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Food Waste from Farm to Fork: A Material Flow Analysis of Austria's Food Supply Chain

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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Vienna, 12.06.2025

Affidavit

I, **OLGA YURKEVICH, BSC**, hereby declare

1. that I am the sole author of the present Master's Thesis, "FOOD WASTE FROM FARM TO FORK: A MATERIAL FLOW ANALYSIS OF AUSTRIA'S FOOD SUPPLY CHAIN", 91 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted the topic of this Master's Thesis or parts of it in any form for assessment as an examination paper, either in Austria or abroad.

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Abstract

Food waste is a complex global issue with environmental, economic, and social consequences. Even though various efforts have been made to address this problem in Austria, there is a lack of consistent and comprehensive measurement of food waste across all stages of the food supply chain. This thesis addresses this gap by implementing a Material Flow Analysis to lay out and estimate food waste flows. Five stages of the food supply chain (primary production, processing & manufacturing, retail & distribution, household consumption, and consumption in food services) and six key food groups (fruits, vegetables, potatoes, meat, dairy, and eggs) are considered.

The Material Flow Analysis framework is applied using Austrian Food Balance Sheets and literature-derived coefficients. Calculations are performed in Microsoft Excel, while the STAN software is used to visualize the results. The analysis is conducted at the national level, following the European Union's definition of food waste wherever possible.

Results show that food waste occurs at all stages of the supply chain, with households generating the largest share. Plant-based foods, particularly vegetables, fruits, and potatoes, are wasted more than animal-based products like meat, dairy, and eggs.

This study adds value by promoting methodological transparency and highlighting key data gaps in Austria's current food waste monitoring efforts. By identifying these shortcomings, it lays the groundwork for more accurate and standardized assessments in the future. The findings can help policymakers and researchers target intervention areas and improve data quality, both of which are essential for achieving Austria's goals under Sustainable Development Goal 12.3.

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List of Abbreviations

ACA	Austrian Court of Audit
BMK	Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology in Austria
BMLUK	Federal Ministry of Agriculture, Forestry, Environment and Water Management
BOKU	University of Natural Resources and Life Sciences, Vienna
CEAP	Circular Economy Action Plan
EC	European Commission
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FBS	Food balance sheets
FL	Food loss
FLW	Food loss and waste
FSC	Food supply chain
FW	Food waste
MFA	Material flow analysis
SDGs	Sustainable Development Goals
UN	United Nations
WFD	Waste Framework Directive

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Lastly, I would like to express my deepest love and gratitude to my family, whose belief in me and continuous support I treasure greatly. Thank you for making this academic journey possible!

1. Introduction

Food waste is one of the most pressing and paradoxical challenges of the 21st century. In a world where over 700 million people go hungry each year (WHO, 2024), the waste of food across supply chains remains unethical and environmentally unsustainable. Globally, around one-third of all food produced for human consumption is lost or wasted (FAO, 2019). This is a huge inefficiency with broad social, environmental, and economic consequences, from greenhouse gas emissions to resource depletion and economic losses. Food waste undermines the sustainability of food systems and the broader goals of sustainable development. According to the United Nations Food and Agriculture Organization "*losing or wasting food is generally viewed as undesirable and something to be avoided. There are probably few issues in the international policy debate around which there is a stronger consensus*" (FAO, 2019).

Within the European Union, reducing food waste is increasingly prioritized in policy agendas and sustainability frameworks, particularly under the Sustainable Development Goal 12.3. This goal aims to halve per capita food waste at the retail and consumer levels and reduce food losses along production and supply chains by 2030 (United Nations, 2025). Austria, as a member of the EU and a signatory to the Sustainable Development Goals, has committed itself to this goal. However, accurately quantifying food waste and identifying points of inefficiency along the food supply chain remains a complex task. It is further complicated through differing definitions, methodologies, and data availability.

This master's thesis addresses the issue of food waste by applying a material flow analysis to Austria's national food supply chain. The approach offers a comprehensive framework for quantifying food waste from primary production to consumption while accounting for by-products, imports, exports, and food donations. This methodology allows for an assessment of the scale and distribution of food waste across different food groups, including fruits, vegetables, potatoes, meat, dairy, and eggs.

This research is relevant because it responds to a knowledge gap in existing Austrian food waste studies, which often focus on selected food categories or individual supply chain stages. Very few studies have attempted to build a unified model that encompasses the entire national food supply chain using a consistent methodological framework. Moreover, this study contributes to ongoing policy development by providing a data-driven overview that can serve as a foundation for future food waste prevention strategies.

1.1 Research Question

The research is structured around the following core research question: *What is the estimated amount of food waste produced in Austria at each stage of the food supply chain and across different food groups, based on a material flow analysis?* To answer this, the study models the national food system using data from Austrian food balance sheets and literature-derived waste coefficients. Each stage of the food supply chain is analyzed in detail with attention to material flows, waste streams, and by-products.

The second chapter defines core concepts and provides an overview of the Austrian food system, regulatory landscape, and prior research findings. The third chapter focuses on the methodology applied in this study. It details the construction of the Material Flow Analysis, including the system boundaries, data sources, assumptions, and limitations. In chapter four the results are broken down by supply chain stage and food groups, and in chapter five the results are discussed in the context of existing literature and policy implications.

The goal of this thesis is to quantify food waste in Austria for selected commodities, and to provide insights that can be used for waste reduction efforts. By mapping waste flows from farm to fork, this research highlights the inefficiencies and data gaps at each stage of the food supply chain, laying the groundwork for a more resource-efficient and environmentally responsible approach to food management in Austria.

2. State of the Art

This chapter presents an overview of the current state of research on food and food waste (FW) in Austria along the food supply chain (FSC). It begins by defining key concepts, including the FSC and FW, and elaborates on the difference between FW and food loss (FL). The chapter then outlines various methodologies used to calculate FW. Finally, it places these concepts in the Austrian context by presenting key facts and figures related to the national FSC and summarizing the existing knowledge on FW in Austria.

2.1 Definitions

Clear and consistent definitions are crucial when measuring progress and formulating policies, as different organizations may interpret terms differently, leading to inconsistent interpretations, measurement approaches, and expectations. This section provides an overview of how FL and FW are defined at both the United Nations (UN) and European Union (EU) levels, along with a general definition of the stages within the FSC. Distinguishing between FL and FW is essential, as these terms refer to different stages of the FSC and consequently require distinct strategies for measurement, prevention, and intervention.

2.1.1 Food Waste and Food Loss

There is no universally accepted definition of FL and FW, as the terms vary depending on the context and the specific issues being addressed. The definitions can differ based on how "food" itself is understood, or whether the term includes only the edible parts of food or also the inedible components. The definitions can also vary depending on whether alternative uses, such as food repurposed for animal feed, are considered. Additionally, how the stages of the FSC are defined and included plays a significant role in shaping the understanding of food loss and waste (FLW) (FAO, 2019).

Although there is no official definition of FL, academic literature offers several approaches to conceptualize it. For instance, the UN define FL as "*the decrease in the quantity or quality of food resulting from decisions and actions by food suppliers in the chain, excluding retail, food service providers and consumers*" (FAO, 2019). In practical terms, this refers to food that exits the FSC prior to the retail & distribution and consumption stages (FAO, 2025). The Joint Research Centre, EC's knowledge hub, defines FL 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 FW at primary production*" (European Commission and Joint Research Centre et al., 2024). According to this definition, FL encompasses any reduction in the quantity of food that takes place at the beginning of the FSC. Creating a common definition is an effort that is worked on up until today, for instance in the scope of the EU-funded research project FOLOU (FOLOU, 2023).

When it comes to FW, the UN define it as "*the decrease in the quantity or quality of food resulting from decisions and actions by retailers, food services and consumers*" (FAO, 2019). According to this definition, FW occurs at the end of the FSC (for example in shops, restaurants and households). It thus aligns with the SDG Target 12.3 which aims at halving FW "*at the retail and consumer levels*" by 2030 (United Nations, 2025). The European Commission (EC) and EU legislation primarily use the term FW for all food that becomes waste along the supply chain. The EU Waste Framework Directive (2008/98/EC, as amended in 2018) defines FW as "*all food, as defined in Article 2 of Regulation (EC) No 178/2002 of the European Parliament and of the Council, that has become waste*" (European Parliament and Council, 2008). Article 2 of Regulation (EC) No 178/2002 of the European Parliament and of the Council defines food as "*any substance or product, whether processed, partially processed or unprocessed, intended to be, or reasonably expected to be ingested by humans*" (European Parliament and Council, 2008). Not considered food are feed, live animals, plants prior to harvesting, medical products, cosmetics, tobacco, narcotic or psychotropic substances, as well as residues and contaminants. Therefore, FW is:

> *any food and inedible parts of food, that has entered in the food supply chain, that then has been removed or discarded from the food supply chain or at the final consumption stage, that is finally destined to be processed as waste, either separately collected as food waste or collected in municipal waste; moreover, food waste is any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed* (Eurostat, 2025).

This definition is closely linked to the definition established by the European Project FUSIONS, that played a vital role in developing a common FW policy in the EU (Östergren et al., 2014).

The EU definition distinguishes between edible and inedible FW. *Edible FW* includes all food that was originally supposed to be eaten by humans but, for various reasons, was not consumed and instead discarded. All parts of the food item that were once safe to eat are included, regardless of its condition at the time of disposal. Hence, moldy bread is considered edible because it could have been eaten before it got moldy (Moreno, 2020). Other examples include spoiled products, overproduction, and expired date products (Silvennoinen et al., 2015). In many papers the term avoidable FW is used instead of edible FW. While the terms edible FW and avoidable FW both refer to food that was suitable for human consumption before being discarded, they differ slightly in scope. For the purposes of this master's thesis, these terms will be used interchangeably to maintain consistency, acknowledging their subtle differences.

Food parts are considered *inedible* when they are not intended for human consumption. Common examples include bones, pits, and stones. However, the classification of inedible food parts can vary depending on cultural norms, socio-economic conditions, and the technological capabilities within a FSC (Ministry for the Environment, n.d.).

It is important to note that, in the calculations presented in this master's thesis, no distinction is made between edible and inedible FW due to limitations in the available data.

Unlike the UN, that only consider FW at the retail & distribution stage as well as the consumption stages, the EU's definition covers all stages after a food item has been produced for human consumption, including primary production (post-harvest/slaughter), processing & manufacturing, retail & distribution, consumption in households, and consumption in food services. This further illustrates that, within the European context, the concept of FW encompasses more stages of the FSC than FL. The EU uses FW as an umbrella term since the revision of the EU Waste Framework Directive in 2018 (Akkerman and Cruijssen, 2024). This, however, hinders comparison with earlier studies and UN efforts (Eurostat, 2025). Figure 1 illustrates the difference between the UN terminology and the EU terminology clearly.

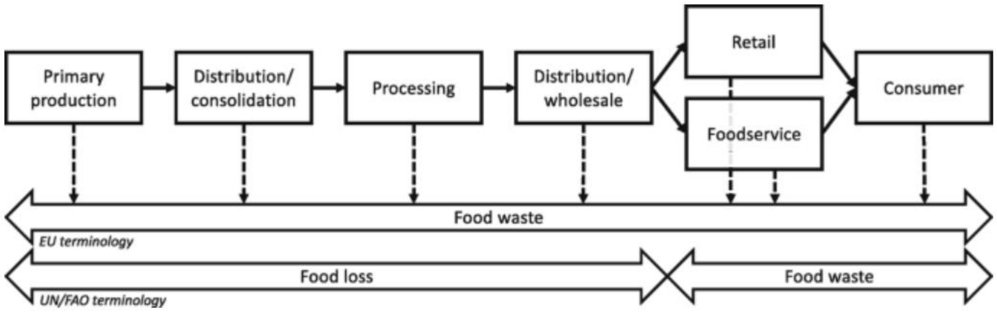

Figure 1: Distinction between FL and FW (Akkerman and Cruijssen, 2024)

This master's thesis adopts the EU's definition of FW, reflecting Austria's strong political and economic integration within the EU and Austria's obligation to apply the WFD on a national level. Moreover, the majority of studies cited throughout this work are closely related to the EU context, further reinforcing the relevance of this definition. The analysis is limited to *quantitative* FW. Q*ualitative* FW, which describes the deterioration in food quality (FAO, 2019), falls outside the scope of this research.

2.1.2 Food Supply Chain

In the EU's policy framework, FW is monitored and addressed across specific stages of the FSC, from farm to fork. The major stages mentioned in the EU Waste Framework Directive are primary production, processing & manufacturing, retail & distribution, and consumption. The consumption stage is further subdivided into food services (hospitality and catering) and households, recognizing the different forms of waste generation in and out of home (European Parliament and Council, 2008). The EU legislation demands Member States to reduce FW at each FSC stage in line with SDG 12.3. This is supported by a standardized methodology for consistent measurement (European Commission, 2025a) (see chapter 2.1.3). Below, each stage is defined as per EU legislation, Eurostat guidelines, and supporting studies.

Primary production

Primary production represents the initial stage of the FSC, encompassing activities such as agriculture and fisheries. It is the point at which raw food materials are first produced or harvested. In EU statistical terms it covers NACE Section A agriculture, forestry, and fishing activities (e.g. crop and animal production, hunting, fishing and aquaculture) (European Commission, 2019a). Given the EU's official FW definition excludes on-farm losses (see chapter 2.1.1), measured FW at the primary production stage focuses on materials that enter the waste stream after harvest/slaughter, for example unmarketable products or animal discards that are disposed of by using waste management facilities (Akkerman and Cruijssen, 2024).

Processing & manufacturing

Processing & manufacturing is the stage where raw agricultural outputs are transformed into food products. It includes food and beverage production industries. In EU statistical terms it encompasses NACE Section C, Division 10 (manufacture of food products) and Division 11 (manufacture of beverages) (European Commission, 2019a). Various processing methods exist, such as heating, canning, drying, juicing, freezing, and pasteurizing (Eufic, 2024). FW at this stage could be generated in the form of processing residues, unmarketable products, or test samples (Raak et al., 2017).

Retail & distribution

The retail & distribution sector covers the stages where food is distributed and sold to consumers. It encompasses institutions like supermarkets, smaller grocery shops, service stations, general retail, and food and beverage wholesale companies (EPA, 2024). In EU statistical terms it encompasses NACE Section G Division 46 (wholesale trade, except of motor vehicles and motorcycles) and Division 47 (retail trade, except of motor vehicles and motorcycles). At this stage, FW mainly consists of unsold or unsalable food that is removed from the market. Examples include products that pass their expiration dates, are damaged, or have clear flaws (Lebersorger and Schneider, 2014b).

Consumption (households and food services)

The consumption stage represents the final step, where food is prepared and consumed. In the EU FW monitoring approach, it is split into two sub-sectors: households and food services (European Parliament and Council, 2008). Households encompass areas such as domestic kitchens and places for dining. FW at this stage includes cooking scraps, not consumed leftovers, and expired food (Schanes et al., 2018).

The food service sector includes facilities such as restaurants, cafeterias, fast-food restaurants, take-out eating places, and mobile food carts, as well as accommodation with food provision (Eurostat, 2008). All institutions are mentioned in the NACE Section 1, Divisions 55 and 56. FW in food services comes from kitchen losses (e.g. trimmings, spoiled ingredients) and plate waste (uneaten food left by customers) (Dhir et al., 2020).

2.1.3 Food Waste Measurement Methodologies

To carry out the Material Flow Analysis (MFA), a comprehensive literature review is made to gather coefficients from existing academic studies. Many of these studies either generate their own data or source it from other research, typically employing one of the methodologies that will be outlined in the following part of the thesis. Therefore, before a review of empirical research studies can be made, an outline of such methodologies is necessary. All methodologies discussed are mentioned in Annex III of the Commission Delegated Decision (EU) 2019/1597 on common methodology and minimum quality requirements for the uniform measurement of levels of FW (European Commission, 2019a). The framework was established in response to mandatory FW reporting requirements for all EU Member States, making it also relevant for Austria. Detailed information on the framework can be found in chapter 2.2.2.

This section describes the methodologies outlined in Annex III of the Commission Delegated Decision (EU) 2019/1597. These methodologies are also defined in the Food Waste Index Report by the United Nations Environmental Programme (UNEP, 2024).

Direct measurement: This method consists of weighing or volumetric assessment (European Commission, 2019a). *Weighing* involves directly measuring the mass of FW using devices like scales or weighbridges. It is considered to be highly accurate, especially for food-only waste streams (UNEP, 2024). *Volumetric assessment* measures the space FW takes up, then uses the known density to estimate mass. It is best used when the waste is homogeneous (e.g. from a single type of processing residue). It is less accurate than weighing but still useful (UNEP, 2024).

Counting/scanning: This method counts individual food items that are discarded, often using scanner or barcode/QR code data (UNEP, 2024). The accuracy is high, but it only works for scannable or countable items (mostly packaged items), and not for bulk or mixed waste (UNEP, 2024).

Waste composition analysis: This method involves physically sorting waste to separate food from other materials (European Commission, 2019a). It gives insights into waste composition, for example on the food type or on whether the FW is edible or inedible (UNEP, 2024). It is very accurate and suitable even when FW is already separated. However, more detailed categorization is needed (UNEP, 2024).

Diaries: Participants record their FW, noting types and quantities (by mass or estimation). It is the only tested method available for measuring FW that is home composted, fed to animals, or goes down the sewer (UNEP, 2024). Diaries are less accurate compared to the above-mentioned methodologies due to behavioral change, underreporting, and estimation errors, but improvements can be made with better study design (UNEP, 2024).

Mass balance: This method deduces FW by calculating the difference between inputs and all measurable outputs (European Commission, 2019a). The mass balance is a cornerstone of all MFA (Brunner and Rechberger, 2020). Given this paper applies an MFA, it relies strongly on mass balances. A more in-depth description of the MFA will be provided in chapter 3.

Coefficients and production statistics: Known waste generation rates (coefficients) are applied to national or sectoral production data (European Commission, 2019a). This approach is useful for generating national estimates when primary data is sparse. This master's thesis works with coefficients.

2.2 Austria's Food Supply Chain

To accurately calculate FW quantities within the Austrian FSC, a clear understanding of the national market is essential. Accordingly, the next section offers an in-depth overview of the Austrian FSC. It outlines each stage and identifies the primary causes of FW. Additionally, this chapter presents a comprehensive summary of regulatory frameworks and the current state of knowledge on FW in Austria.

2.2.1 Overview of the Current State and Underlying Causes of Food Waste

The overview of the current state of Austria's FSC is structured according to the FSC stages relevant for this study. The causes of FW are examined individually for each stage of the supply chain.

The current state of primary production

According to 2020 data, Austria is home to approximately 155,000 farms, with over a quarter operating organically (Statistics Austria, 2022; BMLUK, 2023). Given that much of the country is mountainous, its agricultural sector is predominantly characterized by small, family-run enterprises (Groier, 2016). Austrian primary production yields significant outputs. For example, the 2022/23 harvest included around 5,200 kilotonnes (kt) of cereals, 747 kt of vegetables, and 500 kt of fruits (Statistik Austria, 2024b). On the livestock side, in 2022, domestic farms produced about 853 kt of meat and nearly 4,000 kt of milk, along with 2.38 billion eggs (Statistik Austria, 2024c). This output makes Austria largely self-sufficient in food groups like dairy and meat. Self-sufficiency rates reach 108% for meat and 182% for consumable milk (Statistik Austria, 2024c). It remains less self-sufficient in categories like fruits (45%) and vegetables (58%) (Statistik Austria, 2024b).

The current state of processing & manufacturing

The processing & manufacturing stage is a crucial step that connects the primary production with the retail & distribution stage. In 2023, the Austrian food processing industry comprised around 200 companies (Advantage Austria Cairo, 2025), and 60% of the food products are being distributed to more than 180 countries (Advantage Austria Micronesia, 2025). The key sub-sectors, in terms of revenue, include confectionery, non-alcoholic beverages, meat processing, and the fruit juice industry (U.S. Department of Agriculture and Foreign Agricultural Service, 2012).

The current state of retail & distribution

Food retail in Austria is a mature market. In 2022, food retail sales reached about EUR 25.8 billion (RegioData Research GmbH, 2023). A few large supermarket chains dominate this sector. The top four retail groups (REWE, Spar, Hofer, Lidl) have a combined market share of 91% (BWB, 2023). Despite the dominance of big players, there are also numerous smaller stores, specialty food shops, farmers' markets, and a growing e-commerce grocery segment contributing to distribution. Austria is both a food importer and exporter, with trade of food and beverages nearly balanced. For example, in 2023 Austria's foreign trade with food produce reached EUR 10.30 billion in exports, roughly 5% of the country's total export volume, and EUR 8.29 billion in imports, resulting in a positive trade balance of EUR 2.01 billion (Advantage Austria New Zealand, 2025; OEC, 2025).

The current state of consumption

Per capita food consumption is substantial, especially for animal products. In 2022, Austrians on average consumed 227 kg of animal-based foods per person (meat, dairy, eggs, fish). This included about 88 kg of meat, making it above the EU average which is around 82 kg per year (Askew, 2020), and 79 kg of milk (per capita annual consumption) (Statistik Austria, 2024a). The composition of meat in Austrian diets is typical for central Europe, with pork making the largest component, followed by poultry and beef (Statistik Austria, 2024a). Egg consumption was equal to around 15.3 kg per person (about 248 eggs annually) (Statistik Austria, 2024a). Plant-based foods are prominent in the Austrian diet as well. Vegetable consumption reached 120 kg per capita in 2022/23, and fruit consumption was about 78 kg per capita (Statistik Austria, 2024b).

Given the central role of these food categories in the national diet, this master's thesis focuses on six key food groups: fruits, vegetables, potatoes, meat, dairy, and eggs.

2.2.2 Overview of important Regulatory Frameworks

The following part of the thesis discusses regulatory frameworks that address FW, and that Austria has committed itself to. This is essential because these policies establish guidelines and standards that drive systemic efforts to reduce waste across the FSC.

United Nations Sustainable Development Goals

At the highest level, Austria's FW policy is guided by the United Nations Sustainable Development Goals (SDGs). The 17 SDGs address humanity's most pressing challenges. These goals range from poverty eradication and health to climate action and should be achieved by 2030 (UNEP, 2025). Particularly SDG 12.3 discusses FW. As mentioned in chapter 2.1.1, the global target calls for halving "*per capita food waste at the retail and consumer levels*" (UNEP, 2025) by 2030 and "*reducing food losses along production and supply chains, including post-harvest losses*" (UNEP, 2025). Austria, as a UN Member State, has committed to this goal (Leitbetriebe Austria, 2020). However, achieving SDG 12.3 is challenging. The Austrian Court of Audit (ACA) noted in 2021 that without comprehensive data collection it will be difficult to track progress towards the 2030 goals (Rechnungshof Österreich, 2021).

European Union Frameworks

At the EU level, Austria's FW along the FSC is influenced by several important policies. The *Waste Framework Directive (WFD) 2008/98/EC* is the cornerstone of EU waste legislation. It establishes the waste hierarchy, which states that the prevention, re-use and recycling of waste should be chosen over recovery and disposal. The WFD also requires Member States to adopt waste prevention programs, as mentioned in Article 29 (European Parliament and Council, 2008). In 2018, the WFD was revised to strengthen commitments on FW. Member States are required to measure FW annually across all stages of the FSC and take concrete steps to reduce it. The Commission Delegated Decision 2019/1597 (see chapter 2.1.3) states that Member States are required to measure the total amount of FW produced over a full calendar year, reporting annually in metric tonnes of fresh mass and breaking down the data by stages of the FSC. According to Article 2 of the Commission Delegated Decision (EU) 2019/1597, a national measurement of FW using the methodology outlined in Annex III should be done once every four years (starting with 2020). Article 2 further states that in cases where the methodologies of Annex III are not applied, FW should be calculated using the methodologies from Annex IV. The methodologies mentioned in Annex III are described in chapter 2.1.3. Furthermore, Article 3 states that Member States have the option to voluntarily report additional data on specific aspects of FW. This includes data on FW drained with wastewater, food donated, and food converted to animal feed (European Commission, 2019a).

As part of the European Green Deal, the *Circular Economy Action Plan (CEAP)* was adopted in 2020. It identifies FW as a priority area and led to the EU Commission's proposal of legally binding FW reduction targets for Member States. Legally binding reduction targets have not been implemented yet, even though the European Parliament has reached a provisional agreement encompassing 30% reduction on the retail and consumption levels and 10% for processing and manufacturing (from the 2020 baseline) (European Commission, 2025d).

Another key policy is the *EU Farm to Fork Strategy*, which was established in 2020. It is at the heart of the Green Deal's vision for a sustainable food system and calls for improving action to prevent and reduce FLW "from farm to fork". The strategy is strongly aligned with the commitment to SDG 12.3 and frames it as a "*triple win*" (European Commission, 2025c), given that reducing FW contributes to saving food, saving money, and lowering environmental impacts (European Commission, 2025c). Under Farm to Fork's Action Plan, the EU established platforms like the EU Platform on Food Losses and Food Waste to share best practices. Austria is also an active member of this community (European Commission, 2025b).

Austrian national legislation and initiatives

Austria implements and builds upon these international frameworks through its national laws and programs. The primary legislation is *Austria's Waste Management Act* (Abfallwirtschaftsgesetz), which was first published in 2002 and has been amended since then. The main aim of the Waste Management Act is to ensure that waste management is organized in such a way that harmful effects on humans, animals, and plants are avoided or minimized as far as possible. Another important goal of the Waste Management Act is that resources are conserved, and the efficiency of resource utilization is improved (RIS, 2025). FW reduction greatly contributes to this goal.

Paragraph 11a of the Waste Management Act obliges food retailers with at least one sales outlet of more than 400 m2 or with at least five sales outlets and wholesalers required to keep accounts to report the mass of FW broken down by product group and the mass of food donations. The first report was done for the fourth calendar quarter of 2023 (RIS, 2025).

According to paragraph 8 of the Waste Management Act, the Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLUK) (formerly known as the Federal Ministry for Climate Action, Environment, Energy and Technology (BMK)) is obliged to publish a federal waste management plan at least every six years. In practice, this has led to initiatives across various waste streams, including food. The 2023 version of the Federal Waste Management Plan mentions a national FW prevention strategy. The aim of this strategy is to handle food "*more appreciatively and efficiently*" (BMK, 2023), essentially fostering a culture that values food and avoids it becoming waste.

In terms of concrete initiatives, Austria has launched public and private programs to tackle FW at all levels of the FSC. A flagship program is *"Lebensmittel sind kostbar!" ("Food is* *precious!")*, an initiative organized by the former Federal Ministry for Sustainability and Tourism (BMNT) in 2013 (BMNT, 2018). This initiative serves as a platform that brings various stakeholders such as businesses, municipalities, and organizations together to reduce FW across Austria. The program focuses on awareness-raising, stakeholder dialogue, and supporting practical measures such as facilitating food donations and developing tools for kitchens that help minimizing waste (BMK, 2023).

2.2.3 Food Waste: Key Statistics and Figures in Austria

The objective of this section of the master's thesis is to present the most current national statistics on FW in Austria, based on existing knowledge. The data used are primarily drawn from Austrian sources, including studies and official reports from organizations such as the Environment Agency Austria (Umweltbundesamt), the Federal Ministry (BMLUK), BOKU University, and WWF, supplemented by relevant insights from EU-level research.

Numerous studies have already been conducted on FW in Austria, providing data for various stages of the FSC and selected food groups (Pladerer and Hietler, 2019; Lebersorger and Schneider, 2014b; Obersteiner and Luck, 2020; United Against Waste, 2015). However, these studies typically focus on specific stages or narrow sets of food categories and often apply methodologies other than the MFA approach, which is central to this thesis. In contrast, the present study takes a more comprehensive approach, encompassing all stages of the FSC and a broader range of food groups. Furthermore, it applies more recent data and integrates updated coefficients to deliver a more detailed and nationally applicable analysis.

The following chapter summarizes the current knowledge on FW in Austria. Potential differences in outcomes between this thesis and earlier research will be discussed in chapter 5.

General information

Austria generates a substantial volume of FW each year, with households identified as the primary contributors. When seeking reliable figures, most recent national reports reference data from Eurostat (Broneder, 2024; Obersteiner and Stoifl, 2024). According to Eurostat, Austria produced 1,184 kt of FW in 2022, equivalent to 131 kilograms per person annually (Eurostat, 2022). To put this into perspective, that's more than the average amount of vegetables an Austrian consumes in a year (Statistik Austria, 2024b). A bit more than half of the waste, 635 kt to be exact, was produced at the consumer level in private households. The remainder is distributed among the earlier stages of the FSC (Eurostat, 2022). Figure 2 provides a breakdown by sector for the reference year 2022.

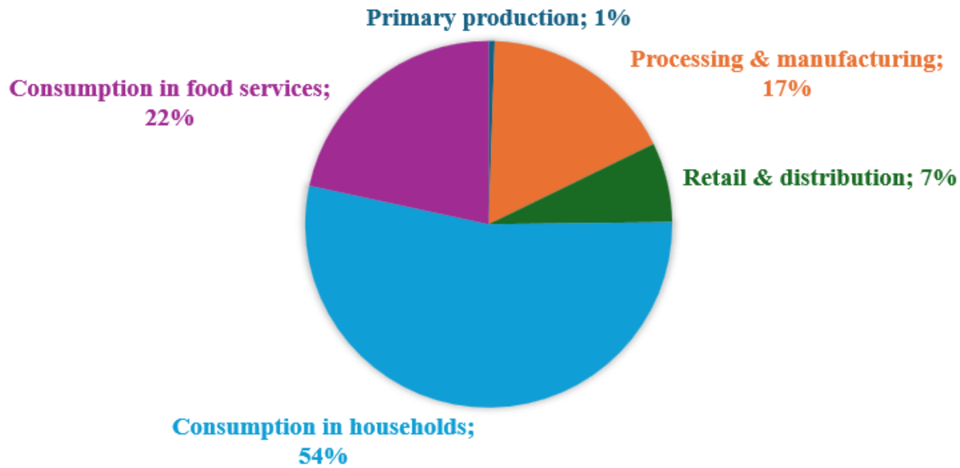

Figure 2: FW in Austria broken down by sector (based on Eurostat, 2022)

As shown, after households, the next largest contributor is the food service sector, followed by processing & manufacturing, retail & distribution, and finally primary production. Although FW on farms is reported to be relatively low in waste statistics, some studies suggest that actual losses during primary production are considerably higher when non-waste streams (e.g. unharvested crops used as feed) are included (Obersteiner and Stoifl, 2024).

Figure 3 demonstrates how FW in Austria has changed over time.

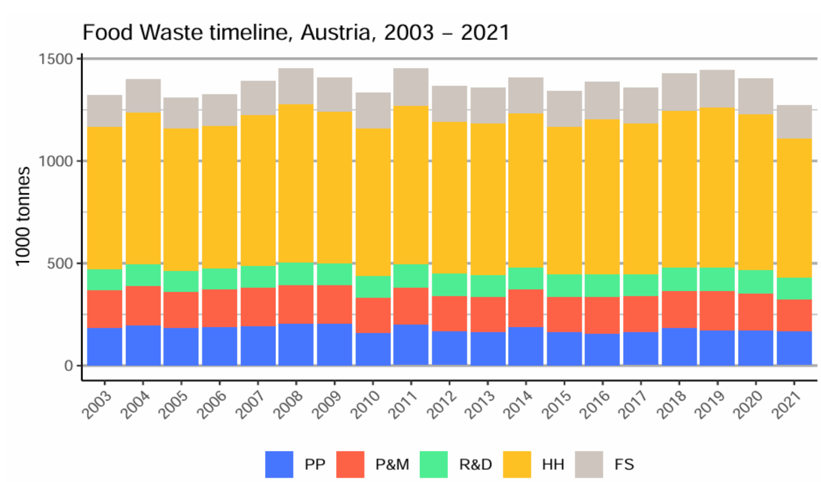

Figure 3: Timeline of FW in Austria by supply chain stage, 2003–2021 (European Commission and Joint Research Centre, 2024). Note: PP = primary production; P&M = processing & manufacturing; R&D = retail & distribution; HH = household; FS = food service

From 2003 to 2021, households consistently contributed the largest share of FW. The total volume of FW shows some fluctuations, with peaks around 2008, 2011 and 2019. However, there is no clear long-term upward or downward trend across the years. The other sectors remain relatively stable in their contributions, with minor variations over time.

Food waste at the primary production stage

According to Eurostat, 6 kt of food are wasted at the primary production stage (reference year 2022) in Austria (Eurostat, 2022), which, as Figure 2 demonstrates, is 1% of the total FW. As previously mentioned, this low figure is somewhat misleading, because it reflects the narrow definition under waste regulations (only counting material that enters the waste management system). A comprehensive unpublished study by BOKU researchers Hrad, M., Ottner, R., Obersteiner, G., Fink, R. and Comploi, K. estimated in 2019 that about 167 kilotonnes of avoidable FW (only vegetables and fruits) is generated annually in Austrian agriculture before reaching the market (Obersteiner and Stoifl, 2024), suggesting that the actual volume of FW is significantly higher. The study was conducted via interviews with producers. Notably, based on this study, potatoes are the single most wasted crop by mass. These losses often occur because the product fails to meet quality or size standards, or due to disease, or weather damage (Obersteiner and Stoifl, 2024). Furthermore, studies have shown that a significant portion of these unharvested crops would have been marketable, for instance, up to 77% of carrots and 38% of onions left in the field were of marketable quality (Obersteiner and Stoifl, 2024). This highlights a large prevention potential on farms.

Generally, at the primary production stage, starting with post-harvest/slaughter handling, several causes contribute to FW. These include inadequate handling, a lack of appropriate storage facilities, and non-conformance to retail specifications. Spillage, short product shelf-life, and poor stacking, filling, and cushioning in bulk bins or crates also play significant roles. Additionally, deterioration in product quality due to disease contamination, and the use of inadequate or defective packaging further intensify losses. Finally, overstock situations caused by take-back agreements and order cancellations also significantly contribute to FW during this stage (Magalhães et al., 2019).

Food waste at the processing & manufacturing stage

In Austria, 204 kt of FW arose from food processing & manufacturing in 2022 (Eurostat, 2022). This represents about 17% of the national FW (Figure 2). An Austrian study published in 2019 indicates that cereal-based products (bread, baked goods, etc.) and dairy products are among the top food groups wasted during manufacturing in Austria, by mass (Pladerer and Hietler, 2019).

In general, at the processing & manufacturing stage, several factors contribute to FW. These include inadequate packaging, improper handling, and storage at incorrect temperatures. Poor processing practices and flawed demand forecasting also lead to significant losses (Magalhães et al., 2019).

Food waste at the retail & distribution stage

In 2022, 83 kt of FW were reported from retail & distribution in Austria (Eurostat, 2022), accounting for roughly 7% of total FW (Figure 2). However, retail chains in Austria also implement redistribution efforts for unsold food, and a portion of surplus food is donated to charities (food banks, soup kitchens). According to the Federal Ministry, in 2020 Austrian grocery retailers had 97 kt of surplus food that was potentially avoidable waste, and of this, 20 kt was donated and 10 kt went to animal feed, leaving 68 kt that were ultimately discarded as waste (BMK, 2024). Fresh fruits, vegetables, and bakery products make up 50% of supermarket FW by mass. These categories dominate because they have short shelf lives and strict quality expectations. Other significant categories in retail waste include meat products, prepared foods, and dairy products (BMLUK, 2025).

At the retail & distribution stage, several factors contribute to FW in general. These include expiration dates, improper storage temperatures, inadequate demand forecasting, and poorly managed pricing strategies (Magalhães et al., 2019).

Food waste in households

As previously mentioned, households are the single largest source of FW in Austria. In 2022, 635 kt of FW were generated at this stage (Eurostat, 2022), representing 54% of all national FW (Figure 2). More than 50% of the FW at this stage is avoidable (Obersteiner and Stoifl, 2024). Detailed waste audits and surveys over the past two decades (many conducted by

BOKU's Institute of Waste Management) showcase the types of foods that are thrown into the garbage. The two biggest contributors by mass are bread and baked goods (28% of avoidable household FW) and fresh fruits and vegetables (27% of avoidable household FW) (BOKU University, 2021). Together they make up more than 50% of avoidable FW in households. Dairy products, eggs, and cheese make up roughly 12% of avoidable household FW, while meat and fish products contribute to about 11%. Although meats are a smaller fraction of the waste, they represent a disproportionately high environmental and economic cost, due to the resources required to produce them (Obersteiner and Luck, 2020).

Food Waste at the food services stage

In 2022, the food services sector generated 256 kt of FW (Eurostat, 2022). This amounts to 22% of the overall FW in Austria (Figure 2). Hence, this sector is the second-largest contributor to Austria's FW after households. A study was conducted in 2014 and 2015 where a waste composition analysis in 50 Austrian facilities was made (United Against Waste, 2015). According to this study, institutional catering (e.g. canteens in school, hospitals, workplaces) contribute to avoidable FW with around 61 kt, the hotel industry with 50 kt, restaurants with 45 kt, and other establishments with 19 kt (United Against Waste, 2015).

At the consumption stage, various factors contribute to FW, for instance oversized meal portions, over-purchasing and poor storage management (especially in households), confusion about date labels in households, and wrong demand forecasting in the food services sector (Magalhães et al., 2019).

3. Research Methodology

To estimate the amount of FW generated in Austria, a Material Flow Analysis (MFA) is conducted. This chapter begins by defining the MFA as a methodological framework and outlining the system boundaries. It then details the data collection process, along with the key assumptions made and the limitations of the analysis.

3.1 Material Flow Analysis as a Methodological Framework

3.1.1 Introduction

MFA is defined as a "*systemic assessment of the state and changes of flows and stocks of materials within a system defined in space and time*" (Brunner and Rechberger, 2020). A fundamental principle of the MFA is the law of conservation of matter, which states that mass cannot be created or destroyed (Ibid.). Therefore, MFA relies on mass balances, described by the equation:

$$Input = Output \pm Storage$$

Brunner and Rechberger (2020) highlight the MFA's value in the field of waste management and related decision-making processes, making it a suitable and effective tool for the scope of this thesis. Within the MFA, the materials analyzed can be either substances (homogeneous types of matter) or goods, which consist of multiple substances and possess economic value. In this context, food is treated as a good (Ibid.).

An MFA is typically applied within a clearly defined *system* bounded in both space and time. This system encompasses all relevant flows of materials, stocks, and processes. The scope of such systems can vary widely: from geographical regions and specific stages of a supply chain to individual production facilities. System boundaries are needed to set the spatial and temporal limits within which the analysis is conducted. For instance, if the system of a study is a region, the spatial boundary may correspond to its physical borders (Ibid.).

The MFA is fundamentally based on *processes*, which are defined as the "*transport, transformation, or storage of materials*" (Ibid.). These processes can be either natural, such as the flow of water in a river, or human-made, such as waste collection systems. Processes are interconnected through flows (measured in mass per unit of time) or fluxes (mass per unit of time and area). When materials enter a process, they are termed inputs or imports, and when they exit, they are referred to as outputs or exports (Ibid.).

Stocks play a crucial role in any MFA, as they represent the storage component within the system. A stock is determined by the difference between a process's input and output (as the formula above demonstrates). When the output is smaller than the input, it indicates that material is accumulating within the system, and hence, the stock is increasing (Ibid.).

3.1.2 STAN software

This master's thesis utilizes the software STAN, which is one of the most widely used tools for conducting an MFA. STAN, short for *subSTance flow ANalysis*, provides a user-friendly platform that supports the MFA in accordance with the Austrian standard ÖNORM S 2096. As noted by Brunner and Rechberger (2020), STAN offers several advantages: users can put data manually or import it from Microsoft Excel, results can be visualized using Sankey-style diagrams, and data uncertainties can be accounted for within the analysis. In this thesis, the STAN software is employed primarily for visualizing the MFA, while Microsoft Excel is used to perform the necessary calculations.

3.2 Defining the Material Flow Analysis

3.2.1 System boundaries

First, clear system boundaries are set to ensure a focused and accurate analysis. The spatial boundary is limited to the national territory of Austria, meaning all food and FW flows considered in the MFA either originate, occur, or end within Austrian borders. No breakdown by federal states or districts is made. Where relevant, imports and exports are included to reflect the movement of food across national borders.

While a consistent temporal boundary would ideally be applied, the availability of up-to-date and comprehensive data across all stages of the FSC is limited. Consequently, a single reference year could not be defined (see Table 4). Instead, the analysis relies on recent and complete data available for each stage and food group. The MFA is developed using a combination of primary data sources, national statistics, and literature-derived coefficients.

Given the heterogeneity and occasional scarcity of data, there are differences in data quality and recency between the various FSC stages and food groups. The author strives to maintain methodological consistency wherever possible.

In line with the scope of this thesis, the analysis focuses exclusively on post-harvest/slaughter stages of the FSC. The following stages are considered, as outlined in chapter 2: primary production (post-harvest/slaughter only), processing & manufacturing, retail & distribution, household consumption, and consumption in food services.

Regarding the material boundary, the analysis includes both the edible and inedible parts of food originally intended for human consumption. Due to limited data availability, no distinction is made between these two fractions in the quantification of FW. Items such as animal feed and industrial by-products are excluded from the definition of FW. Instead, they are grouped under the term "by-products" and are accounted for using coefficients and the mass balance approach at the primary production stage as well as the processing & manufacturing stage. Due to lack of sufficient data, by-products are not considered in other FSC stages. At the retail & distribution stage, surplus food that is diverted through donation rather than wasted is reported separately. Due to data scarcity, donations are not accounted for in other stages of the FSC. In this case as well, estimation relies on the use of applied coefficients.

The following food groups are considered: fruits, vegetables, potatoes, meat, milk, and eggs. These categories are selected based on their significance in the Austrian diet (see chapter 2.2.1), availability of data, and representation across all stages of the FSC, as well as taking into consideration the potential workload within the given master's thesis.

3.2.2 Describing the model

The MFA model presented in Figure 4 (refer to the page 23) forms the foundation of the analysis and offers a comprehensive overview of the Austrian food system. It traces the flow of food materials from primary production through to final consumption and is applied uniformly for all relevant food groups. While it is acknowledged that individual food groups may follow distinct processes along the FSC (for instance this is the case in European Commission and Joint Research Centre (2024), a generalized model is adopted for the purposes of this thesis to maintain analytical consistency. The only exception to this approach concerns the dairy food group, for which export volumes are displayed separately at the processing & manufacturing stage. This distinction is necessary to uphold the principle of mass balance (see chapter 3.1.1) while utilizing the most accurate and up-to-date data available for the calculations. Due to the absence of comparable export data for other food groups at this stage, exports are only reported for dairy.

This model builds on frameworks developed in previous studies, including those by Stenmarck et al. (2016), Caldeira et al. (2019), and European Commission and Joint Research Centre (2021). It encompasses 17 flows and five processes.

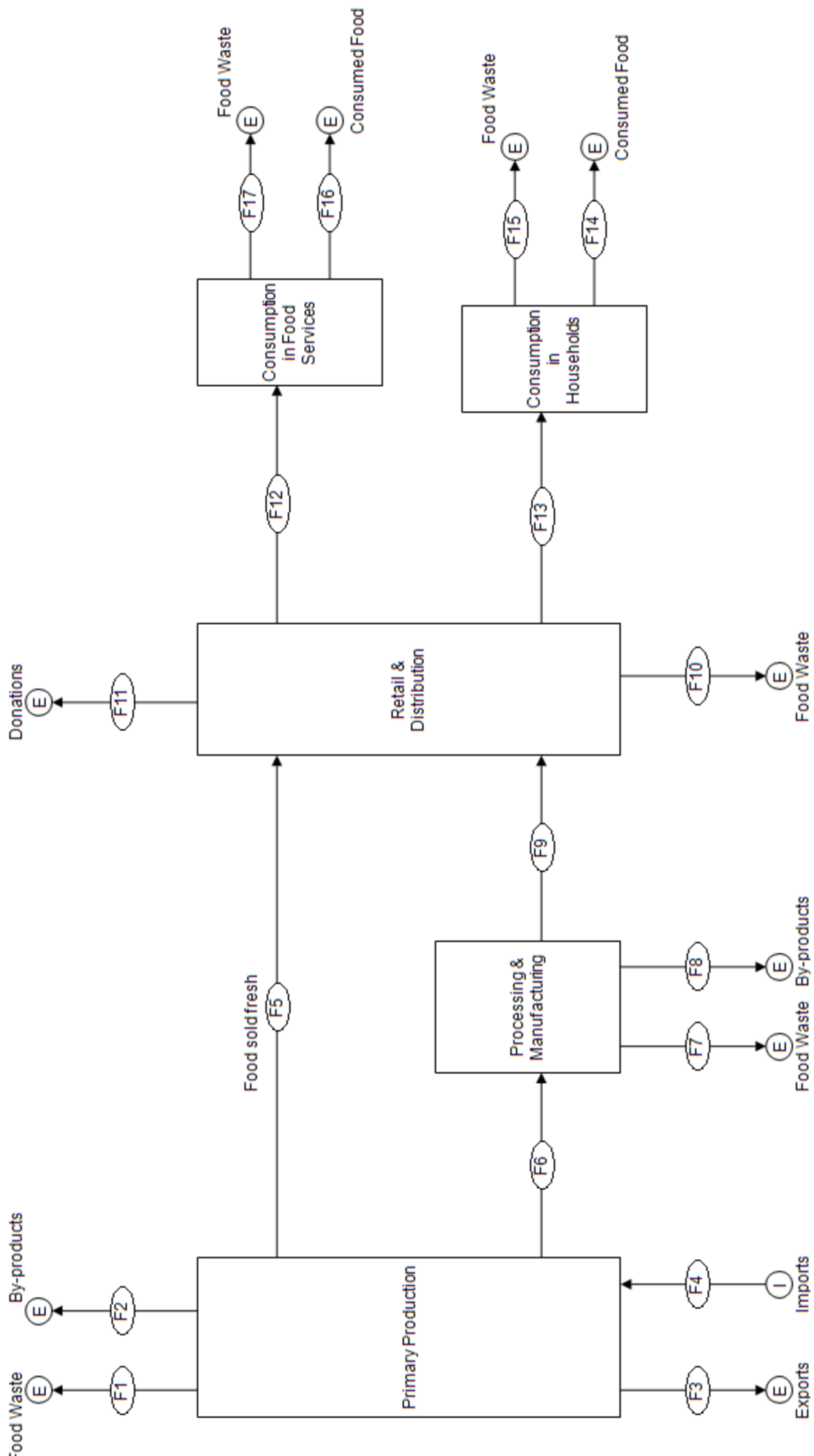

Figure 4: MFA model designed for the present study (own figure)

The system begins at the primary production stage. A portion of the food produced at this stage may also be exported, lost as FW, or diverted into by-products including animal feed or industrial products. Imported food complements domestic production. From here, food flows along two main pathways. It is either directed towards processing & manufacturing to produce processed food products or enters the retail & distribution stage directly as fresh food. At the retail & distribution stage the fresh and processed products merge again. In addition to FW and flows towards consumption, the retail & distribution stage also includes donations as a potential outcome. At the consumption level, food is divided between two key sectors: consumption in households and consumption in food services. In both cases, food is either consumed or discarded, contributing to the final stage of FW generation analyzed in this model. Each stage of the FSC is modeled based on the quantity of food transferred from the preceding stage. Throughout the whole model, product returns are not considered. Table X in the Annex presents all calculations conducted for the MFA. Tables A to W provide information on all required supporting calculations.

3.3 Data Origin and Processing

The following section outlines the data sources used to estimate FW within the Austrian FSC. The calculation of FW quantities is based on existing published data that was compiled and processed for this analysis. No fieldwork or primary data collection was conducted.

This MFA is based on three main data components. The first one are the Austrian Food Balance Sheets (FBS) for both plant- and animal-based products. This source is used to estimate production volumes for all food groups and the quantities of food entering the processing stage for fruits, potatoes, dairy, and eggs. Furthermore, they include the amount of dairy products leaving the processing stage. Although the FBS include data on losses during storage, transport, processing, packaging, and sorting, they do not distinguish between losses from products intended for human consumption and those not intended for it. Moreover, information on which parts of the data refer to the primary production stage and which to the processing & manufacturing stage is not disclosed. For these reasons, FBS loss data is not used in the FW analysis in this thesis.

To address this gap, the second key data source consists of figures obtained from existing literature. These sources provide the necessary coefficients for estimating FW across the FSC and are summarized in Table 3.

The third data component is required to calculate other flows and processes besides FW. They include by-products at the primary production and the processing & manufacturing stages and donations at the retail & distribution stage. The coefficients used can be found in Table 6, Table 7 and Table 8 respectively. The calculations to develop the coefficients are presented in the Annex. Furthermore, an additional literature review is conducted to assess the food volumes entering the processing stage for vegetables, and to assess the distribution between food consumed in households and in food services (see Table 9).

3.3.1 Food Balance Sheets

The FBS are published annually by Statistik Austria, the country's federal statistical office. They provide detailed data on the quantities of food produced, imported, exported, and available for consumption in Austria each year (Statistik Austria, 2024b; Statistik Austria, 2024c). For the purposes of this thesis, the most recent data for the year 2022/2023 is used. The reporting period for animal-based products covers January 1st to December 31st, 2022, while for plant-based products it spans July 1st, 2022 to June 30th, 2023 (Statistik Austria, 2023). Despite these differing timeframes, all FW calculations in this thesis are standardized to a 365-day (one-year) period. As production figures for this period show no significant deviation from historical trends, the data is regarded as representative.

The FBS for plant-based products includes data on 14 solid and liquid food items (Statistik Austria, 2024b). However, this thesis focuses only on three solid food groups: fruits, vegetables, and potatoes. Similarly, the FBS for animal-based products lists seven food groups, of which this thesis considers four: meat, raw milk, dairy products, and eggs. The category of meat includes beef, pig, poultry, sheep, goat, and horse meat. The category of dairy products encompasses milk for human consumption, cream, condensed milk, butter, and cheese (Statistik Austria, 2024c).

3.3.2 Literature Review on Food Waste Coefficients, By-product Coefficients, and Donation Coefficients

Food waste coefficients

To calculate FW at each stage of the FSC, data from scientific literature is used. The literature review conducted for this thesis focuses on identifying FW coefficients, expressed as percentages of total food input, for each food group at each stage of the FSC.

The literature review relies on databases such as SCOPUS, SAGE Journals, JSTOR, ResearchGate, and Google Scholar. Handbook chapters, peer-reviewed articles, and studies are used to gather data. The research is conducted in English and German. ADEME (2016) is the only study that is used in a different language, precisely French. The search terms in English and in German can be found in Table 1. Note that these search terms are used in combination with terms symbolizing FSC stages and food groups. Such terms are listed in Table 2 in English and German.

Table 1: Search terms in English and German used for identifying FW coefficients (own table)

English	“food waste” AND coefficient*, “food loss” AND coefficient*, "food waste" AND estimation, "food waste" AND quantification, "edible food waste" OR "inedible food waste", “avoidable food waste” OR “unavoidable food waste”
German	“Lebensmittelabfall*” AND Koeffizient*, “Lebensmittelverlust*” AND Koeffizient*, „Lebensmittelabfälle“ AND Quantifizierung, „vermeidbare Lebensmittelabfälle“ OR „unvermeidbare Lebensmittelabfälle“, "essbare Lebensmittelabfälle" OR "ungenießbare Lebensmittelabfälle"

Table 2: Search terms in English and German used for identifying FSC stages and food groups (own table)

FSC stage	English	German
Primary production	"primary production", post-harvest, "agricultural production", "farm stage"	Primärproduktion, Nachernte, "landwirtschaftliche Produktion", Erntestufe
Processing & manufacturing	"food processing", "food manufacturing", "food industry", "industrial processing"	Lebensmittelverarbeitung, Lebensmittelherstellung, Nahrungsmittelindustrie
Retail & distribution	retail, supermarkets, grocery stores, wholesalers, "food trade"	Einzelhandel, Supermärkte, Lebensmittelgeschäfte, Großhändler, Lebensmittelhandel
Household consumption	"household consumption", "domestic consumption", "consumer behaviour"	Haushaltskonsum, "privater Verbrauch", Verbraucherverhalten
Consumption in food services	"food services", restaurants, catering, "institutional food", out-of-home eating	Gastronomie, Kantinen, Catering, Außer-Haus-Verpflegung, Gemeinschaftsverpflegung
Food group		
Fruits	fruit, fruits, "fresh fruit", "fruit sector"	Obst, "frisches Obst", Obstsorten, Obstanbau, Frucht, Früchte
Vegetables	vegetable, vegetables, "fresh vegetables"	Gemüse, "frisches Gemüse"
Potatoes	potato, potatoes, "root vegetables", tubers	Kartoffeln, Erdapfel, Erdäpfel, Knollengemüse
Meat	meat, "meat processing"	Fleisch, Fleischverarbeitung
Dairy	dairy, "dairy products", "milk processing", cheese, yogurt	Milch, Milchprodukte, Milchverarbeitung, Käse, Joghurt
Eggs	egg, eggs, "egg production"	Ei, Eier, Eierproduktion

Priority is given to national and international studies that explicitly report FW coefficients for Austria or other EU Member States. There are four exceptions: WRAP (2023) and DEFRA (2010), which are based on data from the United Kingdom, and Beretta et al. (2013) and Willersinn et al. (2015), which cover Switzerland. Alternatively, broader European studies are used: for example, FAO (2011), which provides data for Europe, and European Commission and Joint Research Centre (2024), which provides data for the EU. Preference is given to recent publications (ideally within the past 15 years) to ensure the data reflects current food systems, technologies, and consumption patterns.

All studies considered must clearly describe how the FW coefficients are calculated. Priority is given to peer-reviewed articles and official reports, although government and NGO reports may also be used if their methodology is well-documented. If a study uses coefficients developed by another source, the original source is cited and applied instead.

Studies that follow the EU's definition of FW are preferred. However, in cases where no such sources are available, alternative studies are considered, provided they meet the necessary methodological standards. Additionally, the selected literature must express FW as a coefficient, represented as a percentage of food input.

Based on these criteria, ten studies are selected to provide the FW coefficients required for the MFA (Table 3). Table 4 outlines key details for each source, including the geographical scope, methodology, types of food considered, and the reference year.

Table 3: Selected literature for FW coefficients (own table)

	Primary production	**Processing & manufacturing**	**Retail & distribution**		**Household consumption**	**Consumption in food services**
			fresh	processed		
Fruits	ADEME (2016)	FAO (2011)	Lebersorger and Schneider (2014a)		Eberle et al. (2015)	Beretta et al. (2013)
Vegetables	ADEME (2016)	FAO (2011)	Lebersorger and Schneider (2014a)		Eberle et al. (2015)	Beretta et al. (2013)
Potatoes	O'Connor et al. (2022)	Willersinn et al. (2015)	Willersinn et al. (2015)	Lebersorger and Schneider (2014a)	DEFRA (2010)	Beretta et al. (2013)
Meat	/	FAO (2011)	Lebersorger and Schneider (2014a)		WRAP (2023)	Beretta et al. (2013)
Dairy	ADEME (2016)	ADEME (2016)	Lebersorger and Schneider (2014a)		Eberle et al. (2015)	Beretta et al. (2013)
Eggs	ADEME (2016)	European Commission and Joint Research Centre (2024)	Beretta et al. (2013)	Lebersorger and Schneider (2014a)	DEFRA (2010)	Beretta et al. (2013)

Table 4: Detailed description of the selected literature (own table)

	Source	Country/ Region	Core method	Foods considered	Reference year
1.	ADEME (2016)	France	Waste Composition Analysis, Interviews	Fruits (Apples, Pears, Peaches, Plums, Apricots, Cherries, Bananas, Strawberries), Vegetables (Tomatoes, Salad, Carrots, Cauliflower, Endive, Onions)	2014-2015
2.	Beretta et al. (2013)	Switzerland	Coefficients and Production Statistics	Fruits (Apples, Other fresh fruits, Berries), Vegetables (fresh and storable), Meat (Pork, Poultry, Beef), Dairy (Milk, Cheese, Butter), Eggs	2008
3.	DEFRA (2010)	United Kingdom	Production Statistics	Potatoes, Eggs	2008
4.	Eberle et al. (2015)	Germany	Mass Balance	Fruits, Vegetables	2010
5.	European Commission and Joint Research Centre (2024)	European Union	Coefficients and Production Statistics	Eggs	2021-2022
6.	FAO (2011)	Europe	Coefficients and Production Statistics	Fruits, Vegetables	2007
7.	Lebersorger and Schneider (2014a)	Austria	Production Statistics	Fruits, Vegetables, Meat, Dairy	2013
8.	O'Connor et al. (2022)	Ireland	Interviews, Coefficients and Production Statistics	Potatoes	2018-2019
9.	Willersinn et al. (2015)	Switzerland	Interviews, Diaries	Potatoes	2011-2013
10	WRAP (2023)	United Kingdom	Waste Composition Analysis, Diaries	Meat	2021-2022

Of the ten selected studies, eight offer a national-level perspective on FW coefficients, while two provide data covering Europe or the EU.

A comparison between the methodologies used in these studies and those outlined in chapter 2.1.3 reveals that six studies mainly rely on coefficients and/or production statistics, two utilize waste composition analysis, two employ diary methods, and one applies a mass balance approach. Several studies incorporate more than one method. Table 5 summarizes the FW coefficients extracted from the literature and applied in this thesis.

Table 5: FW coefficients used for the present MFA calculations for the selected product group and different FSC stages (in %) (based on sources in Table 3)

	Primary production	**Processing & manufacturing**	**Retail & distribution**		**Household consumption**	**Consumption in food services**
			fresh	processed		
Fruits	8.08	5	4.62	0.72	25	9.41
Vegetables	12.83	5	4.62	0.72	28.40	10.88
Potatoes	12.18	14	1.75	0.72	24	10.20
Meat	/	5	/	2.57	16	10
Dairy	0.3	2.5	/	1.34	9.50	2
Eggs	2	30	1.3	0.72	10	12

To align the FW coefficients as closely as possible with the EU definition, harvest losses and side flows are deducted at the primary production stage. To exclude FL, FW coefficients for meat are only applied starting from the processing & manufacturing stage. Reductions occurring at the primary production stage, prior to slaughter (see 3.2.1), are classified as losses rather than waste (see chapter 2.1.1). As ADEME (2016) discusses various types of milk, it is important to clarify that this thesis considers only cow's milk. Production from other milk types is negligible and therefore excluded from the analysis. FAO (2011) as well as Lebersorger and Schneider (2014a) provide one coefficient combining fruits and vegetables. It is assumed that 50% of the waste is allocated to fruits and 50% to vegetables, which is why the same coefficient is applied for both food groups in the calculations. This is the case at the processing & manufacturing stage as well as the retail & distribution stage.

Furthermore, at the processing & manufacturing stage as well as at the retail & distribution stage the coefficient for potatoes represents the average between organic and non-organic potatoes, as this is the division used in Willersinn et al. (2015). At the retail & distribution stage, most food groups are assigned distinct coefficients for fresh and processed products. The coefficient for processed foods is based on values from Lebersorger and Schneider (2014a), specifically those related to convenience products. This is not the case for meat and dairy, where 100% of the produced food is processed for human consumption. This is due to the fact that these products need to undergo slaughtering (for meat) or pasteurization (for dairy) in order to be regarded consumable. This kind of food treatment is part of the processing & manufacturing stage (European Commission and Joint Research Centre, 2024). When it comes to meat consumption in households, it is important to note, that although WRAP (2023) aggregates data for meat and fish, this thesis treats fish-related FW as negligible within its scope. Detailed coefficient calculations for each food group and stage of the FSC can be found in the Annex.

It is important to note that broad food groups are treated uniformly. As a result, even though certain sub-groups (e.g. tomatoes) may have different waste rates, the coefficient applied corresponds to the broader category (e.g. vegetables). In cases where available studies provide data only at the sub-group level, an average coefficient is calculated and applied to the broader group. This is the case for fruits and vegetables at the primary production stage, potatoes (organic and non-organic) at the processing & manufacturing stage, potatoes (organic and non-organic) and meat at the retail & distribution stage, and fruits, vegetables, meat, and dairy at the food services stage. Moreover, at the food services stage, the FW estimate represents the average of both avoidable and unavoidable fractions.

Additional literature review

To complete the MFA, additional data is required. Therefore, further literature is reviewed to determine the side flows (by-products, donations), the amount of vegetables sold fresh versus allocated for processing, as well as the distribution of food consumption between households and food service establishments. The results are presented in Table 6 for by-products at the primary production stage, Table 7 for by-products at the processing & manufacturing stage, in Table 8 for donations, and in Table 9 for the distribution between food sold in households and in food services. The relevant calculations can be found in the Annex.

Table 6: By-product coefficients at the primary production stage (in %) (own table)

	Primary production	Source
Fruits	5.32	ADEME (2016)
Vegetables	3.51	ADEME (2016)
Potatoes	/	Food Balance Sheet
Meat	0	ADEME (2016)
Dairy	/	Mass balance
Eggs	0	ADEME (2016)

Table 7: By-product coefficients at the processing & manufacturing stage (in %) (own table)

	Processing & manufacturing	Source
Fruits	0.18	ADEME (2016)
Vegetables	0.86	ADEME (2016)
Potatoes	0.86	Assumed equal to vegetables due to data limitations
Meat	0	ADEME (2016)
Dairy	/	Mass balance
Eggs	8.1	ADEME (2016)

Table 8: Proportion of food donated at the retail & distribution stage (in %) (own table)

	Donation		Source
	fresh	processed	
Fruits	0.12	0.19	Lebersorger and Schneider (2014a)
Vegetables	0.12	0.19	Lebersorger and Schneider (2014a)
Potatoes	0.12	0.19	Assumed equal to vegetables due to data limitations
Meat	/	0.06	Lebersorger and Schneider (2014a)
Dairy	/	0.23	Lebersorger and Schneider (2014a)
Eggs	0.23	0.19	Assumed equal to dairy and processed plant-based products due to data limitations

In the absence of specific data, it is assumed that potatoes are donated at the same rate as vegetables given that both products are plant-based and are produced in relatively similar amounts (747 kilotonnes of vegetables and 686 kilotonnes a year, see Table X in the Annex). Because of data scarcity, fresh eggs are assumed to be donated at the same rate as the animal-product dairy, and it is assumed that processed eggs are donated at the same rate as processed plant-based products.

To estimate the amount of food processed, the data from the FBS were used for fruits, potatoes, dairy, and eggs, assuming no dairy and meat can be sold fresh as it requires processing for human consumption. In the case of vegetables, the FBS do not share data on the amount of food entering the processing & manufacturing stage, which is why a coefficient from European Commission and Joint Research Centre (2024) is applied. According to this source, 63% of vegetables leaving the primary production stage are processed, while 37% are consumed fresh.

This thesis recognizes that various sources report differing figures regarding the distribution of food consumption between households and food services. For example, the Swedish study conducted by Engström and Carlsson-Kanyama (2004) suggests an 80/20 split. According to Beretta et al. (2013), 85% of food reaching the consumption stage is consumed in households, while 15% is consumed in food service settings. This paper relies on data provided by Agrarmarkt Austria Marketing GesmbH (AMA-Marketing), which is Austria's official agriculture marketing organization. Its comprehensive household panel study, called RollAM, provides information on household consumption patterns. The study was published in the year 2020. The results in regard to the separation of food consumption for households and food services can be found in Table 9. Due to lack of data, it is assumed that the coefficient for vegetables and fruits can be applied for potatoes. The required calculations for the meat coefficient can be found in Table W in the Annex.

Table 9: Distribution of food consumption between households and food services (in %) (own table)

	Consumption in households	Consumption in food services	Source
Fruits	66	34	AMA-Marketing GesmbH (2020)
Vegetables	66	34	AMA-Marketing GesmbH (2020)
Potatoes	66	34	Assumed equal to vegetables due to data limitations
Meat	72	29	AMA-Marketing GesmbH (2020)
Dairy	74	26	AMA-Marketing GesmbH (2020)
Eggs	62	38	AMA-Marketing GesmbH (2020)

3.4 Assumptions and Limitations

While the present master's thesis aims to provide a comprehensive estimate of FW along Austria's FSC for the selected food groups, several assumptions and limitations need to be acknowledged since they affect the calculations as well as the interpretability of the study.

Limitations

A fundamental limitation lies in the reliance on secondary data and literature-based coefficients. Many of the FW figures used in this analysis are drawn from existing academic sources, which differ in methodology, temporal relevance, and geographic scope. Austria-specific data required for the scope of this master's thesis is scarce, which is why proxy values from other European countries or studies referring to Europe are applied. While these are selected based on how well they fit the context and based on methodological compatibility, such substitutions raise uncertainty and limit the degree of national specificity. Uncertainty also arises from the lack of consistent temporal boundaries. Not all data sources refer to the same reference year, and some figures have to be drawn from older studies due to limited availability. This makes comparisons difficult.

In terms of methodological coverage, the thesis relies heavily on mass balances and published coefficients, and only includes some primary data collection such as waste composition analysis, diaries, or interviews.

Furthermore, the study only covers selected food groups including fruits, vegetables, potatoes, meat, dairy, and eggs. The scope has been deliberately narrowed due to limited data availability and to ensure the research remains feasible within the scope of this master's thesis.

Assumptions

The study assumes that the entire system can be described using the principle of mass conservation. In theory, this ensures that the sum of inputs equals the sum of outputs and changes in storage. However, in practice, certain flows are difficult or impossible to capture. Informal and unrecorded flows, such as food discarded via household drains, sewer systems, or composted at home, are typically excluded from national statistics. Furthermore, this study does not consider product returns. Imports and exports are only considered at the primary production stage, and at the processing & manufacturing stage for dairy. Additionally, by-products are only considered at two stages and donations only at one FSC stage due to the lack of comprehensive and consistent data available across all stages of the FSC and all food groups. Similarly, water loss through evaporation during cooking or processing is often unreported but may affect accuracy, especially for certain food groups such as vegetables.

It is assumed that FW coefficients remain constant over time and are not affected by seasonal, regional, or socio-economic variability. This simplification is necessary due to a lack of temporally and spatially even data across all stages of the FSC.

Another key assumption is the uniformity of waste rates across broad food groups. For practical reasons, food groups such as vegetables or dairy are treated as homogeneous units, even though sub-groups (e.g., tomatoes vs. carrots, or butter vs. cream) may exhibit very different waste patterns. In certain cases, for example in the instance of the FSC stage primary production, the average coefficient is calculated using data of different sub-groups. This aggregation introduces a potential bias, as it can obscure significant internal variability within food groups.

When studies aggregate waste figures for combined food groups such as fruits and vegetables, the same coefficient is applied for each food group. This simplification is applied unless more specific guidance is available. In cases where data is reported for fruits and nuts as a combined group, it is assumed that the volume of nuts is negligible. Therefore, the full value is attributed to fruits. When data on a food group is not available, the coefficient of a similar food group is applied instead. For instance, this is the case for potatoes and eggs in Table 8.

Finally, the thesis does not distinguish between edible and inedible FW in the final calculations. This decision is made due to the lack of disaggregated data across most FSC stages. In cases where a source does not explicitly state whether the data refers to avoidable, unavoidable, or total waste, it is assumed to represent total FW. As a result, total waste figures may overestimate the portion of FW that is preventable, particularly in categories with high volumes of inedible material.

4. Results

This chapter presents the results of the analysis on FW in Austria, both across the entire FSC and disaggregated by food groups considered in this master's thesis. It begins by illustrating the overall flow of food and total FW along the FSC in kilotonnes. The results are also expressed on a kilograms per capita and year basis. This is followed by a breakdown of results by individual food groups. For each case, a Sankey diagram generated using the STAN software is applied to visually represent the data that can be found in Table X in the Annex. To provide deeper insights into variations across FSC stages and food groups, additional graphs are included. These visualizations highlight and explain key FW hotspots. All findings are reported in kilotonnes (kt) of fresh mass. In the interest of readability, the results presented in the figures and described in the text have been rounded to whole numbers. Percentage totals may not add up to exactly 100% due to rounding. The precise values can be found in the Annex.

4.1 Total Food Waste in Austria along the Food Supply Chain

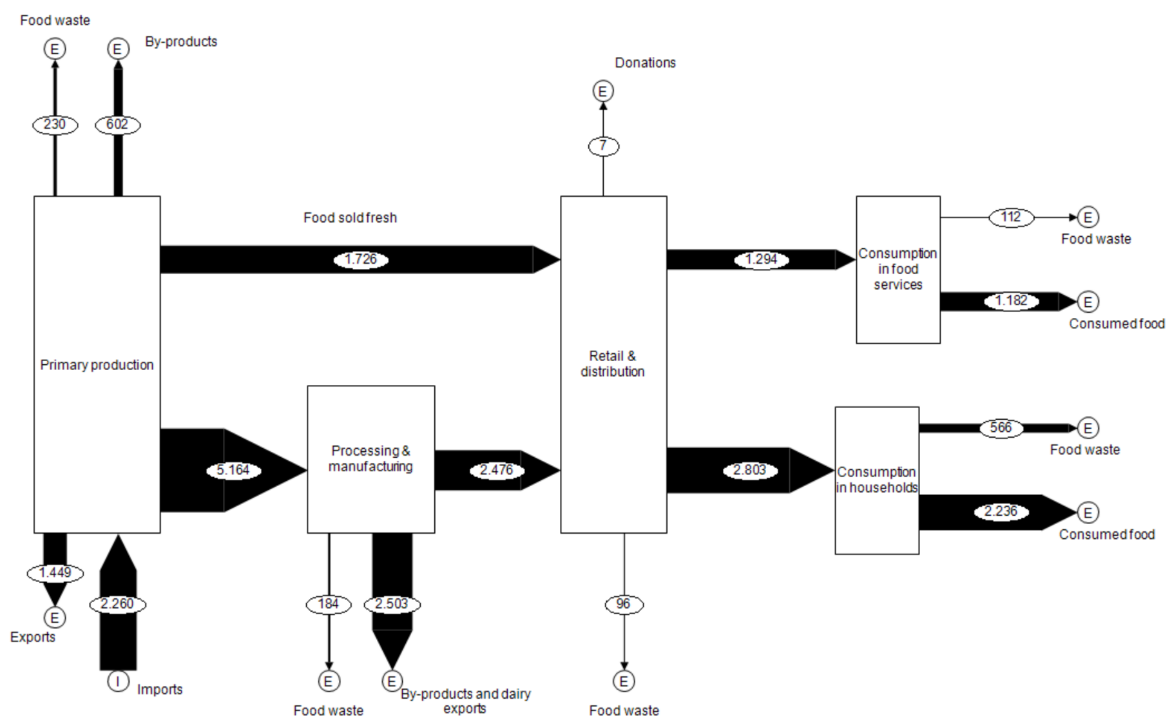

Figure 5: Sankey diagram of total food flows (fruits, vegetables, potatoes, meat, dairy, eggs) including FW in Austria (own figure)

Figure 5 presents the total food flows for fruits, vegetables, potatoes, meat, dairy, and eggs in Austria, tracing how food moves through the supply chain. The thickness of the arrows in this Sankey diagram visually represents the magnitude of the food flows and offers a clear depiction of how food is distributed and wasted along the chain. The pie chart visualized in Figure 6 shows the distribution of FW across different stages of the FSC.

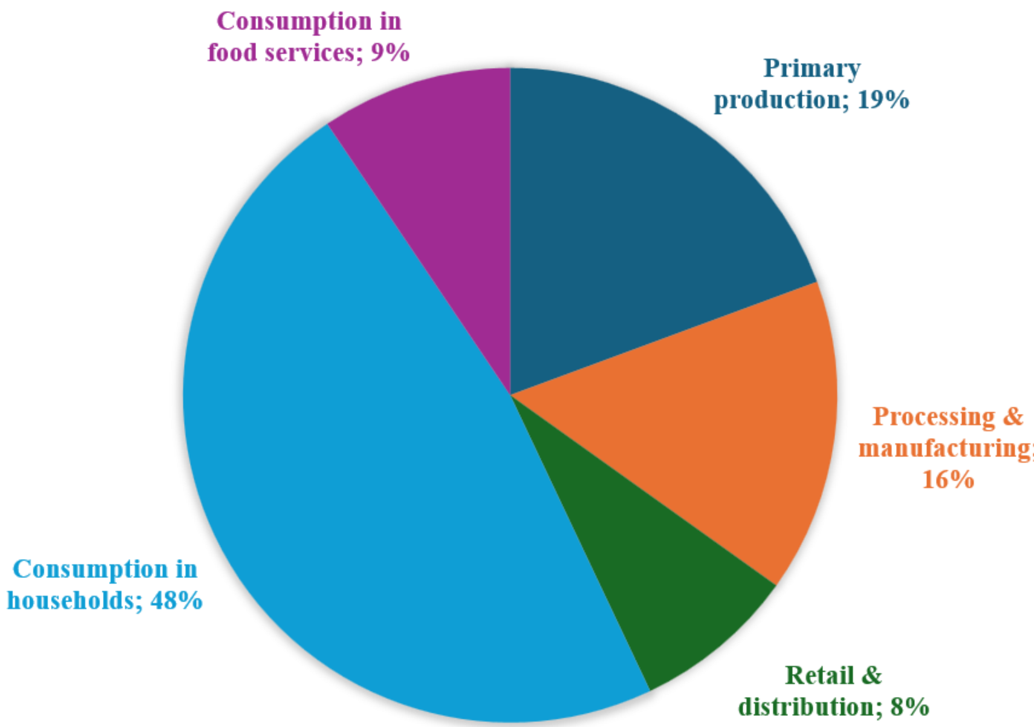

Figure 6: FW per FSC stage relative to total FW (own figure)

By applying the MFA approach, it becomes evident that a total of 1,190 kt of food, specifically fruits, vegetables, potatoes, meat, dairy, and eggs, is wasted annually in Austria. Starting at the primary production stage, a significant portion of food is already lost. While 230 kt of FW at this stage account for just 3% of the overall food production (calculated based on data from Table X), Figure 6 reveals that this volume represents a notable 19% of the total FW across the FSC. Alongside this waste, the primary production stage also yields 602 kt of by-products. These by-products are not counted as waste because they are diverted for other purposes, for example in the form of animal feed.

From the primary production stage, food is directed either straight to retail & distribution or to the processing & manufacturing stage. At the processing & manufacturing stage, raw food products are transformed into alternative consumables, such as juices or snack items. During this transformation process, 184 kt of food are wasted (see Figure 5). This represents approximately 4% of the total input into this stage (calculated based on data from Table X). Despite the relatively low percentage, this stage still contributes 16% of the overall FW, making it the third largest source of FW in Austria (Figure 6). At this stage, a total of 2,503 kt of FW are classified as by-products (Figure 5). It is important to highlight that 765 kt of this amount consists of dairy exports (Table X). These exports have been included in the by-product category to maintain methodological consistency across the analysis. However, for greater transparency, they are presented separately in Table X and in Figure 16.

At the retail & distribution stage, both fresh and processed food groups meet again. Here, a total of 96 kt of food is wasted (see Figure 5), which corresponds to 2% of the food input at this point in the supply chain (calculated based on data from Table X). Of this, 34 kt originate from processed products, while 63 kt come from fresh food groups (Table X). This stage accounts for 8% of the total FW across the FSC, making it the smallest contributor (Figure 6). Importantly, not all surplus food at this stage is discarded. As illustrated in Figure 5, 7 kt of surplus food (both fresh and processed) are donated rather than wasted, reflecting efforts to reduce losses through redistribution. This form of redistribution makes up around 6% of all food that does not enter the next stage in the supply chain directly (calculated based on data from Table X). With 4 kt processed products are donated more frequently than fresh products (2 kt) (Table X).

The food purchased at the retail level reaches end consumers through two main channels: households and food services. The food services sector is the second smallest contributor to overall FW. In absolute terms, this sector is responsible for 112 kt of FW (Figure 5), equating to 9% of the total FW in Austria (Figure 6).

By contrast, households represent the largest source of FW. Austrian households waste 566 kt of food as presented in Figure 5. This figure accounts for 20% of all food entering this stage of the FSC (calculated based on data from Table X) and constitutes a striking 48% of the total FW generated nationwide (Figure 6).

Finally, the MFA results reveal that upstream stages of the FSC (primary production and processing & manufacturing) account for 35% of total FW in Austria. In contrast, the downstream stages, comprising retail & distribution, household consumption, and food services, are responsible for the remaining 65%. This distribution is calculated using data reported in the Annex.

4.1.1 Total Food Waste per capita

On a per capita basis, each Austrian generates an average of 130 kilograms (kg) of FW (calculated using data from Table Y). This calculation is based on a population of 9,158,750 as of January 1, 2024 (Statistik Austria, 2025).

Figure 7 demonstrates the amount of FW generated per person and year (in kilograms) at each stage of the FSC. The majority of this waste occurs at the household level, where Austrians discard an average of 62 kg/cap.yr. The second-largest contributor is the primary production stage, accounting for 25 kg/cap.yr. This is followed by the processing & manufacturing stage, which contributes 20 kg/cap.yr. The retail & distribution stage and food services stages report similar values, with 11 kg/cap.yr and 12 kg/cap.yr of FW per person, respectively.

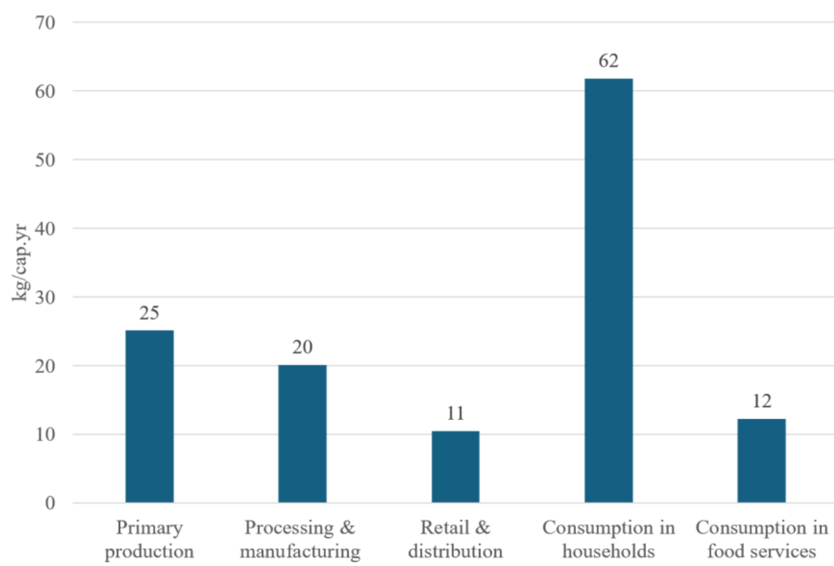

Figure 7: Per capita FW across the supply chain stages in Austria (in kg/cap.yr) (own figure)

When examining FW by food groups, as demonstrated in Figure 8, vegetables account for the highest per capita waste at 44 kg/cap.yr, followed by fruits at 28 kg/cap.yr. Potatoes and dairy show comparable figures, with 21 kg/cap.yr and 20 kg/cap.yr discarded per person and year, respectively. Meat is responsible for 14 kg/cap.yr of FW. Eggs account for the least FW, with just 3 kg/cap.yr of FW per capita in Austria.

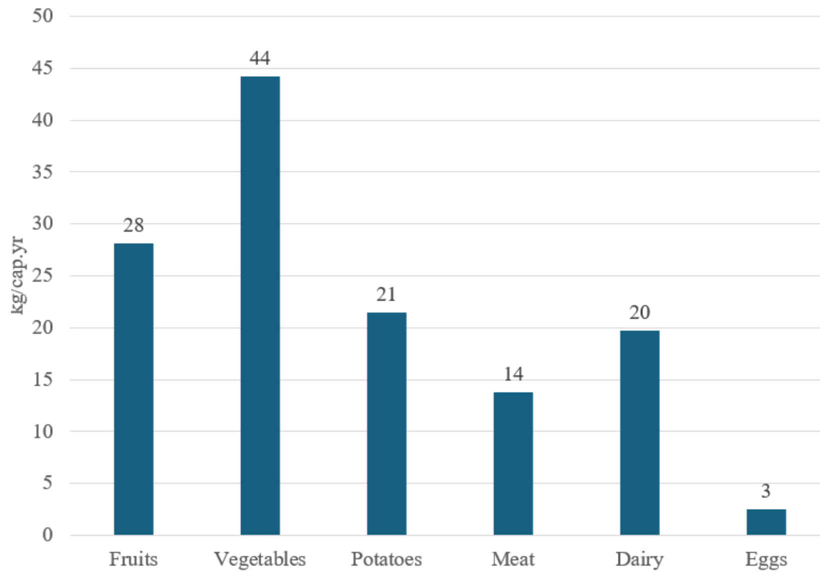

Figure 8: Per capita FW in Austria, disaggregated by food groups (in kg/cap.yr) (own figure)

4.2 Food Waste disaggregated by Food groups

Figure 9 shows the proportional distribution of FW by food groups in Austria, based on the categories analyzed in this master's thesis.

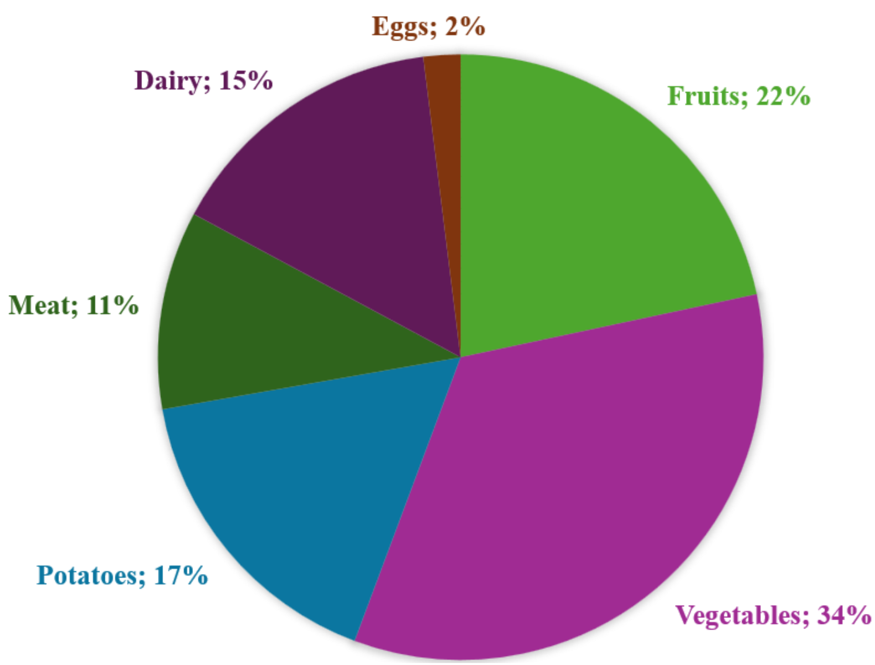

Figure 9: FW disaggregated by food groups in relation to total FW (own figure)

The biggest contributor of FW are vegetables, with 34% (405 kt). Fruits follow with 22% (258 kt), making them the second most wasted food group. Potatoes and dairy show similar results with 17% (197 kt) and 15% (181 kt) respectively. While meat is responsible for 11%

(126 kt) of FW, the smallest contributor are eggs, with only around 2% (23 kt) of all FW attributed to this food group. The absolute numbers were taken from Table Y in the Annex.

Looking at the Figure 9, it becomes evident that plant-based food groups contribute to overall FW more than animal-based products. Fruits, vegetables, and potatoes make up around 73% of overall FW, while meat, dairy, and eggs are responsible for 27%. Notably, in each food category where such a differentiation is made, the share of processed FW is smaller than the share of fresh food wasted (Table X).

The following part of the chapter breaks down the results for each food group. For each product, first, a Sankey diagram is provided. To highlight the relative contribution of each supply chain stage to total FW within individual food groups, Figure 10 provides a comprehensive overview. Complementarily, Figure 11 illustrates how FW is distributed across the FSC stages for all analyzed food groups, offering insight into their respective waste patterns.

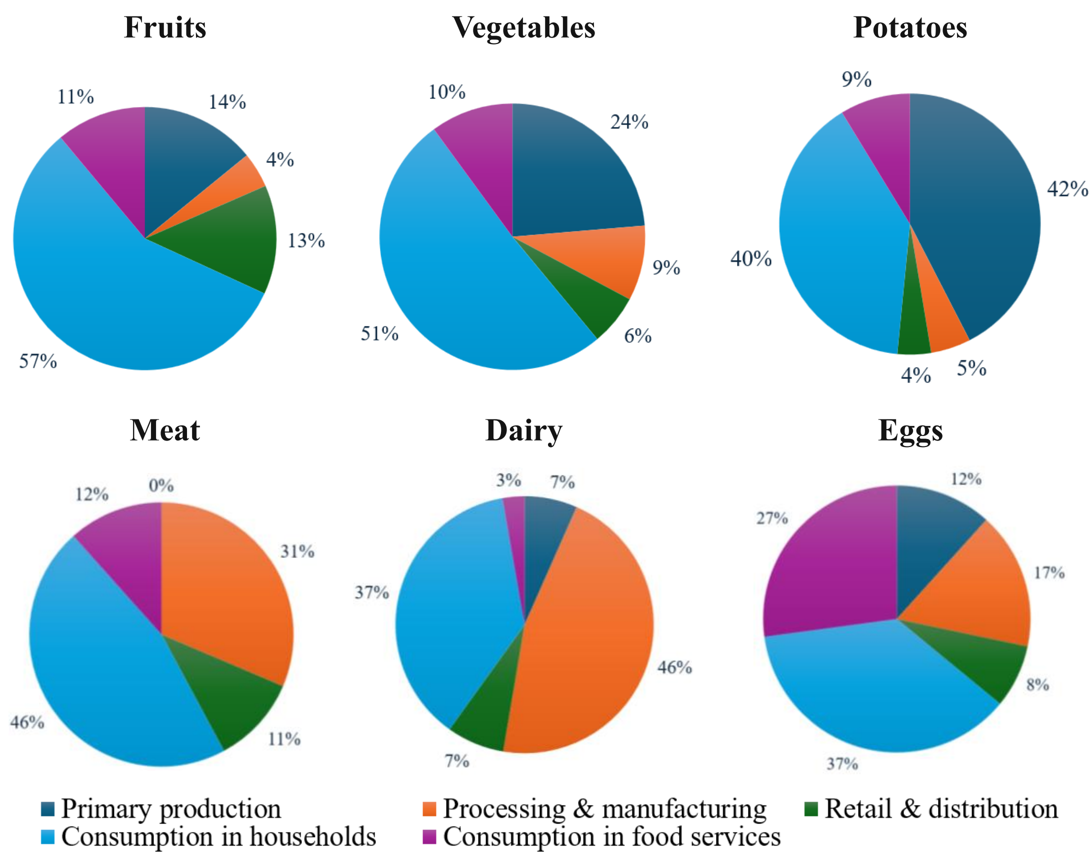

Figure 10: Share of food group waste along the FSC stages (own figure)

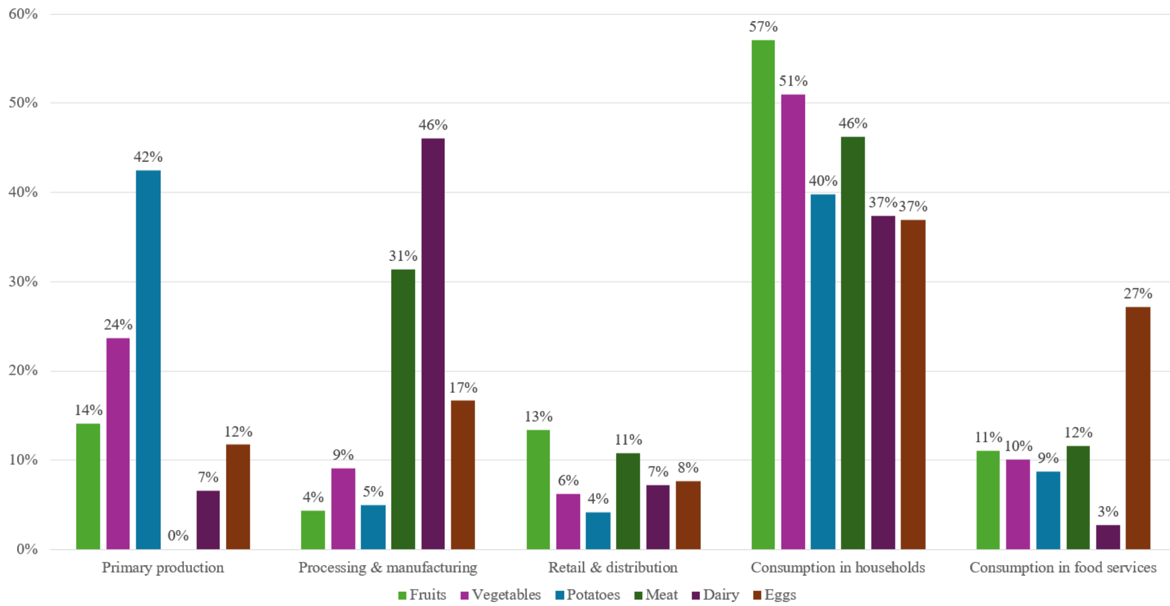

Figure 11: Share of food group waste per FSC stage (own figure)

It is evident that household consumption is the largest source of FW for most food groups. However, the data also reveal that each food group follows a distinct waste pattern across the supply chain which will be presented in the following part of the thesis.

4.2.1 Food Waste distribution across the Fruit Supply Chain

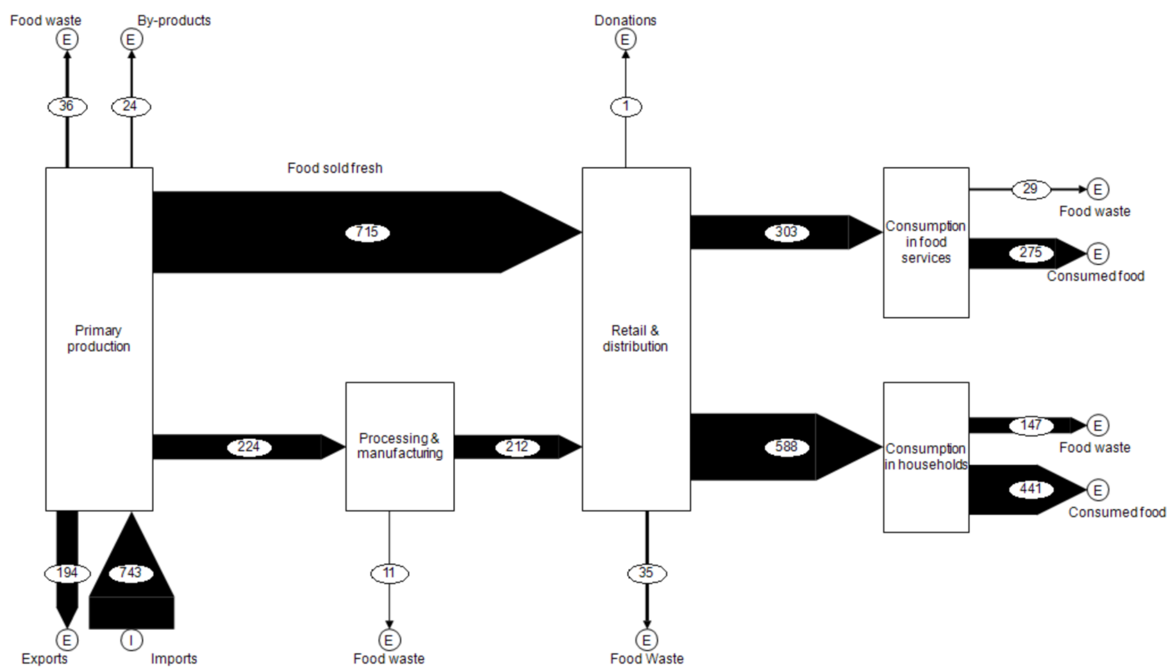

Figure 12: Sankey diagram of fruit-related food flows including FW (in kt/year) (own figure)

Using the MFA approach, it becomes evident that a total of 258 kt of fruit are wasted in Austria annually (Table Y). As shown in Figure 12, the largest share of this waste, 147 kt/year, occurs at the household level. This represents 57% of total fruit waste (Figure 10), which is notably 9% higher than the average share of FW typically attributed to households across all food groups. In contrast, food services, as outlined in Figure 10, account for 11% (29 kt/year as demonstrated in Figure 12) of fruit waste, aligning closely with the average for total FW at this FSC stage.

The primary production and retail & distribution stages contribute 36 kt/year (14%) and 35 kt/year (13%) of fruit waste, respectively, as depicted in Figure 10 and Figure 12. The processing & manufacturing stage accounts for the smallest portion of fruit waste, contributing only 4% (11 kt/year). This stands in contrast to the general FW distribution shown in Figure 6, where this stage is responsible for 16% (184 kt/year) of total FW.

4.2.2 Food Waste distribution across the Vegetable Supply Chain

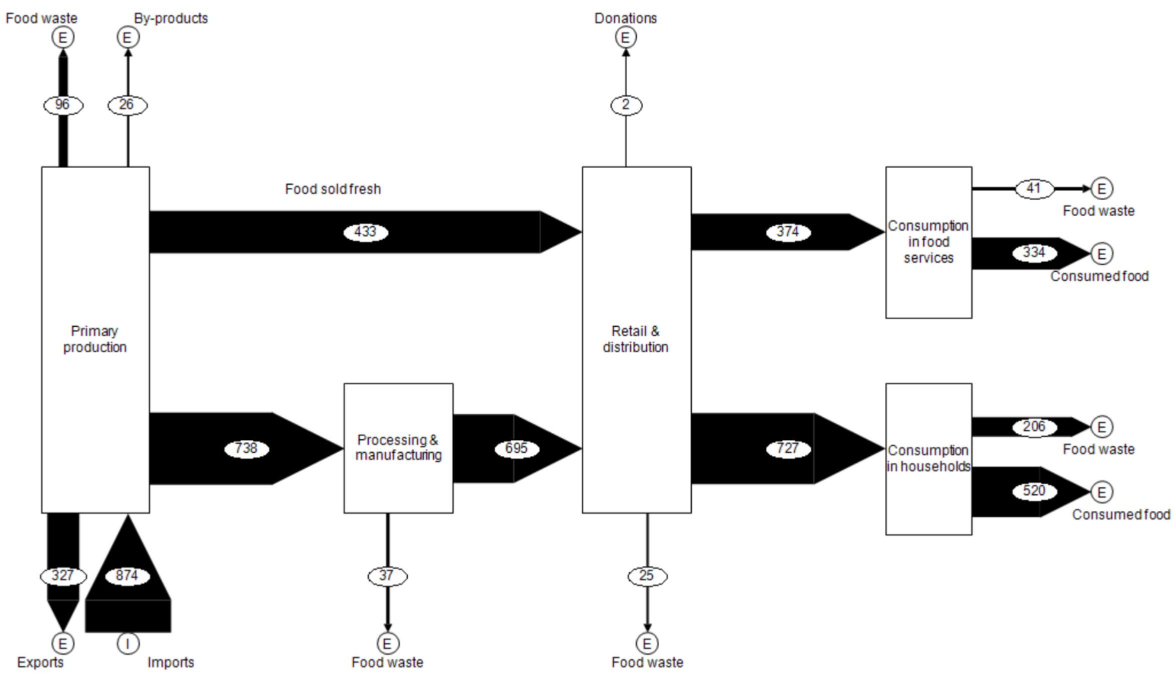

Figure 13: Sankey diagram of vegetable-related food flows including FW (in kt/year) (own figure)

A total of 405 kt of FW is generated from vegetables in Austria yearly (Table Y), while the distribution of this waste along the FSC closely mirrors the general pattern observed for overall FW.

According to Figure 13 households account for the largest share, generating 206 kt/year of vegetable waste, which is approximately 51% of the total, as presented in Figure 10. Just like in the case of fruits, this is more than the share households contribute to total FW, here the same FSC is responsible for 48% of total FW (Table 6). The primary production stage contributes 96 kt as indicated in Figure 13, nearly one-quarter of the total vegetable waste (see Figure 10), which is 10 percentage points higher than the corresponding share for fruit waste (see Figure 10).

The processing & manufacturing and food services stages contribute similarly, accounting for 9% (37 kt/year) and 10% (41 kt/year) of the total vegetable waste, respectively. Meanwhile, as depicted in Figure 13, retail & distribution generates 25 kt/year, making up just 6% of the total (see Figure 10). This is the smallest share across all stages. Notably, with 2 kt, vegetables contribute the largest amount of food redirected through donation for all assessed food groups of this thesis.

4.2.3 Food Waste distribution across the Potato Supply Chain

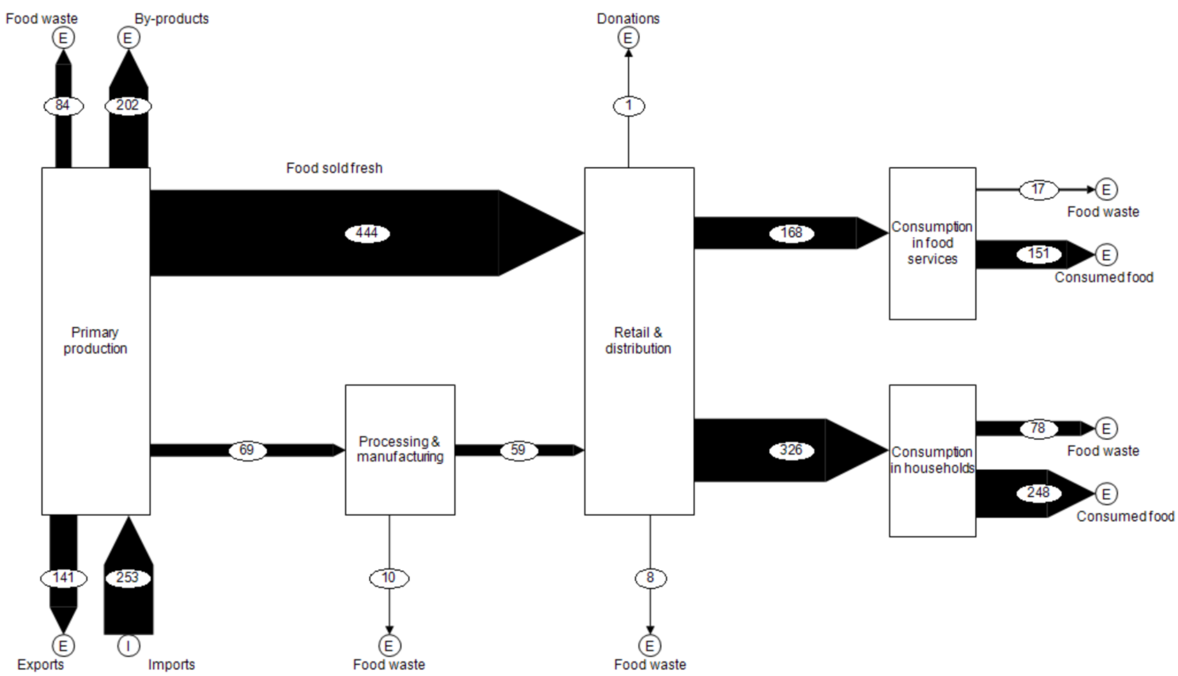

Figure 14: Sankey diagram of potato-related food flows including FW (in kt/year) (own figure)

A total of 197 kt of potato waste is generated in Austria on a yearly basis (see Table Y). The distribution of this waste across the FSC differs significantly from that of other food groups. Unlike all other food groups analyzed, potatoes represent a clear exception where the primary production stage, rather than households, is the primary source of FW. Specifically, as shown in Figure 14, 84 kt/year of waste originate from this stage, accounting for 42% of the total (see Figure 10).

Households represent the second-largest source of potato waste within the FSC, though by just 2%. At this stage, 78 kt of potatoes, as outlined in Figure 14, are discarded, corresponding to 40% of the total waste (see Figure 10). The food services sector contributes a share of 9% (17 kt/year), which aligns closely with the distribution seen for both fruits and vegetables, and the distribution of total FW (see Figure 6 and Figure 10).

In contrast, the processing & manufacturing and retail & distribution stages contribute much smaller portions to the total potato waste, accounting for just 5% (10 kt/year) and 4% (8 kt/year), respectively.

It is worth noting that in the case of fruits and potatoes, where data on processed food was taken from the FBS, a significantly larger share of food is sold fresh compared to vegetables, for which the proportion of processed food was estimated using coefficients. While 76% (715 kt/year) of fruits and 87% (444 kt/year) of potatoes are sold fresh, the share of vegetables sold fresh lies only at 37% (433 kt/year). The calculations are made using data from Table X in the Annex.

4.2.4 Food Waste distribution across the Meat Supply Chain

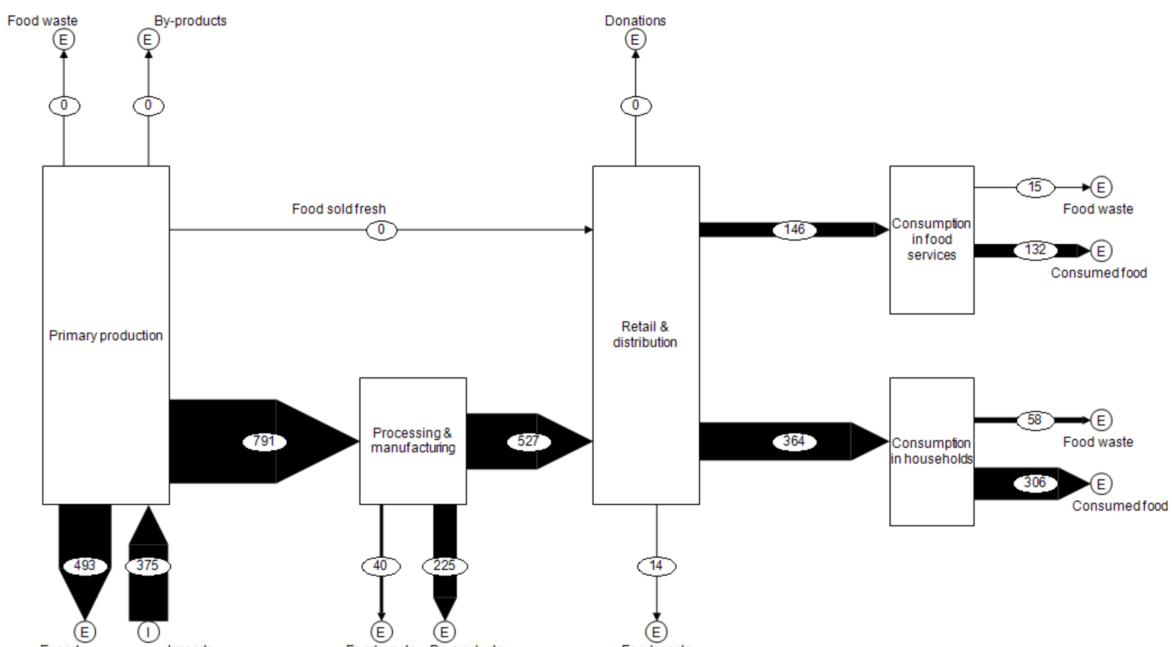

Figure 15: Sankey diagram of meat-related food flows including FW (in kt/year) (own figure)

The MFA approach reveals that Austria wastes a total of 126 kt of meat annually (as indicated in Table Y). While households remain the primary source of FW for this food group, as is typical for most other food groups, they account for less than half of the total FW, generating 46% (58 kt/year) of the overall meat waste, and closely mirroring the results of the share for total FW (see Figure 6 and Figure 10).

The second-largest contributor is the processing & manufacturing stage, responsible for 40 kt/year according to Figure 15 or 31% of the total meat waste (see Figure 10). Notably, meat is the only food group where this stage produces the second-highest amount of FW. This can likely be attributed to the fact that, unlike other food groups except dairy, 100% of the meat that exits the primary production stage undergoes processing in the slaughterhouse. A more detailed explanation can be found in chapter 3.3.2.

Retail & distribution and food services show comparable contributions to meat waste, accounting for 11% (14 kt/year) and 12% (15 kt/year), respectively (see Figure 10 and Figure 15). Since, according to the EU's definition (see chapter 3.3.2), the primary production stage generates FL rather than FW, 0% of the FW is attributed to this stage (Figure 10).

4.2.5 Food Waste distribution across the Dairy Supply Chain

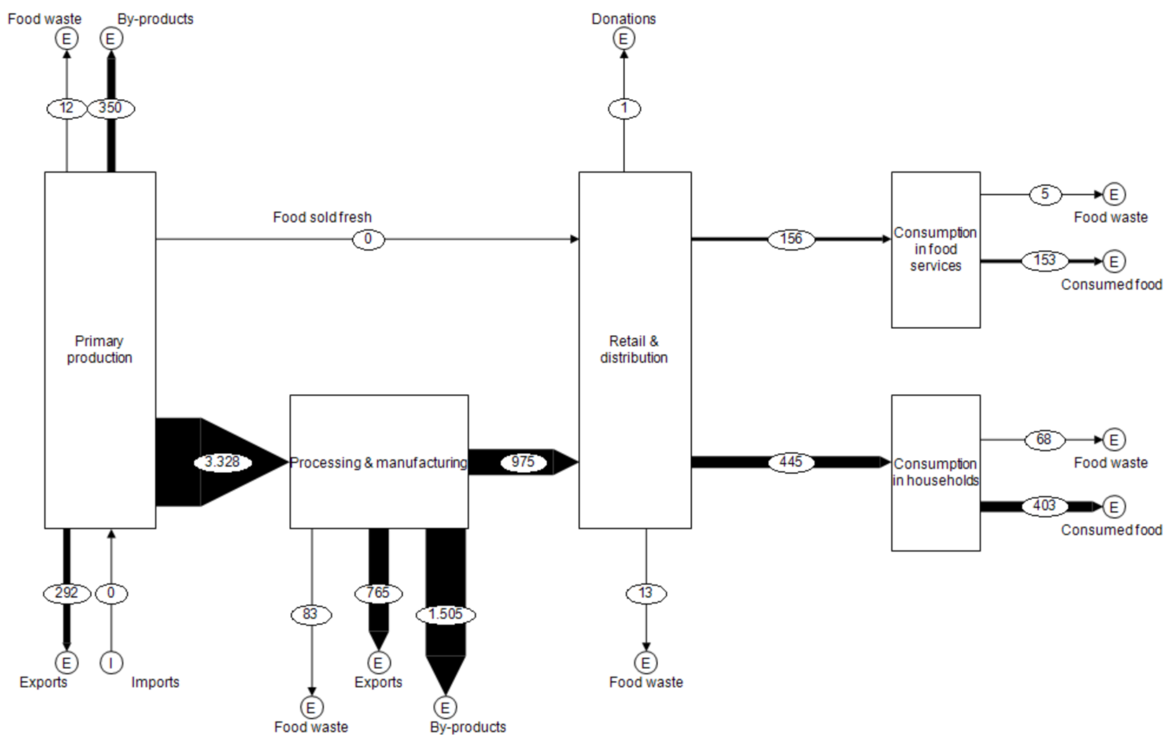

Figure 16: Sankey diagram of dairy-related food flows including FW (in kt/year) (own figure)

In total 181 kt of dairy products are wasted in Austria in a year (Table Y). This food group is the only one where most of the waste is generated at the processing & manufacturing stage. Specifically, this stage is responsible for 83 kt/year of waste (Figure 16), contributing with a share of 46% (Figure 10). Just like in the case of meat, this is partly connected to the fact that 100% of the produced milk enters the processing & manufacturing stage before being distributed. Additionally, a substantial 1,505 kt are redirected during the processing & manufacturing stage, making dairy the food group with the largest quantity converted into by-products. In chapter 5.1 reasons for this high number are discussed. Dairy is also the only food group, where, at the stage of processing & manufacturing, the exports are explicitly shown in the MFA. This is due to the fact that this food group is the only one where the main processed products have their own FBS (see chapter 3.2.2). Just like in the case of potatoes (see chapter 4.2.3), the household stage is the second-largest contributor, responsible for 37% (68 kt/year) of dairy FW.

The primary production stage and the retail & distribution stage contribute similar results, with 12 kt/year (7%) and 13 kt/year (7%) respectively. While the primary production stage contributes the least to meat FW (see chapter 4.2.4), it is the food service sector that generates the smallest share of dairy FW, accounting for just 3% (5 kt/year) according to Figure 10.

4.2.6 Food Waste distribution across the Egg Supply Chain

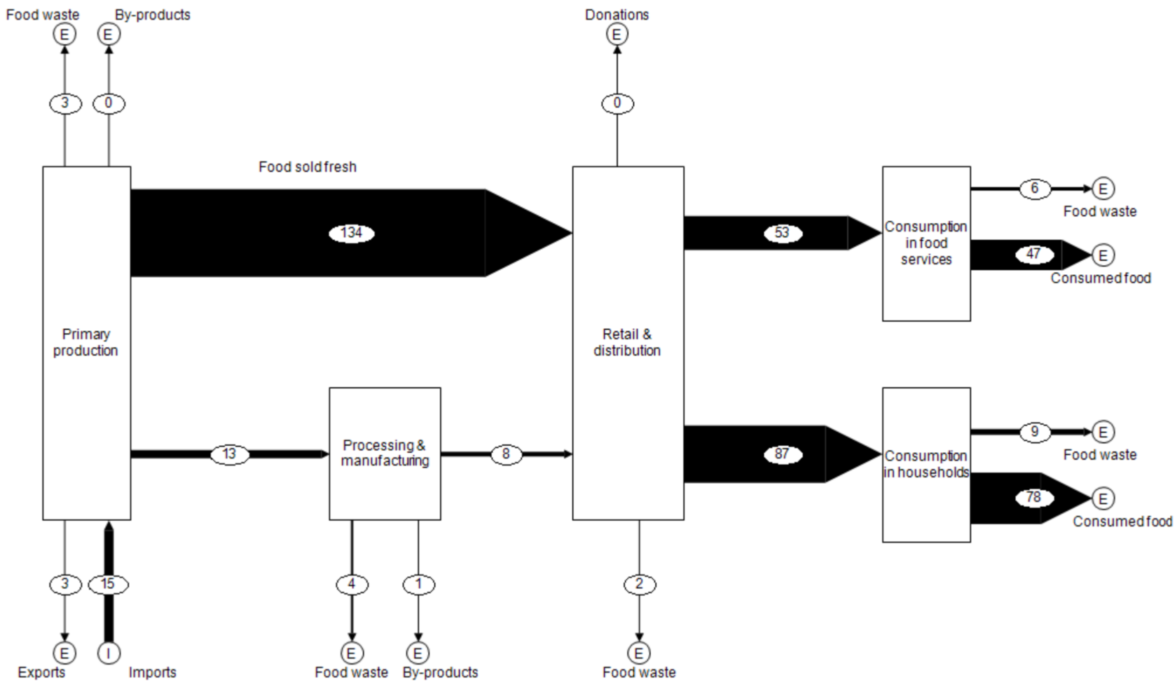

Figure 17: Sankey diagram of egg-related food flows including FW (in kt/year) (own figure)

As previously discussed, eggs contribute the least to overall FW among all food groups. As detailed in Table Y in the Annex, in total, 23 kt of eggs are wasted in Austria yearly. The distribution of this waste across the FSC differs notably from that of other food groups.

Households are the largest source of egg waste, accounting for 9 kt/year (37%) of the total (see Figure 10 and Figure 17). Uniquely, food services represent the second-largest contributor. Eggs are the only food group where this stage is responsible for over 20% of FW, according to Figure 10. Specifically, 6 kt/year of eggs are wasted in food services, making up 27% of the total (see Figure 10 and Figure 17).

Processing & manufacturing is responsible for 4 kt/year (Figure 17), or 17% according to Figure 10, followed by primary production with 12% (3 kt/year) of the total FW. The smallest share comes from the retail & distribution stage, which contributes 2 kt (Figure 17), equivalent to 8% (Figure 10) of the overall egg waste.

5. Discussion

This master's thesis estimates the amount of FW generated in Austria at each stage of the FSC and across various food groups, using an MFA. The following chapter aims to identify key drivers and uncertainties associated with FW generation, interpret the findings in the context of existing literature, and explore recommendations for policies and future research. First, the results are discussed in detail, with potential underlying causes brought up. Second, the methodological approach is evaluated, highlighting its strengths and limitations. Third, the findings are compared with previous estimates from official data sources and similar studies, with attention given to any deviations and their possible explanations. Then environmental and economic considerations are pointed out, and policy recommendations are discussed. Finally, the chapter offers an outlook on directions for future research.

5.1 Discussion of Key Findings

Using the MFA approach, this master's thesis estimates that Austria generates approximately 1,190 kt of FW annually from fruits, vegetables, potatoes, meat, dairy, and eggs. This figure encompasses both edible and inedible fractions and considers all major stages of the FSC, from primary production to consumption in households and food services.

A striking outcome of the analysis is the dominant role households play in FW generation. The study reveals that households are the largest contributors to FW, generating approximately 566 kt/year (see Table Y in the Annex), accounting for 48% of the total FW (Figure 6) or 62 kg/cap.yr (Figure 7). As noted in chapter 2.2.3, key reasons for waste at the household level include over-purchasing, inadequate meal planning, and confusion regarding date labeling. One explanation for this disproportionately high share is that earlier stages of the supply chain tend to employ more systematic waste management practices, such as converting unsellable food into by-products or donating the surplus (Lebersorger and Schneider, 2014a; ADEME, 2016; Xue et al., 2019). Additionally, it can be assumed that these stages often face stronger financial incentives to minimize waste, encouraging more efficient food handling. Moreover, by the time food reaches consumers, it may already have degraded in quality due to poor choices made in preceding FSC stages, for instance the use of ineffective fertilizers (Beausang et al., 2017) or inefficient packaging (Olabode et al., 2025). Such issues might become apparent only at the point of consumption.

Interestingly, primary production is the second-largest contributor to total FW, accounting for 19% of the national total (Figure 6). This is especially prominent in the case of potatoes, where primary production waste surpasses household-level waste (Figure 11). Such waste at the farm level, as previously mentioned in chapter 2.2.3, may result from quality standards, market demands for aesthetic products, and logistical inefficiencies. Despite this stage representing significant resource inefficiencies, it is important to point out that FSC stages are often intertwined. For example, food may be rejected by a retailer and returned to the producer. Although the FW is recorded at the production level, it is partly attributable to the retail & distribution stage (Beausang et al., 2017). Further possible reasons for this outcome of the study are discussed in chapter 5.3.

Retail & distribution contributes the smallest share to total FW, with just 8% (96 kt/year) (chapter 4.1). There are several factors that help explain this trend. Reducing FW at the retail & distribution stage is particularly important for the sector. FW is an additional burden besides the intense competition and the high operational costs in this industry (Todd and Faour-Klingbeil, 2024). Additionally, one could assume that a reduction in FW can have a positive impact on the reputation of retailers. Fortunately, this FSC stage offers multiple opportunities to redirect food before it becomes waste. Besides donations, financial incentives such as discounts or coupons that encourage consumer to purchase more products before they have to be discarded can be mentioned (Beausang et al., 2017). However, this process often does not reduce FW, and instead shifts it to the household stage.

Simultaneously, the retail & distribution stage is important in setting the terms of FW generation elsewhere. Retailers influence consumer purchasing behavior, supplier practices, and even primary production through contracts and standards (Beausang et al., 2017; Horoś and Ruppenthal, 2021).

When analyzing waste by food groups, the findings reveal a strong imbalance between plant-based and animal-based products. Vegetables, fruits, and potatoes account for nearly three-quarters of the total FW, while animal-based products make up only about one-quarter (see chapter 4.2). This imbalance can be attributed in part to the higher perishability of plant-based foods, which have a higher water content that accelerates microbial growth and spoilage. Additionally, fruits and vegetables are more prone to physical damage during handling and transportation (Kinhal, 2024). It is, however, important to keep in mind that, when these results are interpreted in an environmental context, it becomes evident that despite the smaller FW contribution by mass, animal-based products exhibit a higher environmental burden during production. According to a study conducted by the US Environmental Protection Agency, animal products are responsible for around 66% of the agricultural land needed for food production. Furthermore, they are responsible for a significantly higher share of greenhouse gas emissions (GHG) (Faunalytics, 2021).

Among all food groups, vegetables represent the largest share of wasted products, with an estimated 405 kt of FW annually (Figure 9). This is partly explained by the higher volume of vegetable production and imports compared to other products. For instance, 40% more vegetables are produced, and 15% more are imported than fruits (calculated using data from Table X in the Annex). As such, the initial food input for vegetables in the MFA is typically larger. However, this is not the sole factor contributing to the high level of vegetable waste. This becomes evident when the calculations for vegetables are compared with the ones for dairy. Despite a higher input volume for dairy at the primary production stage, the FW for dairy products is significantly lower than for vegetables due to the fact that vegetables exhibit higher FW rates across all stages, particularly at the household level. Specifically, 28.40% of vegetables are wasted by households, compared to just 9.50% for dairy products (Table 5). A higher FW coefficient at the downstream end of the FSC is particularly concerning from an environmental standpoint. By this stage, additional resources such as energy for transportation, materials for packaging, and inputs for processing have already been invested, significantly increasing the environmental footprint of the wasted food (FAO, 2013). For example, in the case of fruits, the primary production and retail & distribution stages show comparable waste volumes as can be seen in Figure 12 (36 kt and 35 kt, respectively). However, waste occurring at the retail & distribution stage has a greater environmental impact due to the cumulative resources used up to that point. A similar pattern is observed in the total FW distribution, where retail & distribution and food services contribute 8% and 9%, respectively (Figure 6). Despite the similar waste shares, food discarded in the food services sector has a higher environmental burden compared to retail, as it occurs at the final stage of the FSC, following all prior investments in processing, transport, and storage.

In strong contrast to vegetables, eggs contribute only 2% to the total FW (Figure 9). Just 23 kt are wasted annually as is illustrated in Figure 17. It is important to mention that the low figure is partly connected to their relative low production volume. For reference, while only 137 kt of eggs are produced annually, it is 450 kt of vegetables and 909 kt of meat (Table X). Interestingly, in the case of eggs, the food services stage contributes a disproportionately high share. 27% of all egg waste is attributed to this stage while for other food groups the share does not go above 12% (Figure 10). Reasons could be the challenges food services experience with portioning and menu planning (see chapter 2.2.3). Since also in the case of eggs the waste is mainly produced at the end of the FSC, a bigger environmental impact can be expected.

A noteworthy finding is that, within the meat food group, the processing & manufacturing stage accounts for the second-largest share of FW, despite considerable efforts in the sector to convert leftovers into by-products. While 225 kt/year of meat are indeed repurposed (Figure 15), the FAO (2011) reports that approximately 5% of meat production is still wasted at the processing level. A major contributing factor, according to FAO (2011), particularly in industrialized countries, is the trimming of meat to meet strict standardization requirements. According to the study, these trimmings are often discarded rather than reused, as disposal is typically more cost-effective than investing in redistribution measures (FAO, 2011). However, it is important to note that the referenced study dates back to 2011. It is reasonable to assume that over the past 14 years advancements in processing technologies and sustainability practices may have led to greater conversion of leftovers into by-products. Moreover, the coefficient used represents a European average and might therefore not be representative for slaughterhouses in Central Europe.

An unexpected finding emerged regarding the large volume of dairy (1,505 kt/year) that is classified as by-products rather than being directly consumed or wasted. To estimate this, a mass balance approach is applied. The quantity of by-products is calculated by subtracting the final processed output (including imports), exports, and FW from the total amount entering the processing stage. Detailed calculations can be found in Table X in the Annex. A key factor behind this substantial by-product figure lies in the data sources used. The input to the processing stage is based on raw milk data from the FBS, while the output is derived from FBS data on processed dairy products, such as milk, cream, and condensed milk. The processed output is significantly lower than the raw milk input: only 975 kt/year leave the stage compared to the 3,328 kt/year entering it (Table X). This discrepancy can be attributed to the difference in water content between raw milk and processed dairy products. This reduces the mass of the final products leaving the processing stage. To uphold the principle of mass preservation in this study, the discrepancy between these figures is attributed to by-products, resulting in a notably big volume of 1,505 kt/year. The most popular by-products made in the dairy industry include buttermilk from butter production and whey that can be applied in sports drinks or packaging films (Mansha Rafiq and Insha Rafiq, 2019).

5.2 Discussion on the Methodology

While the MFA is a robust and systematic approach, the methodology and assumptions made during its application can substantially influence the resulting estimates of FW along Austria's FSC. The following chapter discusses the effects decisions in the methodology might have on the results. It goes beyond listing down assumptions and limitations made for this study, as this part can be found in chapter 3.4, and will instead highlight how decisions made for the MFA contribute to the outcome of the study.

The first limitation of this study lies in the use of FW coefficients derived from various European countries and reference years. As a result, the findings may not always accurately reflect current trends specific to Austria. A notable example is the case of meat, as discussed in chapter 5.1. The high volume of meat waste reported at the processing & manufacturing stage can be largely attributed to a relatively high FW coefficient sourced from FAO (2011). However, it is important to note that many meat products deemed unfit for human consumption are nowadays repurposed into by-products such as animal feed, biodiesel, or biogas (Xue et al., 2019).

Furthermore, the reliance on coefficients from other countries means that socio-economic differences across European countries and potential seasonal variations in production during the reference year are not accounted for. Despite this, it was ensured that the production data sourced from the FBS align with Austria's historical production trends, enhancing the reliability of the estimates used.

Additionally, due to data limitations, it is sometimes necessary to apply coefficients from one food group to others. For instance, the same coefficient is used for both the processing & manufacturing and retail & distribution stages for fruits and vegetables. Similarly, potatoes are assumed to have the same by-product coefficient as vegetables at the processing & manufacturing stage, as well as the same rate of food donation. In the retail & distribution stage, a single FW coefficient is applied to all processed foods across fruits, vegetables, and potatoes. This coefficient represents convenience products in general. While these assumptions have to be made due to the lack of detailed data, they may lead to distortions and limit the accuracy of the results, especially when it comes to capturing the distinct characteristics of each food group.

As mentioned in chapter 3.4, not all flows can be accounted for, despite efforts to uphold the principle of mass preservation. For example, export data at the processing & manufacturing stage is only available for the dairy food group, as FBS do not provide corresponding data for other processed food categories. This is a methodological inconsistency and suggests that future studies should aim to present a more comprehensive and consistent depiction of food flows across all categories.

As chapter 3.3.2 points out, the quantities of food entering the processing & manufacturing stage are derived from FBS for all food groups except vegetables, meat, and dairy. For meat and dairy, it is assumed that 100% of the production is processed in the slaughterhouse/dairy factory, as processing is a necessary step to make the products suitable for human consumption (see chapter 3.3.2). In contrast, for vegetables, a coefficient is applied. According to European Commission and Joint Research Centre (2024), 63% of vegetables are processed before reaching the retail & distribution stage. However, this figure appears relatively high when compared to the proportion of other plant-based foods that undergo processing. For instance, based on FBS data for fruits, only 24% of the output from the primary production stage is processed (Table X), while for potatoes, the figure is even lower at 14% (calculated based on data from Table X). These discrepancies raise questions about the accuracy of the data used, especially given that the FBS do not provide detailed explanations for the volume of food processed. This uncertainty should be considered when interpreting the results, as it may influence the reliability of the estimates.

Several studies using the MFA approach to quantify FW across the FSC offer valuable methodological insights that could enhance the quality of this study. For instance, Amicarelli et al. (2020) analyzed potato waste within the Italian potato industry by conducting interviews with industry stakeholders to address data gaps. Incorporating a similar approach here could help reduce reliance on coefficients in certain FSC stages or for specific food groups. Another example is Beretta et al. (2013), which applied MFA to the Swiss food system. In cases of limited data availability, the study used expert estimates provided by industry representatives. It further adopted a significant methodological refinement by subtracting exports from domestic production before applying FW coefficients. This way it ensured that estimates reflect waste associated only with food intended for domestic consumption. Adopting such a practice could improve the accuracy of the present study. Moreover, while all food groups in this study are assessed using fresh mass, the model does not account for changes in weight between fresh and processed products. Caldeira et al. (2019) recommends using appropriate conversion coefficients that account for factors like water loss or the addition of other substances during processing. This adjustment would enable the reporting of processed products in fresh-equivalent mass and enhance consistency and comparability across food groups and FSC stages.

5.3 Comparison with Previous Estimations

As outlined in chapter 2, numerous studies have previously investigated FW in Austria, focusing either on specific stages of the FSC or on individual food groups. In contrast, this thesis employs an MFA that covers the entire FSC and incorporates multiple food groups, offering a more comprehensive perspective. This chapter places the findings of the current study in the context of existing research, with particular emphasis on comparisons to official Eurostat data and other studies relevant to the Austrian food system.

The total of 1,190 kt/year of FW calculated in this study closely aligns with Eurostat's 2022 estimate of 1,184 kt of FW referencing a time 21 months prior to publication (Eurostat, 2022). Both assessments include edible and inedible fractions (Eurostat, 2025). However, an important distinction lies in the scope of food groups considered. While the present study covers six key food groups, the Eurostat estimate encompasses a broader range, including cereals and fish (Eurostat, 2025). Therefore, it can be reasonably assumed that had this thesis included additional food groups, the total estimated volume of FW would have been even bigger than the figure reported by Eurostat.

While Eurostat does not provide data on individual food groups, it does report FW figures across different stages of the FSC. The distribution of FW by FSC stages, as reported by Eurostat, is presented in Figure 2. According to the data available, households are the largest contributors to FW, accounting for 54% of total FW in the Eurostat data, compared to 48% in this analysis (Figure 6). The results might differ due to a higher relevance of perishability due to the selected food groups. Furthermore, based on the outcome, this study suggests a greater potential for reducing overall FW in Austria by targeting FSC stages beyond consumption in households, as these stages contribute a larger share to total FW compared to the Eurostat data.

The second-largest FW generator, based on Eurostat data, is the food service stage, with 256 kt/year and a 22% share (Eurostat, 2022; Figure 2). This is a sharp contrast compared to the findings of this study, which estimates a share of just 9% (112 kt/year) of the total FW (Figure 6; Table X). Unfortunately, due to the confidential nature of national submissions to Eurostat, the reasons behind such discrepancies cannot be determined (Obersteiner and Stoifl, 2024).

Estimates for the processing & manufacturing and retail & distribution stages show greater alignment. This study calculates FW shares of 16% (184 kt/year) for processing and 8% (96 kt/year) for retail (Figure 6; Table X), compared to Eurostat's estimates of 17% (204 kt/year) and 7% (83 kt/year), respectively (Eurostat, 2022; Figure 2).

The most significant difference between the two sources concerns primary production. This study finds that 19% (230 kt/year) of total FW in Austria originates at the primary production stage, making it the second-largest source of waste (Figure 6). In contrast, Eurostat attributes just 1% (6 kt/year) to this stage. According to Obersteiner and Stoifl (2024), this discrepancy may stem from the fact that Eurostat only includes waste that enters a formal waste management system, potentially underreporting waste generated on farms. Furthermore, given that this study applies FW coefficients from non-Austrian literature, it could be that the results are not fully representative for Austria's reality. For example, in this master's thesis the French study by ADEME (2016) is used to estimate FW for the food groups fruits, vegetables, dairy, and eggs. Based on data from Eurostat (2022), the primary production stage in France accounts for 12% of the country's total FW. This is significantly higher than the 1% reported for Austria. This discrepancy suggests that the FW coefficient derived from the French context may overestimate actual FW generation in Austria for these food groups.

A comparison with the study by the European Commission and Joint Research Centre (2024), which reports 1,083 kt of annual FW in Austria, further highlights the impact of methodological differences. Although the European Commission and Joint Research Centre (2024) study includes both edible and inedible FW and covers a broader range of food groups including sugar, oil crops, fish, cocoa, and coffee, it still reports a significantly lower total than the 1,190 kt/year calculated in this thesis.

To ensure the most accurate comparison, only the food groups covered by both studies (fruits, vegetables, potatoes, meat, dairy, and eggs) are considered. Based on data from Annex 3 of the European Commission and Joint Research Centre (2024) study, these six food groups account for 838 kt/year of FW, compared to 1,190 kt/year in this study. The primary reason for this difference likely lies in the differing data sources. Notably, European Commission and Joint Research Centre (2024) do not use Austrian FBS and do not apply any Austrian-specific data for FW coefficients or the allocation of waste between households and food services. These methodological choices potentially contribute to the differing FW estimation in the European Commission & Joint Research Centre (2024) study.

Despite these differences, there are notable similarities between the two studies. As also observed in Eurostat data, both studies identify households as the largest source of FW. European Commission and Joint Research Centre (2024) report 401 kt/year (48%) from households, compared to 566 kt/year (48%) in this thesis (Table Y), making a difference of 165 kt/year. Food services account for 11% of total FW in the European Commission and Joint Research Centre (2024) study, closely aligned with the 9% found here (Figure 6). Likewise, primary production represents a similar share in both studies: 18% in European Commission and Joint Research Centre (2024) and 19% in this study (Figure 6). Hence in both studies this stage shows significant differences to the results presented by Eurostat

(2020). Based on European Commission and Joint Research Centre (2021) argumentation, it might partly be because the data submitted for Eurostat does not consider FW disposed via processes such as composting, while this study and European Commission and Joint Research Centre (2024) do consider these forms of disposal. Processing & manufacturing also shows consistency, with a 17% share in European Commission and Joint Research Centre (2024) versus 16% here (Figure 6). Retail & distribution consistently account for the smallest share across all studies: 6% in European Commission and Joint Research Centre (2024), 7% in Eurostat, and 8% in this thesis (Figure 6). Possible reasons for such outcomes are discussed in chapter 5.1.

A comparison by food groups further illustrates key differences and similarities. In both studies, vegetables are the largest source of FW. European Commission and Joint Research Centre (2024) attribute 28% of total FW (among the six food groups) to vegetables. This is slightly lower than the 34% found in this thesis (Figure 9). With 22% in both studies, fruits show the same shares. Potatoes make up a share of 17% in this study and 16% in European Commission and Joint Research Centre (2024) (Figure 9).

Dairy and meat show significant variation. Dairy waste accounts for 15% of FW in this study (Figure 9), but only 6% in European Commission and Joint Research Centre (2024). Meat waste, however, presents the most notable discrepancy: 11% in this thesis (Figure 9) versus 22% in European Commission and Joint Research Centre (2024). Notably, while European Commission and Joint Research Centre (2024) also identifies the processing & manufacturing stage as significant, with 14% accounting to total meat waste, it is still less than half the share attributed to this stage in the present study (31%) (Figure 10). Egg waste is the smallest category in both cases, with 5% attributed in European Commission and Joint Research Centre (2024) and 2% in the case of this study (Figure 9).

Another key finding from this study is the significant volume of by-products generated during dairy processing. This study estimates 1,505 kt/year of dairy by-products at the stage of processing & manufacturing (Figure 16) compared to 1,169 kt/year reported by European Commission and Joint Research Centre (2024) for the same food group, indicating a similar order of magnitude.

A key difference between this study and the European Commission and Joint Research Centre (2024) lies in how each addresses missing FW coefficients. In both cases, data gaps emerge across various FSC stages due to the absence of country-specific coefficients, requiring the use of proxies. However, the approaches to filling these gaps differ. This study prioritizes using data from individual other countries when national data is unavailable (see chapter 3.3.2). In contrast, the European Commission and Joint Research Centre (2024) relies first on coefficients representative of the broader EU context. Only when suitable EU-level studies are missing, do they choose data from specific countries, by calculating averages from multiple sources. This differs from the approach in the current study, as it does not use cross-country averages.

An important point of discussion arises when considering the ACA study on FW in Austria, which estimates that 791 kt of avoidable FW was generated in 2021 (Rechnungshof Österreich, 2021). Although this thesis does not distinguish between avoidable and unavoidable waste, based on the ACA's figure one can assume that approximately 66% of the 1,190 kt of total FW identified in this study may be considered avoidable. This conclusion is based on dividing the ACA's estimated figure by the total of 1,190 kt calculated in this study and provides an insight into the country's approximate potential for FW reduction.

5.4 Environmental and Economic Implications and Policy Recommendations

The findings of this study reveal that Austria generates millions of tonnes of FW each year. This issue is not only connected to ethical concerns. It also carries significant economic and environmental implications. The volume of edible food that is discarded leads to the loss of hundreds of millions of Euros annually across the entire FSC. For example, Obersteiner and Luck (2020) estimate that FW in households has a monetary value ranging from EUR 250 to EUR 800 per household per year. Similarly, the initiative United Against Waste reports that the food services sector has losses of approximately EUR 320 million annually (in relation to 175 kt of food wasted) due to FW (United Against Waste, 2016).

The impact of FW is not solely economic. It also poses a substantial environmental burden. Globally, FLW account for 8–10% of all GHG emissions (WRAP, 2024). In Austria, uneaten food is responsible for approximately 16% of GHG emissions concerning the diet

(Obersteiner and Luck, 2020). As discussed in chapter 5.1, different food groups contribute differently to environmental degradation. While plant-based foods are wasted in greater volumes, animal-based products such as meat, dairy, and eggs have a far higher environmental impact. For instance, wasting 1 kg of meat at the household stage results in approximately 9 kg of CO_2 emissions, compared to just 0.7 kg of CO_2 for 1 kg of vegetables (Obersteiner and Luck, 2020).

Austria acknowledges the urgency of addressing FW and is a signatory to the SDGs, including Target 12.3. The country has implemented various national initiatives such as *Lebensmittel sind kostbar* and is also bound by EU-level directives (see chapter 2.2.2). Therefore, any assessment of FW generation should be accompanied by policy recommendations.

This study highlights the interconnectedness of the stages within the FSC and emphasizes the need for cross-sectoral approaches in policymaking. For example, national authorities should address last-minute order cancellations by retailers, which often result in food surpluses at the producer level, forcing them to discard otherwise consumable products (European Commission, 2019b). Additionally, both national and EU policies should encourage the sale of "imperfect" products that do not have the standard shapes or appearances. Popularizing secondary markets (IFSS, 2021) and running awareness campaigns to educate households about the edibility and quality of such products can also play a key role in reducing waste (European Commission, 2019b).

Although this study focuses on food donations at the retail & distribution level, it would be beneficial to establish donation systems across all FSC stages. Progress in this regard is already happening. Organizations such as Die Tafel Österreich frequently focus on the primary production stage (Rotes Kreuz NÖ, 2025). To offset the extra costs associated with donations, government-backed funding or tax incentives should be considered. Furthermore, industries could partner more closely with organizations specializing in food redistribution (European Commission, 2019b).

Technology can also greatly contribute to FW reduction. Investing in innovative and sustainable packaging solutions can help prolong the shelf life of food across the supply chain (European Commission, 2019b). Moreover, funding should be directed toward technologies that convert FW into value-added by-products (European Commission, 2019b). Donation-focused mobile applications that connect consumers and/or organizations with producers, retailers or food services can also ensure food redistribution (European Commission, 2019b).

Lastly, reliable and standardized data is essential for monitoring progress in reducing FW. Therefore, it is recommended to broaden the scope of reporting obligations, for instance under Paragraph 11a of Austria's Waste Management Act (see chapter 2.2.2). This is because, while retailers are required to report total FW, only a limited number of food groups are reported separately. The official report can be found in the Electronic Data Management – Environment. This is a system that supports companies with the fulfillment of environmental protection-related documentation. There, fruits and vegetables are combined into a single category, dairy is reported separately, and no other food groups relevant for this study are distinguished. Furthermore, not all retailers report FW disaggregated by food groups which is why the final amount is not representative (BMIMI, 2025). Therefore, even though there are reporting obligations at the retail & distribution stage, this study still relies on outdated data from the literature rather than primary data. If a wider range of food groups were individually reported, studies like this could rely more on primary data, at least for the retail & distribution stage, rather than on estimated coefficients.

5.5 Suggestions for Future Studies

This thesis shows a general approach how to conduct an MFA, identifies existing data gaps and future research needs. It focuses on six major food groups, including fruits, vegetables, potatoes, meat, dairy, and eggs. To generate a more holistic estimate of FW in Austria, it is recommended that future studies include more food groups such as cereals, fish, and oil crops. This would broaden the scope of the study and would ensure a better comparability to Eurostat. Furthermore, in order to calculate the actual FW reduction potential, it is advisable to differentiate between edible and inedible parts of FW where possible.

Methodological uncertainty can be reduced by implementing MFA models tailored to individual food groups (instead of one model for all food groups as it is the case in this study, see Figure 4). Additionally, more side flows such as returns at the retail & distribution level and exports and imports at the processing & manufacturing stage for products besides dairy could be added. It would also be beneficial to use distinct coefficients for each food group.

In this study coefficients are sometimes shared across groups; for example, the coefficient for vegetables is applied to potatoes, and fruits and vegetables are often assumed to have the same value.

To deepen the understanding of the socioeconomic and environmental dimensions of FW, future studies could build on the results of this thesis to estimate the associated impacts of FW at each stage of the FSC, including CO_2 emissions, transportation costs, and water usage. However, it is important to acknowledge that this study itself is based on a number of estimations and assumptions. As such, layering additional analyses may introduce further uncertainties and limitations in representativeness. This challenge is not unique to this work but is a common constraint across most studies on FW, largely due to persistent data gaps and methodological inconsistencies.

6. Summary and Conclusions

Extensive research on FW exists at the global, European, and Austrian levels. However, much of this work tends to focus either on specific stages of the FSC or limits its scope to individual food groups. Even studies that attempt a more comprehensive analysis of FW across the entire Austrian FSC often lack context and rely solely on non-Austrian data. This master's thesis addresses that gap by offering a holistic and more contextually grounded assessment of FW generation throughout Austria's FSC.

Using an MFA, this study quantifies FW across six major food groups (fruits, vegetables, potatoes, meat, dairy, and eggs). It traces their flows from post-harvest/slaughter primary production through processing & manufacturing, retail & distribution, and ultimately to final consumption in households and food services. This integrated approach offers a better understanding of where, how much, and why food is wasted across each stage of the FSC. Given the supply chain is very interconnected, analyzing these stages collectively within a single methodological framework is essential for highlighting the systemic inefficiencies that contribute to FW.

The findings of this thesis provide critical insights that support both academic discussions and evidence-based policymaking. The paper uncovers significant data gaps and provides a methodological framework.

One of the most significant findings is the dominant role of households in generating FW. Except for potatoes, households are the primary source of waste across all food groups, contributing an estimated 566 kt per year. This is approximately 48% of Austria's total FW. This highlights the central influence of consumer behavior, food literacy, and retail practices in shaping FW outcomes. Reducing household-level FW will thus be pivotal to any successful national strategy. In this respect, the findings support the efforts of the ongoing national strategy which focuses on households as well.

Primary production emerges as the second-largest contributor, responsible for roughly 19% (230 kt/year) of total FW. Here, systemic issues such as strict market regulations, aesthetic standards, and logistical constraints often lead to food being discarded even though it is edible. The findings highlight significant data gaps, underscoring the need for a closer examination of data availability in Austria. Moreover, the strict definition of FW applied at the EU level leaves additional, unreported potential for improving efficiency in the FSC before harvest or slaughter.

A particularly notable insight from the analysis is the imbalance between the volume and environmental impact of different types of FW. Although plant-based food groups (vegetables, fruits, and potatoes) account for nearly three-quarters of FW by mass, animal-based products like meat, dairy, and eggs impose significantly higher environmental costs due to their resource requirements. This distinction has crucial implications for sustainability strategies. Hence, mass-related volume alone is not a sufficient metric for prioritizing action, and environmental impact assessments should complement FW analysis.

To conclude, this thesis demonstrates the scale, complexity, and urgency of addressing FW in Austria. The application of the MFA enables a quantification of material flows and waste streams and uncovers critical intervention points that could support national and international strategies. Reducing FW is not just a matter of minimizing discarded food. It is a step toward fostering a more sustainable, ethical, and resilient food system. As Austria continues its progress toward SDG 12.3 and general circular economy objectives, studies such as this one provide the foundation for further research on FW, data-driven decision-making, and meaningful systemic change.

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Annex

The following Tables present the supporting calculations required to develop the FW coefficients, which can be found in Table 5.

Table A: Supporting calculations for fruit waste coefficients at the primary production stage (own table)

Fruits (ADEME, 2016)	*FW without harvest losses*	*Food not repurposed*
Apples	11.40%	6.16%
Pears	11.00%	5.50%
Bananas	14.00%	12.60%
Peaches, nectarines, apricots	24.00%	14.40%
Strawberries	11.00%	4.40%
Cherries	9.00%	5.40%
average		**8.08%**

Table B: Supporting calculations for vegetable waste coefficients at the primary production stage (own table)

Vegetables (ADEME, 2016)	*FW without Harvest losses*	*Food not repurposed*
Tomatoes	7.00%	3.50%
Carrots	6.00%	3.00%
Salad	25.00%	25.00%
Cauliflower	24.00%	24.00%
Endive	17.00%	3.40%
Onions	19.00%	18.05%
average		**12.83%**

Table C: Supporting calculations for fruit waste coefficients at the primary production stage (own table)

Dairy (ADEME, 2016)	*Food not repurposed*
Cow's milk	**0.30%**

Table D: Supporting calculations for potato waste coefficients at the processing & manufacturing stage (own table)

Potatoes (Willersinn et al., 2015)	*Food Waste*
Non-organic potatoes	13.50%
Organic potatoes	14.50%
average	**14.00%**

Table E: Supporting calculations for dairy waste coefficients at the processing & manufacturing stage (own table)

Dairy (ADEME, 2016)	
	Food not repurposed
Dairy products	**2.50%**

Table F: Supporting calculations for potatoes waste coefficients at the retail & distribution stage (own table)

Potatoes (Willersinn et al., 2015)	
	Food Waste
Non-organic potatoes	1.00%
Organic potatoes	2.50%
average	**1.75%**

Table G: Supporting calculations for meat waste coefficients at the retail & distribution stage (own table)

Meat (Lebersorger and Schneider, 2014a)	
	Food Waste
Fresh meat, poultry	2.75%
Sausage, smoked meats	2.39%
average	**2.57%**

Table H: Supporting calculations for fruit waste coefficients at the food services stage (own table)

Fruits (Beretta et al., 2013)	*Unavoidable FW*	*Avoidable FW (kitchen waste)*	*Avoidable FW (plate waste)*	*average*
Apples	7.10%	15.60%	2.50%	8.40%
Other fresh fruits	32.20%	10%	2.40%	14.70%
Berries	3.20%	12%	0.50%	5.13%
average	14.17%	12%	2%	**9.41%**

Table I: Supporting calculations for vegetable coefficients at the food services stage (own table)

Vegetables (Beretta et al., 2013)	*Unavoidable FW*	*Avoidable FW (kitchen waste)*	*Avoidable FW (plate waste)*	*average*
Fresh vegetables	14.50%	17%	3.20%	11.40%
Storable vegetables	14.50%	13%	3.20%	10.37%
average	14.50%	14.95%	3.20%	**10.88%**

Table J: Supporting calculations for potato waste coefficients at the food services stage (own table)

Potatoes (Beretta et al., 2013)				
	Unavoidable FW	*Avoidable FW (kitchen waste)*	*Avoidable FW (plate waste)*	*average*
Potatoes	14.50%	15%	1%	**10.20%**

Table K: Supporting calculations for meat waste coefficients at the food services stage (own table)

Meat (Beretta et al., 2013)				
	Unavoidable FW	*Avoidable FW (kitchen waste)*	*Avoidable FW (plate waste)*	*average*
Pork	8%	7.30%	3%	
Poultry	40.20%	7.10%	3%	
Beef	8%	5.10%	4.30%	
average	19%	7%	3%	**10%**

Table L: Supporting calculations for dairy waste coefficients at the food services stage (own table)

Dairy (Beretta et al., 2013)				
	Unavoidable FW	*Avoidable FW (kitchen waste)*	*Avoidable FW (plate waste)*	*average*
Milk	0%	3.90%	1.20%	
Cheese	4.80%	6.10%	1.20%	
Butter	0%	3.50%	1.20%	
average	2%	5%	1%	**2%**

Table M: Supporting calculations for egg waste coefficients at the food services stage (own table)

Eggs (Beretta et al., 2013)				
	Unavoidable FW	*Avoidable FW (kitchen waste)*	*Avoidable FW (plate waste)*	*average*
Eggs	29%	3.90%	3.30%	**12%**

The following Tables present the supporting calculations for the distribution between fresh and processed vegetables, the by-product coefficients (for Tables 6 and 7), the donation coefficient for meat (for Table 8), and the distribution of meat consumption between households and food services (for Table 9).

Table N: Supporting calculations for the distribution between fresh and processed vegetables (own table)

Vegetables (European Commission and Joint Research Centre, 2024)		
	Fresh	*Processed*
Onions	36%	64%
Other vegetables	43%	57%
Beans	32%	68%
Peas	9%	91%
Other pulses	66%	34%
average	**37%**	**63%**

Table O: Supporting calculations for fruit by-product coefficients at the primary production stage (own table)

Fruits (ADEME, 2016)			
	FW without Harvest losses	*Food repurposed*	*Reason*
Apples	11.40%	5.24%	Donations
Pears	11.00%	5.50%	Donations
Bananas	14.00%	1.40%	Donations
Peaches, nectarines, apricots	24.00%	9.60%	Donations
Strawberries	11.00%	6.60%	Other
Cherries	9.00%	3.60%	Other
average		**5.32%**	

Table P: Supporting calculations for vegetable by-product coefficients at the primary production stage (own table)

Vegetables (ADEME, 2016)			
	FW without Harvest losses	*Food repurposed*	Reason
Tomatoes	7%	4%	Donations
Carrots	6%	3%	Animal-feed, donation
Salad	25%	0%	
Cauliflower	24%	0%	
Endive	17%	14%	Animal-feed
Onions	19%	1%	Donation
average		**3.51%**	

Table Q: Supporting calculations for fruit by-product coefficients at the processing & manufacturing stage (own table)

Fruits (ADEME, 2016)	*Food repurposed*	*Reason*
Apples	0.40%	Donations
Pears	0.00%	
Bananas	0.70%	Donations
Peaches, nectarines, apricots	0.00%	
Strawberries	0.00%	
Cherries	0.00%	
average	**0.18%**	

Table R: Supporting calculations for vegetable by-product coefficients at the processing & manufacturing stage (own table)

Vegetables (ADEME, 2016)	*Food repurposed*	*Reason*
Tomatoes	2.25%	Animal feed
Carrots	0.60%	Donations
Salad	0.00%	
Cauliflower	1.00%	Donations
Endive	1.00%	Donations
Onions	0.32%	Donations
average	**0.86%**	

Table S: Supporting calculations for meat by-product coefficients at the processing & manufacturing stage (own table)

Meat (Xue et al., 2019)	*Food entering the Processing stage*	*Food becoming a by-product*	*Proportion*
Cattle	207	116	56.04%
Pork	1419	389	27.41%
Poultry	412	74	17.96%
Sum	2038	579	**28.41%**

Table T: Supporting calculations for dairy by-product coefficients at the processing & manufacturing stage (own table)

Dairy (ADEME, 2016)	*Food repurposed*	*Reason*
Dairy	**2.5%**	Animal feed, donations

Table U: Supporting calculations for egg by-product coefficients at the processing & manufacturing stage (own table)

Eggs (ADEME, 2016)	*Food repurposed*	*Reason*
Eggs	**8.1%**	Animal feed, donations

Table V: Supporting calculations for the meat donations coefficient at the retail & distribution stage (own table)

Meat (Lebersorger and Schneider, 2014)	
	Donations
Fresh meat, poultry	0.04%
Sausage, smoked meats	0.07%
average	0.06%

Table W: Supporting calculations for the distribution between meat sold in households and in food services (own table)

AMA-Marketing GesmbH (2020)		
	Consumption in households	Consumption in food services
Meat	54%	46%
Meat products	89%	11%
average	72%	29%

The following three tables present the MFA results and the corresponding distribution of FW across FSC stages and food groups.

Table X: MFA including FW outcomes (own table)

Primary production							
	Fruits	**Vegetables**	**Potatoes**	**Meat**	**Dairy**	**Eggs**	**Total**
Primary production	449840.00	746773.00	686223.00	909447.00	3981759.00	137079.00	6911121.00
Exports	193624.00	326935.00	140536.00	493457.00	291813.00	2567.00	1448932.00
Imports	742776.00	873568.00	253081.00	375231.00	0.00	14919.00	2259575.00
Food waste	36347.07	95810.98	83581.96	0.00	11945.28	2741.58	230426.87
By-products	23931.49	26211.73	202018.00	0.00	349502.72	0.00	601663.94
Food entering the next stage	938713.44	1171383.29	513168.04	791221.00	3328498.00	146689.42	6889673.19
Processing & manufacturing							
	Fruits	**Vegetables**	**Potatoes**	**Meat**	**Dairy**	**Eggs**	**Total**
Food entering this stage	223500.00	737971.47	69344.00	791221.00	3328498.00	13000.00	5163534.47
By-products	402.30	6346.55	596.36	224785.89	1504616.55	1053.00	1737800.65
Food waste	11175.00	36898.57	9708.16	39561.05	83212.45	3900.00	184455.23
Exports					765171.00		
Imports					238756.00		
Food entering the next stage	211922.70	694726.35	59039.48	526874.06	975498.00	8047.00	2476107.59
Retail & distribution							
	Fruits	**Vegetables**	**Potatoes**	**Meat**	**Dairy**	**Eggs**	**Total**
Fresh food entering this stage	715213.44	433411.82	443824.04	0.00	0.00	133689.42	1726138.72
Food waste (food sold fresh)	33042.86	20023.63	7766.92	0.00	0.00	1737.96	62571.37
Food waste (processed food)	1525.84	5002.03	425.08	13540.66	13071.67	57.94	33623.23
Food waste (total)	34568.70	25025.66	8192.00	13540.66	13071.67	1795.90	96194.60
Donations (food sold fresh)	858.26	520.09	532.59	0.00	0.00	307.49	2218.42
Donations (processed food)	402.65	1319.98	112.18	316.12	2243.65	15.29	4409.87
Donations (total)	1260.91	1840.07	644.76	316.12	2243.65	322.77	6628.29
Food entering the next stage	891306.53	1101272.43	494026.75	513017.28	960182.68	139617.74	4099423.41
Consumption in households							
	Fruits	**Vegetables**	**Potatoes**	**Meat**	**Dairy**	**Eggs**	**Total**
Food entering this stage	588262.31	726839.81	326057.66	364242.27	710535.18	86563.00	2802500.22
Food waste	147065.58	206422.50	78253.84	58278.76	67500.84	8656.30	566177.82
Consumed food	441196.73	520417.30	247803.82	305963.50	643034.34	77906.70	2236322.40
Consumption in food services							
	Fruits	**Vegetables**	**Potatoes**	**Meat**	**Dairy**	**Eggs**	**Total**
Food entering this stage	303044.22	374432.63	167969.10	146209.92	249647.50	53054.74	1294358.11
Food waste	28516.46	40738.27	17132.85	14620.99	4992.95	6366.57	112368.09
Consumed food	274527.76	333694.36	150836.25	131588.93	244654.55	46688.17	1181990.02

Table Y: FW results in absolute number (own table)

FW results	Fruits	Vegetables	Potatoes	Meat	Dairy	Eggs	Total
Primary production	36347.07	95810.98	83581.96	0.00	11945.28	2741.58	230426.87
Processing & manufacturing	11175.00	36898.57	9708.16	39561.05	83212.45	3900.00	184455.23
Retail & distribution	34568.70	25025.66	8192.00	13540.66	13071.67	1795.90	96194.60
Consumption in households	147065.58	206422.505	78253.8374	58278.7626	67500.8425	8656.30	566177.82
Consumption in food services	28516.46	40738.2699	17132.8477	14620.9924	4992.94994	6366.57	112368.09
Total	257672.81	404895.98	196868.81	126001.47	180723.19	23460.35	1189622.62

Table Z: Proportion of FW by supply chain stage and food group (%) (own table)

	Fruits	Vegetables	Potatoes	Meat	Dairy	Eggs	% of total FW
Primary production	14.11%	23.66%	42.46%	0.00%	6.61%	11.69%	19.37%
Processing & manufacturing	13.42%	6.18%	4.16%	10.75%	7.23%	7.66%	15.51%
Retail & distribution	4.34%	9.11%	4.93%	31.40%	46.04%	16.62%	8.09%
Consumption in households	57.07%	50.98%	39.75%	46.25%	37.35%	36.90%	47.59%
Consumption in food services	11.07%	10.06%	8.70%	11.60%	2.76%	27.14%	9.45%
% of total food waste	21.66%	34.04%	16.55%	10.59%	15.19%	1.97%	