in fresh and perishable products such as fruit, bread, and



vegetables. Food waste is distributed along the entire supply chain, with significant percentages also occurring in collective catering, large-scale retail outlets, and the processing stage.

The Italian study area includes three regions: Veneto, Abruzzo, and Puglia. These regions present heterogeneous socio-economic and agri-food characteristics:

Veneto is highly industrialized, with structured agri-food supply chains and a strong presence of large-scale retail (GDO).

Abruzzo is characterized by more fragmented agriculture and a significant share of family consumption and traditional catering.

Puglia, with high fruit, vegetable, and cereal production, faces challenges related both to the management of agricultural surpluses and to waste occurring in processing and distribution.

In Croatia, per capita food waste is estimated at approximately 71 kg/year (FAO, 2021), a value consistent with the average for Southern European countries. The distribution of waste along the supply chain reflects a pattern similar to that observed in other Mediterranean contexts, with specific hotspots of generation.

A major contributor is the tourism and hospitality sector, which, due to its seasonal nature and strong dependence on mass catering, produces significant food surpluses, especially during peak tourist periods. In addition, small-scale retail outlets often experience inefficiencies in stock management and demand forecasting, leading to a higher incidence of unsold products and subsequent disposal. Structural limitations are further aggravated by the insufficient development of cold chain and storage



infrastructure, as well as by the absence of coordinated systems for the recovery, redistribution, and valorization of surplus food.

At the behavioral level, awareness of food waste among consumers and supply chain operators remains limited. This low level of perception reduces the adoption of preventive practices and hampers the implementation of systemic solutions. Overall, the combination of sector-specific inefficiencies, infrastructural constraints, and limited stakeholder awareness results in a structural challenge, highlighting the need for integrated strategies that include awareness-raising programs, digital tools for supply-demand alignment, and enhanced logistics and redistribution frameworks.

2. METHODOLOGY

Data collection was designed and carried out with the objective of obtaining primary, specific, and representative information on the quantities and characteristics of food waste in the different segments of the agri-food supply chain within the geographical areas of interest of the ECOFOODCYCLE project (Veneto, Abruzzo, Puglia in Italy and Primorje–Gorski Kotar, Karlovac, Zadar, Lika–Senj in Croatia). The process took place over the 2023–2025 period and involved the direct participation of operational stakeholders across the main stages of the food supply chain.

The methodological approach relied on tailor-made data collection tools, developed according to the specific characteristics of each stakeholder category and designed ex-ante to ensure consistency with the LCA framework (EN ISO 14040:2021 EN ISO 14044:2021). Dedicated technical questionnaires, differentiated by stakeholder type,



were developed and administered to gather primary data on food waste under real operating conditions.

The questionnaires, structured into thematic sections, enabled the collection of:

- Quantitative data on waste (expressed in kg/week or as a percentage of processed/purchased volumes), broken down by food category;
- Identification of main causes of waste;
- Information on management of surplus food (reuse, donation, disposal);
- Additional operational details (e.g., company size, type of products, storage methods).

Administration was carried out through mixed channels: direct interviews, technical project meetings, controlled digital submissions, focus groups and telephone interviews. The collected data were subsequently verified, validated, harmonised, and aggregated in line with the LCA study framework, ensuring traceability, quality, and methodological consistency.

Annex B presents an example of the questionnaire applied within the data collection campaign, aimed at quantifying and characterizing food waste across the different stakeholder categories under investigation.

Where primary data were partial or unavailable, they were supplemented with reliable secondary sources, including peer-reviewed scientific literature, institutional reports (FAO, Eurostat, ISPRA, Waste Watcher), LCA databases (Ecoinvent, Agribalyse), and, where applicable, relevant PEFCR contents.

All data collected were finally recalibrated against the declared unit of the study—one week of Mediterranean diet per capita—in order to enable homogeneous



environmental modelling across the different supply chain stages and to quantify the environmental impacts of food waste in each territorial context.

3. QUESTIONNAIRE RESULTS

The data collected through the questionnaires represent the empirical basis for the quantification of food waste within the ECOFOODCYCLE project. In total, 186 questionnaires were received and processed across the two pilot countries, with a distribution by stakeholder category as reported in Table 1. The majority of responses came from consumers, who represent the final stage of the agri-food supply chain, while relevant contributions were also gathered from primary producers, the retail sector, and the hospitality industry.

Table 1: number of questionnaires received and processed

CATEGORY	ITALY	CROATIA	TOTAL/CATEGORY
Primary Producers	6	10	16
Retail Sector	5	1	6
Consumers	106	42	148
Food Service Sector	6	7	13
Not Declared (ND)	0	3	3
Total	123	63	186

In the following sections, the results are presented in a disaggregated manner by stakeholder category and food group, highlighting the main trends observed in Italy and Croatia, and discussing the implications in terms of environmental impacts along the supply chain.



3.1. QUANTIFICATION OF FOOD WASTE

Primary production

Table 2: Questionnaires results - primary production

		LP LIRA	PP3 ZADRANOVA	PP6 ECAMRICERT	OVERALL AVERAGE	ITALY AVERAGE	CROATIA AVERAGE
MACRO-CATEGORY	Description	kg/week					
White meat	Pork	0,107	-	-	0,107	-	0,107
	Veal	0,077	-	-	0,077	-	0,077
	Chicken	0,067	-	-	0,067	-	0,067
	Lamb	0,133	-	-	0,133	-	0,133
	Turkey	0,017	-	-	0,017	-	0,017
Red meat	Beef	0,073	-	-	0,073	-	0,073
	Game meat	0,167	-	-	0,167	-	0,167
Cereal	Oats	0,017	-	-	0,017	-	0,017
Fruit	Citrus fruits	6,000	-	-	6,000	-	6,000
	Berries	6,060	-	-	6,060	-	6,060
	Nuts	4,217	100,000	-	52,108	-	52,108
	Stone fruits	4,000	-	-	4,000	-	4,000
	Fresh fruit and vegetables	1,667	-	-	1,667	-	1,667

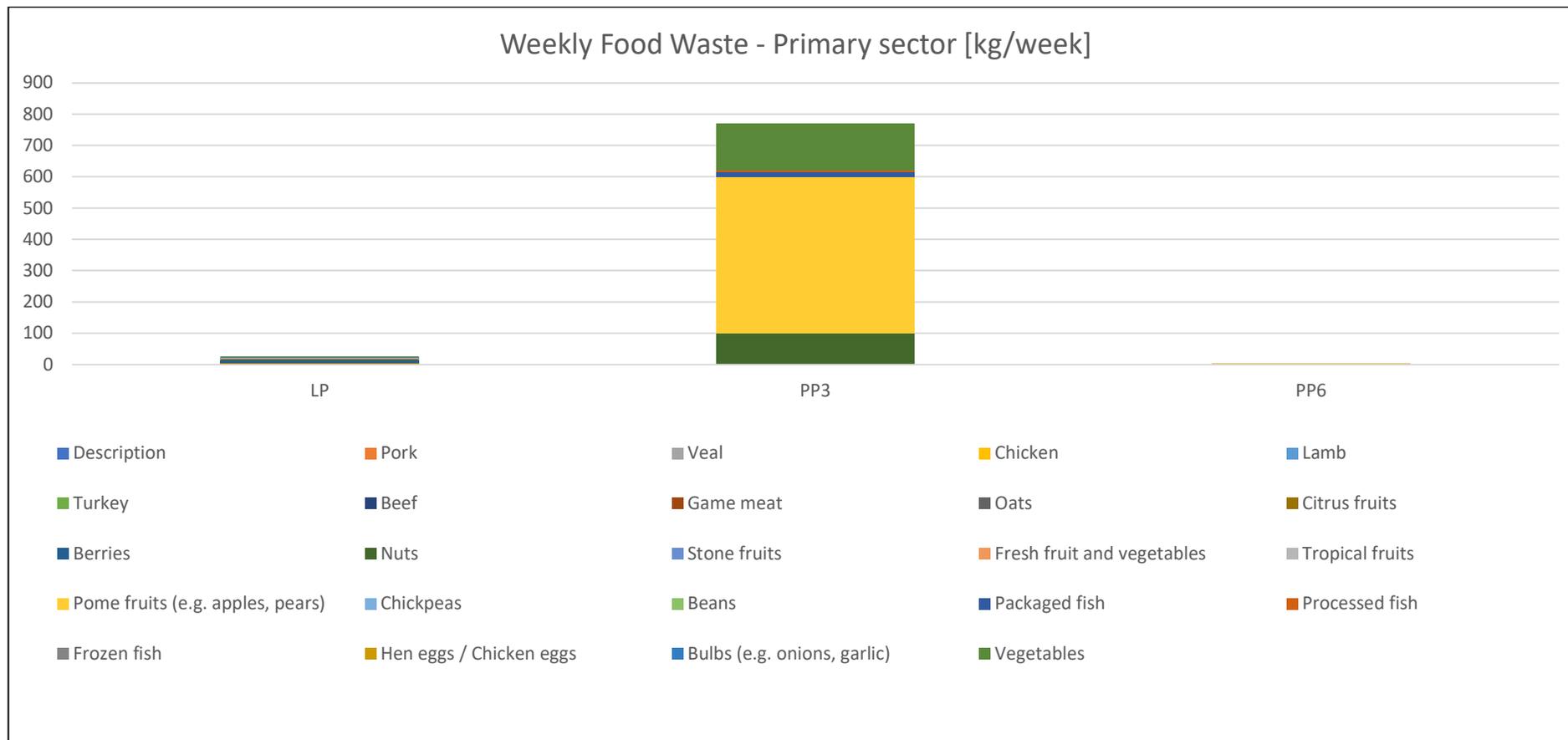


Italy – Croatia



	Tropical fruits	0,040	-	-	0,040	-	0,040
	Pome fruits (e.g. apples, pears)		500,000	-	500,000	-	500,000
Legumes	Chickpeas	0,040	-	-	0,040	-	0,040
	Beans	0,040	-	-	0,040	-	0,040
Fish	Packaged fish		15,000	-	15,000	-	15,000
	Processed fish		5,000	-	5,000	-	5,000
	Frozen fish	0,017		-	0,017	-	0,017
Eggs	Hen eggs / Chicken eggs	0,200	-	3,920	2,060	3,920	0,200
Vegetables	Bulbs (e.g. onions, garlic)	0,060	-	-	0,060	-	0,060
	Vegetables	3,433	150,000	-	76,717	-	76,717
	TOTAL	28,775	210,000	3,920	80,898	3,920	119,388





Graph 1: Weekly Food Waste - Primary sector [kg/week]



Retail sector

Table 3: Questionnaires results – retail sector

		PP8 CNA ABRUZZO	PP3 ZADRANOVA	PP7 UNIFG	OVERALL AVERAGE	ITALY AVERAGE	CROATIA AVERAGE
MACRO-CATEGORY	Description	Kg/Week					
Milk And Dairy Products	Short-Shelf-Life Dairy And Plant-Based Products	-	12,50	429,30	220,90	429,30	12,50
	Long-Shelf-Life Dairy And Plant-Based Products	-	5,87	79,84	42,86	79,84	5,87
	Medium-Shelf-Life Dairy And Plant-Based Products	-	53,33	192,00	122,67	192,00	53,33
Meat	Cold Cuts / Sliced Meats	0,77	4,30	20,00	8,36	10,38	4,30
	Lamb/Goat	-	-	48,02	48,02	48,02	0,00
	Processed Meat	-	14,20	21,33	17,77	21,33	14,20
	Horse Meat	-	-	4,33	4,33	4,33	0,00
	Rabbit	-	-	22,64	22,64	22,64	0,00
	Pork	-	-	477,85	477,85	477,85	0,00
	Beef	-	-	57,33	57,33	57,33	0,00
	Chicken	-	-	541,20	541,20	541,20	0,00
	Game Meat	0,20	-	5,27	2,74	2,74	0,00
	Turkey	-	-	86,46	86,46	86,46	0,00
Veal	-	-	53,23	53,23	53,23	0,00	
Packaged Food	Canned And Long-Shelf-Life Foods	-	5,15	0,13	2,64	0,13	5,15



	Short-Shelf-Life Products	-	145,87	1,07	73,47	1,07	145,87
	Medium-Shelf-Life Products	-	50,03	1,43	25,73	1,43	50,03
Fruit And Vegetables	Fresh fruit and vegetables	-	355,68	5754,67	3055,17	5754,67	355,68
	Long-shelf-life fruit and vegetables	-	71,10	31,67	51,38	31,67	71,10
	Special fruit and vegetable products	-	7,10	2,00	4,55	2,00	7,10
Bread And Similar Products	Long-shelf-life bread and similar products	-	10,50	64,60	37,55	64,60	10,50
	Medium-shelf-life bread and similar products	-	9,39	582,68	296,04	582,68	9,39
	Fresh bread and similar products	2,30	277,48	297315,67	99198,48	148658,98	277,48
Fish	Long-shelf-life fish	-	-	35,00	35,00	35,00	0,00
	Fresh fish	-	-	554,07	554,07	554,07	0,00
	Frozen fish	-	-	16,17	16,17	16,17	0,00
	Processed fish products	-	-	23,33	23,33	23,33	0,00
Eggs	Non-hen eggs	-	-	0,00	0,00	0,00	0,00
	Hen eggs	-	-	33,02	33,02	33,02	0,00
	Processed eggs	-	-	0,81	0,81	0,81	0,00
Other		4,50	488,02	21,33	171,28	12,92	488,02
TOTAL WEEKLY QUANTITY		2,25	-	-	-	2,25	0,00





Graph 2: Weekly Food Waste - Retail sector [kg/week]



Consumers

Table 4: Questionnaires results – Consumers

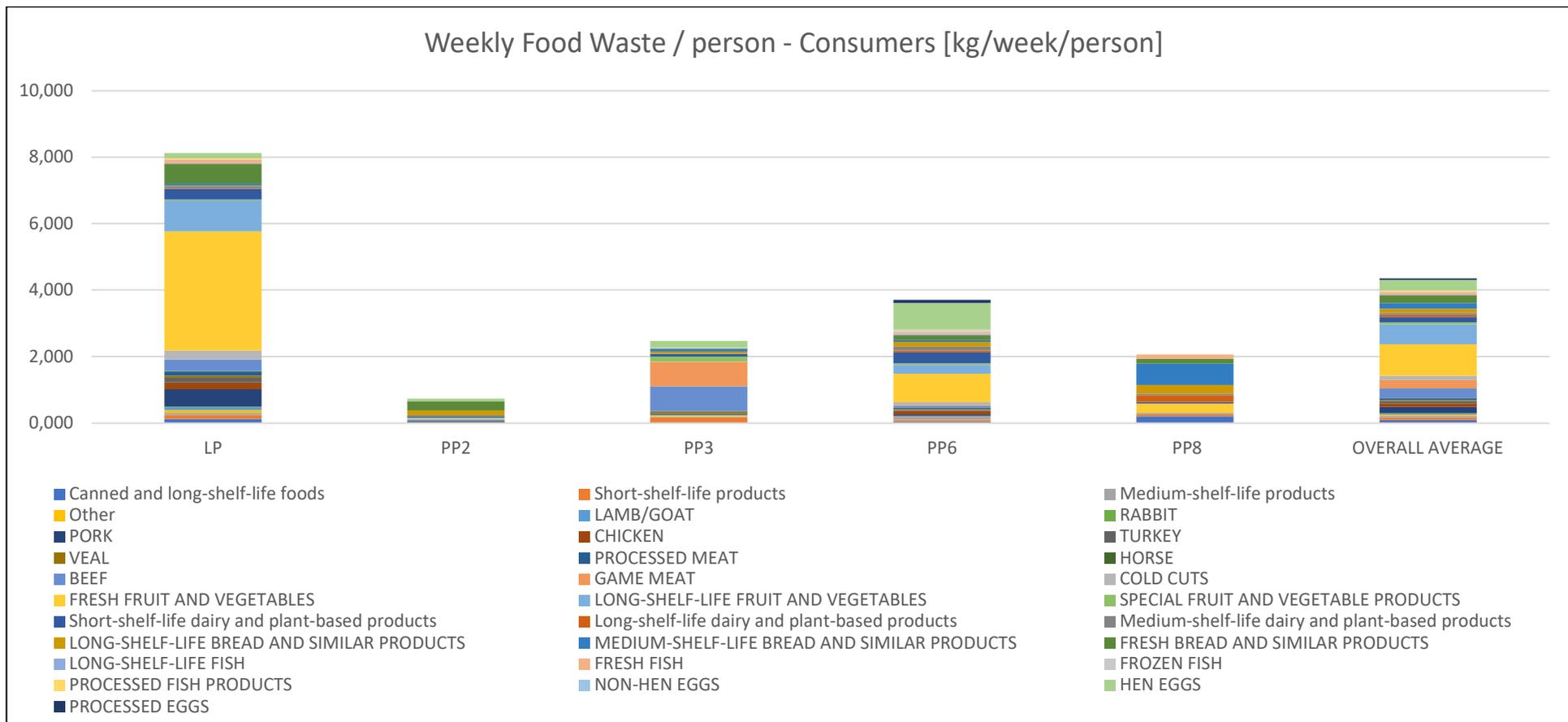
MACRO-CATEGORY	Description	PP6 ECAMRICER T	LP LIRA	PP8 CNA ABRUZZO	PP2 JURRA	PP3 ZADRANOV A	OVERALL AVERAGE	ITALY AVERAGE	CROATIA AVERAGE
		Kg/week/person							
Packaged food	Canned and long-shelf-life foods	0,036	0,120	0,200	0,000	-	0,089	0,118	0,060
	Short-shelf-life products	0,056	0,115	0,050	0,008	0,158	0,078	0,053	0,094
	Medium-shelf-life products	0,110	0,063	0,050	0,000	0,031	0,051	0,080	0,031
Other	Other	0,000	0,084	-	-	0,031	0,038	0,000	0,058
White meat	Lamb/goat	0,003	0,089	-	0,001	0,010	0,026	0,003	0,033
	Rabbit	0,004	0,017	-	-	0,006	0,009	0,004	0,011
	Pork	0,043	0,526	-	0,007	-	0,192	0,043	0,267
	Chicken	0,108	0,204	-	0,018	-	0,110	0,108	0,111
	Turkey	0,033	0,147	-	0,005	0,054	0,060	0,033	0,069
	Veal	0,022	0,061	-	0,001	0,050	0,034	0,022	0,037
Red meat	Processed meat	0,038	0,124	-	0,032	0,013	0,052	0,038	0,056
	Horse	0,007	0,020	-	-	0,004	0,010	0,007	0,012
	Beef	0,060	0,338	-	0,026	0,740	0,291	0,060	0,368
	Game meat	0,022	0,000	-	-	0,740	0,254	0,022	0,370
Fruit and vegetables	Fresh fruit and vegetables	0,850	3,588	0,283	0,021	0,013	0,951	0,567	1,207
	Long-shelf-life fruit and vegetables	0,270	0,925	-	-	-	0,598	0,270	0,925
	Special fruit and vegetable products	0,047	0,033	-	0,018	0,146	0,061	0,047	0,065
	Short-shelf-life dairy and plant-based products	0,327	0,322	0,050	0,045	0,079	0,165	0,189	0,149



Italy – Croatia

Milk and dairy products	Long-shelf-life dairy and plant-based products	0,058	0,013	0,200	0,000		0,068	0,129	0,006
	Medium-shelf-life dairy and plant-based products	0,118	0,050	0,050	0,031	0,006	0,051	0,084	0,029
Bread and similar products	Long-shelf-life bread and similar products	0,146	0,035	0,255	0,146	0,066	0,129	0,200	0,082
	Medium-shelf-life bread and similar products	0,053	0,063	0,650	0,000	0,079	0,169	0,351	0,047
	Fresh bread and similar products	0,140	0,584	0,151	0,271	0,017	0,233	0,145	0,291
Fish	Long-shelf-life fish	0,037	0,029	-	0,000		0,022	0,037	0,014
	Fresh fish	0,057	0,097	0,125	-	0,008	0,072	0,091	0,053
	Frozen fish	0,037	0,017	-	-	0,017	0,024	0,037	0,017
	Processed fish products	0,024	0,031	-	-	-	0,027	0,024	0,031
Cold cuts	Cold cuts	0,082	0,271	-	0,017		0,123	0,082	0,144
Eggs	Non-hen eggs	0,025	0,000	-	-	0,008	0,011	0,025	0,004
	Hen eggs	0,796	0,161	-	0,083	0,192	0,308	0,796	0,145
	Processed eggs	0,090	0,000	-	-	-	0,045	0,090	0,000
Total weekly quantity		3,914	2,117	0,750	0,730	-	1,878	1,369	1,182





Graph 3: Weekly Food Waste / person - Consumers



Hospitality

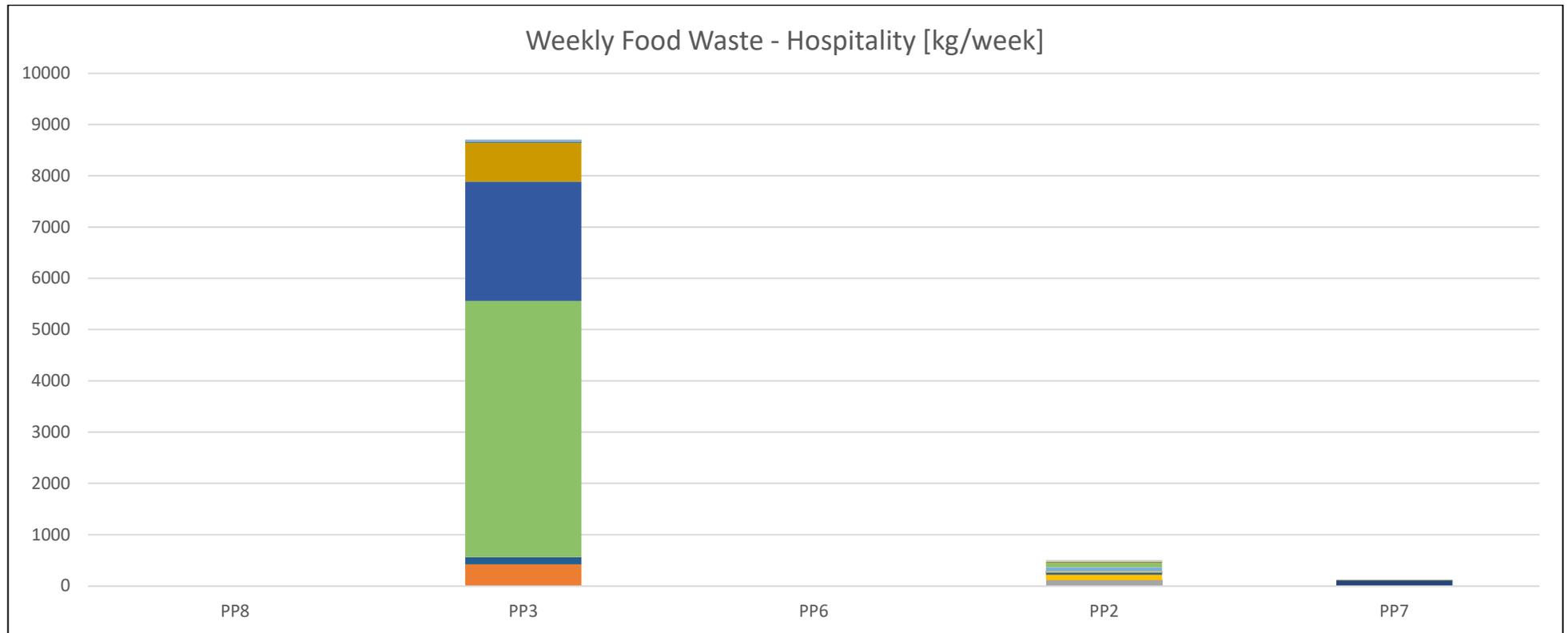
Table 5: Questionnaires results – Hospitality

		PP8 CNA ABRUZZO	PP3 ZADRANOVA	PP6 ECAMRICERT	PP2 JURRA	PP7 UNIFG	OVERALL AVERAGE	ITALY AVERAGE	CROATIA AVERAGE
MACRO-CATEGORY	Description	kg/week							
Milk and dairy products	Short-shelf-life dairy and plant-based products	1,000	416,000	-	10,000	-	142,333	1,000	213,000
	Long-shelf-life dairy and plant-based products	-	-	-	100,000	-	100,000	-	100,000
	Medium-shelf-life dairy and plant-based products	0,120	-	-	100,000	0,015	33,378	0,068	100,000
Meat	Cold cuts / Sliced meats	0,524	0,5	-	1	-	0,674667	0,524	0,75
	Lamb/Goat	-	-	-	-	-	-	-	-
	Processed meat	1	0,5	-	6,5	100	27	50,5	3,5
	Horse meat	-	-	-	-	-	-	-	-
	Rabbit	-	-	-	-	-	-	-	-
	Pork	-	5	-	10	-	7,5	-	7,5
	Beef	-	135	-	18	10,3	54,43333	10,3	76,5
	Chicken	-	2	-	14	0,15	5,383333	0,15	8
	Game meat	-	-	-	-	-	-	-	-
	Turkey	-	-	-	14	-	14	-	14
Veal	-	-	-	1	-	1	-	1	



Packaged food	Canned and long-shelf-life foods	0,064	2,000	-	10,000	80,000	23,016	40,032	6,000
	Short-shelf-life products	0,083		-	80,000	-	40,042	0,083	80,000
	Medium-shelf-life products		4997,000	-	80,000	-	2538,500		2538,500
Fruit and vegetables	FRESH FRUIT AND VEGETABLES	0,369	2329,000	-	-	0,015	776,461	0,192	2329,000
	LONG-SHELF-LIFE FRUIT AND VEGETABLES			-	-	-	-	-	-
	SPECIAL FRUIT AND VEGETABLE PRODUCTS			-	-	-	-	-	-
Bread and similar products	LONG-SHELF-LIFE BREAD AND SIMILAR PRODUCTS	0,093	764,000	-	1,000	0,150	191,311	0,121	382,500
	MEDIUM-SHELF-LIFE BREAD AND SIMILAR PRODUCTS		0,500	-	-	-	0,500		0,500
	FRESH BREAD AND SIMILAR PRODUCTS	0,385	10,000	-	19,000	-	9,795	0,385	14,500
Fish	LONG-SHELF-LIFE FISH		38,000	-		-	38,000	-	38,000
	FRESH FISH			-	2,000	-	2,000	-	2,000
	FROZEN FISH		3,000	-	30,000	-	16,500	-	16,500
	PROCESSED FISH PRODUCTS			-		-		-	
Eggs	NON-HEN EGGS			-		-		-	
	HEN EGGS		0,500	-	3,000	-	1,750	-	1,750
	PROCESSED EGGS			-	-	-		-	
TOTAL WEEKLY QUANTITY		6,200	512,000	-	-	-	259,100	6,200	512,000





Graph 4: Weekly Food Waste / person - Hospitality



The data presented above should be interpreted with caution, as they are subject to several methodological limitations:

Consumer perception: The information related to the consumer sector is derived from questionnaires based on the subjective perception of respondents. Consequently, the results do not represent objective measurements and may be influenced by biases linked to memory, habits, or individual sensitivity regarding food waste.

Production, retail, and hospitality: For the production, retail, and hospitality categories, the data collected showed a high degree of variability, mainly due to the different size of the organizations involved (e.g., small artisanal businesses vs. large retail chains, or hospitality structures with varying capacities).

It was not possible to normalize these results due to the lack of additional objective information (such as turnover, total volumes of food managed, number of guests/users served, etc.), since these sections of the questionnaire were often incomplete or left unanswered.

Presentation of results: For the reasons outlined above, the results are presented as the average of the responses collected and are broken down by geographical region of reference. The values are expressed in absolute and non-normalized form, and therefore cannot be directly compared across stakeholder categories of different nature and size.

In summary, the data provide an indicative snapshot of the trends observed within the surveyed sample, but they should not be considered as an exhaustive or statistically normalized representation of the entire sector analyzed.

In **Annexes D and E**, comparisons between literature-based data and survey findings are reported. Specifically:

- **Annex D** presents the comparison between consumer food waste as reported in literature and the values collected through surveys;



- **Annex E** shows the data normalised per meal served in the food service sector, compared with the average literature values for consumers.

The analyses indicate that consumers tend to generate significantly higher amounts of food waste compared to enterprises, particularly in categories such as meat, fruit, and vegetables. On the other hand, food service activities display much lower levels when data are normalised per meal served — a result that appears plausible considering the stronger economic and management focus in professional settings.

It should also be noted that no comparison was carried out between production vs. consumers and retail vs. consumers, as these system levels are not directly comparable. In fact, the lack of consistent scientific data for a robust normalisation of flows (e.g., production units vs. household consumption units) would not allow a reliable alignment of functional units, and could introduce methodological bias.



3.2. MAIN CAUSES OF FOOD WASTE

The questionnaire results provide a clear picture of the main causes of food waste across different sectors. At the **consumer level**, the primary cause of food waste is food spoiling before consumption, identified by 65.96% of respondents. Other important contributors include cooking oversized portions, excessive food purchasing, and poor inventory management (each 23.4%), as well as inadequate leftover management (21.28%). Less frequent causes include difficulty using leftovers or edible food parts (10.64%), selective eating habits (6.38%), misinterpretation of food labels such as “use by” versus “best before” (5.67%), dietary changes or restrictions (5.67%), high aesthetic and quality standards, e.g., discarding imperfect produce (4.96%), and lack of knowledge on proper food storage (4.96%) (*Graph 5*). These results highlight that consumer-level food waste is mainly driven by **perishability and portion control**, but also influenced by purchasing behavior, leftover management, food labeling understanding, and individual preferences or knowledge.

In **primary production**, the leading causes of waste are losses during harvesting or product selection (31.25%) and raw materials expiring before use (25.00%), followed by overproduction compared to demand and pests or diseases affecting crops or livestock (each 18.75%). Other contributing factors include rejection of food due to quality standards or damage (12.50%), damage from extreme weather events (12.50%), and smaller contributors such as poor inventory management, cooking oversized portions, inadequate leftover management, storage or preservation issues, and deficiencies in logistics and transportation (each 6.25%). This shows that food waste in primary production is largely driven by **harvesting losses, perishability, and overproduction**,



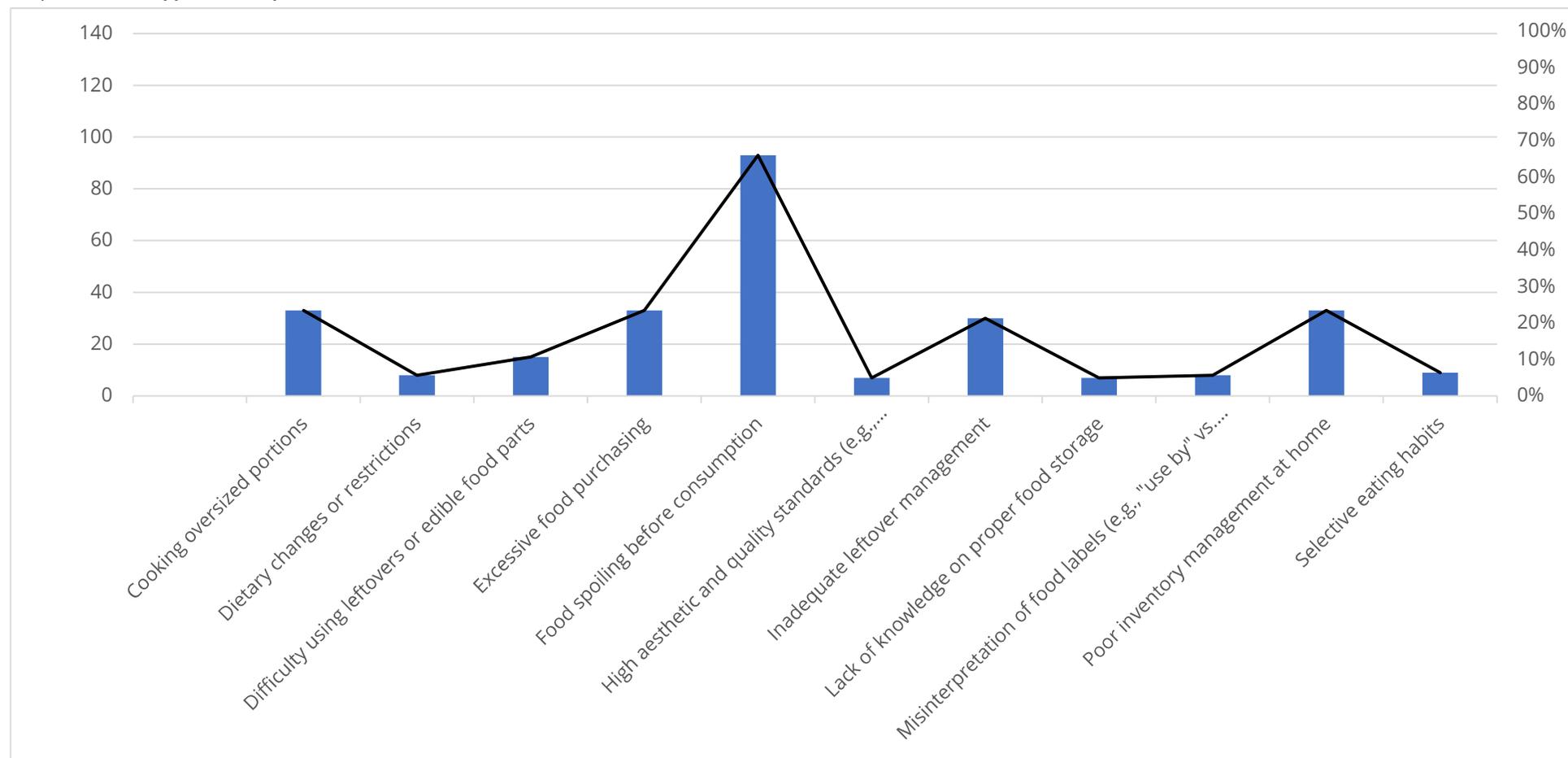
with environmental factors and operational challenges playing a significant role (*Graph 6*)

Within the **hospitality sector**, the main cause of food waste is leftovers from customers or patients not being reused (50.00%), followed by health and safety regulations restricting food reuse (28.57%) and overproduction or excess inventory (21.43%). Other contributing factors include incorrect handling or preparation of food, changing or uncommunicated customer preferences, and lack of awareness or incentives to reduce waste (each 14.29%), along with smaller causes such as raw materials expiring before use, cooking oversized portions, selective eating habits, high aesthetic standards, and non-continuous use of raw materials (each 7.14%). These findings suggest that food waste in hospitality is primarily influenced by customer leftovers and regulatory constraints, with operational practices and awareness also affecting waste levels (*Graph 7*)

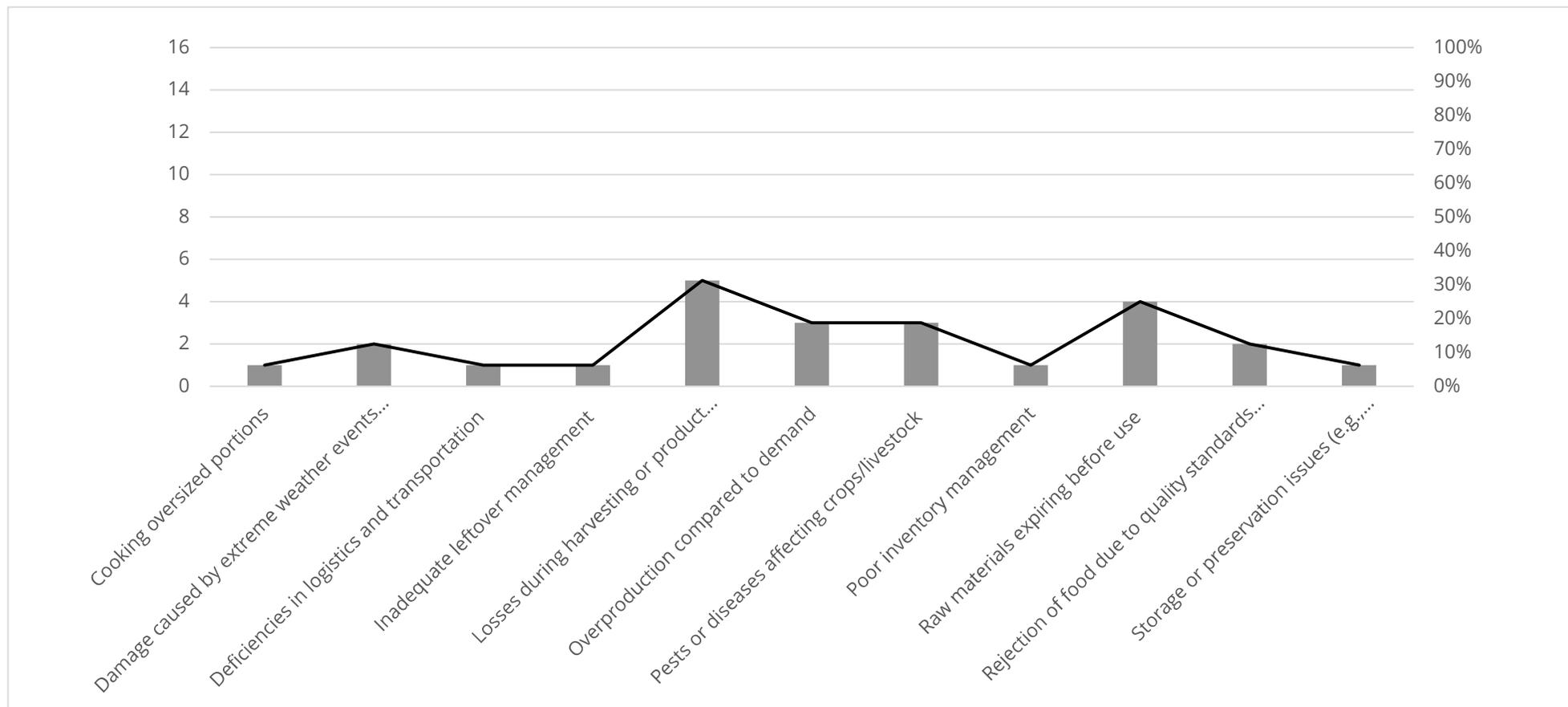
Finally, in the **retail sector**, the leading causes of food waste are raw materials expiring before use (70.00%) and rejection of food due to quality standards, such as appearance or packaging damage (60.00%). Other less frequent causes, all at 10.00%, include leftovers from customers, overproduction or excess inventory, incorrect handling or preparation, high aesthetic standards, overproduction compared to demand, storage or preservation issues, deficiencies in logistics and transportation, food spoiling before consumption, and inefficiencies in processing or packaging (*Graph 8*). These results indicate that food waste in retail is primarily driven by **expiry and quality standards**, while operational and logistical factors also contribute.



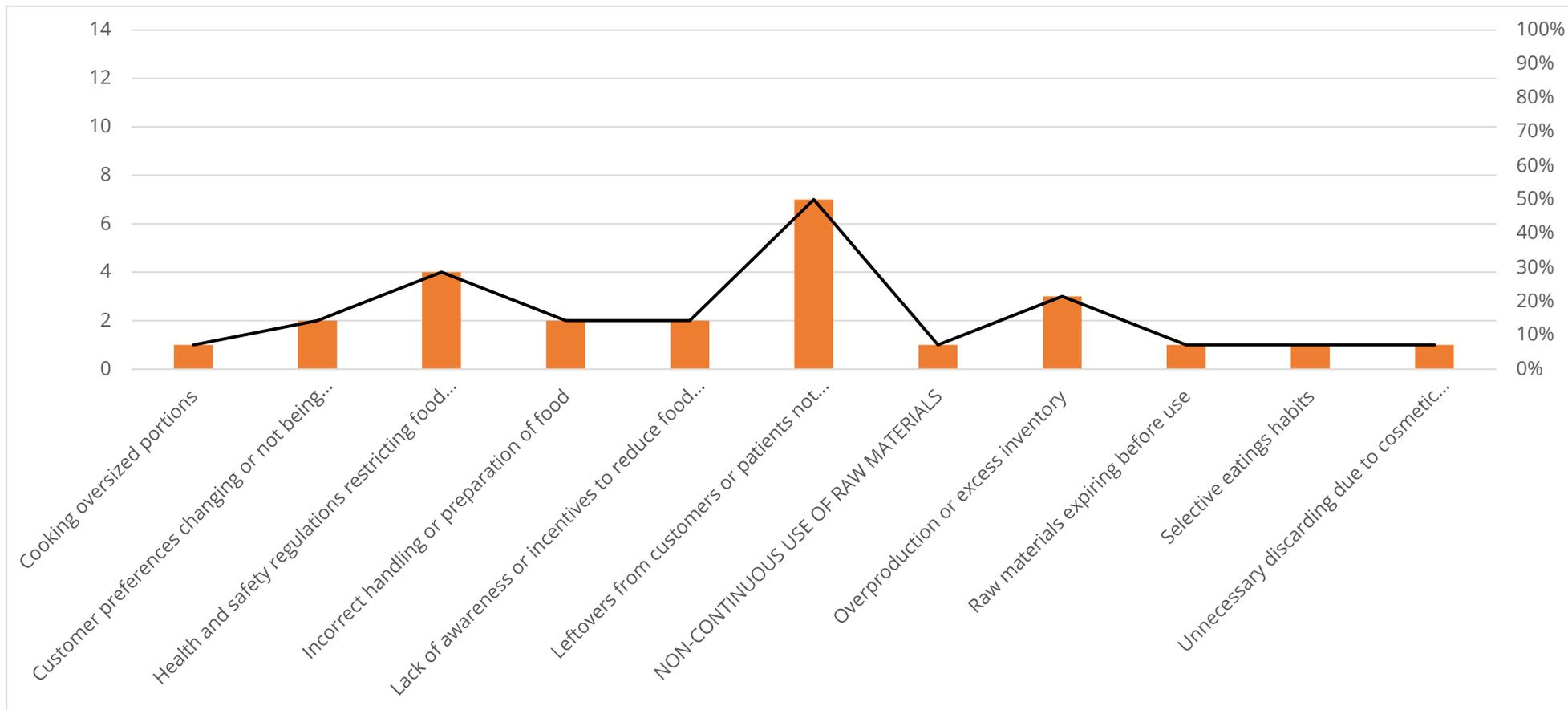
Graph 5: Causes of food waste for consumers



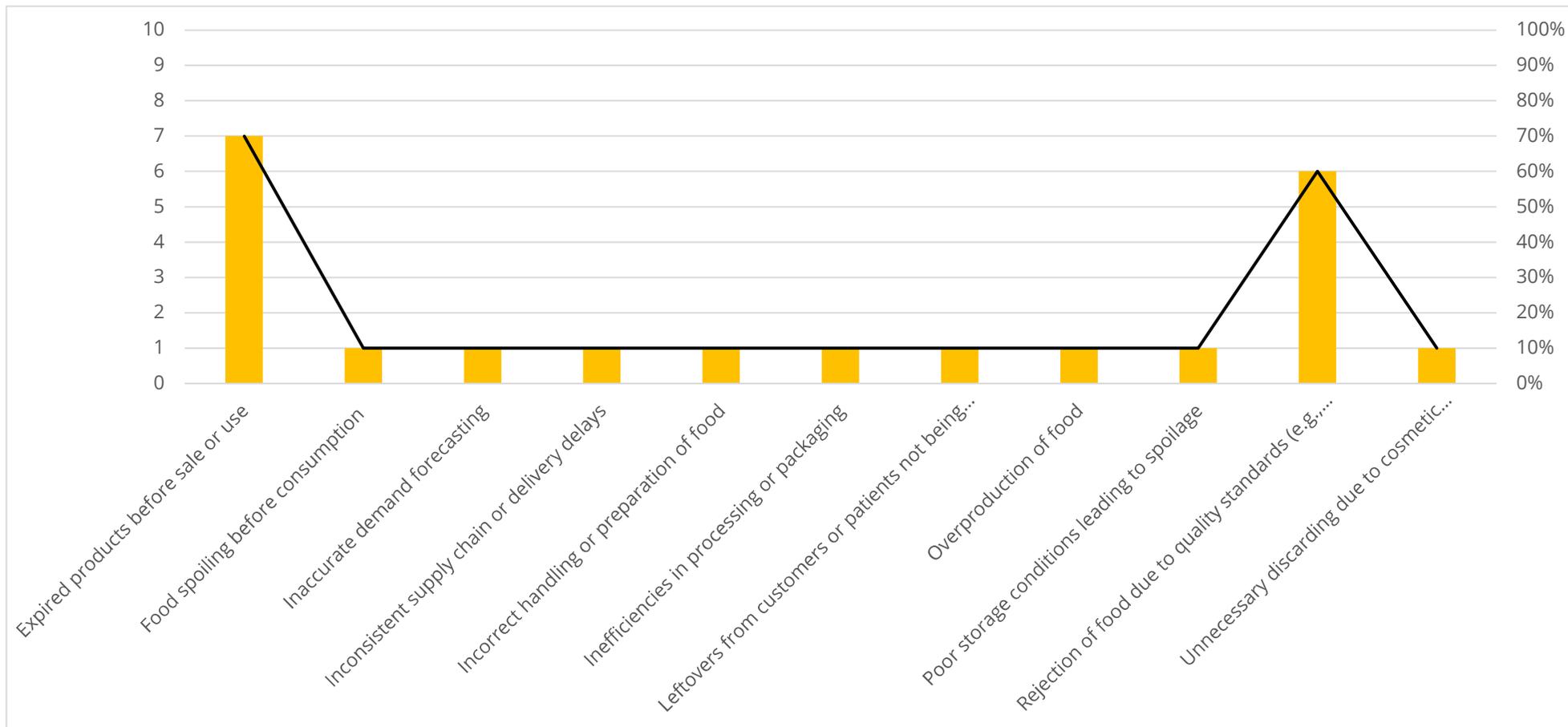
Graph 6: Causes of food waste for primary production



Graph 7: Causes of food waste for hospitality .



Graph 8: Causes of food waste for retail



3.3. WASTE REDUCTION STRATEGIES & TRACKING SYSTEMS

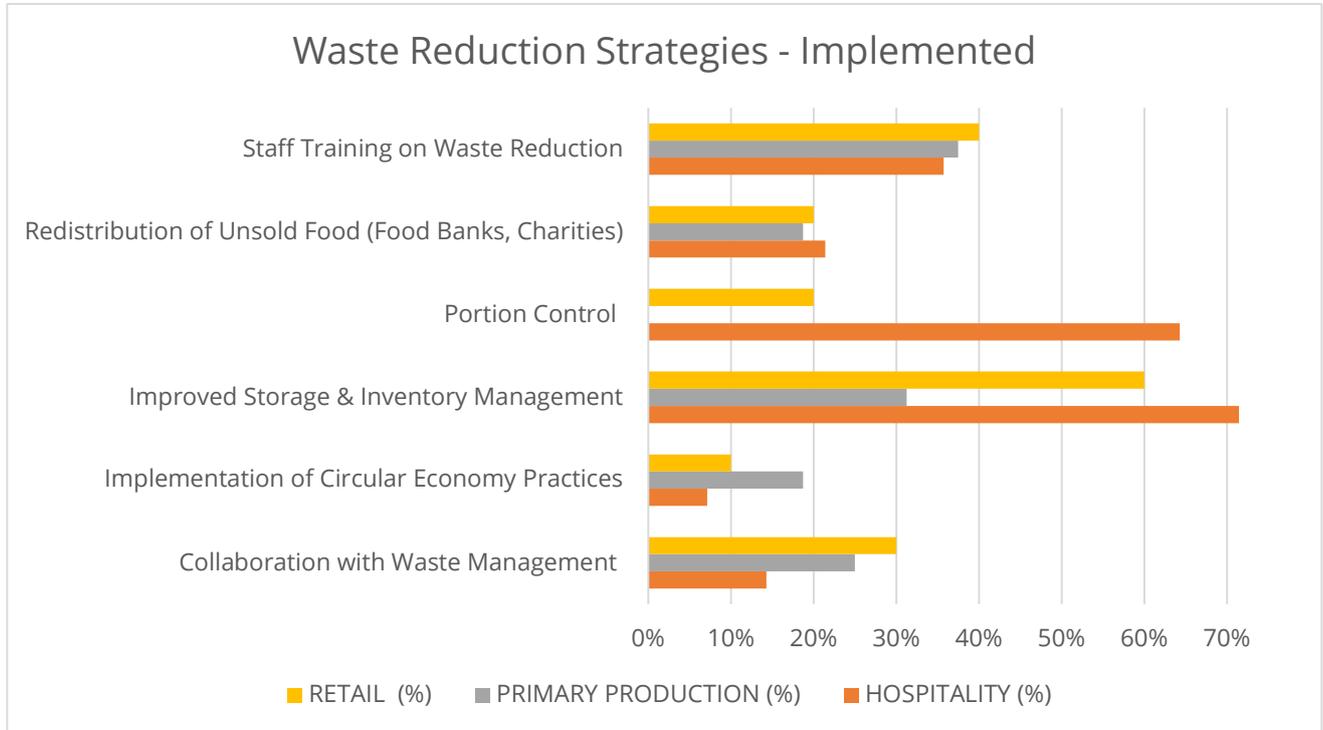
Across all sectors, **improved storage and inventory management** and **staff training on waste reduction** are the most commonly implemented strategies. In hospitality, **71.43%** of businesses have adopted improved storage, **64.29%** use portion control, and **35.71%** provide staff training, while **redistribution of unsold food** and **collaboration with waste management** are less widespread. In primary production, **37.50%** have implemented staff training and **31.25%** improved storage, with additional measures including collaboration with waste management and circular economy practices. Retail shows high adoption of **improved storage (60.00%)** and **staff training (40.00%)**, with moderate use of collaboration, redistribution, and circular economy practices.

Businesses also expressed significant **interest in implementing further strategies**. In hospitality, interest is strongest for **redistribution of unsold food (28.57%)** and staff training (28.57%), while primary production shows interest in **redistribution (31.25%)** and collaboration with waste management (31.25%). Retail businesses are particularly interested in **redistribution of unsold food (50.00%)** and **circular economy practices (40.00%)**.

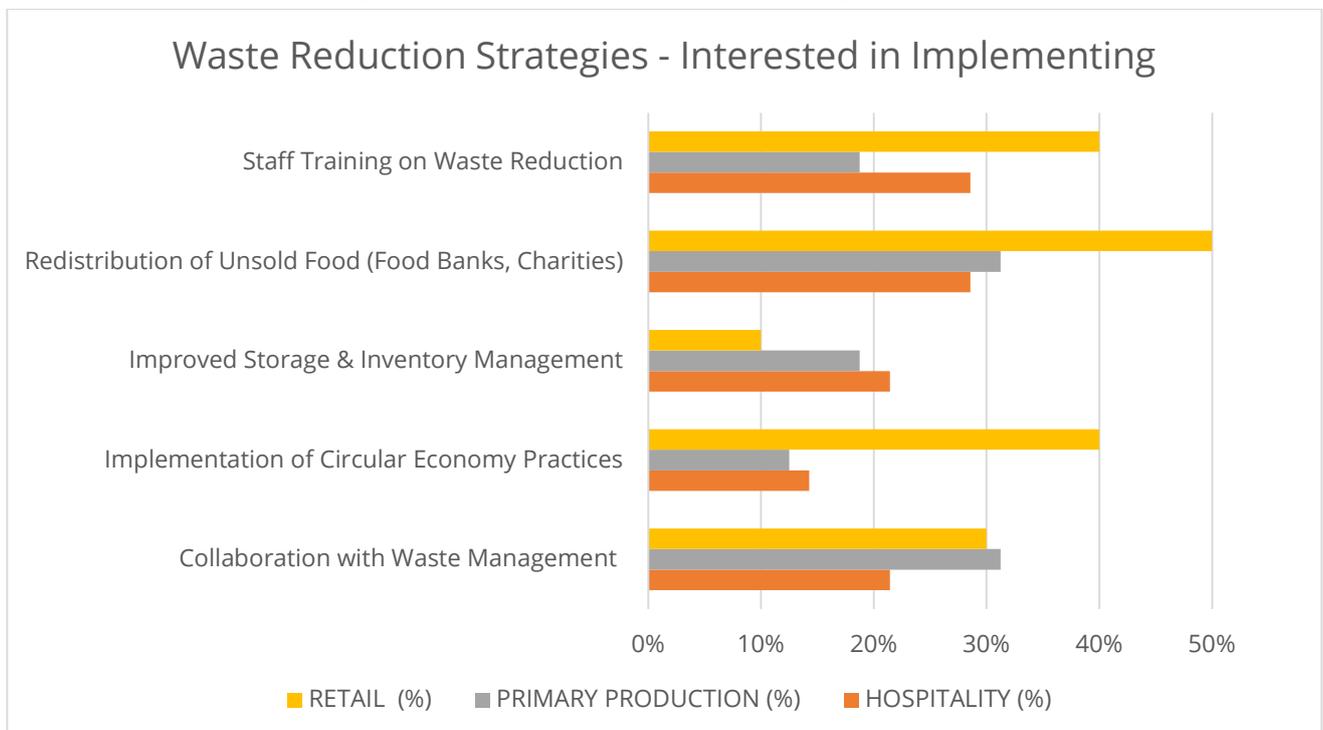
The accompanying charts provide a visual summary of both the implemented strategies and the strategies businesses are interested in adopting across the three sectors (Graph 9; Graph 10).



Graph 9: Waste reduction strategies already implemented by businesses



Graph 10: Waste reduction strategies businesses are interested in implementing



The survey also explored whether businesses **track food waste levels** and how these data are managed (*Graph 11; Graph 12*). In the **hospitality sector**, **42.86%** of respondents track food waste, compared to **37.50%** in primary production and **50.00%** in retail. Manual logs are common in primary production (**33.33%**) and hospitality (**33.33%**), while digital tracking software is more widely used in hospitality (**50.00%**) and retail (**20.00%**). Some retail businesses combine both manual and digital tracking (**40.00%**).

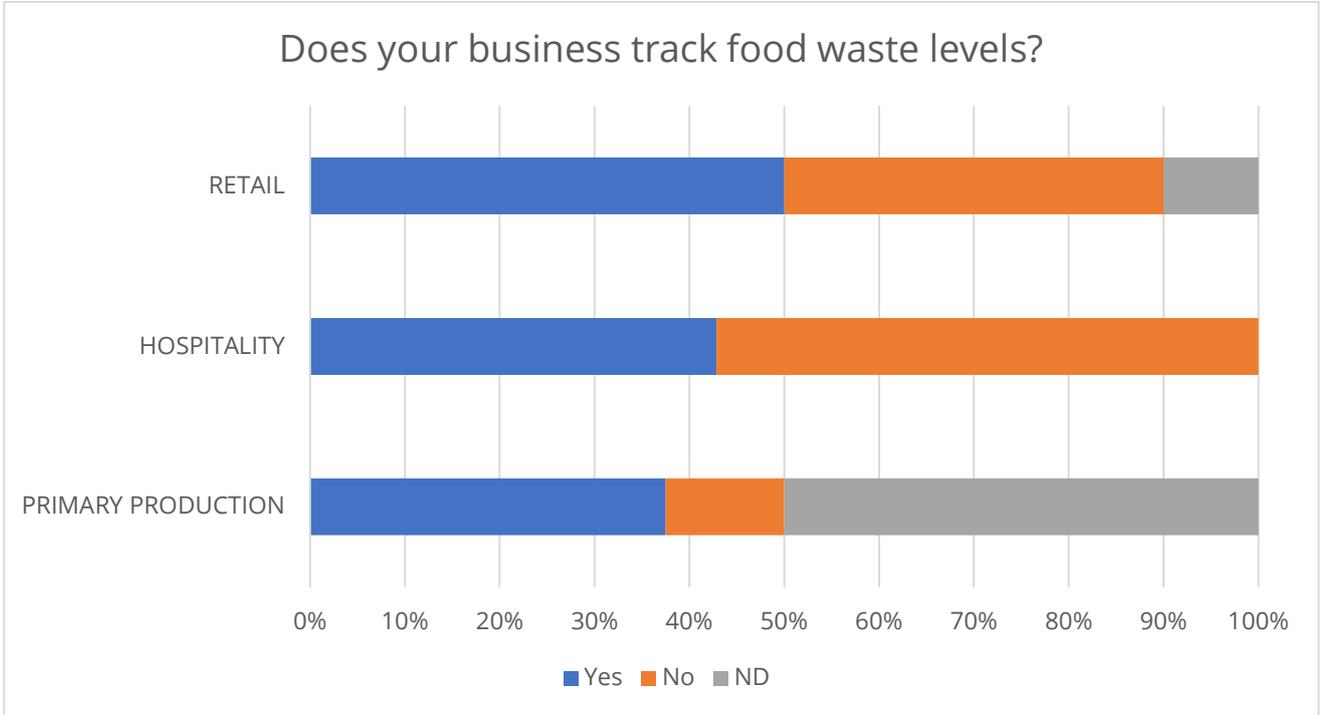
When asked whether they **report food waste data to regulatory agencies or sustainability programs** (

Graph 13), most hospitality businesses (**85.71%**) and retail businesses (**60.00%**) reported not doing so, while a smaller share in primary production (**12.50%**) and retail (**20.00%**) confirmed reporting.

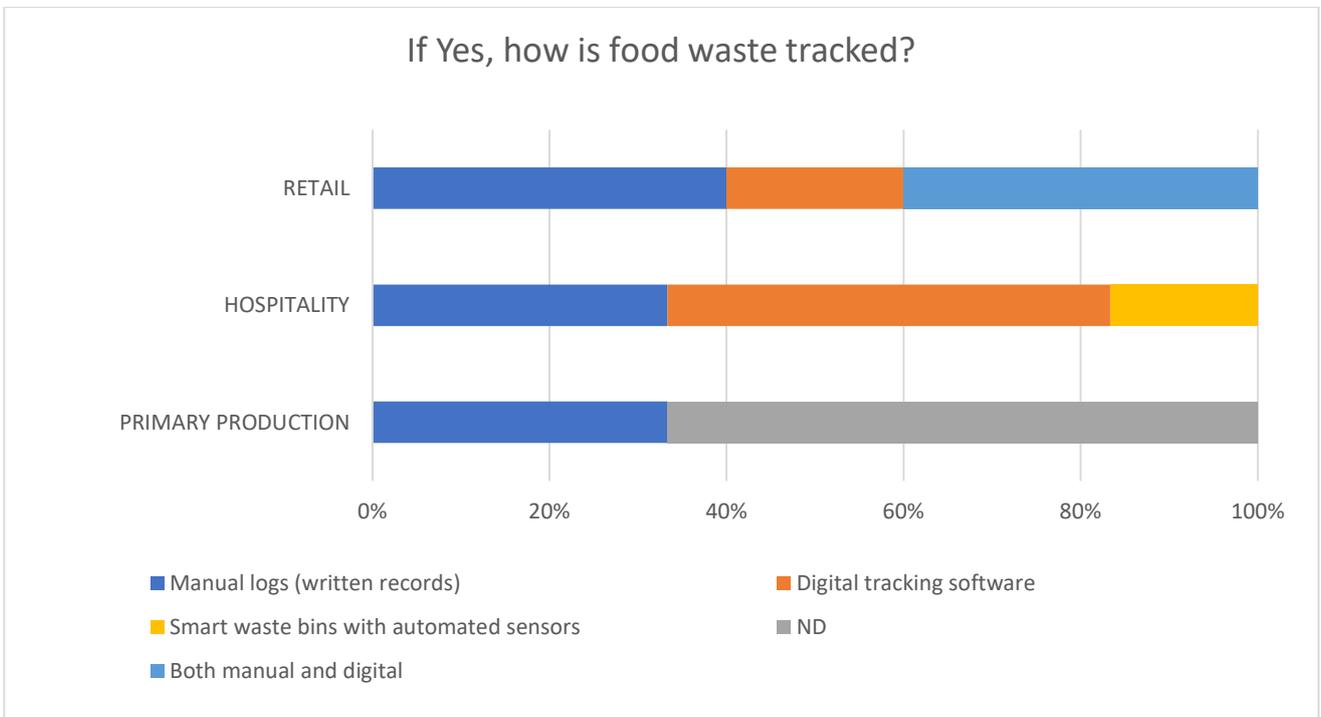
Regarding **financial incentives** (*Graph 14*), businesses in retail (**60.00%**) and hospitality (**35.71%**) indicated that incentives such as tax benefits or subsidies could encourage waste reduction, whereas a majority of primary production respondents were less convinced (**31.25%** said no, **37.50%** maybe).



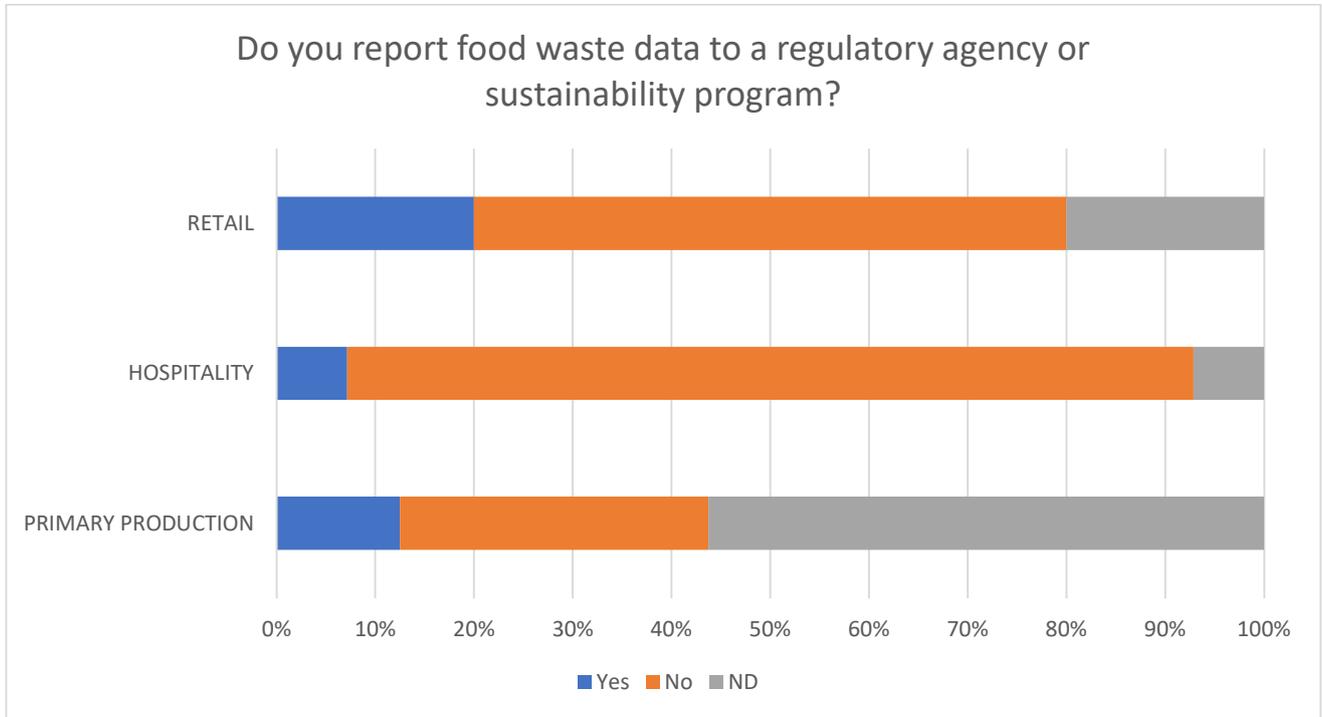
Graph 11: Businesses tracking food waste levels



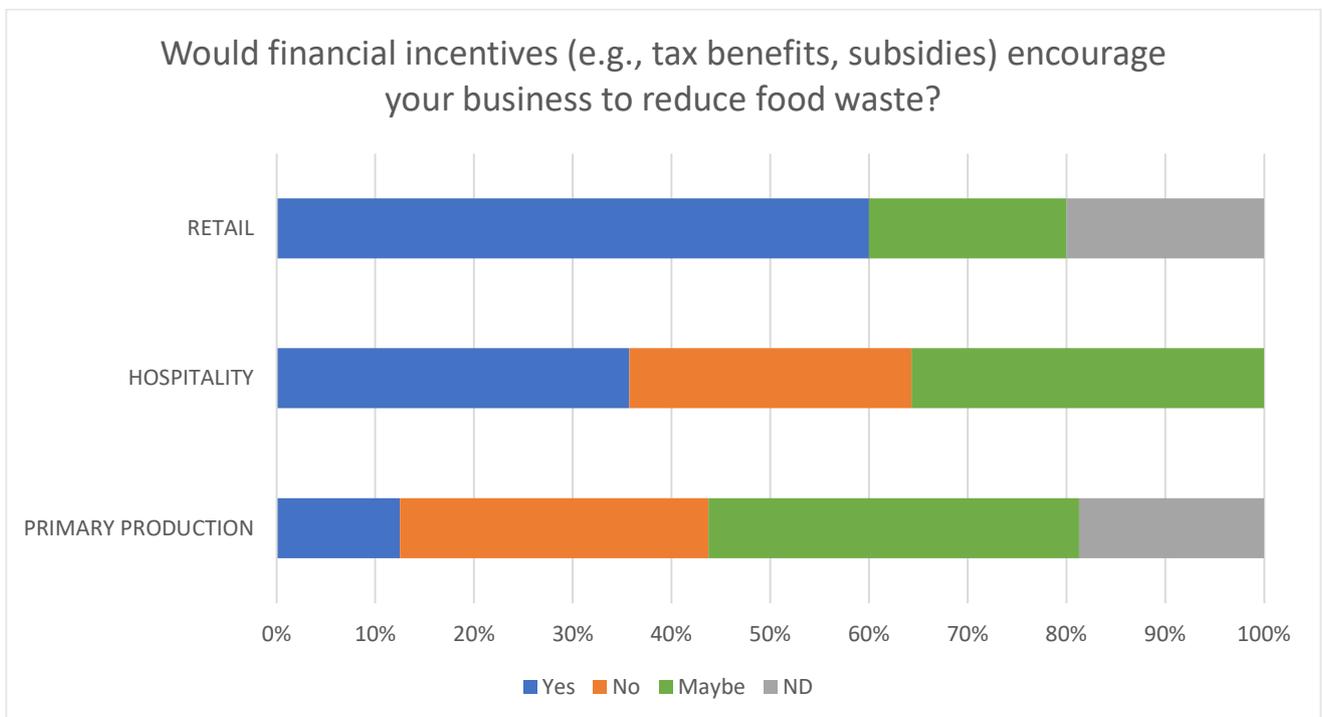
Graph 12: Methods of tracking food waste



Graph 13: Reporting food waste data to external entities



Graph 14: Impact of financial incentives on food waste reduction



3.4. REGULATORY COMPLIANCE & POLICY ENGAGEMENT

The results reveal varied levels of **awareness, compliance, and engagement** with national and EU food waste regulations across the primary production, hospitality, and retail sectors.

Awareness of regulations is highest in **primary production (37.5%)** and **hospitality (35.7%)**, while only **20%** of retail respondents are aware. A significant share in hospitality (**64.3%**) and retail (**60%**) reported not being aware of the regulations. Some respondents did not provide an answer (ND), notably **43.8%** in primary production and **20%** in retail (*Graph 15*).

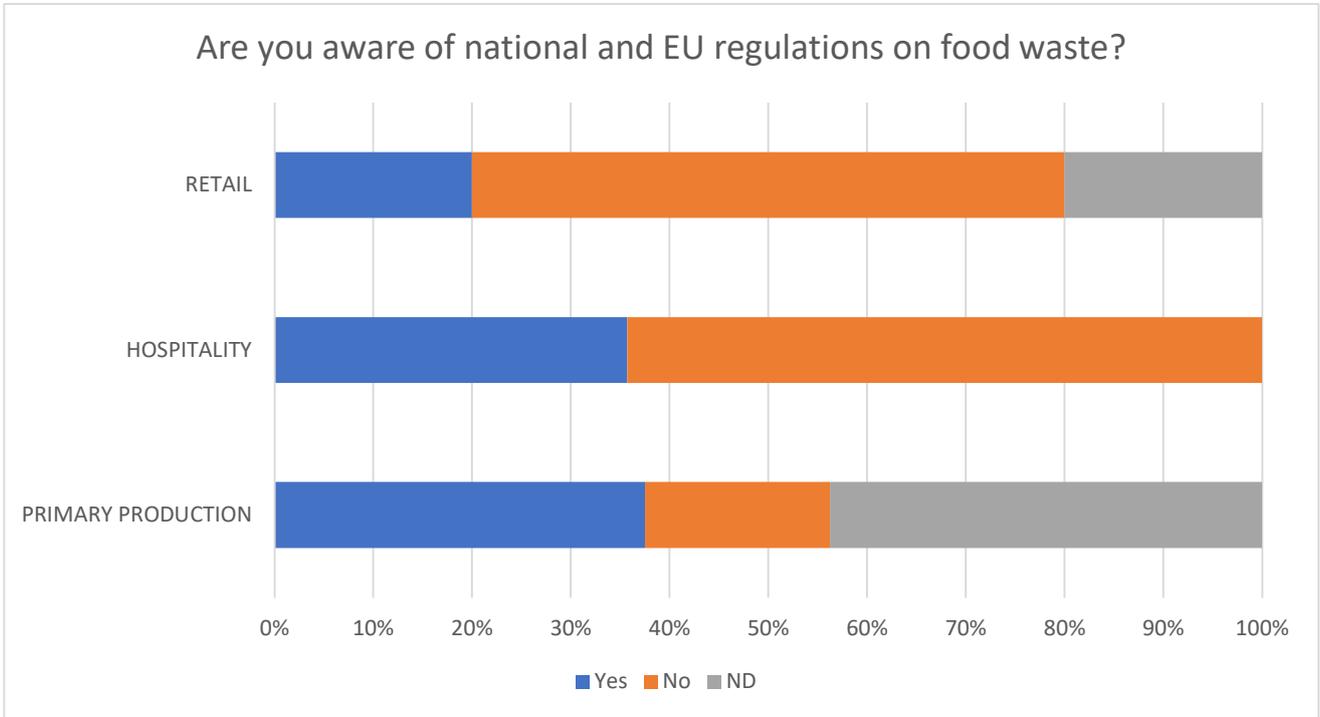
Compliance is generally uncertain: in primary production, **50%** of businesses are not sure, and only **12.5%** confirm compliance. Hospitality shows **42.9%** compliance, with the remainder unsure, and retail has **30%** compliance with **50%** uncertain. ND responses account for **37.5%** in primary production and **20%** in retail (*Graph 16*).

Most hospitality respondents (**78.6%**) support existing regulations, compared to **43.8%** in primary production, while **60%** of retail respondents remain indifferent (*Graph 17*).

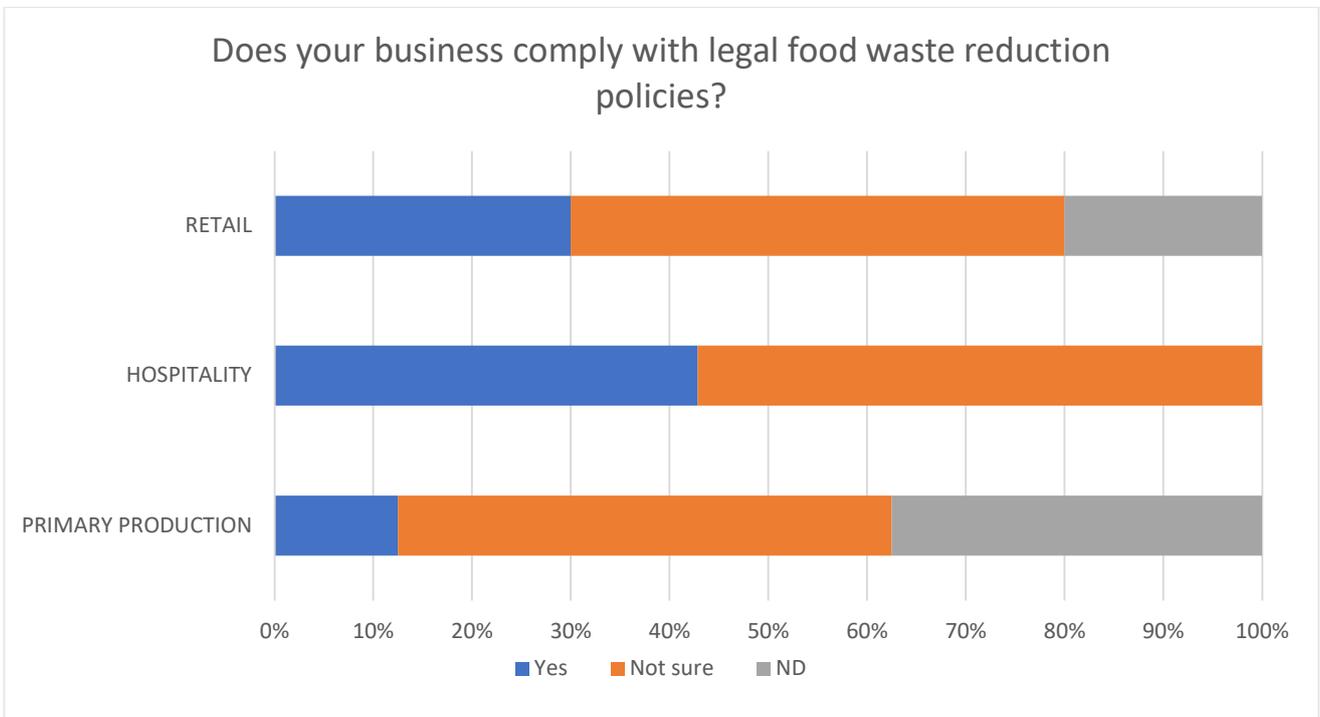
The importance of mandatory food waste tracking and reporting is widely recognized in hospitality (**85.7% consider it quite or very important**) and in retail (**70%**), while primary production is more mixed, with **50%** rating it slightly important (*Graph 18*).



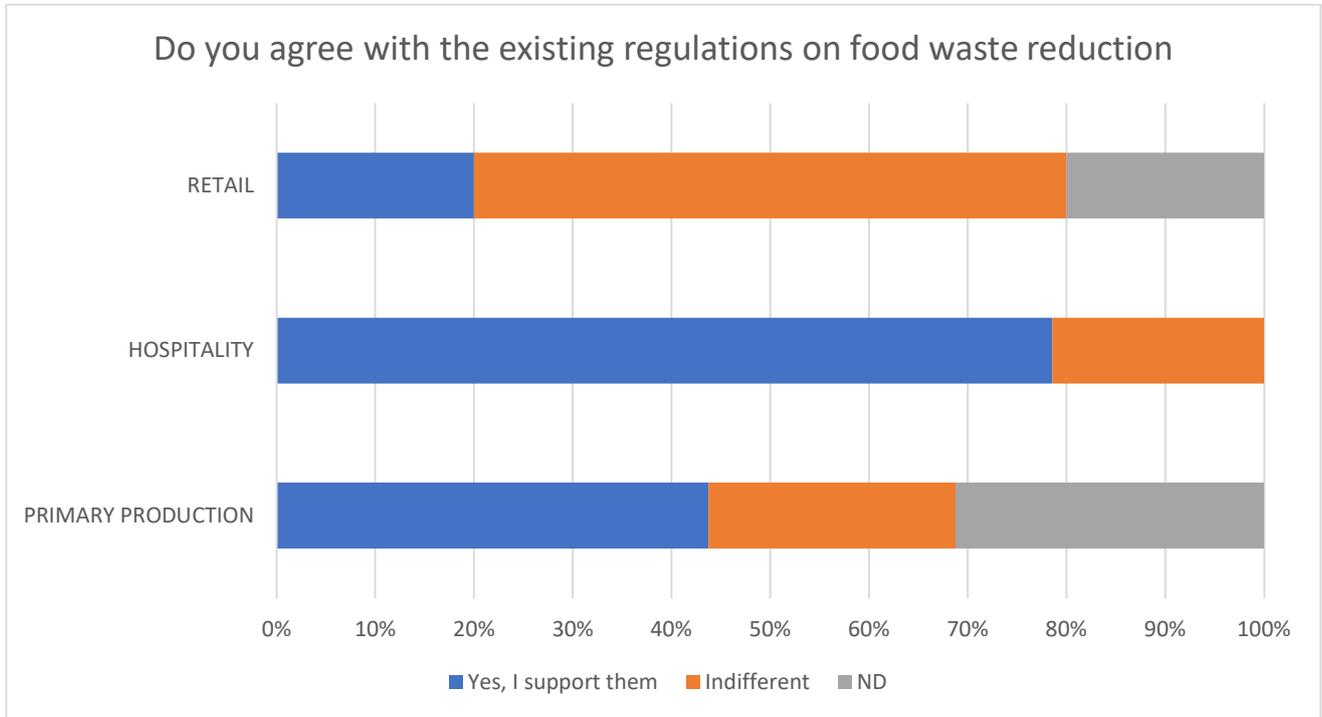
Graph 15: Awareness of national and EU food waste regulations



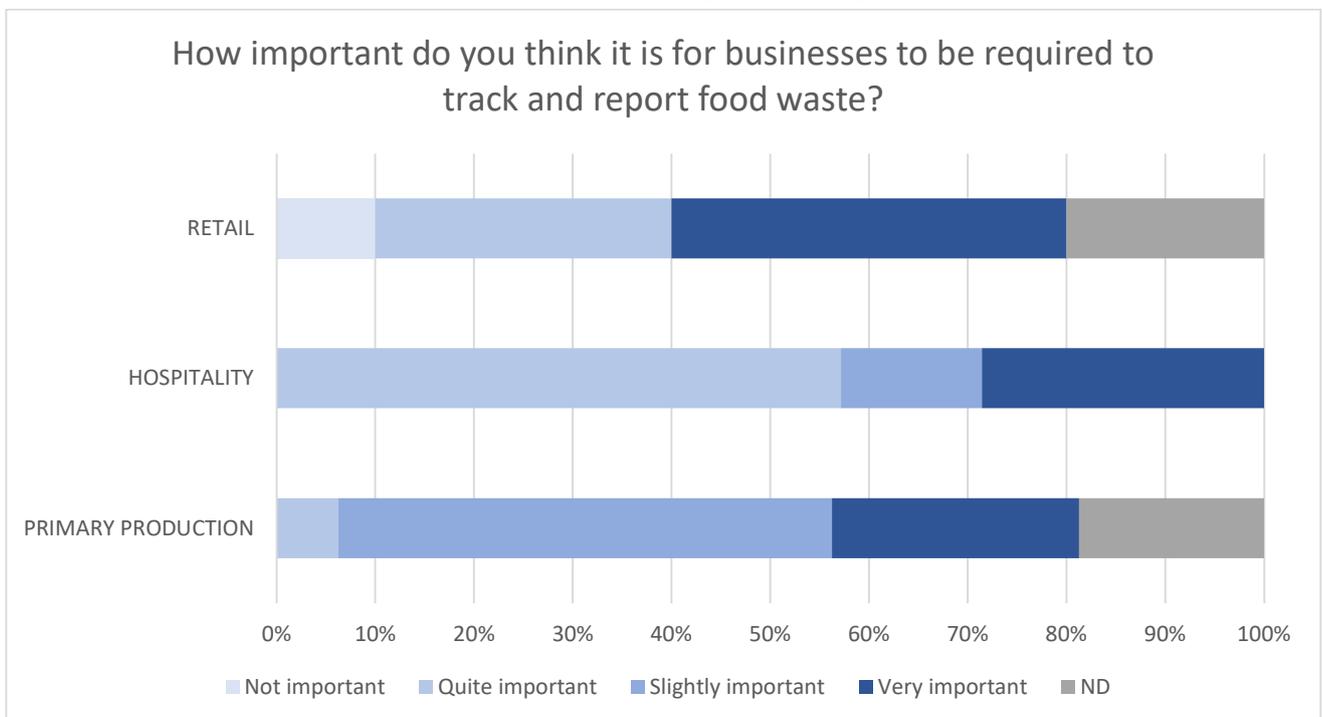
Graph 16: Business compliance with food waste reduction policies



Graph 17: Agreement with existing food waste regulations



Graph 18: Perceived importance of mandatory food waste tracking and reporting

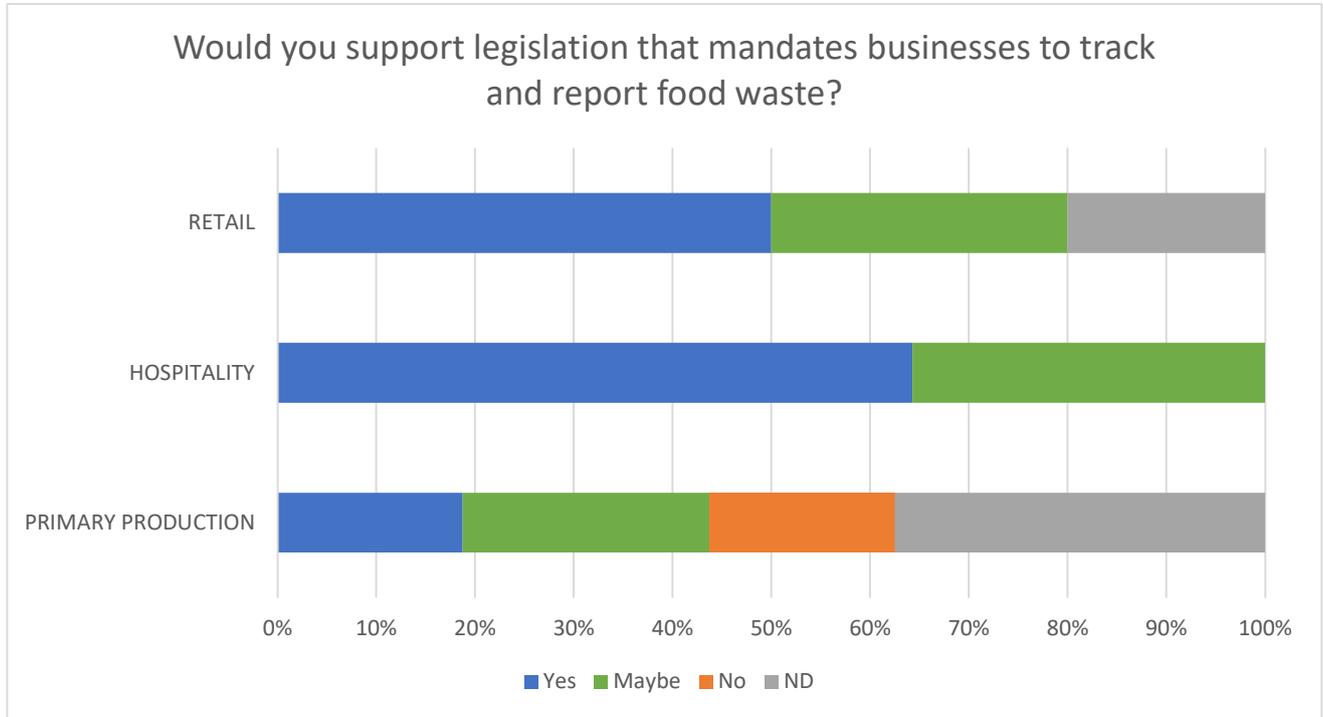


Support for legislation mandating tracking and reporting is strong in hospitality (**64.3% yes**) and retail (**50% yes**), while primary production is more cautious (**37.5% ND, 25% maybe, 18.8% yes**) as reported in *Graph 19*. Financial incentives, such as tax benefits, are seen as effective motivators, particularly in retail (**60%**) and hospitality (**57.1%**), with primary production showing moderate support (**43.8% yes, 25% maybe**) (*Graph 20*). Similarly, interest in government grants or subsidies is high in hospitality and retail (**50% each**), while primary production respondents are more cautious (**56.3% maybe, 12.5% yes**) (*Graph 21*).

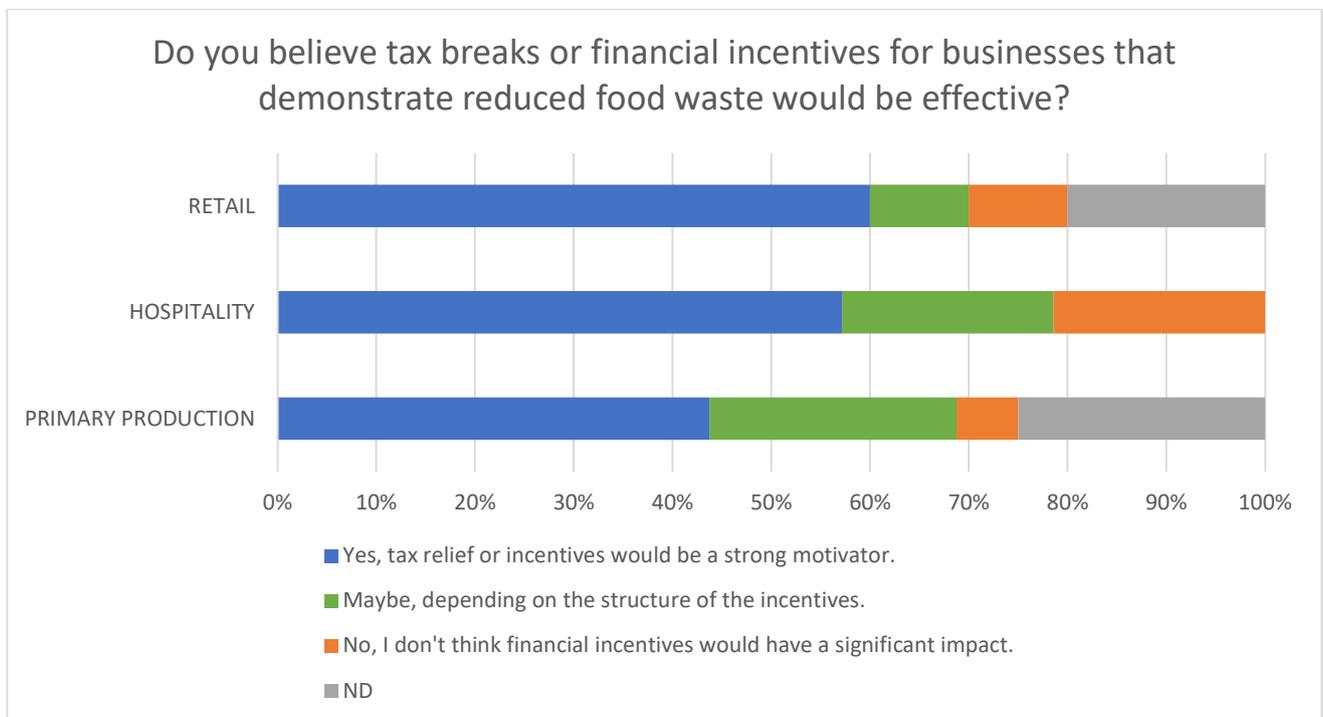
Regarding penalties for exceeding food waste thresholds, **retail respondents (40%)** and **primary production (31.3%)** see them as effective, while hospitality respondents favor a balanced approach combining penalties and support (**50%**). ND responses are noted where applicable (*Graph 22*).



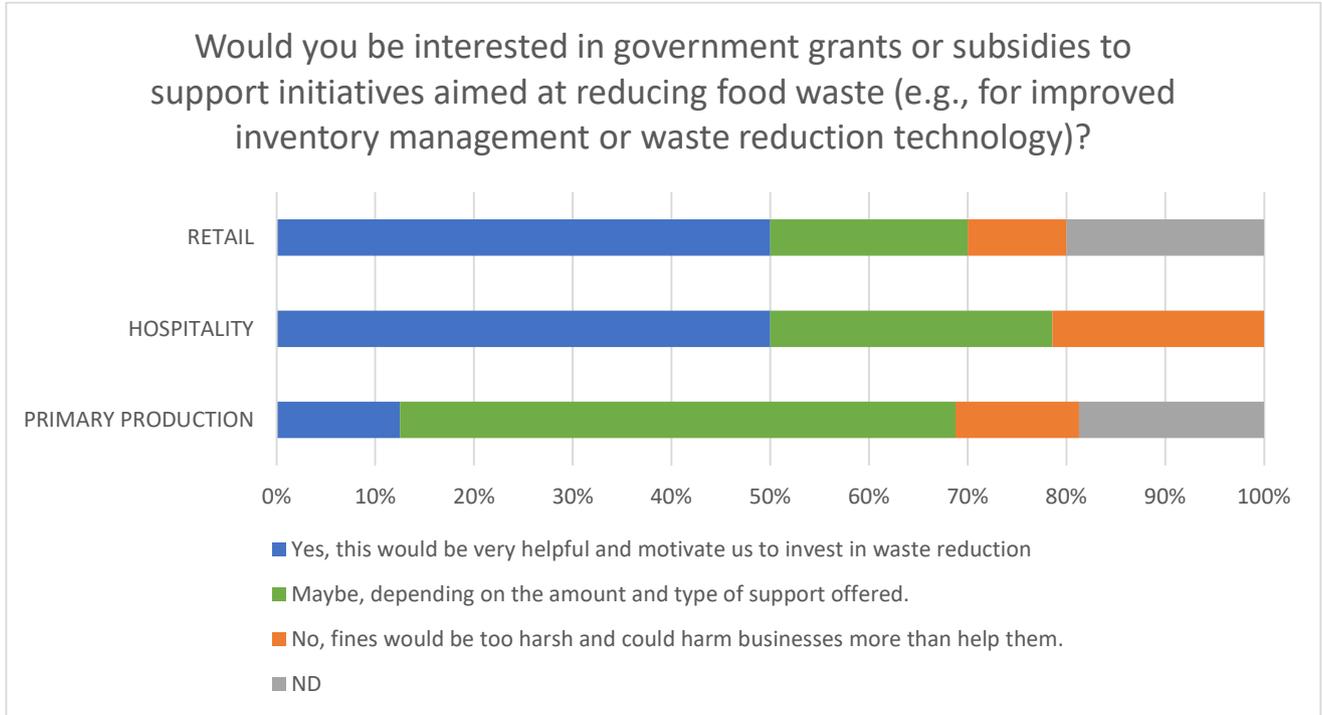
Graph 19: Support for mandatory food waste tracking legislation



Graph 20: Effectiveness of financial incentives for reducing food waste



Graph 21: Interest in government grants or subsidies for food waste reduction



Graph 22: Effectiveness of penalties or fines in encouraging food waste reduction



4. ENVIRONMENTAL IMPACT ASSESSMENT

The aim of this phase is to convert the results of the inventory analysis—that is, all input and output flows associated with the investigated unit processes—into environmental impact data (i.e., the product’s eco-profile), in order to produce results that are both reliable and easy to interpret, as well as to assess their magnitude across the analysed information modules. Based on the resulting environmental performance, it is possible to define the environmental profile of the food waste generated in the contexts under study.

The Life Cycle Approach is an analytical methodology that allows the assessment of the environmental impacts associated with a product, service, or system throughout its entire life cycle, from the production of raw materials to end-of-life management. This approach underpins the Life Cycle Assessment (LCA) methodology and is regulated by the EN ISO 14040:2021 and EN ISO 14044:2021 standards.

The Life Cycle Approach is based on the principle that environmental impacts should not be analyzed solely in the final stage of a process, but must consider all upstream and downstream stages to avoid impact transfers between different life cycle phases or environmental compartments. This systemic approach ensures a complete and objective view of the environmental performance of the analyzed system.

In the case of food waste, the Life Cycle Approach makes it possible to quantify not only the impacts associated with the waste itself but also those linked to all the resources unnecessarily consumed to produce, process, transport, and distribute food that is ultimately not consumed.



4.1. APPLICATION TO THE ECOFOODCYCLKE CASE STUDY

Within the ECOFOODCYCLE project, the Life Cycle Approach was applied to estimate the environmental impacts associated with the quantities of wasted food in four stakeholder categories:

- Primary production and Processing sector
- Distribution (large-scale retail and small commerce)
- Final consumption - households
- Final consumption - food service

For each category, the wasted mass flows were quantified and linked to the environmental profiles of the corresponding food types, using data from reference LCA databases.

The analysis followed an attributional approach, modelling the environmental impacts related to the production of wasted food under the assumption that such food did not fulfil its primary function (nutrition) and is therefore considered a net environmental burden.

For the purposes of this study, the analysis of environmental impacts related to food waste was structured by considering the main operational stages of the agri-food supply chain, in line with the methodological framework of the ECOFOODCYCLE project. Food waste can occur at different points along the value chain, each representing a different environmental contribution, as it reflects a varying number of resources already invested (raw materials, energy, water, etc.). For this reason, environmental impacts were quantified separately for each stage in order to clearly highlight where and how the greatest impacts are generated.

The analysed supply chain stages are as follows:



Supply Chain Stage	Description and Main Associated Environmental Impacts
Primary production	Includes cultivation, harvesting, and livestock farming. Impacts related to the use of fertilisers, pesticides, water consumption, fossil energy, and land use.
Food processing	Industrial or artisanal processing of food products. Impacts associated with energy consumption, water use, process waste, and packaging.
Distribution and retail	Storage, logistics, and sales. Impacts linked to transport, refrigeration, energy losses, and the generation of packaging waste.
Final consumption – household	Preparation and consumption in households. Cumulative impacts of the entire supply chain, plus energy for cooking and the use of water and gas in domestic settings.
Final consumption – food service	Activities in restaurants, canteens, and hotels. High impacts due to wasted food downstream, with significant energy and water resource intensity.

In a Life Cycle Assessment, **the declared unit** represents the functional reference against which material, energy, and emission flows are calculated. It is fundamental for ensuring consistency, comparability, and transparency in the results. It defines how much of the system is analysed and allows environmental impacts to be related to the functions provided by the system itself.

In this study, the declared unit is defined as one week of Mediterranean diet per capita, adopted as the reference scenario for modelling food consumption. This choice is based on the intention to anchor the analysis to a sustainable nutritional model, internationally recognised (FAO, 2010) and representative of the predominant dietary habits in the territorial contexts considered (Italy – Veneto, Abruzzo, Puglia – and Croatia- Primorje–Gorski Kotar, Karlovac, Zadar, Lika–Senj).

This unit was used as the basis for estimating the quantities of food consumed and, consequently, the quantities wasted along the different stages of the agri-food supply



chain. The study is structured into four distinct analyses, each referring to a specific stage of the supply chain: primary production, processing, distribution and retail, and final consumption (household and hospitality). For each stage, the data collected were related to the weekly dietary composition, integrating food-category-specific waste rates.

The use of a common declared unit enables the harmonised and comparable assessment of the environmental impacts generated by food waste across the entire value chain, highlighting the contribution of each stage to the overall results.

4.2. SELECTION OF IMPACT CATEGORIES, CATEGORY INDICATORS

For the Life Cycle Impact Assessment (LCIA), the following impact categories and corresponding characterisation factors were selected. The categories considered are reported in Table 2:

Table 6: List of Impact Categories Used in Accordance with the Reference Standard and Related Characterisation Factors

Impact Categories	Characterisation factor	Category indicator results
Climate change (GHG emissions)	GWP - Total	kg CO ₂ eq
Acidification	AP	mol H ⁺ eq
Resource use – Fossil fuels	ADP-fossil	MJ
Land use	SQP	Pt
Water use	WDP	m ³ deprived
Human toxicity – Cancer and Non-cancer effects	HTTP-c / HTTP-nc	CTUh

The reference databases selected for process and elementary flow modelling were AGRIBALYSE v3.2, the latter specifically used for agri-food products. AGRIBALYSE, developed by ADEME (French Agency for Ecological Transition), is one of the leading



European LCA databases in the agricultural and food sector, providing primary data representative of European farming practices, technical inputs, yields, and geographical conditions.

For the characterisation phase—quantifying the potential environmental impacts associated with the system’s input and output flows—the Environmental Footprint (EF) 3.1 method was applied. Developed by the European Commission under the Product Environmental Footprint (PEF) initiative, the EF method represents the harmonised European approach to life cycle impact assessment. It is based on midpoint-oriented modelling, with a set of impact categories selected according to criteria of scientific robustness, methodological consistency, and data availability.

The combined use of Ecoinvent, AGRIBALYSE, and the EF 3.1 method ensured methodological coherence and representativeness in the modelling, supporting the analysis of environmental impacts associated with food waste across the different stages of the supply chain.

The impact categories selected for the study include:

- Climate Change
- Acidification
- Use of Fossil Resources
- Land Use
- Water Use
- Human Toxicity (carcinogenic and non-carcinogenic)

CLASSIFICATION

After selecting impact categories and calculation models, the inventory flows (materials and energy) are assigned to the relevant categories according to their potential



contribution to environmental issues. The areas of damage considered include: ecosystem effects, human health and safety, resource depletion, and habitat degradation.

CHARACTERIZATION

Characterization quantifies the potential impacts of the classified flows. Using models developed by research centers or certified bodies (e.g., IPCC), specific conversion factors are applied to each input/output. These factors translate inventory data into comparable impact results, expressed in the units of each category (e.g., kg CO₂eq for climate change). Summing all contributions per flow within the same category provides the total impact for that category process then involves compiling the inventory and converting the data into environmental impacts for each pre-selected category according to a well-defined unit of measure that depends on the category itself and allows for comparison. The aggregation of all impacts generated by each input or output element of the inventory, grouped within the same impact category, generates the total impact of the entire category.

4.3. LIFE CYCLE ANALYSIS APPROACH

In order to assess the environmental impact of food waste within the project, two complementary methodological approaches were adopted. This choice was motivated by the limited quality and representativeness of the primary data collected through questionnaires. When compared with existing bibliographic sources and scientific literature, the collected data showed inconsistencies and deviations from values generally recognized at international level.



To ensure robustness and comparability, the analysis was therefore structured as follows:

1. Bibliographic approach – A first scenario was developed on the basis of a reference Mediterranean diet, applying average food waste rates derived from authoritative bibliographic sources (Waste Watcher for Italy and FAO for Croatia). This approach provides a harmonized and literature-based benchmark, ensuring alignment with existing studies and data reliability.
2. Questionnaire-based approach – A second scenario was built using the primary data collected through dedicated surveys and questionnaires administered to stakeholders in the agri-food supply chain (producers, retailers, hospitality sector, consumers). Although affected by variability and data gaps, this approach allows for the representation of real operating conditions and provides insight into specific patterns of waste generation across stakeholder categories.

4.4. BIBLIOGRAPHIC APPROACH METHODOLOGY AND RESULTS

The assessment of food waste and its environmental impacts was conducted through a harmonised methodological framework designed to ensure consistency and comparability between the two geographical contexts under study (Italy and Croatia).

As a first step, a reference Mediterranean diet was defined and applied uniformly to both countries. This diet was selected because it represents a balanced nutritional model, widely recognised at European level, and provides a robust baseline for comparing food waste patterns across different regions.



Table 7: Mediterranean Diet - Weekly consumption and food Waste

Food category	Weekly consumption (kg/person/week) ¹	Food waste - Italy (kg/person/week)	Food waste - Croatia (kg/person/week)
Milk and dairy products	1,27	0,075	0,165
Bread and cereals	1,16	0,068	0,150
Legumes	0,16	0,009	0,021
Fish	0,74	0,043	0,096
Meat	0,38	0,022	0,049
Cold cuts	0,08	0,004	0,010
Eggs	0,24	0,014	0,031
Vegetables	2,80	0,164	0,363
Fruit	3,15	0,185	0,408
Cakes and pastries	0,15	0,009	0,019
Total	10,13	0,594	1,312

Subsequently, food waste percentages were derived from bibliographic sources. For Italy, the value applied was 5.86%, based on the most recent Waste Watcher survey data. For Croatia, a food waste rate of 12.98% was adopted, in line with FAO estimates. These percentages were applied to the food categories of the reference diet in order to quantify the average amount of wasted food per capita on a weekly basis.

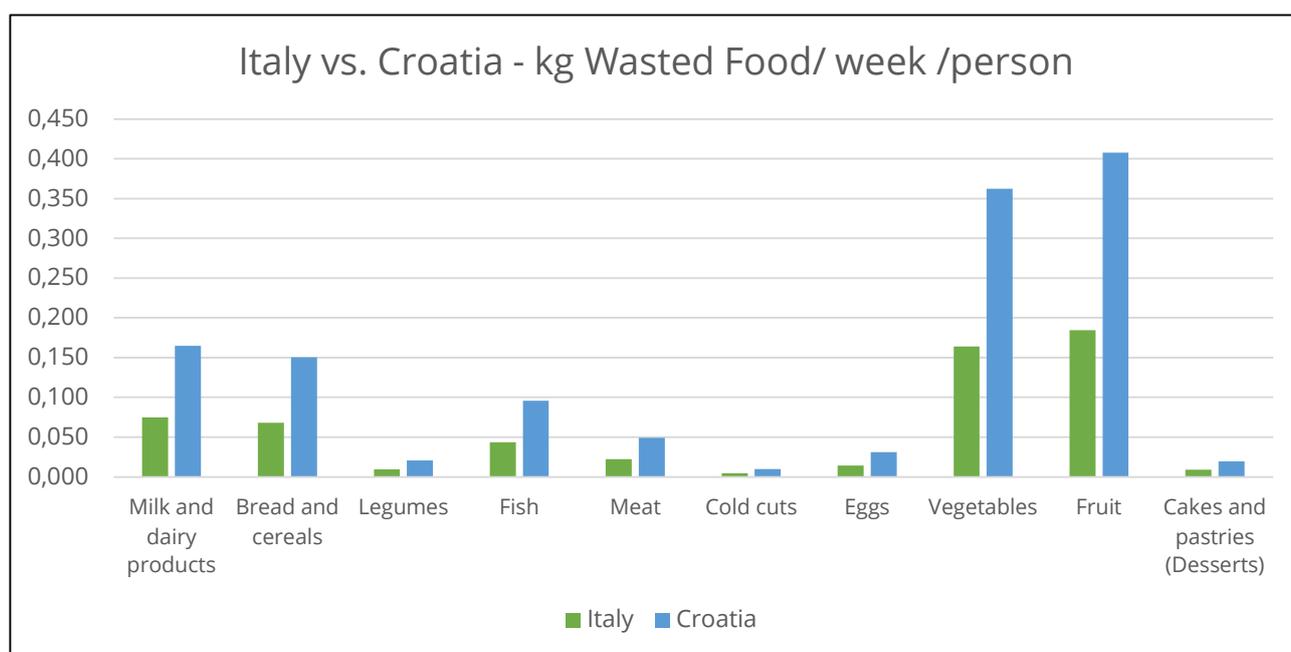
To evaluate the environmental impacts, the Agribalyse database (version 3.1) was used as the main source of life cycle inventory data. Agribalyse provides process-specific data for agricultural and food products and is consistent with the Life Cycle Assessment (LCA) methodology as defined in EN ISO 14040:2021 and EN ISO 14044:2021 standards. The database allowed the attribution of environmental impact profiles to each food category, covering the entire supply chain (agriculture, processing, packaging, transport, distribution and consumption).

¹ The reference diet was elaborated on the basis of multiple European, with the aim of providing the most representative average weekly consumption pattern for the population



By integrating the dietary model, waste percentages, and Agribalyse datasets, it was possible to quantify the environmental intensity of food waste per food category. Results were expressed both in terms of wasted mass (kg/week·person) and in terms of environmental impact (mPt/kg of wasted food). This dual perspective enabled the identification of categories critical either for their high waste volumes (e.g. fruit and vegetables) or for their disproportionately high environmental burden (e.g. meat and fish).

Graph 23: Italian and Croatian Weekly Food waste



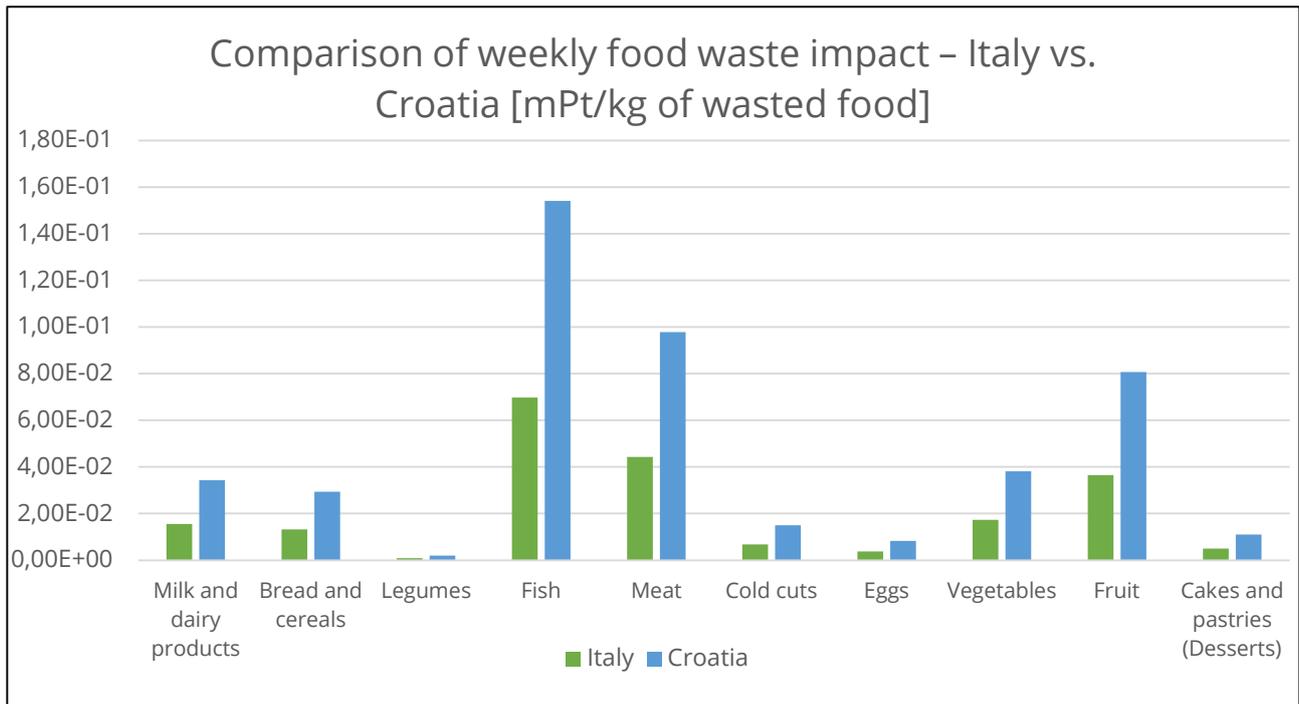
The figure illustrates the average weekly per capita food waste, disaggregated by food category and calculated on the basis of a reference Mediterranean diet.

- For Italy, a waste rate of 5,86% was applied (Waste Watcher).
- For Croatia, a waste rate of 12,98% was applied (FAO, 2021). The resulting amounts are expressed in kg/week/ person and provide a representative



overview of the distribution of food waste across the main food categories at the consumption stage.

Graph 24: Italian and Croatian Weekly Food waste impact [mPt]



The second figure reports the environmental impact intensity of food waste for the same categories, expressed in mPt/kg of wasted food. This indicator derives from the application of the Life Cycle Assessment (LCA) methodology, accounting for burdens associated with primary production, processing, transport, and distribution. The normalization into milli-Points (mPt) allows for direct comparison of different food categories based on their unit environmental footprint.

The combined analysis of the two graphs highlights that the relationship between wasted quantity and environmental impact is neither direct nor proportional.

- Fruit and vegetables show the highest waste volumes, mainly due to their intrinsic perishability. Nevertheless, the unit environmental impact of their waste



remains relatively low, reflecting the lower intensity of their agricultural production systems.

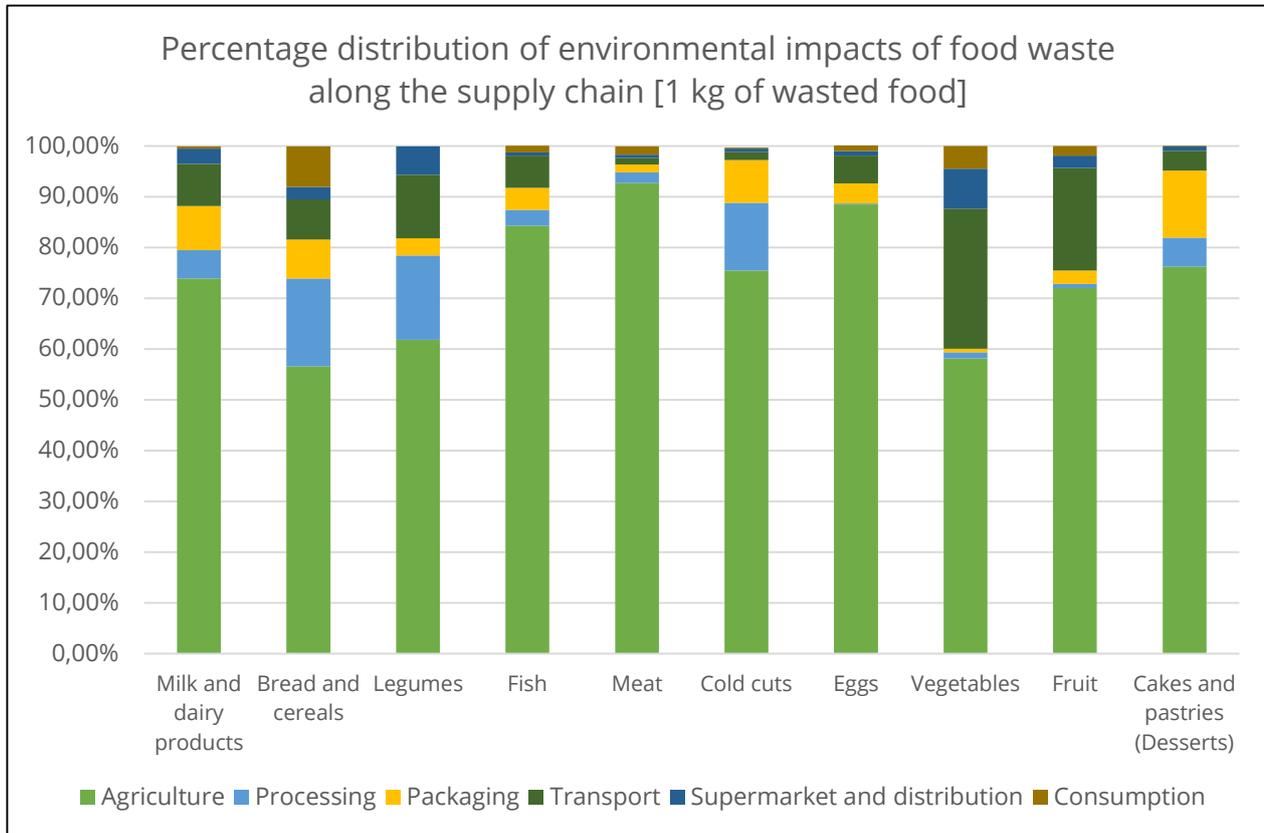
- Meat and fish, conversely, are wasted in smaller amounts but are characterized by a much higher unit environmental impact. This finding is consistent with the scientific literature, which attributes to these supply chains a high consumption of natural resources (land, water, energy) and significant greenhouse gas emissions (e.g., methane and nitrous oxide for livestock, biodiversity impacts and energy use for fisheries).
- Intermediate categories, such as milk and dairy products and bread and cereals, combine non-negligible waste volumes with moderate unit impacts, making them relevant contributors to the overall balance.

The results demonstrate that food waste cannot be assessed solely in terms of mass. It is necessary to incorporate evaluation through environmental intensity indicators (mPt/kg) to identify the most critical categories. In particular, the waste of food items with a high environmental footprint (meat and fish) represents a strategic priority for action, even when wasted quantities are lower compared to more perishable but less intensive categories (fruit and vegetables).

Graph 25: Percentage distribution of environmental impacts of food waste along the supply chain, by food category (per 1



kg of wasted food)



The graph illustrates the percentage breakdown of environmental impacts associated with food waste across the main life cycle stages (agriculture, processing, packaging, transport, supermarket and distribution, and consumption) for each food category.

It is important to note that the results are calculated per 1 kg of wasted food. Therefore, the analysis does not account for the fact that more or less waste may occur during the agricultural phase itself; it only considers the environmental burden of the different life cycle stages for one unit of food that is ultimately wasted.

- For all categories, the agriculture stage emerges as the dominant contributor, confirming that primary production represents the main source of environmental pressure linked to food waste.



- For fruit and vegetables, the relative share of agriculture is lower compared to other food groups, while transport and distribution play a more significant role due to the perishability of these products and the need for cold chains.
- Animal-based products (meat, fish, eggs) are almost entirely dominated by the agricultural stage, often exceeding 90% of the total impact. This reflects the high resource intensity and greenhouse gas emissions associated with livestock and fisheries.
- For processed foods (e.g. bread, pastries, cold cuts), the processing and consumption stages contribute more prominently, highlighting the role of industrial transformation and end-use activities.

In summary, the graph demonstrates that food waste amplifies environmental burdens generated throughout the supply chain, with agriculture generally being the most critical stage. However, the relative contribution of other stages varies according to the product type. The analysis is unit-based (1 kg of wasted food), focusing exclusively on the environmental footprint of wasted food rather than on the amount of waste generated at different production stages.

4.5. METHODOLOGY FOR CALCULATING THE ENVIRONMENTAL IMPACT OF FOOD WASTE BASED ON QUESTIONNAIRE DATA

In order to quantify the environmental impacts associated with food waste collected through the questionnaires administered to the various actors along the supply chain, it was necessary to define an aggregation criterion that would take into account the size of the organizations under analysis.



A direct approach, based solely on the comparison of absolute values of wasted food, would have led to an overestimation of the impact for larger companies, which inherently manage higher food volumes and therefore present greater total waste compared to small-scale organizations. To ensure greater representativeness and comparability of the data, a dimensional clustering criterion was therefore adopted.

Specifically:

- For each respondent, the total amount of food handled (kg/week) was calculated.
- Based on this parameter, companies were divided into three dimensional classes:
 - Small enterprises (low total waste volume),
 - Medium enterprises (intermediate total waste volume),
 - Large enterprises (high total waste volume).
- For each class, the average amount of food waste was determined.

The average values thus obtained were subsequently used as the basis for the quantification of environmental impacts, applying to the inventory data the corresponding characterization factors derived from reference LCA.



This approach makes it possible to:

- normalize the information with respect to different organizational scales,
- reduce intra-class variability linked to anomalous behaviors or outliers,
- provide a more robust and representative estimate of the average impact for each enterprise cluster.

The final result is a calculation of the environmental impact of food waste stratified by dimensional class, allowing for comparative evaluation and supporting the identification of intervention priorities for each segment of the supply chain.



PRODUCTION AND PROCESSING

The clustering of retail operators was carried out on the basis of the total amount of food handled per week (kg/week). The following dimensional classes were defined:

Table 8: Dimensional classes

Class	Threshold (kg of food handled/week)
Large enterprises	> 100 kg
Medium enterprises	50 – 100 kg
Small enterprises	< 50 kg

The table below reports the distribution of weekly food waste quantities (kg) and relative shares (%) for agricultural and processing enterprises, disaggregated by enterprise size.

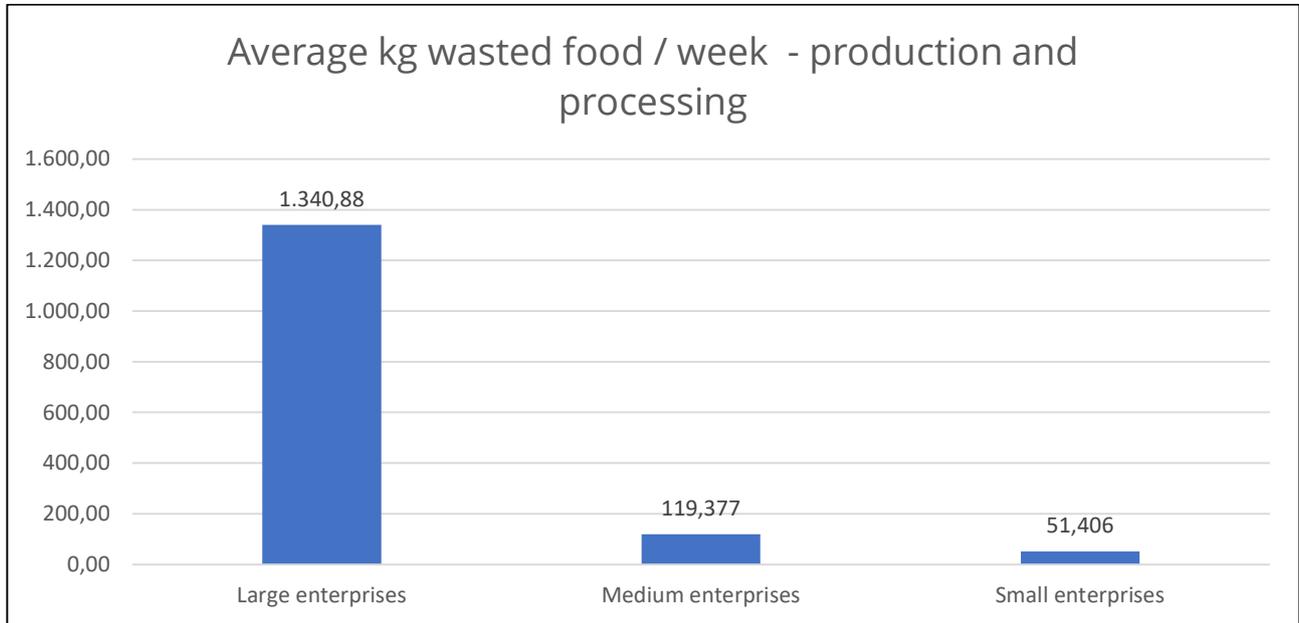
Table 9: distribution of food waste quantities (kg) and their relative shares (%) by food category

Food Category	Large enterprises	%	Medium enterprises	%	Small enterprises	%
Meat	164,70	12,3%	4,500	3,8%	0,932	1,8%
Fruit and vegetables	1.174,43	87,6%	110,927	92,9%	48,870	95,1%
Fish	1,03	0,1%	0,330	0,3%	0,880	1,7%
Eggs	0,72	0,1%	3,620	3,0%	0,724	1,4%
TOTAL	1.340,88	100,0%	119,377	100,0%	51,406	100,0%

- Large enterprises are mainly characterized by fruit and vegetables waste (87,6%), followed by meat (12,3%), while fish and eggs contribute negligibly.
- Medium enterprises show a very similar profile, with fruit and vegetables representing the vast majority of waste (92,9%), complemented by small contributions from meat (3,8%) and eggs (3,0%).
- Small enterprises display the highest relative share of fruit and vegetables (95.1%), with marginal contributions from meat (1,8%), fish (1,7%), and eggs (1.4%).



Graph 26: average Kg of wasted food in a week – Primary production



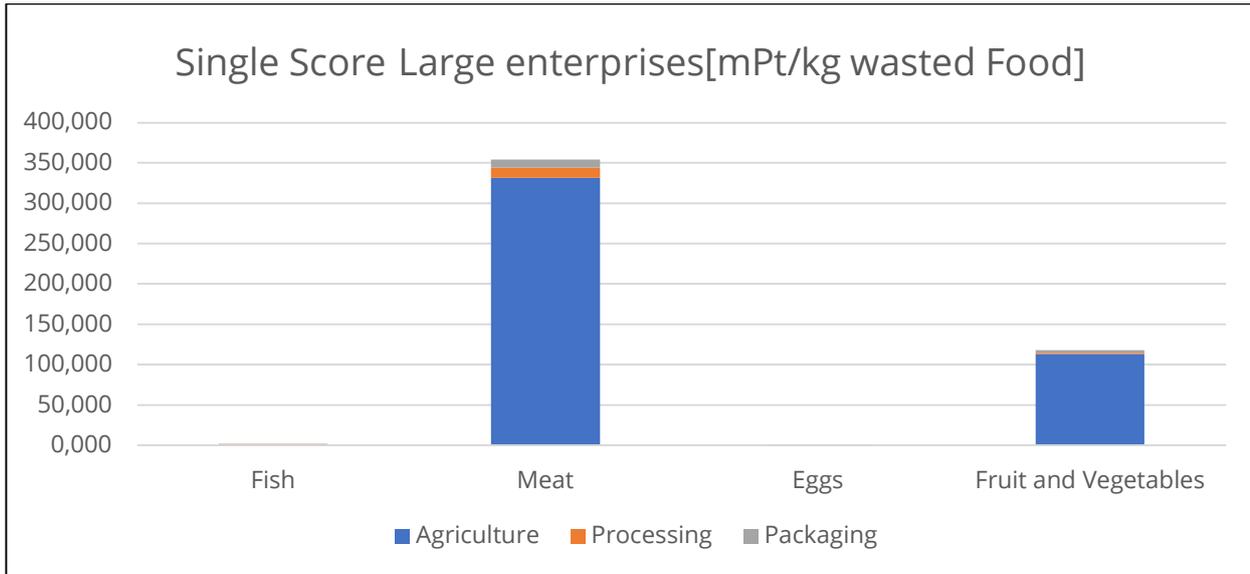
For the production and processing sector, the impacts related to the transport from the production site to distribution (supermarkets and, ultimately, final consumers) were not included in the system boundaries. Likewise, the impacts associated with supermarket operations and with the actual food consumption phase were excluded. The analysis therefore focuses on the agricultural stage, the processing of raw materials, and the associated packaging.



PRODUCTION AND PROCESSING RESULTS

Large enterprises

Graph 27: Single Score results for Big Enterprises



The figure shows the Single Score results (mPt/kg of wasted food) for large agricultural and processing enterprises, disaggregated by product category and life cycle stage (agriculture, transformation, and packaging).

The results highlight meat waste as the dominant hotspot, with impacts exceeding 330,000 mPt/kg, almost entirely driven by the agricultural stage. Transformation and packaging provide smaller, though still visible, contributions.

Fruit and vegetables represent the second main contributor, with values around 110,000 mPt/kg, again mainly attributable to the agricultural phase.

By contrast, fish and eggs show negligible contributions in this enterprise class, having little influence on the overall impact profile.

In conclusion, for large enterprises in the agricultural/processing sector, meat emerges as the critical hotspot in terms of impact intensity, while fruit and vegetables remain

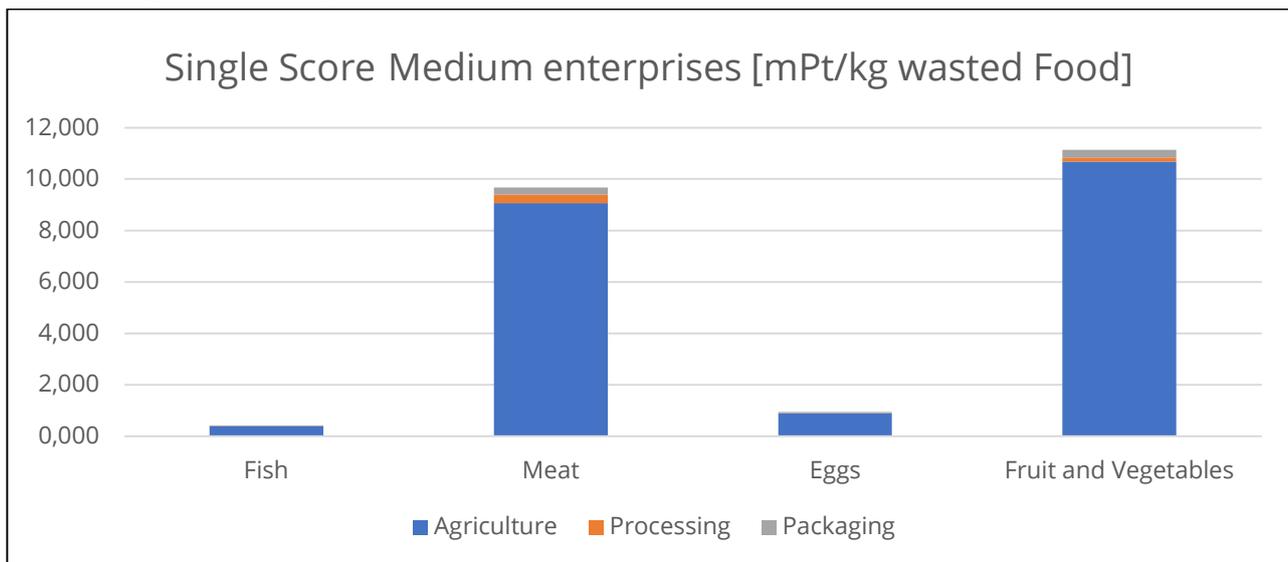


significant due to their high volumes. This suggests that mitigation measures should prioritize meat waste reduction, while also addressing inefficiencies in the handling and storage of fresh produce.

The results for the other impact categories investigated (e.g. Climate Change, Acidification, Use of Fossil Resources, Land Use, Water Use, Human Toxicity – carcinogenic and non-carcinogenic) are provided in Annex C.

Medium enterprises

Graph 28: Single Score results for Medium Enterprises



The figure illustrates the SingleScore results (mPt/kg of wasted food) for medium agricultural and processing enterprises, disaggregated by product category and life cycle stage (agriculture, transformation, and packaging).

The analysis highlights two main hotspots: fruit and vegetables (over 11,000 mPt/kg) and meat (around 9,500 mPt/kg). In both cases, the agricultural stage dominates the impact profile, reflecting the resource intensity and environmental burden of primary production. Transformation and packaging make minor but visible contributions.



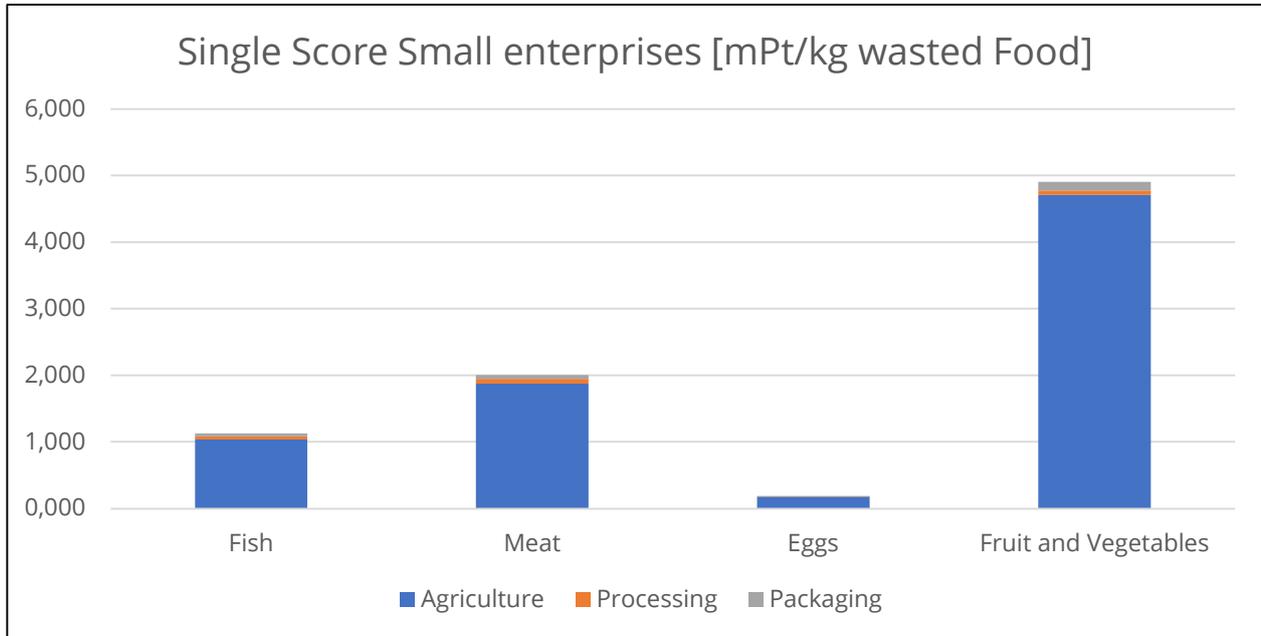
Eggs and fish represent much smaller contributors, with impacts well below 2,000 mPt/kg, and therefore play only a marginal role in the aggregated results for this cluster. Overall, for medium enterprises, the results indicate a dual hotspot structure, with both fruit and vegetables (due to high waste volumes) and meat (due to high impact intensity per kg) emerging as critical categories. This suggests that effective mitigation strategies should simultaneously address fresh produce losses and meat waste reduction in order to achieve significant environmental benefits.

The results for the other impact categories investigated (e.g. Climate Change, Acidification, Use of Fossil Resources, Land Use, Water Use, Human Toxicity – carcinogenic and non-carcinogenic) are provided in Annex C.



Small enterprises

Graph 29: Single Score results for Small Enterprises



The figure reports the Single Score results (mPt/kg of wasted food) for small agricultural and processing enterprises, disaggregated by product category and life cycle stage (agriculture, transformation, and packaging).

The analysis indicates that fruit and vegetables are the most impactful category, with values close to 5,000 mPt/kg, predominantly driven by the agricultural stage. Meat follows as a secondary contributor, while fish also accounts for a visible share. Eggs, by contrast, have only a marginal impact within this cluster.

Overall, small enterprises show a more diversified impact distribution compared to large and medium enterprises, where single categories tend to dominate. In this case, fruit and vegetables remain the main hotspot, but meat and fish also represent relevant contributors.



These findings suggest that for small agricultural/processing enterprises, mitigation strategies should not only focus on fruit and vegetable waste but also address animal-based products (meat and fish), in order to effectively reduce the environmental burden of food waste.

The results for the other impact categories investigated (e.g. Climate Change, Acidification, Use of Fossil Resources, Land Use, Water Use, Human Toxicity – carcinogenic and non-carcinogenic) are provided in Annex C.

PRODUCTION AND PROCESSING CONCLUSIONS

The results obtained for the agricultural and processing sector highlight both common trends and differences across enterprise sizes.

In large enterprises, food waste is dominated by fruit and vegetables ($\approx 88\%$), with meat representing a secondary fraction ($\approx 12\%$). However, when impacts are expressed in terms of Single Score, meat emerges as the main hotspot, largely driven by the agricultural stage, while fruit and vegetables remain relevant due to their high absolute volumes.

Medium enterprises present a similar structure, with fruit and vegetables accounting for more than 90% of total waste. Yet, the impact profile is shaped by a dual contribution, where both fruit and vegetables and meat play a significant role.

Small enterprises show the highest relative share of fruit and vegetables ($\approx 95\%$), but their results are more diversified compared to larger operators. In this case, alongside fruit and vegetables, meat and fish also contribute to the overall environmental burden, making the profile less concentrated on a single category.

Overall, the analysis indicates that across all enterprise sizes, fruit and vegetables consistently represent the dominant waste stream in terms of quantities, whereas meat



waste constitutes the most critical hotspot in terms of impact intensity per kilogram discarded. This dual perspective underlines the importance of distinguishing between waste volumes and environmental significance: while fresh produce drives the largest share of food waste mass, even limited amounts of meat (and, to a lesser extent, fish) result in high environmental impacts.



RETAIL SECTOR

The clustering of retail operators was carried out on the basis of the total amount of food handled per week (kg/week). The following dimensional classes were defined:

Table 10: Dimensional classes

Class	Threshold (kg of food handled/week)
Large enterprises	> 100 kg
Medium enterprises	50 – 100 kg
Small enterprises	< 50 kg

The table below presents the distribution of food waste quantities (kg) and their relative shares (%) by food category, disaggregated according to enterprise size (large, medium, and small enterprises). The data include seven product categories: milk and dairy products, meat, packaged food, fruit and vegetables, bread, fish, and eggs. Reported values represent weekly average amounts, derived from primary data collection and expressed both in absolute terms and as percentage contribution to the total waste generated within each enterprise class.

This breakdown highlights structural differences across enterprise sizes: while large enterprises show a predominance of bread waste (97,1% of the total), medium enterprises are mainly affected by meat waste (71,4%), and small enterprises display a more balanced distribution, with meat (59,7%) and bread (36,4%) representing the largest fractions. Such evidence is relevant for identifying hotspots in the food supply chain and for supporting targeted mitigation strategies in the subsequent LCA modelling phase.

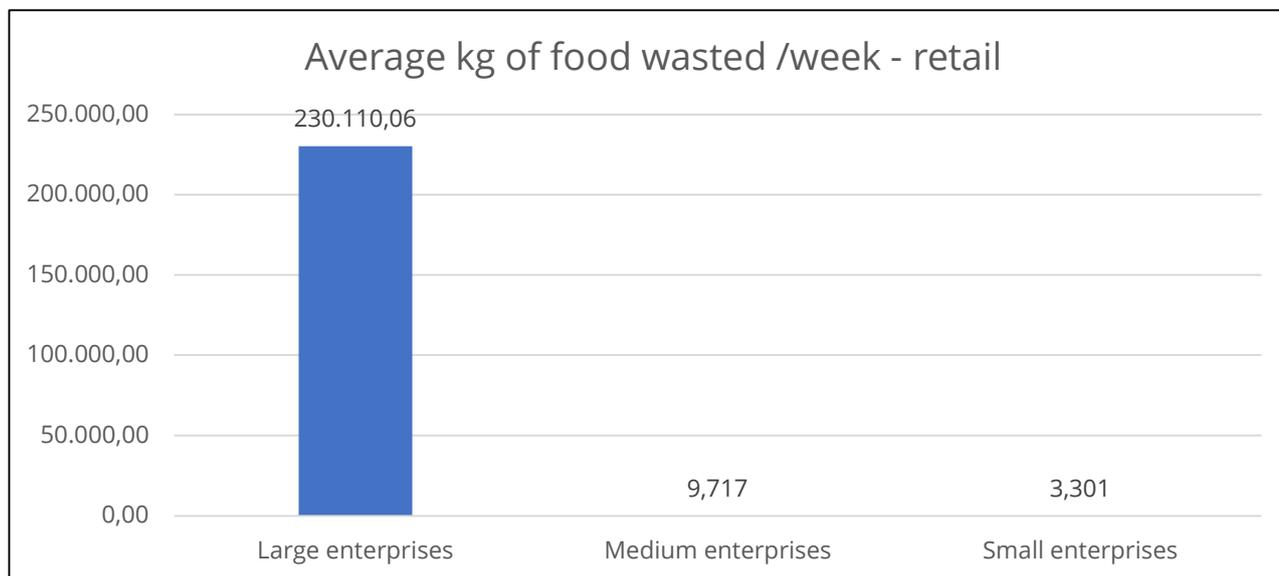


Table 11: distribution of food waste quantities (kg) and their relative shares (%) by food category

Food Category	Large enterprises	%	Medium enterprises	%	Small enterprises	%
Milk and dairy products	543,78	0,2%	0,019	0,2%	0,008	0,2%
Meat	1.021,38	0,4%	6,942	71,4%	1,971	59,7%
Packaged food	51,82	0,0%	0,003	0,0%	0,001	0,0%
Fruit and vegetables	4.449,72	1,9%	0,273	2,8%	0,073	2,2%
Bread	223.546,55	97,1%	2,310	23,8%	1,203	36,4%
Fish	471,43	0,2%	0,170	1,7%	0,046	1,4%
Eggs	25,37	0,0%	0,001	0,0%	0,000	0,0%
TOTAL	230.110,06	100,0%	9,717	100,0%	3,301	100,0%

For the retail category, the impacts related to the consumption phase as well as the transport from the supermarket to the final consumer’s destination have been excluded from the system boundaries.

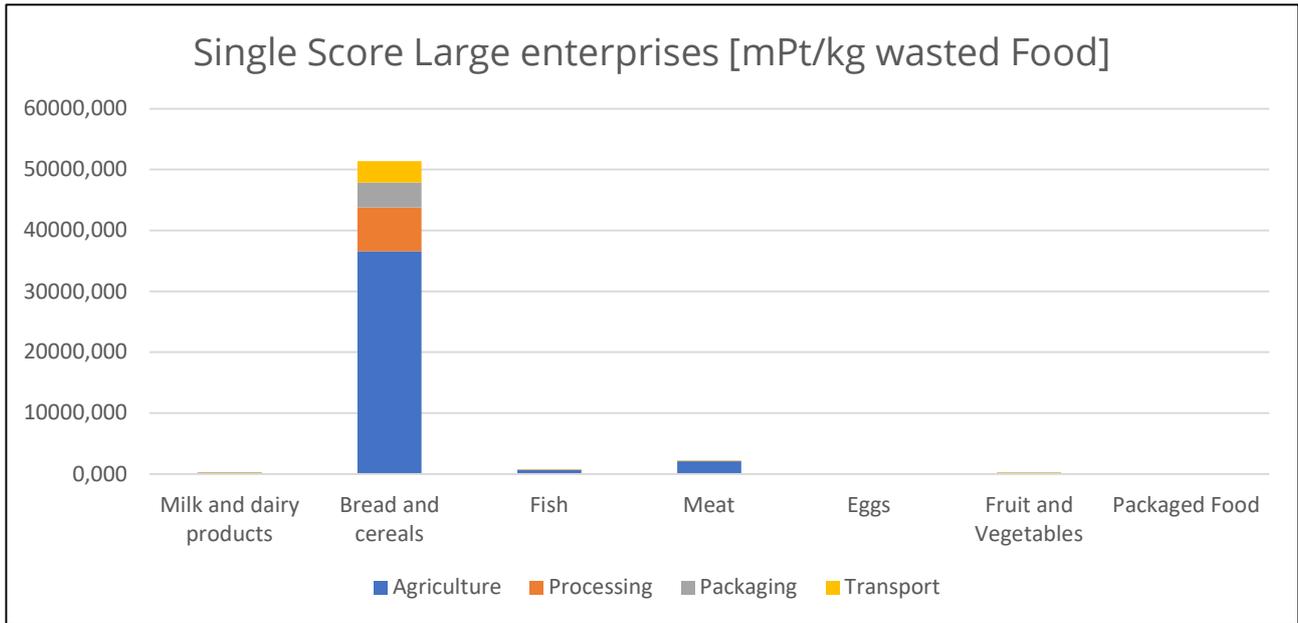
Graph 30: average Kg of wasted food in a week – Retail Sector



RETAIL RESULTS

Large enterprises

Graph 31: Single Score results for Big Enterprises



The graph shows the Single Score results (mPt/kg of wasted food) for different product categories, disaggregated by life cycle stage (agriculture, transformation, packaging, and transport).

The results clearly highlight that bread and cereals represent the dominant hotspot, with an environmental burden significantly higher than all other food categories. This contribution is mainly driven by the agricultural phase, which accounts for the largest share of the impact, followed by transformation, packaging, and transport.

Other categories (meat, fish, milk and dairy, fruit and vegetables, packaged food, and eggs) exhibit comparatively minor contributions, almost negligible when compared to bread and cereals. Meat and fish show a visible contribution, again mostly related to



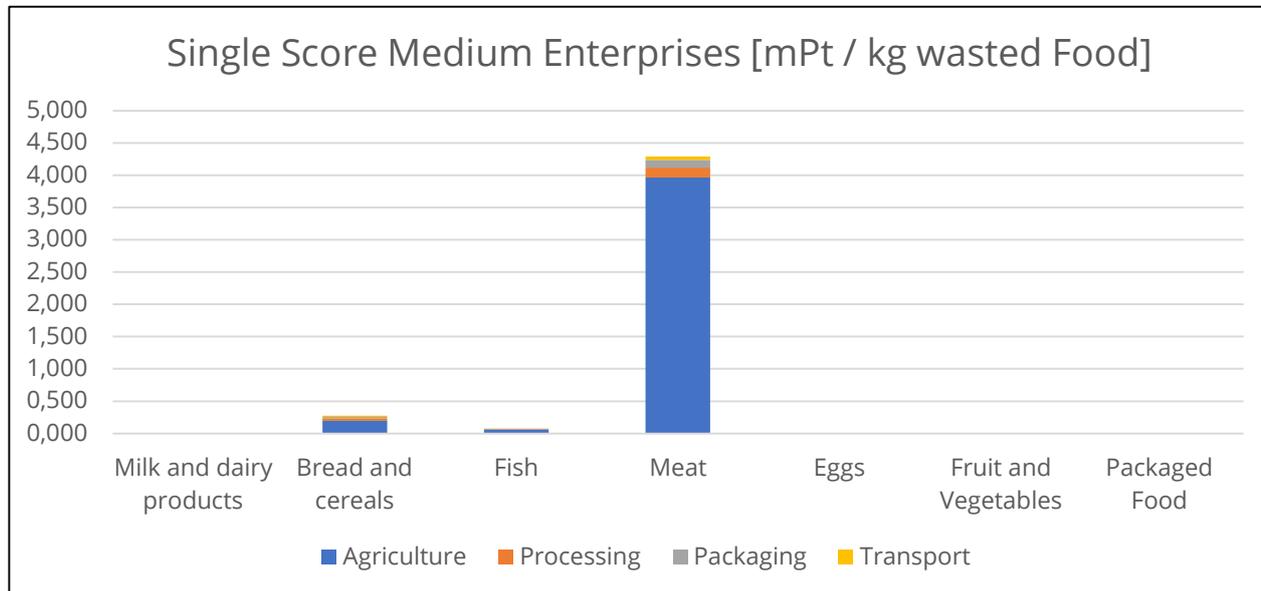
agricultural production, while for the other categories the impacts are close to zero in relative terms.

Overall, the results suggest that the waste of bread and cereals is by far the most critical driver of environmental impacts, both due to the absolute quantities wasted and the intensive agricultural inputs associated with cereal production. This confirms the importance of targeting waste reduction strategies in this product group as a priority in order to achieve effective mitigation across the retail sector.

In Annex C, the results are reported also with reference to the other impact categories considered in the study.

Medium enterprises

Graph 32: Single Score results for Medium Enterprises



The figure shows the Single Score results (mPt/kg of wasted food) by product category, with contributions disaggregated by life cycle stage (agriculture, transformation, packaging, and transport).



The results indicate that meat waste is by far the most impactful category per kilogram of product wasted, reaching values above 4,000 mPt/kg. The main contribution arises from the agricultural stage, reflecting the high resource intensity and environmental burden associated with livestock production. Transformation and packaging provide additional, though comparatively smaller, contributions.

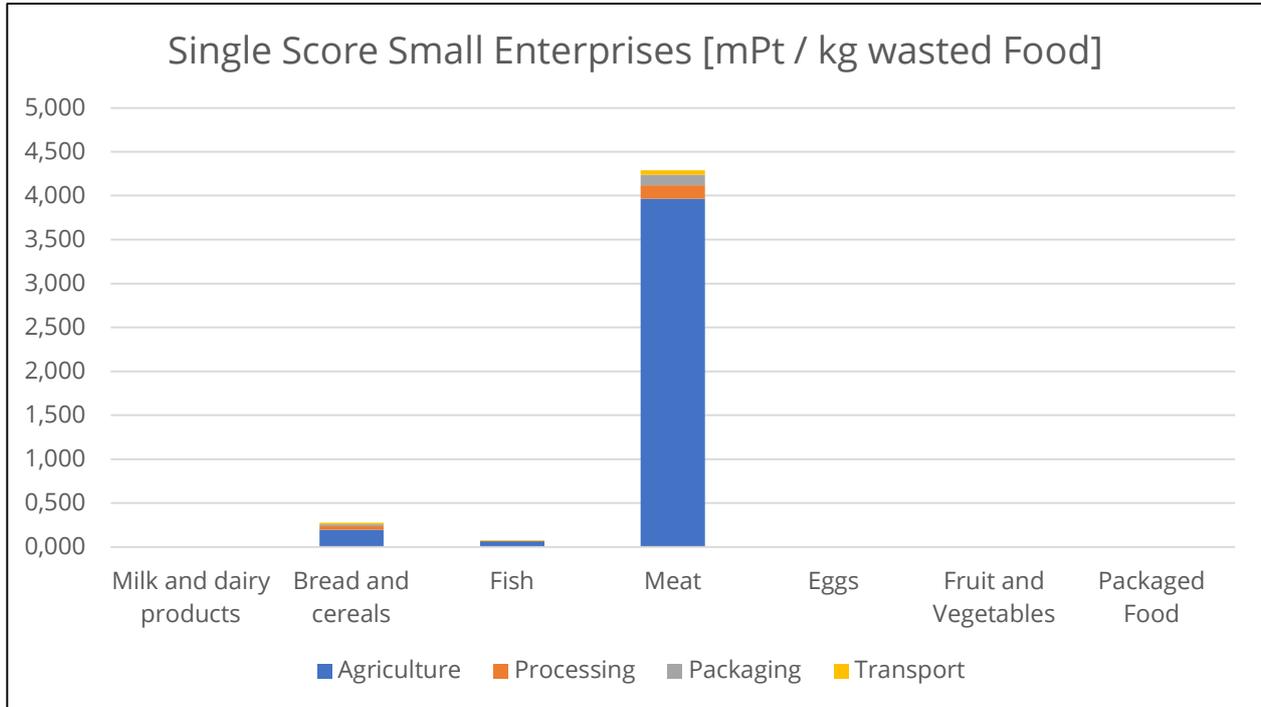
Other categories such as bread and cereals, fish, and milk and dairy products show significantly lower impacts per unit of waste, while eggs, fruit and vegetables, and packaged food register negligible values in comparison.

In Annex C, the results are reported also with reference to the other impact categories considered in the study.



Small enterprises

Graph 33: Single Score results for Small Enterprises



The figure illustrates the Single Score results (mPt/kg of wasted food) for small enterprises, broken down by life cycle stage (agriculture, transformation, packaging, and transport).

For this cluster, meat waste clearly emerges as the dominant contributor per unit of wasted food, with a score exceeding 4,000 mPt/kg, largely driven by the agricultural phase. This confirms the high environmental intensity of meat production, even when waste occurs in relatively small quantities.

Other categories such as bread and cereals and fish show visible, but much lower, contributions, while milk and dairy products, eggs, fruit and vegetables, and packaged food are negligible in comparison.



In Annex C, the results are reported also with reference to the other impact categories considered in the study.

RETAIL CONCLUSIONS

The comparative analysis of the three enterprise clusters highlights how the environmental relevance of food waste strongly depends both on the quantities discarded and on the intrinsic impact intensity of the wasted product.

- In large enterprises, bread and cereals clearly dominate the overall impact profile, due to the very high amounts wasted despite their relatively lower impact per kilogram.
- In medium enterprises, meat emerges as the primary hotspot, reflecting a composition of waste where animal products are more prevalent.
- In small enterprises, the results show that even limited amounts of meat waste translate into disproportionately high environmental burdens, confirming its critical role when impacts are expressed on a per-kilogram basis.

Overall, the findings demonstrate a dual perspective: on one hand, reduction strategies in large enterprises should prioritize high-volume categories such as bread and cereals; on the other, for medium and small enterprises, efforts should focus on high-impact categories such as meat and fish.



HOSPITALITY SECTOR

The clustering of retail operators was carried out on the basis of the total amount of food handled per week (kg/week). The following dimensional classes were defined:

Table 12: Dimensional classes

Class	Threshold (kg of food handled/week)
Large enterprises	> 100 kg
Medium enterprises	50 – 100 kg
Small enterprises	< 50 kg

The table presents the distribution of food waste quantities (kg/week) and percentages by product category for large, medium, and small Food Service enterprises.

Table 13: Distribution of food waste quantities (kg) and their relative shares (%) by food category

Food Category	Large enterprises	%	Medium enterprises	%	Small enterprises	%
Milk and dairy products	522,23	80,8%	1,840	25,1%	1,218	43,4%
Meat	70,20	10,9%	3,007	41,0%	0,586	20,9%
Packaged food	25,71	4,0%	0,200	2,7%	0,689	24,5%
Fruit and vegetables	0,09	0,0%	1,000	13,6%	0,126	4,5%
Bread	18,90	2,9%	1,215	16,6%	0,157	5,6%
Fish	0,00	0,0%	0,000	0,0%	0,000	0,0%
Eggs	9,00	1,4%	0,070	1,0%	0,033	1,2%
TOTAL	646,14	100,0%	7,332	100,0%	2,808	100,0%

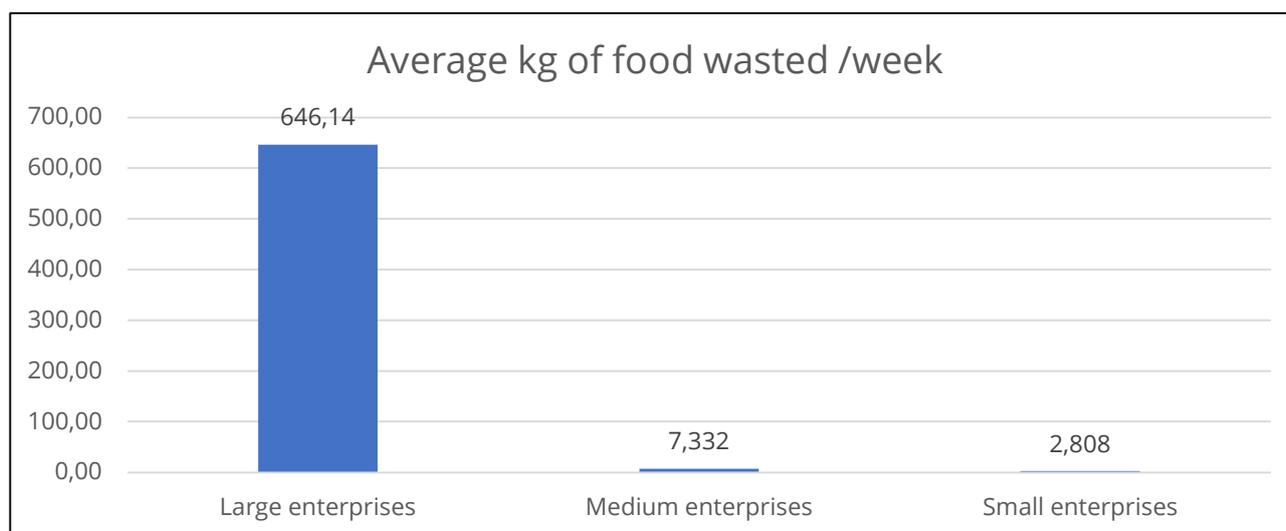
- Large enterprises show a strong predominance of milk and dairy products (80,8%), followed by meat (10,9%) and packaged food (4,0%). Other categories represent only marginal contributions.
- Medium enterprises present a more diversified profile, with meat as the main contributor (41,0%), followed by dairy (25,1%), bread (16,6%), fruit and vegetables (13,6%), and smaller shares from packaged food (2,7%) and eggs (1,0%).



- Small enterprises display a waste composition more evenly distributed across categories: milk and dairy (43,4%) and packaged food (24,5%) are the most relevant, followed by meat (20,9%) and smaller fractions of bread, fruit and vegetables, and eggs.

Overall, the results highlight a shift in waste composition depending on enterprise size: while large Food Service operators are mainly characterized by dairy waste, medium enterprises show a strong incidence of meat waste, and small enterprises report a more balanced distribution, with a relevant share of packaged food.

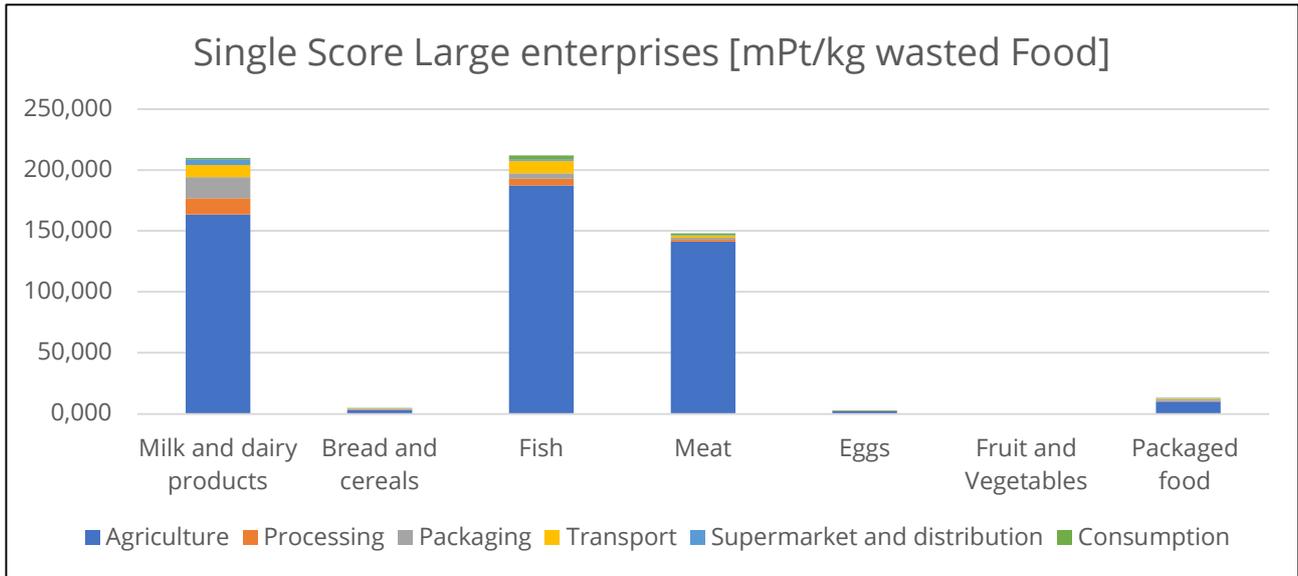
Graph 34: average Kg of wasted food in a week – Retail Sector



FOOD SERVICE SECTOR RESULTS

Large enterprises

Graph 35: Single Score results for Big Enterprises



The figure shows the Single Score results (mPt/kg of wasted food) for large Food Service enterprises, broken down by product category and life cycle stage.

The analysis highlights that the highest impacts are linked to milk and dairy products, fish, and meat, with scores exceeding 150,000–200,000 mPt/kg. In all these categories, the agricultural stage is the dominant contributor, reflecting the resource- and emission-intensive nature of livestock and fish production systems. Transformation, packaging, transport, and distribution provide additional but comparatively smaller contributions.

Bread and cereals, eggs, fruit and vegetables, and packaged food show relatively low single-score values, indicating that their waste plays a minor role in the overall impact profile of large Food Service operators.

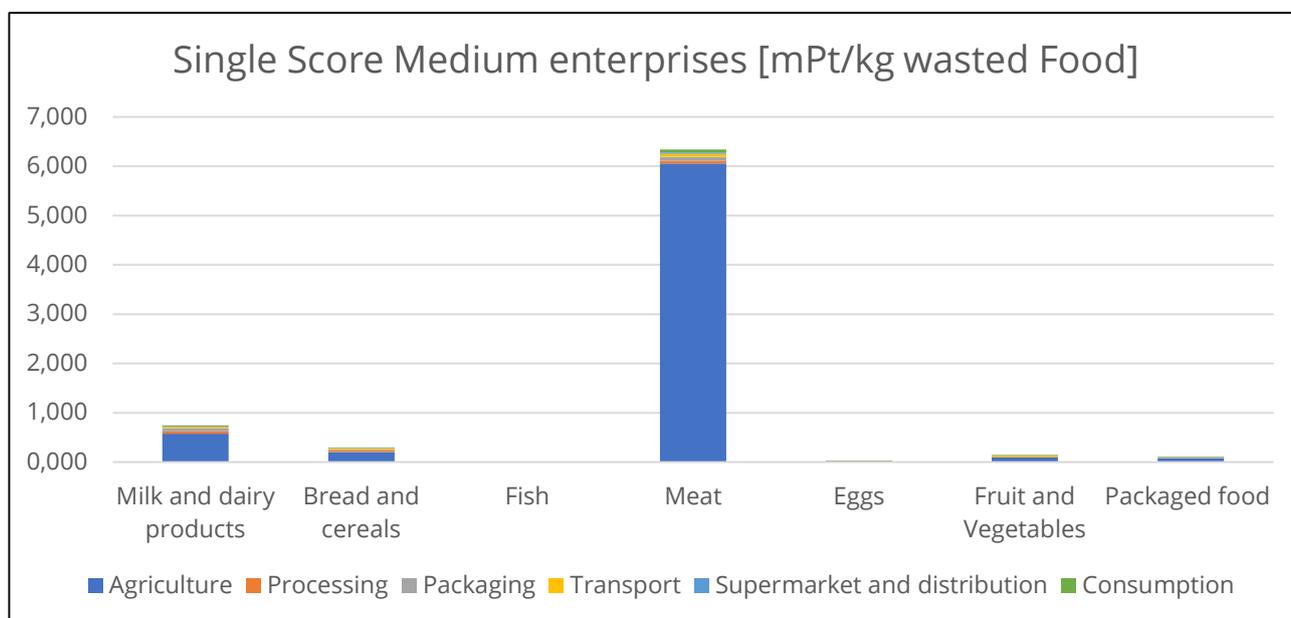


In conclusion, for large enterprises in the Food Service sector, the waste of animal-based products (milk and dairy, fish, and meat) represents the main environmental hotspot, confirming the need for targeted waste prevention measures in these categories to effectively reduce environmental burdens.

The results for the other impact categories investigated are reported in Annex C.

Medium enterprises

Graph 36: Single Score results for Medium Enterprises



The figure illustrates the Single Score results (mPt/kg of wasted food) for medium Food Service enterprises, disaggregated by food category and life cycle stage.

The results show a clear predominance of meat waste, with values exceeding 6,000 mPt/kg, making it by far the most impactful category in this cluster. The main driver is the agricultural stage, which accounts for the vast majority of the impacts, reflecting the intensive resource use and emissions of livestock production.



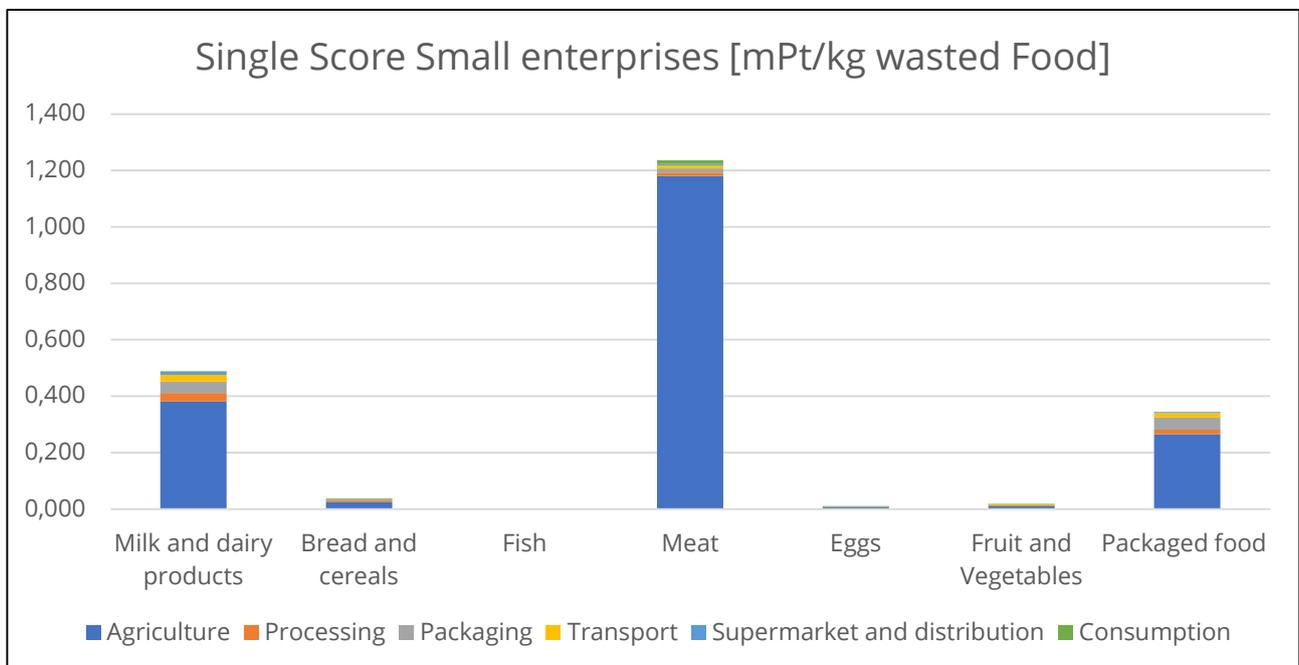
Milk and dairy products and bread and cereals present significantly lower contributions, although still visible compared to other categories. Eggs, fruit and vegetables, and packaged food register negligible scores, while fish does not appear in the dataset for this enterprise class.

The results for the other impact categories investigated are reported in Annex C.

Overall, the analysis highlights that in medium-sized Food Service enterprises, meat waste represents the critical environmental hotspot, even when compared to traditionally relevant categories such as dairy. This underlines the importance of implementing waste prevention strategies focused on meat products in order to achieve significant reductions in environmental impacts.

Small enterprises

Graph 37: Single Score results for Small Enterprises



The figure presents the Single Score results (mPt/kg of wasted food) for small Food Service enterprises, disaggregated by product category and life cycle stage.

The analysis shows that meat waste is the most impactful category, reaching values above 1,200 mPt/kg, largely driven by the agricultural stage. Milk and dairy products and packaged food follow, with intermediate contributions (around 400–500 mPt/kg and 300 mPt/kg, respectively). Bread and cereals, eggs, and fruit and vegetables register much lower values, while fish is not represented in this enterprise class.

Compared to medium and large Food Service enterprises, small operators exhibit a more balanced distribution of impacts across different categories, with relevant shares from both animal-based products (meat, dairy) and packaged food.

Overall, these results suggest that in small Food Service enterprises, mitigation strategies should not only target meat waste but also address dairy and packaged food, as they jointly account for a significant share of the environmental burden per kilogram of waste.

The results for the other impact categories investigated are reported in Annex C.

FOOD SERVICE SECTOR CONCLUSIONS

The comparative assessment across the three Food Service enterprise classes highlights how the environmental relevance of food waste varies depending on both the waste composition and the impact intensity of the product categories discarded.

- In large enterprises, the highest contributions are linked to milk and dairy products and fish, with meat also playing a significant role. These categories dominate due to the large volumes wasted, even if their single-score intensity differs.



- In medium enterprises, the results are strongly driven by meat waste, which largely outweighs all other categories. The agricultural stage is the predominant contributor, reflecting the high environmental footprint of livestock production.
- In small enterprises, the waste profile appears more balanced, with relevant shares from meat, milk and dairy products, and packaged food. While the absolute impacts are lower than in larger operators, the distribution shows multiple hotspots rather than a single dominant one.



CONSUMERS

For the assessment of the environmental impact associated with food waste generated by consumers, the data collected through the questionnaires administered in the different countries and regions involved in the project were used. All questionnaires were taken into account and the values were then processed by calculating the average for each food category. This approach made it possible to obtain a representative value of the average consumer behavior in relation to food waste.

The table below reports the average results, expressed by food category, which form the basis for the subsequent LCA modelling.

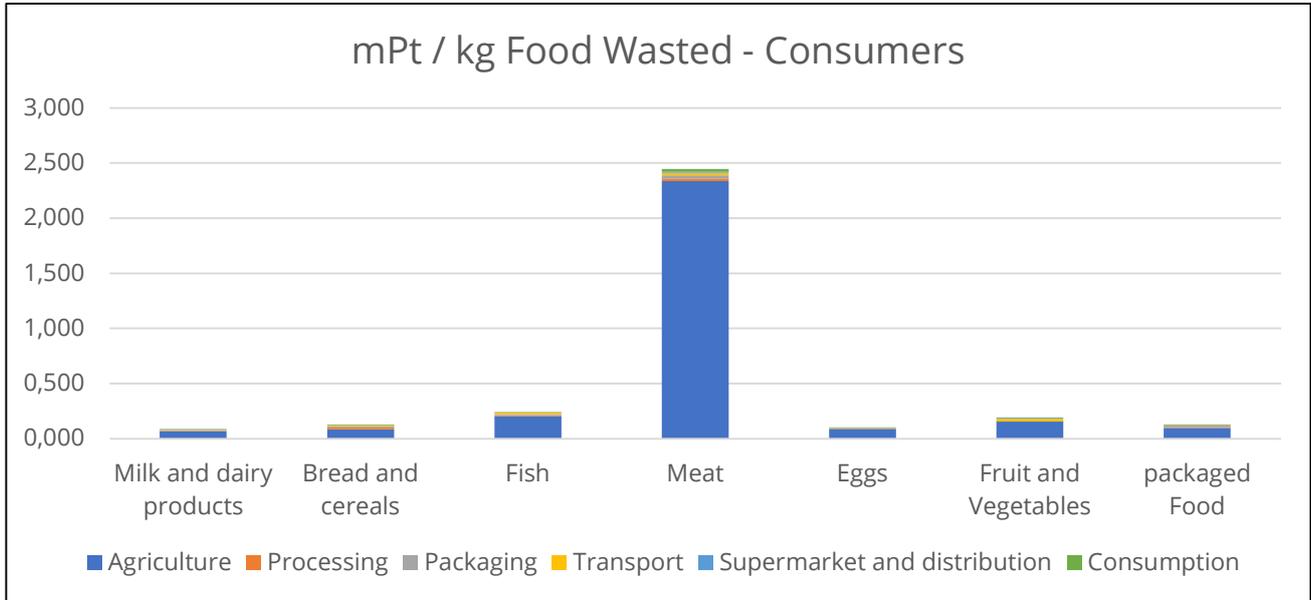
Table 14: Average consumer food waste by food category [kg/week]

Food category	Average food waste [kg/week]
Dairy	0,22
Bread and derivatives	0,53
Fish	0,14
Other	0,26
Meat	1,16
Eggs	0,36
Fruit and vegetables	1,61
TOTAL	4,28



CONSUMERS RESULTS

Graph 38: Single Score results for consumers



The results show that meat waste is by far the category with the highest environmental impact per kg wasted, with values exceeding 2,000 mPt/kg. This impact is mainly driven by the agricultural phase, which dominates the overall contribution compared to all other life-cycle stages.

For all the remaining categories (milk and dairy products, bread and cereals, fish, eggs, fruit and vegetables, packaged food), the impact is significantly lower and more evenly distributed among the different stages of the supply chain. In these cases, agriculture still represents the main contributor, followed by processing, packaging and transport, with consumption and supermarket/distribution phases playing only a minor role.

These results confirm that animal-based products (in particular meat, but also fish and dairy) have a higher environmental intensity per unit of food wasted compared to plant-based products (bread, fruit, vegetables, packaged foods).

The results for the other impact categories investigated are reported in Annex C.



5. KEY FINDINGS AND CONCLUSIONS

The audit carried out within the ECOFOODCYCLE project provided a first harmonized analysis of the quantities and environmental impacts of food waste in the Italian and Croatian regions involved. The results show that the most frequently wasted products are fresh and perishable items, particularly fruit, vegetables, and bread, which dominate in terms of mass. However, the categories with the highest environmental intensity are meat and fish: even relatively small amounts of waste in these sectors generate disproportionate impacts, especially due to the high greenhouse gas emissions and resource consumption associated with their production.

The analysis along the value chain confirms that agriculture represents the main hotspot for most food categories, while in processed products the processing and consumption phases also play a relevant role. This highlights the need to consider food waste not only as a loss of product, but as a multiplier of the impacts generated throughout all preceding stages of the supply chain.

The methodological approach adopted – combining bibliographic data with primary data collected through questionnaires – allowed for a balance between robustness and representativeness: the former ensured comparability with existing studies, while the latter provided an overview of real operating conditions. Nonetheless, some critical issues remain, particularly concerning the quality and completeness of the information collected in the production, distribution, and hospitality sectors, as well as the subjectivity of consumer responses. For this reason, the present results should be interpreted as a baseline indicative of the phenomenon rather than an exhaustive or



statistically normalized representation. Future surveys will need to be simplified, broadened and better supported, in order to increase completeness, consistency and representativeness.

To further improve the effectiveness and reliability of the audit results, it will be essential to broaden the reference sample, involving a larger and more diverse set of stakeholders along the supply chain. A wider and more homogeneous data collection would reduce the variability observed in the current surveys, ensure greater statistical representativeness, and strengthen the robustness of the environmental assessments. Only through a broader informational base will it be possible to achieve an ambitious and comparable picture capable of effectively guiding food waste prevention and reduction strategies.

Overall, this work represents a solid starting point for developing strategies for the prevention, recovery, and valorization of food waste. In particular, actions should focus both on high-volume categories (fruit, vegetables, and bread) and on high-impact categories (meat and fish). A multi-indicator approach, taking into account both the quantities and the environmental intensity of waste, is essential to identify effective priorities and maximize the environmental, economic, and social benefits of food waste reduction policies.



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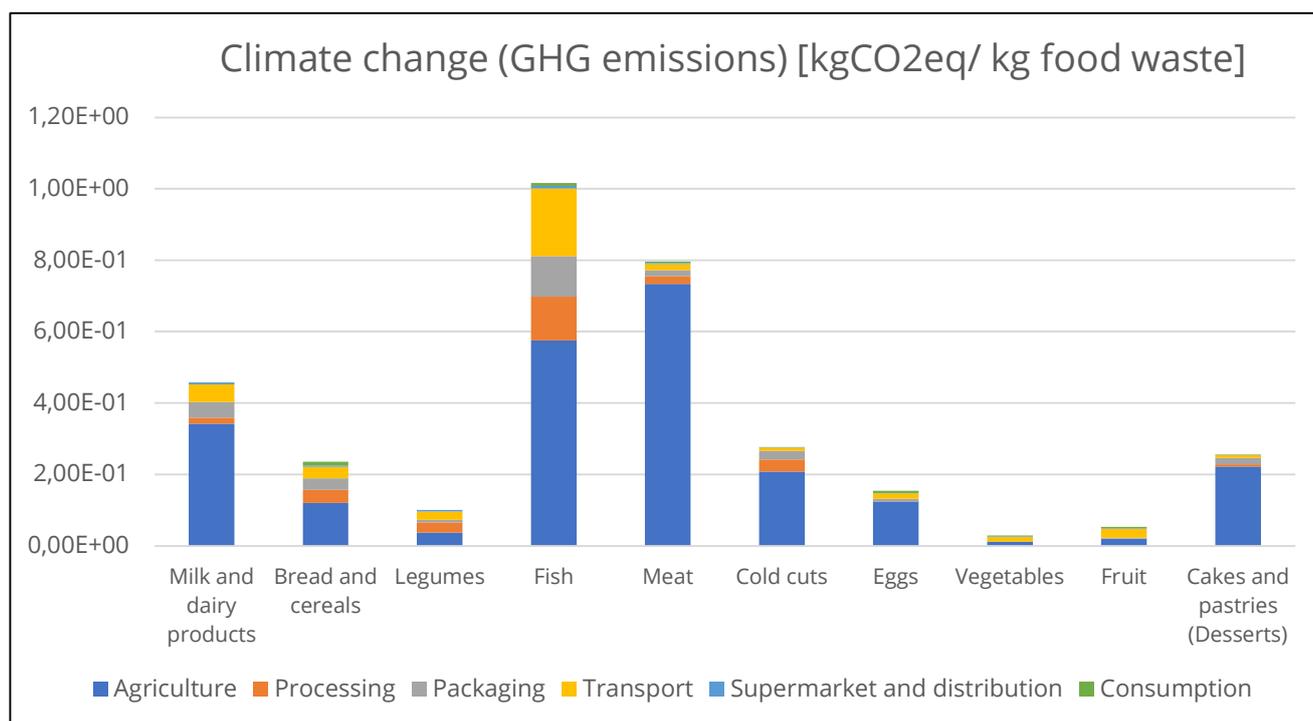
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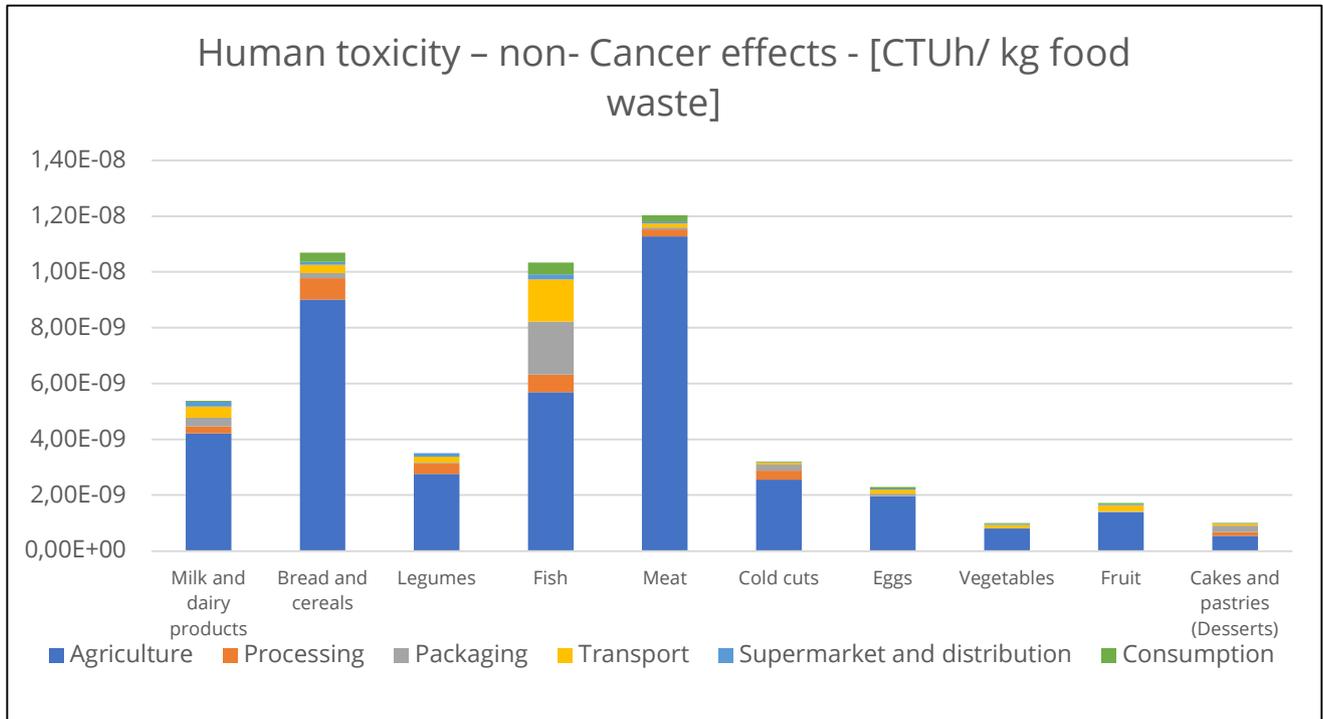
ANNEX A – OTHER INDICATORS BIBLIOGRAPHIC APPROCH

The following graphs present the results of the environmental assessment carried out on 1 kg of wasted food across different categories (meat, fish, dairy, cereals, fruit, vegetables, etc.). Each food type has been evaluated against several LCA indicators – from *Climate Change* to *Water Use*, including *Land Use*, *Acidification*, *Resource Use – Fossil fuels* and *Human Toxicity*. This graphical representation allows a direct comparison of how one kilogram of wasted product contributes differently to environmental impacts across the food supply chain.

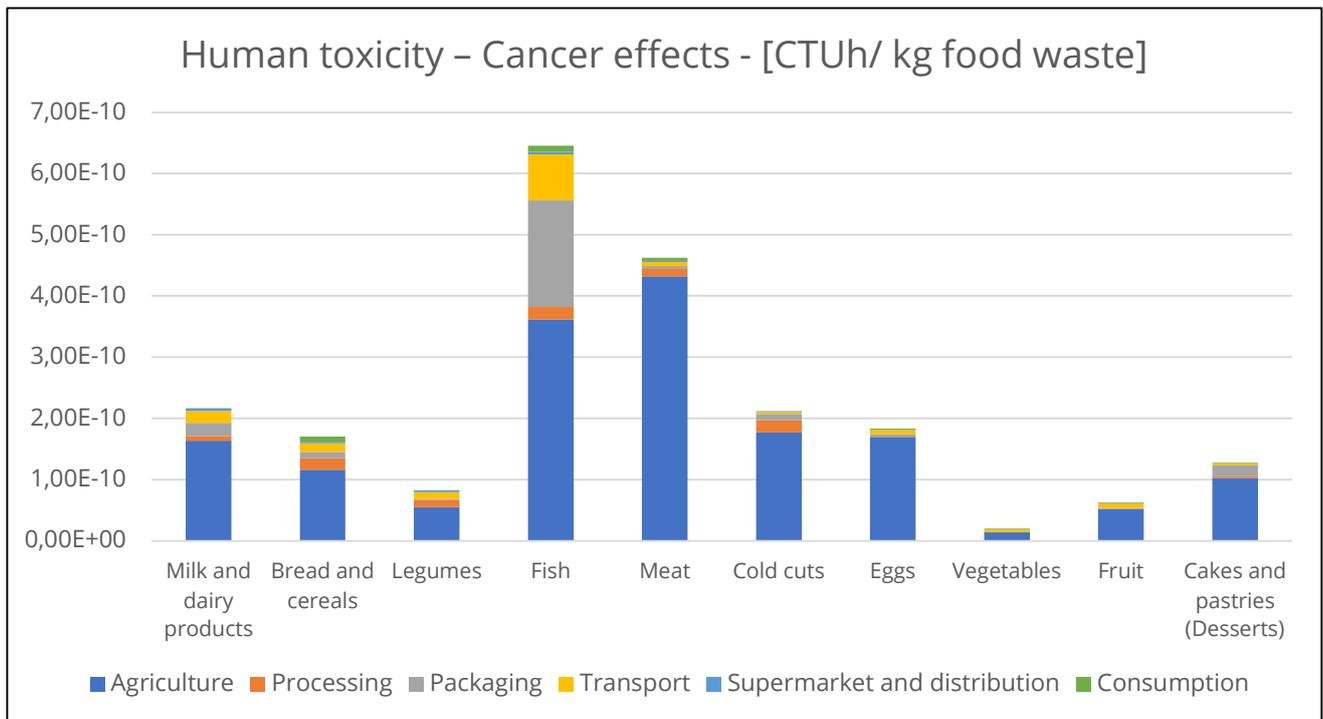
Graph 39: Food waste impact - Climate change (GHG emissions) [kgCO₂eq/ kg food waste]



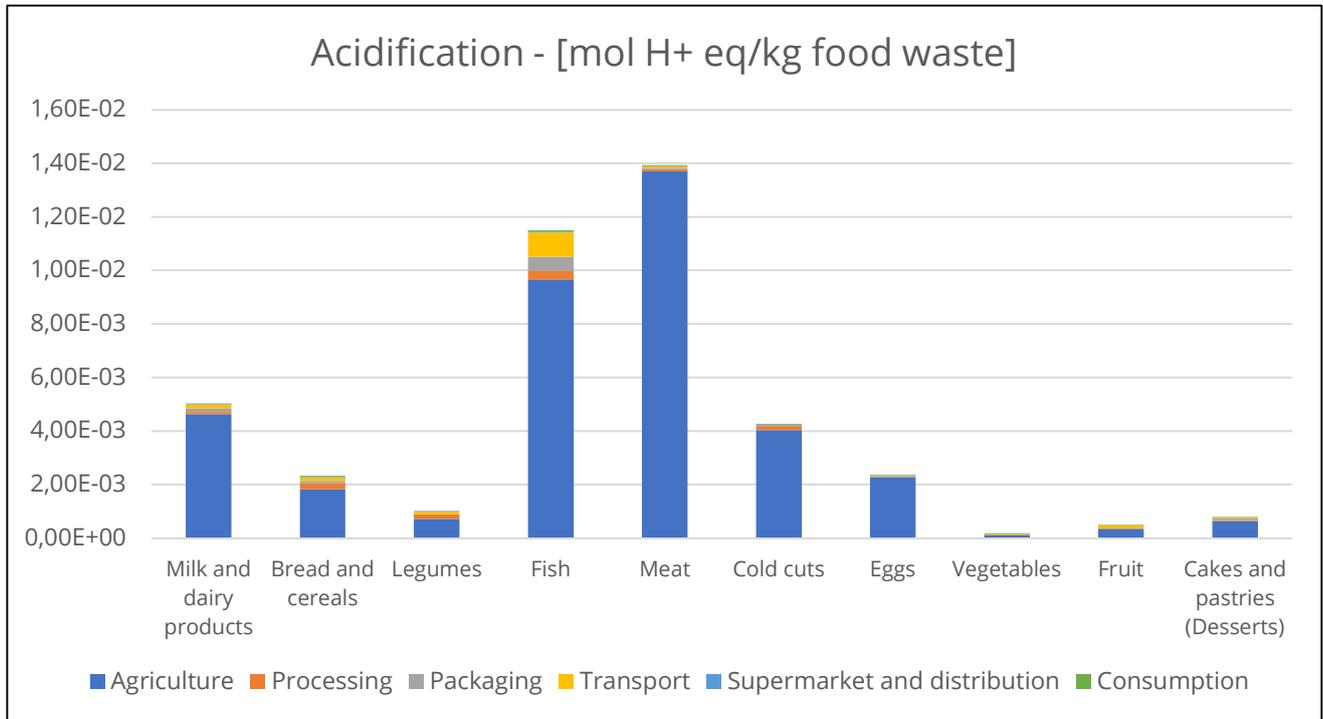
Graph 40: Food waste impact - Human toxicity – non- Cancer effects - [CTUh/ kg food waste]



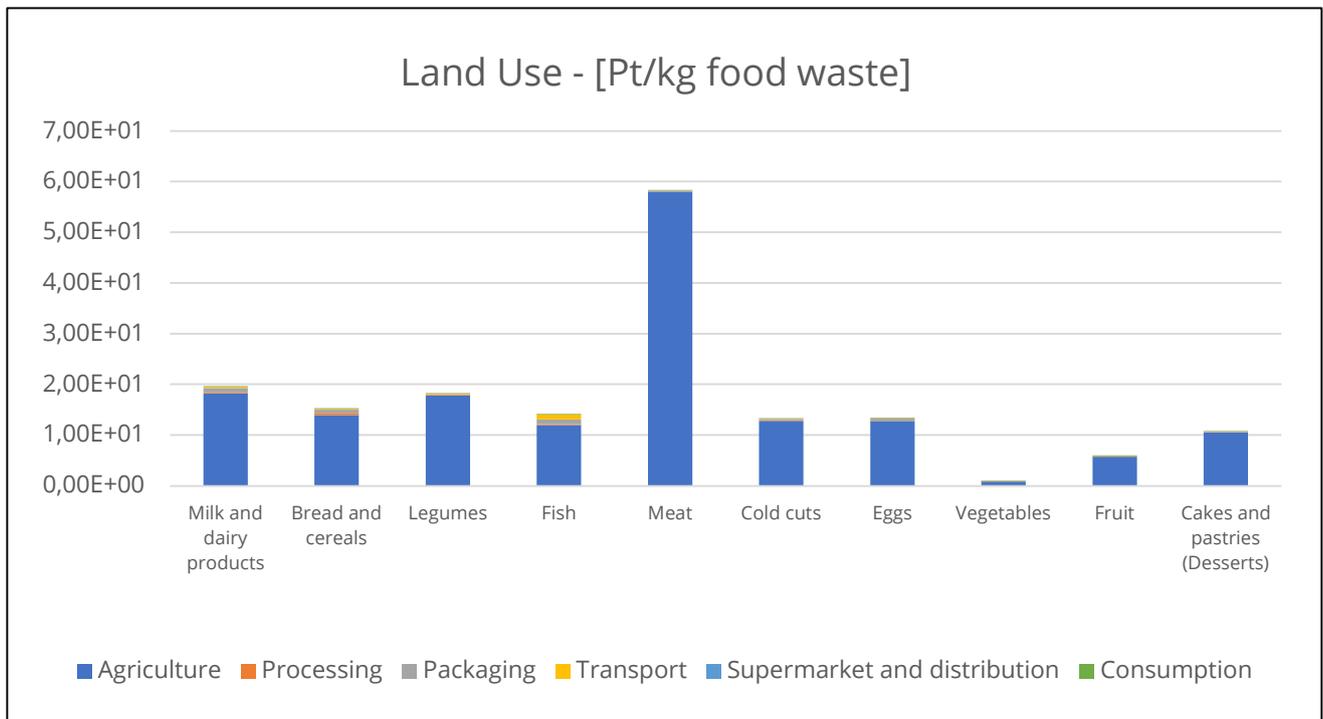
Graph 41: Food waste impact - Human toxicity – Cancer effects - [CTUh/ kg food waste]



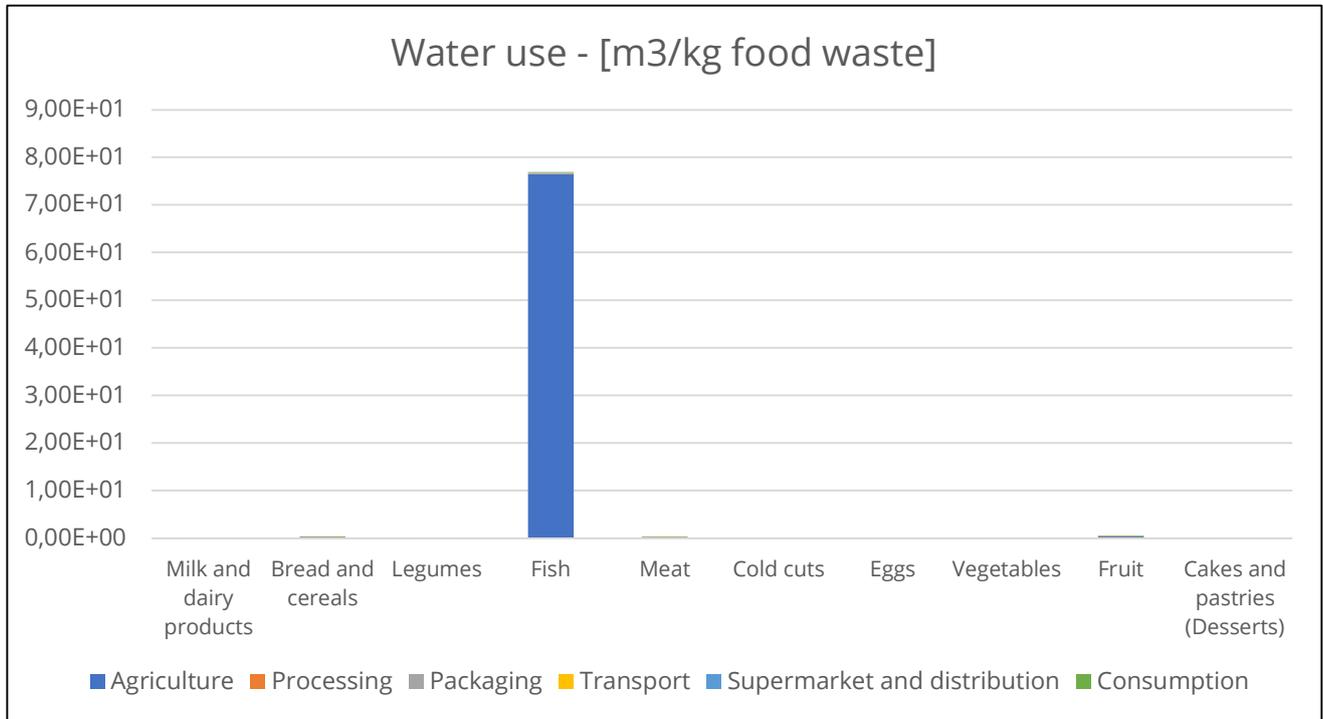
Graph 42: Food waste impact - Acidification - [mol H+ eq/kg food waste]



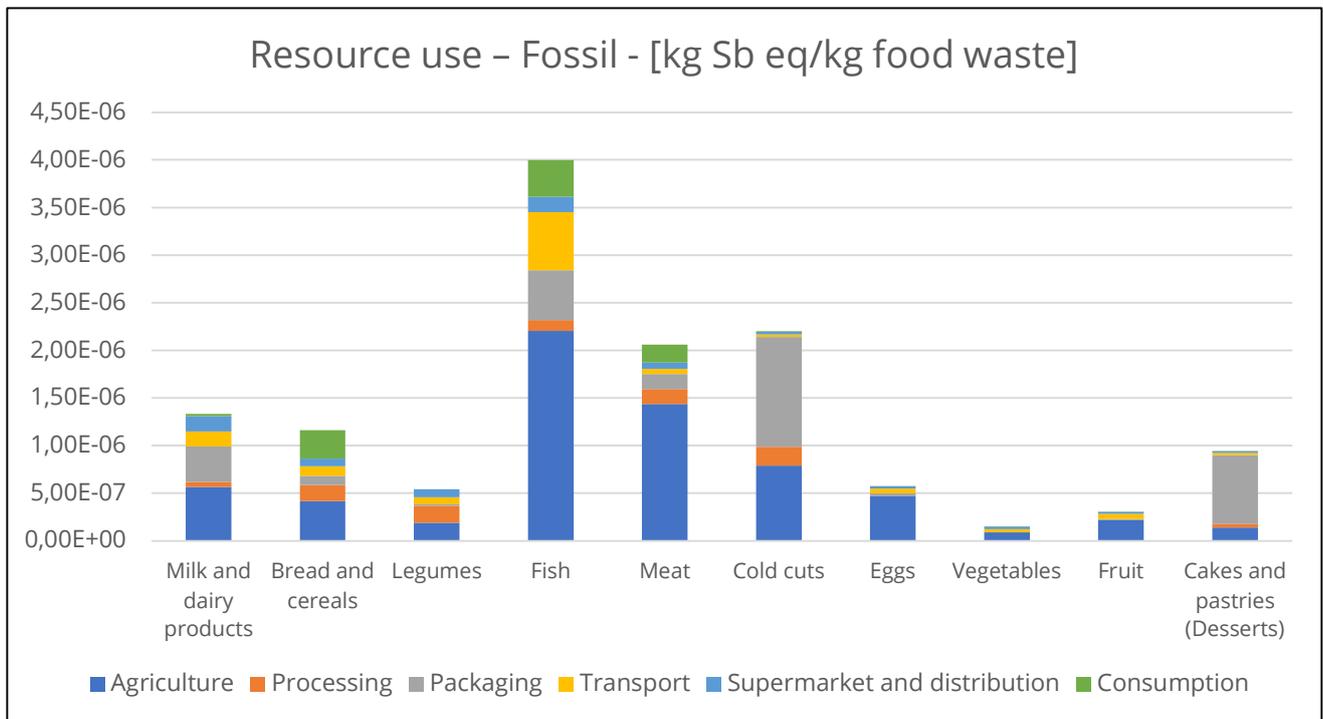
Graph 43: Food waste impact - Land Use - [Pt/kg food waste]



Graph 44: Food waste impact - Water use - [m3/kg food waste]



Graph 45: Food waste impact - Resource use – Fossil - [kg Sb eq/kg food waste]



The graphs clearly show that the environmental impact of food waste varies significantly depending both on the type of food and on the indicator considered. For example, meat and fish stand out with particularly high contributions to *Climate Change (GHG emissions)* and *Land Use*, as their production requires large amounts of resources and generates considerable emissions. In the case of *Water Use*, fish is the most relevant category, due to the high-water consumption associated with aquaculture and related agricultural processes. Other indicators, such as *Human Toxicity* or *Resource Use – Fossil fuels*, reveal different patterns, where not only agricultural production but also later stages such as packaging, processing and transport play a relevant role. This highlights that there is no single “most impactful” food item; instead, the waste of each product has distinct consequences depending on the perspective adopted. To fully understand the environmental significance of food waste, it is therefore essential to consider multiple indicators simultaneously.



ANNEX B – EXAMPLE OF THE QUESTIONNAIRE SUBMITTED FOR FOOD WASTE DATA COLLECTION

Annex B presents an example of the questionnaire applied within the data collection campaign, aimed at quantifying and characterizing food waste across the different stakeholder categories under investigation. In addition to the PDF/Word and hard-copy versions, the questionnaires were also made available through Google Forms in order to facilitate completion and streamline the processing of the collected data.

Table 15: example of the questionnaire submitted for food waste data collection

TYPE OF FOOD WASTE	%	kg	SPECIFIC CATEGORIES FOR TYPE OF FOOD WASTE <i>(complete if possible)</i>			%	kg	PACKAGING TYPE
MEAT			Fresh raw meat	Fresh red meat	TOTAL Fresh red meat			
					Beef e.g., steak, ground beef, brisket			
					Veal e.g. steaks, tenderloin, ground beef			
					Lamb/goat e.g., lamb chops, leg of lamb			
					Pork e.g., pork chops, ribs, tenderloin			
				Horse				
				Fresh white meat	TOTAL Fresh white meat			
					Chicken e.g. whole, breast, thighs, wings			
			Turkey					
			Game meat	e.g. duck, quail, feral pig, deer				
			Fresh packaged	Fresh packaged red meat	TOTAL Fresh packaged red meat			
					Beef e.g., steak, ground beef, brisket			
					Veal e.g. steaks, tenderloin, ground beef			
					Lamb/goat e.g., lamb chops, leg of lamb			



TYPE OF FOOD WASTE	%	kg	SPECIFIC CATEGORIES FOR TYPE OF FOOD WASTE <i>(complete if possible)</i>		%	kg	PACKAGING TYPE
			Fresh packaged white meat	Pork <i>e.g., pork chops, ribs, tenderloin</i>			
				Horse			
				TOTAL Fresh packaged white meat			
				Chicken <i>e.g. whole, breast, thighs, wings</i>			
				Turkey			
				Rabbit			
			Game meat	<i>e.g. duck, quail, feral pig, deer</i>			
			Deli meat <i>e.g. Cured ham, Cooked Ham, Salami</i>				
			Processed Meat <i>e.g. Sausages, hot dogs, wurstel, hamburger, meatballs</i>				
			EGGS			Chicken Eggs	
Eggs from other birds <i>e.g. quail, duck, ostrich</i>							
Processed eggs <i>e.g. Liquid, Pasteurized, powder</i>							
FISH			Fresh Fish, Shellfish & Crustaceans <i>(Sold at the counter)</i>				
			Frozen Fish, Shellfish & Crustaceans <i>(Whole, filleted or sliced)</i>				
			Canned & Packaged Fish <i>(Long shelf-life products)</i>				
			Processed Fish Products <i>(Ready-to-eat or semi-processed dishes)</i>				
BREAD & PASTA			Fresh products <i>e.g. Fresh bread, Fresh pasta (Tagliatelle, tortellini)</i>				
			Medium shelf-life Products <i>e.g. pre-cooked bread, instant noodles</i>				
			Long shelf-life products <i>e.g. Dry pasta, crackers</i>				
DAIRY & PLANT BASED PRODUCTS			Short shelf-life Dairy products <i>e.g. Fresh milk, yogurt, Kefir, Fresh cheese - mozzarella, ricotta, mascarpone</i>				
			Medium shelf-life Dairy products <i>e.g. UHT milk, soft/semi-hard cheese, processed/spreadable cheese, Ghee, butter</i>				
			Long shelf-life Dairy products <i>e.g. powdered/condensed milk, Industrial Ice cream, hard cheese</i>				
FRUITS & VEGETABLES			Whole fresh				
			Special Product <i>e.g. fruit cups, baby carrots, veggie sticks, ready to eat</i>				



TYPE OF FOOD WASTE	%	kg	SPECIFIC CATEGORIES FOR TYPE OF FOOD WASTE <i>(complete if possible)</i>	%	kg	PACKAGING TYPE
			Canned & Shelf-Stable <i>e.g. legumes, tomatoes, mushrooms, dried fruits, frozen</i>			
PACKAGED/ PROCESSED FOOD (excluded what mentioned above)			Short shelf-life products <i>e.g. croissant, pastries, cakes, prep meals</i>			
			Medium shelf-life products <i>e.g. frozen pizza, ready to cook meals, fruit juice with preservatives</i>			
			Canned and Shelf-Stable Foods <i>e.g. Dehydrated soups and ready meals</i>			
OTHER (SPECIFY)						



Table 16: example of the questionnaire submitted for food waste data collection – Google Forms

QUANTIFICATION OF FOOD WASTE

FOOD WASTE TYPE - This section quantifies the amount and types of food waste generated weekly, to estimate waste levels and associated environmental impacts.

Note: If it is not possible to quantify waste for a specific food category, please select the "ND" column.

Meat (kg/week):

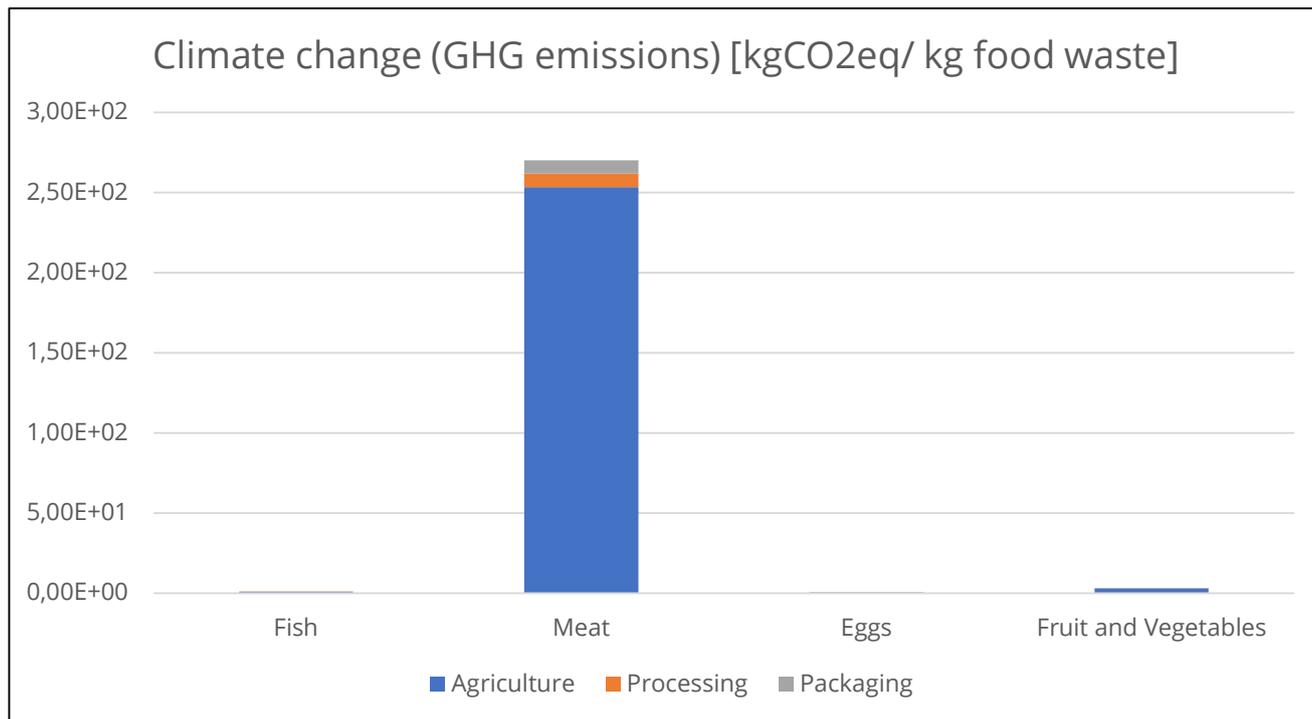
	0	0.01-0.1	0.1-0.25	0.25-0.5	>0.5	ND
BEEF (e.g. steak, ground beef)	<input type="radio"/>					
VEAL (e.g. steaks, fillets, minced meat)	<input type="radio"/>					
LAMB/GOAT (e.g. lamb chops, lamb leg)	<input type="radio"/>					
PORK (e.g. pork chops, spare ribs)	<input type="radio"/>					
HORSE	<input type="radio"/>					
CHICKEN (e.g. whole, breast, thighs, wings)	<input type="radio"/>					
TURKEY	<input type="radio"/>					
RABBIT	<input type="radio"/>					



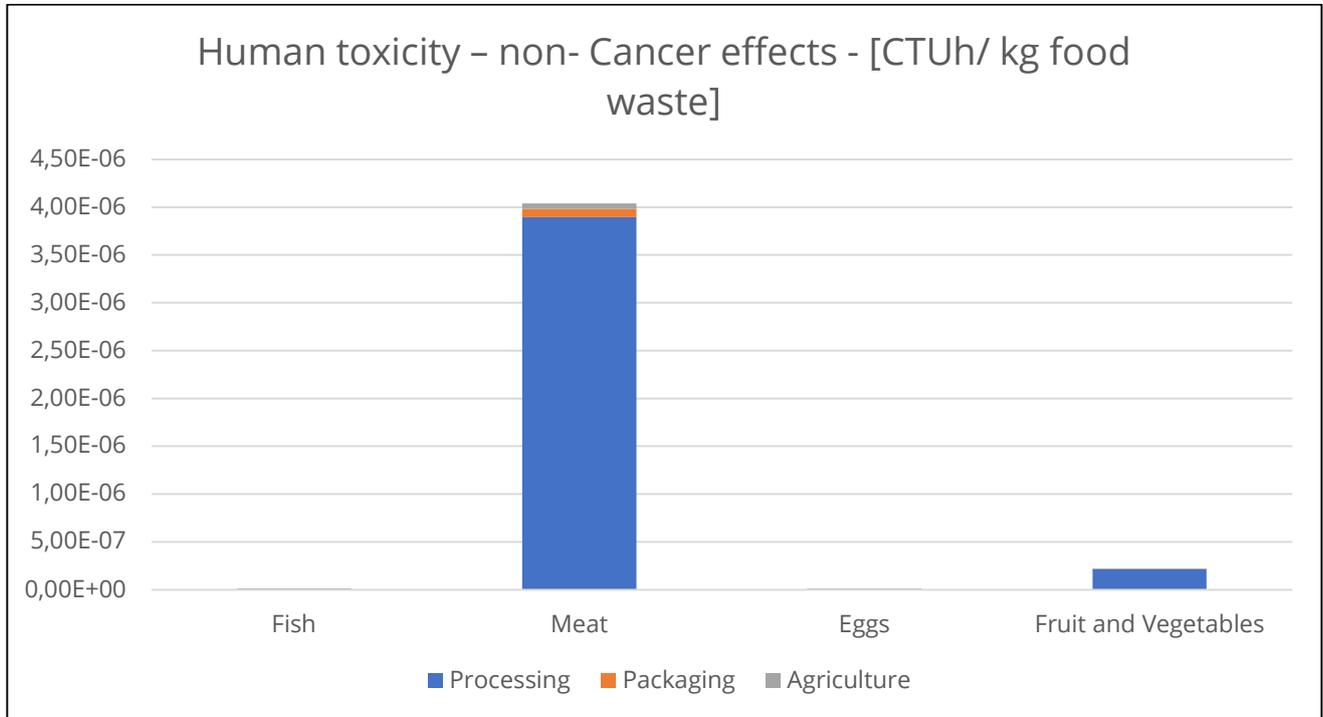
ANNEX C: OTHER INDICATORS QUESTIONNAIRE DATA APPROCH

Big enterprises

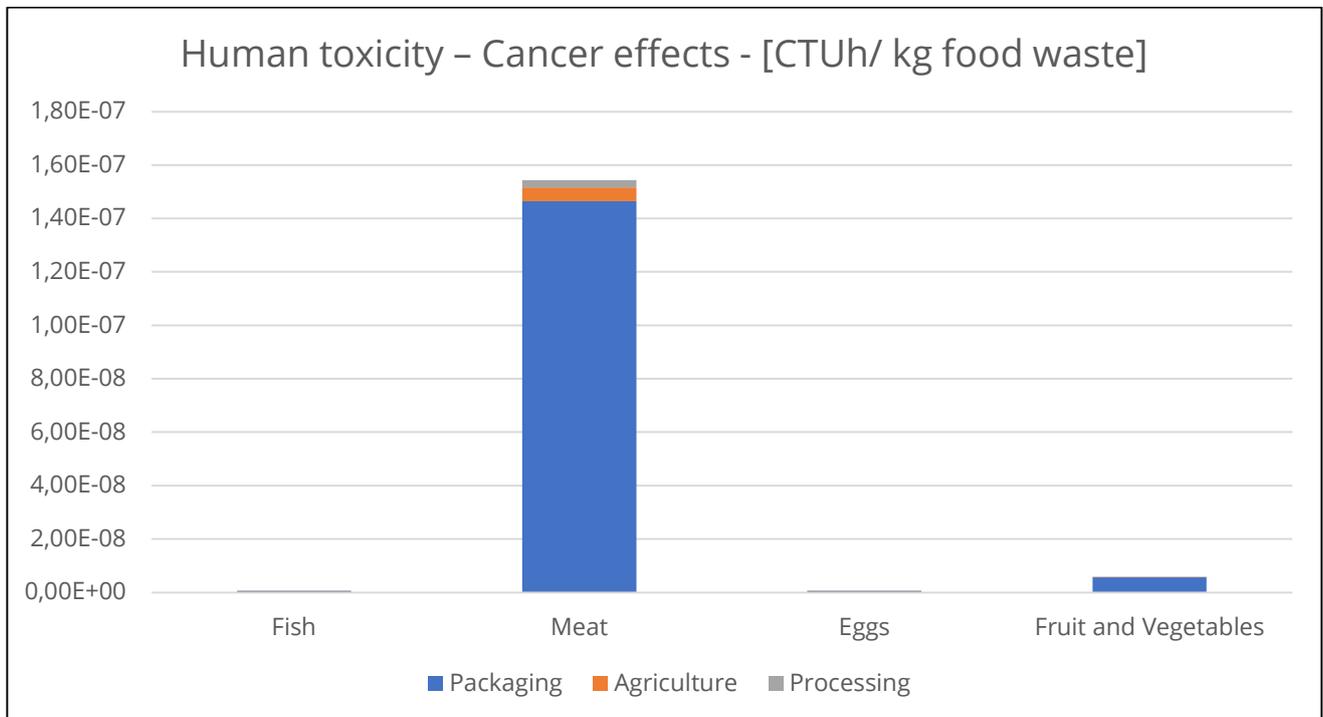
Graph 46: Food waste impact - Climate change (GHG emissions) [kgCO₂eq/ kg food waste]



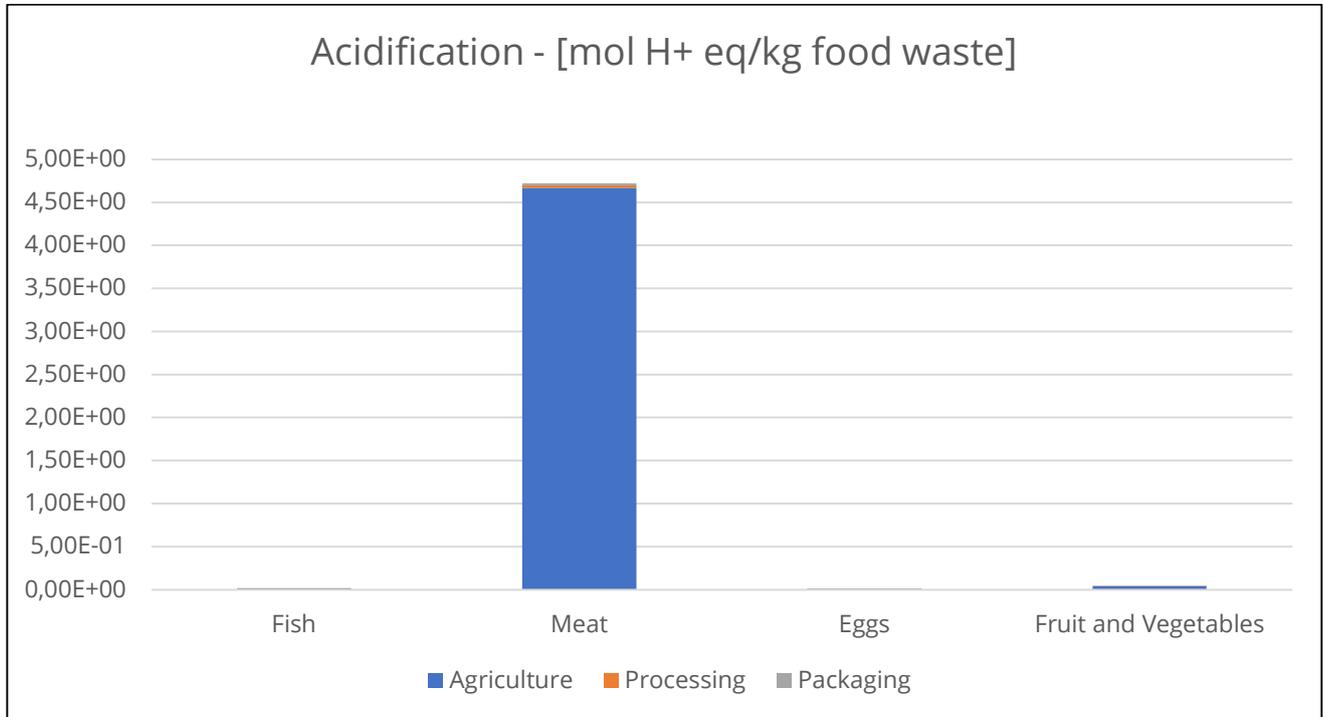
Graph 47: Food waste impact - Human toxicity – non- Cancer effects - [CTUh/ kg food waste]



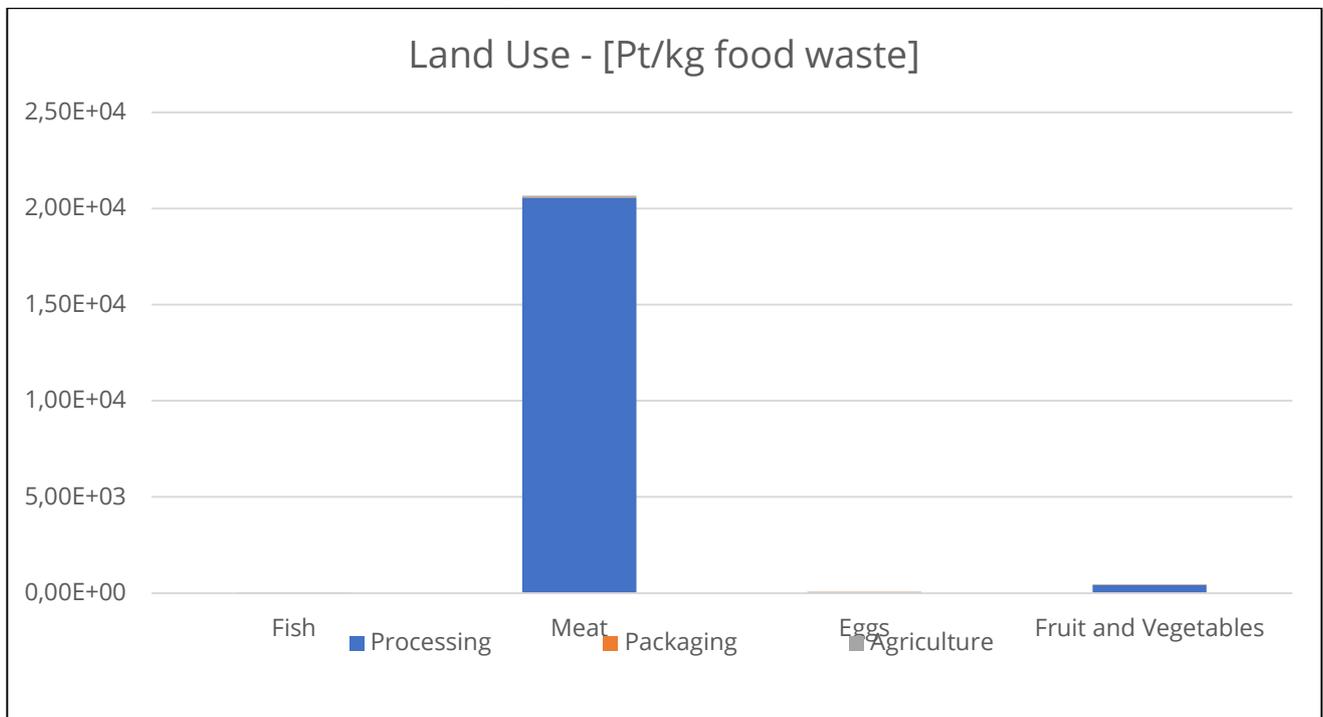
Graph 48: Food waste impact - Human toxicity – Cancer effects - [CTUh/ kg food waste]



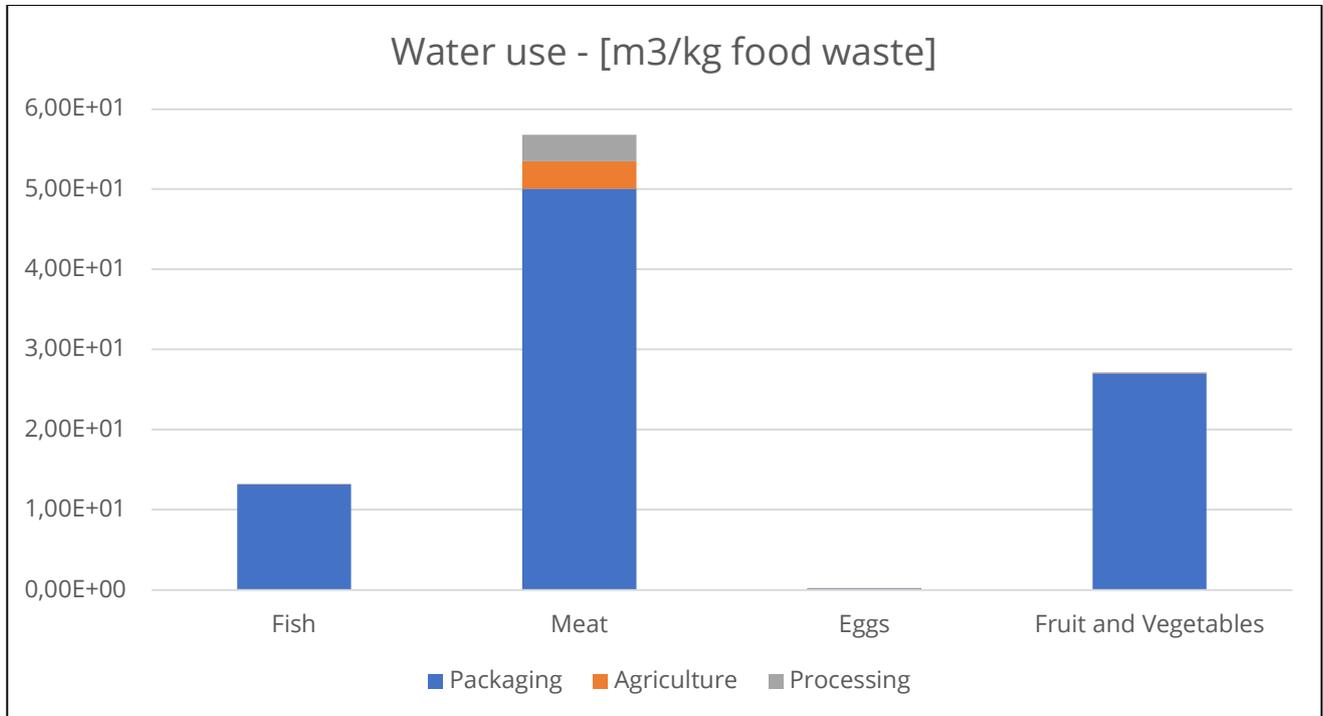
Graph 49: Food waste impact - Acidification - [mol H+ eq/kg food waste]



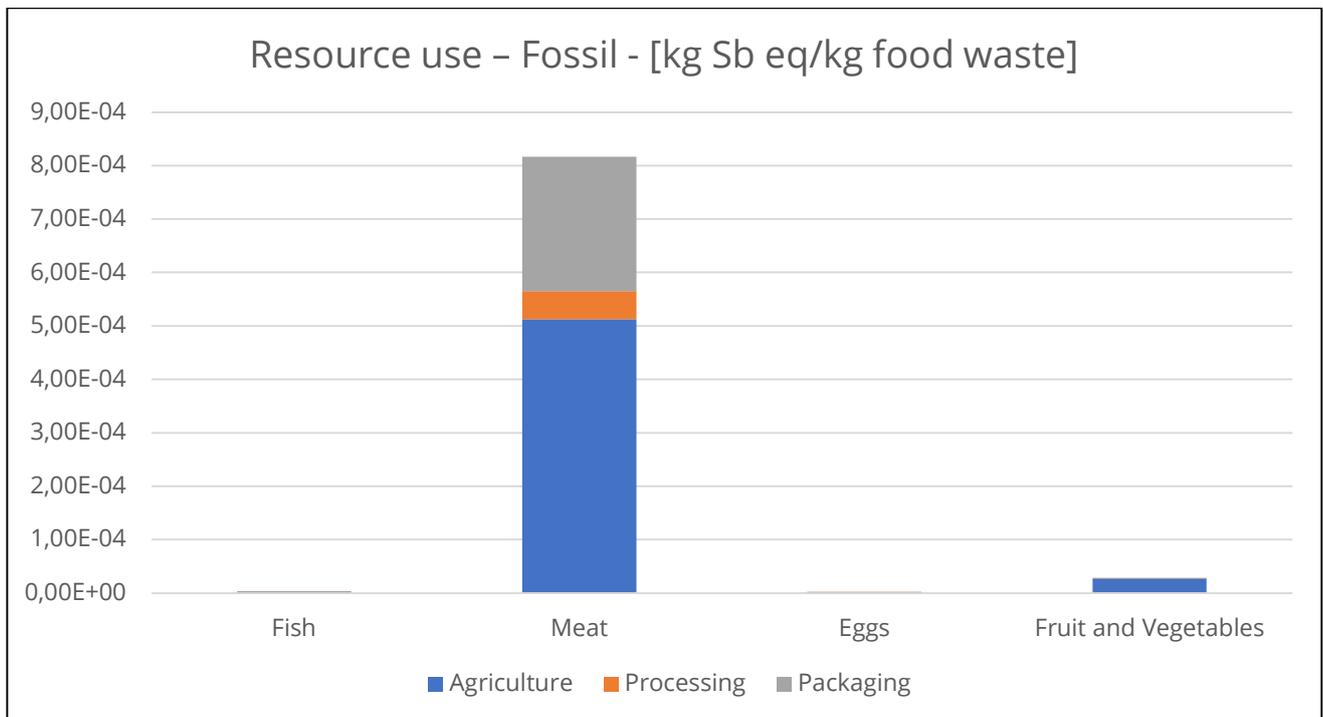
Graph 50: Food waste impact - Land Use - [Pt/kg food waste]



Graph 51: Food waste impact - Water use - [m3/kg food waste]

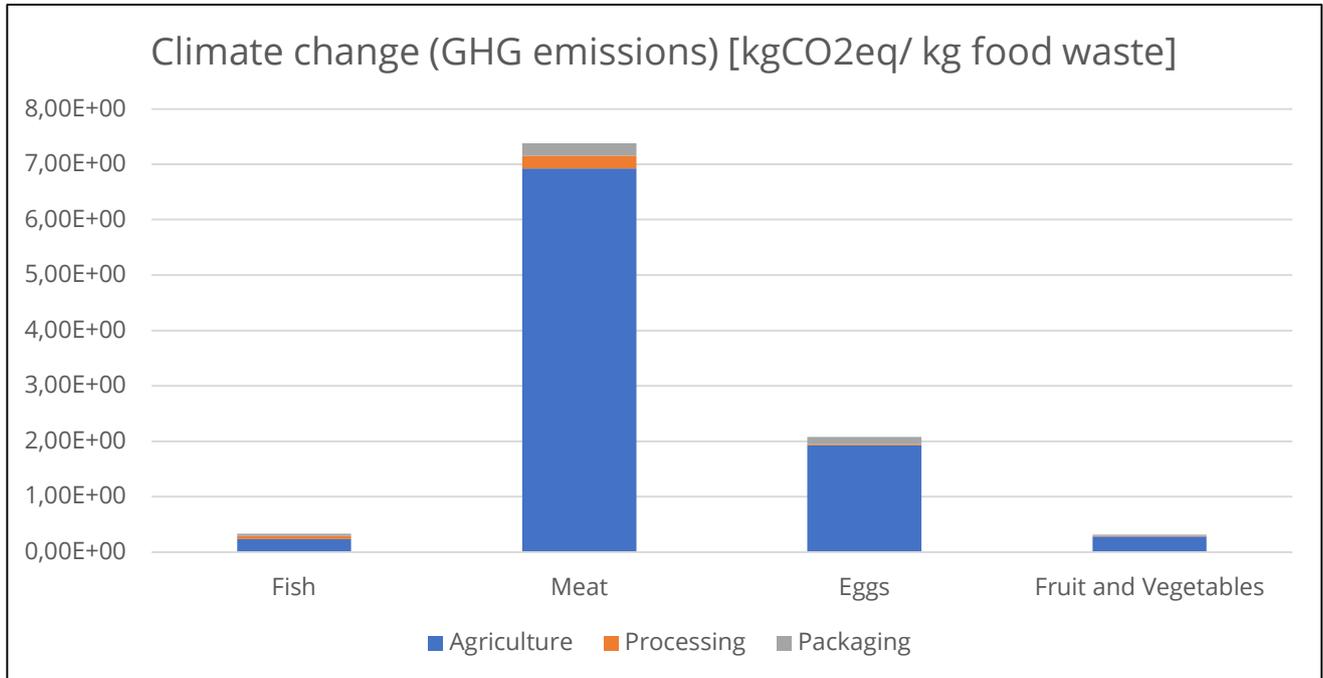


Graph 52: Food waste impact - Resource use – Fossil - [kg Sb eq/kg food waste]

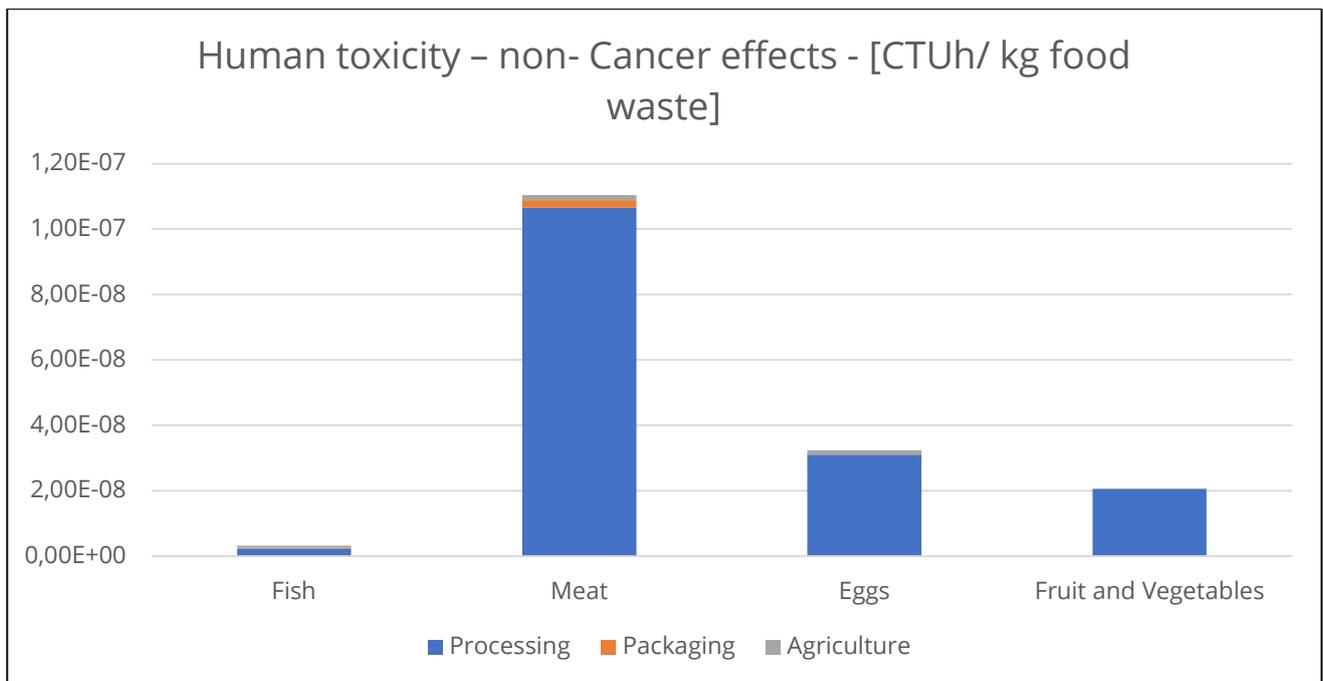


Medium enterprises

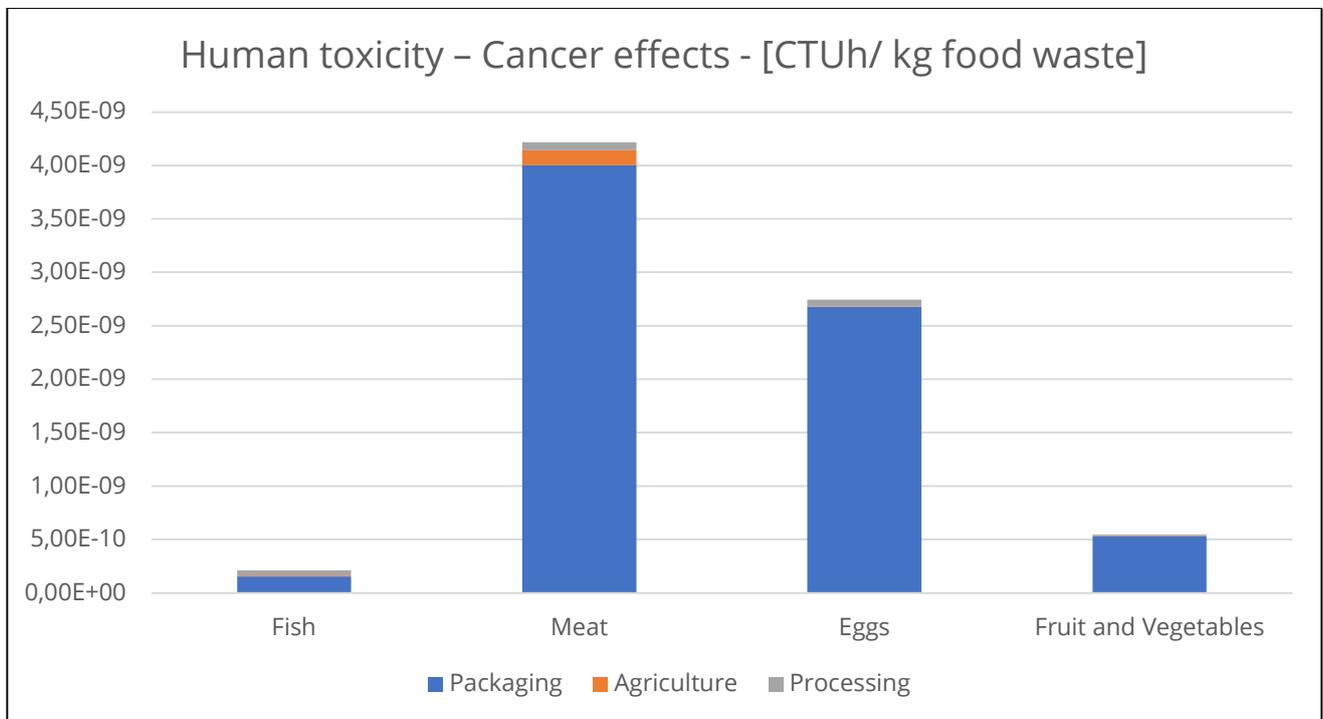
Graph 53: Food waste impact - Climate change (GHG emissions) [kgCO₂eq/ kg food waste]



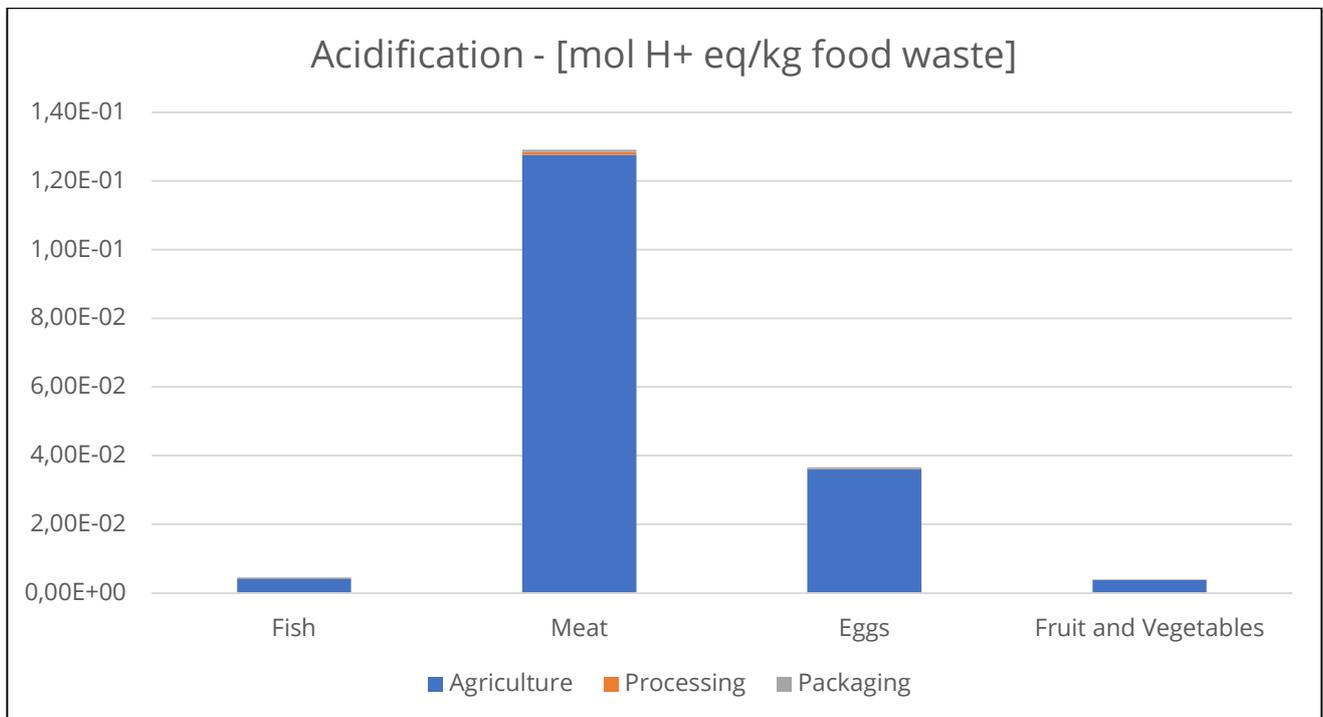
Graph 54: Food waste impact - Human toxicity – non- Cancer effects - [CTUh/ kg food waste]



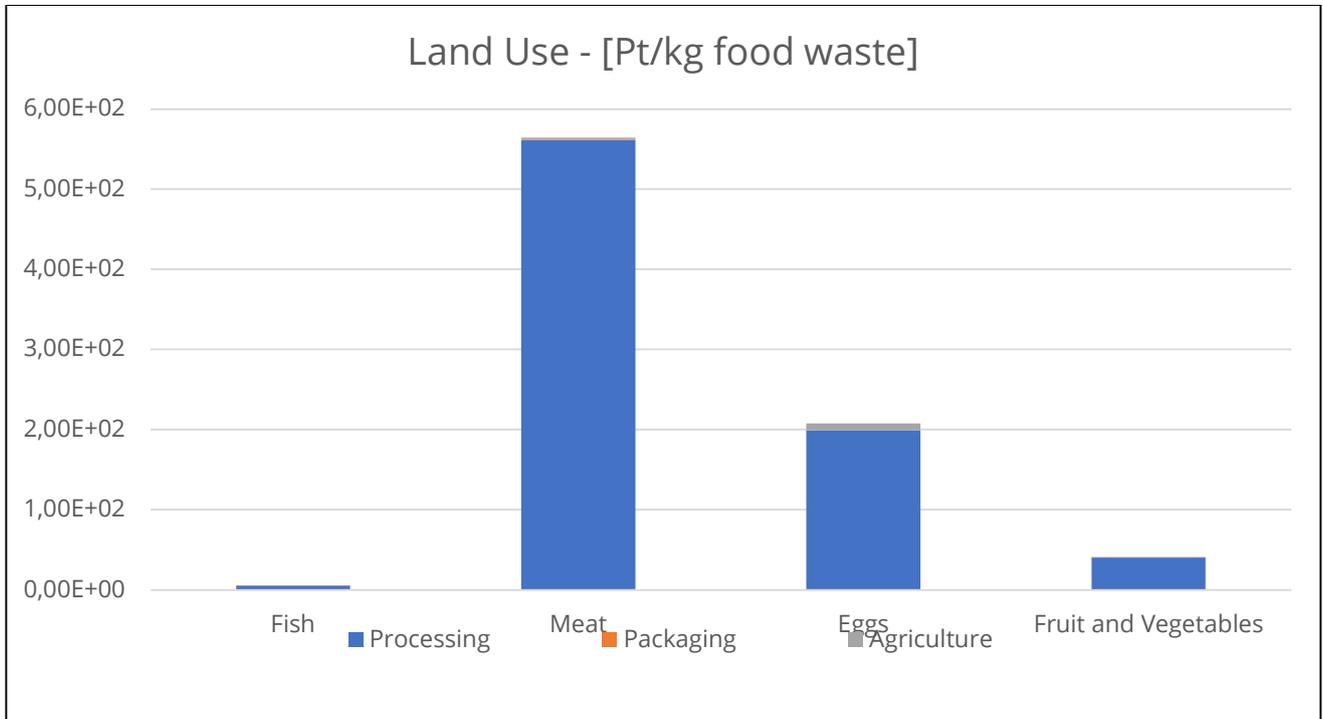
Graph 55: Food waste impact - Human toxicity - Cancer effects - [CTUh/ kg food waste]



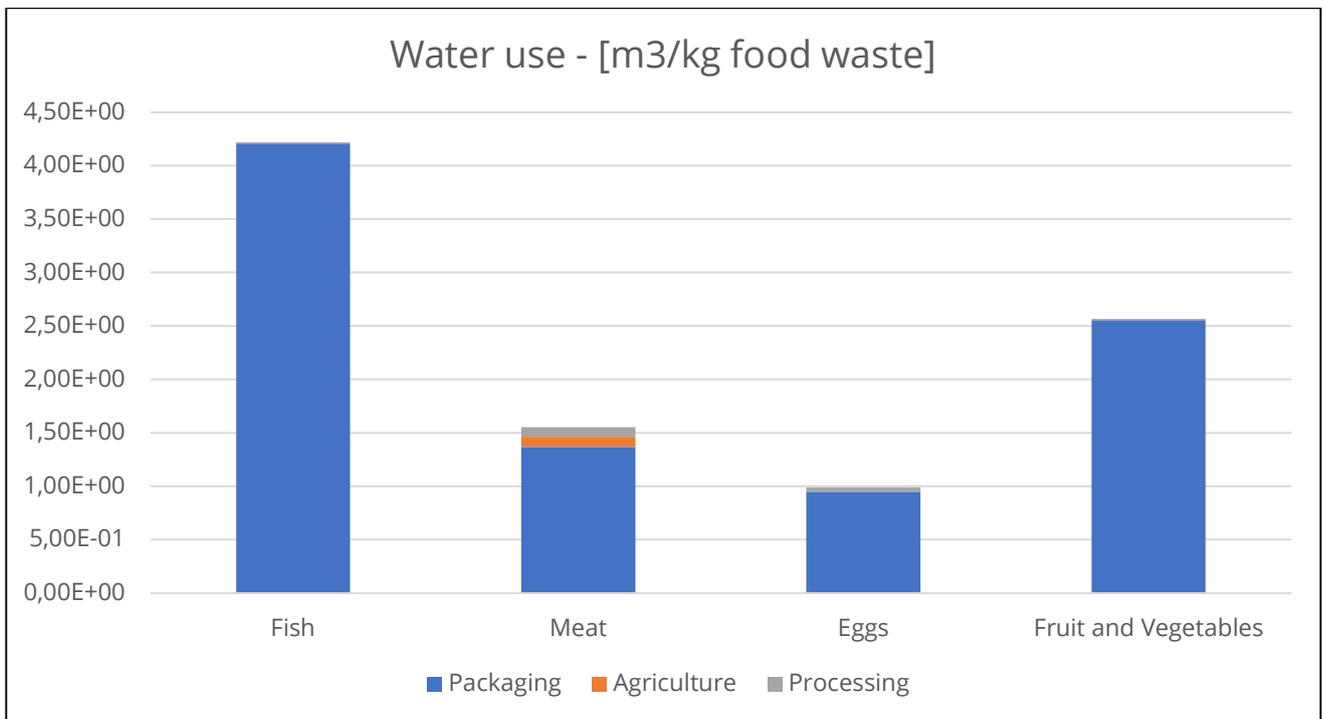
Graph 56: Food waste impact - Acidification - [mol H+ eq/kg food waste]



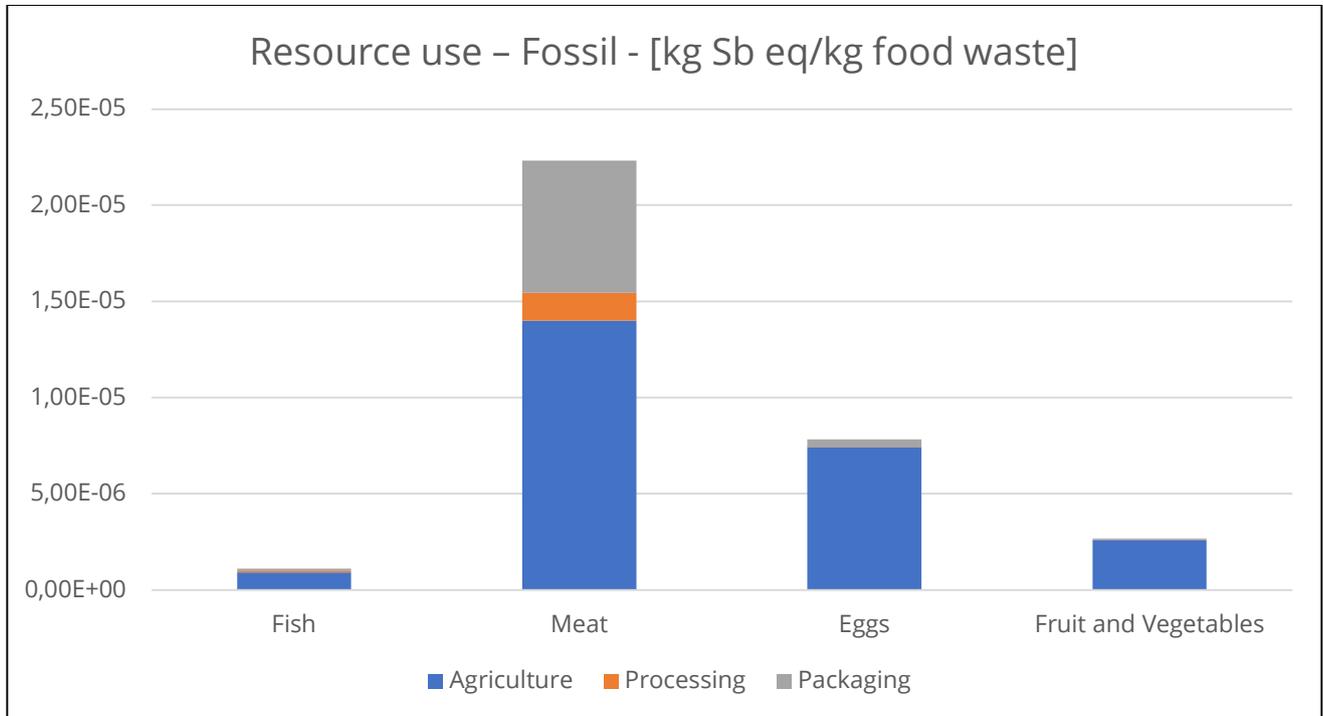
Graph 57: Food waste impact - Land Use - [Pt/kg food waste]



Graph 58: Food waste impact - Water use - [m3/kg food waste]

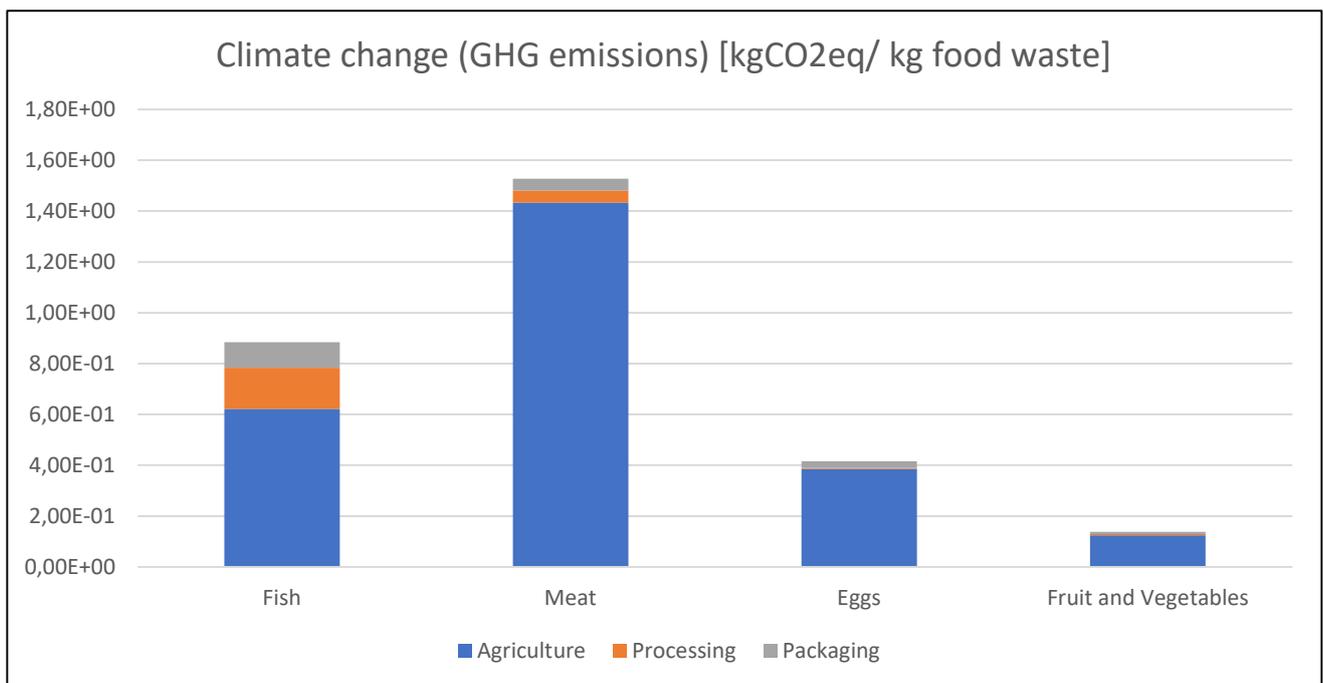


Graph 59 Food waste impact - Resource use – Fossil - [kg Sb eq/kg food waste]

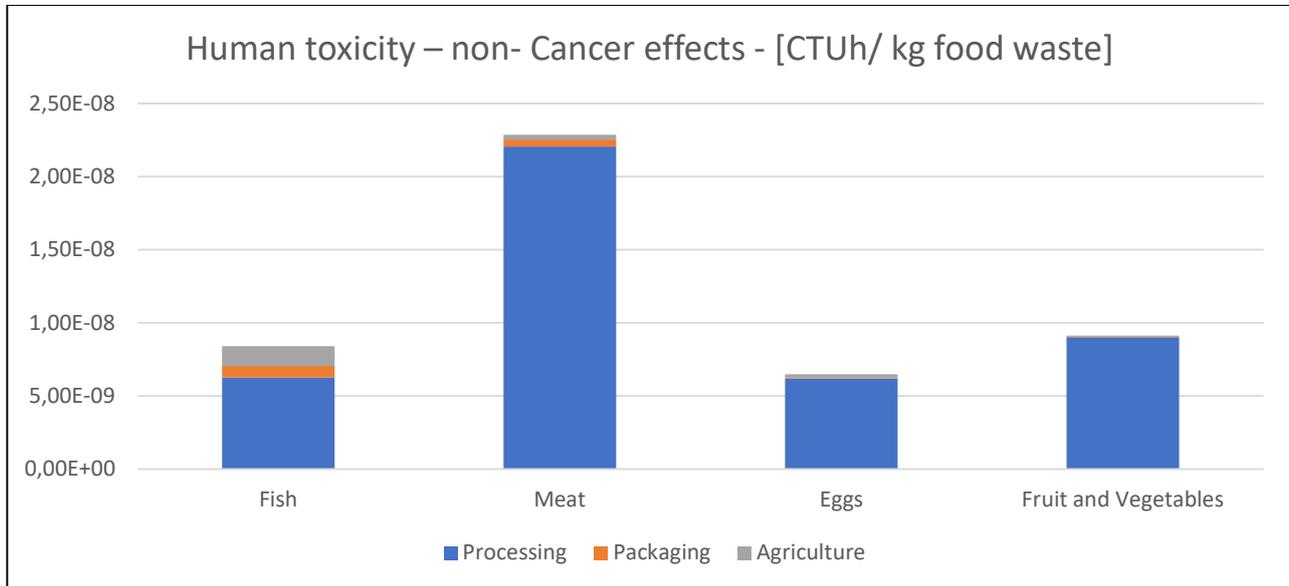


Small enterprises

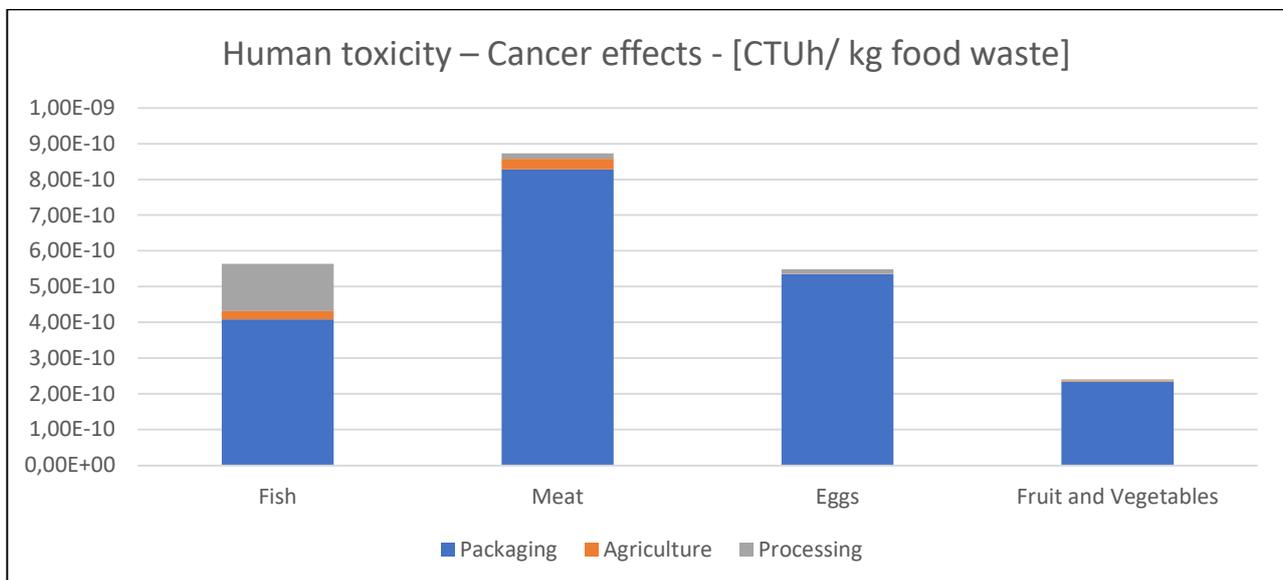
Graph 60: Food waste impact - Climate change (GHG emissions) [kgCO₂eq/ kg food waste]



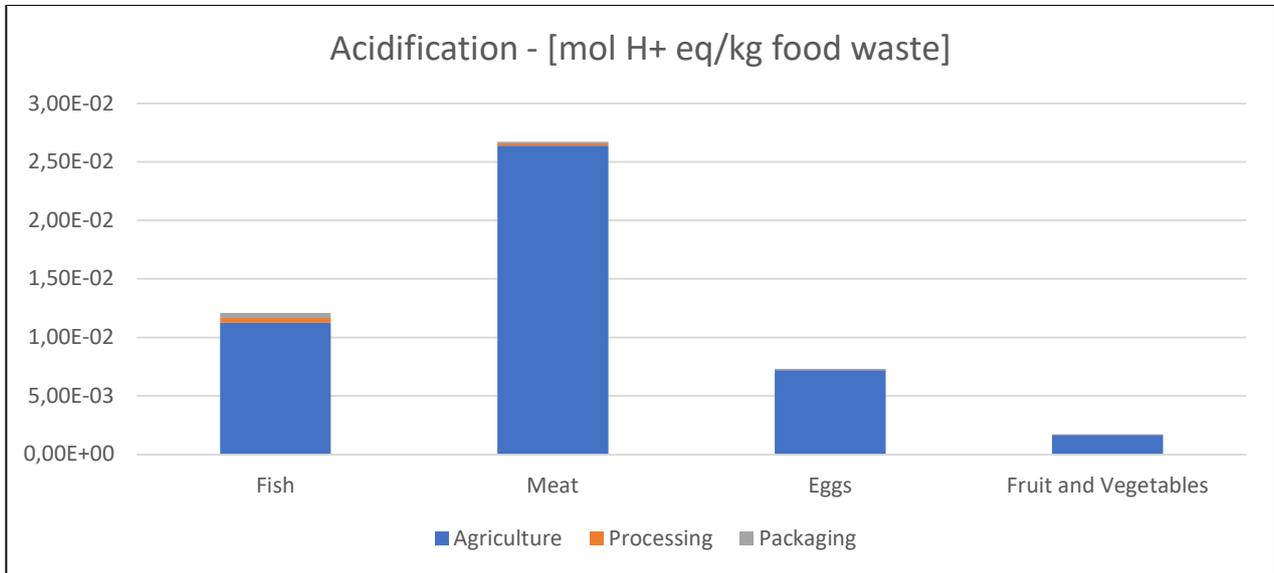
Graph 61 Food waste impact - Human toxicity - non- Cancer effects - [CTUh/ kg food waste]



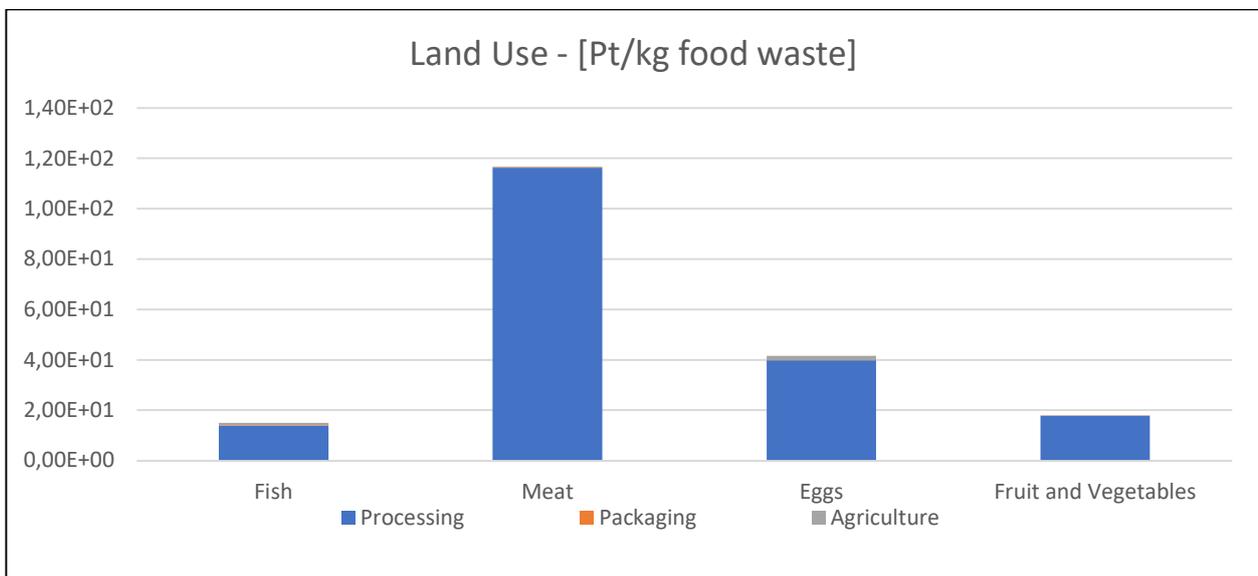
Graph 62: Food waste impact - Human toxicity – Cancer effects - [CTUh/ kg food waste]



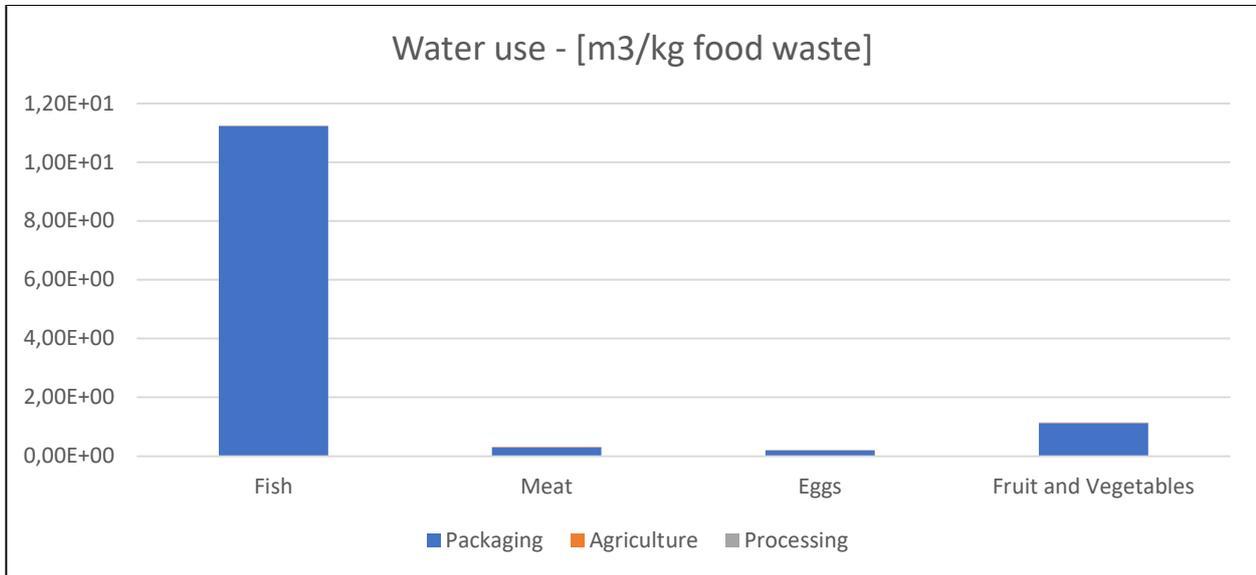
Graph 63: Food waste impact - Acidification - [mol H+ eq/kg food waste]



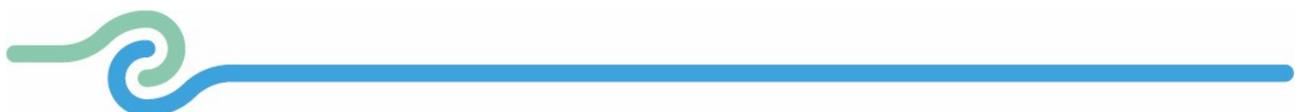
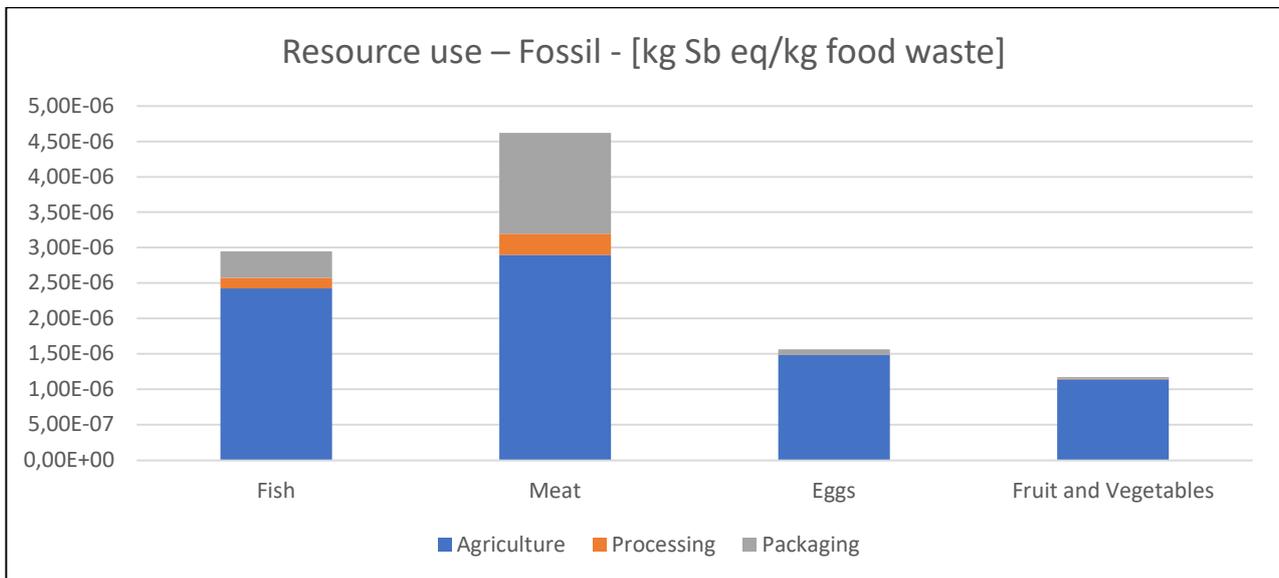
Graph 64 Food waste impact - Land Use - [Pt/kg food waste]



Graph 65: Food waste impact - Water use - [m3/kg food waste]



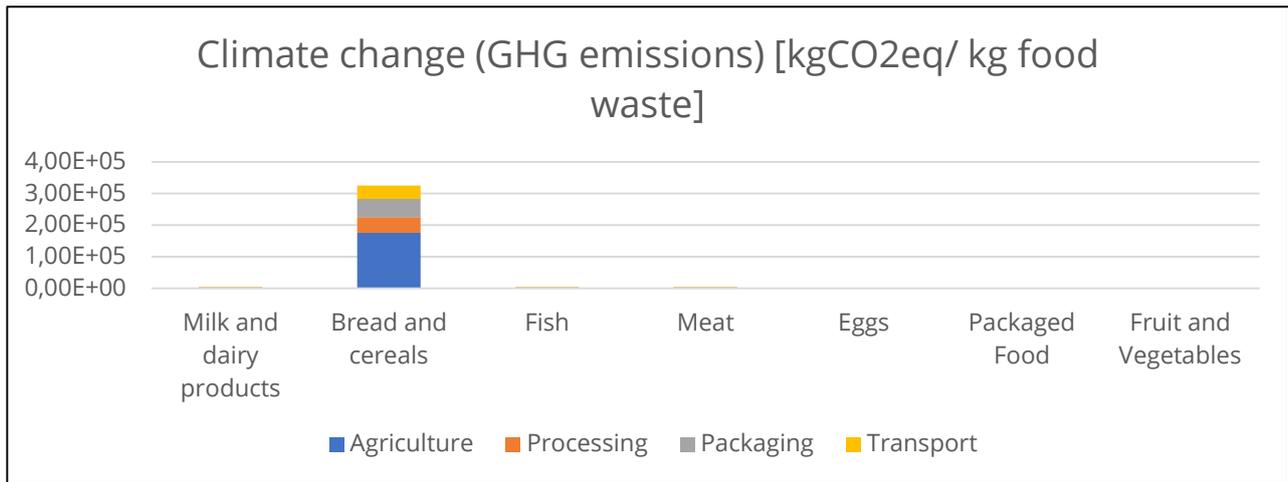
Graph 66: Food waste impact - Resource use – Fossil - [kg Sb eq/kg food waste]



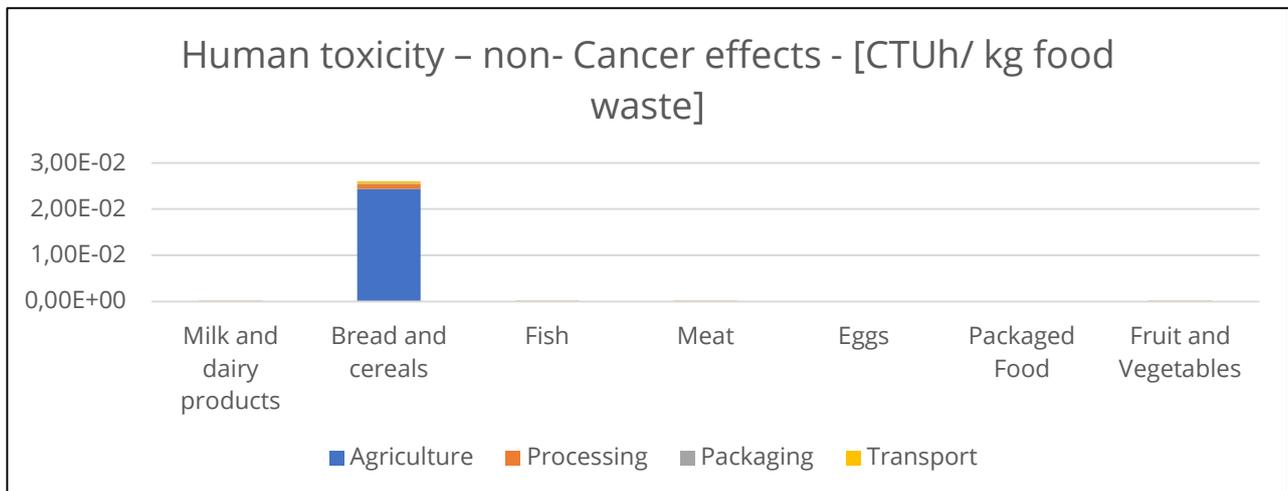
RETAIL

Big Enterprises

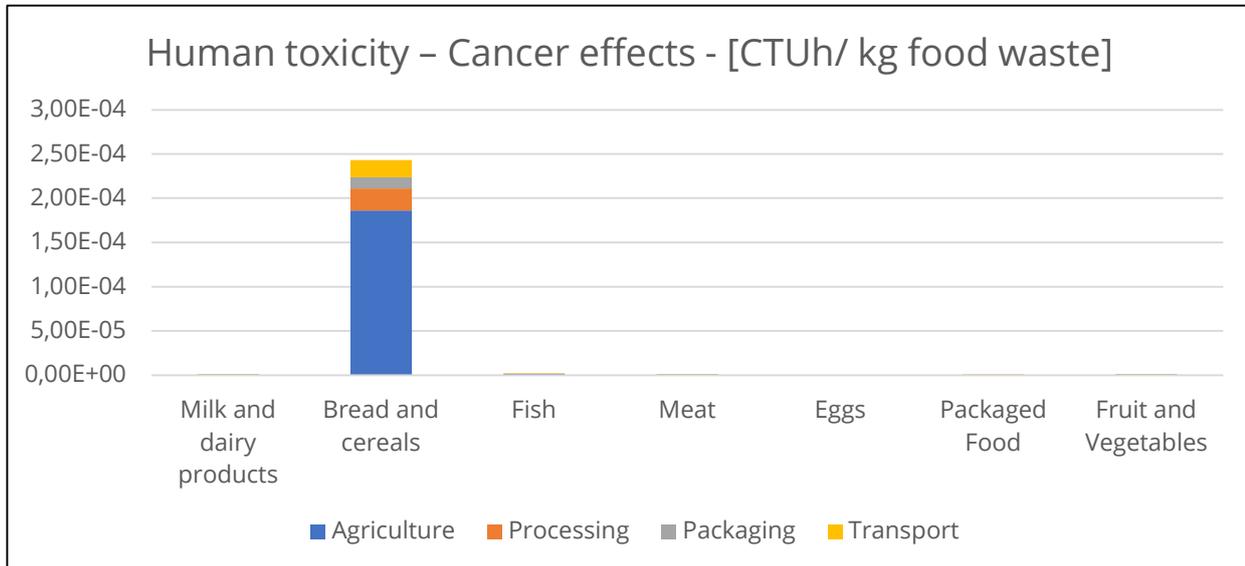
Graph 67: Food waste impact - Climate change (GHG emissions) [kgCO₂eq/ kg food waste]



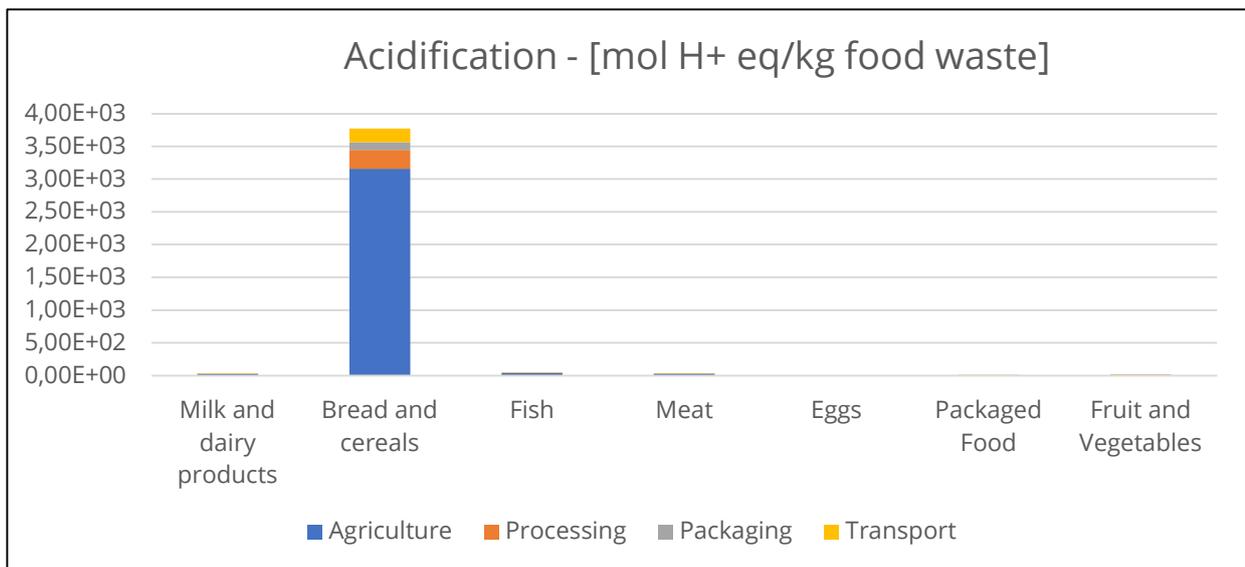
Graph 68: Food waste impact - Human toxicity – non- Cancer effects - [CTUh/ kg food waste]



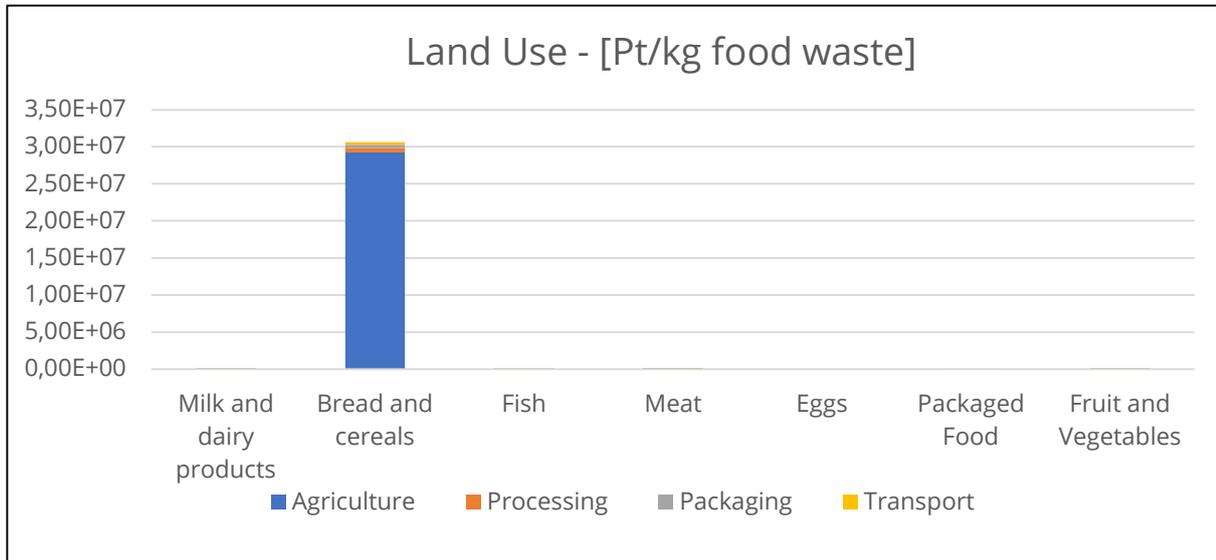
Graph 69: Food waste impact - Human toxicity - Cancer effects - [CTUh/ kg food waste]



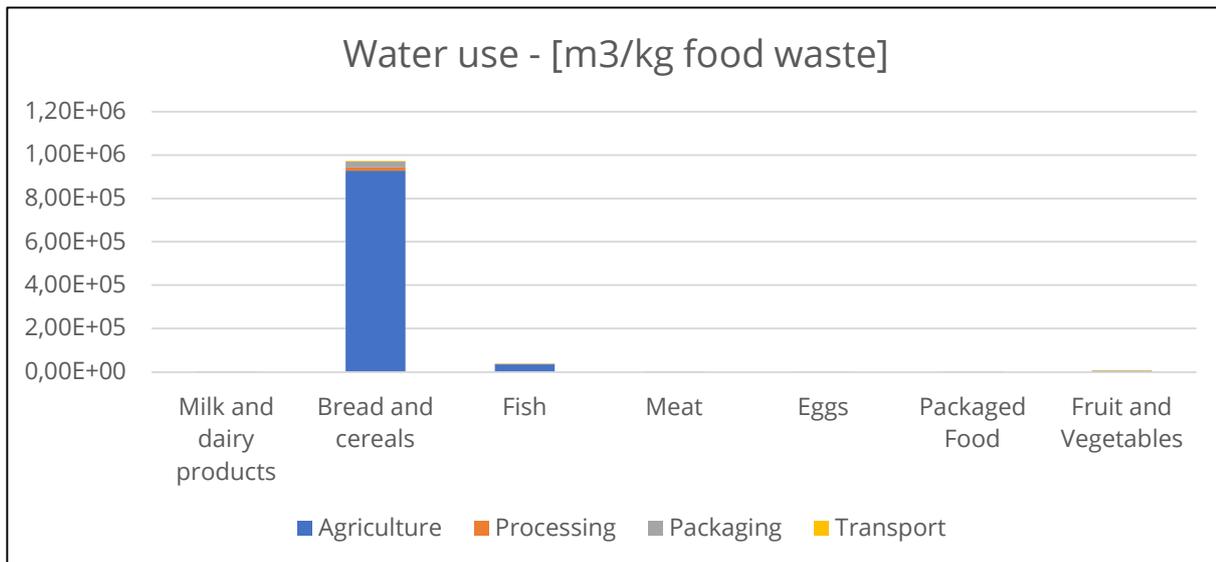
Graph 70: Food waste impact - Acidification - [mol H+ eq/kg food waste]



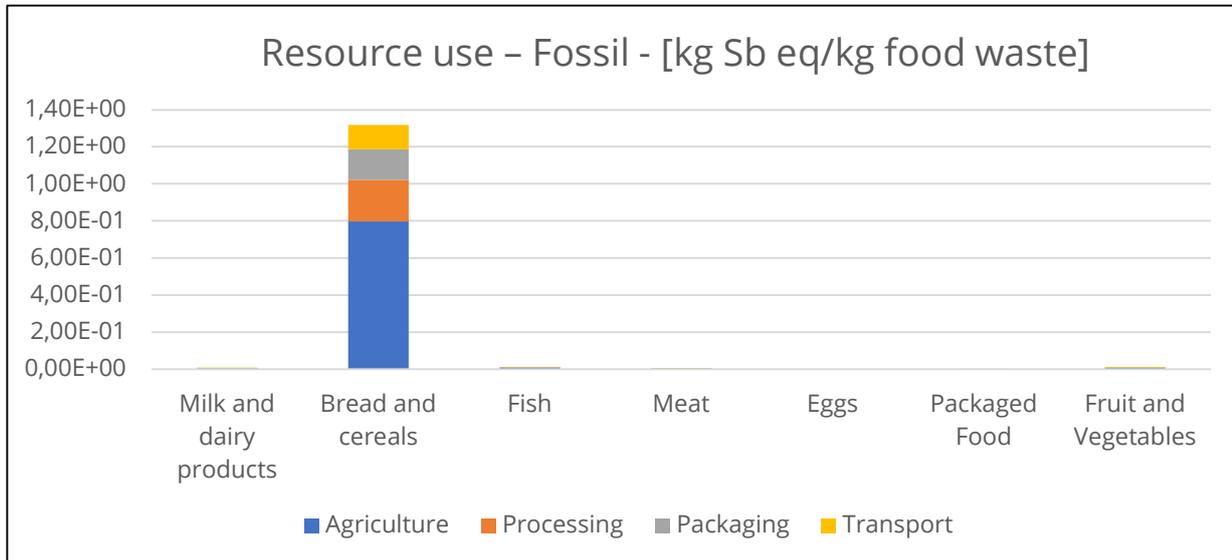
Graph 71: Food waste impact - Land Use - [Pt/kg food waste]



Graph 72: Food waste impact - Water use - [m3/kg food waste]

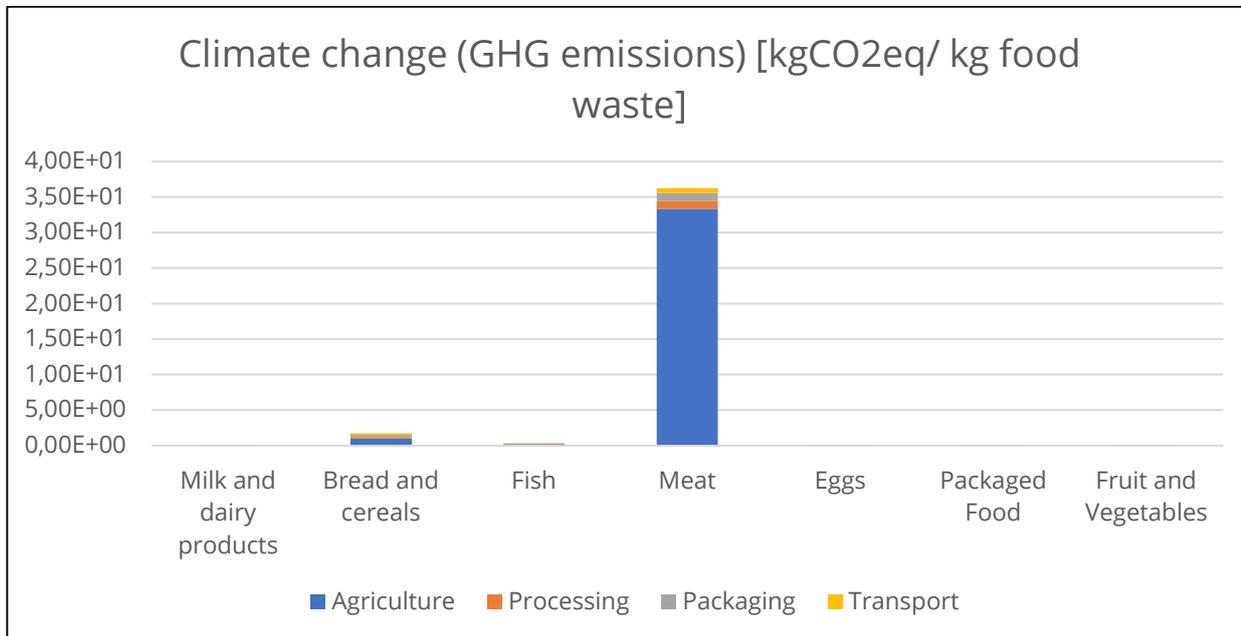


Graph 73: Food waste impact - Resource use – Fossil - [kg Sb eq/kg food waste]

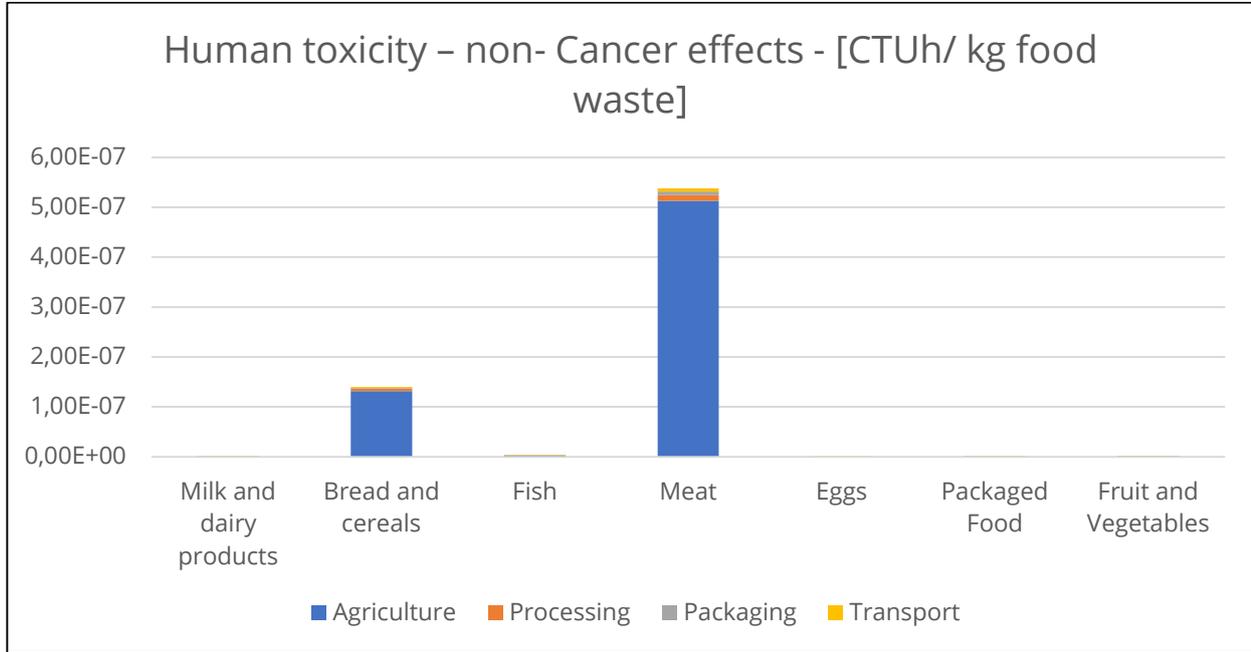


Medium Enterprises

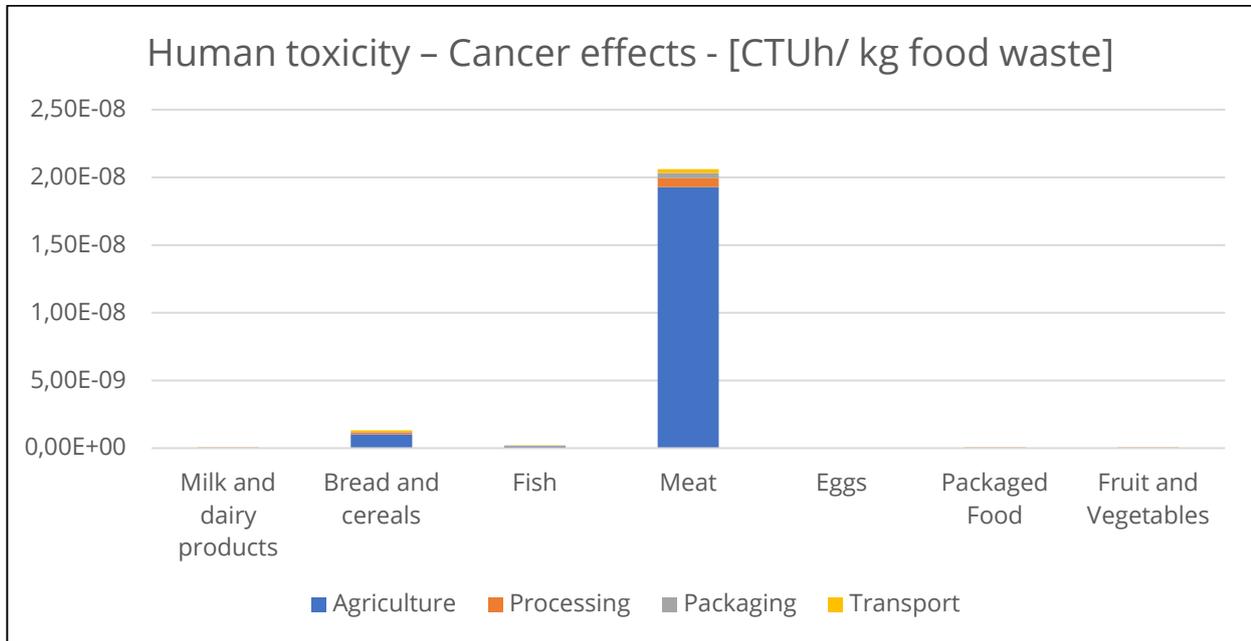
Graph 74: Food waste impact - Climate change (GHG emissions) [kgCO2eq/ kg food waste]



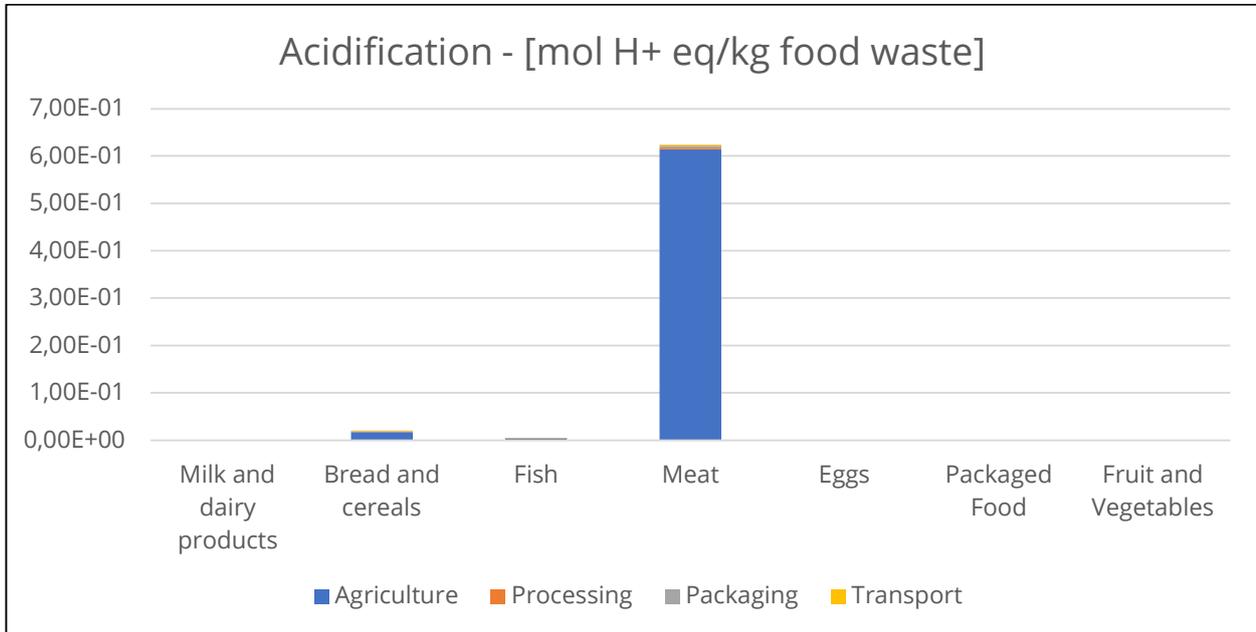
Graph 75: Food waste impact - Human toxicity – non- Cancer effects - [CTUh/ kg food waste]



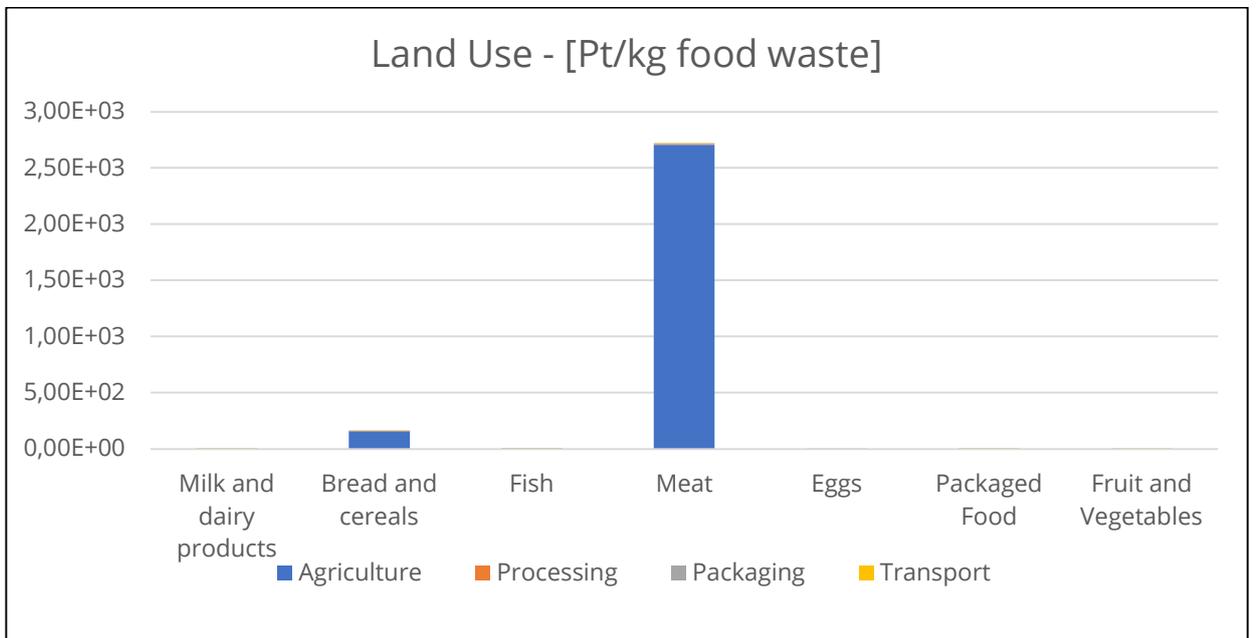
Graph 76: Food waste impact - Human toxicity – Cancer effects - [CTUh/ kg food waste]



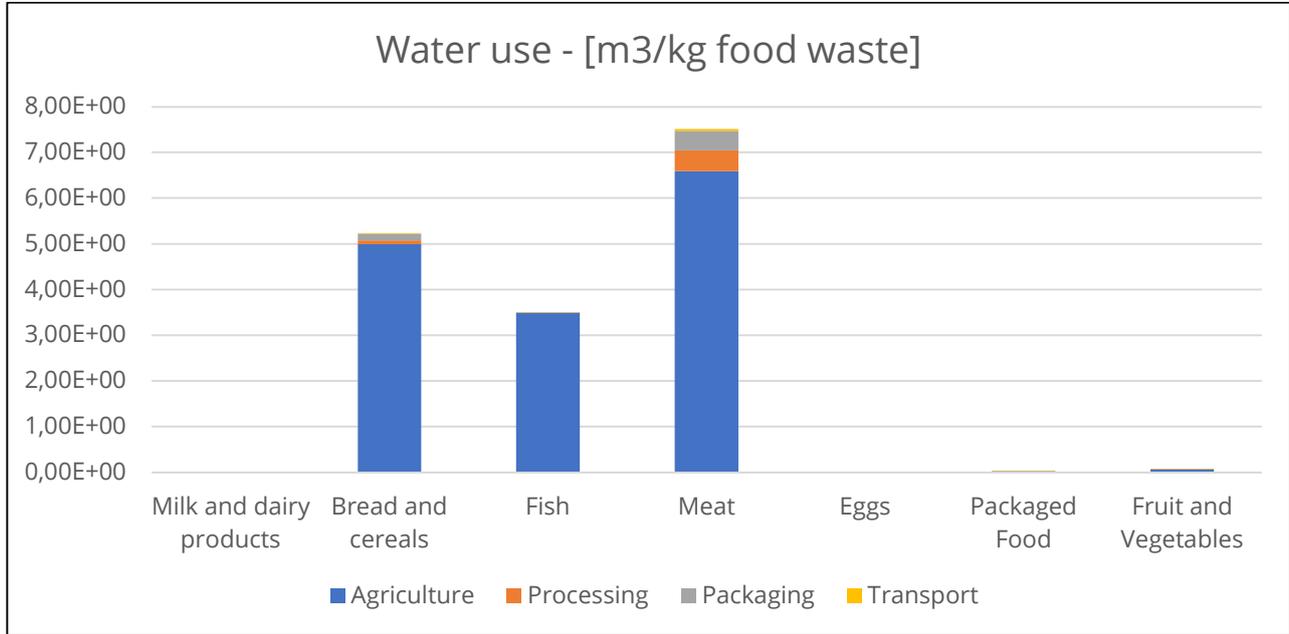
Graph 77: Food waste impact - Acidification - [mol H+ eq/kg food waste]



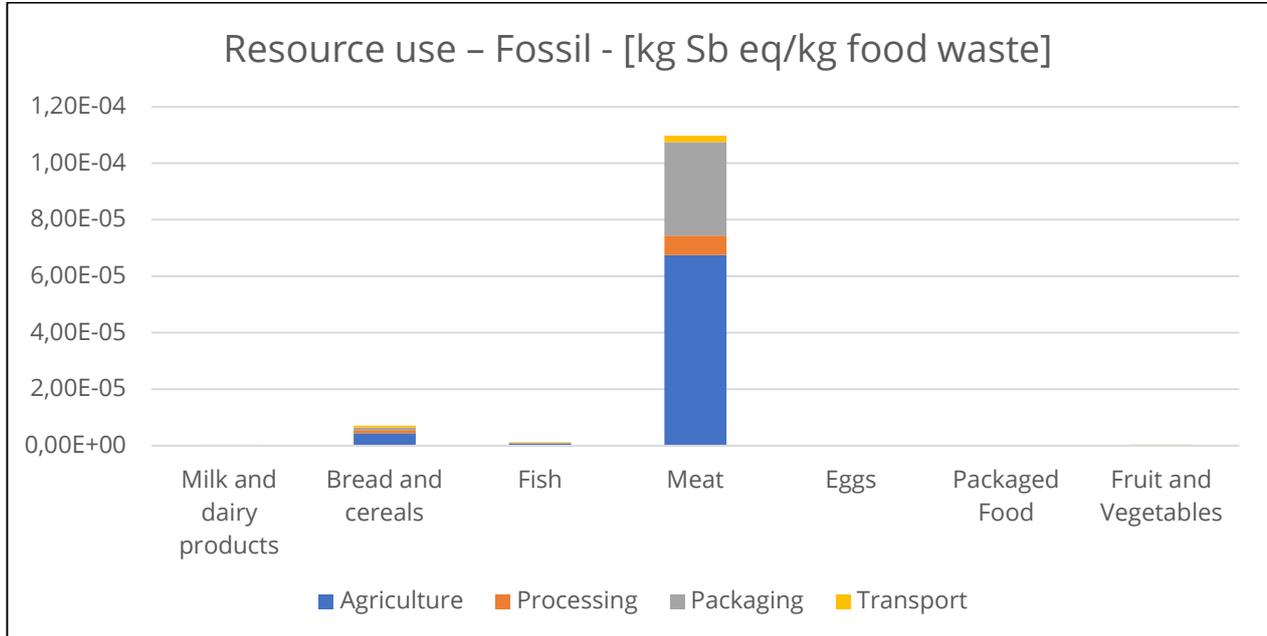
Graph 78: Food waste impact - Land Use - [Pt/kg food waste]



Graph 79: Food waste impact - Water use - [m3/kg food waste]

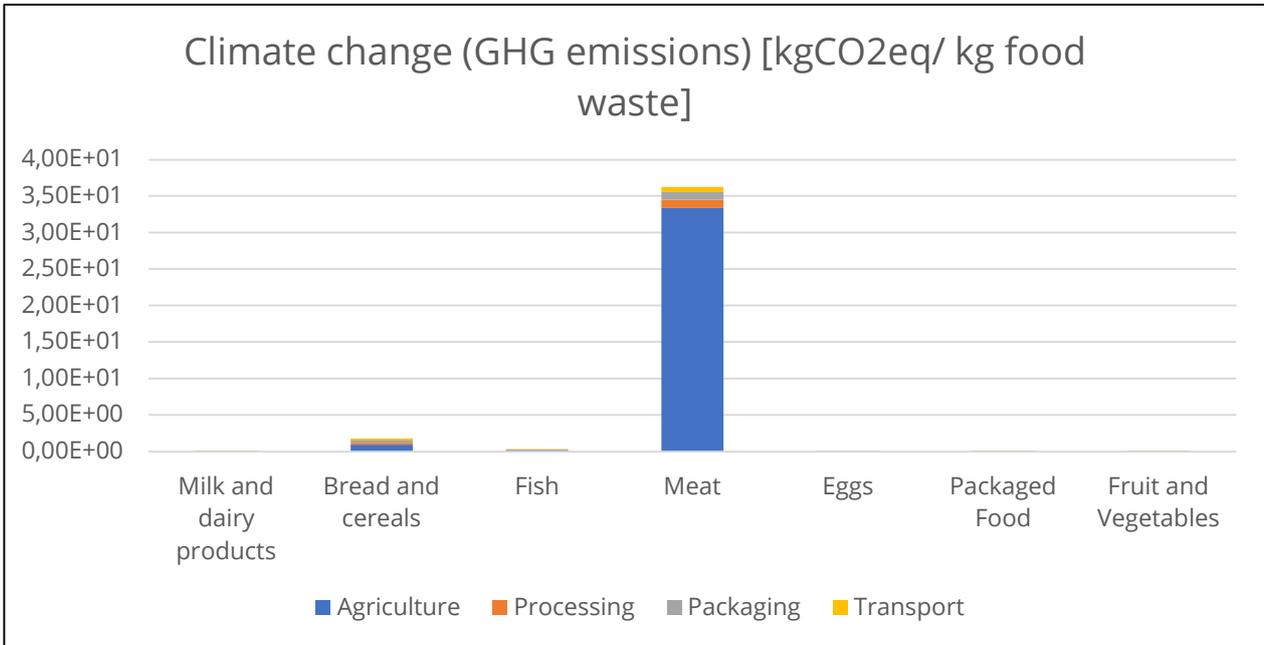


Graph 80: Food waste impact - Resource use – Fossil - [kg Sb eq/kg food waste]

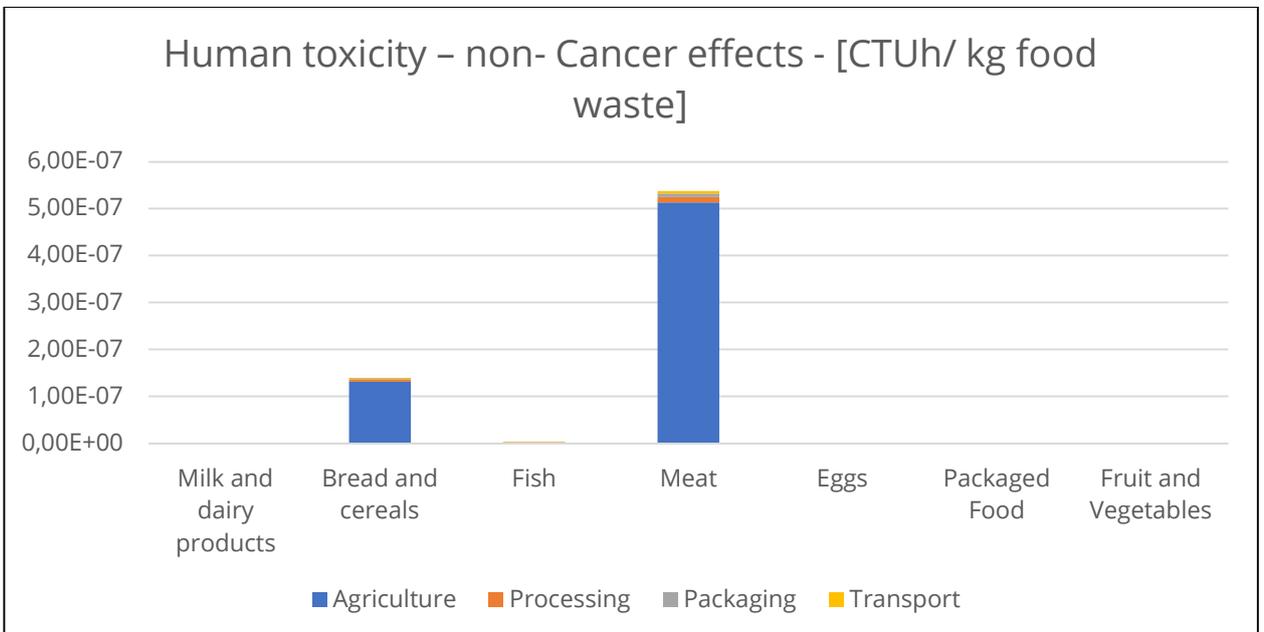


Small Enterprises

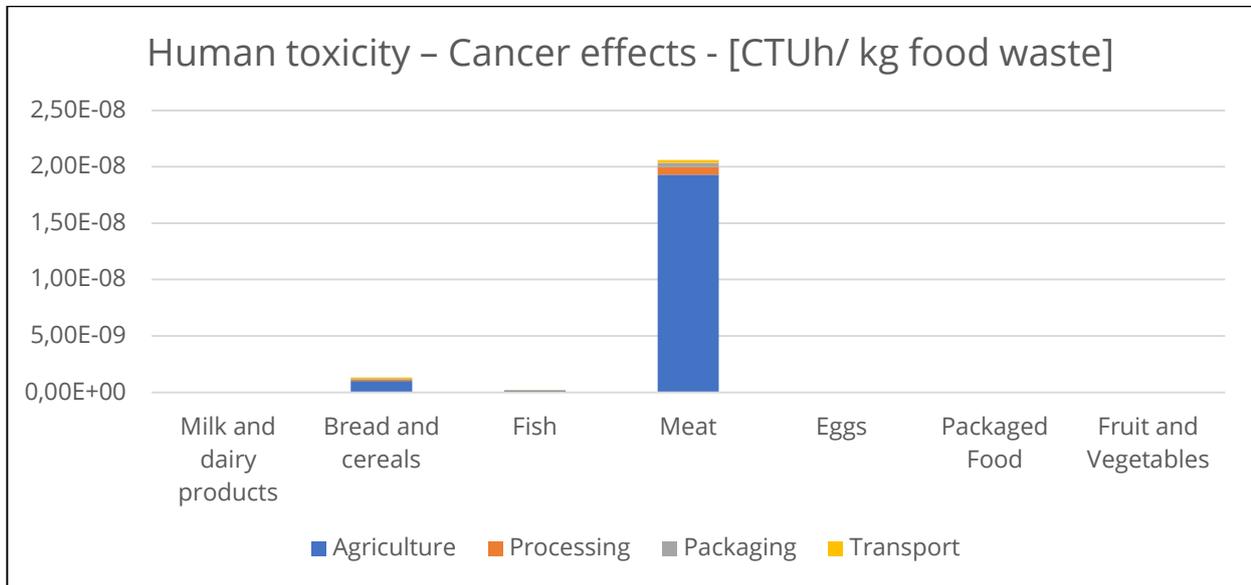
Graph 81: Food waste impact - Climate change (GHG emissions) [kgCO₂eq/ kg food waste]



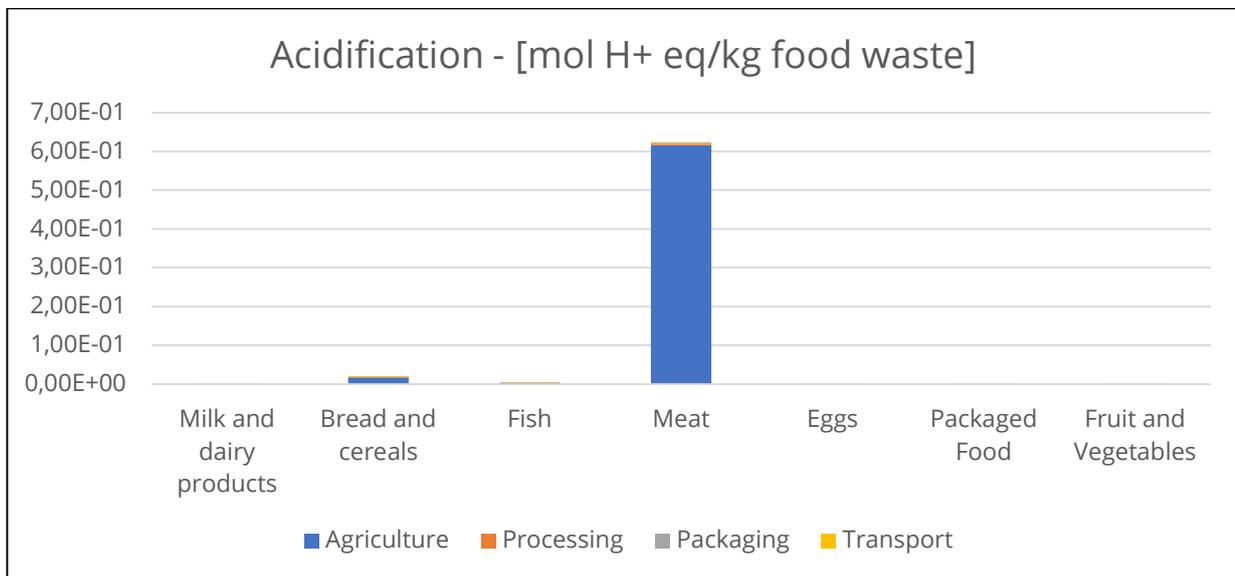
Graph 82: Food waste impact - Human toxicity – non- Cancer effects - [CTUh/ kg food waste]



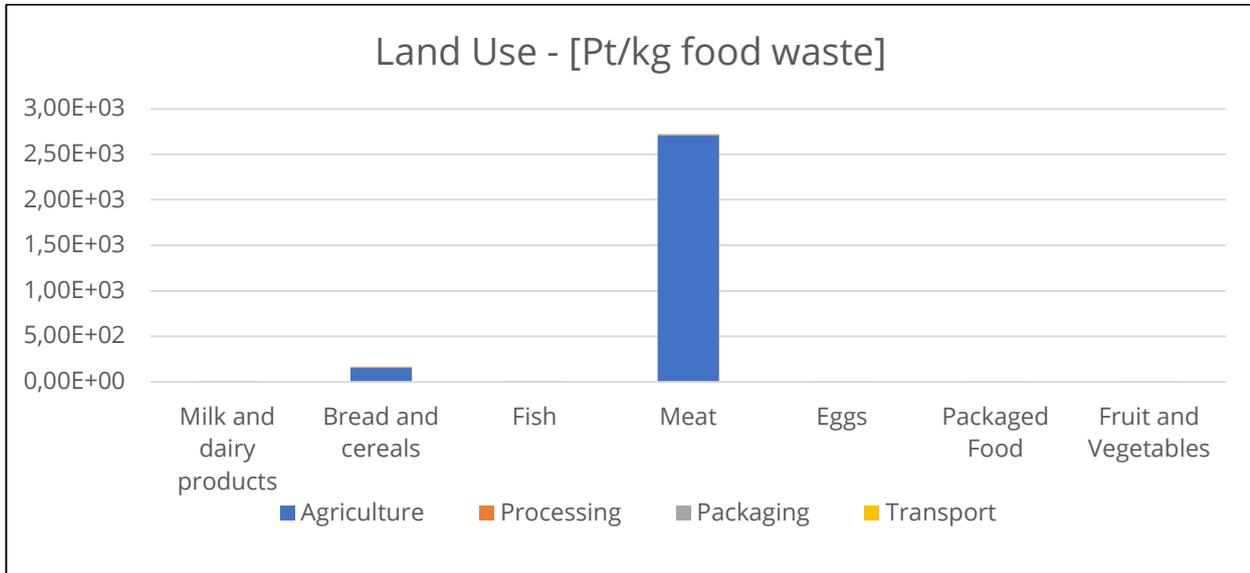
Graph 83: Food waste impact - Human toxicity – Cancer effects - [CTUh/ kg food waste]



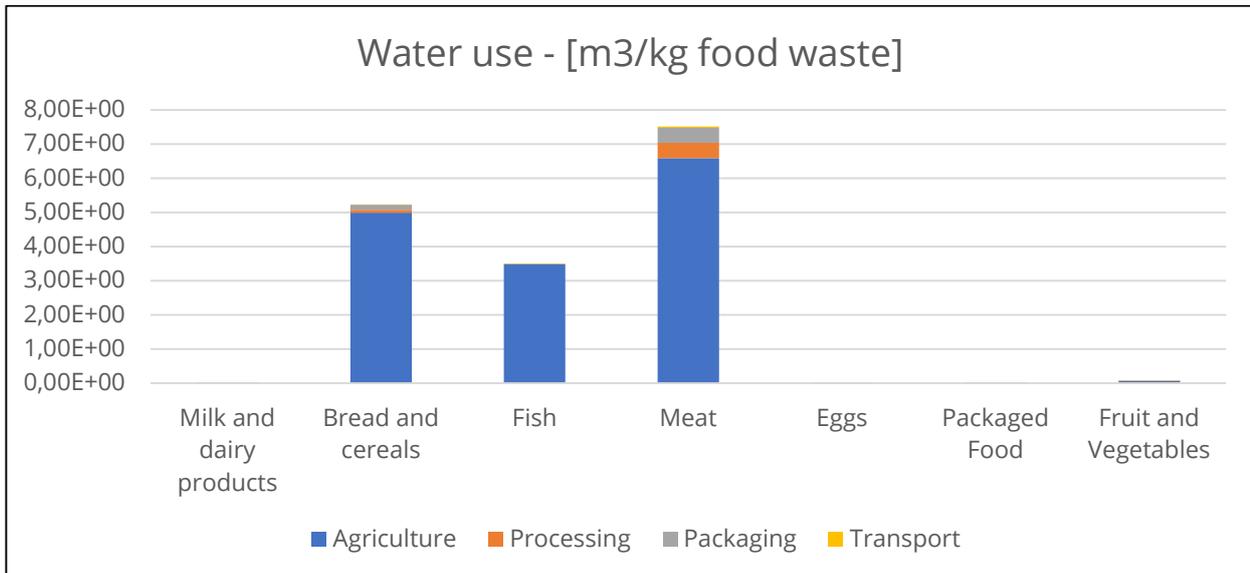
Graph 84: Food waste impact - Acidification - [mol H+ eq/kg food waste]



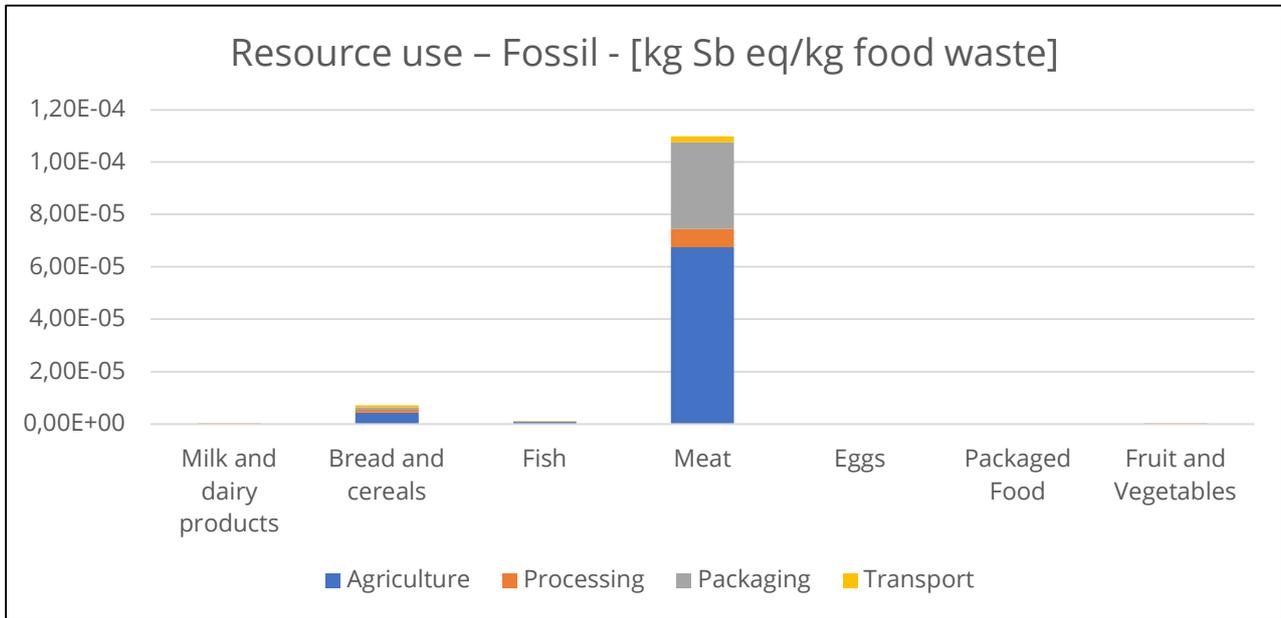
Graph 85: Food waste impact - Land Use - [Pt/kg food waste]



Graph 86: Food waste impact - Water use - [m3/kg food waste]



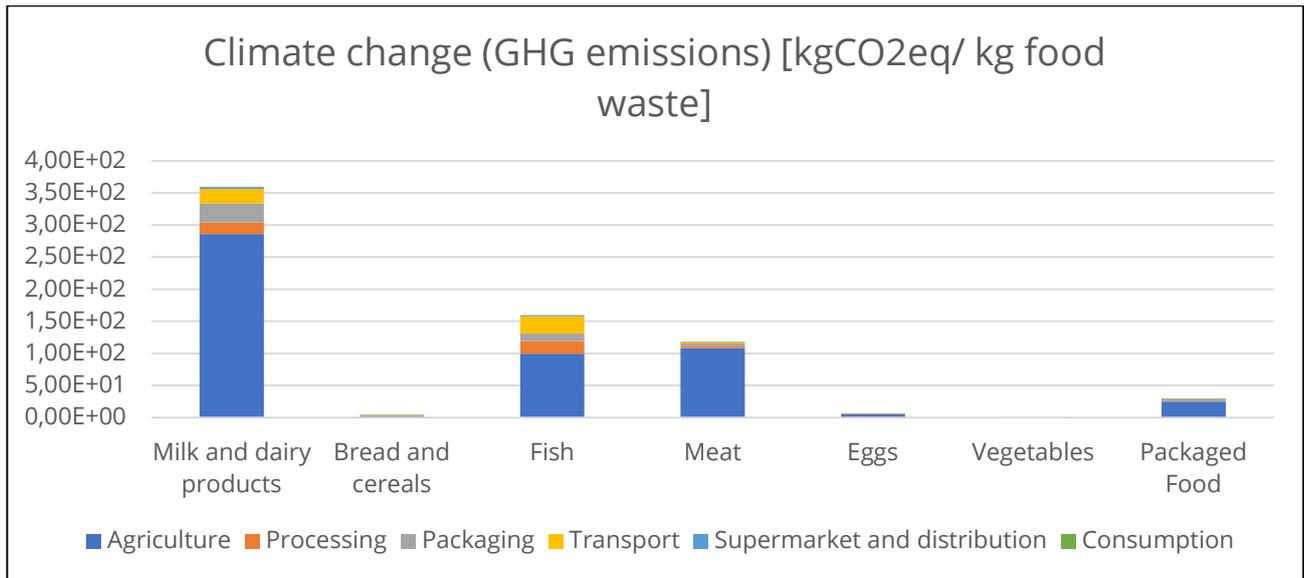
Graph 87: Food waste impact - Resource use – Fossil - [kg Sb eq/kg food waste]



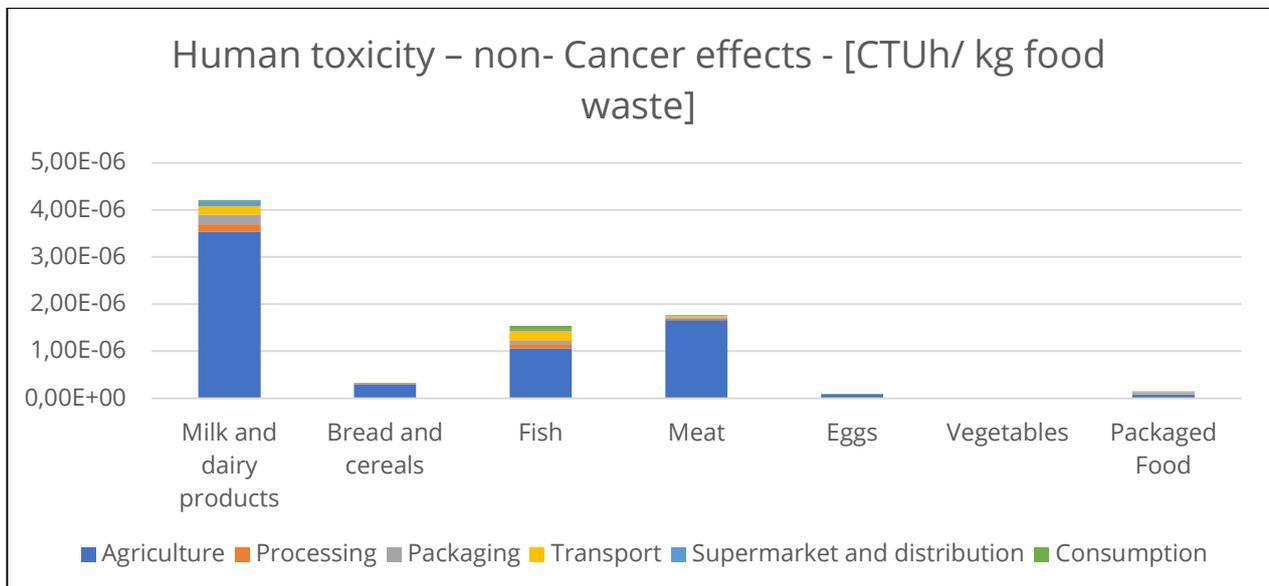
FOOD SERVICE SECTOR

Big enterprises

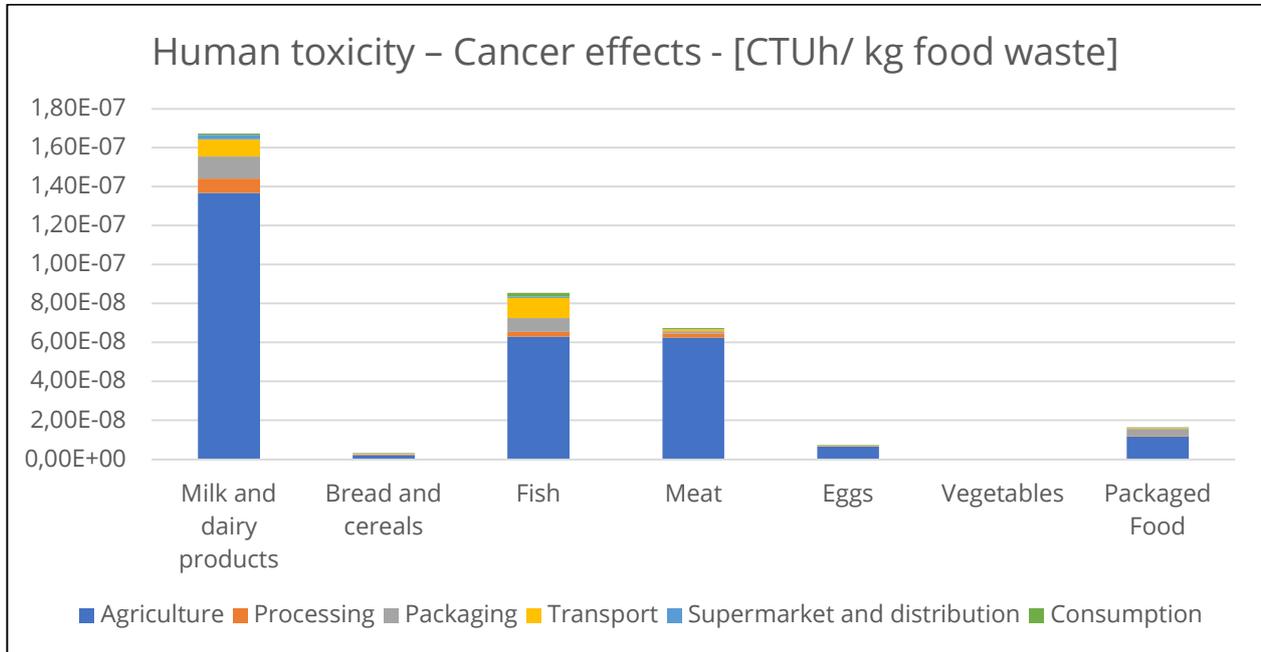
Graph 88: Food waste impact - Climate change (GHG emissions) [kgCO₂eq/ kg food waste]



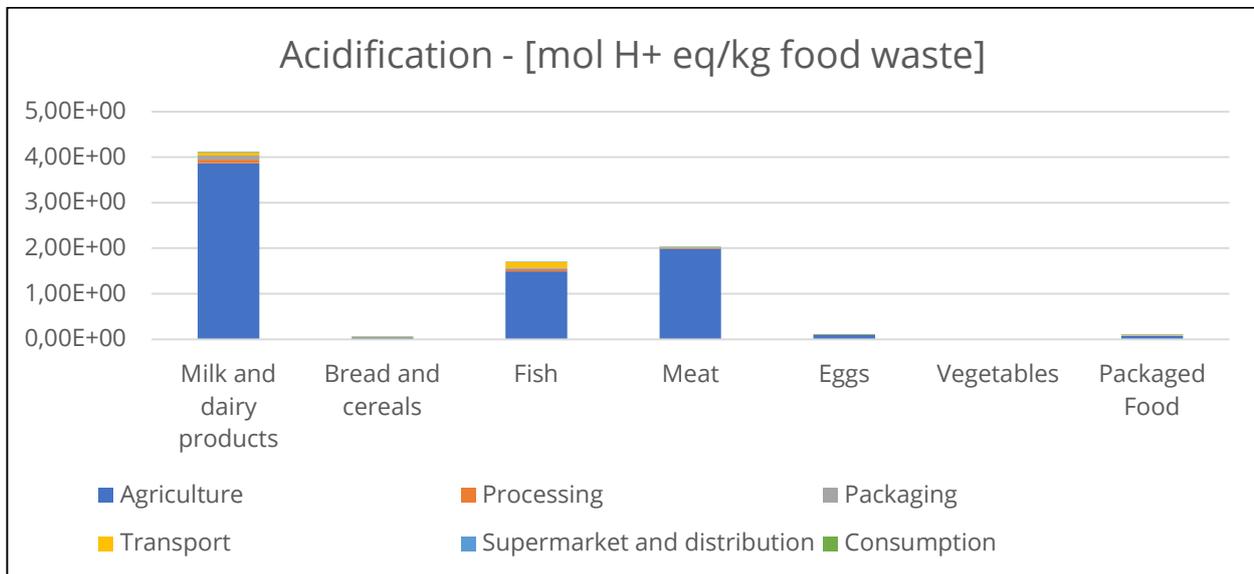
Graph 89: Food waste impact - Human toxicity – non- Cancer effects - [CTUh/ kg food waste]



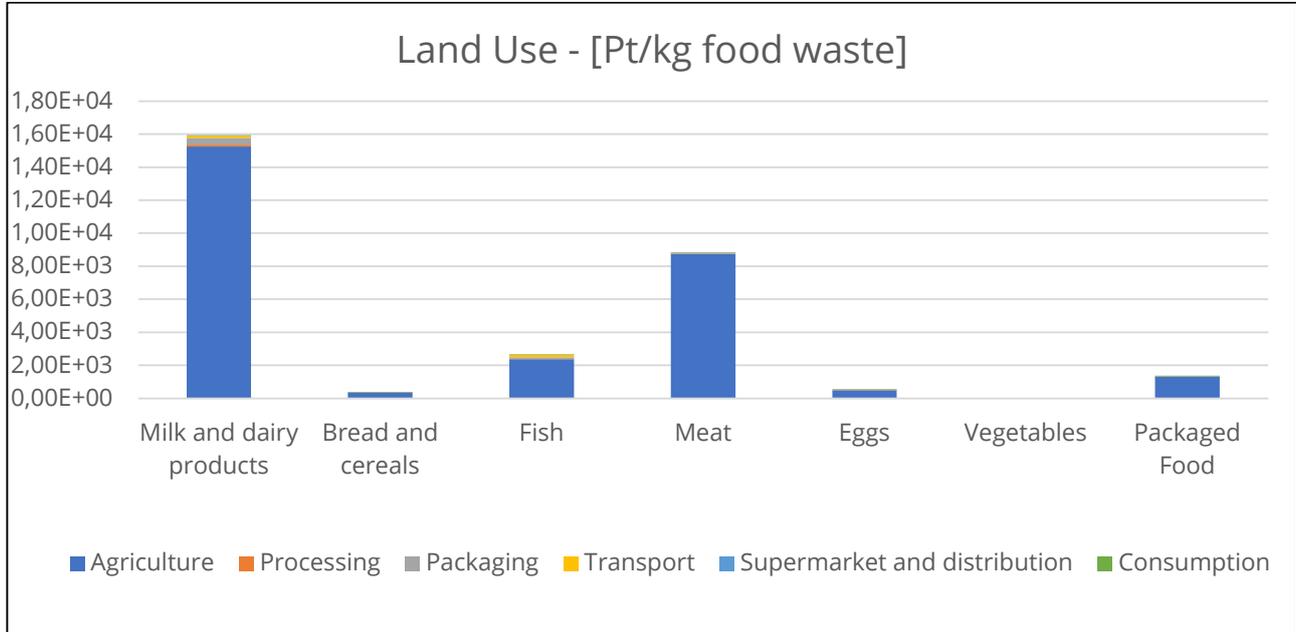
Graph 90: Food waste impact - Human toxicity - Cancer effects - [CTUh/ kg food waste]



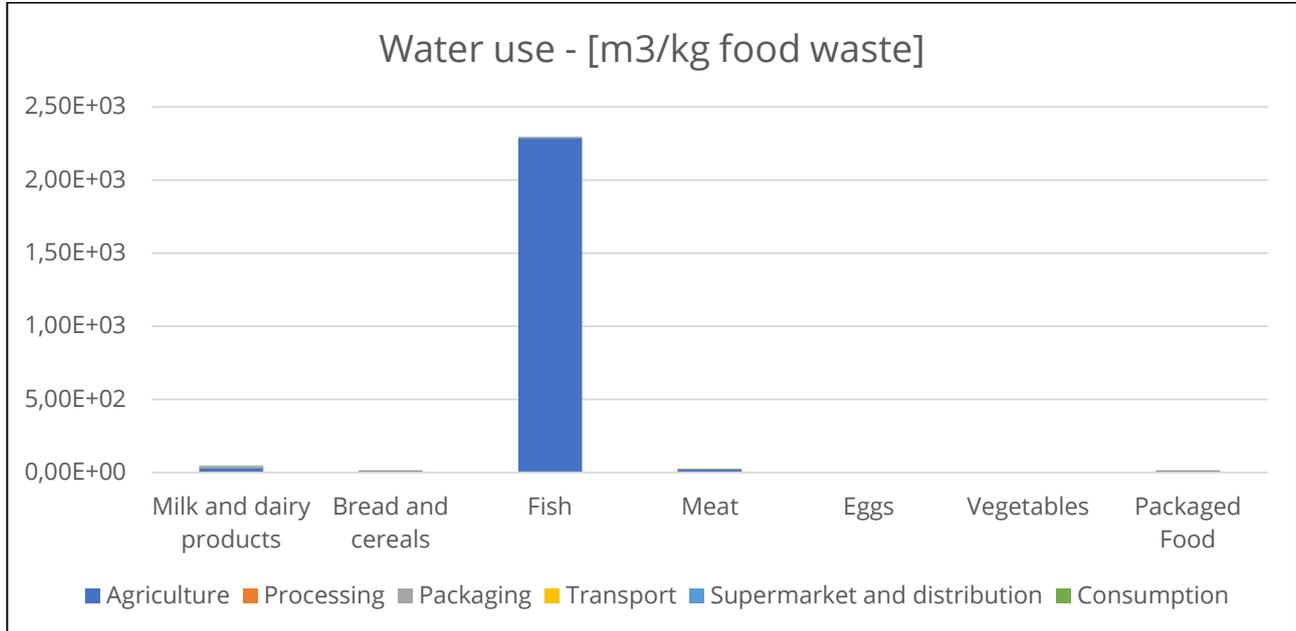
Graph 91: Food waste impact - Acidification - [mol H+ eq/kg food waste]



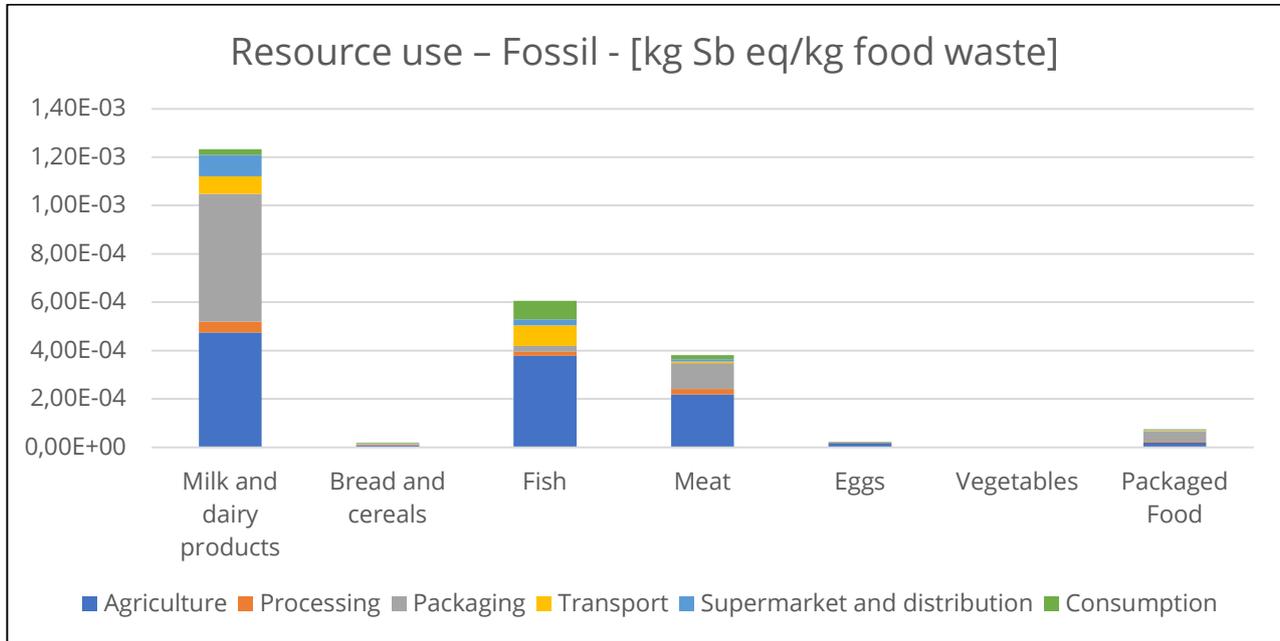
Graph 92: Food waste impact - Land Use - [Pt/kg food waste]



Graph 93: Food waste impact - Water use - [m3/kg food waste]

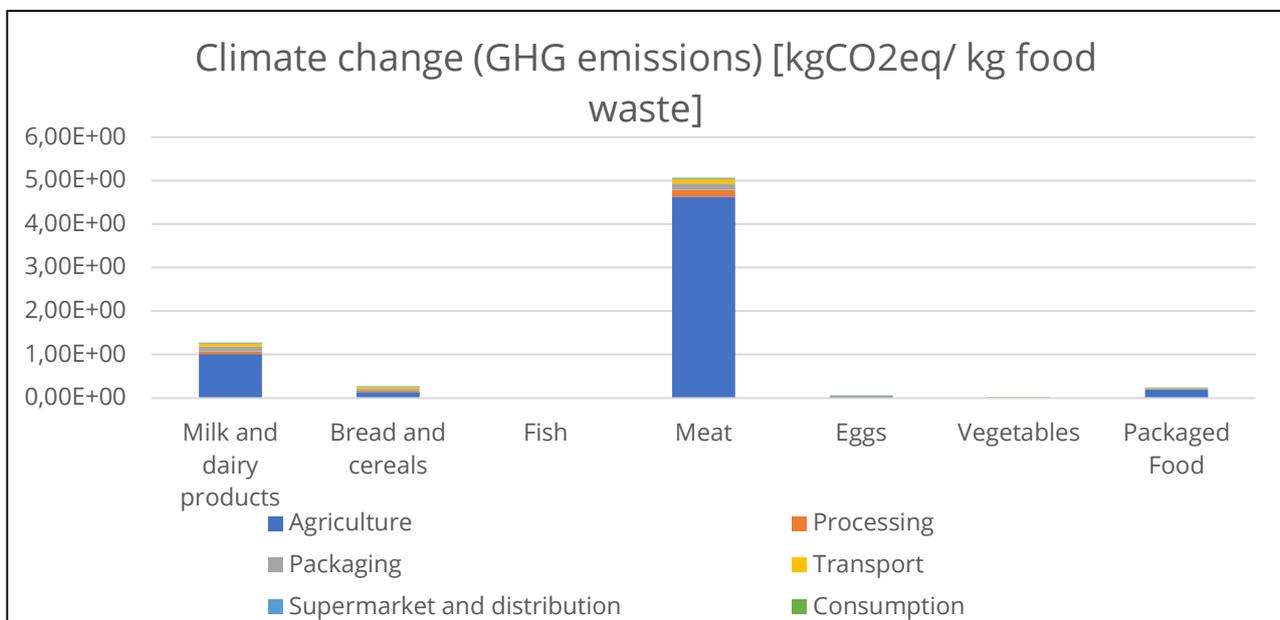


Graph 94: Food waste impact - Resource use – Fossil - [kg Sb eq/kg food waste]

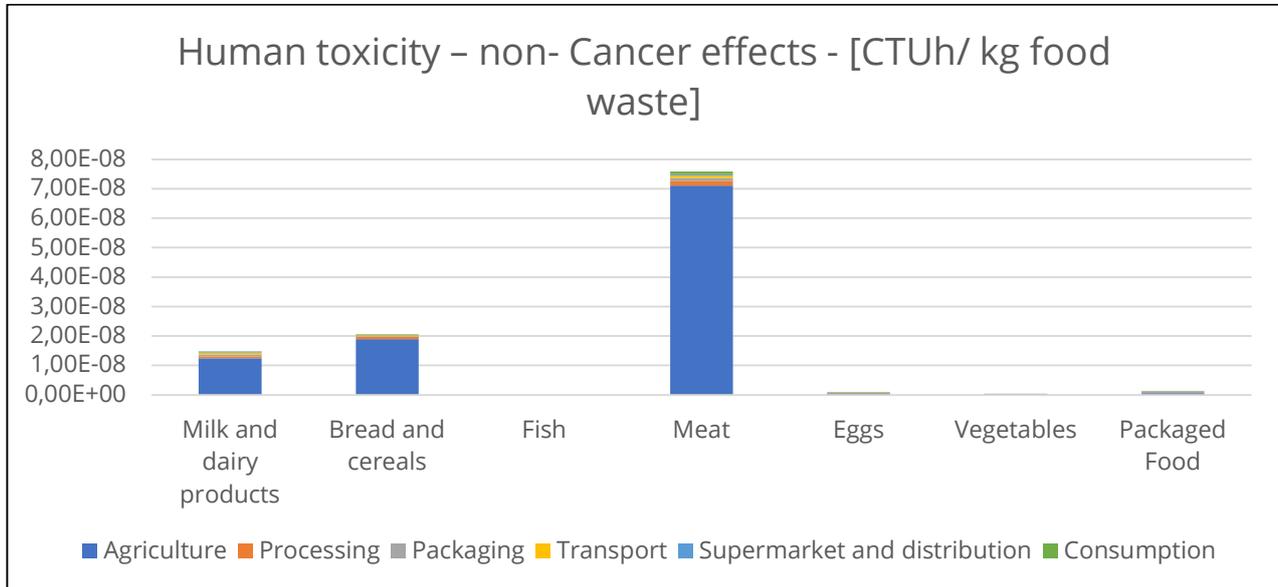


Medium enterprises

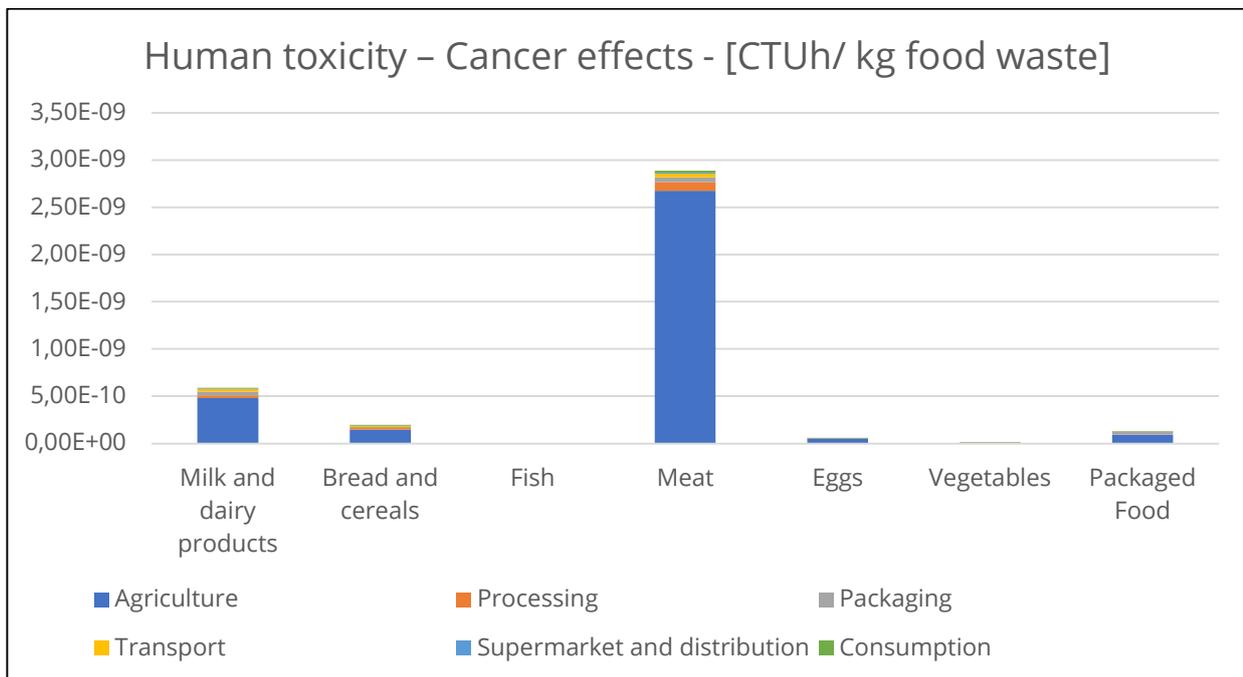
Graph 95: Food waste impact - Climate change (GHG emissions) [kgCO2eq/ kg food waste]



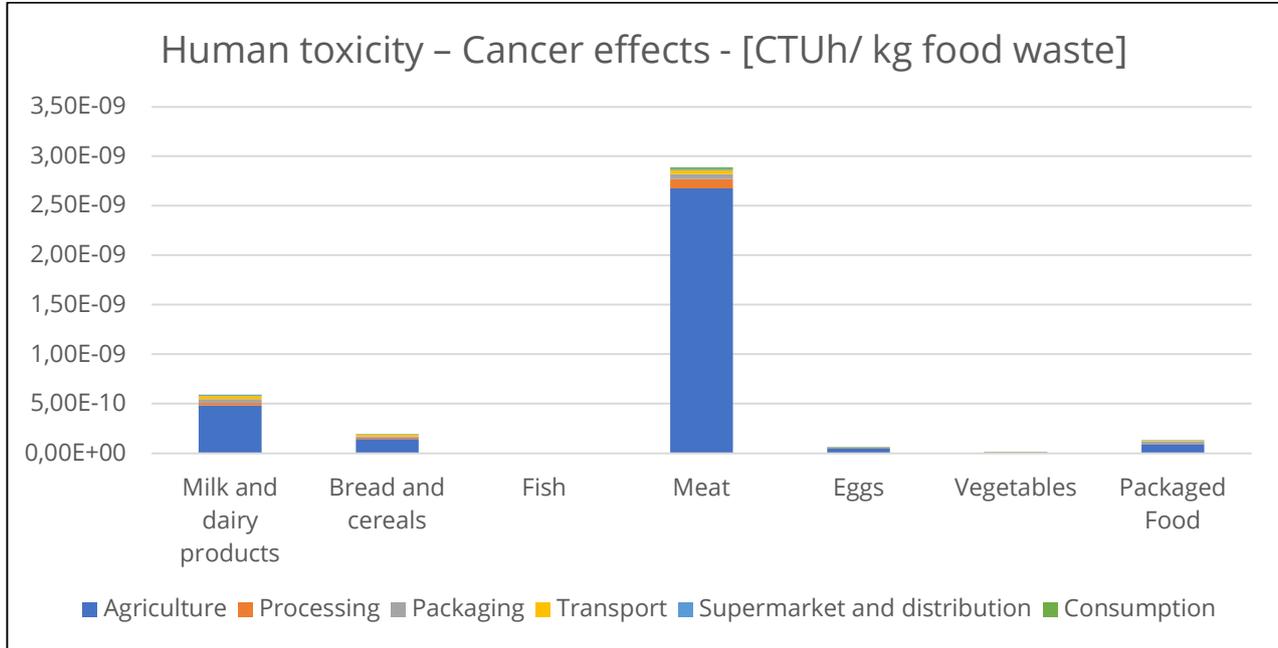
Graph 96: Food waste impact - Human toxicity – non- Cancer effects - [CTUh/ kg food waste]



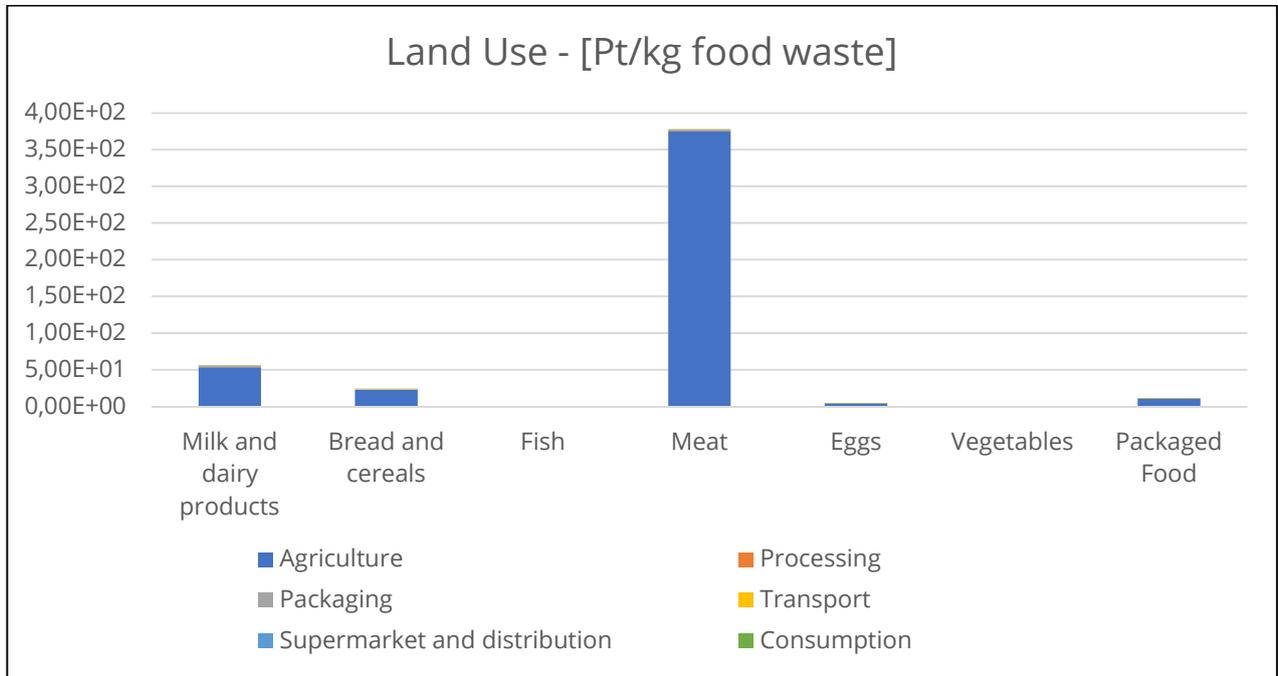
Graph 97: Food waste impact - Human toxicity – Cancer effects - [CTUh/ kg food waste]



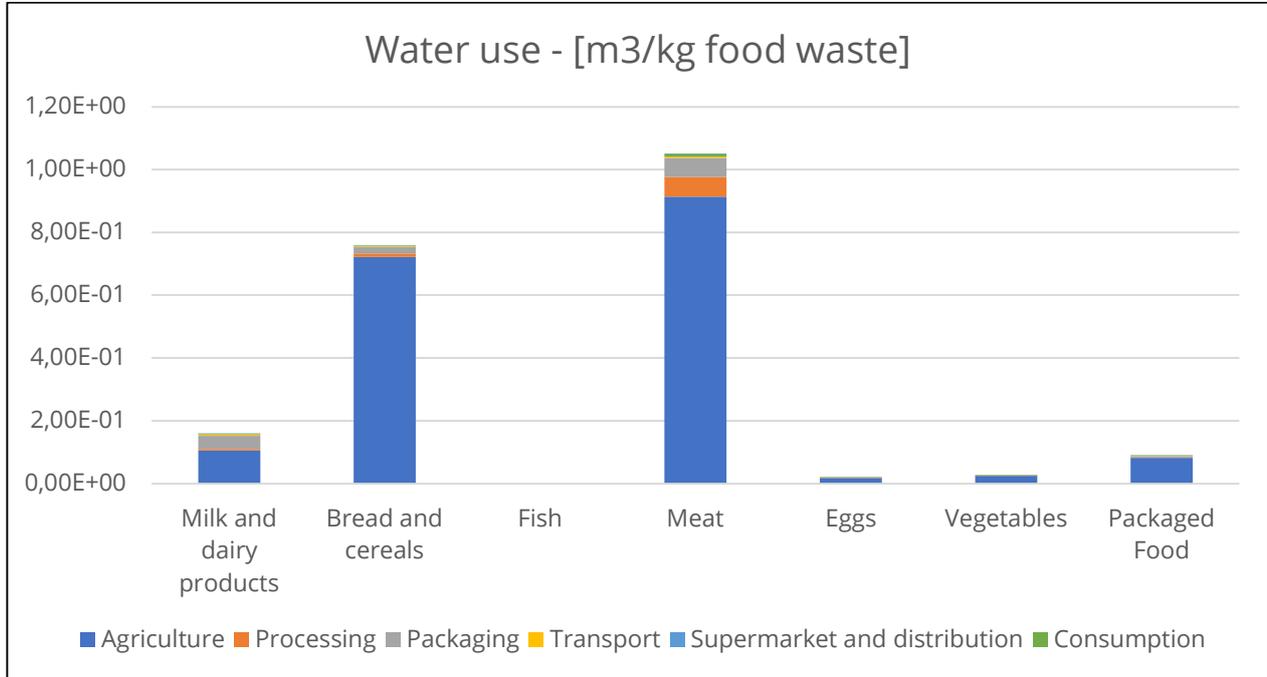
Graph 98: Food waste impact - Acidification - [mol H+ eq/kg food waste]



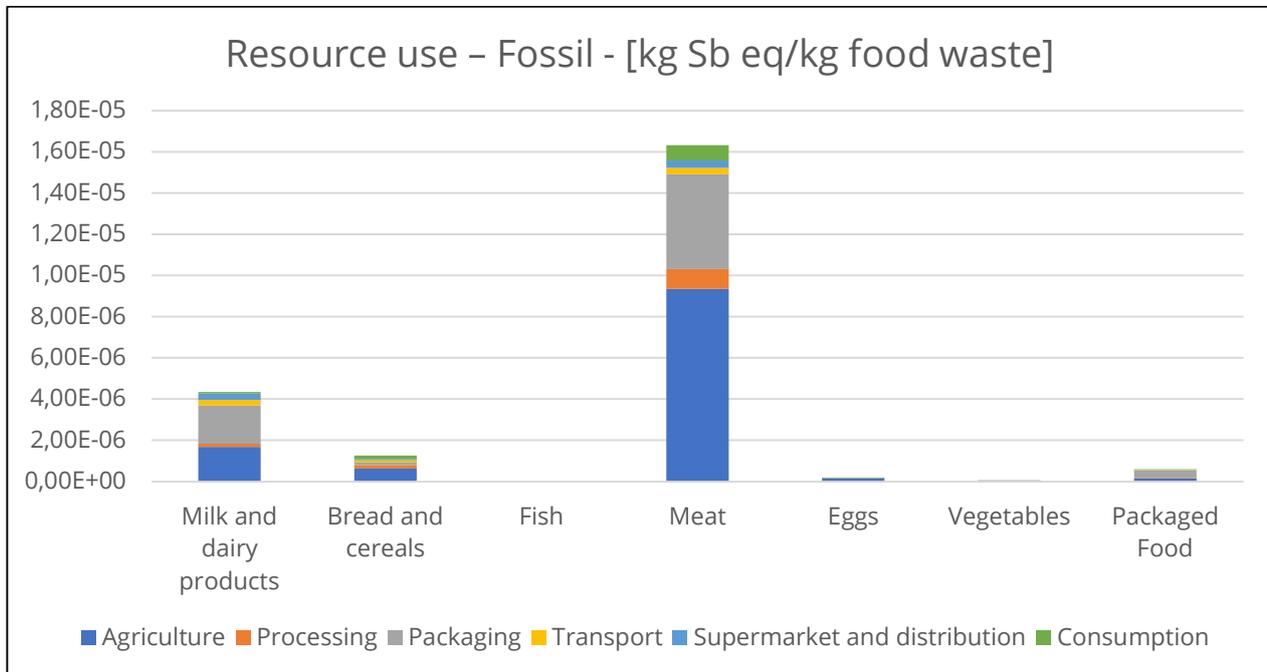
Graph 99: Food waste impact - Land Use - [Pt/kg food waste]



Graph 100: Food waste impact - Water use - [m3/kg food waste]

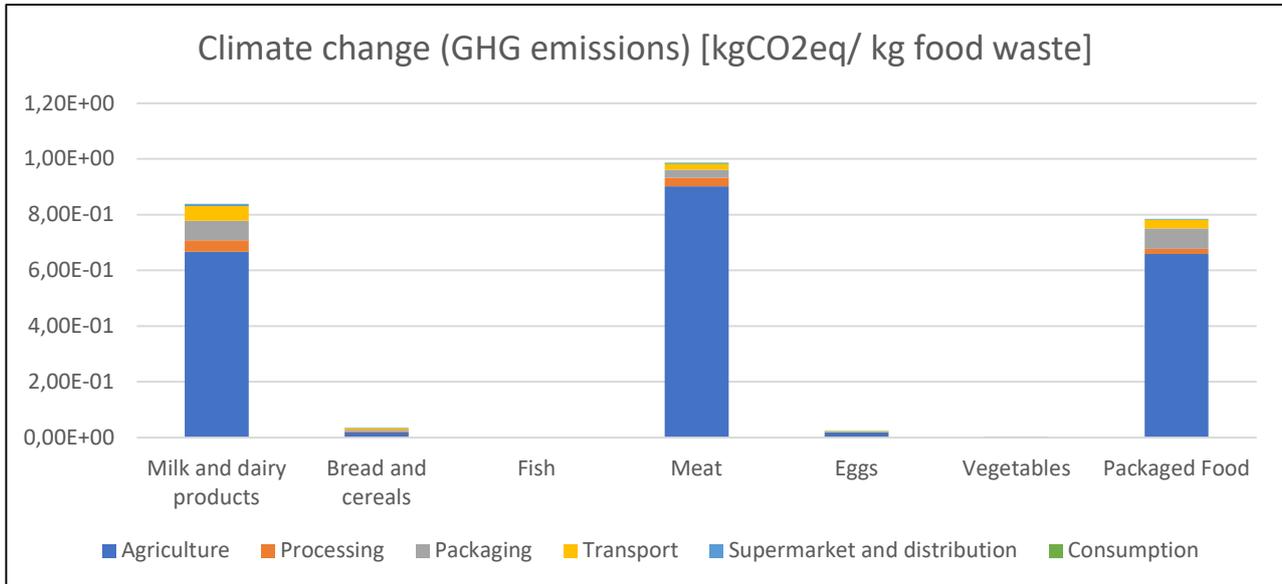


Graph 101: Food waste impact - Resource use - Fossil - [kg Sb eq/kg food waste]

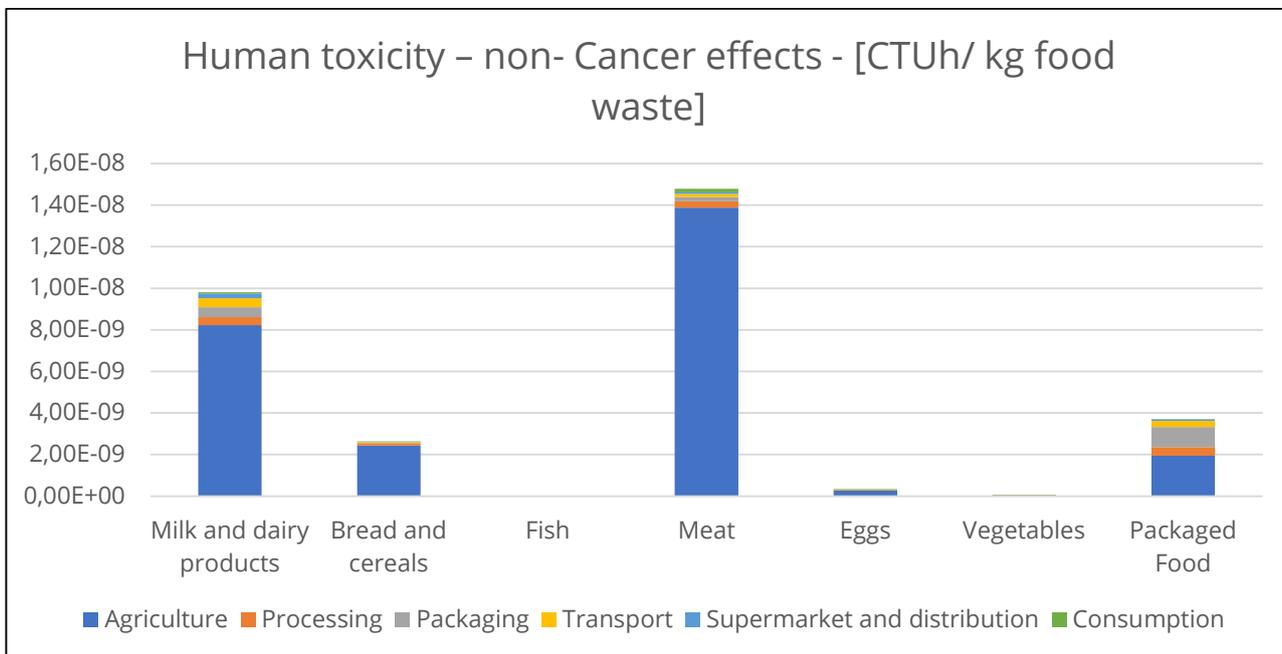


Small enterprises

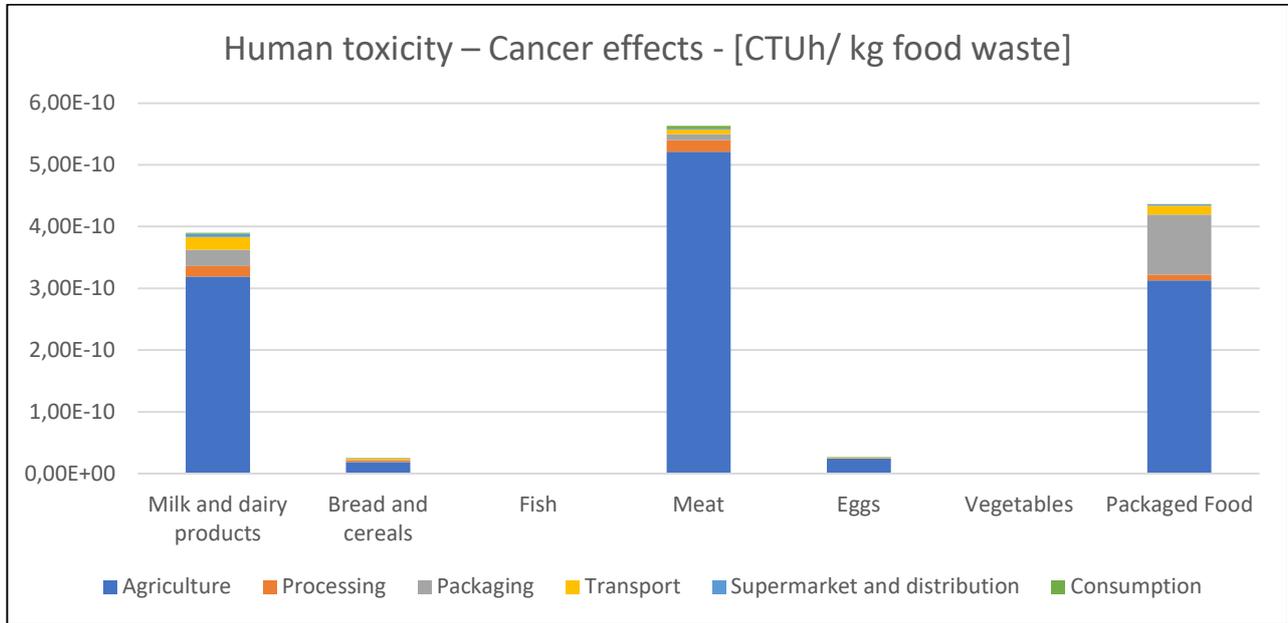
Graph 102: Food waste impact - Climate change (GHG emissions) [kgCO₂eq/ kg food waste]



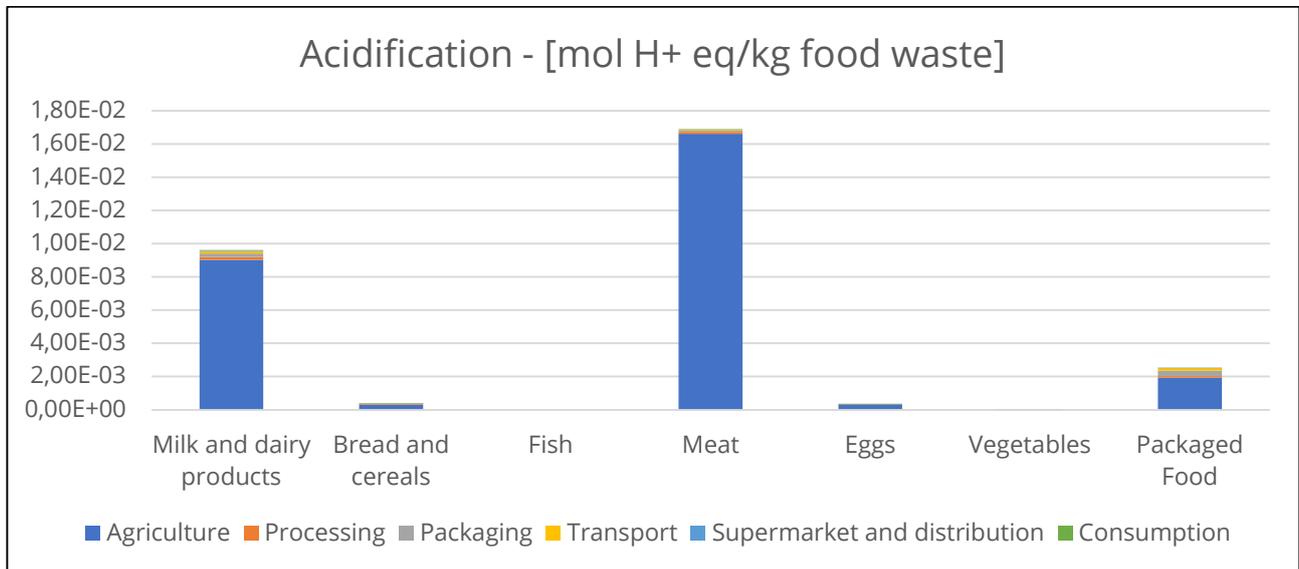
Graph 103: Food waste impact - Human toxicity – non- Cancer effects - [CTUh/ kg food waste]



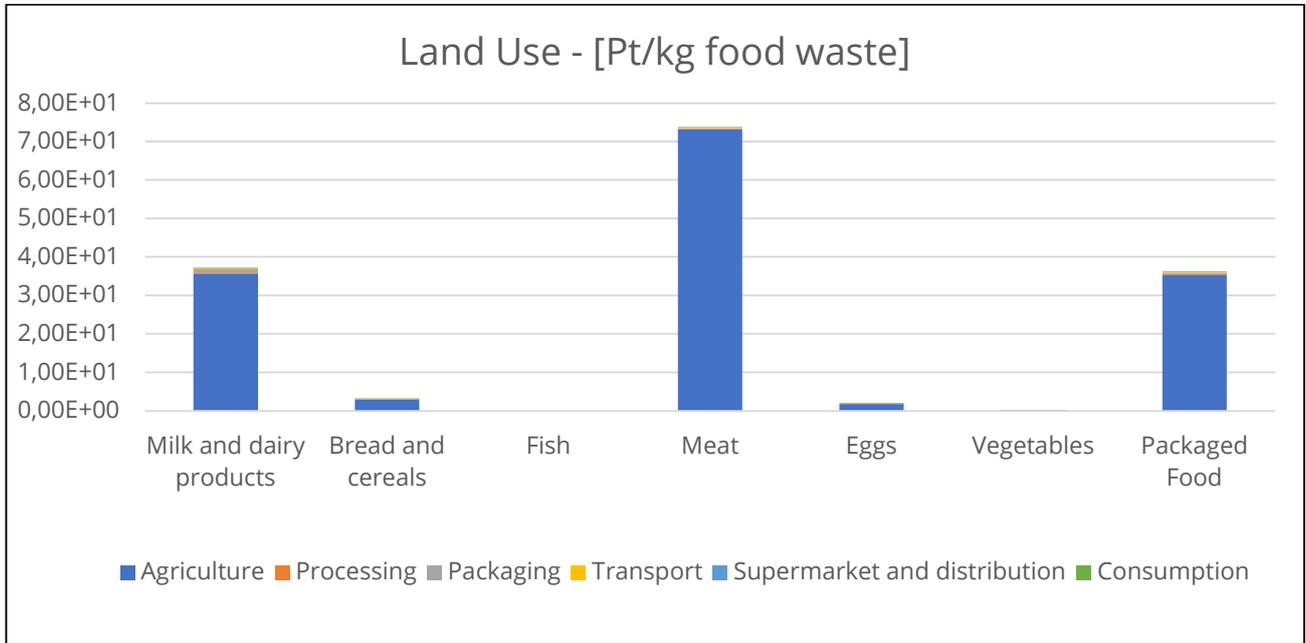
Graph 104: Food waste impact - Human toxicity – Cancer effects - [CTUh/ kg food waste]



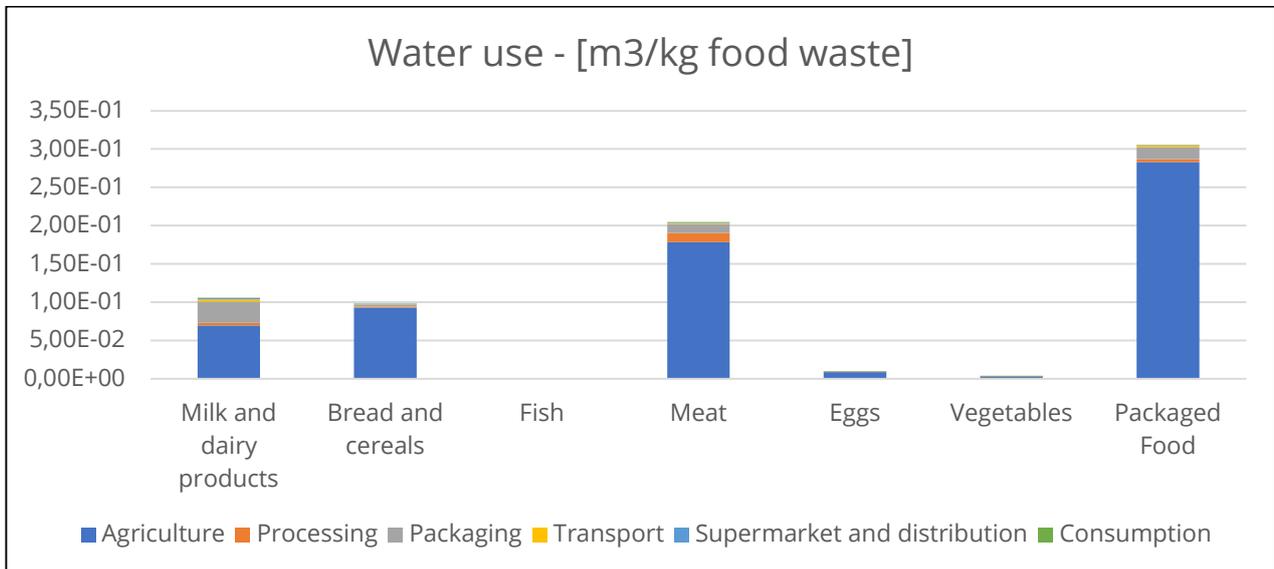
Graph 105: Food waste impact - Acidification - [mol H+ eq/kg food waste]



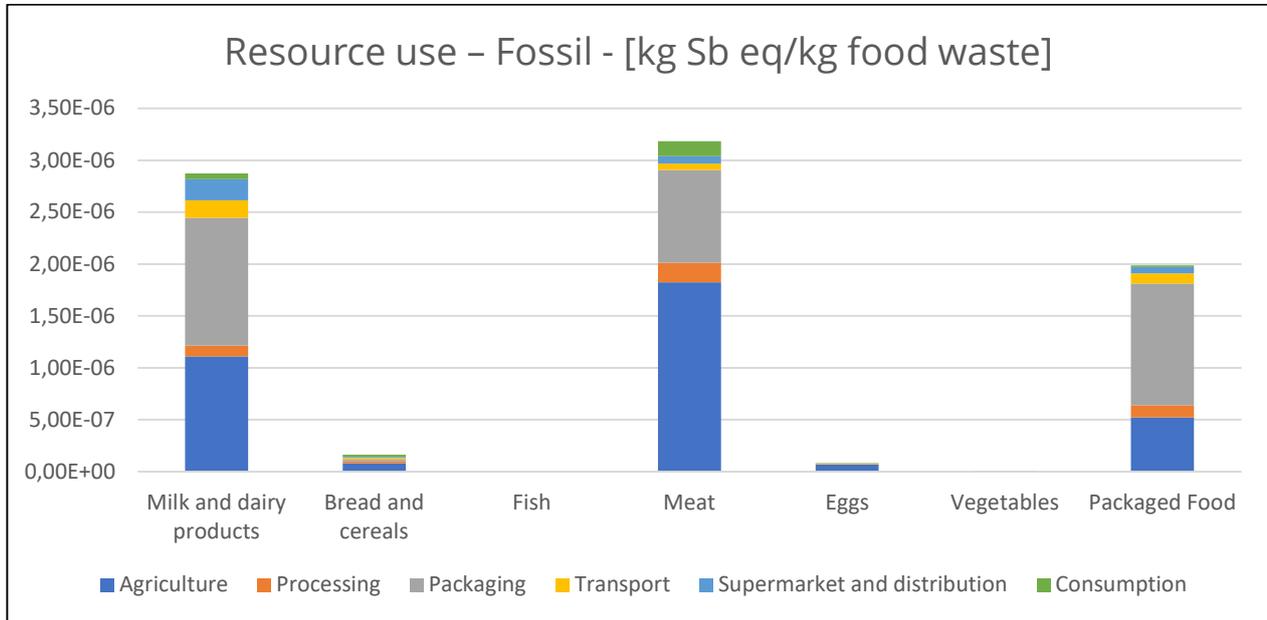
Graph 106: Food waste impact - Land Use - [Pt/kg food waste]



Graph 107: Food waste impact - Water use - [m3/kg food waste]

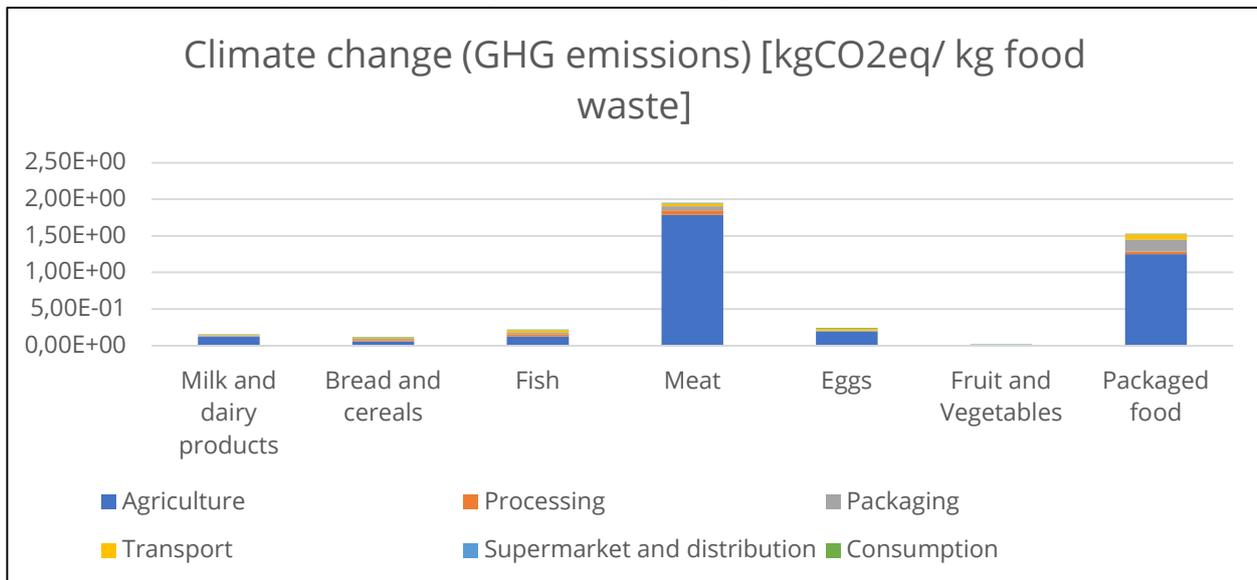


Graph 108: Food waste impact - Resource use - Fossil - [kg Sb eq/kg food waste]

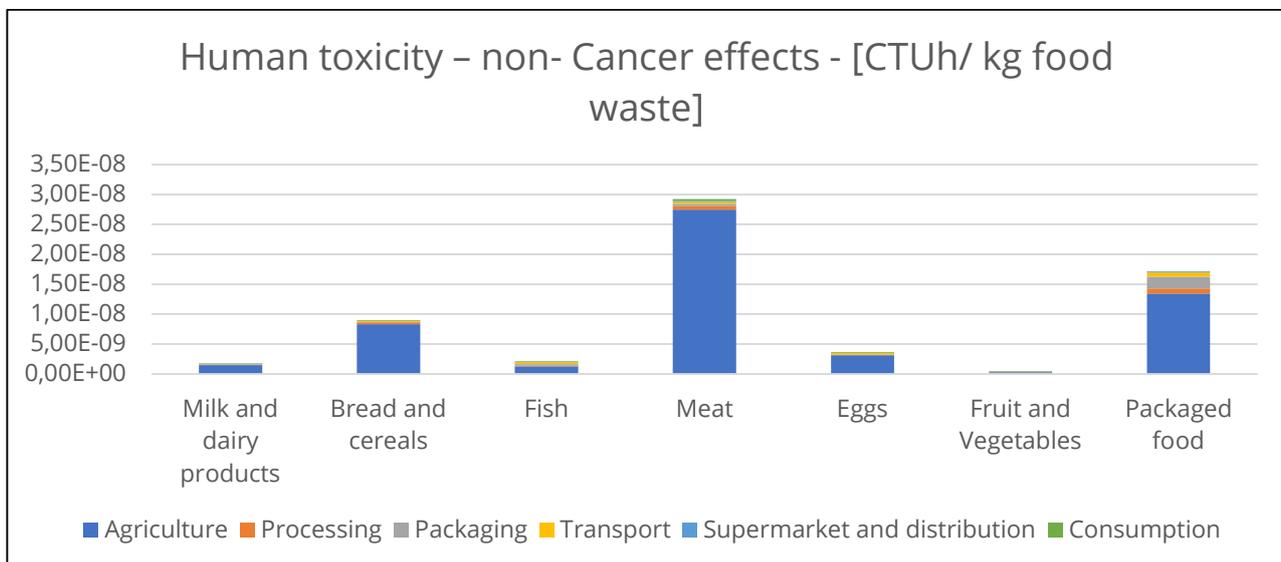


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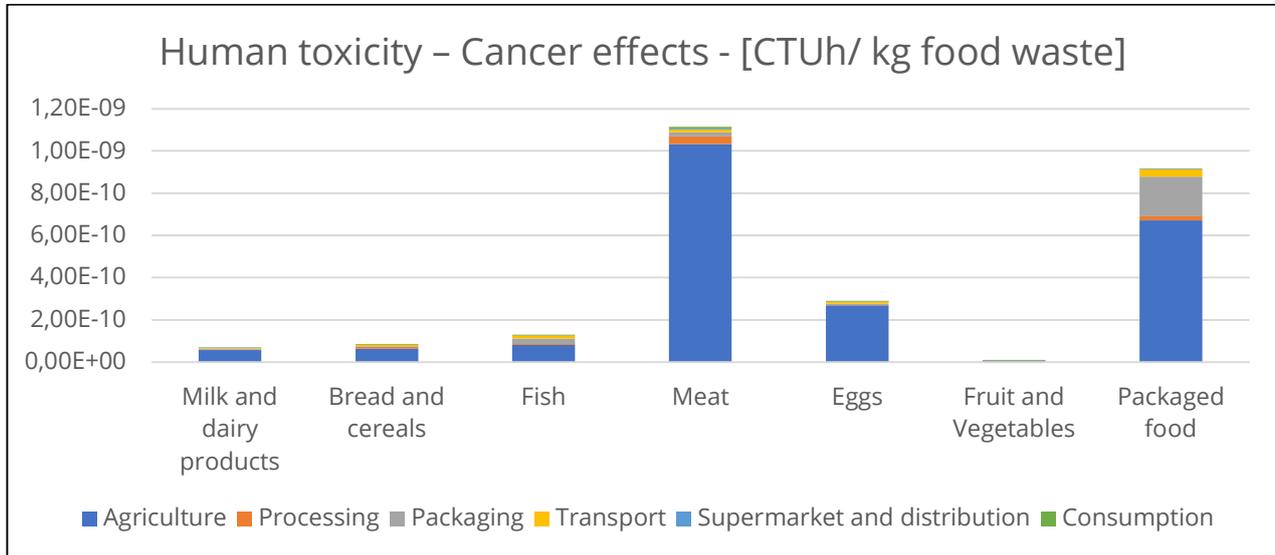
Graph 109: Food waste impact - Climate change (GHG emissions) [kgCO₂eq/ kg food waste]



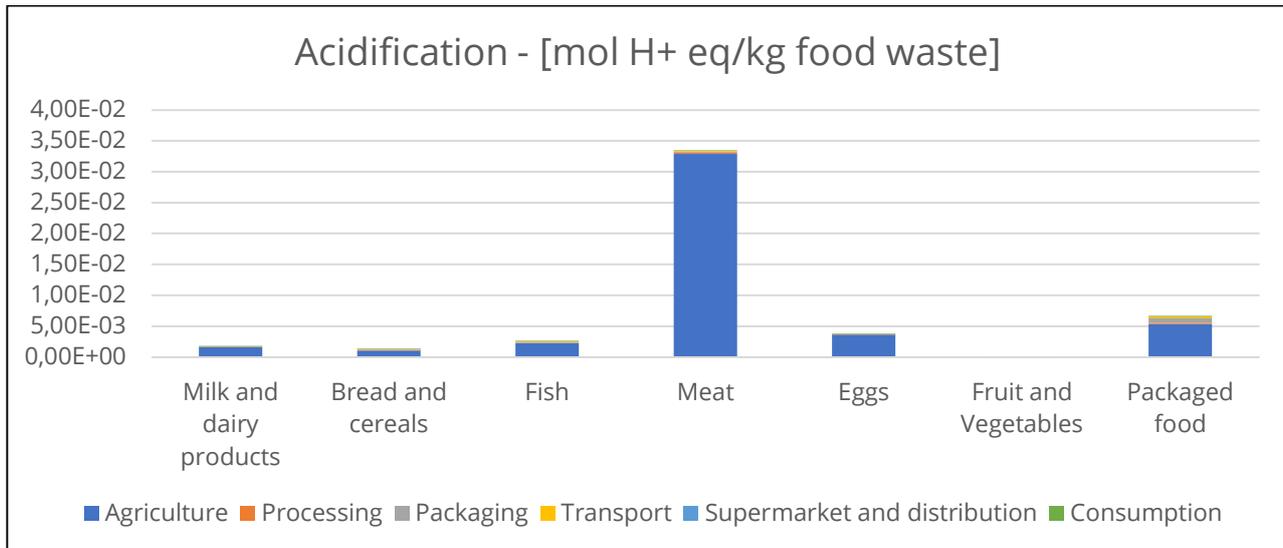
Graph 110: Food waste impact - Human toxicity – non- Cancer effects - [CTUh/ kg food waste]



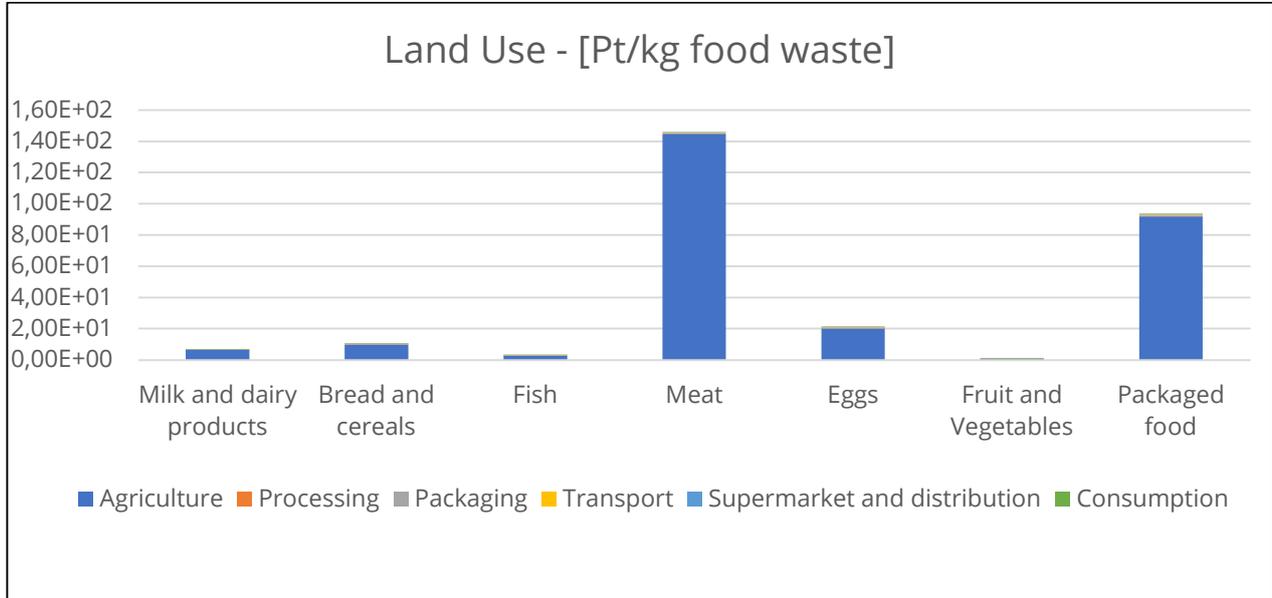
Graph 111: Food waste impact - Human toxicity – Cancer effects - [CTUh/ kg food waste]



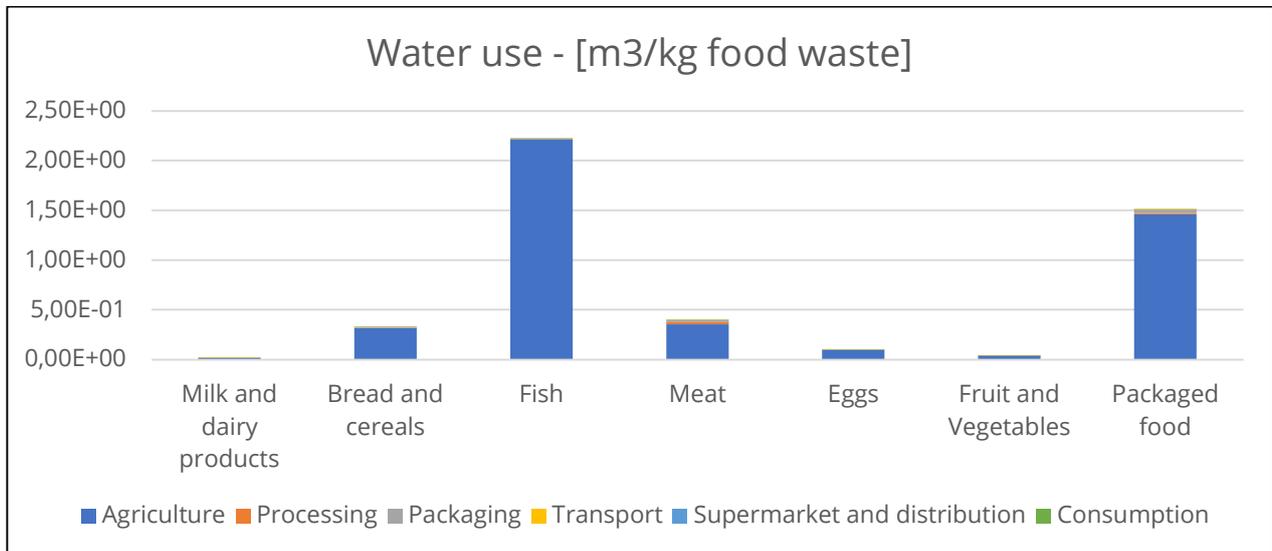
Graph 112: Food waste impact - Acidification - [mol H+ eq/kg food waste]



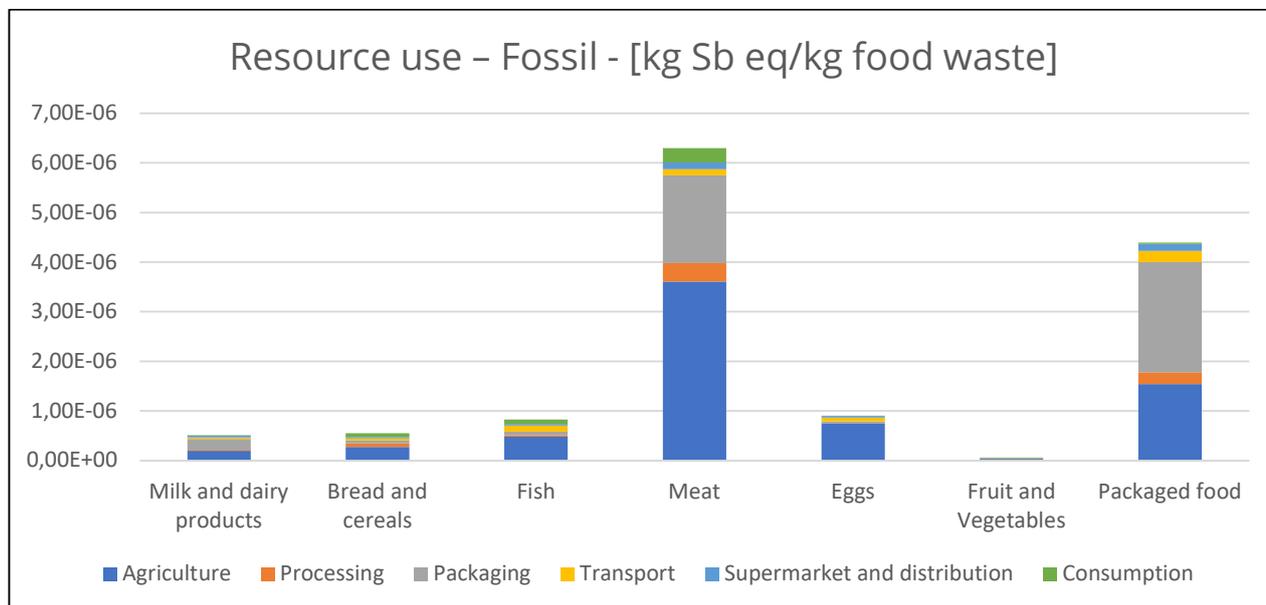
Graph 113: Food waste impact - Land Use - [Pt/kg food waste]



Graph 114: Food waste impact - Water use - [m3/kg food waste]



Graph 115: Food waste impact - Resource use – Fossil - [kg Sb eq/kg food waste]



ANNEX D – Comparison between literature-based estimates and survey results

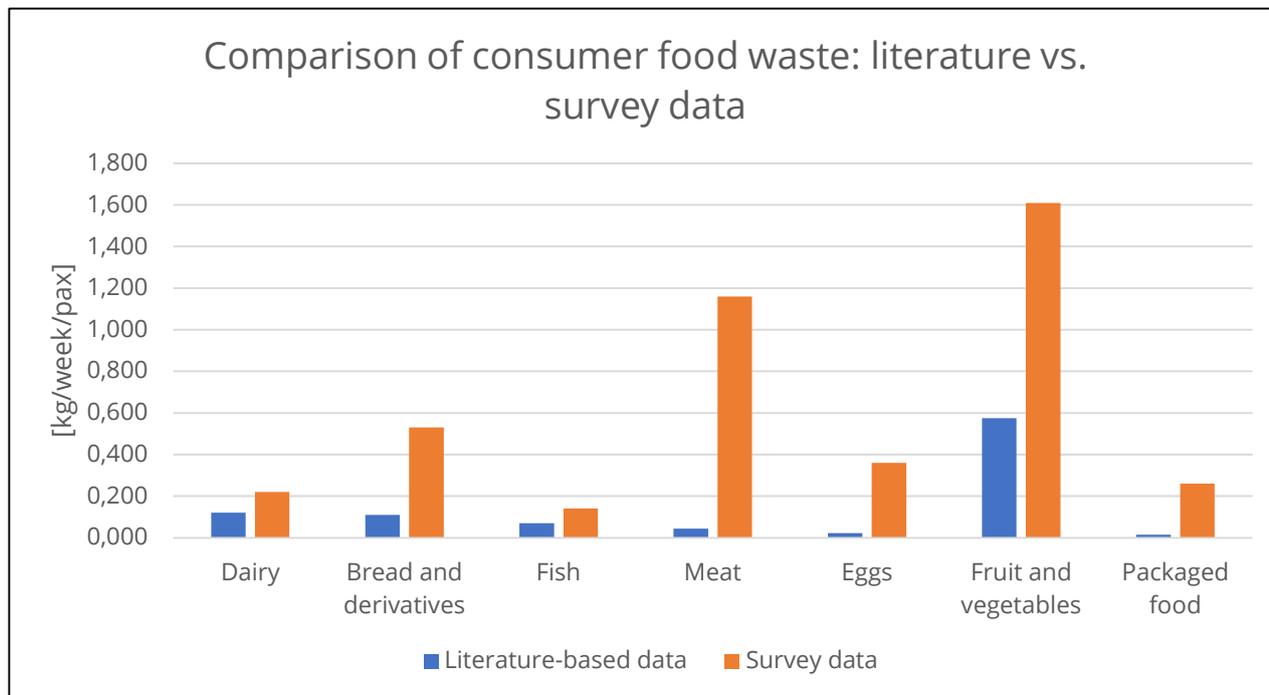
This annex presents a comparison between food waste values derived from literature and those collected through consumer surveys within the framework of the food waste audit. The aim is to evaluate possible discrepancies between consolidated scientific references and self-reported data, in order to better understand both the reliability of the estimates and the potential influence of consumer perception on the quantification of food waste.

Table 17: Comparison between literature-based estimates and survey results

Average food waste [kg/week/person]			
Food category	Literature-based data	Survey data	Ratio (Survey vs. Literature)
Dairy	0,120	0,220	*1,84
Bread and derivatives	0,109	0,530	* 4,86
Fish	0,070	0,140	*2,01
Meat	0,043	1,160	*26,81
Eggs	0,023	0,360	*15,95
Fruit and vegetables	0,575	1,610	*2,80
Packaged food	0,014	0,260	*18,43
TOTAL	0,939	4,020	*4,28



Graph 116: Comparison between literature-based estimates and survey results



The comparison highlights significant differences between the two approaches.

- According to surveys, total food waste reaches 4,02 kg/week/pax, more than four times higher than the literature-based estimate (0,94 kg/week/pax).
- The most pronounced gaps are observed for meat (+2,8 times), packaged food (+18,4 times), and eggs (+15,9 times).
- Even in categories that are already critical in literature studies, such as fruit and vegetables, the reported values are almost three times higher.

These results indicate that survey data tend to overestimate the actual quantity of discarded food. This can be attributed to:

- Overestimation bias by respondents, linked to difficulties in quantifying waste or a tendency to overreport;



- High variability of individual consumption habits, which inflates the overall average when data are self-reported;
- The more conservative nature of literature-based values, generally obtained from standardized methodologies and controlled measurements.

In conclusion, while surveys provide useful insights into consumer behaviour and highlight the categories most affected by waste (especially perishable products such as meat and fresh produce), they should not be considered as absolute measures. A combined use of literature references and survey evidence is recommended, in order to obtain a more balanced and robust assessment of consumer-level food waste.



ANNEX E: Normalisation of food service data compared to the average consumer

To compare food waste generated in the food service sector with that of an average consumer, the data were normalised based on the number of meals declared by operators.

Specifically:

1. The average number of meals served per day was collected, assuming that each meal corresponds to one customer.
2. This figure was then multiplied by 7 days, in order to estimate the total number of meals/customers served in a week.
3. The weekly food waste reported by each food service operator was then divided by the number of weekly meals, obtaining the amount of waste generated per meal served.
4. These values were compared with literature-based reference data on food waste for an average consumer, expressed as kg of food wasted per person per week.
5. A further comparison was carried out between consumers and large, medium, and small enterprises, in order to highlight possible differences in waste generation according to the size of the food service business.

This methodology allows the evaluation of unit food waste per meal served in the food service sector and provides a coherent comparison with both household-level waste (consumers) and enterprise-level waste (by company size), according to literature benchmarks.



Table 18: Food waste per meal unit: comparison between consumers and food service enterprises

Average food waste [kg/week/pax]							
Food category	Literature (Consumers)	Large enterprises	Ratio (Literature / Large)	Medium enterprises	Ratio (Literature / Medium)	Small enterprises	Ratio (Literature / Small)
Dairy	0,120	0,049	*2,43	0,006	*19,64	0,036	*3,36
Bread and derivatives	0,109	0,002	*45,46	0,004	*27,28	0,005	*24,24
Meat	0,043	0,004	*12,03	0,010	*4,33	0,017	*2,58
Eggs	0,023	0,001	*20,55	0,000	*113,00	0,001	*28,25
Fruit and vegetables	0,575	0,00001	*51078,58	0,003	*174,12	0,004	*133,63
Packaged food	0,014	0,003	*4,41	0,001	*20,14	0,028	*0,50
TOTAL	0,939	0,060	*15,76	0,024	*38,65	0,090	*10,39

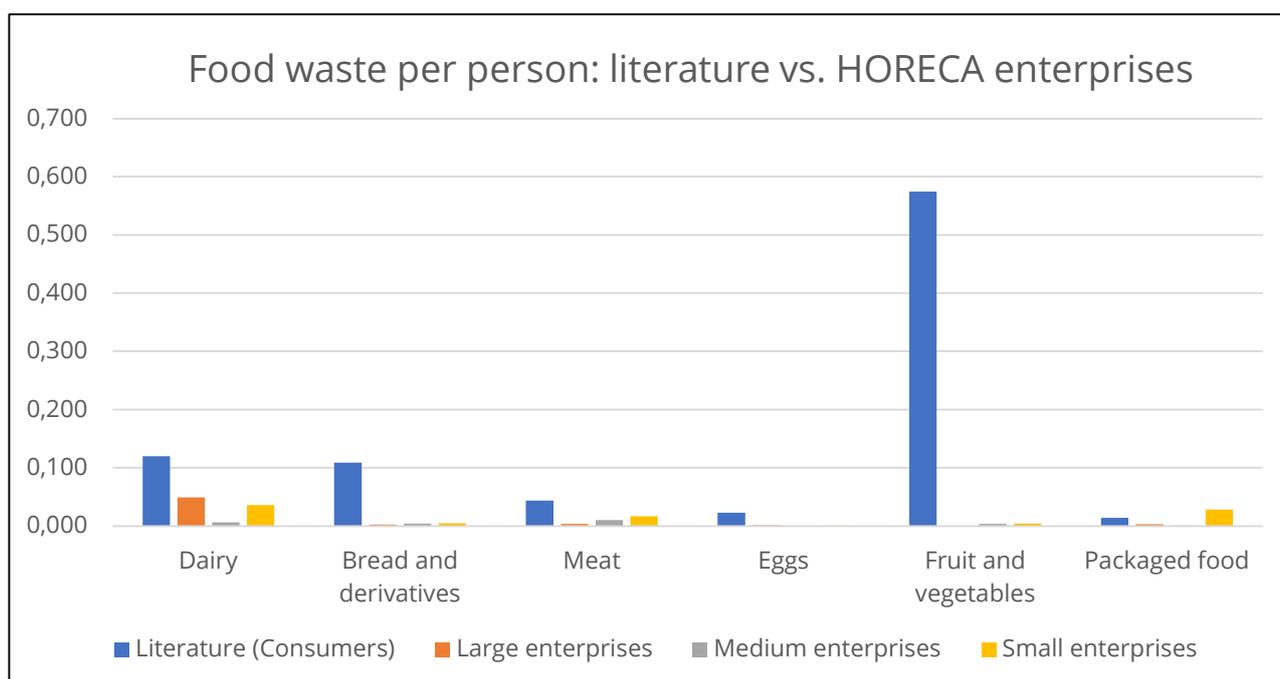
The normalisation of food service data based on the number of meals served shows that food waste per meal unit is systematically lower than the average literature values for consumers.

- For large enterprises, the ratio between literature and observed data ranges from *2,4 times* (dairy) to over *45 times* (bread and derivatives), with an overall gap of about *16 times*.
- For medium enterprises, the differences are even more pronounced: up to *174 times* for fruit and vegetables and *113 times* for eggs, with an overall average ratio of about *39 times*.
- Small enterprises also show lower values compared to consumers, with ratios from *2,6 times* (meat) up to over *133 times* (fruit and vegetables). The only exception is packaged food, where waste per meal is about double that of the average consumer.



- Overall, the weekly waste per meal is:
 - 15,8 times lower in large enterprises,
 - 38,7 times lower in medium enterprises,
 - 10,4 times lower in small enterprises.

Graph 117: Food waste per person: literature vs. Food service enterprises



The results suggest that an average consumer, according to literature values, generates substantially more food waste than food service enterprises when figures are normalised per meal. This interpretation is consistent with evidence at both the European and global levels.

The UNEP Food Waste Index Report (2021) highlighted that households are responsible for about 61% of global food waste, while the food service sector contributes 26% and retail 13%. This confirms that households are the main hotspot of food waste



generation, largely due to lower efficiency in meal planning, storage, and portion control.

Similarly, Stenmarck et al. (2016) estimated that, at the EU-28 level, households accounted for around 53% of total food waste, compared with only 12% from the food service sector. Even in Europe, where food service is highly developed and organised, household food waste remains dominant.

The results of the ECOFOODCYCLE Food Waste Audit analysis fit within this broader framework: normalised food waste per meal in food service enterprises is consistently lower than literature-based consumer estimates. This suggests that professional food management—driven by cost control, planning, and standardised procedures—enables significant reductions in waste. By contrast, households remain the primary hotspot, highlighting the importance of targeting consumer behaviour as a key leverage point for systemic waste reduction.

