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WASTEWISE
Waste Avoidance Strategies for Environmental Sustainability

D1.1 - Database on food products with high waste impacts

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History of changes

Version	Date	Modifications	Prepared by	Approved by
1	29/10/2025	Initial version	Manika RÖDIGER (AGR)	EUCORE (Irene LIVERANI) LUKE (Hanna HARTIKAINEN) Scientific Group members

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Acronyms and abbreviations

EU	**European Union**
FAO	Food and Agricultural Organization of the United Nations
FLW	Food Loss and Waste
FW	Food Waste
JRC	Joint Research Centre of the European Union
MS	Member States of the European Union
UN	United Nations

Acronyms used to identify consortium members

Ref.	Organisation	Acronym
B1	EU CORE Consulting S.r.l.	EUCORE
B2	Natural Resources Institute Finland	LUKE
B3	University of Tuscia	UNITUS
B4	National University of Science and Technology Politehnica Bucharest	NUSTPB
B5	Swedish University of Agricultural Sciences	SLU
B6	Espigoladors Foundation	ESP
B7	Elhuyar Foundation	ELH
B8	University of Bologna	UNIBO
AP1	Agroscope	AGR

Executive summary

Aligned with the priorities of the European Green Deal and the Farm-to-Fork strategy, combating Food Waste (FW) stands as a cornerstone for fostering a fair, healthy and environmentally friendly food system. WASTEWISE has been conceived to design realistic pathways of food waste prevention and reduction, to deliver co-benefits for climate change mitigation, biodiversity and circularity with a holistic, multi-actor approach across the food supply chain as well as to measure environmental impact of food waste prevention and reduction in order to propose evidence-based measures and drive systemic shifts for sustainable food consumption, poverty alleviation, and environmental sustainability in prioritised supply chains. The main ambition of WASTEWISE is to deepen the existing knowledge concerning the real extent of environmental impacts that can be achieved through food waste prevention and reduction efforts, and how they can accelerate the progress towards the EU's climate targets. In doing so, WASTEWISE will analyse food waste data, develop reliable methods to assess environmental impacts, and conduct policy analysis, to inform evidence-based and realistic scenarios for food waste prevention and reduction. Through these evidence-based insights and pragmatic scenarios, WASTEWISE will equip policy makers with key information, recommendations and the instruments to accelerate progress towards climate targets.

This report presents the work carried out within Task 1.1 "Micro-level FW quantification" aimed at compiling food loss and waste (FLW) quantities from existing studies into a database to facilitate further analyses within and outside the WASTEWISE project. The objective is to compile product-level FLW quantities for 10–20 products for all supply chain stages, from primary production to consumption.

Through a literature search and personal inquiries within and outside the project consortium, 64 sources contributing FLW data were identified. Data were only included if they were collected using a method eligible for the European Union (EU) food waste (FW) reporting by member states (MS). The database contains data on 12 food groups and 53 food items (products) with varying degrees of specification and processing. The largest share (32%) of FLW data from 13 European countries comprises quantities lost in primary production. Regarding the food groups, the largest share (22%) was data on quantities lost from vegetables. According to the FAIR principles (Findable, Accessible, Interoperable, Reusable), the database is published open access on the online repository Zenodo (DOI: 10.5281/zenodo.17067509) including a description of its content.

A definitional framework based on previous published work for the food groups 'fruit and vegetables', 'cereals', 'dairy', 'meat' and 'fish' is used as a conceptual foundation to categorise and, if necessary and possible, recalculate the FLW quantities. The database contained several categories to structure the information of the studies. The categories are on the food group and food item classification, on the geographic and temporal scope, classifications of the corresponding food supply chain stage, the FLW quantities as well as the variance and ways of disposal or utilisation, methodological information, and lastly, the source.

Three material flow analyses serve as application examples of the database, demonstrating its value and limitations. To conduct the material flow analyses, data from the database on FLW quantities were used, if

available. For many food supply chains, information on FLW quantities is incomplete, and using data from other countries as proxies is sometimes challenging due to considerable differences between studies. These differences could be due to different methods of measurement, different system boundaries and FLW definitions or actual country-specific differences.

To conclude, recommendations on the conceptual frameworks and collection of primary data are provided. First, regarding the conceptual frameworks of FLW quantifications, we recommend further developing and synthesising existing frameworks and guidelines on the definition of food supply chain stages and the related FLW to increase the comparability and interoperability of FLW data. Therefore, frameworks

- covering the complete lifecycle of products, including pre-harvest phases;
- specific to food groups on a detailed level;
- specifying the phases of the lifecycle;
- and clarifying at which stage certain materials or co-products should be accounted for.

It will be helpful for studies quantifying FLW to indicate the specific processes to which their results refer.

Moreover, the quality and quantity of available data should be improved to produce reliable and valid analyses of material flows and FLW in the food industry. For data collection to be more targeted, it is recommended to investigate which products are similar regarding the processes in which FW is generated as well as the share of FW that is generated. In addition, supply chain strains, which are of lower importance than the main ones, are often ignored in studies. It is recommended to investigate the structure of supply chains in more detail, including a quantification of how much of a product flows into specific stages, such as farmers' markets. For future studies, it is further recommended that:

- standard deviations, sampling methods and representativeness of the samples are reported since they allow an assessment of the reliability of the results;
- data collection methods are improved, for instance direct measurements, e.g. with drones for crops for which it is feasible, or improving farmer estimations by repeated estimations in intervals or at different seasons or by complementing farmer estimations with expert interviews;
- the share of FLW of the total quantity entering a supply chain stage is reported;
- the stages of processing and manufacturing and restaurants and food services are analysed;
- FLW quantities for several years are compared;
- data on legumes and oil crops are collected as there are relatively few.

A further valuable task would be to create a harmonised database, based on the presented micro-level database. It is suggested to consolidate existing findings and fill data gaps with assumptions where necessary for each product and supply chain stage. For such a database to be useful, country-specific differences should also be analysed and included in the database.

1. Introduction

As a cascade project, the WASTEWISE project has several interlinked tasks. Within Work Package 1 (WP1), the aim was to create databases to be used for further analysis in the project. In Task 1.1 within WP1, the focus of the database is on FW quantities at a disaggregated level— that is, food items such as apples or tomatoes. With this, the project contributes to a better understanding of leverage points to decrease FW quantities and impacts by enabling product-level analyses of environmental effects, in line with the 2030 Agenda for Sustainable Development (EU Directive (EU) 2018/851). The scope of Task 1.1 allows for all kinds of food items, including composite dishes, which are discarded in significant quantities in households and restaurants or other food services (Boschini et al. 2020; Silvennoinen et al. 2022; Sundin et al. 2024). The objective of Task 1.1 is to generate a database of FW quantities of 10–20 food items for different countries within Europe.

Through a literature search and personal inquiries within and outside the project consortium, 64 sources contributing FLW data to the database were identified. Only data collected with methods accepted for the MS FW reporting to the EU were included. The database contains data on the 12 broad food groups: 'legumes', 'grains and grain-based products', 'vegetables and vegetable products', 'starchy roots and tubers', 'fruit used as fruit', 'meat and meat products', 'fish (meat)', 'milk and dairy products', 'eggs and egg products', 'composite dishes' and 'beverages'. Data on 53 food items of varying degrees of specification (e.g. 'citrus fruit' vs. 'hake') and of processing (e.g. 'bovine carcase' vs. 'bovine meat'; 'tomatoes' vs. 'processed tomato products') are entered in the database. A list of these 53 food items can be found in Annex A2. Overall, the database was filled with 504 rows. The FAIR principles are applied by publishing the database with a permanent link to the online repository Zenodo (DOI: 10.5281/zenodo.17067509) together with a description of its content.

The remainder of the report is structured as follows: Section 2 contains definitional frameworks of FLW as well as explanations of relevant terms and concepts. Section 3 includes a detailed description of the content of the database. Section 4 presents application examples of the database in the form of material flow analyses, and Section 5 discusses the value and limitations of the database. Section 6 closes the report with concluding remarks and recommendations for future studies.

2. Definitions and framework

Readers are sometimes confronted with a lack of clarity regarding the content of data on FLW because different viewpoints on the problem and different objectives for measurement may lead to different concepts of FLW (Boiteau & Pingali 2023). This section provides working definitions of relevant terms and concepts regarding food and waste to increase the comprehension of the content of the database and to highlight where the content of the database deviates from the EU definitions that are used as our basic reference. In Table 1, definitions of **food and its loss and waste**, which are built upon in this report, are provided, and their application in the database is explained.

Table 1. Definitions of relevant terms and concepts

Term	Definition	Application in the database
Food	Food is, as defined in Article 2 of the Regulation (EC) No 178/2002 by the EU, understood as "any substance or product, whether processed, partially processed or unprocessed, intended to be, or reasonably expected to be ingested by humans. [...] "Food" includes drink, chewing gum and any substance, including water, intentionally incorporated into the food during its manufacture, preparation or treatment." Feed, plants before harvest and live animals (except if they are prepared to be placed on the market for human consumption) are not food, according to the Regulation (EC) No 178/2002.	Even though plants before harvest (mature or immature) and live animals (mature or immature) are not defined as food, they are included in the database if information is available since they are a potential source of food.
Food Loss	"Food losses can be defined as losses of crops prior to harvesting (including crops ploughed in or left on the field) and mortality of animals ready for slaughter, as these streams are excluded from the definition of food waste at primary production, according to Article 2 of REGULATION (EC) No 178/2002 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL)" (European Commission et al. 2024, p. 8). Food loss is any "harvest-mature plant, animal or living being (including inedible parts) that is not successfully harvested of collected, as well as food removed from the supply chain [...] during post-harvest phase that does not become animal feed,	The specific process in the supply chain to which quantities refer are given in the database whenever possible. Therefore, different definitions can be applied to the data. Crops left on the field and technically caused losses during harvest are accounted as 'harvest loss' in the database.

	by-product, or food waste" (FOLOU project 2023, p. 9).	
Food Waste	"[F]ood [...] that has become waste" (Directive 2018/851), while waste is what has been or is intended to or needs to be discarded (Directive 2008/98/EC). "[...] food and the associated inedible parts removed from the human food supply chain." (United Nations Environmental Program [UNEP] 2024, p. V) "Food also includes inedible parts, where those were not separated from the edible parts when the food was produced, such as bones attached to meat destined for human consumption. Hence, food waste can comprise items which include parts of food intended to be ingested and parts of food not intended to be ingested" (European Commission et al. 2024, p. 9). "Food waste is the decrease in the quantity or quality of food resulting from decisions and actions by retailers, food services and consumers" (Food and Agriculture Organization 2019, p. 5).	FW is generated at all stages of the food supply chain, including primary production, processing and manufacturing, retail and other distribution of food, restaurants and food services, and households. Disposed food was categorised as waste in the database if it was used for: • Biogas/ anaerobic digestion • Compost/ fertiliser • Sewer • Wastewater • Bio waste/ animal waste/ waste • Bioethanol • Fuel • Incineration • Not used/ otherwise used • Landfill Harvested plant material or animal material after slaughter, which is used as livestock feed or finds its way to human nutrition through donations or similar, is not included in the FW quantities in the database. When necessary, FW quantities were recalculated in the database to comply to this definition. Exceptions when this was not possible are marked with colour and commented.
Side stream	The side stream is composed of raw material, product(s), or part(s) of a product produced or manufactured for human nutrition that is removed from the food chain and thereby does not become food. By-products are, for instance, utilised as animal feed, fertiliser, or energy, or they can end up in landfills without being utilised (based on Hartikainen et al. 2014).	In the categorisation of data and information in the database, we deviate slightly from the given definition. The information is classified either as disposal and other non-food uses which are considered FLW, or as utilisation, which is not considered FLW, for instance livestock feed or food donated to social entities. The latter does not comply with the given definition as side

		stream, as it ends up as human food. Moreover, pet or mink food, utilization for the textile or starch industry are not considered FW. These products can be regarded as by-products.
Edible parts of food	"Edible food parts are the components associated with a food, in its fresh mass status, that are usually consumed by humans in the [Member States], either as is (raw consumption) or after processing or cooking. The definition of edible food parts might differ from country to country, or from region to region, according to local culture and habits" (European Commission et al. 2024, p. 9). According to UNEP (2024), bones, rinds and pits/stones, for instance, are considered as inedible.	Quantities are represented as edible, inedible or both, based on the information provided in the original sources. No recalculation was done. In some cases, when it was obvious and no explicit information was given in the original source, the material type was interpreted. For instance, if the quantity of unharvested apples was reported, the quantity was labelled as including edible and inedible parts since it is common knowledge that apples contain pits, which are considered inedible.
Food supply chain	A food supply chain is composed of the intermediaries between primary production and consumption or "the system of organizations, people, and activities involved in moving food from its producer (usually the farmer) to the consumer" (Beretta et al. 2013). The FAO definition (2019) of food waste considers the stages retail, food services and consumers, while the framework of the FUSIONS project (2016) as well as the EU also include the stages of harvest (in case of FUSIONS project), post-harvest handling in primary production, and manufacture and processing (Leverenz et al. 2021).	Since the loss of potential edible food parts along the entire process of food generation and handling is relevant to increasing the resource use efficiency and decreasing detrimental environmental impacts, quantities of losses also prior and at harvest were included in the database, as suggested by FOLOU project (2024). The deviation from expected or potential to harvested quantities in the sense of the genetic potential of the plants or animals, which is not realised due to weather, feeding or other circumstances is not included in the database. However, data on pre-harvest losses such as damage to crops from wild animals or crops that were not harvested due to insufficient demand are included in the database.

The processes in food supply chains, and hence the processes relevant to consider when studying FLW, strongly depend on the product. Therefore, definitional frameworks for FLW in supply chains for the product groups 'fruit and vegetables', 'cereals', 'dairy', 'meat' and 'fish' are outlined. Figures 1–5 illustrate the definitional frameworks. The frameworks are based on previous projects (WASTELESS, FUSIONS and FOLOU) and the EU and UN frameworks, as explained in Leverenz et al. (2021) and by the European Union (2020). Even though the FLW quantities are illustrated in the figures per process, in the database, they are further differentiated into quantities categorised as FLW and quantities categorised as non-FLW side streams. The frameworks include the general supply chain stages of primary production, processing and manufacturing, distribution through wholesale and retail ('retail and other distribution of food' as labelled by the EU FLW reporting) and consumption in households, restaurants and food services. These are assumed to represent the main stages of food supply chains. Not represented in the frameworks are, for instance, consumption by producers and direct sales from farmers through farm shops or farmers' markets.

Specifications of the general supply chain stages differ between product groups. In the case of vegetables and fruit in primary production, the stage is further split into pre-harvest losses (immature or harvest-ready plants), harvest losses and post-harvest losses during transportation in the production site or post-harvest handling (see Figure 1). The FLW of vegetables and fruit in primary production might occur due to overproduction, handling during harvest and timing of harvest, storage or non-compliance with marketing standards (FOLOU project 2023; WASTELESS project 2023). After primary production, vegetables and fruit either enter the market for consumption as fresh produce or go to the market for processing to juices, canned, frozen or other products. Then, the products enter the distribution stage, and finally the consumption stage (see Figure 1). FLW may occur at all stages.

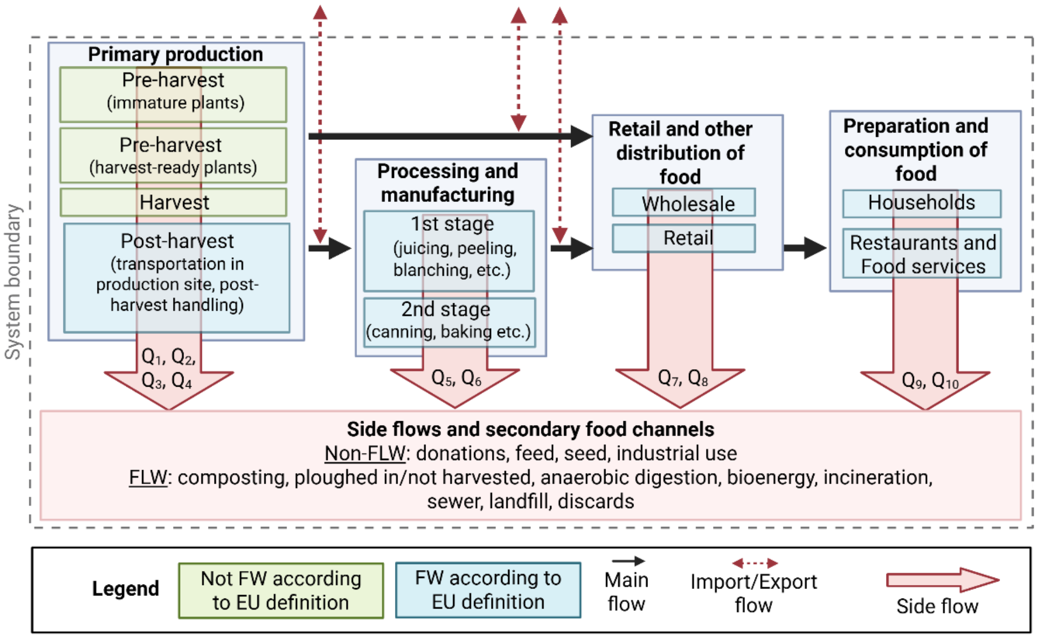

Figure 1. Definitional framework of food loss and waste in vegetables and fruit supply chains
(based on FOLOU project 2023, FUSIONS project 2016, Leverenz et al. 2021, WASTELESS project 2023; Created in BioRender. Rödiger, M. (2025) https://BioRender.com/npvajl2; Q1-Q10 represent the side flow quantities per process).

For cereals, primary production is also split into pre-harvest losses of immature plants, harvest-ready plants, harvest losses, and post-harvest losses (see Figure 2). FLW in the primary production of cereals might occur due to insufficient quality of the crops, shedding losses during harvest, grain damage and losses during threshing, or spoilage during storage (WASTELESS project 2023). Then cereals enter the market for grains to be further processed. A common processing step is milling, which is considered as the first processing stage. From milling, significant quantities of bran deviate from the main flow to feed or other utilisation (Nabi Dar 2024). Further food might get lost during the manufacturing of cereal products, for instance, to bread or pasta, which is considered the second processing stage, and then in the following stages of distribution and consumption (see Figure 2).

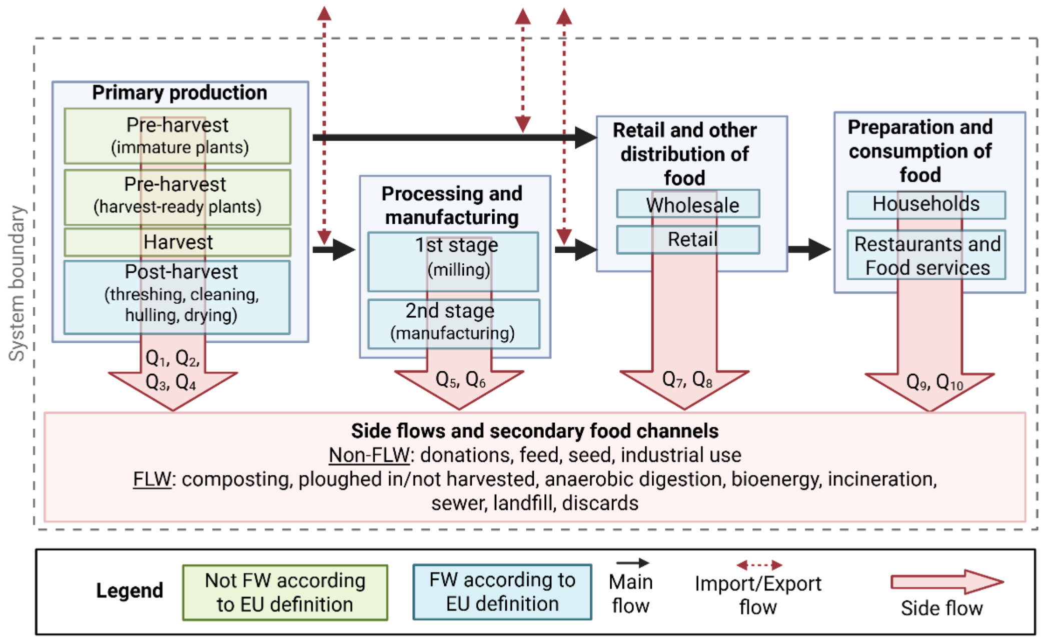

Figure 2. Definitional framework of food loss and waste in cereals supply chains
(based on FOLOU project 2023, FUSIONS project 2016, Leverenz et al. 2021, WASTELESS project 2023; Created in BioRender. Rödiger, M. (2025) https://BioRender.com/npvajl2; Q1-Q10 represent the side flow quantities per process).

Figure 3 depicts the definitional framework for FLW in a dairy supply chain. In primary production, the stages of milking and milk storage are considered. Potential milk losses due to dairy cows' premature deaths are not accounted for in the definitional framework or in the database. From milk storage on a farm, the raw milk proceeds to be processed to sales-ready milk (first-stage processing) and non-milk dairy products (second stage-processing). Some cheese types are produced from raw milk and therefore include only one processing stage in the definitional framework. Significant amounts of whey are produced as a by-product from cheese and other products (Siso 1996). The final supply chain stages are, as for the other frameworks, the distribution with wholesale and retail and the preparation and consumption in households, restaurants and food services, where FLW of dairy products might also occur (Beretta et al. 2013, Cicatiello et al. 2017).

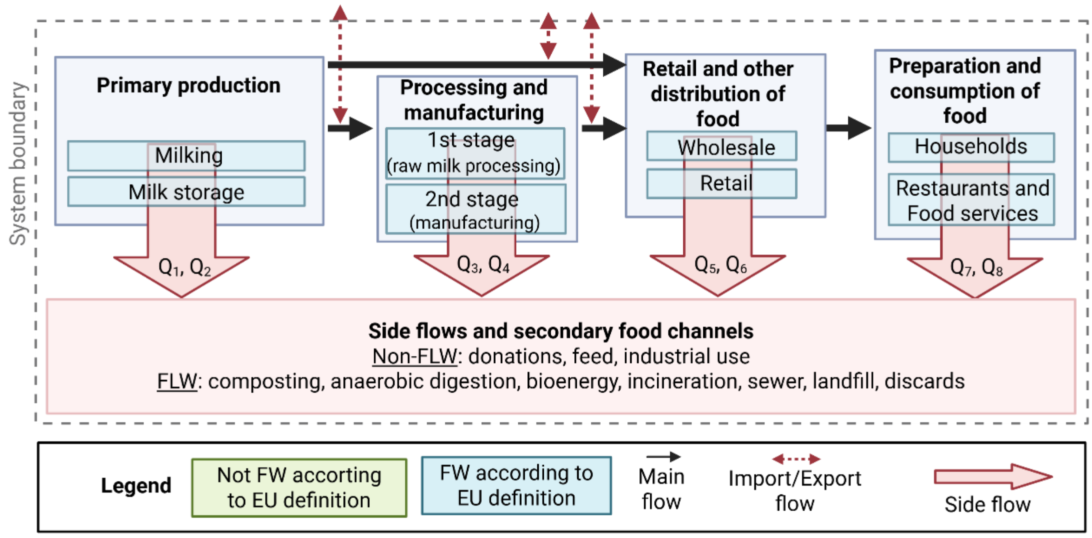

Figure 3. Definitional framework of food loss and waste in dairy supply chains
(based on FOLOU project 2023, FUSIONS project 2016, Leverenz et al. 2021, WASTELESS project 2023; Created in BioRender. Rödiger, M. (2025) https://BioRender.com/npvajl2; Q1-Q10 represent the side flow quantities per process).

In the framework for meat, primary production is further distinguished into the phases of deaths of immature animals, deaths of animals that are ready for slaughter and deaths of animals that are being transported to the slaughterhouse (see Figure 4). The slaughtering is conceptualised as part of the processing and manufacturing stage, where further processing to sales-ready meat products is also located. At the primary production stage, immature and mature animals that die of a disease before they can be slaughtered are classified into category 1 material, based on the EU regulation on animal by-products, and leave the food system because they are unsafe for consumption (The European Parliament and the Council of the European Union 2009). They are not considered FLW but are still represented since their side flows are interesting from a circular economy perspective. In other cases, it might be possible to conduct emergency slaughter and process immature and mature animals to meat for consumption.

Animals that died during transportation and are rejected from the slaughterhouse are classified based on the EU regulation on animal by-products, which leave the food system, but could also be considered FL. During the processing and manufacturing stage relevant quantities of co- and by-products and FW occur, such as offal, blood, skin and feathers (Amicarelli et al. 2021). A large share of these co- and by-products leave the food system as category 1, 2 or 3 material (Liu et al. 2019, Pishgar-Komleh et al. 2021). Category 3 material, however, contains as well animal parts that are edible for humans but not consumed for preference reasons (BLV 2018). Further losses occur during the stages of distribution via wholesale and retail, as well as during preparation and consumption at home and through food services (Boschini et al. 2020, Cicatiello et al. 2017, Silvennoinen et al. 2022).

Figure 5, finally, shows the definitional framework for the FLW in the supply chain of fish from marine fishing and aquaculture. The primary production stage is composed of the losses of immature fish, for instance in aquaculture if immature fish are dying in ponds, losses of mature fish and at catching, for instance, if fish are injured during catching so that it cannot be used as human food. These are classified according to the EU animal by-products regulation and leave the food system. As for meat, these side streams are represented in the definitional framework. The processing stage is conceptualised as composed of the first stage, where fish is sorted, bycatch is sorted out, and fish is iced. The second processing stage occurs when fish products are produced. The last two supply chain stages, retail and other distribution of food and preparation and consumption in households, restaurants and food services, are the same as previously.

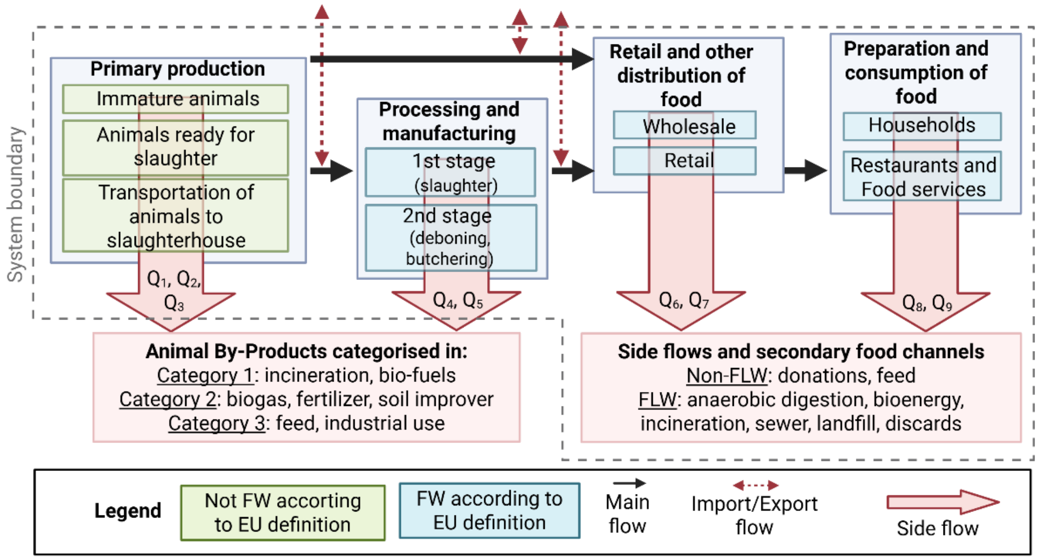

Figure 4. Definitional framework of food loss and waste in meat supply chains
(based on FOLOU project 2023, FUSIONS project 2016, Leverenz et al. 2021, WASTELESS project 2023; Created in BioRender. Rödiger, M. (2025) https://BioRender.com/npvajl2; Q1-Q9 represent the side flow quantities per process).

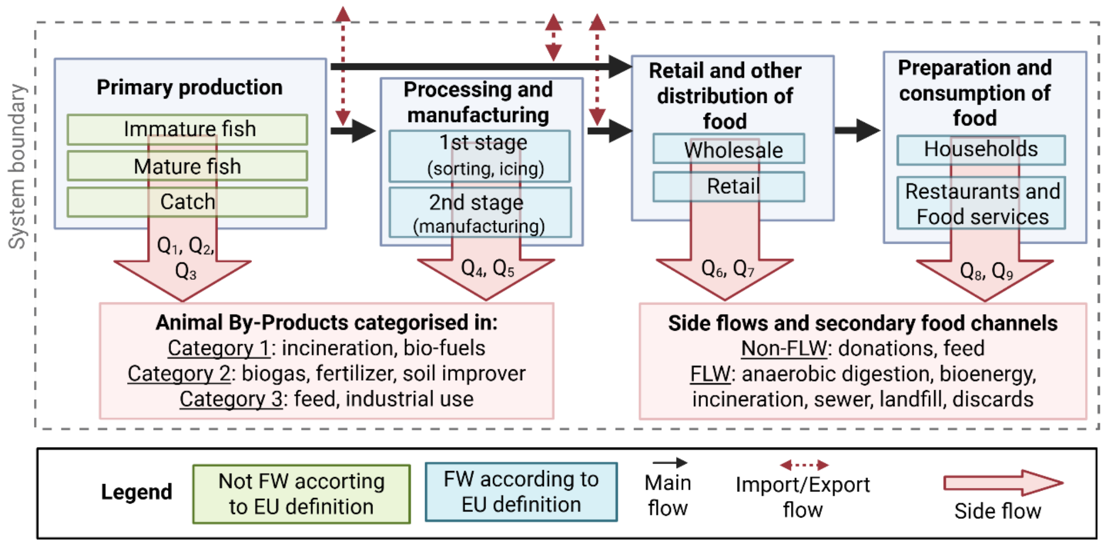

Figure 5. Definitional framework of food loss and waste in fish supply chains (marine fishing and aquaculture)
(based on FOLOU project 2023, FUSIONS project 2016, Leverenz et al. 2021, WASTELESS project 2023; Created in BioRender. Rödiger, M. (2025) https://BioRender.com/npvajl2; Q1-Q9 represent the side flow quantities per process).

3. Structure and overview of the database

Definitional frameworks serve as a conceptual basis for the database. An overview and description of the categories used to structure the data and information in the database are provided in Table 2. The database mostly follows the requirements set out by Hanson et al. (2016) for FLW inventories. Specifically, information on the timeframe (**year of data collection**), **material type** (edible or inedible) and **destination** of removed material if information is available, and on the boundary, that is on the **geographical scope** (country that the data refer to) and the **supply chain stage** is provided. For the location of the FLW within the food supply chain, three classification systems were used. The first is the classification of supply chain stages, as they are reported to the EU: primary production, processing and manufacturing, retail and other distribution of food, restaurants and food services, and households (EUROSTAT 2022). Second, a more detailed classification of the supply chain stages was adapted from the FAO Food Loss and Waste Database (FAO 2025). Third, the statistical classification of economic activities (NACE) of the EU (EUROSTAT 2025) was included. Data on pre-harvest losses and deaths of immature animals are included, if available, and entered as separate data points from other phases of primary production, if possible.

The **FLW quantities** are reported in different units in the consulted publications, depending on the supply chain stage. All quantities are given in **fresh mass**. Information on FLW quantities is completed by indications of **variance**, if available, as well as information on further utilisation or ways of disposal. To specify the products for which FLW quantities were contained in the database, two food **product classification** schemes were used: the FoodEx2 classification of the European Food and Safety Authority (EFSA) and the Statistical Classification of Products (CPA). Some product groups were excluded a priori due to the resource-related necessity of limiting the scope and the following decision to include food groups with the highest share of waste volume or the highest relevance with regard to negative environmental effects. Excluded are, for instance, oil crops, nuts and sweets. In addition, the food items included were a priori limited to products that were produced at primary production stage in Europe and products with relatively high market share. Hence, bananas, for example, were excluded because they were not grown in Europe, and sheep and goat meats were not included because they have relatively low market shares.

Finally, the database contains **methodological information** on the studies providing FLW quantities, such as the method of data collection, the number of observations or sample size and a description of the sample. Only studies applying the methods eligible for the national reporting of FW to EUROSTAT are included in the database (see https://eur-lex.europa.eu/eli/dec_del/2019/1597/oj). With methodological information on FLW quantities, it is aimed at enabling users of the database to assess the quality of the data. For this purpose, additional information on known uncertainty regarding the validity of the data and further detailed descriptions of the studies are included. Lastly, the source of the data is given. There are 22 rows that contain FLW data, certainly or possibly deviating from the definitional framework, but they were kept in the database because the information was assessed as potentially useful. The FLW quantities of these 22 rows are marked and a note is made in the column addressing uncertainties regarding the data. Excerpts of the database are presented in Annex A5.

Table 2. Variables contained in the micro-level database

Variable Category	Variable name	Type	Description of content
Food item	Food group (FoodEx2)	Categorical	This variable indicates in which category the food items from the studies are classified based on the scheme of EFSA FoodEx2. Here, broader categories are used, e.g. 'vegetables'. Further information: https://www.efsa.europa.eu/en/data/data-standardisation
	Food product (FoodEx2)	Categorical	This variable indicates in which category the food items from the studies are classified based on the scheme of EFSA FoodEx2. Here, more specific categories are used, such as 'carrots'. The food product is given as: a) food product leaving primary production, b) food product entering a supply chain stage, and c) food product leaving a supply chain stage.
	Food product (CPA)	Categorical	The CPA is the Statistical Classification of Products by activity (CPA 2.2), which is another classification scheme for, among other, food items. Further information: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Statistical_classification_of_products_by_activity_(CPA) The food product is given as: a) food product leaving primary production, b) food product entering a supply chain stage, and c) food product leaving a supply chain stage.
Geographic scope	Country of data collection	Text	The elements of FW might differ between regions due to different diets. Therefore, the country in which data were collected was indicated in the database.
Temporal scope	Year of data collection	Numeric	FW quantities may change throughout different historical contexts. Thus, the year in which the FW data were collected was included in the database.
	Year of publication	Numeric	The year of publication was included in the database as well to have a rough idea about the time of data collection, in case that information on the year of data collection was not available.
Location of food loss and waste within the supply chain	Supply chain stage (broad)	Categorical	Based on the categorisation that is used in the FW reporting to the EU, information on the stage within the supply chain that the FW occurs is indicated. Categories: • Primary production • Processing and manufacturing • Retail and other distribution of food

Variable Category	Variable name	Type	Description of content
			• Restaurants and food services • Households
	Supply chain stage (specific)	Categorical	A more detailed categorisation of processes in the food supply chain that the data refer to was used in the database. It was developed from the categories included in the FAO FLW database, the definitional frameworks and the studies providing the data.
	NACE code	Categorical	This variable contains relevant categories of the statistical classification of economic activities (NACE) in the EU. The list of categories included in the menu of the dataset are addended in Appendix A1. Household consumption is not included in this classification because it is not an economic activity. For household consumption, the field is left blank. More information on the NACE codes can be found here: https://ec.europa.eu/eurostat/web/nace/overview
Food waste quantity	Quantity	Numeric	This variable contains the quantity of FLW reported by a study in fresh mass. The database includes two columns for entering a quantity, which was used to indicate quantities of edible and inedible FLW, for instance.
	Unit	Categorical	The unit of the reported quantity is provided in this variable. The quantities are in relative or absolute units.
	Edible/inedible	Categorical	This variable provides an indication of the kind of materials that were included in the FW measurement. The categories are ‘edible’, ‘inedible’, or ‘edible&inedible’.
	Variance	Numeric	If available, the indication of variance in the FW quantity was given in this variable. Usually, the variance was expressed as the range or the standard deviation.
	Disposal or other use	Text	If available, the part of the side stream that was considered FLW is captured. For instance, utilisation for biogas, composting, industrial uses, or starch production .
	Non-FLW use	Text	If available, the part of the side stream that was not considered FLW is captured. For instance, utilisation as feed or donations to social entities.
Methodological information on	Method of data collection	Categorical	Only studies that used methodologies eligible for the EU FW reporting were included in the database (see https://eur-lex.europa.eu/eli/dec_del/2019/1597/oj).

Variable Category	Variable name	Type	Description of content
the study delivering the data	Number of observations / sample size	Numeric	Dependent on the method of measurement applied by a study, this variable contains the number of participants in a study, e.g. households, experts, industry stakeholders or farmers or it contains the number of plots or fields sampled.
	Sample description	Text	Here, it is stated to which subjects or objects the number of observations / sample size refers, for instance farmers, households or plots.
	Uncertainty	Text	If the quantities of FLW are known to be compromised in validity, for instance, due to a small sample size or due to incompatibility with the definitional framework, a remark is added here.
	Further description	Text	Sometimes, it was assumed helpful to provide further details of the study for interpretation. Moreover, it was indicated if the FLW quantity was recalculated to fit the definitional framework.
Source of the data	Source of the data	Text	The source of the data was indicated.

Overall, the database contains 484 rows in which FLW quantities and corresponding information are entered. Most FLW quantities included in the database are from the primary production stage (34%, see Figure 6). Large shares of data points are also allocated to the stages of household consumption (26%) and retail and other distribution of food (20%). Hence, a lack of data seems to be more prevalent in the processing and manufacturing stages (10%) and in restaurants and food services (9%), even though the processing and manufacturing stages are not applicable to all food items, as many vegetables and fruits are mainly consumed as fresh products. Several studies on household FW had to be excluded since they did not use a methodology accepted for EU FW reporting. For the same reason, several studies from the retail and other distribution of food stage had to be excluded. Other data on the household stage could not be included, because their differentiation into packaged wasted foods and unpackaged wasted foods could not be aligned with the other quantities in the database. If these studies were included in the database, the share of data points in the supply chain stages would be different.

Figure 6. Shares of data points in the database per food supply chain stage

The processes in the food supply chain stages were further specified into processes or specific vs. broad supply chain stages, as described in Table 2. Especially the stages of processing and manufacturing and primary production were subdivided into many processes and combinations thereof, based on the original studies. This shows the diversity of the coverage of processes by the studies and that the FLW quantities are often not comparable because different processes are covered. The categorisation of specific processes as it is in this report should be further improved. The full list is in Appendix A3.

Figure 7 shows the shares of data points in the database per country. It should be noted though that the data included in the database are not complete for Europe and are biased towards countries with representatives in the project consortium. Most of the 484 data points entered are from studies conducted in Sweden (22%), followed by studies from Switzerland (17%), Italy (17%) and Spain (15%). A reasonable share of data points is also included from studies conducted in Finland, and to a lesser extent from the Netherlands, Austria, Norway, France, Greece, Denmark, the United Kingdom and Romania.

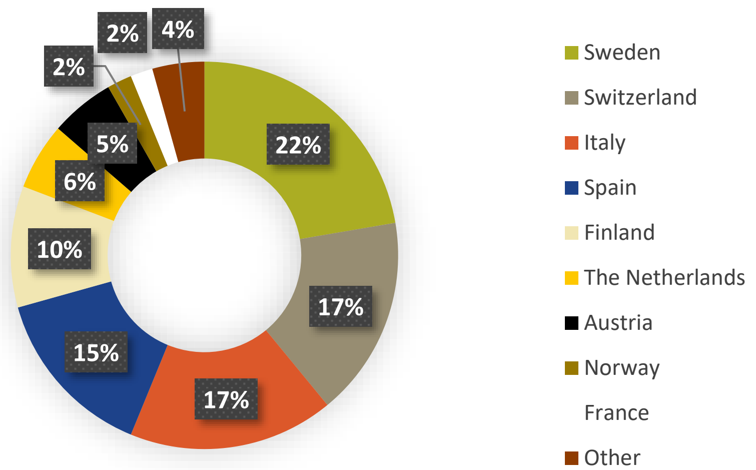

Figure 7. Shares of data points in the database per country

Most of the 484 data points in the database are for food items belonging to the food group 'vegetables' (23%, see Figure 8). A considerable number of data points are also included for the food groups 'fruit' (15%) and 'meat and meat products' (16%). The remaining 46% of the data points were composed of 'grains and grain-based products' (12%), 'potatoes' (8%), 'fish' (7%), 'milk and dairy products' (7%) and, to a lesser extent, 'eggs', 'composite dishes' and 'beverages'.

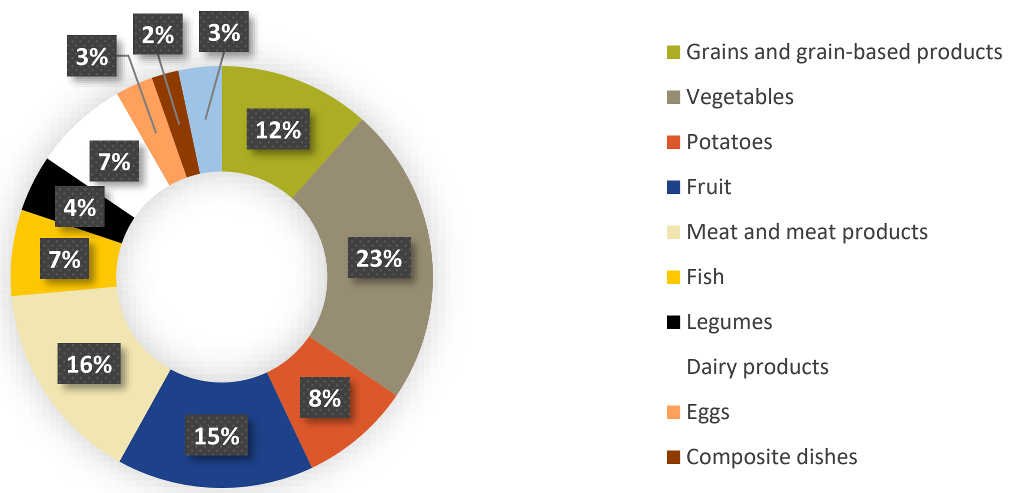

Figure 8. Shares of data points in the database per food product group

4. Application example for the database

4.1. Materials and Methods

In this section, three material flow analyses are presented as application examples for the database. The material flow analyses are based on the definitional frameworks described in Section 2. A further conceptual basis is the work of de Laurentiis et al. (2024). The definition of the quantities of yield and FLW at the primary production stage was adopted from de Laurentiis et al. (2024) (see Figure 10).

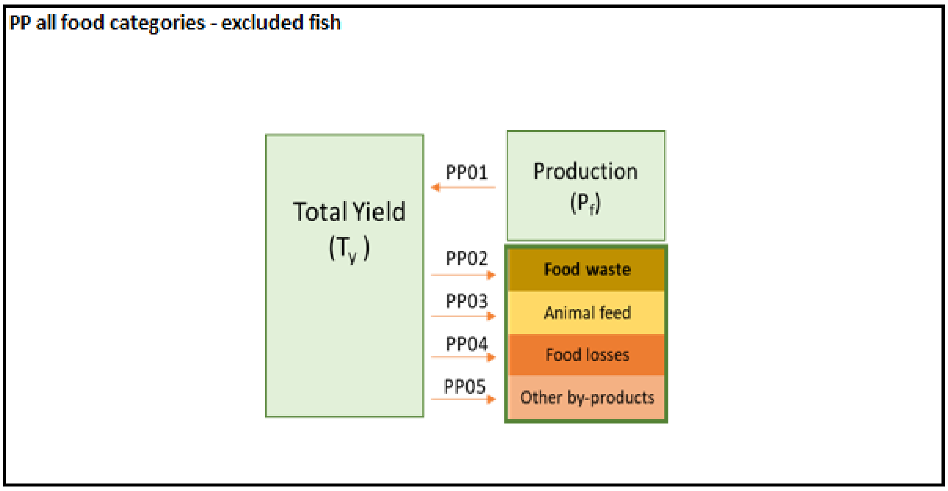

Figure 9. Conceptual representation of quantities of Food Loss and Waste at primary production (de Laurentiis et al. 2024)

The main source of FLW rates is the micro-level FW database, which was introduced in Section 3. In some cases, additional data from the literature or loss rates established by de Laurentiis et al. (2024) had to be used due to a lack of applicable data in the database. The data for the quantities of production (harvest), import, export and share of produce being processed are taken from statistics publicly provided by the Food and Agricultural Organization of the United Nations (FAO), except if stated otherwise. These quantities are calculated as a three-year average, with specific years depending on the defined time frame of the material flow. The distribution stage is not further disaggregated into different distribution channels, such as retail, wholesale and direct sale to consumers, due to incomprehensive data. This approach is in line with the model of de Laurentiis et al. (2024).

The shares of products that flow into the stages of household consumption and restaurant and food services are taken from de Laurentiis et al. (2024). Information on the type and quantity of side streams is given at a disaggregated level, as is available in the micro-level FW database. The quantities of consumption at the households and restaurants and food services stages are calculated based on mass flow or published data. All quantities are presented as edible fractions to facilitate comparisons between the food supply chain stages.

For the material flow analyses, the aim was to include products of different product categories and differing degrees of processing. Moreover, products with better data coverage in the database were selected. Therefore, in the following sections, the material flows of lettuce, tomatoes and bread is presented. The data tables containing full information on the figures and sources used for the material flow analyses can be found in Annex A4.

4.2. Material Flow Analysis of Lettuce in Sweden

The first application example is a material flow analysis of lettuce in Sweden. The geographic scope and system boundaries are the national territory of Sweden. The time frame of the analysis is 2013. The material of interest is the raw produce lettuce produced on open field. Due to a lack of data on the share of lettuce that is produced in greenhouses in Sweden, the same loss rate for lettuce produced on open field was assumed even though the loss rates in greenhouse production might differ. As lettuce is mostly sold as fresh, unprocessed product and packaging is accounted for as a post-harvesting procedure of primary production, no processing stage is considered. It could be argued that cut and packed lettuce are processed but this type of product is not analysed separately here. Therefore, the system considered for the material flow of lettuce comprises the supply chain stages primary production, retail and other distribution of food, household consumption, and consumption at restaurants and food services. The import and export of fresh lettuce is accounted for in the representation of the material flow of lettuce.

As outlined in Section 4.1, the data sources stem from the database created in the project and from the FAO database. It is assumed that the inedible fraction of an iceberg lettuce head at retail, mostly consisting of the stem part, is 8% (de Laurentiis et al. 2018). The mass flow is calculated based on the mass of edible lettuce parts. At the primary production stage, losses might occur for unmature plants, mature plants, at harvest and at post-harvest processes. At harvest, the outer leaves of iceberg lettuce are weeded. These outer leaves account for a large share of waste mass but are considered inedible for this mass flow analysis. According to Jordbruksverket (2014), about 90% of the total loss at primary production consist of the outer leaves. If these were included in the analysis, the results would change greatly. Table 3 shows, however, that other studies found different rates of FLW at the primary production stage. For the harvesting processes, a study in Sweden found a FLW rate of 65% of agricultural production for edible and inedible material (Jordbruksverket 2014), while a study in Finland quantified the same process at 16% (Hartikainen at al. 2014) and a study in Austria at 42.1% (Bundesministerium Land- und Forstwirtschaft, Regionen und Wasserwirtschaft 2025). This range of loss rates shows that it is of high importance that studies report transparently and detailed what they have quantified. The choice of the loss rate strongly influences the results of mass flow analyses.

For the mass flow analysis, FLW rates for primary production and retail and other distribution of food were used from Jordbruksverket (2014). For quantities of production, import and export the FAOstat database was consulted. The share of supply allocated to consumption in households and restaurants and food services was used from de Laurentiis et al. (2024). The quantity of wasted lettuce in households was taken from a yet unpublished study by consortium partners at the Swedish University of Agricultural Sciences. The FW quantity at restaurants and food services was calculated as the mass balance from the quantity entering the stage and the quantity of lettuce consumed based on consumption statistics by Jordbruksverket (2023).

Table 3: FLW quantities for harvest losses of lettuce from different studies (source: Micro-level database D1.1)

Country of study	Process in primary production	FLW quantity	Unit	Material type
Sweden	Harvest	65	% of agricultural production	edible & inedible
Finland	Harvest	16	% of agricultural production	edible & inedible
Austria	Harvest	42	% of agricultural production	edible & inedible

As the Sankey diagram in Figure 10 and the bar chart in Figure 11 show, the main share of the total FLW of lettuce in the supply chain occurred at the stage of consumption at households and restaurants, with 12,976 tonnes which is about 25% of the supply. The second highest share of FLW was allocated to the primary production stage, with about 9% of the supply and 5,658 tonnes of fresh mass. The FLW at the stage retail and other distribution accounted for a smaller share of inflowing mass (12%) and FLW from the supply (<5%) but exceeded the wasted mass at primary production in absolute terms (7,212 tonnes).

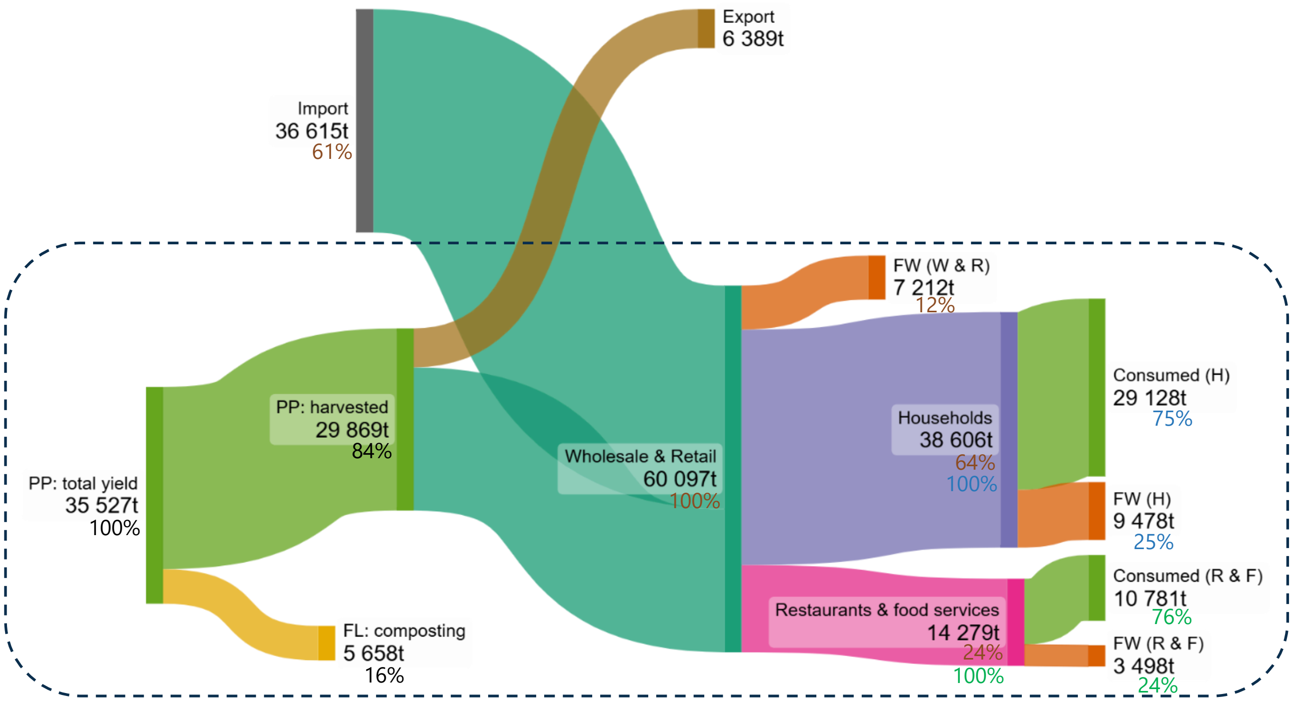

Figure 10. Material Flow of lettuce in Sweden (2013) in tonnes of edible parts per year and shares
(PP: Primary Production; FL: Food Loss; FW: Food Waste, created with SankeyMATIC)

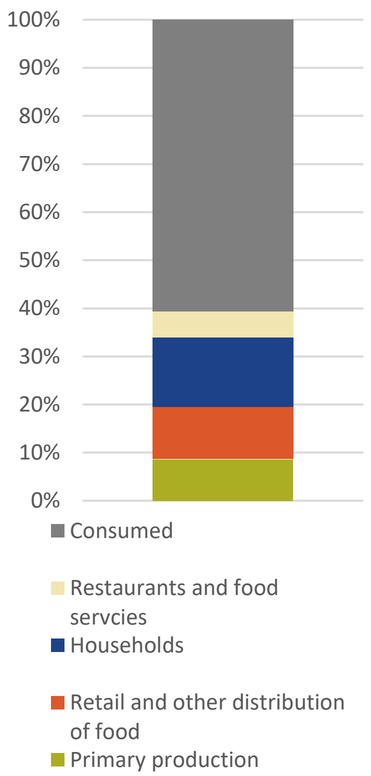

Figure 11: Shares of Food Loss and Waste per supply chain stage of lettuce supply in Sweden

The database can be used to compare the results from the material flow analysis of lettuce in Sweden to the rates of FLW found in other countries. For the primary production stage, a share of FL of 16% was reported for Finland, mainly 21%–30% for Switzerland, 40%–50% for the United Kingdom and 39.5% of unharvested edible lettuce parts for Austria (Beausang et al. 2017, Bundesministerium Land- und Forstwirtschaft, Regionen und Wasserwirtschaft 2025, Hartikainen et al. 2014, Visco 2025). These figures vary strongly, from 16% to 50% FL in the primary production stage. Before interpreting this variance, the details of measurement in the respective studies should be reviewed in case these differences emerge from conceptual (e.g. definitions or system boundaries) or methodological (e.g. data collection method) reasons. Even though the database is aimed at evening out conceptual differences by applying the definitional framework explained in Section 2 to the categorisation of the figures from the studies, there is a limit to the level of detail up to which it is possible to harmonise the data reporting in the database depending on the information available from publications. It can be further noted that the loss rate used in the mass flow analysis for Sweden is at the lower end of the range. The loss rates were elaborated based on direct measurements at five farms in Sweden (Jordbruksverket 2014). Even though the sample size is small, the confidence in the data can be rated as relatively high, since the sample covers at least some variability and for lettuce direct measurements are rated relatively reliable (Hartikainen 2025).

There are fewer figures in the database available to compare loss rates for the distribution stage. The figure of 12.7% FW at the distribution stage for lettuce in Sweden was aggregated for the material flow analysis from 2.9% FW from wholesale and 9.7% from retail (Jrodbruksverket 2014). For Finland, the database shows a 3.5% FW of lettuce at the wholesale and retail stage (Hartikainen 2025), while for Italy, a figure of 8.1% wasted lettuce of the total of sold lettuce from one Italian hypermarket is available (yet unpublished data from the LOWINFOOD project). A study in Spain differentiated the FW quantity over all products between different types of retail and reported shares of FW at the retail level ranging from 3.5% to 14.4% (HAZI et al. 2023).

For FW at the household stage, yet unpublished preliminary results of a study on household FW in Sweden quantified the wasted lettuce at 10,302 tonnes per year (Swedish University of Agricultural Sciences). It was assumed that the wasted lettuce consisted of inedible parts and edible plate waste. Due to a lack of data on the shares of edible and inedible parts, 8% inedible fractions were subtracted (de Laurentiis et al. 2024) to estimate the quantity of edible wasted lettuce. 73% of lettuce supply was assumed to enter households, while the remaining 27% were assumed to enter the restaurants and food services sector (de Laurentiis et al. 2024). Based on these calculations the share of wasted lettuce in Swedish households was estimated to account for about 12% of the supply and 25% of the purchased lettuce. In the database, there is a quantity available for Swiss households which is less than half the resulting FW rate for Sweden. On the other hand, estimates of the

FLW of vegetables per supply chain stage in the EU indicate that about 39% of vegetable FW occurs at the household stage of which about half is considered edible (Caldeira et al. 2019). Hence, the uncertainty regarding the validity of the share of FW generated at the household stage from this mass flow analysis is assumed to be high.

The material flow analysis revealed FW rates of 24% of the quantity that entered the supply chain stage or less than 5% of the supply at the stage of restaurants and other food services. Since there are no figures on FW of lettuce at the stage of restaurants and other food services included in the database, the FW at this stage was calculated by subtracting the quantity of lettuce consumed at the stage as reported by Jordbruksverket (2023) from the derived quantity of lettuce leaving the retail and other distribution of food stage. Caldeira et al. (2019) calculated that through restaurants and other food services, only 18% of the FW quantity of vegetables by households is thrown away. Based on our mass flow analysis, this share is estimated twice as high at about 37%. A study from Spain reported FW over all products differentiated between types of restaurants and food services and reported shares between 3.5% and 34.1% (HAZI et al. 2023). Based on these references, the assessment of the validity of the FW share resulting from the material flow analysis is difficult and hence, the uncertainty remains high.

4.3. Material Flow Analysis of Tomatoes in Italy

The second material flow analysis is on tomatoes in Italy for the annual average of the years 2018–2020. The analysis includes the supply chain stages primary production, processing and manufacturing for a share of the produce, retail and other distribution of food, households and restaurants and food services. Moreover, it is distinguished between tomatoes grown in a greenhouse, which have a lower FLW share at primary production, and tomatoes grown in open fields. It is assumed that tomatoes grown in greenhouses are produced for the purpose of consumption as fresh produce. Due to a lack of data on the share of tomatoes grown in open fields for consumption as fresh produce, it is assumed that the total quantity from open field tomatoes are produced for processing. Both unprocessed and processed tomatoes are considered for export and import trade flows. It is assumed that only greenhouse tomatoes are exported, while for imported tomatoes it is assumed that the same share goes to processing and the fresh market as the share of the total of tomatoes that go to processing and to the fresh tomato market (based on FAOstat data). For the mass flow of processed tomatoes, only the tomato sauce product was considered. Tomato sauce consists of two processing stages: pulp production and sauce production (Secondi et al. 2019). In the FAOstat database, trade and production statistics for the processed tomato products 'juice', 'pulp', 'peeled' and 'other' are available. The largest share of processed tomato products is represented by 'other' (56.5%, own calculation based on FAOstat 2018–2020). The FLW shares for primary production, processing and manufacturing and retail and other distribution of food were deduced from Secondi et al. (2019) and then applied to the total tomato processing. To calculate the FW quantities at the retail and other distribution of food stage for fresh tomatoes and at the consumption stages of households and restaurants and food services, information from de Laurentiis et al. (2024, Annex 1) was used. Based on de Laurentiis et al. (2018), an inedible fraction of 0% was assumed.

Figures 12 and 13 show the results of the mass flow analysis of fresh and processed tomatoes in Italy for the 2018–2020 timeframe. The total FLW sums up to 2,304,647 tonnes annually (range of uncertainty is shown in Figure 13). There are clear differences between the mass flow of greenhouse tomatoes and that of processing tomatoes. For processing tomatoes, a relatively high share of loss occurs at the primary production and processing and manufacturing stages. For greenhouse tomatoes for fresh consumption, the largest share of FW occurs at the retail and other distribution of food stage, with relevant shares also being generated at households and the restaurants and food services stage due to the perishability of the product.

The harvest losses in the mass flow analysis accounted for 10% to 10.6% of the total yield for processing tomatoes (open field) and 0% to 2.4% for greenhouse tomatoes. These ranges were derived from several studies: for Sweden loss rates of 0%–2% and for Austria of 1.1% were found, even though for the Swedish study the detailed phases of primary production to which the share corresponds is not known, and for Austria the share includes loss of harvest-ready tomatoes and losses of tomatoes during harvesting (Andersson 2013, Bundesministerium Land- und Forstwirtschaft, Regionen und Wasserwirtschaft 2025). The FLW rate of tomatoes grown in greenhouses was quantified to be close to zero in Finland (Hartikainen 2025). A recent study from Switzerland reported that most interviewed farmers estimated the loss of tomatoes during harvest and post-harvest phases to range between 0% and 10% (Visco 2025). A study conducted in Spain quantified the loss of tomatoes in primary production to be 10.1% (CREDA et al. 2021).

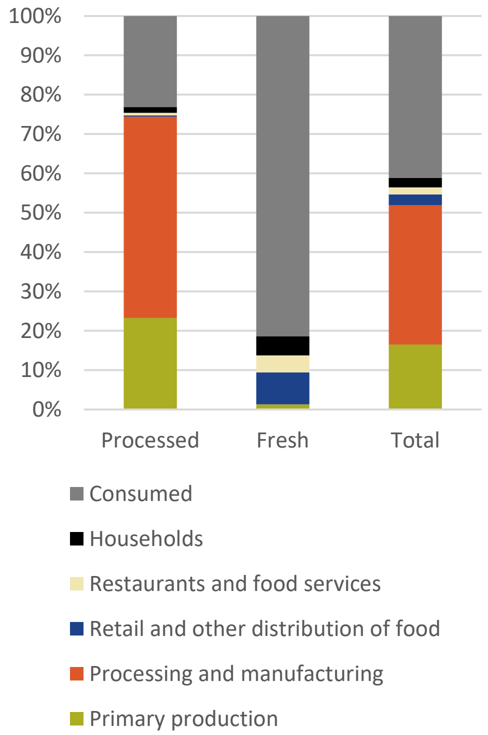

Figure 12: Shares of FLW per supply chain stage of tomatoes for fresh consumption and processing tomatoes

At the processing and manufacturing stage, approximately 67% of the total FLW for processing tomatoes is generated, and 33.5% of the mass flowing in that stage is going to waste. For pulp and sauce production the waste consists mostly of peels and pits (Secondi et al. 2019) for which it can be discussed whether they should be accounted for as edible in the case of pulp and sauce. The results would change a lot when they were excluded.

There are no other studies on FW in tomato processing available than that by Secondi et al. (2019), who reported that 36.9% of losses linked to tomato sauce production originated from the processing and manufacturing stage. A study from Finland reported a 3% loss of vegetables at the processing stage (Riipi et al. 2021). Another study from Italy found a waste rate of 7.5% during the processing of carrots (Pietrangeli and Cicatiello 2024), while a study from Sweden even quantified the loss of carrot processing at 44%, which likely contains a very high share going to animal feed (Hartikainen et al. 2017). However, the processes measured in these studies for vegetables other than tomatoes might differ a lot, so the waste rates cannot be directly compared. To include some variation and uncertainty in the mass flow, we added a range of +/- 10% of the calculated waste mass.

The waste rates at the retail and other distribution of food stage were 8% (+/-5%) for fresh tomatoes and 1.2% (+/-1%) for processed tomatoes. These were based on other studies that quantified the loss rates for fresh tomatoes as 6.8% at retail (Sweden, Eriksson 2015), 3.4%–9.2% at wholesale (Spain, CREDA et al. 2021) and 12.9% of sold tomatoes at retail (Italy, unpublished data from LOWINFOOD project). In Finland, the waste rate for fresh vegetables and fruit at retail is 3%-5% (Hartikainen 2025). For processed tomato products, an uncertainty range of 10% of the wasted mass was included.

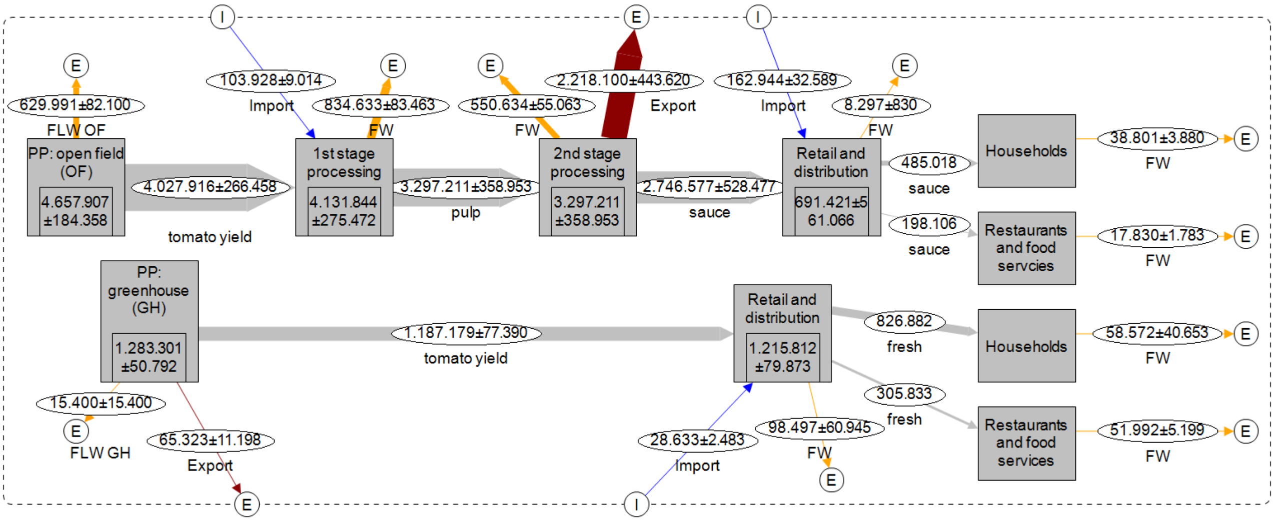

Figure 13. Material Flow of fresh and processed tomatoes in Italy (2018-2020)
(quantities are in tonnes; PP: Primary Production, GH: greenhouse (tomatoes for fresh consumption), OF: open field (processing tomatoes), FLW: Food loss and waste; FW: Food waste; yellow arrows: FLW, blue arrows: imports, red arrows: exports; created with STAN, Cencic and Rechberger, 2008)

For the consumption stages, the waste rates were 7% for fresh and 8% for processed tomatoes at households and 17% for fresh and 9% for processed tomatoes in restaurants and food services. Except for fresh tomatoes at households, the of de Laurentiis et al. (2024) were applied due to a lack of other data. For fresh tomatoes at households, the FW quantity range was derived from the rate given by de Laurentiis et al (2024, 12%) and dairy studies, from Sweden and Finland that quantified losses of fresh tomatoes to be 0.3 kg/capita/year (unpublished data by SLU, Hartikainen 2025). Multiplied by 59.73 million inhabitants of Italy this quantity would accumulate to 17,919 tonnes. Applying these quantities would result in a wasted share of about 2%, which is clearly lower than the rate given by de Laurentiis et al. (2024). A study on household FW in Switzerland reported a waste quantity for fresh tomatoes of 1 kg/capita/year, resulting in 63 224 tonnes when multiplied with Italy's 59.73 million inhabitants. Applying the of de Laurentiis et al. (2024) would result in a mass of wasted fresh tomatoes at households of 99,226 tonnes. Based on these values, a waste rate of 7% (+/-5%) was deduced, resulting in an estimated mass of 58,572 (+/- 40,653) tonnes of fresh tomatoes. To include a range of uncertainty also for the wasted mass of processed tomatoes at households and restaurants and fresh tomatoes at restaurants, we applied a 10% of the wasted mass margin, which is a fictive number due to a lack of data.

4.4. Material Flow Analysis of Soft Wheat in Italy

The third material flow analysis focuses on soft wheat in Italy. Data from FAOstat are used as the average for the years 2015–2017. Some studies delivering data on FLW rates refer to different times. The edible fraction of soft wheat grain is assumed to be 100% (de Laurentiis et al. 2024, Annex 1). The mass flow analysis contains the supply chain stages primary production, 1st stage processing (milling), 2nd stage processing (bread and bakery wares manufacturing), retail and other distribution of food, and households and restaurants and food services. It accounts for production, import and export of soft wheat grains, flour, bran and bakery wares (bread and pastries). Other products from wheat were ignored in the analysis. For instance, starch and glucose production from wheat is not included after the primary production stage. For flour, no data on the waste rates at the stages of retail and other distribution of food, in households and in restaurants and food services was available. Therefore, the material flow of flour stops at the retail stage in the analysis.

Figures 14 and 15 show graphical representations of the mass flow and distribution of the total FLW among the supply chain stages. Overall, the highest share of the total FW occurs at restaurants and food services, at about 39%. The second highest share is represented by the household stage, at about 29%. Retail and other distribution of food accounts for about 13% of the total FW represented by surplus products. At the primary production stage, soft wheat is lost at harvest for technical reasons and due to its utilisation for fuel or energy production, which adds up to about 19% of the total FLW.

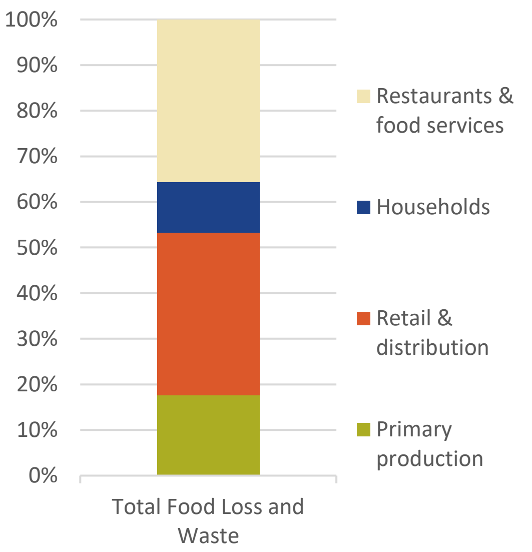

Figure 14: Shares of FLW per supply chain stage for soft wheat in Italy

It was assumed that no FLW was generated at either processing stage. The assumption of no waste occurring at the 1st processing stage, i.e. milling, is in accordance with Hartikainen et al. (2014) and Jordbruksverket (2024). The assumption that no waste occurs at the 2nd processing stage is in line with Amicarelli et al. (2023). A study from Spain quantified the losses in the 1st and 2nd processing stage together to be 0.03% of the weight of the incoming wheat (Euskadiko Itun Berdea et al. 2022).

Surplus bread is accounted for at the retail and other distribution of food stage in our material flow analysis. However, surplus bread might also occur at the 2nd

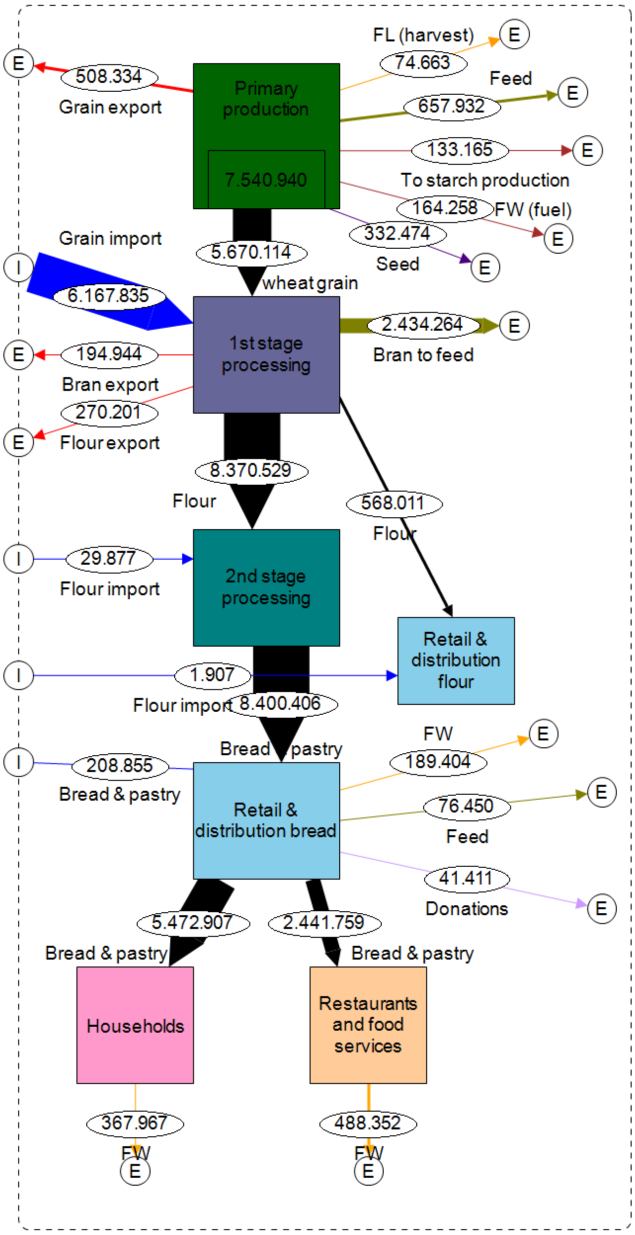

Figure 15: Material Flow of soft wheat in Italy (2015-2017)

(quantities are in tonnes; FL: Food loss; FW: Food waste; created with STAN, Cencic and Rechberger, 2008)

processing stage, when too much bread is produced that cannot be sold. The Italian study that served as a basis for the processing and retail stages of our mass flow analysis investigated the FLW in small-scale bakeries where both stages, 2nd processing and retail and other distribution of food, are happening in one company (Pietrangeli et al. 2023). Bartek et al. (2025) showed that, for the bread supply chain on a larger scale, not only 9% of bread remains unsold at retail, but 6% of produced bread remains unsold at the bakeries. Therefore, the rate of 2.2% FW at the retail and other distribution of food stage used in this analysis might underestimate the real quantity of bread and pastries wasted.

The loss rates for the different processes in primary production are only partly comparable among the sources in the database because the reported quantities sometimes refer to combinations of different processes. The quantities that were comparable based on the process to which they refer were rather similar. For instance, the technical harvest losses were quantified to account for 1.4% in Finland, 0.7% in Norway, 1.0% in Denmark (Hartikainen et al. 2017) and 1.0% in Austria (Bundesministerium Land- und Forstwirtschaft, Regionen und Wasserwirtschaft 2025). Only the figure from a Swiss study represents an outlier compared to the other values with estimated losses of 5%–15% (Beretta et al. 2018), which is most likely due to definitional differences. Since no data on technical harvest losses were available for Italy from the database, we used the average of the FLW rates from Finland, Norway, Denmark and Austria to estimate the quantity of FLW in the mass flow analysis. The same approach was taken for the process of post-harvest FLW going to fuel or energy production. Since no data were available for Italy, the average of the available figures from Norway and Sweden was used (Hartikainen et al. 2017).

For the 1st processing stage, we assumed that bran is separated from 100% of the wheat before milling, meaning that no whole-grain flour is produced. This is a simplification for modelling purposes and, even though it is probably correct for most of the flour, it is certainly not true in all cases. Therefore, the quantity of the resulting bran is potentially slightly overestimated. Moreover, we assumed that 100% of the bran from milling was fed to animals since we did not have other information on the usage of bran.

For households, the reported quantities of wasted bread differ strongly between countries. In our mass flow analysis, we used the figure from Finland of 4.0 kg per person per year (Silvennoinen et al. 2022). However, this figure is certainly overestimating the quantity of wheat bread because rye bread is also included. Alternatively, the average of reported quantities (0.6 kg/cap/year, Switzerland, Kanton Aargau 2024; 0.7 kg/cap/year, Finland, 1.5 kg/year/cap, Hartikainen 2025; Sweden; 4.0 kg per capita per year, unpublished results by Swedish University of Agricultural Sciences, Finland; 7.2 kg/cap/year, Silvennoinen et al. 2022, Greece, Sigala et al. 2024), which is 2.8% with a deviations of about 2.2% could be used to generate a better estimate. These figures show the high uncertainty linked to actual wasted bread quantities in households. The studies used different methods: diaries, waste composition analysis and a combination of weighting and composition analysis with photos. Different methods for FW measurement in households are known to produce different results (Hartikainen et al. 2025, Merian et al. 2024).

For the stage restaurants and food services data from Italy were available. We used a share of 20% of the bread and bakery wares wasted, as in Boschini et al. (2020). The figure reported by Falasconi et al. (2025), another study conducted in Italy, is very similar with 17.6%. The result of 0.3% from a Swedish study was very different (Sundin et al. 2024). All three studies applied direct measurements of FW in school canteens. The two studies from Italy conducted analyses on the same sample; therefore, the similarity in their results is not surprising. Comparing the Italian sample with the Swedish sample revealed a large discrepancy between the quantities of wasted bread. While the Italian study included plate waste, unserved food and unconsumed food, the Swedish study only included plate waste. This certainly contributes to the large discrepancy. Nonetheless, the results of the mass flow analysis regarding the quantity of wasted bread and bakery wares at restaurants and food services should be interpreted cautiously.

5. Value and limitations of the database

The product-level database of FLW quantities represents, to our knowledge, a unique open-access collection of original figures from published research and reports. Two research groups even agreed to include unpublished data in the database. Adding value to the current situation of data accessibility is that, through the collaboration within the project consortium, data published in national languages such as Finnish, Swedish or Spanish could be included in the database. Also, personal communication was used to get access to unpublished and product group specific data. Hence, these data are made more easily accessible to people who do not understand these languages.

In some cases, the original figures were recalculated to fit the definitional framework to increase the comparability of the FLW figures. FLW quantities from the model results are not included. Moreover, some studies were not included because they did not use one of the methods eligible for FW reporting to the EU; for instance, survey data based on self-assessment questionnaires from households were excluded due to their generally low validity. The scope is currently limited to FLW figures from European countries, excluding studies and reports from outside Europe. Another limitation of the database is that the scope was reduced to certain product groups and food items due to resource constraints. Hence, some product groups, such as oil crops, were ignored. In addition, products that are not grown in Europe but represent a considerable source of waste, such as bananas, were ignored.

Even though the compilation of FLW figures at the product level from European countries is not complete and it will be valuable to update the database to include more data, it currently comprises a lot of available data for different products and from different countries. With this, further research can benefit from using the database for analyses, for instance of material flows or life-cycle assessments. Possibly, the database could be an additional useful supplement to the sources database of the Food Systems Material Flow Analysis model developed at the Joint Research Centre of the EU. Moreover, the database offers a good starting point for analysing the data situation regarding data availability for different stages of the food supply chain, for different products and countries. Moreover, the database potentially offers value to businesses or other non-academic actors who want to compare their FLW performance or perform other analyses.

Since the database cannot show what is not included in the publications, the variance of the FLW figures is, in many cases, not included. Furthermore, missing data points can be noted in the database. For instance, for many products, there is no information about the rate of food wasted at restaurants and food services available. Another shortcoming of the data situation is that, for good reasons, research has often focused on the main food supply chain stages, leaving rather white spots on the data landscape for smaller distribution channels, such as farmers' markets or farm shops. Sometimes, the reported quantities cannot directly be used for analyses due to their unit; for example, household FW is often reported as g/capita/day or kg/capita/year from which we cannot easily infer what the share of the wasted foods from purchased foods is. The same issue occurs with the restaurants and food services stage.

The FW quantities included in the database were measured in different years. Very few publications included data for the same products, countries and supply chain stages for several years. For analyses using data from different sources, possible variability in FLW quantities between years should be considered.

The material flow analyses showed that the database can be useful for modelling the material flow of a product in a specific country. Either because the FLW data for the product in a specific country are available, or possibly even more, data for the same product and supply chain stage are also available for other countries for comparison. Alternatively, if FLW data for a specific product, supply chain stage and country are missing, data from other countries or from similar products can be identified and used as a proxy. However, for some products and supply chain stages, the use of other countries' data proved to be challenging due to a remarkable variation in FLW rates. Moreover, the application examples in Section 4 show that there are many data gaps in the database that have to be filled with supplementary information.

6. Conclusion and recommendations

This report is meant to explain and describe the content of the product-level database of FLW compiled in Task 1.1 of the WASTEWISE project. Fifty-three food items were included in the database. The food items are classified according to two food classification systems (EFSA FoodEx2 and CPA), were measured in 13 European countries, and are categorised into food supply chain stages based on the categories used for the EU FW reporting, the NACE classification and a more detailed version of the EU FW reporting categories. The database offers further value by comprising data from reports written in Finnish, Swedish or Spanish, and by categorising and presenting all data according to a common definitional framework. This provides a useful basis for conducting further research.

Resulting from the discussion of the limitations of the database, the following is recommended for future work to improve the data situation. First, besides average quantities, it would be beneficial if studies reported the standard deviation, sampling methods, sample sizes and other factors introducing uncertainties to the quantities for FLW quantification. For supply chain-wide analyses of FLW quantities, it is also useful to know the share of a product that was wasted in reference to the total quantity of this product that entered a certain supply chain stage. For instance, the absolute quantity of wasted carrots at the retailers is less useful in modelling mass flow compared to the share of the total quantity of carrots entering the retailer. Therefore, it is recommended to collect and report data on the reference quantity of wasted products or as a percentage of the inflowing mass. Furthermore, it is recommended that studies be conducted to analyse the structure of supply chains in more detail, including supply chains that are smaller in terms of mass flowing through and to quantify how much of products flow through which parts of supply chains. In particular, the stages of processing and manufacturing and restaurants and food services seem to be underexplored. Few studies have compared the FLW quantities of products for two or more years. It would be insightful to have a broader overview of changes over time in different countries. Additionally, overall data quality and quantity should be improved in future studies. In the primary production stage, for instance, many studies use estimates from farmers to quantify FLW. The quality of these estimates might differ on how the information is asked and whether it is retrieved repeatedly in time-intervals. Moreover, there are few data available for FLW at the primary production stage for legumes, for instance. Large data gaps also exist for oil crops. Finally, in future studies, it is recommended to investigate which products are similar regarding the processes in which FW is generated, as well as the share of FW that is generated, to enable a more targeted collection of primary data. For instance, to our knowledge, it is unknown to which cereals the existing FLW rates of wheat can be applied or whether there are process-related differences for some.

The database can be further developed in the future by including data that are missing so far and by including additional food groups and food products, such as oil crops and nuts. Moreover, the indication of the geographical boundary could be complemented by UN country codes. A next step in providing value for further studies is the development of a harmonised database in which, for each product and supply chain stage, an FLW rate is suggested consolidating existing findings and filling data gaps with assumptions where necessary. For such a database to be useful, country-specific differences should be also analysed and included in the database. The structure of the database can help future studies to structure their data collection.

The work on the database showed the need to synthesise and further develop the existing valuable concepts on FLW definitional frameworks and measurement, such as the Food Loss and Waste Protocol (Hanson et al. 2016) or the FOLOU standard research protocol (Masotti et al. 2023). To increase the comparability of FLW data being collected and, by this, to build a body of conceptually consistent FLW data, further development of frameworks for the complete lifecycle of products would be supportive —including pre-harvest phases and specific to food groups on a detailed level, specifying the phases of the lifecycle and clarifying at which stage certain materials or co-products should be accounted for. The lack of comprehensive frameworks and the lack of stringent application of frameworks or guidelines, such as the FLW protocol (Hanson et al. 2016), by existing studies compromised the quality of the data categorisation in the database. However, it must be acknowledged that, first, studies have different objectives, and clear differentiation, for instance, between supply chain stages, might not have been necessary or even meaningful for some. Second, pioneer studies on FLW lack the currently available conceptual basis. Therefore, future research will potentially build on the current achievements of this relatively young discipline and continue advancing the field.

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Appendix

A1. List of NACE codes included in the menu of the micro-level database

Categories of the NACE classification included in the menu of the dataset
1.1 Growing of non-perennial crops (en)
01.2 Growing of perennial crops (en)
01.4 Animal production (en)
01.5 Mixed farming (en)
01.11 Growing of cereals, other than rice, leguminous crops and oil seeds (en)
01.12 Growing of rice (en)
01.13 Growing of vegetables and melons, roots and tubers (en)
01.14 Growing of sugar cane (en)
01.21 Growing of grapes (en)
01.22 Growing of tropical and subtropical fruits (en)
01.23 Growing of citrus fruits (en)
01.24 Growing of pome fruits and stone fruits (en)
01.25 Growing of other tree and bush fruits and nuts (en)
01.26 Growing of oleaginous fruits (en)
01.27 Growing of beverage crops (en)
01.28 Growing of spices, aromatic, drug and pharmaceutical crops (en)
01.29 Growing of other perennial crops (en)
01.41 Raising of dairy cattle (en)
01.42 Raising of other cattle and buffaloes (en)
01.43 Raising of horses and other equines (en)
01.44 Raising of camels and camelids (en)
01.45 Raising of sheep and goats (en)
01.46 Raising of swine and pigs (en)
01.47 Raising of poultry (en)
01.48 Raising of other animals (en)
03.1 Fishing (en)
03.11 Marine fishing (en)
03.12 Freshwater fishing (en)
03.2 Aquaculture (en)
03.21 Marine aquaculture (en)
03.22 Freshwater aquaculture (en)
10 Manufacture of food products (en)
10.1 Processing and preserving of meat and production of meat products (en)

10.20 Processing and preserving of fish, crustaceans and molluscs (en)
10.3 Processing and preserving of fruit and vegetables (en)
10.4 Manufacture of vegetable and animal oils and fats (en)
10.5 Manufacture of dairy products and edible ice (en)
10.6 Manufacture of grain mill products, starches and starch products (en)
10.7 Manufacture of bakery and farinaceous products (en)
10.8 Manufacture of other food products (en)
10.11 Processing and preserving of meat, except of poultry meat (en)
10.12 Processing and preserving of poultry meat (en)
10.13 Production of meat and poultry meat products (en)
10.31 Processing and preserving of potatoes (en)
10.32 Manufacture of fruit and vegetable juice (en)
10.39 Other processing and preserving of fruit and vegetables (en)
10.41 Manufacture of oils and fats (en)
10.42 Manufacture of margarine and similar edible fats (en)
10.51 Manufacture of dairy products (en)
10.52 Manufacture of ice cream and other edible ice (en)
10.61 Manufacture of grain mill products (en)
10.62 Manufacture of starches and starch products (en)
10.71 Manufacture of bread; manufacture of fresh pastry goods and cakes (en)
10.72 Manufacture of rusks, biscuits, preserved pastries and cakes (en)
10.73 Manufacture of farinaceous products (en)
10.81 Manufacture of sugar (en)
10.82 Manufacture of cocoa, chocolate and sugar confectionery (en)
10.83 Processing of tea and coffee (en)
10.84 Manufacture of condiments and seasonings (en)
10.85 Manufacture of prepared meals and dishes (en)
10.86 Manufacture of homogenised food preparations and dietetic food (en)
10.89 Manufacture of other food products n.e.c. (en)
11.0 Manufacture of beverages (en)
46.2 Wholesale of agricultural raw materials and live animals (en)
46.21 Wholesale of grain, unmanufactured tobacco, seeds and animal feeds (en)
46.22 Wholesale of flowers and plants (en)
46.23 Wholesale of live animals (en)
46.31 Wholesale of fruit and vegetables (en)
46.32 Wholesale of meat, meat products, fish and fish products (en)
46.33 Wholesale of dairy products, eggs and edible oils and fats (en)
46.34 Wholesale of beverages (en)
46.35 Wholesale of tobacco products (en)
46.36 Wholesale of sugar, chocolate and sugar confectionery (en)

46.37 Wholesale of coffee, tea, cocoa and spices (en)
46.38 Wholesale of other food (en)
47.11 Non-specialised retail sale of predominately food, beverages or tobacco (en)
47.2 Retail sale of food, beverages and tobacco (en)
47.21 Retail sale of fruit and vegetables (en)
47.22 Retail sale of meat and meat products (en)
47.23 Retail sale of fish, crustaceans and molluscs (en)
47.24 Retail sale of bread, cake and confectionery (en)
47.25 Retail sale of beverages (en)
49.4 Freight transport by road and removal services (en)
56 Food and beverage service activities (en)
56.11 Restaurant activities (en)
56.12 Mobile food service activities (en)

A2. List of food items included in the database

List of food items included in the database (EFSA FOODEX2 classification)	LangualL Code
00030 - CEREAL GRAINS (AND CEREAL-LIKE GRAINS)	A000L
00380 - RICE GRAIN	A001D
00500 - RYE GRAIN	A001K
00570 - COMMON WHEAT GRAIN	A001N
00670 - CEREAL AND CEREAL-LIKE FLOURS	A04KS
00880 - WHEAT FLOUR	A003X
01160 - BREAD AND SIMILAR PRODUCTS	A004V
01750 - PASTA AND SIMILAR PRODUCTS	A007D
03650 - LETTUCES (GENERIC)	A00KX
04730 - HEAD CABBAGES AND SIMILAR	A00FX
05250 - BROCCOLI	A00FN
05310 - CAULIFLOWERS	A0DLL
05800 - ONION BULBS FOR FRESH CONSUMPTION	A0DND
06330 - TOMATOES	A0DMX
06500 - SWEET PEPPERS	A00JA
06700 - CUCUMBERS	A00JM
06770 - COURGETTES (Zucchini)	A00JR
07120 - CARROTS	A00QH
09330 - PROCESSED TOMATO PRODUCTS	A04MB
09580 - POTATOES	A00ZT
10130 - STARCHY ROOT AND TUBER PRODUCTS	A00ZR

14230 - CITRUS FRUITS	A01BT
14360 - ORANGES, SWEET	A01CR
14730 - APPLES	A01DJ
14770 - PEARS	A01DP
15050 - PEACHES AND SIMILAR	A01GL
15270 - BERRIES AND SMALL FRUITS	A01DT
15300 - TABLE GRAPES	A01DX
15380 - STRAWBERRIES	A01EA
18780 - BOVINE CARCASE	A049Q
18790 - PIG CARCASE	A04AA
18870 - CHICKEN CARCASE	A04DQ
19150 - BOVINE FRESH MEAT	A01QV
19260 - PIG FRESH MEAT	A01RG
22120 - FISH (MEAT)	A026V
23510 - HAKES	A02CB
23630 - MULLETS	A02AD
24020 - SARDINES AND SARDINE-TYPE FISHES	A02DA
24050 - ANCHOVIES	A02DD
24170 - TUNA	A02DX
24180 - ALBACORE	A02DY
24290 - SEERFISH	A02CS
26530 - COW MILK	A02LV
26810 - CREAM, PLAIN	A02ML
26940 - YOGHURT, COW MILK	A02NF
27310 - CHEESE	A02QE
29510 - HEN EGGS	A031G
31480 - BUTTER	A039C
31570 - FRUIT AND VEGETABLE JUICES AND NECTARS (INCLUDING CONCENTRATES)	A039K
31710 - JUICE, APPLE	A039M
34020 - COFFEE, COCOA, TEA AND INFUSIONS	A03GG
9630 - POULTRY FRESH MEAT (MUSCLE MEAT)	A01SN

A3. List of specific processes in the supply chain

Specific process	Number of data points
immature plants/animals (pre-harvest/raising/hatching)	6
immature & mature plants/animals (Pre-harvest/raising/hatching)	7
mature plants/animals (Pre-harvest/raising/hatching)	4

immature & mature plants/animals & Harvest/Transport to slaughter/catch/milking	1
mature plants/animals & Harvest/Transport to slaughter/catch/milking	20
Harvest/Transport to Slaughter/catch/milking	54
Harvest & Post-Harvest	12
mature plants/animals (Pre-harvest) & Harvest & Post-Harvest	2
Post-harvest (storing, first processing, packaging)	21
Secondary use of laying hens/dairy cows	3
Harvest & Post-Harvest & Processing	1
Processing	19
Processing 1st stage (Slaughter, Milling, tomato pulp, dairy production)	18
Processing 2 stage (Butchering, pasta production, bread production, tomato sauce production)	4
1st and 2nd stage processing (slaughter & butchering, milling & bread production)	3
1st and 2nd stage processing (milling, bread production) & retail	1
Storage	1
Packing	1
Transport	3
Wholesale	26
Retail	69
Canteens, school canteens, nursery food service	34
Restaurants and food services	10
Households	126
no information available	38

A4. Data tables for the Material Flow Analyses

Table A 1: Data table for the Material Analysis of lettuce in Sweden

Process	**Figure (edible)**	**Source**
Total yield	85,341.0 t	Calculation: sum of Production and pre-harvest and harvest FL
Production (realised yield)	29,869.4 t	FAOstat Supply Utilization Accounts, 2012-2014 (3-year average)
FLW Primary Production	55,471.7 t	https://www2.jordbruksverket.se/webdav/files/SJV/trycksaker/Pdf_rapporter/ra146.pdf (calculated as 65% of the potential yield is lost and 35% is harvested and further goes to consumption)
Imports of lettuce	36,615.4 t	FAOstat Supply Utilization Accounts, 2012-2014 (3-year average)
Exports of lettuce	6,388.9 t	FAOstat Supply Utilization Accounts, 2012-2014 (3-year average)

Quantity of lettuce entering the stage Retail and other distribution of food	60,095.9 t	Calculated based on Production, Imports and Exports and the edible fraction
Quantity of lettuce leaving stage Retail and other distribution of food	52,463.7 t	Calculation based on the Food Waste generated at this stage subtracted from the Quantity of lettuce entering the stage Retail and other distribution of food
Food Waste from Retail and other distribution of food	7,632.2 t	https://www2.jordbruksverket.se/webdav/files/SJV/trycksaker/Pdf_rapporter/ra146.pdf
Quantity of lettuce entering households	38,298.5 t	Calculation based on Quantity of lettuce leaving stage Retail and other distribution of food and the share of "vegetables, other" consumed at households (73%) used in the JRC Food System Material Flow Model version 3.0 Annex 1
Food Waste at household stage	9,477.8 t	Based on preliminary data analysis from SLU
Quantity of lettuce entering stage Restaurants and food services	14,165.2 t	Subtraction of Quantity of lettuce leaving stage Retail and other distribution of food and Quantity of lettuce entering households
Food Waste at Restaurants and Food Services	3,384.5 t	Subtraction of Quantity of lettuce entering stage Restaurants and food services and Quantity consumed at stage Restaurants and Food Services. Quantity consumed at stage Restaurants and Food Services was calculated based on: 60,700 t of lettuce were consumed in 2013 in Sweden (source: https://statistik.jordbruksverket.se/PXWeb/pxweb/sv/Jordbruksverkets%20statistikdatabas/Jordbruksverkets%20statistikdatabas__Konsumtion%20av%20livsmedel/JO1301K1.px/table/tableViewLayout1/). Share of household consumption based on JRC 73% (44,311 tonnes = 60,700 t *0.73. Hence 16,389 t remaining for out of home consumption. However, this figure is higher than the entering quantity. Therefore, I calculated the share of 31,326.8/44,311= 71.5% -> and applied this share to the amount consumed out of home: 16,389*0.715 = 11,718.1 t. From this the edible fraction was calculated.

Table A 2: Data table for the Material Flow Analysis of tomatoes in Italy

Process	**Figure (edible)**	**Source**
Total yield	6,601,998.1 t	Calculation: sum of production and harvest losses

Production (realised yield)	5,941,207.7 t (total) 4,657,906.8 t (open field) 1,283,300.9 t (greenhouse)	FAOstat Supply Utilization Accounts, 2018-2020 (3-year average) for total. Share of processing tomatoes based on the share of processed tomatoes of 78.4%, and 21.6% unprocessed tomatoes which were assumed to be produced under greenhouse.
FLW Primary Production	629,991.2 t harvest losses from open field; 8,381.8 t post-harvest losses from open field (transport); 30,799.2 t harvest and post-harvest losses from greenhouse	For processing tomatoes: calculated based on Secondi et al. (2019). The shares of losses for one glass of tomato sauce per supply chain stage were extrapolated to the total tomato production by applying the FLW shares from Secondi et al. (2019) to the total FLW amount of tomatoes for Italy from FAOstat. For greenhouse tomatoes: The average from studies from other countries, 2.4%, was calculated (Andersson, 2013; Visco, 2025; Bundesministerium Land- und Forstwirtschaft, Regionen und Wasserwirtschaft, 2025).
Imports of fresh tomatoes	132,561.6 t	FAOstat Supply Utilization Accounts, 2018-2020 (3-year average). Assumption: same share of open field and greenhouse tomatoes is imported as are processed (78.4%) and used fresh (21.6%)
Exports of fresh tomatoes	65,322.7 t	FAOstat Supply Utilization Accounts, 2018-2020 (3-year average). It was assumed that the export quantity is composed of 100% greenhouse grown tomatoes.
Quantity of tomatoes entering the stage Processing and Manufacturing	4,027,915.6 t from domestic production; 103,928.3 t from imported quantity	Domestic production: quantity of processing tomatoes leaving primary production. Imported quantity: calculated from FAOstat: processed tomatoes/fresh tomato stock -> 78.4% of fresh tomatoes are being processed. This share is applied the imported tomatoes.
Quantity of tomatoes leaving stage Processing and Manufacturing	2,746,577.1 t	Calculated by subtracting Food Waste from Processing and Manufacturing from the Quantity of tomatoes entering the stage Processing and Manufacturing
Food Waste from Processing and Manufacturing	1st stage processing: 834,632.5 t; 2nd stage processing: 550,634.3 t	Calculated based on Secondi et al. (2019). The shares of losses for one glass of tomato sauce per supply chain stage were extrapolated to the total tomato production by applying the FLW shares from Secondi et al. (2019) to the total FLW amount of tomatoes for Italy from FAOstat.
Quantity of fresh tomatoes entering	1,215,812 t	From domestic production: The quantity of greenhouse tomatoes leaving primary production minus the export.

Retail and other distribution of food		For imported tomatoes: 21.6% of imported tomatoes are assumed to be sold as fresh produce.
Quantity of processed tomatoes entering Retail and other distribution of food	691,421.1 t	Calculated based on the Quantity leaving the stage Processing and Manufacturing, subtracting the exported processed tomato products (FAOstat) and adding the imported processed tomato products (FAOstat).
Quantity of fresh tomatoes leaving the Retail and other distribution of food stage	1,139,216.1 t	Subtracting the losses of fresh tomatoes at the stage Retail and other distribution of food from the Quantity of fresh tomatoes entering the stage Retail and other distribution of food.
Quantity of processed tomatoes leaving the Retail and other distribution of food stage	683,124.0 t	Subtracting the losses of processed tomatoes at the stage Retail and other distribution of food from the Quantity of processed tomatoes entering the stage Retail and other distribution of food.
Food waste of fresh tomatoes at the stage Retail and other distribution of food	76,596.2 t	Calculation: Average waste rate of 6.3% based on Andersson (2013) and CREDA et al. (2021).
Food waste of processed tomatoes at the stage Retail and other distribution of food	8,297.1 t	Calculated based on Secondi et al. (2019).
Quantity of fresh tomatoes entering the stage Household consumption	831,627.7 t	Calculation based on the Quantity of fresh tomatoes leaving the stage Retail and other distribution of food and JRC FS-MFA model 3.0 Annex 1 share of fresh tomatoes going to households: 73%.
Quantity of processed tomatoes entering the stage Household consumption	485,018.0 t	Calculation based on the Quantity of processed tomatoes leaving the stage Retail and other distribution of food and JRC FS-MFA model 3.0 Annex 1 share of processed tomatoes going to households: 71%.
Food waste of fresh tomatoes at stage Household consumption	99,795.3 t	Calculation based on the Quantity of fresh tomatoes entering the stage Household consumption and JRC FS-MFA model 3.0 Annex 1 share of wasted fresh tomatoes: 12%.
Food waste of processed tomatoes at stage Household consumption	38,801.4 t	Calculation based on the Quantity of processed tomatoes entering the stage Household consumption and JRC FS-MFA model 3.0 Annex 1 share of wasted processed tomatoes: 8%.

Quantity of fresh tomatoes entering the stage Restaurants and food services	307,588.3 t	Calculation based on the Quantity of fresh tomatoes leaving the stage Retail and other distribution of food and JRC FS-MFA model 3.0 Annex 1 share of wasted fresh tomatoes: 27%.
Quantity of processed tomatoes entering the stage Restaurants and food services	198,106.0 t	Calculation based on the Quantity of fresh tomatoes leaving the stage Retail and other distribution of food and JRC FS-MFA model 3.0 Annex 1 share of wasted fresh tomatoes: 29%.
Food waste of fresh tomatoes at the stage Restaurants and food services	52,290.0 t	Calculation based on the Quantity of fresh tomatoes entering the stage Restaurants and food services and JRC FS-MFA model 3.0 Annex 1 share of wasted fresh tomatoes: 17%.
Food waste of processed tomatoes at the stage Restaurants and food services	17,830 t	Calculation based on the Quantity of processed tomatoes entering the stage Restaurants and food services and JRC FS-MFA model 3.0 Annex 1 share of wasted fresh tomatoes: 9%.

Table A 3: Data table for Material Flow Analysis of soft wheat in Italy

Process	**Figure (edible)**	**Source**
Total yield	7,540,940.0 t	Sum of production (realised yield) and harvest losses
Production (realised yield)	7,466,277.3 t	3-year average (2015-2017) of soft wheat yield in Italy from FAOstat Supply Utilization account
Harvest losses	74,662.8 t	Applied a rate of 1% loss, which is the average of harvest losses elaborated by Hartikainen et al. (2017) and Bundesministerium Land- und Forstwirtschaft, Regionen und Wasserwirtschaft (2025)
Post-harvest FW: use for energy/fuel	164,258.1 t	Applied a FW rate of 2.2%, which is the average of values elaborated by Hartikainen et al. (2017)
Side flow: livestock feed	657,032.4 t	Applied a rate of 8.8% feed side flow, which is the average of values elaborated by Hartikainen et al. (2017) and Bundesministerium Land- und Forstwirtschaft, Regionen und Wasserwirtschaft (2025)
Side flow: seed	332,473.9 t	3-year average (2015-2017) of FAOstat Supply Utilization Account
Outflowing quantity from primary production	6,312,512.9 t	Post-harvest losses, seed and feed quantities subtracted from the production

Imports of grains	7,410,427.3 t	3-year average from FAOstat Supply Utilization Accounts; according to FAOstat 1,780,554 t grain were used for feed in Italy. Therefore, it is assumed that part of the import (difference between feed from side flow feed and FAO number) is used for feed as well.
Exports of grains	508,334.1 t	3-year average from FAOstat Supply Utilization Accounts
Quantity of grains entering mills	11,846,062.6 t	The ratio grains being processed to flour and starch was 2.17% starch and 97.83% flour based on FAOstat. This ratio is applied to the result of Outflowing quantity from primary production minus exports of grain plus imports of grain
Quantity of grains entering starch production	262,761.5 t	
Side flow from milling: livestock feed	2,369,212.5	It is assumed that the bran is removed from 100% of the grains. It is further assumed that all bran is used for livestock feed (cf. Nabi Dar 2024). Therefore, 20% of the quantity of grains entering the mills are assumed to be used as livestock feed (cf. Cui et al. 2013, Saini et al. 2024).
Quantity of flour leaving mills	9,476,850.1 t	Result of Quantity entering mills minus side flow from milling: livestock feed.
Quantity of flour imports	31,784.3 t	3-year average (2015-2017) of FAOstat Supply Utilization Account; 1,907.06 t imported flour going to retail and other distribution of food (6%, based on Caldeira et al. 2024, Annex 1)
Quantity of flour exports	270,200.6 t	3-year average (2015-2017) of FAOstat Supply Utilization Account
Quantity of bran exports	194,943.8 t	3-year average (2015-2017) of FAOstat Supply Utilization Account
Quantity of flour entering the 2nd stage processing (manufacturing of bread and pastries)	8,684,127.7 t	94% of the result of quantity of flour leaving mills minus the flour exports, plus 94% of the imported flour (Caldeira et al. 2024, Annex 1, Courtonne et al. 2015).
Quantity of bread and pastries leaving 2nd stage processing	8,684,127.7 t	It is assumed that no waste occurs.
Quantity of flour entering retail and other distribution of food	57,718 t	568,011 t (milling) + 1,907 t (import); 6% of produced and imported flour

Quantity of bread and pastries entering retail and other distribution of food	8,609,261 t	Quantity of bread leaving 2nd stage processing plus imported bread (FAOstat 3-year average (2015-2017)).
Food waste of bread and pastries at retail and other distribution of food	189,403.7 t	Applied a rate of 2.2% waste based on Pietrangeli et al. (2022).
Side flow: livestock feed at retail and other distribution of food	76,450.2 t	Applied a rate of 0.888% based on Pietrangeli et al. (2022).
Side flow: donations at retail and other distribution of food	41,410.5 t	Applied a rate of 0.481% based on Pietrangeli et al. (2022).
Outflowing quantity at retail and other distribution of food	7,914,665.8 t	Quantity of bread and pastries entering retail and other distribution of food minus Food waste of bread and pastries at retail and other distribution of food, minus Side flow: livestock feed at retail and other distribution of food, minus Side flow: donations at retail and other distribution of food
Quantity of bread and pastries entering households	5,472,907.2 t	65% of breads and 78% of pastries leaving retail and other distribution of food (Caldeira et al. 2024, Annex 1 / Euromonitor)
Food Waste at households	367,966.5 t	4.0 kg per capita (Silvennoinen et al. 2022) and year multiplied by the Italian population (58.99 million)
Quantity of bread and pastries at restaurants and food services	2,441,758.6 t	35% of breads and 22% of pastries leaving retail and other distribution of food (Caldeira et al. 2024, Annex 1 / Euromonitor)
Food Waste at restaurants and food services	488,351.7 t	20% waste rate based on Boschini et al. (2022)

A5. Excerpts of the database

Supplementary Figure 1: Excerpt 1 of the database

	A	B	C	D	E	F	G	H	I
1	Food group/item								Geographic scope
2	Food group leaving primary production (FoodEx2)	Product leaving primary production (FoodEx2)	Product entering supply chain stage (FoodEx2)	Product leaving supply chain stage (FoodEx2)	Product leaving primary production (CPA 2.2)	Product entering supply chain stage (CPA 2.2)	Product leaving supply chain stage (CPA 2.2)	Product specification based on study	Country of data collection
3	categorical	categorical	categorical	categorical	categorical	categorical	categorical	text	text
4	10210 - LEGUMES	not further disaggrega	not further disaggrega	not further disaggrega	Fresh leguminous ve	Several, not further d	Several, not further d	Legumes	Switzerland
5	00010 - GRAINS AND GRA	00570 - COMMON WI	00570 - COMMON WI	00570 - COMMON WI	Wheat	Wheat	Wheat	Bread wheat	Switzerland
6	00010 - GRAINS AND GRA	00380 - RICE GRAIN	00380 - RICE GRAIN	00380 - RICE GRAIN	Rice, not husked	Husked rice	Husked rice	rice	Switzerland
7	00010 - GRAINS AND GRA	00380 - RICE GRAIN	00380 - RICE GRAIN		Rice, not husked	Husked rice		rice	Switzerland
8	00010 - GRAINS AND GRA	not further disaggrega	00030 - CEREAL GRAINS (AND CEREAL-LI		Cereals, other than ri	Cereals, other than rice, leguminous crops		Bread and milling	Spain
9	00010 - GRAINS AND GRA	00570 - COMMON WI	00570 - COMMON WHEAT GRAIN		Wheat	Wheat	Wheat	Wheat grain	Sweden
10	00010 - GRAINS AND GRA	00570 - COMMON WI	01750 - PASTA AND SIMILAR PRODUCTS		Cereals, other than ri	Macaroni, noodles and similar farinaceous		Grains (pasta)	Sweden
11	00010 - GRAINS AND GRA	00030 - CEREAL GR	00670 - CEREAL ANI	01160 - BREAD AND	Wheat	Wheat or maslin flou	Fresh bread	Bread	Sweden
12	00010 - GRAINS AND GRA	00030 - CEREAL GR	01160 - BREAD AND SIMILAR PRODUCTS		Wheat	Fresh bread		Bread	Sweden
13	00010 - GRAINS AND GRA	00030 - CEREAL GR	01160 - BREAD AND SIMILAR PRODUCTS		Wheat	Fresh bread		Bread	Sweden
14	00010 - GRAINS AND GRA	00380 - RICE GRAIN	00380 - RICE GRAIN		Husked rice	Husked rice		Rice Grain	Sweden
15	00010 - GRAINS AND GRA	00380 - RICE GRAIN	00380 - RICE GRAIN		Husked rice	Husked rice		Rice Grain	Sweden
16	00010 - GRAINS AND GRA	00570 - COMMON WI	01160 - BREAD AND SIMILAR PRODUCTS		Cereals, other than ri	Fresh bread	Fresh bread	Common bread, f	Italy
17	00010 - GRAINS AND GRA	00570 - COMMON WI	00570 - COMMON WHEAT GRAIN		Durum wheat	Durum wheat	Durum wheat	for Barilla Blue	Italy
18	00010 - GRAINS AND GRA	00570 - COMMON WI	00570 - COMMON WI	00670 - CEREAL ANI	Wheat	Wheat	Wheat or maslin flou	Barilla Blue Box	Italy
19	00010 - GRAINS AND GRA	00570 - COMMON WI	00670 - CEREAL ANI	01750 - PASTA AND S	Wheat	Wheat or maslin flou	Macaroni, noodles ar	Barilla Blue Box	Italy
20	00010 - GRAINS AND GRA	00030 - CEREAL GR	01160 - BREAD AND	01160 - BREAD AND	Cereals, other than ri	Bread, fresh pastry g	Bread, fresh pastry g	Bakery (mostly br	Italy
21	00010 - GRAINS AND GRA	00030 - CEREAL GR	01160 - BREAD AND	01160 - BREAD AND	Cereals, other than ri	Bread, fresh pastry g	Bread, fresh pastry g	Bread	Italy
22	00010 - GRAINS AND GRA	00030 - CEREAL GR	01160 - BREAD AND	01160 - BREAD AND	Cereals, other than ri	Bread, fresh pastry g	Bread, fresh pastry g	Bread	Italy
23	00010 - GRAINS AND GRA	00030 - CEREAL GR	01160 - BREAD AND	01160 - BREAD AND	Cereals, other than ri	Fresh bread	Fresh bread	Common bread, f	Italy
24	00010 - GRAINS AND GRA	00500 - RYE GRAIN	00500 - RYE GRAIN	00500 - RYE GRAIN	Rye	Rye	Rye	Rye	Finland

Supplementary Figure 2: Excerpt 2 of the database

J	K	L	M	N	O	P	Q	R	S	T	U	V	W
Temporal scope		Location of food waste within the supply chain			Food waste and side stream quantity								
Year(s) of data collection	Year of publication	Supply chain stage (broad)	Supply chain stage (specific)	NACE code	FLW Quantity 1	Unit 1	Edible/ Inedible	FLW Quantity 2	Unit 2	Edible/ Inedible+edible	Variance	Disposal or other use	Non-FLW uses
numeric	numeric	categorical	categorical	categorical	numeric	categorical	categorical	numeric	categorical	categorical	numeric	text	text
2011	2018	Primary Production	Harvest/Transport tc	01.11 Growing of ce	12.5	% of agricultural pro	edible	17.5	% of agricultural pro	edible & inedible		12.5% edible and 5%	2.5% animal feed
2011	2018	Primary Production	Harvest/Transport tc	01.11 Growing of ce	10	% of agricultural pro	edible & inedible				5%-15%	all to field composting	
	2018	Retail and other distribution of	Retail	47.2 Retail sale of fo	0.3	% of mass flowing ir	edible					0.3% anaerobic dige	0.07% donations
	2018	Restaurants and food services	Restaurants and foc	56.11 Restaurant ac	39.6	% of mass flowing ir	edible					24.5% incineration;	0.23% donations
2022	2023	Processing and manufacturing	1st and 2nd stage pı	10 Manufacture of	0.03	% of mass flowing ir	edible & inedible					Not utilized 0.59%	Animal feed
2020	2023	Primary production	unmature plants/ani	01.11 Growing of ce	2.6	% of agricultural pro	edible & inedible						
2023 (8 days	2024	Restaurants and food services	Canteens, school ca	56.11 Restaurant ac	3.2	% of served/purchas	edible & inedible	37.1	kg	edible & inedible			
2023-2024	2025	Processing and	Processing 2 stage	10.71 Manufacture c	3.0	% of produced good	edible	9440	tonnes/year	edible		There is 17730 tons	There is 17730 tons
2023-2024	2025	Retail and other distribution of	Retail	47.24 Retail sale of	8.7	% of mass flowing ir	edible	26086	tonnes/year	edible		There is 26860 tons	There is 26860 tons
2023-2025	Expected in	Households	Households		16286	tonnes/year/country	edible & inedible	1.5	kg/year/capita	edible & inedible			
2023 (8 days	2024	Restaurants and food services	Canteens, school ca	56.11 Restaurant ac	1.4	% of served/purchas	edible & inedible	16.1	kg	edible & inedible			
2023-2025	Expected in	Households	Households		7771	tonnes/year/country	edible & inedible	0.7	kg/year/capita	edible & inedible			
2022	2023	Retail and other distribution of	Retail	47.24 Retail sale of	2.2	% of produced good	edible					37% of surplus brea	63% of surplus brea
2015, 2016	2019	Primary production	Harvest/Transport tc	01.11 Growing of ce	54.5	g/kg of final product	edible	1363.0	g/kg of final product	edible & inedible		Of complete supply	Of complete supply
The study	2019	Processing and manufacturing	Processing 1st stag	10.61 Manufacture c	0	g/kg of final product	edible	340.74	g/kg of final product	edible & inedible		Of complete supply	Of complete supply
2015, 2016	2019	Processing and manufacturing	Processing 2 stage	10.73 Manufacture c	21.8	g/kg of final product	edible	23.5	g/kg of final product	edible & inedible		Of complete supply	Of complete supply
2015	2017	Retail and other distribution of	Retail	47.24 Retail sale of	88	kg/year	edible						21511 kg (99.6% of
2016-2017	2020	Restaurants and food services	Canteens, school ca	56.11 Restaurant ac	20	% of served goods	edible					Most waste discarded;	Some intact brea
November 20	2018	Restaurants and food services	Canteens, school ca	56.11 Restaurant ac	1.3	kg/day						Disposal (plate wast	Human consumptio
February–Jun	2024	Retail and other distribution of	Retail	47.24 Retail sale of	6.9	% of produced good	edible	4791.3	kg/day	edible			
	2017	Primary production	no information availa	01.11 Growing of ce	1.6	% of agricultural pro	edible & inedible				the side flow varies	about 15% of the wa	68% of "wasted rye

Supplementary Figure 3: Excerpt 3 of the database

X	Y	Z	AA	AB	AC
Methodological information on the study delivering the data					Source of the data
Data collection method	Number of observations	Sample description	Uncertainty about data	Further detailed description	
categorical	numeric	text	text	text	text
Questionnaires and interviews		2 farmers	"The composition of d	"Eulenhof (2011) and Rüchihof (2011) estimate the technical harvest losses of bread wheat at 5-15%."	Beretta, C. (2018): Environmental Assessment of Food Losses and Reduction Potential i
Questionnaires and interviews		2 farmers	"The composition of d	"Eulenhof (2011) and Rüchihof (2011) estimate the technical harvest losses of bread wheat at 5-15%."	Beretta, C. (2018): Environmental Assessment of Food Losses and Reduction Potential i
Mass balance		2 super market	"The composition of d	"Two supermarket chains and one discounter provided data to estimate the overall food	Beretta, C. (2018): Environmental Assessment of Food Losses and Reduction Potential i
Direct measurement		4 Foof service	"The composition of d	"SV Group has done measurements of food waste in 225 out of its more than 300	Beretta, C. (2018): Environmental Assessment of Food Losses and Reduction Potential i
Questionnaires and inter	18	companies			Euskadiko Itun Berdea, elika, Eusko Jaurlaritza Gobierno Vasco (2022). Análisis del Desp
Questionnaires and	15	farmers (It is		food loss of unharvested product and wildlife damage. Method: Survey (farmers): The	Jordbruksverket (2023). Livsmedelsförluster vid produktion av kvarnvete. Rapport 2023:1
Multiple (specified in furtl	2	school canteens		Plate waste from two elementary school canteens in Uppsala, Sweden, serving pupils	Sundin, N., Halvarsson, R., Schwerhaufer, S., Schneider, F., Eriksson, M. (2024). From p
Multiple (specified in furtl	Steakholder	Data from		Calculated based on figure 4 to comply with definitional framework of study.	Bartek, L., A. Sjölund, P. Brancoli, C. Cicatiello, N. Mesiranta, E. Närvänen, S. Scherhaufe
Multiple (specified in furtl	Steakholder	Data from		Calculated based on figure 4 to comply with definitional framework of study.	Bartek, L., A. Sjölund, P. Brancoli, C. Cicatiello, N. Mesiranta, E. Närvänen, S. Scherhaufe
Multiple (specified in	43	households		Method: weighing + picture composition analysis.Preliminary data, aggregated to	SLU unpublished results. Results expected to be published late 2025
Multiple (specified in	2	school canteens		Plate waste from two elementary school canteens in Uppsala, Sweden, serving pupils	Sundin, N., Halvarsson, R., Schwerhaufer, S., Schneider, F., Eriksson, M. (2024). From p
Multiple (specified in	43	households		Method: weighing + picture composition analysis.Preliminary data, aggregated to	SLU unpublished results. Results expected to be published late 2025
Direct measurement	12	small-scale bakeries, with a total of 16 branc		Recalculated to fit definitional framework. Measurement: February–June. Direct sales in small bakeries that also produce the bread. Directly measuring the quantity of surplus bread through	Pietrangeli, R., Eriksson, M., Strotmann, C., Cicatiello, C., Nasso, M., Fanelli, L., Melaragni, L., &
Multiple (specified in furtl	na	Primary production:	The FLW quantity may	Method: Direct measurement or mass balance. The study was initiated in March 2016	Principato, L., Ruini L., Guidi M., Secondi L. (2019) Adopting the circular economy approa
Multiple (specified in furtl	na	Milling: Data from 3	The FLW quantity may	Method: Direct measurement or mass balance. Three different sources of data were	Principato, L., Ruini L., Guidi M., Secondi L. (2019) Adopting the circular economy approa
Multiple (specified in furtl	na	Pasta production:	The FLW quantity may	Method: Direct measurement or mass balance. The study was initiated in March 2016	Principato, L., Ruini L., Guidi M., Secondi L. (2019) Adopting the circular economy approa
Direct measurement	1 retail store	Large retail store		"Data on the waste produced by these departments was collected during the year 2015	Cicatiello, C., Franco, S., Pancino, B., Blasi, E., & Falasconi, L. (2017). The dark side of r
Direct measurement	109656	78 primary schools in		The data was obtained from a large-scale study carried out involving 78 Italian primary	Boschini, M., Falasconi, L., Cicatiello, C., & Franco, S. (2020). Why the waste? A large-sc
Direct measurement	about 1600 meals	school cantine meals	The FLW quantity may	The canteen serves primary and secondary students an average of 800 meals per week,	Lagorio, A., Pinto, R., & Golini, R. (2018). Food waste reduction in school canteens: Evide
Direct measurement	14 bakeries branches			Directly measuring the quantity of surplus bread through daily diaries. Common bread:	D1.6 LOWINFOOD "Evaluation of the efficacy of innovations" Authors: Claudia Giordano (LUKE), Fa