Systems maps and analytical framework

Mapping food waste drivers across the food supply chain

D3.1

REFRESH is funded by the Horizon 2020 Framework Programme of the European Union under Grant Agreement no. 641933. The contents of this document are the sole responsibility of REFRESH and can in no way be taken to reflect the views of the European Union

Authors

Stephanie Burgos, Deloitte Sustainability

Manuela Gheoldus, Deloitte Sustainability

Flavien Colin, Deloitte Sustainability

Alfred Charles Cummins, Deloitte Sustainability

Åsa Stenmarck, IVL

Johan Hultén, IVL

Lena Yohanan, IVL

Julian Parfitt, Anthesis

Matteo Vittuari, University of Bologna

Simone Piras, University of Bologna

Keighley McFarland, Ecologic Institute

Stephanie Wunder, Ecologic Institute

With thanks to

Katherine Salès, Deloitte Sustainability

David Rogers, WRAP

Hilke Bos-Brouwers, Wageningen University & Research

Patrick Mahon, WRAP

Karin Ostergren, SP

Project coordination and editing provided by Wageningen University & Research

Manuscript completed in [July 2017]

This document is available on the Internet at: www.eu-refresh.org

Document title	System maps and analytical framework
Work Package	WP3
Document Type	Deliverable
Date	July 2017
Document	Final draft

Acknowledgments & Disclaimer

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 641933.

Table of Contents

List of Figures

List of abbreviations

ABP	Animal By-product
AD	Anaerobic Digestion
EfW	Energy from Waste
FW	Food Waste
FUSIONS	Food Use for Social Innovation by Optimising Waste Prevention Strategies FUSIONS was a four year long project (from 2012-2016) funded by the European Commission Framework Programme 7 about working towards a more resource efficient Europe by significantly reducing food waste.
KPI	Key performance indicator
MLOR	Minimum Life On Receipt
REFRESH	Resource Efficient Food and dRink for the Entire Supply cHain REFRESH is a four year long (from 2015-2019) Horizon 2020 EU research project taking action against food waste. The project's goal is to contribute towards Sustainable Development Goal 12.3 of halving per capita food waste at the retail and consumer level and reducing food losses along production and supply chains, reducing waste management costs, and maximizing the value from un-avoidable food waste and packaging materials.
QA	Quality assurance
WP	Work Package

Terminology

Term	Definition	Source
Food	Any substance or product, whether processed, partially processed or unprocessed, intended to be, or reasonably expected to be consumed by humans. Food includes drink, chewing gum, and any substance, including water, intentionally incorporated into food during its manufacture, preparation or treatment.	This definition of food complies with official documents (such as existing legislation) using present definitions of "food"; presented in the EU Regulation (EC) No 178/2002 on general principles and requirements of food law as well as the FAO/WHO Codex Alimentarus Commission on food safety (ALINORM 04/27/33A) Article 3: EU Regulation No 178-2002: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2002:031:0001:0024:EN:PDF & FAO/WHO Codex 04/27/33A: http://www.codexalimentarius.org/input/download/report/618/al0433ae.pdf#page=46
Food and inedible parts of food	Edible food, which has or had the potential to be eaten, removed from the food supply chain, and associated inedible parts of food removed from the food supply chain.	EU FUSIONS Definitional Framework for Food Waste
Food waste	Food and inedible parts of food removed from the food supply chain to be recovered or disposed (including: composted, crops ploughed in/not harvested, anaerobic digestion, bioenergy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea).	EU FUSIONS Definitional Framework for Food Waste
Policy	Policy is a course or principle of action, proposed or adopted by a government, party, business or individual, intended to influence and determine coherent decisions, actions, and other	Elaborated from Gupta J et al., 2013; Weimer D. L. et al., 2010

	matters; usually with a common long-term purpose(s).	
Top-down approach	This approach identifies drivers in a wholistic manner. Research on specific food categories was not conducted.	Elaborated by REFRESH WP3 policy partners
Bottom-up approach	This approach identifies drivers via a "value chain approach" focusing on each step of the value chain for particular food categories.	Elaborated by REFRESH WP3 policy partners
Drivers	Influences that either cause or prevent food loss and waste.	Elaborated by REFRESH WP3 policy partners
Systemic drivers	Drivers that are inter-linked with more than one step of the value chain which furthermore cause food loss and waste within these different stages.	Elaborated by REFRESH WP3 policy partners
Value chain	Each step of the food chain; the REFRESH project team separates the value chain into four steps: primary production, processing & packaging, retail & logistics, and foodservice & household.	Elaborated by REFRESH WP3 policy partners

1 Executive summary

ANALYTICAL FRAMEWORK ON POLICY

Within this report, "Systems maps and analytical framework", the different stages of the food **value chain** are identified to study the numerous drivers that affect food loss and waste in their policy context. These drivers were then linked with the main waste streams they generate. The influences on food waste generation (both direct and indirect) can be defined within this report as follows:

- **Drivers** that **cause** food loss and waste, such as overstocking of food items in supermarkets to ensure full-shelves & surplus stock of unsold products.

It should be noted that drivers are not only characterised as causes for food loss or waste. Certain drivers, although excluded within this report, have the potential to help reduce food loss and waste. These type of drivers are for example include the use of innovative packaging during transportation to reduce food waste.

Drivers were identified via a two-step approach:

- **Top-down analysis**: For this step, the REFRESH project team capitalised on the previously conducted work on drivers within the FUSIONS project, which consisted of non-product-specific research on food waste drivers. This FUSIONS study resulted in the identification of 105 drivers that cause / affect food waste generation (see Canali et al., 2014). These drivers were identified collecting the main causes of food waste from experts via additional (grey) literature review, expert interviews/questionnaires, followed by the identification of drivers per value chain segment, and categorisation of the identified drivers.

  Within this step, the value chain was divided into five steps: (1) primary production, (2) processing & packaging/processing of farm staples, (3) wholesale & logistics, (4) retail & markets, and (5) food services & households.

Top-down analysis of food waste drivers provide valuable insights. For the purpose of the REFRESH study, more insight was needed on the effect of drivers at the different stages of the value chain, as well as waste and valorisation streams. Also, drivers that affect multiple stages of the supply chain required further investigation to create better understanding of food waste arisings. To tackle this need, the REFRESH project team focused to perform a second step in the approach:

- **Bottom-up analysis**: For this analysis, the REFRESH project team took a "value chain approach" to identify food waste drivers. The waste drivers were also connected to the waste streams they involve. Within this approach, five food categories with different "complexity levels" were selected and analysed starting from primary production and ending with foodservice and household sectors. The following table illustrates the breakdown of the selection of food categories and countries

Food product category	Countries covered in the study				
	DE	FR	IT	SE	UK
Bread	x	x			x
Dairy (milk)				x	x
Potatoes/tomatoes		x	x	x	x
Prepared meals (sandwiches)					x
Processed meat/poultry			x		x

The product categories were selected based on specific selection criteria, including data availability, product category "complexity level" (to ensure that selected products represented a variety of Flavien Colin, Deloitte Sustainability transformation/processing levels), country. Also, the study into priority waste streams performed earlier in the REFRESH project (WP6 – valorisation of waste streams and co-products) provided useful criteria for selection. The report "Valorisation appropriate waste streams" (Sweet et al., 2016) lists an inventory of priority waste streams across the EU.

For the purpose of the bottom-up analysis, the REFRESH project team focused on 4 steps of the value chain, including (1) primary production, (2) processing & packaging, (3) retail & logistics, and (4) food services & households. It was found that in the majority of the selected product-categories, the wholesale and logistics step of the value chain (included in the top-down analysis) was largely associated under the responsibility of retail businesses.

RESULTS SUMMARY

The top-down analysis of the food value chain resulted in a three-way classification of food waste drivers. These categories were (1) technological, (2) institutional (public – legislative & private – business), and (3) social drivers. Earlier findings within the FUSIONS project identified specific drivers per sector of the value chain.

To the purpose of this study, more insight was needed to identify systemic drivers that operate along supply chains and across sectors that induce food surpluses and increase food waste arisings. This was achieved through the detailed systems maps generated for five contrasting product types that were investigated along their supply chains. The selected products include bread, dairy (milk), potatoes/tomatoes, prepared meals (sandwiches) and processed meat/poultry.

The systems mapping exercise allowed to identify:

- **Product specific drivers**: drivers specific to the selected food products at a specific stage of the supply chain;
- **Generic drivers**: drivers which concern two or more selected products;
- **Systemic drivers**: drivers that are inter-linked with more than one step of the supply chain.

Product specific vs generic drivers

Systems maps allowed to distinguish drivers specific to one product at a particular stage of the supply chain from more generic drivers applicable to more products categories. For example, if for bread the main driver at the primary production stage is inventory shrinkage in wheat silos, for tomatoes, one of the main causes of waste at this stage is the high expectations in cosmetic standards. On the other hand, the limited shelf life is a food waste driver for both bread and tomatoes at the retail stage (generic driver).

Moreover, the systems map approach shed light on two key dimensions characterising the impacts of drivers according to the product specificity:

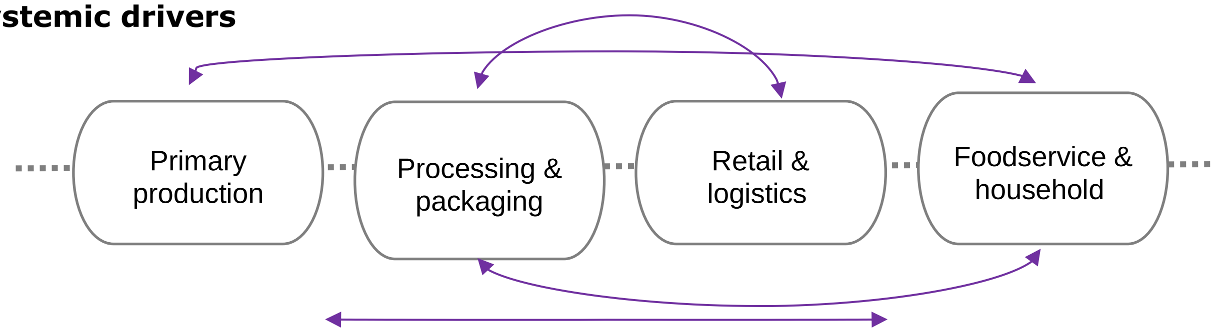
- Food safety, risk and food temperature

Impacts of food waste drivers highly depend on the level of perishability and microbiological risk of food products. For example, less perishable food products such as frozen and canned products are more likely to be wasted because of product damage, labelling errors and/or equipment breakdown. More perishable and higher risk food products are more likely to be wasted when approaching the "best before" date or because of **supply and demand imbalances** and **poor information sharing** along supply chain.

- **Supply chain complexity and level of cooperation**

The bottom up analysis underlined communication and cooperation as central drivers of food waste. The impacts of their malfunctioning are heightened for highly complex products/supply chains where trouble with one ingredient affects the whole material (e.g. prepared meals).

Systemic drivers



The bottom-up approach provided useful insights into mapping food waste drivers, shedding light on systemic drivers. Those drivers are by definition linked to more than one step of the supply chain. Some examples of systemic drivers include **minimum orders, last minute cancellation, lack of data and communication, minimum life on receipt criteria** etc.

These cross cutting systemic drivers emphasized **supply chain issues** regarding notably the interactions between the different businesses and unfair trading practices. For example, the bread systems maps pointed out that in Germany, retailers can return the unsold industrial bread to their suppliers unlike France and the UK. Because of these unclear responsibilities on which actor owns waste or surplus at each stage, data representation of food wasted per step of the value chain may not depict an accurate picture of the current situation.

Last but not least, the systems mapping shed light on drivers which were "hiding" behind other drivers. For example, the question of date expiration and date labelling is a well-known cause of waste for perishable products, but very often there are drivers behind (e.g. overstocking in the retail sector). In the same way, the "real drivers" hidden behind supply and demand imbalance are as varied as forecasting errors or demand associated with promotional offer.

2 Introduction

Food waste (FW) generation along the value chain is an interlinked and complex problem which makes it challenging to apply blanket policy recommendations to address all issues.

Considering today's current situation of food waste in Europe, estimates suggest that in the EU-28, annual food waste amounts to 88 million tonnes, i.e. 173 kilograms per person (Stenmarck et al. 2016). This report's analytical framework aims at addressing how these food waste levels are influenced.

PROJECT OBJECTIVES ON POLICY

As defined in FUSIONS and equally applicable within REFRESH, **policy** is defined as a course or principle of action, proposed or adopted by a government, party, business or individual, intended to influence and determine coherent decisions, actions, and other matters; usually with a common long-term purpose(s) (Gupta J et al., 2013; Weimer D. L. et al., 2010). Considering this definition, policy is not limited to legislation, but also includes other facets, such as voluntary agreements, communication, etc. Within REFRESH, policy (as previously defined) is to be considered to form recommendations throughout the project.

Backed by research to better understand the drivers of food waste, the REFRESH project supports better decision-making by industry and individual consumers in relation to food surplus and waste. The project takes an innovative, **systemic** approach to curbing food waste through a holistic approach. The policy work conducted within REFRESH focuses on **evidence-based** recommendations to policy-makers in order to **improve the policy framework** for the prevention, reduction, reuse and valorisation of food loss and waste **based on the outcomes of** the following project objectives:

- consumer behavioural insights;
- strategic agreements to reduce food waste with governments, business and local stakeholders;
- environmental and life cycle cost analysis;
- behavioural economic approaches and scenarios;
- studies on improving food waste valorisation.

OBJECTIVES OF THIS REPORT

The objective of this report is to provide an **analytical framework** which identifies **non-systemic** as well as **systemic drivers** behind these levels of food waste across the food supply chain. These **policy drivers** are furthermore presented through system maps which visually illustrate drivers per step of the value chain using both the top down and bottom up analyses.

METHODOLOGY

Analytical framework – top-down analysis

Within this approach, the FUSIONS project team split the value chain into five steps: primary production, processing & packaging/processing of farm staples, wholesale & logistics, retail & markets, and foodservice & household. It should be noted that these steps were considered to be generally applicable to food categories, although these five steps are not always followed by every food product.

Upon the consideration of the 105 food waste drivers, the FUSIONS project team found commonalties within the drivers, facilitating a categorisation per "theme". The definitions of these categories, which are inspired from the FUSIONS report on drivers can be seen below (Canali et al. 2014). It should be noted that for the purpose of clarity the institutional drivers were spilt up into two families for this report:

- **Driver family 1: Technological (technology development)**
    - Driver family definition:
        - Inherent to characteristics of food, and of its production and consumption, where technologies have become limiting
        - Related to collateral effects of modern technologies
        - Related to suboptimal use of, and mistakes in the use of food processing technology and chain management
    - Driver example:
        - Transhipment loss within the primary production stage → loss of food

- **Driver family 2: Institutional (public - legislative)**
    - Driver family definition:
        - Legislation/policies affecting food supply chain management, whether they be direct or indirect
    - Driver example:
        - Animal feed regulation → unclear procedures on how to valorise food waste via this channel)

- **Driver family 3: Institutional (private - business)**
    - Driver family definition:
        - Business initiatives/solutions affecting food supply chain management
        - Driven by business/sales operations
        - Addressable at micro level (bottom-up level)
    - Driver example:
        - Limited data tracking/inadequate data systems on waste levels and inventories on the retail level →limited tracking leads to difficulties in managing waste

- **Driver family 4: Social (Consumer behaviour and lifestyles)**
    - Driver family definition:
        - Related to social dynamics and individual behaviours which are not readily changeable
        - Related to individual behaviours modifiable through information and increased awareness
    - Driver example:
        - Over-serving/over-portioning on plates → taboo associated with eating leftovers

After consideration of the current context for food waste generation, it was determined that the drivers identified within FUSIONS are still pertinent at present day and are therefore applicable to the research outlined in this report.

Analytical framework – bottom up analysis

Initial desk research was conducted to identify a shortlist of food product categories that could be the subject of bottom-up analysis, as seen below:

Food product category	Countries covered in the study				
	DE	FR	IT	SE	UK
Bread	x	x			x
Dairy (milk)				x	x
Potatoes/tomatoes		x	x	x	x
Prepared meals (sandwiches)					x
Processed meat/poultry			x		x

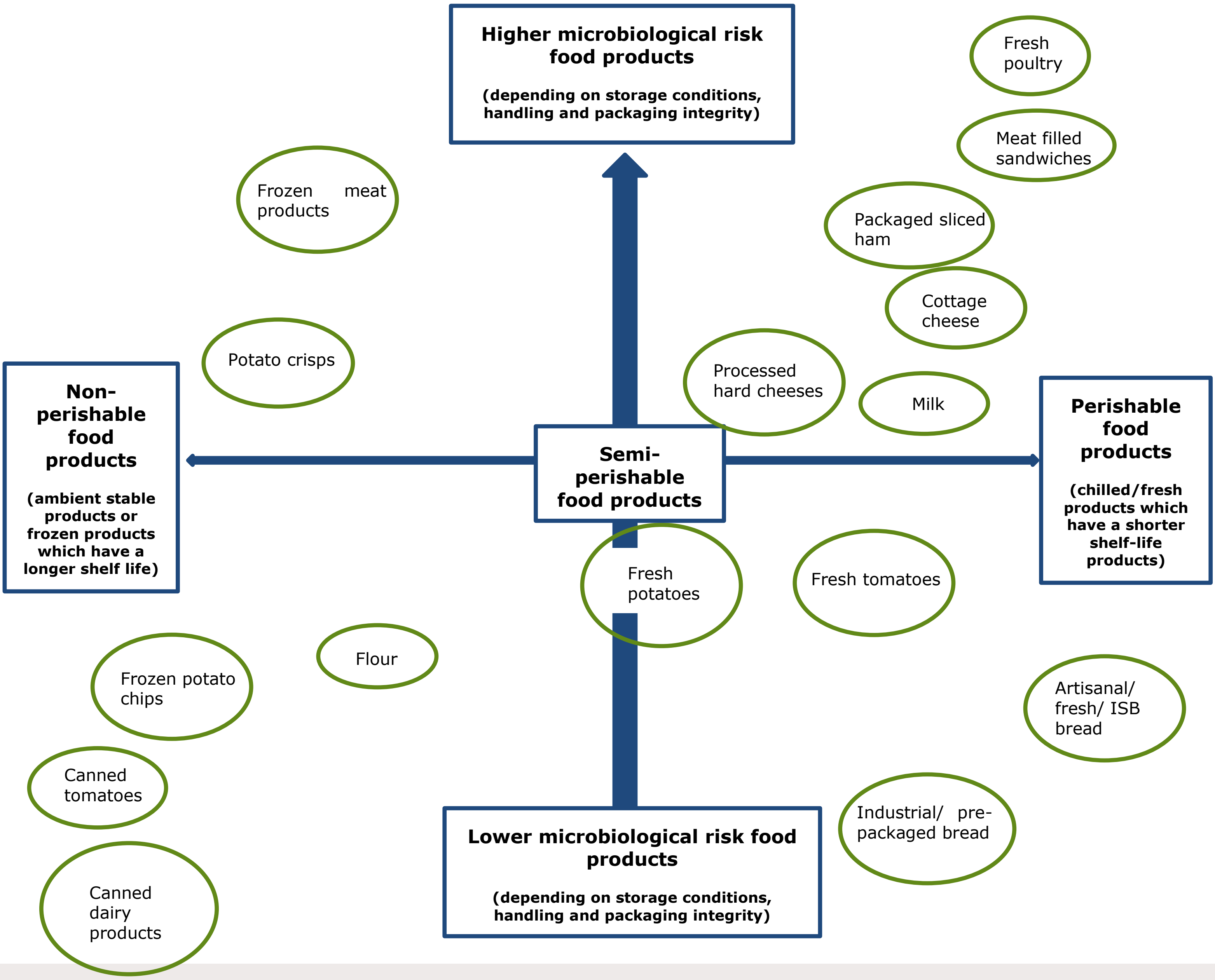
The selection criteria used to identify the food categories included:

- **Data availability**: the preliminary desk research gave some indications on whether literature is available for some specific food categories and in which EU MS.
- **Identification of "most wasted" product categories:** the project team created a shortlist of "most wasted" product categories based on the results of REFRESH report "Valorisation of appropriate waste streams" which identified top 40 priority waste streams across the EU, which is largely based off of UK-based research.
- **Consideration of product "Complexity level":** From the shortlist created from the findings of to the abovementioned REFRESH report, the final 5 food categories were selected to represent different **"complexity levels"**, defined below:
    - **Lower complexity**: single-ingredient products or low number of ingredients with few points of handling and processing stages from farm to fork.
        - Ex: **potatoes/tomatoes**
    - **Medium complexity**: products comprised of more than one ingredient, several points of handling and processing from farm to fork.
        - Ex: **dairy, bread**
    - **Higher complexity**: multi-ingredient products and numerous points of handling and processing from farm to fork and/or complex processing and value chain management.
        - Ex: **prepared meals**
- **Perishability:** The selection of the 5 product categories also took perishability, the degree of a product's deterioration in quality and food safety into account. Perishable foods' lifespan and/or food safety require preservation methods such as chilling or freezing or special storage specifications. Within the selection of products in dark spaces, etc.

- **Microbiological risk**: Defined as a risk of bacterial growth on foods that may result in food poisoning, certain food categories have a higher microbiological risk than other. This could be because they are cooked incorrectly, stored at the wrong temperature, or have exceeded their 'use by' date. This criteria was taken into consideration for the selection of the 5 product categories which have variant levels of microbiological risk. Furthermore, this criteria was important to highlight as microbiological risk is one aspect of food safety, alongside toxins, allergens and food contamination that is considered within the EU REGULATION (EC) No 178/2002 (which lays down food safety procedures).

Illustration of the degree of perishability and microbiological risk for selected 5 food categories

The produc**ts/**ingredients listed in the **below** diagram **are examples of products/ingredients that** fall within each of the 5 **selected** food categories **listed in the table at the beginning of this section:**



In addition to a consideration for the previous work on drivers within the FUSIONS project, the REFRESH project team has conducted:

- Desk research to obtain data and information on the selected food products in France, UK, Italy, Sweden and Germany. It should be noted that these countries were selected based on the countries of origin of the REFRESH policy project team to facilitate data collection.
- Interviews with 2-3 stakeholders per each selected country to obtain an on-the-ground viewpoint from the industry as well as to fill in information gaps and cross check information found through desk research.

RELEVANCE AND LIMITS OF THIS REPORT

The added value of studying the value chain using a bottom-up analysis is that **it better captures business behaviour and the relationship between actors across** the food supply chain that are not always apparent when assessing the food value chain using a top-down analysis. Using a product group approach also allows to link drivers to product properties (complexity, perishability, risk etc.).

In parallel, the top-down analysis is more efficient in identifying drivers at each step of the supply chain (e.g. the need to increase food donation), but it does not provide a systemic view of drivers (e.g. the link between increase in food donation and increase in food price discounts).

Regarding the limits of this report, as a top-down approach on food waste driver identification has already been conducted within FUSIONS, this report will not extensively detail and transcribe the findings of FUSIONS. Rather, it will refer the reader back to the original report, and only when relevant will highlight pertinent findings from FUSIONS.

Regarding the selection of countries in which the report zoomed in on through desk research and interviews, as only five were used to draw conclusions, limitations arise from a limited country sampling.

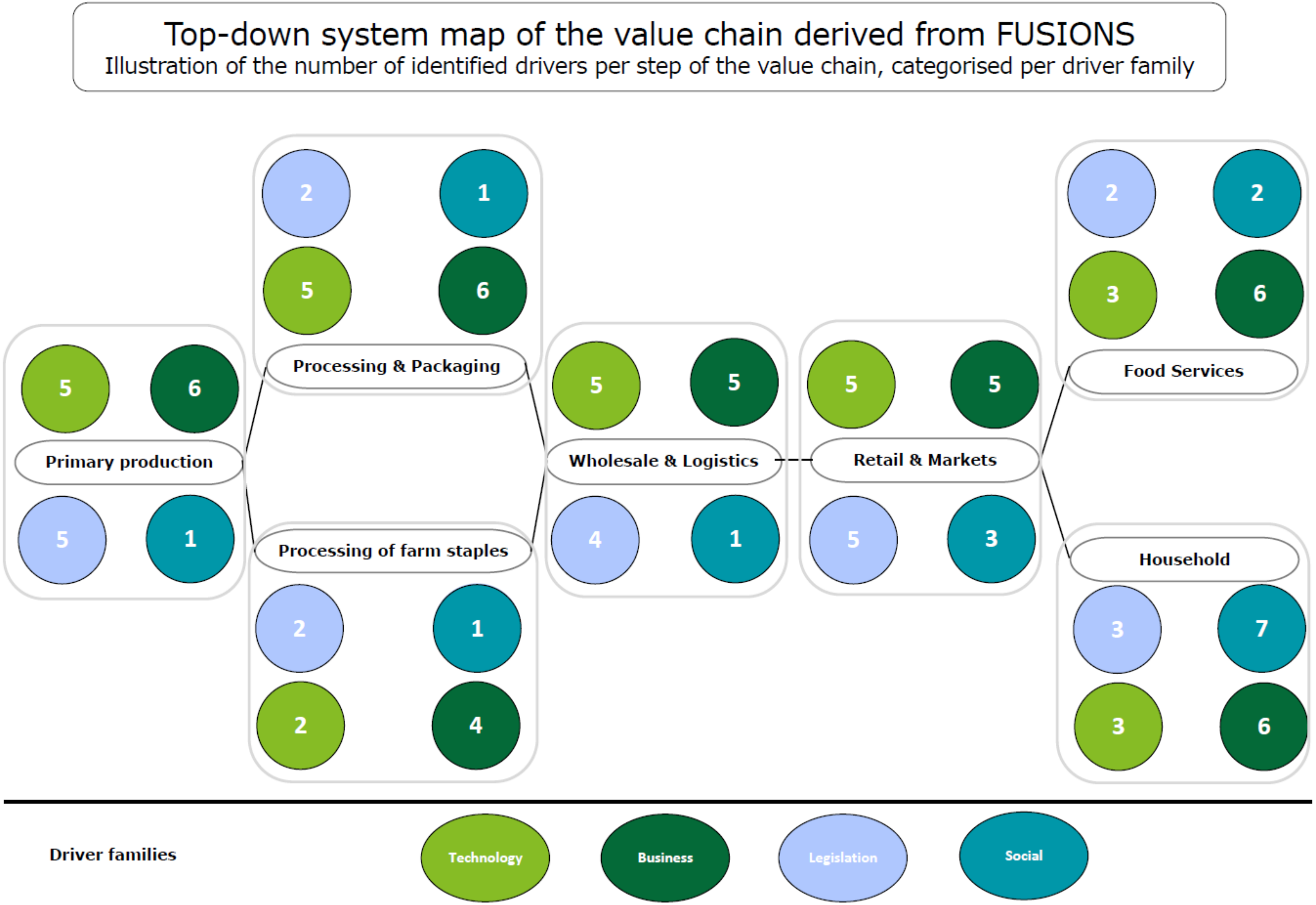
Furthermore, while this report is not intended to directly provide solutions and recommendations to policy makers, the key findings identified through the analytical framework will be further explored and will feed into further REFRESH policy work, including task 3.2 EU Policy Review and task 3.3 Policy-mix Assessment, with the objective of forming potential policy recommendations.

3 Top-down analysis

For the **top-down approach**, the REFRESH project team capitalised on the previously conducted work on drivers within the FUSIONS project. The 105 drivers identified within the report "Drivers of current food waste generation, threats of future increase and opportunities for reduction" provided useful insight into the influences of technological, institutional (public – legislative), institutional (private - business), and social drivers (Canali et al. 2014). These drivers families, which are illustrated in the following section were identified within the FUSIONS project via literature review and expert interviews by considering the entire supply chain without looking at particular food categories. These drivers were further examined in a scientific publication written by the FUSIONS project team. Special attention was given to identify legislative policies as comprehensively as possible. The full list of policy drivers, including legislative policies can be found within the FUSIONS report (Canali et al. 2014).

LAYOUT OF THE FOLLOWING SECTION

Based on the previous FUSIONS report, the REFRESH project team created a system map as seen below, to illustrate the number of identified drivers per driver family within each step of the value chain, categorised per the driver families listed above. It should be noted that the detailed list of the identified 105 drivers is not included within this system map, however it can be accessed within the FUSIONS report (Canali et al. 2014).


Top-down system map of the value chain derived from FUSIONS
Illustration of the number of identified drivers per step of the value chain, categorised per driver family
2
1
5
6
Processing & Packaging
2
2
3
6
Food Services
5
6
Primary production
5
1
5
5
Wholesale & Logistics
4
1
5
5
Retail & Markets
5
3
Processing of farm staples
2
1
2
4
Household
3
7
3
6
Driver families
Technology
Business
Legislation
Social

This system map exercise facilitated the identification of high impact areas along the value chain according the conclusions from the identfied drivers within FUSIONS. In other words, through this mapping exercise, the amount of drivers per step of the value chain is easily seen. It should however be noted that although FUSIONS work conducted a general analysis of the value chain, because of lack of data and information availability within certain stages, these identified drivers were not completely exhaustive. Hence, the breakdown of the drivers per stage should be considered with caution.

Figure 1 below gives an overall picture of how the 105 identified drivers are broken down into the various steps of the value chain. It should be noted that the "primary production" section of Figure 1 groups together the number of drivers in the "primary production" and the "processing of farm staples" within the above system map as these steps were considered to be closely associated. Furthermore the "food service & household" section of Figure 1 groups the separate "food services" and "household" steps of the value chain as seen in the above system map, also because these steps were considered to be closely associated.

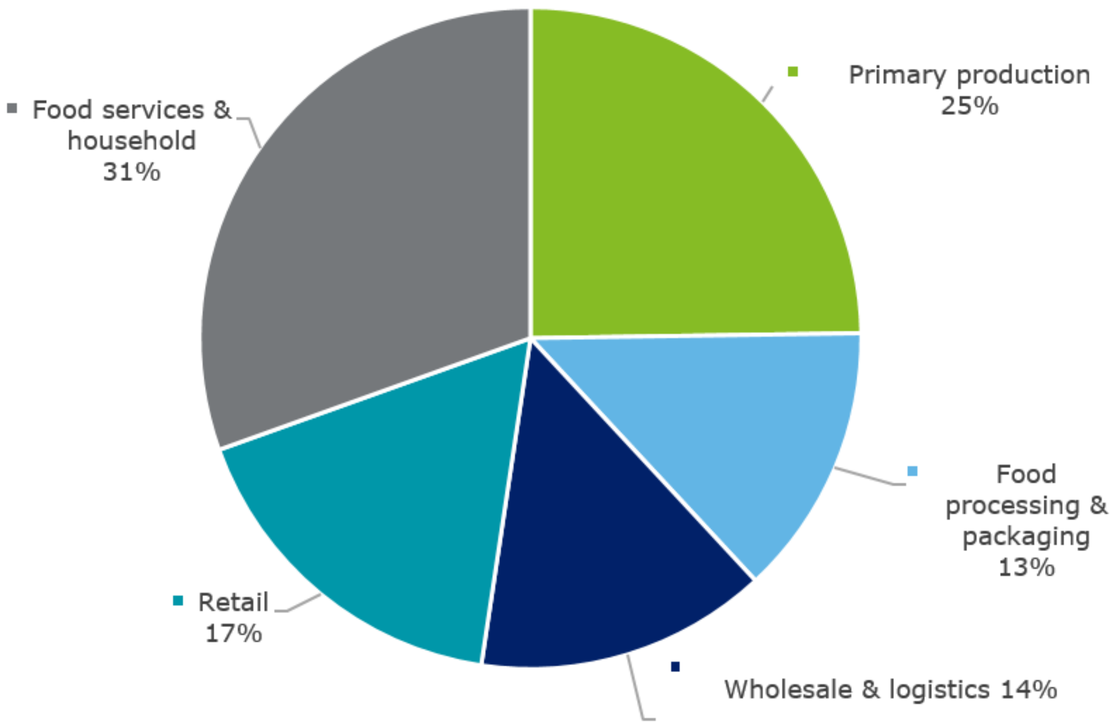


Figure 1: Breakdown per value chain step of FUSIONS-identified 105 drivers

Figure 1 shows that the food service & household step accounts for 31% of the identified food waste drivers. Furthermore, the FUSIONS report "Food waste data set for EU-28", found that the household sector contributes the most to food waste at around 47 million tons per year, plus food services at around 11 million tons per year. Collectively these two sectors account for nearly 65% of waste generation within the value chain. A clear link between the number of drivers and the amount of food waste was seen with this value chain step.

The primary production step has the second highest amount of food waste drivers, accounting for 25% of the 105 drivers. Considering this figure with the same logic as with the food service and household sector, it could be inferred that food waste **generation** would also be the second highest within this sector. However, the FUSIONS estimation concluded that this step of the value chain was assessed as the third highest generator of food waste at 10%, falling behind the processing step, which accounts for 19% of food waste. As FUSIONS suggested. FUSIONS determined that there is **considerable uncertainty** and reason to believe that waste generation data in the primary production was underestimated because of lack of data. It was therefore concluded that within REFRESH, a focus would be given to primary production, especially since 25% of food waste drivers were identified within this step of the value chain (as seen in Figure 1). Also, if the viewpoint was extended to focus on loss of value/downgrades within the primary production sector, identified food drivers would surely increase. For example, potatoes used as stock feed is a poor substitute for selling potatoes to the intended (consumer) market.

This approach is seen within the "bottom-up" analysis section below.

While the break down of food waste drivers provides information on the hotspot areas of food waste generation, this breakdown should be interpreted with caution. It does not show how these drivers effect and are effected by other stages of the value chain, nor is it a direct reflection of the significance or impact of food waste within a particular sector. As emphasised in Chapter 4, many of these drivers are inter-linked with more than one step of the value chain and defined as "systemic drivers".

4 Bottom-up analysis

The "bottom-up" analysis was conducted in order to complement the top-down approach conducted within FUSIONS. This "bottom-up" analysis focuses on following the life stages of different food categories to better understand how food waste is generated from production all the way to consumption, including food surplus, waste and valorisation at each successive stage per product category. This approach facilitates a qualitative understanding of the various food waste drivers within each step of the value chain and specific for each product. When relevant, the "complexity" of the product (i.e. the level of processing that it has undergone) was considered, as well as any country differences. These details were not a main focus in the top-down approach. It furthermore facilitates an illustration of food waste/valorisation flows, which was not conducted within the top-down approach.

The analytical framework presented within this bottom-up analysis aims to generate more insight on which drivers are product specific and facilitates the identification of the role that different actors play. It also shows how drivers affect the value chain, either as drivers non-systemic within a particular step of the value chain, or as systemic drivers, which affect more than one of these steps.

LAYOUT OF THE FOLLOWING SECTIONS

Within each of the sub-sections, which detail the value chain of: bread, dairy, potatoes, tomatoes/potatoes, prepared meals (sandwiches), and processed meat/poultry, the following layout is followed:

- **Context of each particular food category**, setting the stage for the analysis and including **EU-28 production and consumption data**. This data is interesting to consider, as it shows where potential imbalances/differences may lie in food production and its consumption, and how potential policies may be more relevant to apply in particular countries.
- An illustration of the drivers and value chain of each particular food category via:
    - A **system map which provides an overview of each product's value chain**. This system map highlights the drivers that were identified by REFRESH partners as being common throughout all stages of the value chain for each product. This system map facilitates the identification of different driver family categories, as discussed in relation to the top-down approach: technological, institutional (public – legislative & private - business), and social.
    - A written **overview analysis** of each food categories' key findings/drivers.
- **Zoom on each step of each product's 4 value chain steps via:**

- A **system map**, zoomed in on each of the 4 steps of the value chain.
- **Summary** of each step of the value chain following each system map, outlining the value chain steps' main "take-aways".
- **Description** of each step of the value chain, going into further detail than in the summary, highlighting country specific information and data when relevant.

It should be noted that as data and qualitative information availability varied from country to country, certain product categories contain more or less information.

4.1 Bread

For the **bread** food category, the following country-specific information is detailed below per value chain step:

Food product category	Countries covered in the study				
	DE	FR	IT	SE	UK
Bread	x	x			x

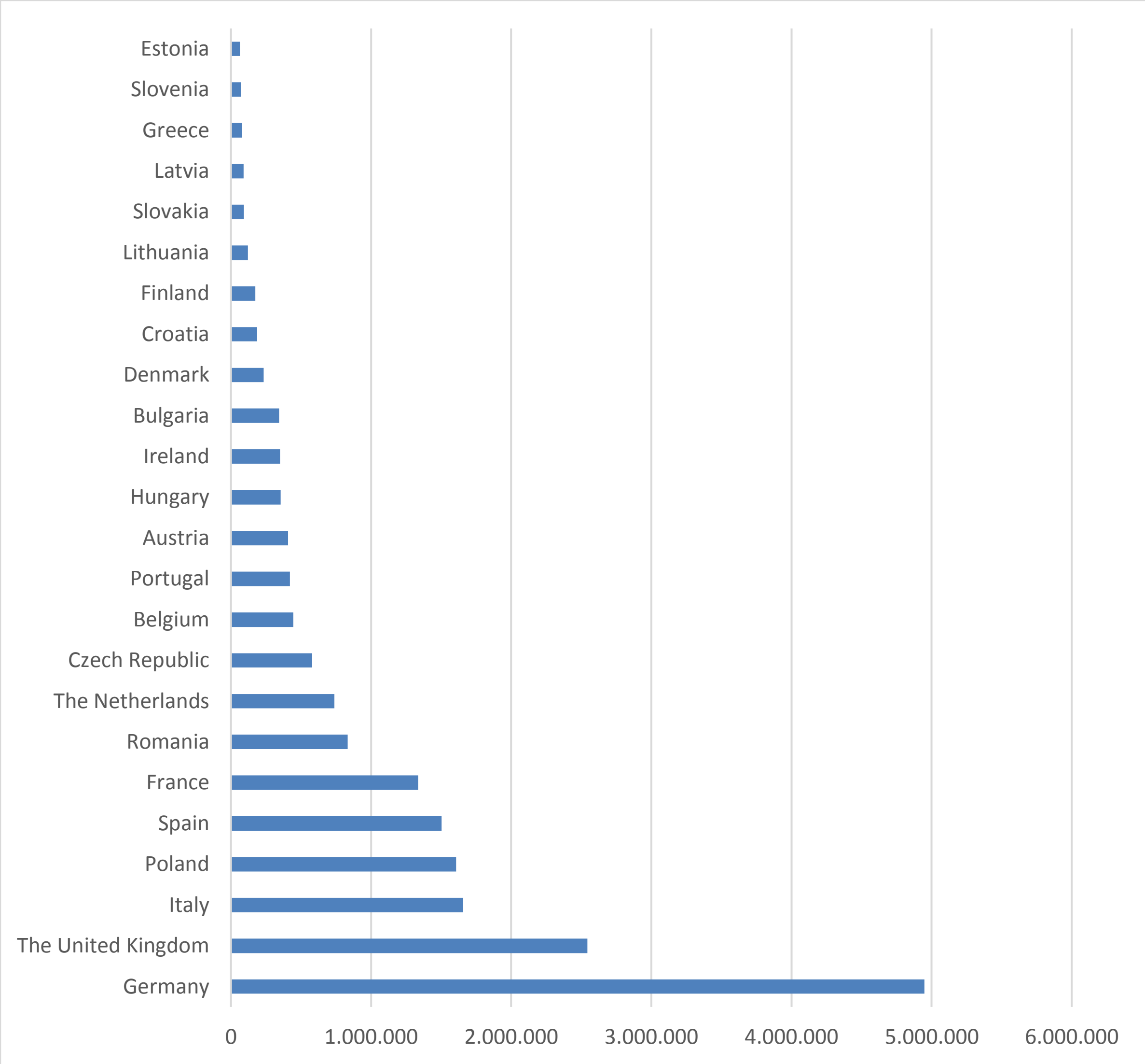
4.1.1 Context

The bakery sector produces a wide variety of products that include both shelf-stable and perishable breads, leavened or unleavened and dough–based baked products. These products do not typically contain eggs.

40.6 Mt of bakery products (bread) are manufactured in the EU-28 according to 2012 Eurostat PRODCOM data (Eurostat, 2012). However, this total is limited to industrial bakeries within the food manufacturing sector and excludes small bakeries/SMEs (hence lower than expected values for certain MS which have a large representation of small bakeries, such as France).

As seen in the graph below, the most significant producers within this scope were Germany with almost 5,000,000 tonnes and the UK with 2,500,000 tonnes (Eurostat, 2012). In line with high production, along the food supply chain bread is also one of the most wasted product groups in Germany (Ritter u. a. 2015). An estimated 10-20% of bread produced in Germany is not consumed, amounting to between 573,000 and 763,000 tonnes of bread waste annually (Ritter et al, 2015).

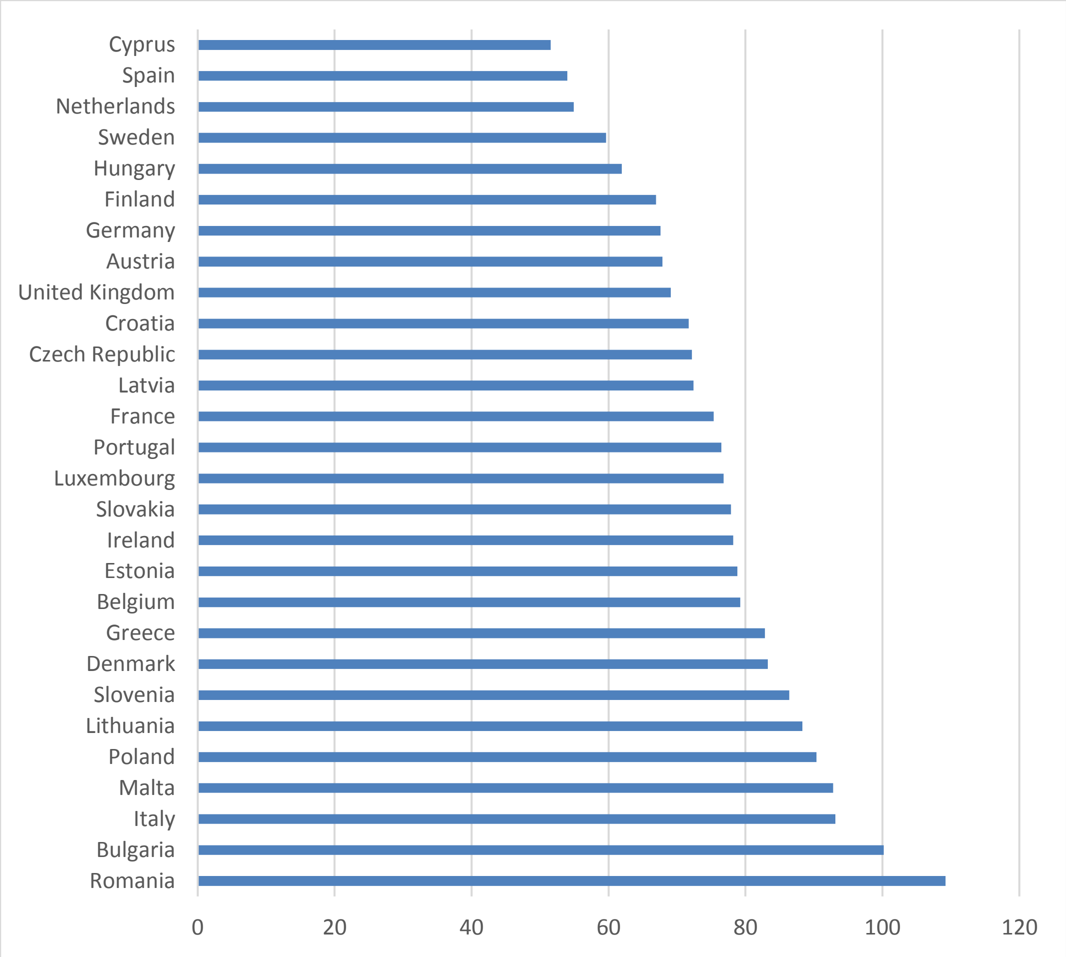
EU-28 bread production across Europe, tonnes in 2012 (Eurostat, 2012)



Regarding the repartition of bread production by different methods, the data from different sources differ greatly. According to Gira Food, the type of supply for EU countries in 2015 was 33% of artisanal supply and 67% of industrial supply (Gira, 2016). Among the total amount, this study estimates that 22% of the supply was provided by in-store bakeries (18% of industrial bake-off bread and 4% of in-store artisanal bread) (Gira, 2016).

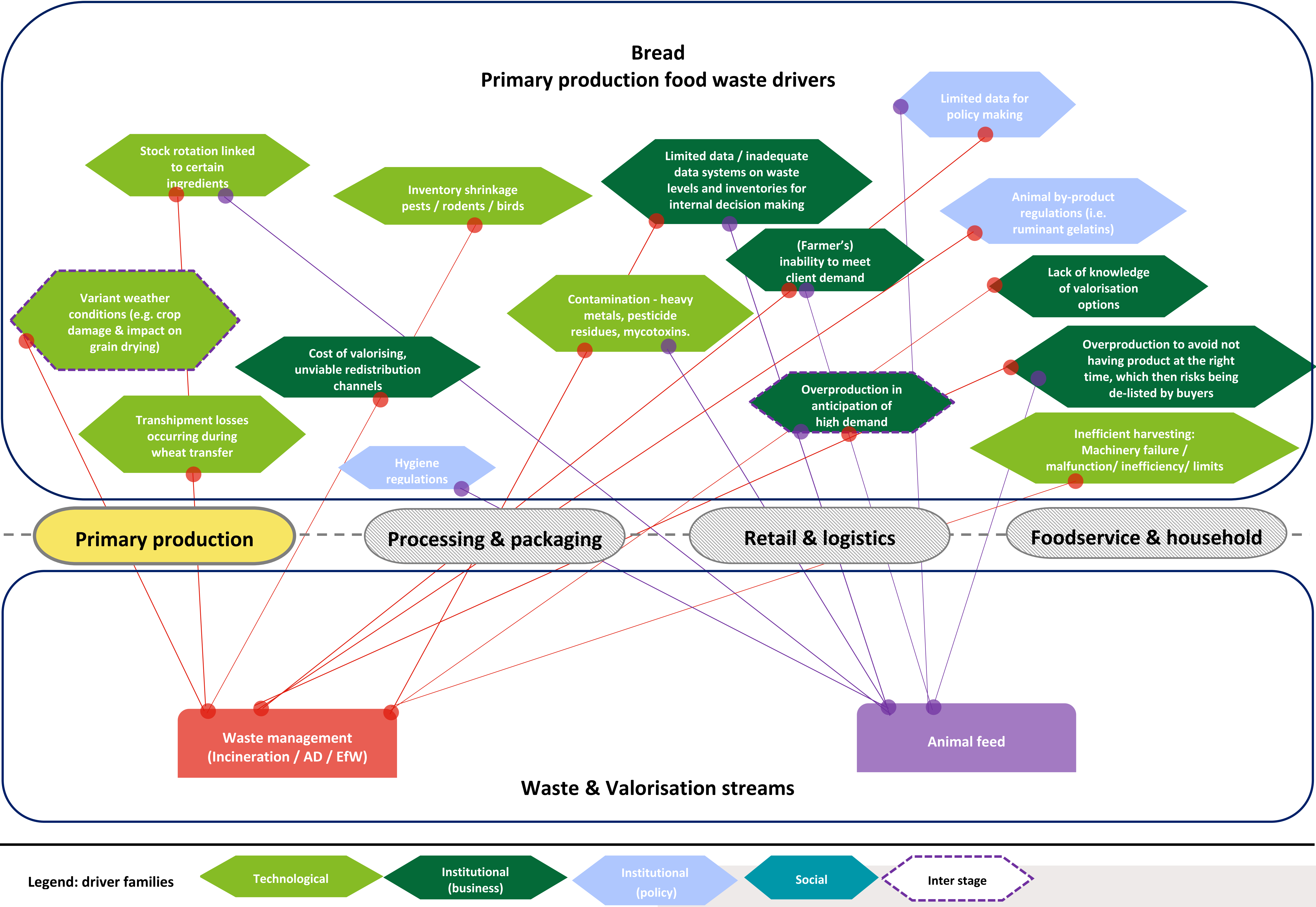
The conclusion of the research lead by AIBI was that in Europe 2013, the share of craft bakers was 52% and the one of industrial bakers 48% (AIBI, 2015). This study demonstrated that major discrepancies exist between the European countries since the market share of industrial bakers is 85% in the Netherlands while it is only 15% in Italy (AIBI, 2015).

EU-28 Bread consumption: kg per capita (FAO Stat 2011)



4.1.2 Bread system maps per sector of the supply chain

The following section covers in detail the drivers that affect the different stages of the supply chain. For each step of the value chain, a dedicated system map provides a zoomed-in illustration of the identified drivers and waste/valorisation streams for each particular step:


Bread
Primary production food waste drivers
Limited data for policy making
Stock rotation linked to certain ingredients
Inventory shrinkage pests / rodents / birds
Limited data / inadequate data systems on waste levels and inventories for internal decision making
Animal by-product regulations (i.e. ruminant gelatins)
(Farmer's) inability to meet client demand
Lack of knowledge of valorisation options
Variant weather conditions (e.g. crop damage & impact on grain drying)
Contamination - heavy metals, pesticide residues, mycotoxins.
Cost of valorising, unviable redistribution channels
Overproduction to avoid not having product at the right time, which then risks being de-listed by buyers
Overproduction in anticipation of high demand
Transhipment losses occurring during wheat transfer
Inefficient harvesting: Machinery failure / malfunction/ inefficiency/ limits
Hygiene regulations
Primary production
Processing & packaging
Retail & logistics
Foodservice & household
Waste management (Incineration / AD / EfW)
Animal feed
Waste & Valorisation streams
Legend: driver families
Technological
Institutional (business)
Institutional (policy)
Social
Inter stage

BREAD: SUMMARY OF PRIMARY PRODUCTION STAGE

Within the primary production stage, the production of bread starts with wheat harvesting.

At this stage, food waste drivers are predominantly technological (contamination, inventory shrinkage, inefficient harvesting, etc.) or institutional (business management) like overproduction, minimum orders or cost of valorising. There are also some institutional (policy) drivers such as hygiene and animal by-product regulations for instance (European Commission, 2011; European Parliament, Council of the European Union, 2005).

It seems that the loss at the primary production for bread has the same origin in the three countries studied (UK, Germany and France), even if the waste quantities which will be presented later on in this section tend to show minor discrepancies. Within this stage, food loss drivers can be divided in two major categories: non-systemic (specific to the agricultural sector only) and systemic (connected with the other stages of the value chain and influence by their actors).

- The drivers non-systemic to the primary production stage, such as variant weather conditions, inventory shrinkage, inefficient harvesting, etc. which generate food loss can be tackled by the producer himself. This may involve technological investment, discussion about the storage practices or disease prevention.
- When it comes to systemic drivers, since farmers are the first actors to handle food production within the value chain, every decision (such as product orders) made by downstream actors have a direct or an indirect impact on their activity and hence, influence their food loss levels. Overproduction, minimum orders, lack of data and lack of communication have an impact on wheat farmers. Fortunately, wheat is not a perishable product which allows a certain degree of storage flexibility when this crop is harvested with a surplus.

The main valorisation stream for food loss within this step is animal feed as it is unlikely that grain that does not meet the necessary requirements for use in bread production is incinerated or sent to AD. For that reason, it is not considered waste, however as a recovery/valorisation operation according to the FUSIONS definition (Canali et al., 2014). If grain is considered unsuitable for use in animal feed (because of poor quality), it is usually composted.

BREAD: DESCRIPTION OF PRIMARY PRODUCTION STAGE

The primary actors within this stage are farmers, which have the objective of ensuring meeting the quality standards of milling companies and selling their crop for the best economic value.

On the field, bad **weather conditions** – especially heavy rain and hail – can lead to diseases or premature sprouting (Juin, 2015). Losses are higher during wet harvesting conditions, for if the grain has a high moisture content. In the case that the drying solutions cannot reverse the water-saturated grain, it will be redirected to valorisation.

The presence of **pest and rodents** in the fields also diminishes the available amount of products which can be harvested (France Nature Environnement, 2015). It is still very complicated to evaluate the quantity of wheat lost in these cases because of insufficient means to track this loss (INRA, 2015).

Harvesting machines lack a degree of speed and precision which can lead to **inefficient harvesting** loss. This is due to technical machinery issues which is estimated at 6% depending on the type of equipment used.

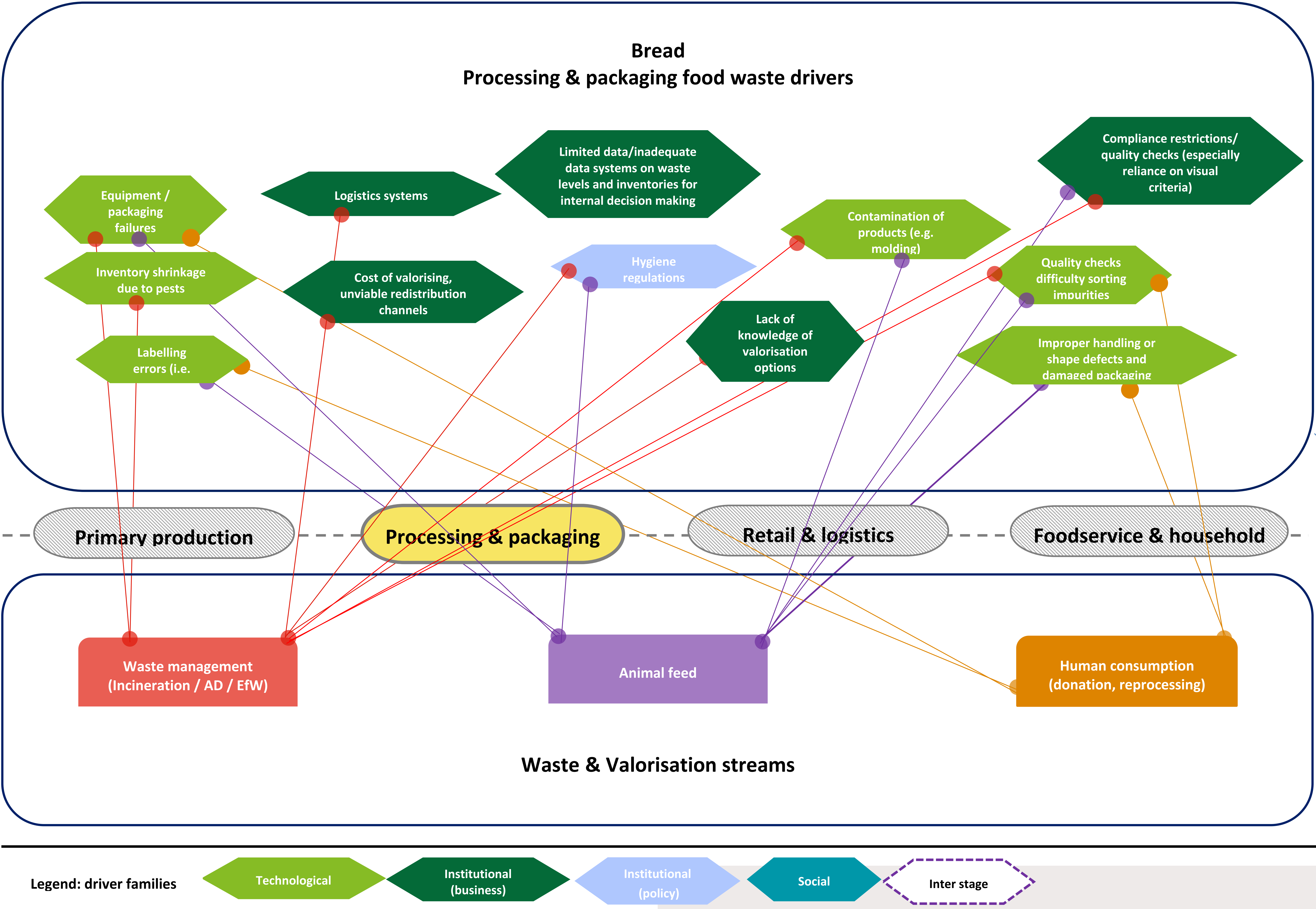
Once the wheat is harvested, it is often stored in silos before it is either sent for offsite milling or transformed onsite. There is some waste at this stage which is called "**inventory shrinkage**" and it is evaluated at 0.1% of the grand total of grain. This phenomenon is due to rodents, birds and insects but also to storage failures. Since the farmers are encouraged to use less pesticides and rodenticides, the shrinkage might increase in the future, as long as they meet feed quality standards.

Finally, after the harvesting stage but before processing the grain, another 2% of the harvest is lost because they are not suitable for human consumption according to **hygiene regulations for human food** (European Parliament, Council of the European Union, 2005) (in terms of quality, humidity or contaminants). The main **contaminants** found within these grains that render the crop unsuitable for human consumption are: are heavy metals (such as lead, cadmium or mercury), pesticides residues and mycotoxins. The food loss deemed unfit for human consumption but still respecting the criteria of **animal feed regulations** (European Commission, 2011) (for example on ruminant gelatines) are usually fully valorised via animal feed. In spite of these regulations, **diversion to animal feed is perceived as a source of revenue** compared to other food scrap redistribution sectors. Even though this is a valorisation route, it might be less desirable as others since it is lower on the waste hierarchy. This is due to l**ack of knowledge of valorisation options and their cost.**

Limited data or inadequate data systems on waste levels and inventories for internal decision making is also a key driver to food loss during primary production. Farmers' direct contacts with actors within the value chain are milling companies. Farmers tend to **overproduce** to ensure having sufficient wheat stock to be able to supply it to milling companies at a moment's notice and furthermore to compensate for unforeseeable weather conditions that may harm crop yield. The **inability to meet a client's demand** puts farmers at risk of being de-listed by the buyer. In regards to **overproduction**, since farmers do not control the market, its fluctuating nature creates uncertainty for a farmer's activity; depending on the varying degrees of product demand from the actors at the end of the value chain, it is not uncommon to have peaks of market saturation (INCOME Consulting - AK2C, 2016).

Furthermore, **transhipment losses,** which occur when the wheat is transferred from one container to another when transporting grain from the farmer to the buyer/milling company. The losses at this level can be handling errors, labelling errors, packaging failures, etc. Therefore limiting the transfers to a minimum leads to waste reduction.

All in all, it is estimated that during the primary production stage, losses vary from 1 to 5%, which represent around 300000 tons a wheat yearly in France (INCOME Consulting - AK2C, 2016). In the UK, harvesting of grain in highly mechanised arable farming systems results in losses of 2-3%. In Germany, the available data is not sufficient enough to identify which type of grain is used to produce bread, and therefore its levels of waste at this stage of the value chain.



Bread
Processing & packaging food waste drivers
Equipment / packaging failures
Logistics systems
Limited data/inadequate data systems on waste levels and inventories for internal decision making
Compliance restrictions/ quality checks (especially reliance on visual criteria)
Contamination of products (e.g. molding)
Inventory shrinkage due to pests
Cost of valorising, unviable redistribution channels
Hygiene regulations
Quality checks difficulty sorting impurities
Lack of knowledge of valorisation options
Labelling errors (i.e.
Improper handling or shape defects and damaged packaging
Primary production
Processing & packaging
Retail & logistics
Foodservice & household
Waste management (Incineration / AD / EfW)
Animal feed
Human consumption (donation, reprocessing)
Waste & Valorisation streams
Legend: driver families
Technological
Institutional (business)
Institutional (policy)
Social
Inter stage

BREAD: SUMMARY OF PROCESSING & PACKAGING STAGE

Within the processing & packaging stage, the bread product is in its grain stage and undergoes milling and baking.

These two transformation stages are considered to be well mastered with less risk of food waste than at the primary production stage. It can be generally said that this stage's main waste driver is compliance to client quality standards.

Similarly to the primary production stage, other drivers identified at this stage are mainly technological or institutional (business) related to manufacturing and processing systems but also related to data/information management.

Drivers non-systemic to the processing & packaging stage such as contamination, human mistakes, and equipment failure, are usually related to the transformation/milling process itself. The systemic ones such as minimum orders (from clients), data systems or quality controls are independent from milling processes or the bread baking and concern all the stakeholders of this stage (milling companies, procurement companies, and industrial bakeries). Furthermore, the first batch of bread baked is usually thrown out as the oven's temperature goes through an initial period of temperature variations. The personnel uses the outcome of the first batch of bread to then calibrate the oven accordingly.

As detailed below within milling and baking, France, UK and Germany have waste quantity differences, which could have two different causes. The most apparent is that the management of grain milling is more efficient in some countries (better equipment, better worker training, etc.). Sharing best practices for waste-reduction within this sector could benefit all actors involved and thus have a leverage effect on food waste reduction.

Another explanation for this waste quantity differences is that it is not quantified in the same manner.

It is worth noting that food waste cannot be tackled similarly for industrial bread and artisanal bread. The production process is not structured in the same way and even if some loss cause can be similar (e.g. flour contamination), potential food waste reduction solution have to be specific for each of these two sectors.

The waste and valorisation streams for this stage are incineration or anaerobic digestion and use as animal feed is human consumption by way of donation or reprocessing.

BREAD: DESCRIPTION OF PROCESSING & PACKAGING STAGE

Given the complexity of how bread is processed, this section is divided into two parts: milling and bread production. Milling consists of transforming the wheat grain into flour and bread production is the baking process.

Milling

The amount of waste generated within this stage (without taking into account the quality controls) varies between the countries and is slightly different depending on the source: around 5% in France (Juin, 2015), 10,5% in Germany (Jepsen u. a. 2014) and below 1% in the UK. This shows an incoherency of data across countries within the same sector of the value chain which could be attributed to how food waste is managed, quantified and monitored. For example, one country may count grain rusk as waste while another country may not. These definitional differences therefore greatly influence data comparability.

Before milling, grain is sorted on site by milling companies in order to remove grain that is unfit for processing (for example, grain is sorted out if it is broken, fusarium-infected, etc.). Special attention is made to only process grain that is considered by the milling company as compliant to hygiene regulations (European Parliament, Council of the European Union, 2005). Furthermore, if any particular specifications are laid out by the client, the milling company must take it into account. About 2% of the eliminated grain is removed from the stock due to **quality control** and **compliance restrictions** before the milling process (Juin, 2015).

During milling, in France about 3% of the input is wasted during process and storage. Another 3% are refused by the clients (damaged bags, etc.) and 1% is lost during transport and handling (INCOME Consulting - AK2C, 2016). One third of this total goes to landfill, one third goes to animal feed and the last third (especially the damaged bags where flour still meets quality criteria) is reused in the chain for human consumption (INCOME Consulting - AK2C, 2016). Even if grain milling is known to be rather efficient, equipment failure or equipment that is not calibration to its optimal state remains an issue (Ritter 2017). These mechanical issues may lead to the presence of by-products generated from the machine's self-cleaning (or manual cleaning) processes, from the presence of **contaminates** within the processed grain, which may be generated from issues with the machine's filter. It should be noted that by-products (especially the grain husk or brans) are sent to animal feed and they are not considered as waste otherwise they would account for 20% of the transformed volume (Juin, 2015).

Some loss has been identified during packaging: bags are pierced, humid or the transfer can encounter a problem. In that case, the wasted flour goes to animal feed but when there are issues in the bag sealing operations the products are definitely lost. Products can also be rejected by clients (distributor, bakeries) due to packaging issues such as damaged bags (3%) (Juin, 2015). However most of the times the loss is only superficial and does not affect the quality of the goods as the flour is usually repackaged for human consumption.

The same "**inventory shrinkage**" phenomenon that occurs during the primary production step happens during storage because of the presence of birds and rodents in the stock space. The amount of products lost (0.1%) is the same (Juin, 2015).

Finally, **waste during transportation** (both before and after the processing stage) and transhipment are inevitable. This can come from the deterioration of the bags but also from blockages during loading. Concentrating the whole production-transformation process (collect, storage and milling onsite) and working with big volumes leads to a diminution of the loss.

Bread production (large and small scale baking)

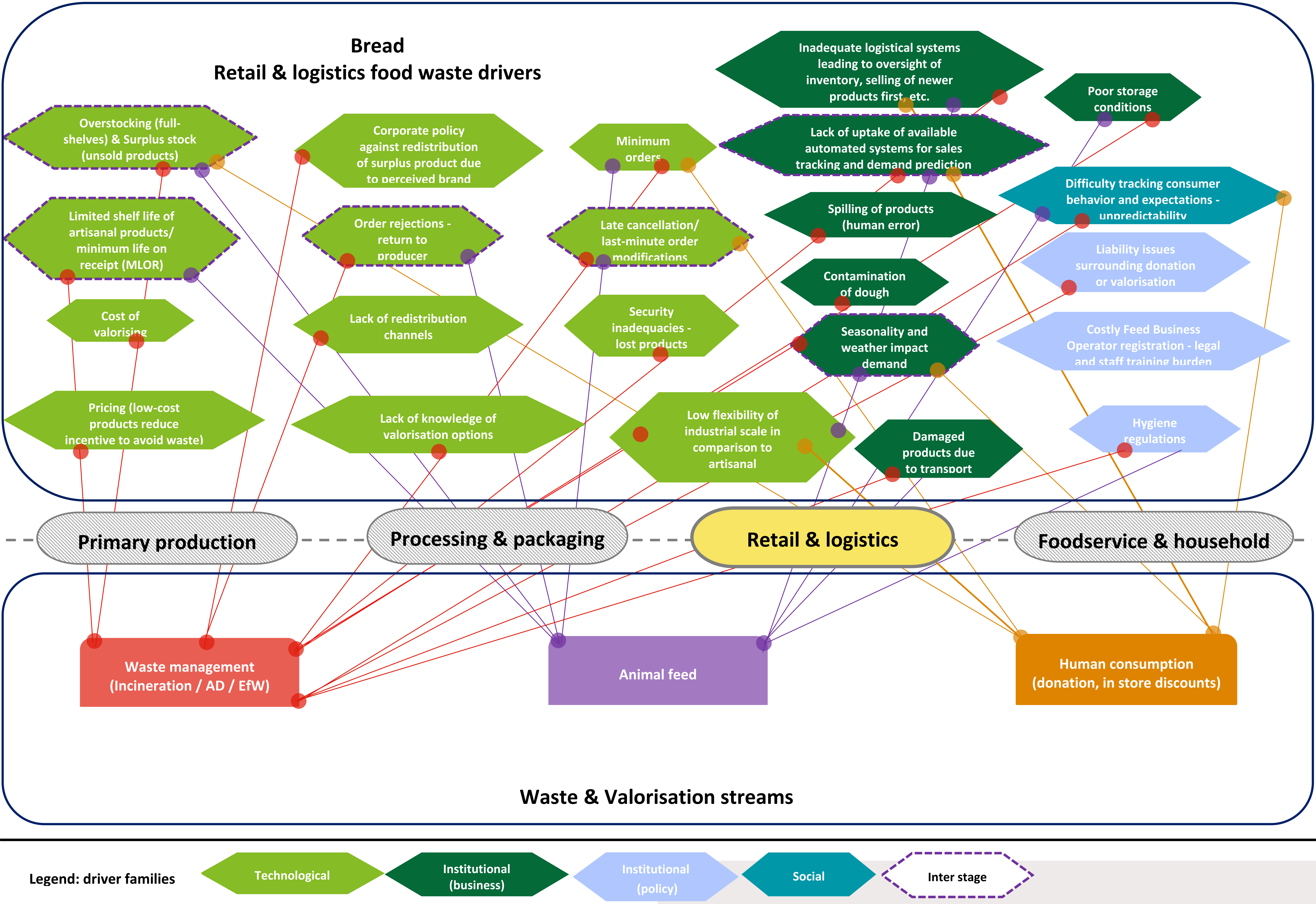
Bread production can be divided within two main categories: large scale (industrial production) and small scale (production in bakeries and within the supermarkets). The loss during production is similar for both categories. In France, it is estimated that between 2% and 3% is lost during this process (INCOME Consulting - AK2C, 2016). Differences can be seen in waste in industrial bakeries as opposed to artisanal bakeries. In industrial bakeries, quality management tends to be more standardised. If the quality management does not take into account the whole process system, this might lead to less waste. However, due to the higher volume of bread processed at once, one production error can in turn produce a significant amount of waste. Halting production to correct an error within industrial baking takes more time than in small scale baking, and employees operating the machinery may lack the training or decision making power to recognise and correct errors quickly.

In artisanal bakeries, errors may occur with more frequency due to the lack of automated processes/machinery, but the amount of waste produced with each error is smaller. Artisanal bakeries also have more direct contact with consumers and shorter and more agile decision-making chains, which can facilitate quicker reactions and more flexibility to conditions that can drive waste. (Ritter 2017). The causes of product loss during the baking process are wide:

- Flour infestations (flour beetle) are rare but result in need to be disposed as hazardous waste.
- Dough mixing, fermentation, dividing, panning and moulding, proofing: any dough scrap that cannot be re-worked may be baked and sent to animal feed.
- Baking: over or under baked bread: sent to animal feed, unless bread product contains animal by-products that are ineligible for use in animal feed (e.g. ruminant gelatines (WRAP, 2016).
- Slicing/bagging: handling errors and shape defects in loaves, labelling errors, packaging failures and customer returns

Human mistakes such as flour spilling are also to be considered but complex to quantify as ingredient spill is usually done in small quantities over larger periods of time. Multi-ingredient bread products with complex recipes leaves more room for human error at the mixing stage. On the opposite spectrum, products with simpler recipes have a reduced error potential.

As several ingredients are needed to bake bread, such as spices, flavouring or yeast, the logistics associated (storage, use before they get outdated, etc.) are an issue which needs to be addressed efficiently. In order to manage properly all these different types of input, efficient **data systems on waste levels and inventories** are needed but they may sometimes be inadequate. This driver is one of the most important waste factors according to German data. This slows down internal decision making but is also a limit to stock rotation. **Minimum order volumes** (the fact that bread producers have to buy a minimum quantity of inputs, sometimes higher than what they really need) for the ingredients prevent producers from managing their stock as efficiently as they would otherwise.



Bread
Retail & logistics food waste drivers
Overstocking (full-shelves) & Surplus stock (unsold products)
Corporate policy against redistribution of surplus product due to perceived brand
Minimum orders
Inadequate logistical systems leading to oversight of inventory, selling of newer products first, etc.
Poor storage conditions
Lack of uptake of available automated systems for sales tracking and demand prediction
Limited shelf life of artisanal products/ minimum life on receipt (MLOR)
Order rejections - return to producer
Late cancellation/ last-minute order modifications
Spilling of products (human error)
Difficulty tracking consumer behavior and expectations - unpredictability
Liability issues surrounding donation or valorisation
Contamination of dough
Cost of valorising
Lack of redistribution channels
Security inadequacies - lost products
Seasonality and weather impact demand
Costly Feed Business Operator registration - legal and staff training burden
Pricing (low-cost products reduce incentive to avoid waste)
Lack of knowledge of valorisation options
Low flexibility of industrial scale in comparison to artisanal
Damaged products due to transport
Hygiene regulations
Primary production
Processing & packaging
Retail & logistics
Foodservice & household
Waste management (Incineration / AD / EfW)
Animal feed
Human consumption (donation, in store discounts)
Waste & Valorisation streams
Legend: driver families
Technological
Institutional (business)
Institutional (policy)
Social
Inter stage

BREAD: SUMMARY OF FOODSERVICE & HOUSEHOLD STAGE

Within the retail and logistics stage which may also include the wholesale sector, the bread product has already undergone baking and is in its consumable state, sensitive to perishability.

The main categories of drivers are economic and business management, with a principal factor being **order volumes.** This is especially true in public catering because price often decreases when quantities rise and contracts are not flexible about the amount of bread which can be ordered. The question of how to best consider **bread perishability** within this stage it is also a major concern. In fact, most of the drivers at this stage focus around perishability: how deal with supply and demand for products with an intrinsically short term life span?

In the retail sector a major difference can be observed between the **ownership/responsibility of the bread** in countries such as France and Germany. In Germany, the contracts between retailers and suppliers allow German suppliers to return industrial bread products back to the miller/baker (sometimes more than 20% of the total shipment) (Ritter 2017) whereas France and the UK do not allow this. This finding shows that the responsibility of bread waste/surplus is assumed by different actors in different countries, leading to data incomparability.

A distinction was made between artisanal bakeries, in store bakeries and industrial bread sold in supermarkets to show how drivers differ within the context of each sub sector. For small scale bakeries, a main challenge is to delicately take demand tendencies into consideration in order to ensure a supply of fresh bread throughout the day without having leftover bread at the end of the day. This is especially important as this type of bread is not packed for long-term storage. For industrial bread, the issue is centred around ensuring that their clients supply them with bread with the longest possible expiry date (i.e. management of minimum life on receipt criteria). As for in-store bakeries, the main food waste driver is the shelf over-stocking.

The waste & valorisation streams within this step of the value chain for Germany include human consumption (in-store discounts, donations), animal feed, compost, and incineration. Animal feed is the preferred valorisation route of bread surplus for retailers since it is perceived as a revenue stream. However, each European country has different approaches to waste management in the retail sector. For example, supermarkets in certain countries are not held responsible for valorising this waste and instead mix it in with municipal waste.

BREAD: DESCRIPTION OF RETAIL & LOGISTICS STAGE

This description will first focus on the drivers identified for all types of retailers. Since some differences between the categories of retailers (artisanal bakeries, industrial bread sold in supermarkets and in-store bakeries) have been identified via the country specific research for the UK and France, these sub-sectors are presented separately.

Consumer behaviour and expectations have an indirect, yet significant effect on the entire supply chain and are therefore a major food waste driver. Macro/top-down factors such as **seasonality and the weather** affect sales at the retail level in ways that can be difficult to predict or react. As bread is generally consumed on a regular basis, seasonality does not have as much impact on consumer expectations, as would be the case for there to be ample supply of seasonal fruits and vegetables). In a general sense, the **difficulty to predict consumer behaviour** leads to waste.

This is exacerbated in badly equipped retail shops and small stores by the **lack of application** of available **automated systems** for sales tracking, which cannot be a tool to implement **demand prediction** systems. (Ritter u. a. contribute to waste by contributing to low prices of bread and baked goods, reducing the incentive 2015; Göbel u. a. 2012; Ritter 2017).

In Germany it was noticed that around 0.3% of bread products are wasted at the wholesale level and that an estimated 2.4% is wasted at the retail sector (Jepsen u. a. 2014). This is a clear example of how unclear responsibilities lead to stress on the value chain and lead to higher risk for food waste generation. Furthermore, because of these **unclear responsibilities** on which actor owns waste/surplus at each stage, data representation of food wasted per step of the value chain may not depict an accurate picture of the current situation.

Corporate policy to not redistribute surplus bread has been observed. This is motivated by the fact that they do not want to put their **brand at risk**. There are indeed hygiene and food safety risks in redistribution for which the donor could be considered responsible for. There is also a general sense that 'charities could not use so much bread' as a reason for the policy (UK expert interview, 2017). This influence the valorisation route, especially to **animal feed which is considered as revenue generating** (UK expert interview, 2017). However, the difference in sales value between the intended market versus that of use in animal feed (particularly if the product is rejected post-packing) is very significant.

High **price competition** and **market concentration** seem to be factors which amplify the risks of waste. Indeed, having available fresh products throughout the day is a top priority for the retailers but this might lead to overproduction.

Instore waste rates vary for each type of bakery products, depending on whether or not they are freshly baked and intended for same-day consumption, or longer shelf-life packaged bakery products (sliced packaged bread) or dry, stable long-life products, such as rusks.

Artisanal bread

In France, 9.6% of ready-to-consume baked bread goes to waste. This represents 3.5 tons of unsold (surplus) products a year per bakery: 15% goes to donation, 25% to animal feed and 60% is not valorised (Juin, 2015). Even though individual initiatives are launched to redirect this food surplus, such as partnerships between bakers and charitable associations, there is a lack of large-scale schemes/infrastructure to best manage this surplus.

A main reason behind wasted bread within small scale bakeries lies in misperceived **consumer demand. Fresh bread quickly goes stale as bread is preservative-free and as bakeries' packaging is not intended to preserve**

the fresh bread. Within France for example, the availability of fresh bread on a daily basis is culturally important. These bakeries are sensitive to supply and demand (for reasons relating to direct economic impacts on their business activity). Therefore it is not totally uncommon for these bakeries to run out of types of fresh bread during the day, meaning that they generally overproduce less than supermarkets. However, in the case of surplus bread, these smaller businesses usually do not have the means to organise elaborate recovery scheme, meaning that it is often time thrown out without recovery.

Industrial bread

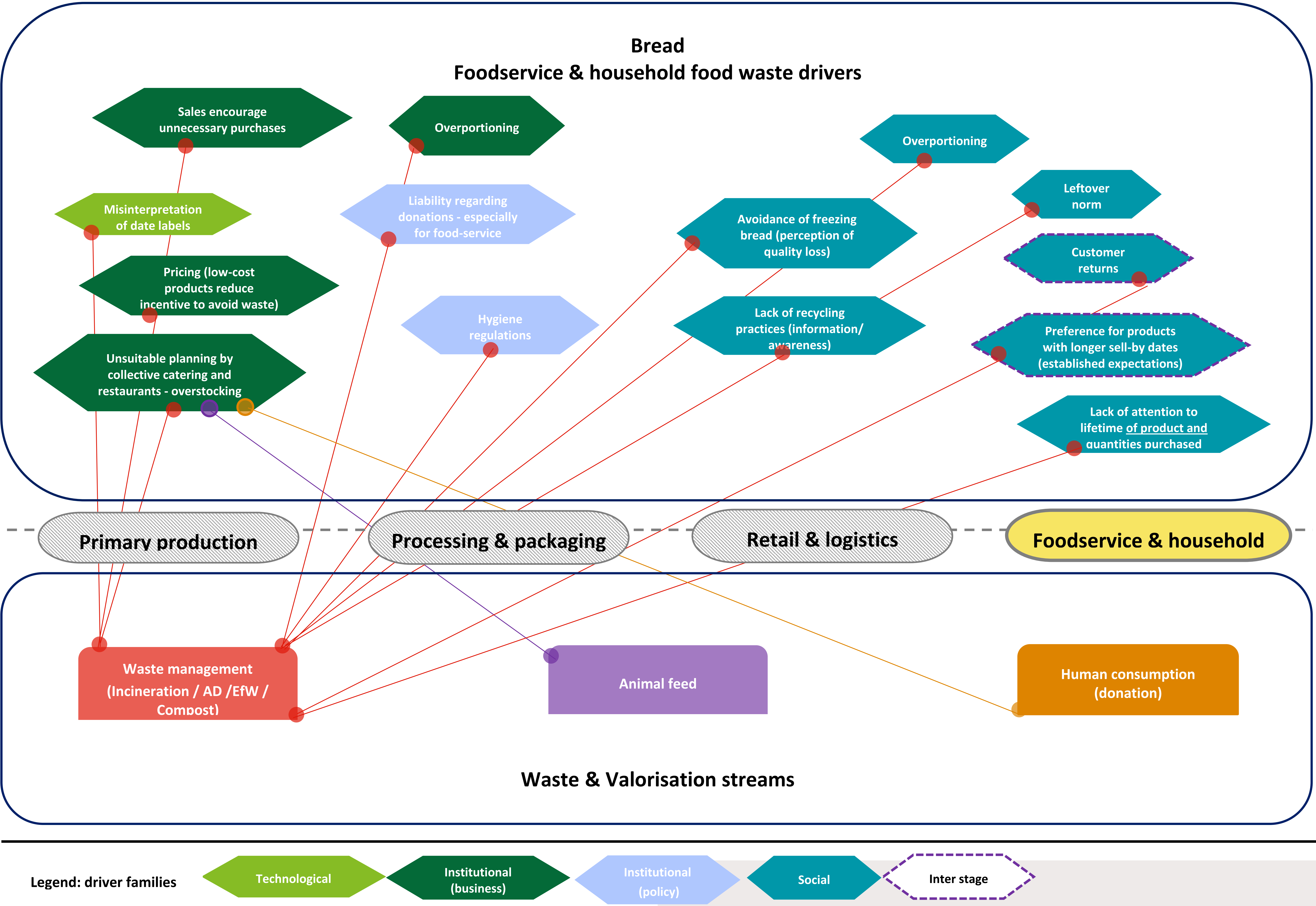
In Germany, contracts authorise retailers to **reject food products** or return it to producers for a variety of reasons, or to make **last minute changes to orders**. For the retail sector, return rates to the producer below 10% are considered good, between 10% and 20% normal, and over 20% excessive, though exact data on actual levels is not available (Ritter 2017). **Optical criteria** (overly-baked bread, product appearance) are most commonly used to determine quality and influence decisions to reject, return, or dispose of the product, despite the fact that other quality criteria such as taste, freshness, etc. may still be met.

For bread from industrial bakeries, deliveries to retail stores tend to be frequent and in small batches in order to guarantee **minimum life on receipt criteria (MLOR).** In the UK, a WRAP study identified MLOR for bread as 86% of product life for bread delivered to convenience stores while in France the norm is around 2/3 (WRAP, 2015; interview Lidl 2017). The high % MLOR preserves greater remaining life for the product in store and in the home (thus reducing probability of date expiry before sale, or risk of becoming stale in consumers' homes).

In-store baked bread (ISB)

In France, the total loss of in-store baked bread is 7% (2% during production, 5% of unsold products) (INCOME Consulting - AK2C, 2016). It is lower than for the two other types of bread because it reaps the advantages of both the industrial bread production sector and small bakery sector. To explain, as retailer in-store bakeries generally have the means to purchase high tech baking equipment and have access to internal monitoring systems, these bakeries have the advantage over smaller independent bakeries as they can use internal tracking systems to keep close track of sales. According to the peaks and dips in sales, these in-store bakeries can then bake bread in intervals throughout the day to adapt their production. Furthermore, these bakeries can take advantage of the available shelf space in supermarkets to display discounted day-old bread. Moreover, as these in-store bakeries are part of retail activity, they are subject to the French law that obliges retailers to make contracts with charitable organisations to donate surplus food. Bread from this sector is therefore either used for human consumption or for animal feed.

In the UK the abovementioned scenario is not the same. In fact, in-store bakery bread waste is significantly wasted on retail level. UK in-store bakeries also take advantage of their ability to produce based on demand, however, these bakery shelves are often times **over-stocked** and filled with a variety of bread products in order to meet consumer demand to have a selection of ample types of bread products. With **limited shelf life**, there is little flexibility when the demand for ready-to-consume bread products unexpectedly drops.


Bread
Foodservice & household food waste drivers
Sales encourage unnecessary purchases
Overportioning
Overportioning
Misinterpretation of date labels
Liability regarding donations - especially for food-service
Leftover norm
Avoidance of freezing bread (perception of quality loss)
Customer returns
Pricing (low-cost products reduce incentive to avoid waste)
Hygiene regulations
Lack of recycling practices (information/ awareness)
Preference for products with longer sell-by dates (established expectations)
Unsuitable planning by collective catering and restaurants - overstocking
Lack of attention to lifetime of product and quantities purchased
Primary production
Processing & packaging
Retail & logistics
Foodservice & household
Waste management (Incineration / AD /EfW / Compost)
Animal feed
Human consumption (donation)
Waste & Valorisation streams
Legend: driver families
Technological
Institutional (business)
Institutional (policy)
Social
Inter stage

BREAD: SUMMARY OF FOODSERVICE & HOUSEHOLD STAGE

Within the foodservice and household stage, the bread product has reached its final destination to the end consumer and is very sensitive to perishability.

Social drivers related to consumer behaviour and common practices such as over-portioning, lack of attention to lifetime of product or lack of recycling practices are the main types of drivers in this stage. Consumer behaviour plays a direct role as a driver, though consumer behaviour and expectations also have an indirect effects on the entire supply chain (as systemic drivers).

Even if there is not always reliable quantitative data, most studies indicate that foodservice and households generate more waste than the other steps of the supply chain. Quantity is a redundant driver at this stage. This can either mean that quantities bought sometimes are not in accordance with what is really needed, or that quantities served at home or in foodservice are inadequate. Combined with the intrinsic short term conservation of bread and its relatively low price, these are many reasons explaining why consumers cause food waste.

Since this is the last step of the supply chain, most of waste is not valorised in any and goes to waste management. An additional local valorisation stream is identified as composting/AD.

BREAD: DESCRIPTION OF FOODSERVICE & HOUSEHOLD STAGE

For the purpose of this analysis, the data gathered is separated between bread wasted in foodservice and households. In the case of bread, an interesting distinction can be made between "avoidable" waste which is bread lost even though it was completely edible and the "potentially avoidable" waste when it comes to crusts, since some people eat it while others do not (Ministère de l'agriculture, ministère de l'économie, 2014).

Foodservice

Waste rates for bread at the food service/out-of-house consumption stage are the highest among the production supply chain stages, reaching 33.3% (UK expert interview, 2017).

Bread is often times more wasted in collective catering and restaurants since it is usually free with meals (Juin, 2015). It appears that in that case of bread placement, slicing it in advance has an impact on the consumption and thus on waste. **Unsuitable planning by collective catering and restaurants** causing overstocking as well **as non-adapted portioning** play relevant roles as well. A French study showed that at the food service sector, consumers tend to think that it is normal to have leftovers to not appear gluttonous (Sebbane M., Costa-Migeon S, 2015). These kinds of **social leftover norms** tend to make consumer waste even though they are aware of the effects of their wastage.

Household

Bread is mentioned as one of the most wasted products at the household level, representing in France around 15% of the total food waste produced within this step of the supply chain (France Nature Environnement, 2016). The majority of bread wasted in households is table scraps left over after a meal, often correlated to **over-serving**.

Consumer preferences lean towards **fresh bread with small conservation time** (baguette) in France (Juin, 2015). As fresh bread does not have an expiry date label, as it is evident when it becomes stale and inconsumable. The driver around bread waste at the consumer level is overestimating the amount of bread to buy. Moreover, **reduced prices at the retail shop** caused by purchases **high price competition and market** encourage consumer to buy unnecessary amounts of bread. The question of "who owns the waste" is relevant here. When retailers apply discounts for products close to expiration date, consumers have to adapt to this short term conservation, which is not always easy. The responsibility for waste in these cases can therefore be shared between retailers and consumers, but also with all the actors upstream who participate in the short conservation time of the product.

Furthermore consumers are **reluctant to freeze** the bread for fear of a drop in product quality (Ministère de l'agriculture "Pertes et gaspillages alimentaires, 2011). Moreover, **loss of know-how for reusing surplus bread** (by making French toast in France) has been observed (Ministère de l'agriculture "Pertes et gaspillages alimentaires, 2014).

4.2 Dairy

For the **dairy** food product, the following country-specific information is detailed below per value chain step:

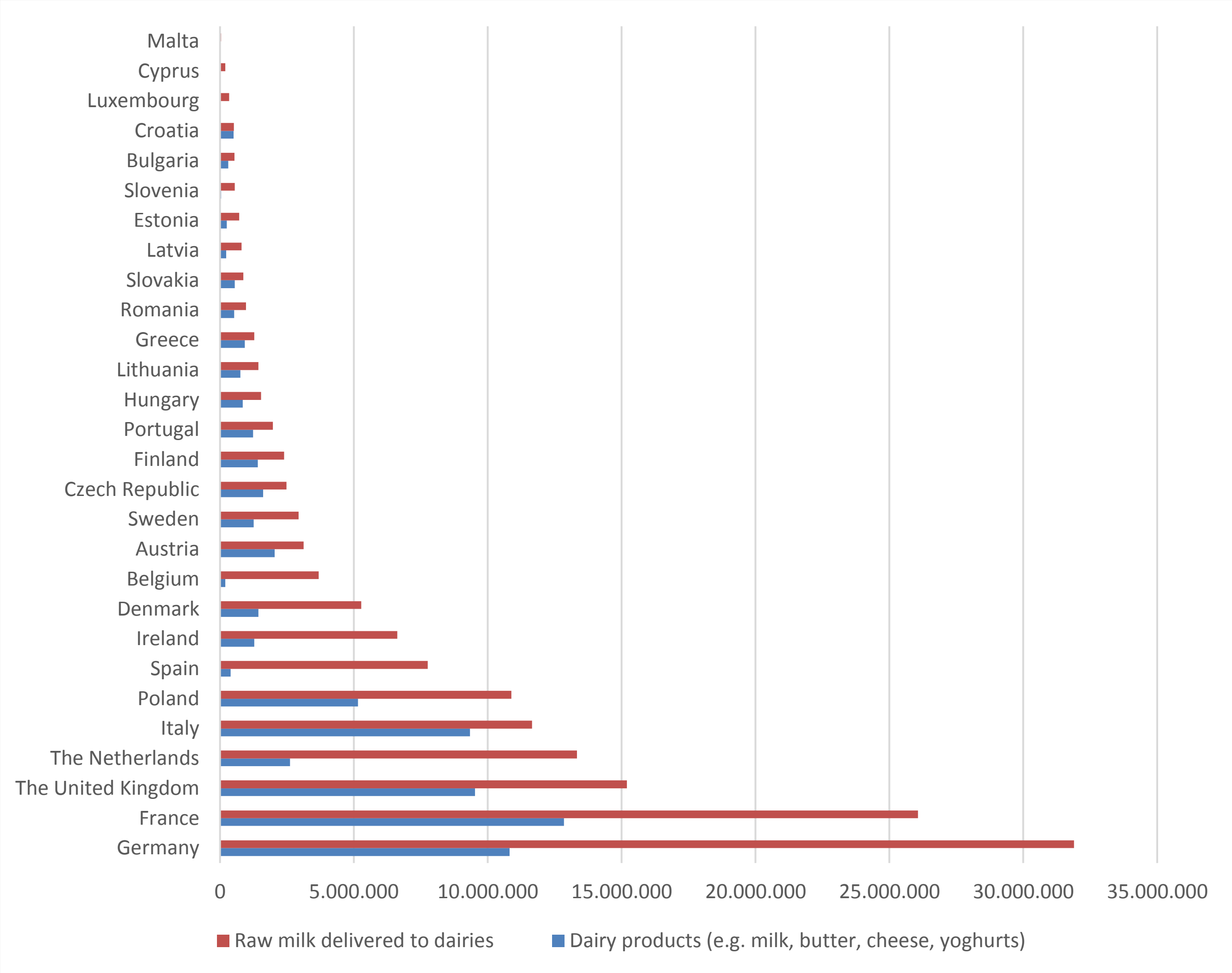
Food product category	Countries covered in the study				
	DE	FR	IT	SE	UK
Dairy				x	x

4.2.1 Context

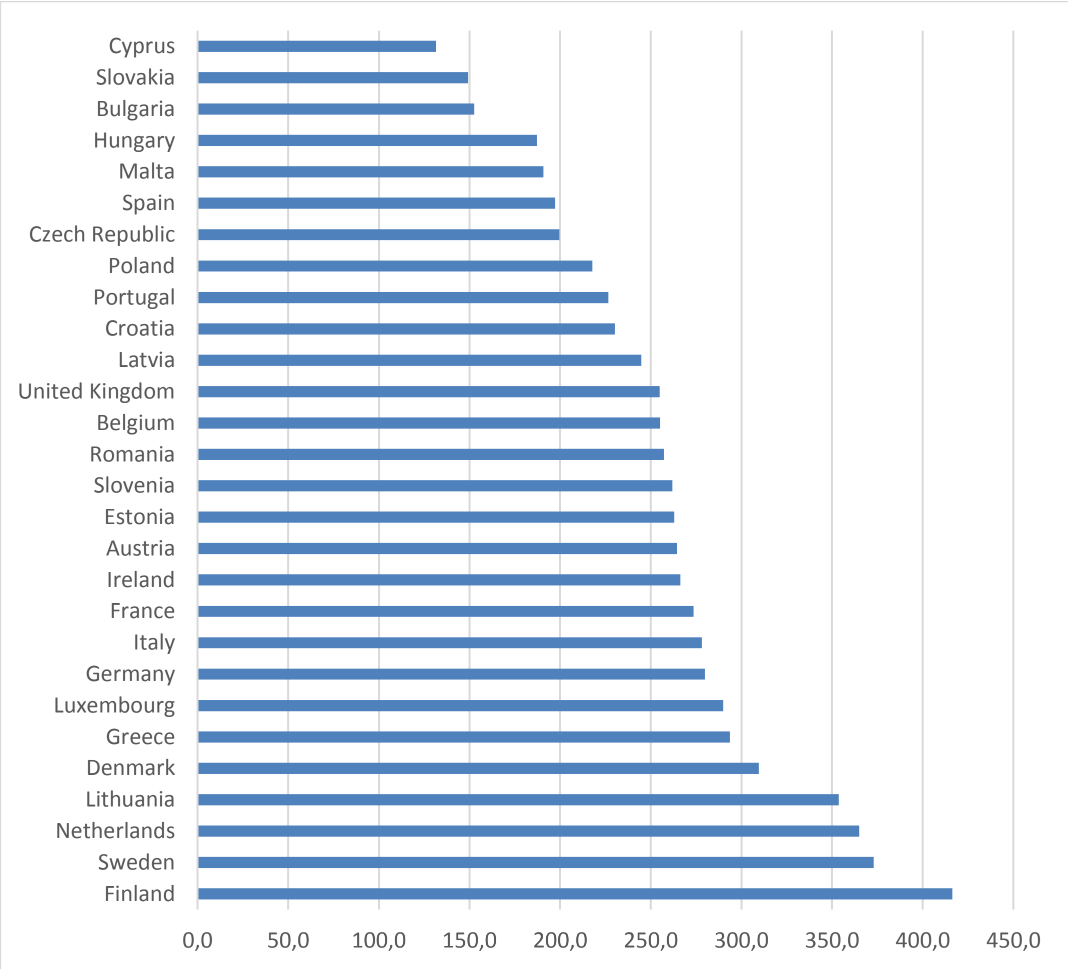
Dairy production across the EU-28 amounts to 66 Mt (Eurostat, 2012).The dairy sector includes a wide variety of different products including milk, cream, cheese (soft and hard), yoghurts, yoghurt drinks, butter, crème fraiche, ice cream, dried powders and other dairy products. The main dairy products produced in the EU-28 are cheese (36% of EU whole milk), butter (30%), cream (13%), drinking milk (11%) and other products (10%). The three largest milk producers are Germany, France and the UK. The scope of this study covers all of dairy but focuses on milk.

Finland, Sweden, Netherlands and Lithuania are the largest per capita consumers of dairy products, with a significant range between the lowest and highest consumers across the EU-28 (between 130 kg per capita and 416 kg).

EU-28 Dairy production (Eurostat, 2012) and Dairy deliveries (EUROSTAT, 2015)

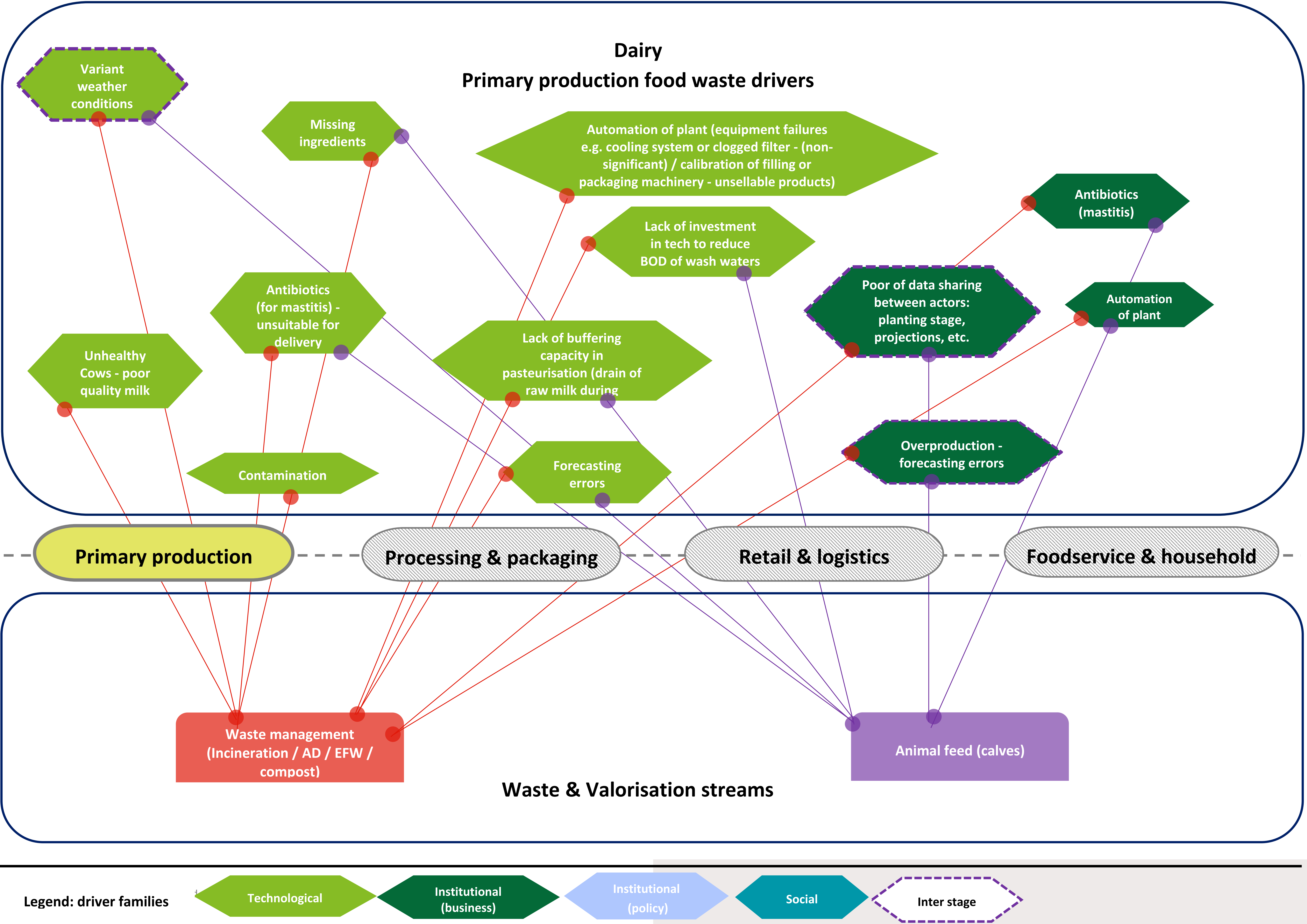


EU-28 Dairy consumption, kg per capita in 2011 (FAO Stat, 2011)



4.2.2 Dairy system maps per sector of the supply chain

The following section covers in detail the drivers that affect the different stages of the supply chain. For each step of the value chain, a dedicated system map provides a zoomed-in illustration of the identified drivers and waste/valorisation streams for each particular step:



Dairy
Primary production food waste drivers
Variant weather conditions
Missing ingredients
Automation of plant (equipment failures e.g. cooling system or clogged filter - (non-significant) / calibration of filling or packaging machinery - unsellable products)
Antibiotics (mastitis)
Lack of investment in tech to reduce BOD of wash waters
Poor of data sharing between actors: planting stage, projections, etc.
Automation of plant
Antibiotics (for mastitis) - unsuitable for delivery
Lack of buffering capacity in pasteurisation (drain of raw milk during
Unhealthy Cows - poor quality milk
Overproduction - forecasting errors
Contamination
Forecasting errors
Primary production
Processing & packaging
Retail & logistics
Foodservice & household
Waste management (Incineration / AD / EFW / compost)
Animal feed (calves)
Waste & Valorisation streams
Legend: driver families
Technological
Institutional (business)
Institutional (policy)
Social
Inter stage

DAIRY: SUMMARY OF PRIMARY PRODUCTION STAGE

The major drivers at the primary production stage are technical, related to the maintenance of plant equipment and the health of the cows, which is related to milk quality and contamination. These would generally be considered non-systemic drivers, although the health of cows and quality of milk may also have an impact on the processing and packaging stage. There are also institutional economic and business drivers, notably production errors and insufficient data sharing, the latter being a critical systemic driver.

The main waste & valorisation streams are principally, composting and animal feed, especially for calves but also energy for waste, incineration or anaerobic digestion.

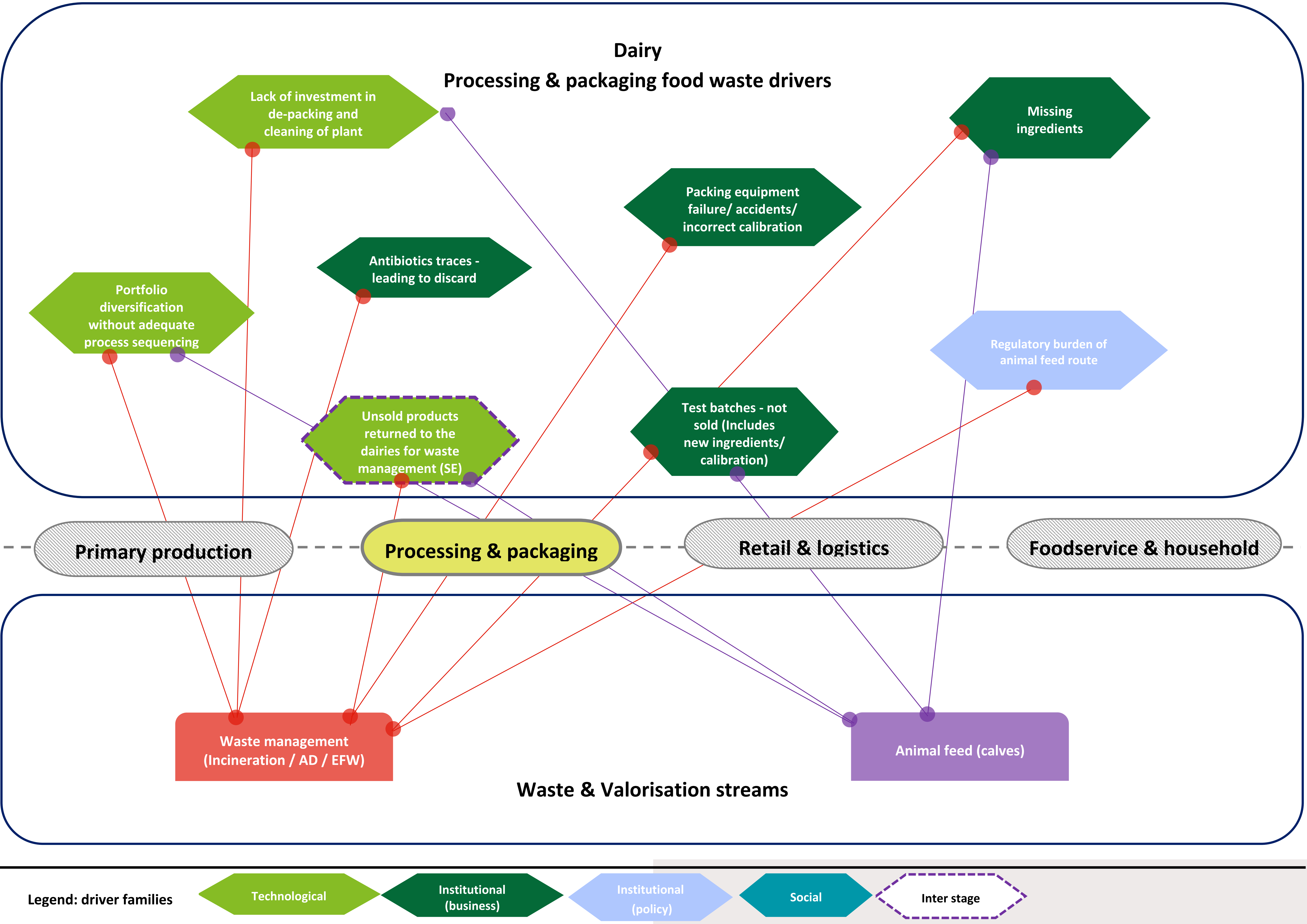
DAIRY: DESCRIPTION OF PRIMARY PRODUCTION STAGE

Unhealthy (disease afflicted) cows may yield poor quality milk, which can lead to rejected milk batches. A major pre-production driver therefore concerns the **health of cows** on farms. In addition, it is worth noting that **extreme weather conditions** could have an impact on the welfare of livestock and hence the quality of milk.

Contamination of cows and milk is a key driver of waste. Medical treatment of unhealthy cows during the primary production stage will also lead to waste however, a principal reason being the **use of antibiotics**, notably for mastitis. Milk with antibiotic residues is generally sent to the manure well or given to calves throughout the treatment period or only during the withdrawal period, though the use of this quantity varies depending on the farm.

Tests on the antibiotic content of milk are regularly conducted on dairy herds and on milk supplied by farms. For instance, a sensory test is also conducted at the moment of delivery to dairy facilities to ensure that non-compliant milk in the tanker is not mixed with milk from other farms. Quality criteria are set by the dairies to encompass hygiene standards, milk quality and other requirements.

Overall however, there seems to be relatively little waste at the farm stage. This is estimated to be as low as 0.3 % of production in Sweden for example. The main waste & valorisation streams are identified as waste management through manure compost, and **animal feed**, especially for rejected milk fed to calves as well as **incineration or anaerobic digestion**.


Dairy
Processing & packaging food waste drivers
Lack of investment in de-packing and cleaning of plant
Missing ingredients
Packing equipment failure/ accidents/ incorrect calibration
Antibiotics traces - leading to discard
Portfolio diversification without adequate process sequencing
Regulatory burden of animal feed route
Unsold products returned to the dairies for waste management (SE)
Test batches - not sold (Includes new ingredients/ calibration)
Primary production
Processing & packaging
Retail & logistics
Foodservice & household
Waste management (Incineration / AD / EFW)
Animal feed (calves)
Waste & Valorisation streams
Legend: driver families
Technological
Institutional (business)
Institutional (policy)
Social
Inter stage

DAIRY: SUMMARY OF RETAIL & LOGISTICS STAGE

There is an overall balance between technological drivers such as system and equipment failure or inefficiency and institutional economic and business drivers including the systemic driver returned products and lack of investment in de-packaging. It is worth noting that the driver of antibiotics traces is carried forward from the primary production stage.

The waste & valorisation streams are the same as those in the primary production stage. The principle streams are anaerobic digestion and animal feed but the specific process in which waste is generated may determine the waste stream. For example waste in wash water is sent for AD particularly early on in the washing processes. Anaerobic digestion is also identified as principal waste stream for packaged products. On the other hand, lack of investment in de-packaging reduces the capacity of companies to send packaged waste for use as animal feed.

DAIRY: DESCRIPTION OF PROCESSING & PACKAGING STAGE

Within the processing stage, there are several different kinds of dairies: fresh products, butter, cheese or powdered milk. Milk is usually not transported between dairies, but allocation occurs depending on price levels of different products. To cut down on transportation costs, dairy processers give a preference to working with local farmers/producers. Waste arises for several reasons, mainly at fresh product dairies which also produce the widest range of products.

The dominating dairy companies in Sweden for example are cooperatives owned by the farmers. Their objectives are thereby to buy all milk that is produced and place it in suitable markets (Anna-Karin Modin-Edman, 2017). Milk is collected from farms and delivered to the nearest dairy facility, although in some cases farmers may sell to other dairies directly if they offer better prices. This efficient arrangement causes negligible waste in the logistics and sale system.

As aforementioned in the previous stage, discoveries of **antibiotics traces** lead to the discard of large batches at different types of dairy facilities. In addition, abnormal smell or taste may lead to discard. If the amount lost in that case is consequent, this is extremely rare thanks to the verifications carried out earlier on in the chain. These may worsen overtime, meaning discards may be late in the process as the produce affected may not be identified immediately. As the cause originates at the farm, the dairies and farmers cooperate in preventive actions for animal health and hygiene routines, since there are mutual economic incentives for this.

During the next steps, within the processing and packaging stage of the supply chain, major technological drivers include**, plant automation and process inefficiency** and **equipment failures**.

Human error within dairy processing and product packaging/ labelling is also a factor. Apart from **accidents**, human errors may be related to **quality control rejection** of dairy products.

Test batches which are not sold (products including new ingredients or made for the purposes of calibration) cause some waste. The latter cases may be linked to the efficiency of lines. Test drives of new flavours or packaging will produce products that cannot be sold, although they are usually edible. There will also be waste of edible products produced due to inadequate calibration of machines, for example during the process of filling packages at high speed, machines may not be fine-tuned to get the correct fill level.

Automation inefficiency and malfunction may include the **lack of buffering capacity** in pasteurization (draining of raw milk during breakdown) for example. Machinery malfunction may also include a defective cooling system or a clogged filter for example. But the largest losses occur at product start up and shut down in particular for products like yoghurt because of loss during the machine's calibration period until it reaches its optimal performance. By producing large batches this can be avoided but it can also lead to stock losses so the balance needs to be found.

The maintenance of plant equipment is hence especially important in reducing dairy product waste. Similarly, the **lack of investment in new technologies** to intercept food products entrained in wash water in order to reduce BOD in effluent discharges is a key factor. For example, the lack of deployment of existing technologies that trap fats and other residues before discharge to drains and lack of investment in 'Clean In Place' technologies may be drivers of waste. **These technologies require a full cost-benefit analysis which is difficult to undertake without full information on the likely quantities currently discharged to waste water and also undermined by the low and falling price of milk.** Except for the wash water, most waste and side flows are collected in tanks and sent to feed channels or to be used for AD. By planning of these flows, some can be utilized for new kinds of products instead, but only if the price enables higher processing costs.

Portfolio diversification without adequate process sequencing was identified as a key business and technological driver. Fresh product dairies produce many products making waste quantification in relation to production unit or driver more difficult to assess. Waste is usually measured as a mass balance of fat or volume. Waste is inevitable when routinely washing the line. Washing is also necessary when changing between products such as lactose to non-lactose milk, but not when changing the other way around. Waste is thereby driven by portfolio diversification, but can be alleviated through process sequencing. At the start of the wash phase, the effluent will contain mostly milk which can be used for feed or AD, whereas later on, effluents will be sent to sewage and thereby waste water plants.

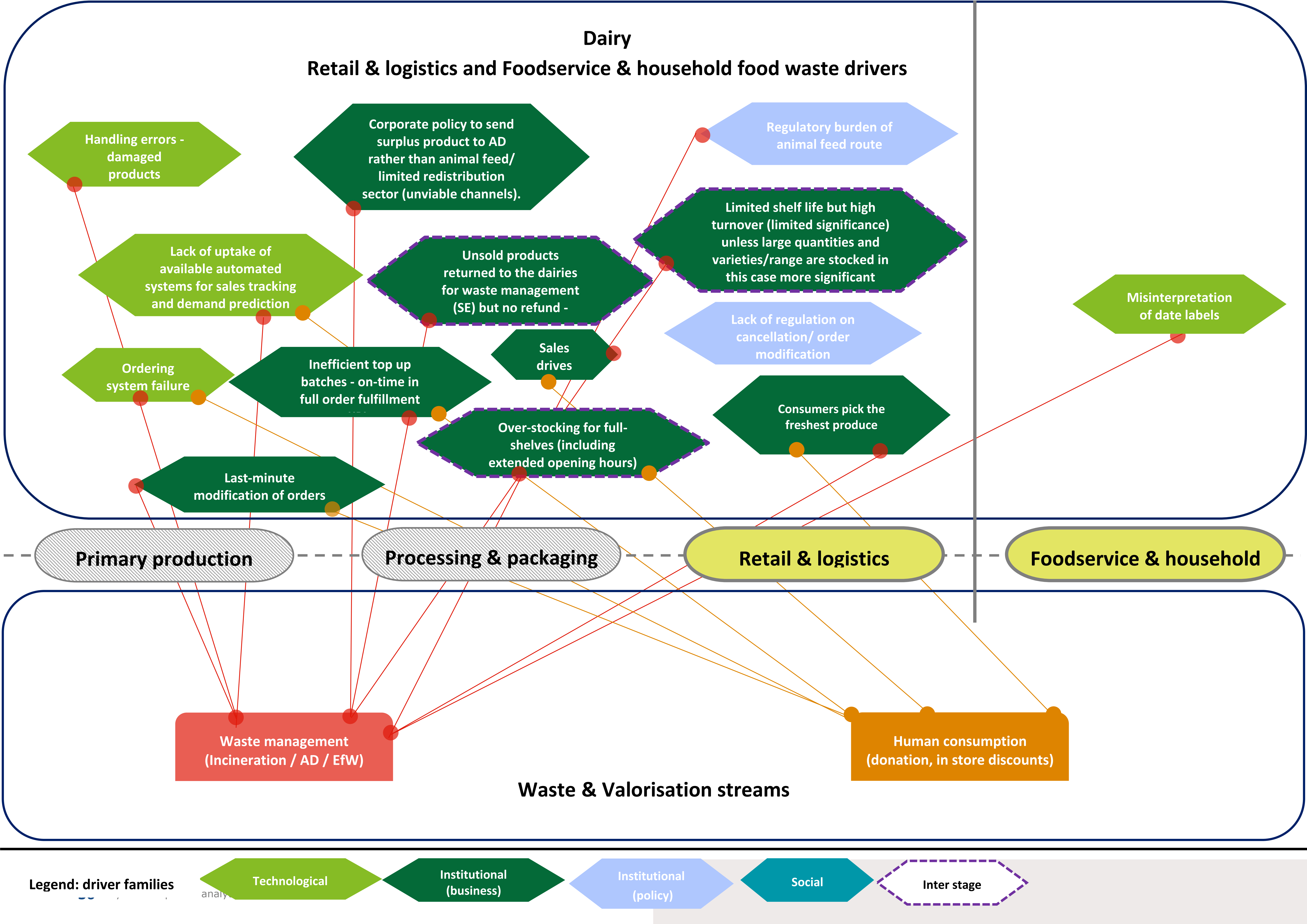
Generally, waste from **damaged packaging** or **labelling errors** is crushed by the manufacturers and sent to AD. Much of the food slurry remains in the packaging and the process is relatively expensive to operate and inefficient. Regarding food surplus to animal feed use, although this route does operate at a number of large dairy facilities, it is poorly developed through **lack of investment in de-packaging** infra-structure (WRAP, 2016). For food surplus to remain suitable for use in animal feed the product must be collected regularly and for the farmer to direct investment toward de-packing and cleaning facilities, which may be lacking to enable safe and hygienic processes to allow for feeding farm animals. There is a perception among site operators that the legislative framework is complex surrounding diversion of food surplus to animal feed and there is a lack of understanding relating to diversion to animal feed.

It is worth noting that in terms of production, for more **complex dairy products, missing ingredients** may lead to some food waste as fresh milk does not conserve particularly well and may be discarded along with other ingredients.

Cheese making produces little waste, but subsequent cutting and grating will create side flows. Much of that can be melted into cheese for the food industry but some is sent to AD plants (Javensköld, 2017). To make 1 kg of cheese about 10 kg of milk is needed, also producing 9 kg of whey. Whey can be used to produce many products, usually after evaporation. But some whey may be sent to AD or feed. Other by-products are produced in different dairies and if they are to be processed further will depend on business decisions (Modin-Edman. and Javensköl, 2017). Hence local markets for by-products are important.

Overproduction leads to significant amounts of milk surplus being left with the producer or the dairy company, according the specific county operating mode. This may be linked to a **lack of sufficient information sharing** or be due to over-optimistic projections. A key root problem is the lack of data sharing along the dairy chain to the extent that this phenomenon may not be widely acknowledged or fully measured.

During the study (UK) it was found that there are data reporting inadequacies and a **lack of granularity in the food waste reporting system**, resulting in a poor understanding of food waste and its full cost. It was not possible to examine losses at individual unit processes within the production line and relate these to a mass balance for the treatment sludge, packaged product sent to AD. A further issue with reporting was the difficulty of relating product losses via effluent treatment sludge and discharge to the water environment. With extensive use of wash water to clean the plant and flush pipework and tanks throughout the site it was difficult to quantify food losses to drain.


Dairy
Retail & logistics and Foodservice & household food waste drivers
Handling errors - damaged products
Corporate policy to send surplus product to AD rather than animal feed/ limited redistribution sector (unviable channels).
Regulatory burden of animal feed route
Limited shelf life but high turnover (limited significance) unless large quantities and varieties/range are stocked in this case more significant
Lack of uptake of available automated systems for sales tracking and demand prediction
Unsold products returned to the dairies for waste management (SE) but no refund -
Misinterpretation of date labels
Lack of regulation on cancellation/ order modification
Sales drives
Ordering system failure
Inefficient top up batches - on-time in full order fulfillment
Consumers pick the freshest produce
Over-stocking for full-shelves (including extended opening hours)
Last-minute modification of orders
Primary production
Processing & packaging
Retail & logistics
Foodservice & household
Waste management (Incineration / AD / EfW)
Human consumption (donation, in store discounts)
Waste & Valorisation streams
Legend: driver families
Technological
Institutional (business)
Institutional (policy)
Social
Inter stage

DAIRY: SUMMARY OF RETAIL & LOGISTICS STAGE

A focus was not made on the household & foodservice sector within this report.

Institutional economic and business management drivers are predominant at the retail and logistics stage. These include in particular drivers related to surplus of supply at retail stage, such as lack of uptake of available automated IT systems for sales tracking, deliberate over-stocking of large quantities and varieties of a product. Systemic drivers include last-minute cancellations and returns of products, affecting upstream actors.

The major waste & valorisation streams include incineration, anaerobic digestion and energy from waste in addition to human consumption through donations or instore discounts. However, it is generally corporate policy to send surplus products to AD rather than animal feed or other channels due to the perception of a limited redistribution sector (unviable channels) and due to the perceived brand risks.

DAIRY: DESCRIPTION OF RETAIL & LOGISTICS STAGE

Overall, in Sweden, thanks to rather well functioning retail and logistics centre, dairy food loss and waste seems to be low with around 0.36 % of delivered products in a study of low price stores or below 1 % in another study, though this may possibly higher in small stores (Eriksson and Strid, 2011). First of all, on the stage of transport from dairies to retail, most Swedish fresh dairies for instance act as distribution centres, although some logistics may be handled by wholesalers in other regions. It is noted that there will be some losses of damaged products but distribution is generally too quick to generate much other waste.

Institutional economic and business management drivers are predominant at the retail and logistics stage. For instance, the **lack of uptake of available automated IT systems for sales tracking** and demand prediction limits the capacity to order more accurately leading to surplus supply, which is not sold. In a similar manner, order system failure may also have this effect at this stage. There may however be peaks in waste generation, when mistakes are made in ordering or after sales drives (Eriksson and Strid, 2011). Preventing mistakes is of course in the interest of store owners but sales drives are a marketing tool, meaning there is a conflict of interests (Eriksson and Strid, 2011).

Retail actors may also **cancel orders at the last minute,** which may generate waste upstream in the supply chain if demand is not replaced. Inefficient top up batches and on-time in full order fulfilment KPIs may also have a detrimental effect on waste further up the supply chain.

On the other hand retail actor make a deliberate decision to have surplus goods, **ensure over-stocking** for the purpose of having full-shelves (including extended opening hours). This raises the chances of a product not to be picked by a customer before its expiry date. It is important to note that the variety of products is ever increasing and in recent years the retail chains own brands are becoming more common (Naturvårdsverket, 2014). This makes prognoses difficult and some over ordering is necessary (Javensköld; Møller et al, 2016).

Limited shelf life but low turnover is a problem when large quantities and varieties/range are stocked. This is generally of limited significance however unless large quantities and varieties or range are stocked. Milk has a very high turnover at the retail stage and thereby little risk of reaching the best before date, but a medium size store can have hundreds of dairy products where most have lower turnover and thereby more wastage as it sits on the shelf for too long. Stores with a larger range of products, with low product turnover, and smaller stores, with lower turnover in general, may have higher ratios of food waste.

Dairy products are generally sold in sealed packaging with printed ""use by" or "best before" date marks (depending the exact product). This means it is impossible for the consumer to assess the quality before purchase. Customer's pick the freshest products by date. Therefore, the main reason for discarding dairy products in the retail sector is that of approaching date expiry. **The main drivers being the demand for full shelves and high product availability.**

Other factors at the retail stage **include simple mishandling of products by staff or customers in stores.** Accidents may involve products falling on the shop floor or in storage rooms leading to some waste.

The major waste & valorisation streams identified include **waste management through incineration and anaerobic digestion as well as energy from waste in addition to human consumption through donations or instore discounts**. Flows are somewhat restricted however by the propensity of retail and logistics actors to follow a corporate policy of sending waste for AD as a preference to other channels. It is generally corporate policy to send surplus products to AD rather than animal feed or other channels due to the perception of a limited redistribution sector (unviable channels) and due to the perceived brand risks. This is an issue that needs further work within the redistribution sector, to strengthen their approach to protecting brand integrity, concerns linked to traceability and product recalls. There is also a perceived regulatory burden associated with the animal feed route.

It is important to note that in Sweden, although there is no refund (claiming of refunds is very uncommon), it is industry practice for unsold products to be returned to dairies, which might then be responsible for waste management. The incentive is based on direct waste minimisation at retail stage, shifting waste back upstream.

As a focus was not made on the household & foodservice sector within this report, the only waste drivers identified within the study were consumer misinterpretation of date marking as well as residual product left within a container/packaging because of its unoptimised design. This may be related to the choice of use-by as opposed to best before by production, packaging or retail actors, the latter choice implying that consumption could occur after the date marked. Other drivers could be linked to over-purchasing because of in-store discounts, etc. The waste & valorisation streams identified for this stage of the value chain are restricted to waste management through incineration or anaerobic digestion due to the lack of other channels at the downstream end of the supply chain.

4.3 Potatoes and tomatoes

For the **potatoes and tomatoes** food category, the following country-specific information is detailed below per value chain step:

Food product category	Countries covered in the study				
	DE	FR	IT	SE	UK
Potatoes/tomatoes		x	x	x	x

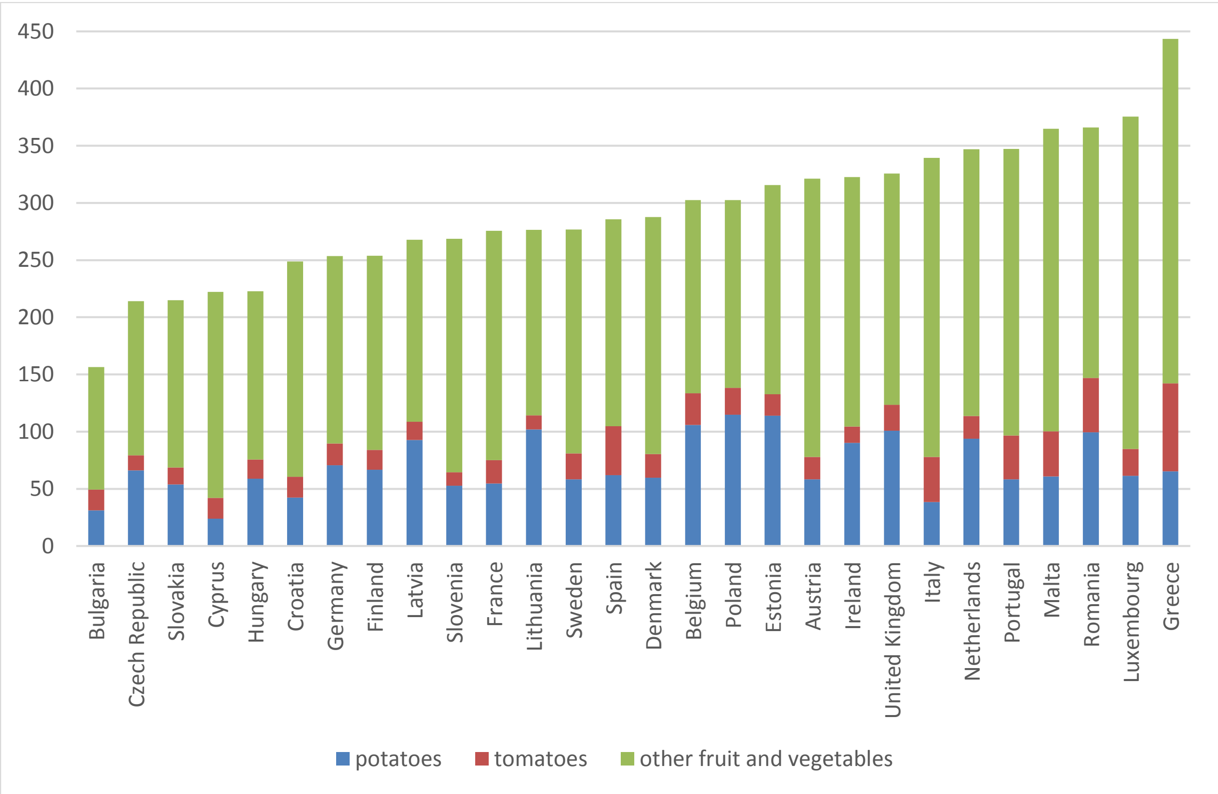
4.3.1 Context

The EU-28 produce over 28 Mt of fruit and vegetable products, including 7.5 Mt of potato products (frozen, powdered, crisps, dried) and 4.8 Mt of tomato products (puree, paste, sauces, dried).

Potatoes and tomatoes are often used in both their primary form and processed (sauce for tomatoes and chips, crisps, fries, and potatoes). Even if the global trend seems to be a slight decrease in the consumption of the raw products, they remain a central element of the Europeans diet.

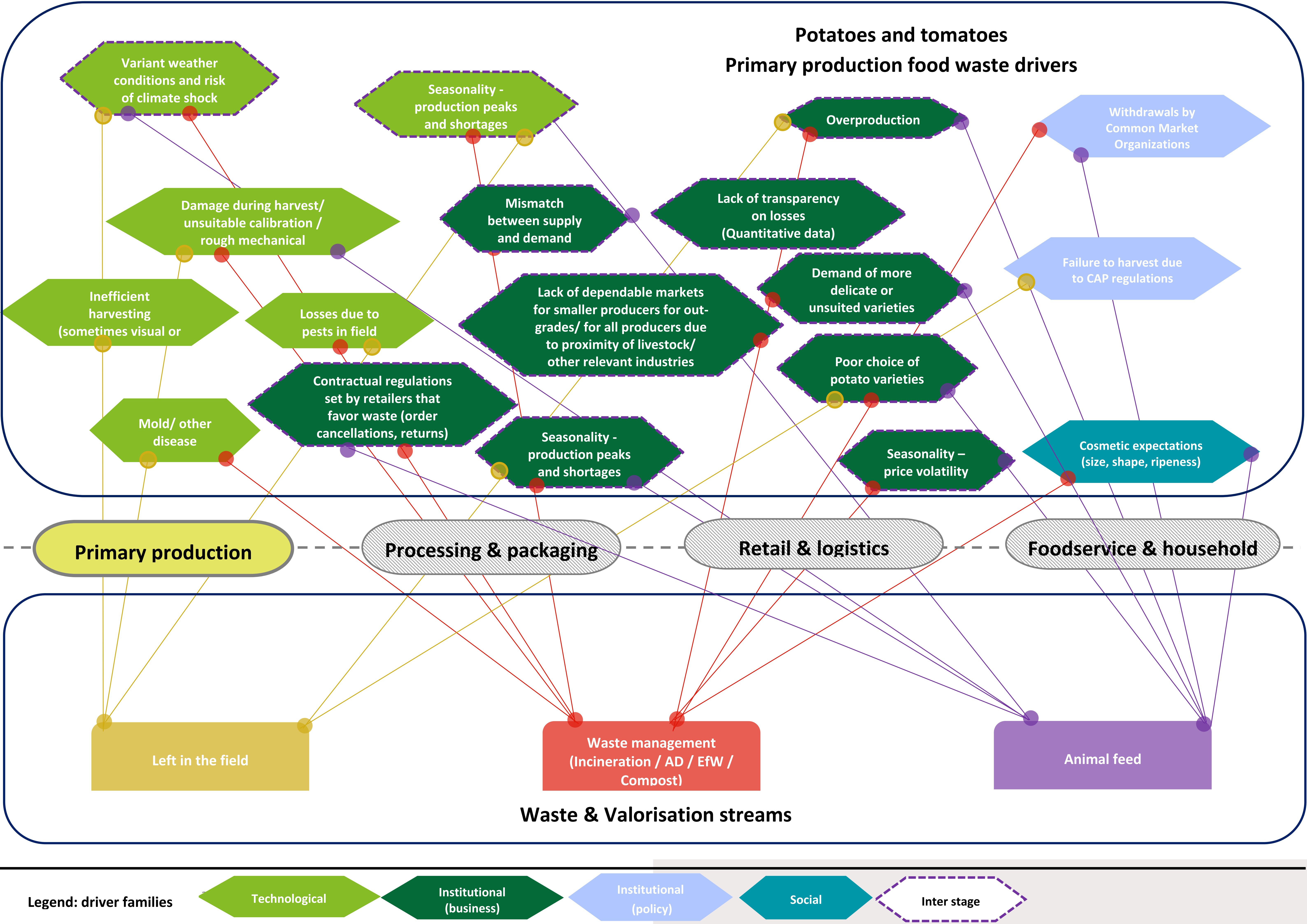
Below is an illustration of production per EU Member State.

EU-28 tomato, potato and other fruit and vegetables production across Europe (Eurostat, 2012)



4.3.2 Potato and tomato system maps per sector of the supply chain

The following section covers in detail the drivers that affect the different stages of the supply chain. For each step of the value chain, a dedicated system map provides a zoomed-in illustration of the identified drivers and waste/valorisation streams for each particular step:



Potatoes and tomatoes
Primary production food waste drivers
Variant weather conditions and risk of climate shock
Seasonality - production peaks and shortages
Overproduction
Withdrawals by Common Market Organizations
Damage during harvest/ unsuitable calibration / rough mechanical
Mismatch between supply and demand
Lack of transparency on losses (Quantitative data)
Failure to harvest due to CAP regulations
Inefficient harvesting (sometimes visual or
Losses due to pests in field
Lack of dependable markets for smaller producers for out-grades/ for all producers due to proximity of livestock/ other relevant industries
Demand of more delicate or unsuited varieties
Poor choice of potato varieties
Mold/ other disease
Contractual regulations set by retailers that favor waste (order cancellations, returns)
Seasonality - production peaks and shortages
Seasonality – price volatility
Cosmetic expectations (size, shape, ripeness)
Primary production
Processing & packaging
Retail & logistics
Foodservice & household
Left in the field
Waste management (Incineration / AD / EfW / Compost)
Animal feed
Waste & Valorisation streams
Legend: driver families
Technological
Institutional (business)
Institutional (policy)
Social
Inter stage

POTATOES AND TOMATOES: SUMMARY OF PRIMARY PRODUCTION STAGE

Within the primary production stage, the production of potatoes and tomatoes starts with harvesting.

Similarly to wheat, food waste drivers at this stage are predominantly technological (inefficient harvesting, loss die to west, to weather, etc.) or related to business management (mismatch between supply and demand, price volatility).

For potatoes and tomatoes, the same categorisation of drivers (systemic/non-systemic) as the one presented in wheat primary production could be made. It is possible to distinguish the waste due to internal reasons (weather, pest infestation, etc.) and due to systemic drivers (contractual regulations, etc.). The same conclusions can also be drawn. However, regarding potatoes and tomatoes in particular, harvesting these vegetables by keeping their shape or size (**cosmetic standards**) in mind are more important than for wheat. Certain harvesting machines are calibrated to only harvest potatoes/tomatoes of a certain size, leaving the rest in the fields. For manual harvesting, field workers furthermore consider the appearance of the vegetable when determining whether or not to harvest it.

Even if appearance is a significant concern in all countries, this has been particularly underlined by the Swedish study with an emphasis on potato classes (premium, I, II). The major difference between potatoes and tomatoes is their perishability, which is higher for the tomatoes. The latter are also more subject to weather conditions and therefore the question of the place of crop (in greenhouse or not, etc.) determines partly the yields of the harvest, while it is not the case for potatoes.

There are three main waste & valorisation streams at this stage: leaving the vegetables in the field (usually unquantified by the farmer), waste management (AD, Energy from Waste and compost) or redirecting them to animal feed. The valorisation option depends also on the proximity and ease of the available networks.

POTATOES AND TOMATOES: DESCRIPTION OF PRIMARY PRODUCTION STAGE

Even if external factors such as temperature have a direct impact on the yield of a field, **potatoes** are not too subject to **climatic changes in weather** since these vegetables grow underground (Jeannequin et al., 2015). However, significant rain during the harvest can lead to heavy loss because of the adhesion of the dirt to the potato and impossibility for the machines to access to the vegetables. While in soil, potatoes can also be attacked by parasites, but spoiled vegetables are not harvested because it would be a waste of time and money for the farmer. There is therefore a **lack of data** on the amount of tubers lost due to **parasites and pests**. Between weather conditions and natural causes, food loss of these vegetables can reach 5%. **Heat and weather forecasting** are therefore key elements for farmers to take into account during the harvest season. Farmers are however unable to escape **seasonal phenomena** like price volatility or production peaks and shortages.

This is relatively similar for **tomatoes** since pre-harvest loss can be due to **disease and parasites**, like insects or fungi (downy mildew). Genetic improvement in farming (genetically modified organisms – GMOs) is a solution that has proven its efficiency to fight this phenomenon. Due to the fact that tomatoes grow above ground, they are more sensitive than potatoes to external variations in weather. Fresh tomatoes are produced either in open field, or in greenhouses. In Italy, the largest share (about 90%) is produced in greenhouses (open-field cultivation is less convenient since tomatoes are exposed to more risks). Cold greenhouses and open-field cultivation produce more waste due to **climatic shocks**, which cause deformities in tomatoes. The usual share of tomatoes discarded for aesthetical reasons goes from 2 - 30%, depending on climatic conditions. This share is higher in cold greenhouses. **Deformed and under-sized tomatoes** destined for consumption in its raw vegetable state cannot be recovered in down-grade markets, such as to produce tomato puree, since their composition is not suitable (e.g., they contain too much pectin) even though there might be some exceptions for cherry tomatoes.

During harvest, **non-conform potatoes are not gathered** (because of size, shape and appearance). Since machines only harvest each row of potatoes only once, there is no way to recover the potatoes if the equipment is poorly calibrated. Technology plays a big role in that step. At more developed farms, losses are marginal as these places usually have better means to invest in more efficient techniques (Agreste 2012).

In Sweden, **potato** farmers have invested in **better equipment** and more pest control, but still much cannot be classed I or premium. This is straining the economy of the farmers who sell much of the harvest for a low price, but does not seem to cause much waste (Andrae; Pålsson; Envall, 2017). The **market for lower grade potatoes** is well developed with much sold to the starch industry, for food or technical applications or production of mashed potato powder (Starch, 2017; Andersson, 2017). Provided there are local beef farmers, much can also be sold as feed (Andrae, 2017).

Some **tomato** typologies are suited for machine harvesting and grading. However, contrarily to potatoes, in Italy almost all tomatoes are harvested by hand and **graded visually**. They are packed on-field and sent to wholesalers or retailers. In the case of fresh tomatoes, genetic innovation to allow the simultaneous ripening of all fruits is not feasible.

Sometimes, tomatoes are not harvested due to **misconceptions between the expected and actual demand**. Market-based drivers also intervene when there is demand of more delicate varieties, with consequent higher perishability or contracts including **order cancellations or returns**.

Farmers tend to be **limited in the potato varieties that are grown, which is influenced by retailer/consumer demand**. This can be the case even if the demanded varieties are more difficult to grow and give lower yields. Range rationalisation is needed to address this issue, based on a whole supply chain view of crop utilisation and wastage from farm to fork (UK expert interview, 2017).

New potatoes are often times not grown by large-scale farms, run as companies, but at smaller fields as a side income for non-professional farmers, although it can provide large income if the harvesting time is right and the price is high. In Sweden, the value chain is different for new potatoes as they are usually sold to stores, via wholesalers, unwashed and unpeeled. Conserving potatoes unwashed and unpeeled ensures this vegetable's natural protection against perishability. In Sweden, as the washing and peeling of potatoes (if sold as a raw potato) is usually only usually carried out in the household, meaning that it is conserved for longer.

In France, during on-site sorting after bringing in the harvest, a second and more thorough sweep is carried out by farmers to remove non-compliant potatoes (INCOME Consulting - AK2C, 2016)**Error! Bookmark not defined.**. **Attention is given to the cosmetic appearance** of the potato. Part of loss within this primary production stage are recovered via animal feed (INCOME Consulting - AK2C, 2016). On-site washing and conservation before transportation can result in various types of losses: removal due to weight because of water loss within the potato, damages caused by harvesting machinery or mould spread can lead to a more general loss (Jeannequin et al., 2015). Recovery via animal feed is practiced at this stage.

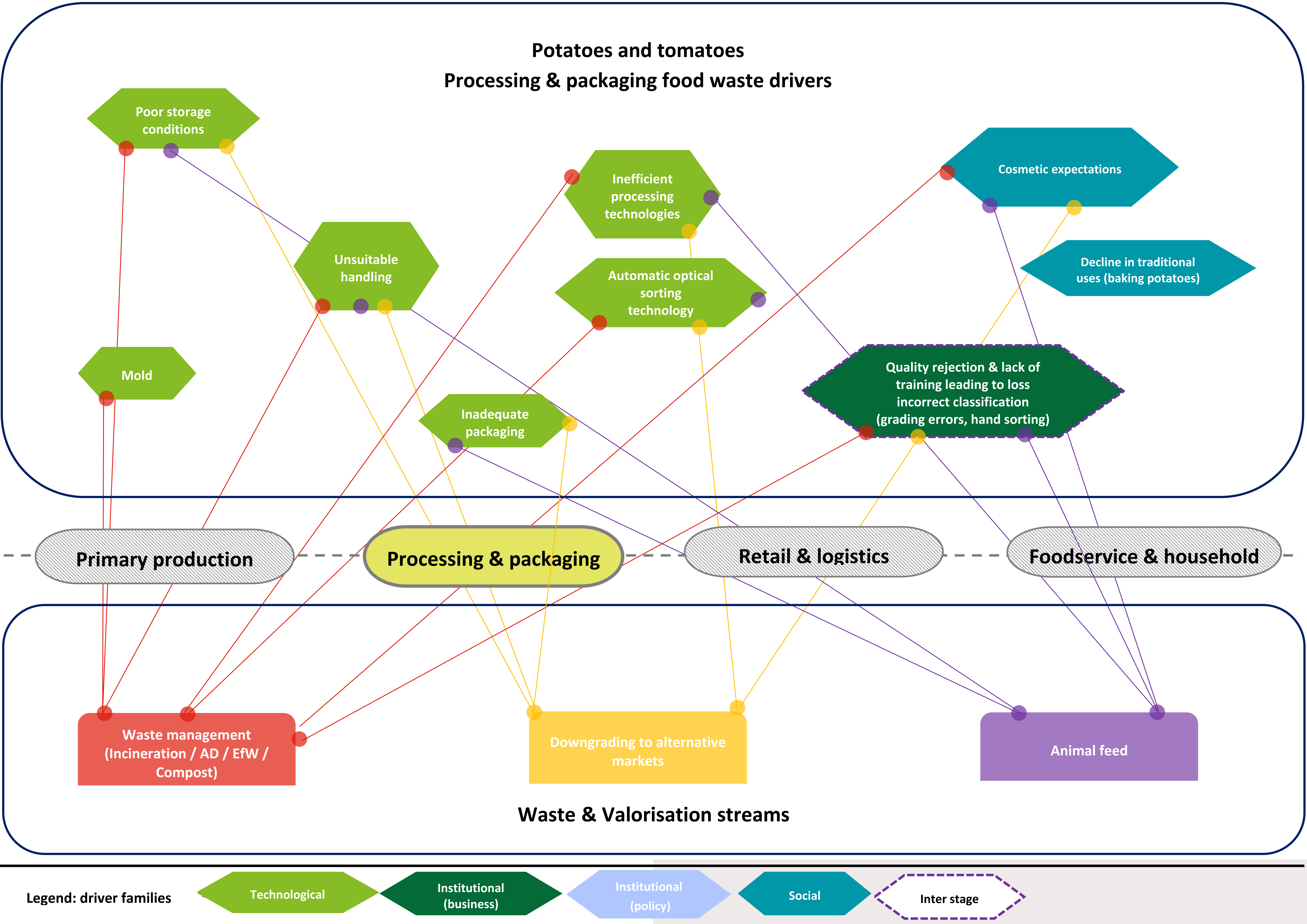
The share of unharvested **tomatoes** depends on their typology. Tomato prices rarely fall under harvesting cost so they are almost always harvested, especially by small producers. **Under-sized and anaesthetic tomatoes are either eaten by the producer's family (auto-consumption), thrown away (e.g. ploughed in, thus fertilizing the field), or used to feed animals.** However, if machinery does not allow for efficient harvesting, or if manual labour outweighs the cost of harvesting all crops, it is possible that it is more profitable to only harvest a portion of the crops in the fields. On a small-scale level, gleaning is practices, but it is unclear as to how impactful this initiative is. Another share can be donated to charities, also due to EU and regional regulations that foresee a compensation for vegetable and fruit donating producers.

On a small farm scale, these losses can also be cut if farmers have an on-site shop: they can have an "ugly fruit and veg" discount section within their store. Farmers know that a certain percentage of **potatoes** will be rejected (because of cosmetic standards, etc.), therefore they tend to **overproduce** in order to make up for foreseen economic losses.

Retailer specifications for potatoes, which directly influences farmer production, have become more stringent over time in relation to cosmetic standards. This pushes up the quantity of unharvested or out-graded product (UK expert interview, 2017). If the growing season is particularly challenging, such as through poor weather conditions early in the season and reduced yields, retailers need to provide greater flexibility on product specifications (UK expert interview, 2017).

According to French figures, there are between 14% and 20% of products discarded at the production stage (INCOME Consulting - AK2C, 2016; Jeannequin et al., 2015). The figures found in the UK are around 10%. It is worth noticing that onsite there is a distinction made between potatoes used for consumption as such and potatoes which will be transformed. **Aesthetics** at this point is a more relevant point for potatoes intended for direct consumption as a raw vegetable (15% excluded) than for the others (4 % excluded) (INCOME Consulting - AK2C, 2016).

It is estimated that 20% of the potatoes discarded at the production stage go back in the circuit for human consumption, 20% is used for animal feed and the remaining 60% stay in the field or are used as compost (INCOME Consulting - AK2C, 2016).



Potatoes and tomatoes
Processing & packaging food waste drivers
Poor storage conditions
Inefficient processing technologies
Cosmetic expectations
Unsuitable handling
Decline in traditional uses (baking potatoes)
Automatic optical sorting technology
Mold
Quality rejection & lack of training leading to loss incorrect classification (grading errors, hand sorting)
Inadequate packaging
Primary production
Processing & packaging
Retail & logistics
Foodservice & household
Waste management (Incineration / AD / EfW / Compost)
Downgrading to alternative markets
Animal feed
Waste & Valorisation streams
Legend: driver families
Technological
Institutional (business)
Institutional (policy)
Social
Inter stage

POTATOES AND TOMATOES: SUMMARY OF PROCESSING & PACKAGING STAGE

Within the processing & packaging stage, the production of potatoes and tomatoes is in its raw vegetable stage. Within this report, the transformation of potatoes was studied, while tomatoes were only considered in their raw vegetable state.

The influence on packaging for both types of products varies according to each products' perishability (higher perishability for tomatoes than for potatoes).

The drivers for this step of the value chain are especially technical (unsuitable handling, poor storage conditions, inadequate packaging, etc.) and a few of them are institutional (related to business or to policy). Aesthetic qualities were also important drivers to waste, as potato size for transformation is key (as machinery is calibrated to process certain sizes of food products). The perishability of the product during storage also is a key factor to consider within this stage.

Since there are numerous recovery and reprocessing options for these products, these are also several ways to redirect vegetables that are not suitable for their original purpose to down-grade markets. On the other hand, the risk to this option is to over-develop down-grading to the point where it harms the profitability of the actor's activity (as the vegetable will lose value) and can lead to a destabilisation of the supply chain.

POTATOES AND TOMATOES: DESCRIPTION OF PROCESSING & PACKAGING STAGE

This section presents a distinction of tomatoes/potatoes destined to be sold in their raw "fresh product" stage, or sold as a transformed product.

Generally speaking, potatoes are less perishable and more resistant to transportation than tomatoes, in fact, they can technically be stored up to 12 months under proper conditions. While potatoes' resistant nature could help hinder food waste, its **adapted storage and packaging specifications** (in terms of light exposure, humidity and temperature) are usually not met by actors within the supply chain, which significantly reduces its lifespan. Moulding or greening are common side-effects of mismanaged potatoes (Jeannequin et al., 2015). An innovative solution to reduce damage during grading involves the use of 'electronic potatoes' to test handling and grading systems (UK expert interview, 2017).

a) Potatoes and tomatoes as a fresh produce

For **potatoes**, even if a first screening is done during harvest to only select viable products, this remains one of the first cause of loss at this level. Sometimes class I potatoes are miss-graded. **These grading errors** can exceed 5% and mostly goes to stock feed. As retailer product specifications may sometimes be difficult to identify, staff are trained 'if in doubt grade it out'. **Staff training** and a greater tolerance of potatoes that are at the margins of the specification would reduce the scale of this problem. **Automation such as optical sorting** may reduce labour costs but result in higher sorting errors (UK expert interview, 2017).

Once harvested, **tomatoes** undergo cleaning, grading, sizing and, eventually, packaging. These operations are usually implemented on-field, rather than at a packaging intermediary firm. First, the residual plant matter (leaves, small branches) is removed. Then, fruits are washed and this causes a small reduction in the weight and shortens the residual life of the tomatoes. As for the potatoes, an **additional waste flow derives from grading: undersized or misshaped products are discarded.** Grading errors are also a concern, since visual grading potentially leading to viable tomatoes being out-graded. Despite their appearance, tomatoes are also selected on their ripeness level. Overall, losses amount to 3% of the tomatoes available after imports and exports (1,050,000 tons) in Italy (ISMEA, 2012).

In Sweden, all harvested **potatoes**, except new potatoes in summer, are sorted into different classes. The first **sorting** may be at the farm, to remove damaged, green or badly misshapen ones along with dirt and stones. This is then ploughed into the field. A very rough estimate is that 2.5% of the harvested potatoes are returned to the field, after sorting or during harvest as mentioned above (Hartikainen, 2017; Ulrika Franke et al., 2016).

Edible **potatoes** then remain and will be sorted in subsequent steps. Retailers are usually interested in class I or above, **meaning sorting is somewhat stricter than necessary** (Mattsson, 2015; Andrae, 2017; Pålsson, 2017). This is especially true for more expensive varieties sold in small packages. Class II or below are often diverted to the peeling, mashed potato or starch industries. **If prices are low at the time, downgrade vegetables will be sent to animal feed if there is demand in the area or to AD.** In particular, around 10%, of the harvest is diverted to feed or the starch industry at this stage (Franke et al., 2016; Andrae, 2017; Hartikainen, 2017).

Most potatoes sold to retail or food services are washed, although there are regional differences such as in Sweden. This is done after storage as the potatoes become more susceptible to spoiling, but chilled storage is becoming common to alleviate this. Aesthetic flaws become more apparent after washing meaning much will be downgraded. These can however be sold for industrial peeling, mashing or starch production (Andrae, 2017; Pålsson, 2017). Some damage will occur in the process, sending waste potatoes to feed or AD.

Regarding the end markets for utilisation of **potatoes** that are out-grades, it is not always cost-effective to redistribute higher quality out-grades if further sorts required and transportation costs are high. **It may therefore be cheaper to donate Class I product from further down the supply chain** (UK expert interview, 2017).

Market-based drivers are linked to the demand for **tomato** varieties that are either more delicate or shaped differently compared to the **traditional ones, which are more and more declined by consumers**. These dynamics derive from consumers' preferences or from retailers' standards.

In relation to the food utilisation hierarchy **for potatoes,** the best case on reporting transparency is where pack houses work closely with farmers to review overall crop utilisation and the fate of out-grading. This needs to include on-farm assessment of harvesting losses, data on the number of trailers turned away at the pack house, etc. (UK expert interview, 2017). For sites that operate AD facilities, although there are environmental benefits in offsetting site energy use (such as for the control of conditioning temperatures), this flow should be accounted for separately to stock feed and use of alternative markets (UK expert interview, 2017).

Most of the **tomatoes** discarded or damaged during processing operations are used as animal feed or to produce compost. A smaller amount, including the plant matter, are sent to anaerobic digestion.

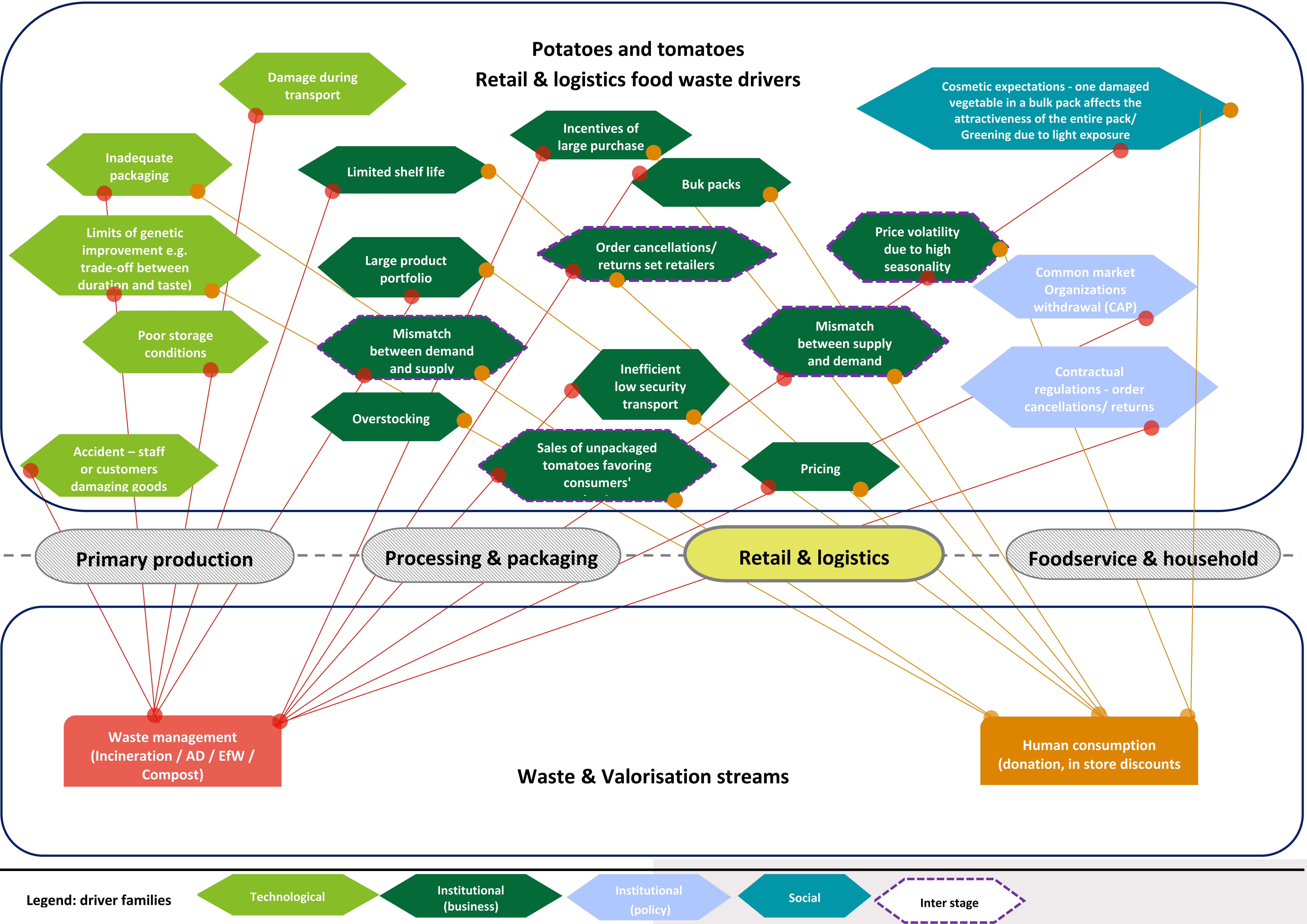
b) Potatoes transformed

On-site sorting can be performed at farms or at a packaging intermediary. The loss at this stage can be divided in two big categories: loss before transformation (at the farm level via sorting out non-conform potatoes) and loss due to the transformation process (freezing, canning, pasteurisation, etc.) (Jeannequin et al., 2015).

Before processing, another sorting process is carried out, removing about 1.4% of the potato stock (INCOME Consulting - AK2C, 2016). For the transformation process, waste is generated by: sorting out the vegetables, removing parts unfit for consumption, line losses (**inefficient processing technologies*)***. However, a large part of these losses are recovered. For example, French fry preparation generates a considerable amount of scraps because they need to be cut into the recognisable "French fry" shape. 80% of this loss is salvaged via a drying process to be later transformed into instant mashed potato (Jeannequin et al., 2015). In total, this represents 20% of the original potato stock which is lost (INCOME Consulting - AK2C, 2016).

Once the product is processed, another percentage of potato is discarded based on the **quality standards** (biological and physical hazards). **Aesthetic standards** at this stage remain very important, even for the transformed products. For example, for French fries production, long potatoes are favoured and for crisps it is important to have round products. When the potatoes are **not handled gently enough**, bruising can occur. The dry matter content is also significant and even the colour of the potatoes plays a role. **Inadequate packaging** (easily breakable, not airtight or waterproof enough) can lead to waste, sometimes for whole batches.

Badly damaged or misshapen potatoes sorted out in the processing industry can be redirected to the starch industry (Envall, 2017). For example, in Sweden, a lot of starch is produced, mainly from contracted farmers culturing special varieties (Törnquist, 2015). In recent years, the starch industry has high amounts of downgraded and surplus food potato in the springtime (Starch, 2017; Andrae, 2017). Production losses from the processing industry are often sent to AD.



Potatoes and tomatoes
Retail & logistics food waste drivers
Damage during transport
Inadequate packaging
Limited shelf life
Incentives of large purchase
Buk packs
Cosmetic expectations - one damaged vegetable in a bulk pack affects the attractiveness of the entire pack/ Greening due to light exposure
Limits of genetic improvement e.g. trade-off between duration and taste)
Large product portfolio
Order cancellations/ returns set retailers
Price volatility due to high seasonality
Common market Organizations withdrawal (CAP)
Poor storage conditions
Mismatch between demand and supply
Mismatch between supply and demand
Inefficient low security transport
Contractual regulations - order cancellations/ returns
Overstocking
Accident – staff or customers damaging goods
Sales of unpackaged tomatoes favoring consumers'
Pricing
Primary production
Processing & packaging
Retail & logistics
Foodservice & household
Waste management (Incineration / AD / EfW / Compost)
Waste & Valorisation streams
Human consumption (donation, in store discounts
Legend: driver families
Technological
Institutional (business)
Institutional (policy)
Social
Inter stage

POTATOES AND TOMATOES: SUMMARY OF RETAIL & LOGISTICS STAGE

Within the retail & logistics stage, which also may include the wholesale sector, the production of potatoes and tomatoes is either in its fresh stage or has undergone transformation.

Institutional drivers related to business (large products portfolio, pricing, overstocking, etc.) are prominent within this sector.

It appears that there are two drivers of food waste: loss caused by human or machines mistakes (improper handling, transportation, etc.) and loss due to lack of predictability of consumer behaviour (god forecast of demand highs and lows). If reaching a logistic with no mistakes seems unlikely, it is always possible to bring them to a minimum.

Within this stage, more waste is generated than is valorised. Donations are also viable, however these channels are harder to set up.

POTATOES AND TOMATOES: DESCRIPTION OF FOODSERVICE & HOUSEHOLD STAGE

For **tomatoes**, retailers include both traditional shops (44% of Italian tomato consumption in 2012), which are supplied by local small producers and wholesalers, and large-scale ones (56%, ISMEA 2012), that have long-term agreements with large farms, packinghouses, and wholesalers.

For **potatoes**, distribution is conducted in several steps, with short storage time at each step resulting in limited waste levels. Once potatoes are packaged, a best before date is generally set to 10-14 days (although even washed potatoes will not spoil for much longer if stored properly). This means some fraction will not be sold in time and will be prematurely disposed of.

Compared to potatoes, fresh **tomatoes** are more fragile and perishable; therefore, a relatively sizeable share can be damaged during **transportation** (from producers to wholesalers, and then to retailers). Generally, the tomatoes damaged during transport and storage can be neither sold, nor processed to make tomato puree or other products. They could either be valorised via animal feed, or be used to produce compost. Inadequate packaging and storage in transit will not be sufficiently protective of the produce.

Tomatoes can also be damaged by **improper handling** by staff or customers. When the tomatoes are sold in loose bundles, their manipulation by consumers makes them deteriorate faster, thus accelerating waste generation.

Market-related drivers are shortage of demand that leads to longer storage periods as well as the demand of more delicate **tomato** varieties that require more protective transport and storage conditions. Other drivers are linked to the characteristics of the product: since the production peak is during summer, when temperatures are higher, storage conditions are less favourable; moreover, the need to manage a large amount of produce in a limited timespan generates coordination issues.

Tomatoes and **potatoes** can also deteriorate during storage if conditions are not right. Pre-packed **tomatoes** with damaged packaging before reaching retail stores are sent to waste or valorisation streams along with other damaged or decomposed produce. The same happens when the content is only partially damaged.

Greening of potatoes is in part induced by modern packaging. As packaging is designed to visibly present potatoes (and other food products) for consumers, this high-exposure display of products can be problematic, especially for vegetables such as potatoes that grow underground and are accustomed to dark lighting. This point, coupled with extended store opening hours which exposes potatoes to more light, induces a greening phenomenon via the formation of chlorophyll within the potato skin in response to light and temperature exposure. As consumers have cosmetic standards when selecting food products, green potatoes are not placed on display for purchase. So far, suitable packaging innovations that meet retailer requirements whilst shielding potatoes from light wavelengths that cause the greening have not been developed. Furthermore, plastic packaging, which closes off air-exchange between the vegetable and air may lead to further issues, such as humidity which can also shorten life.

Consumers make a **visual selection** of tomatoes in the supermarket, disregarding those which are either unripe or too ripe, or which look damaged. Finally, another share of tomatoes can simply become too ripe to be displayed without having been sold. This is linked to the retailers own involving quality controls, where a lack of training may lead to incorrect classification (i.e. grading errors, hand sorting). In addition, a large product portfolio, increasing choice in varieties make clients privilege the finest products and the others are not picked. When combined with overstocking, with the aim of presenting surplus in order not to present empty shelves, produce may perish if turnover is not sufficient.

Fruit and vegetable waste is a major portion of food waste in the retail sector. However as potatoes are quite robust and sold in high turnover, percentage loss is small and mostly consists of store waste. This typically consists in unpacked potatoes dropped on the floor or not selected by customers (Eriksson, 2017). Waste of packed **potatoes** may be higher in percentage (although not specifically examined during the study). They may be discarded when close to best before date or if one potato in a bag is spoiled, which is less likely when sold unpacked. The volume of packed potatoes sold is small, but becoming more common with new varieties put on the market.

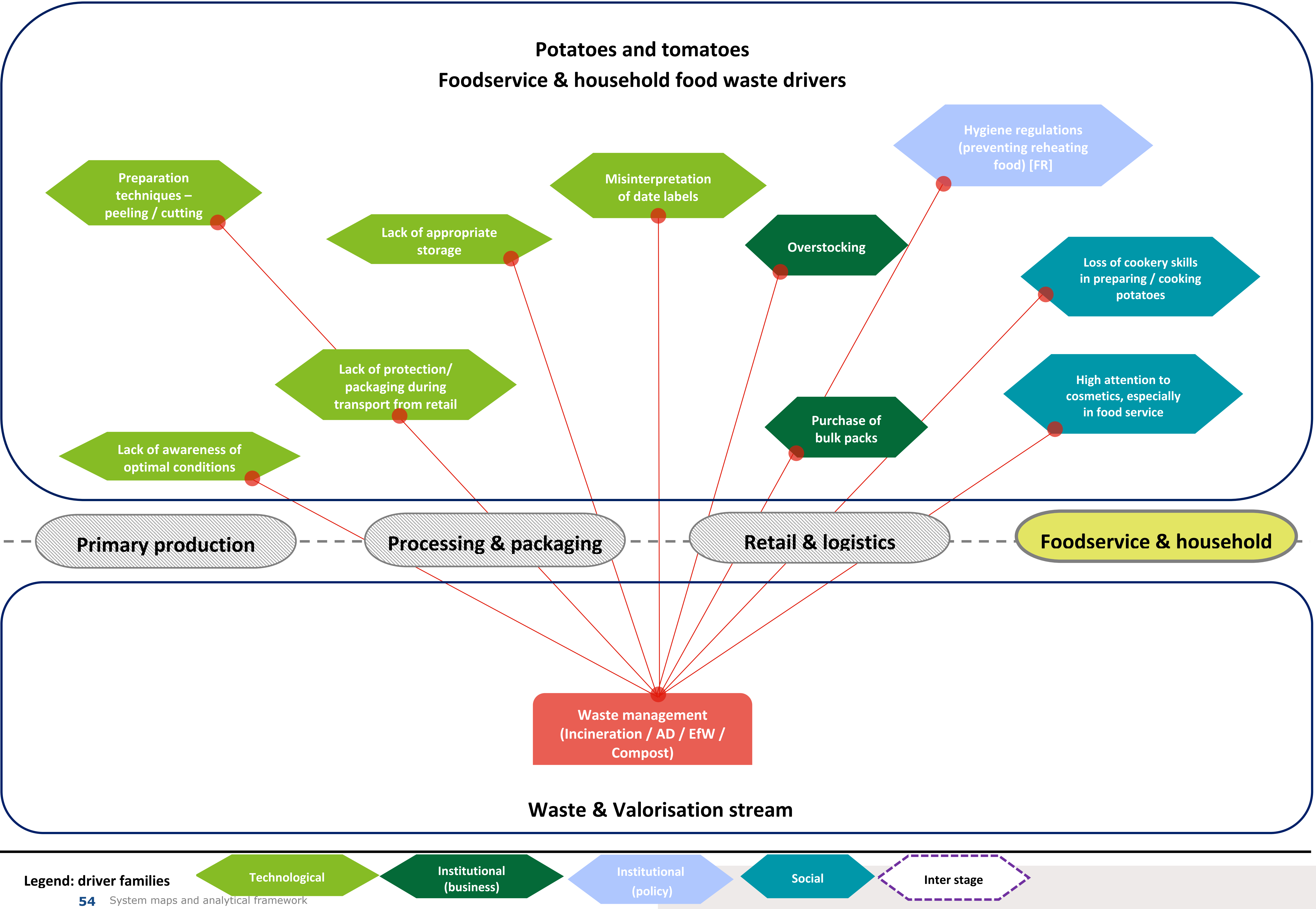
Pricing of potatoes and tomatoes is also an important factor. Products that are deemed too expensive are not sold and therefore sent to waste streams or sold at a discount. **The impact on food waste of discounts at the consumer level are most likely negative but need further examination.** With regard to bulk packs, when a single item within the pack does not meet the clients' criteria, the whole pack cannot be sold at the original price. Consumers are more likely to waste this food at the household level. Price volatility can also occur due to high seasonality.

Order cancellation and returns are decisions made at retail level that cause waste further upstream. In Sweden, **retailers have the possibility of returning spoiled batches for a refund.** There might be some overuse of this possibility, but systems are in place to avoid abuse of that, although not always enforced. **The**

batch may be transported several steps back along the value chain, depending on the problem, before being sent to feed or AD (Pålsson, 2017; Eriksson, 2017).

In France, there are only slight losses at this stage. In the case of **potatoes** for direct consumption, there are only 3% of products unsold (INCOME Consulting - AK2C, 2016). Since this includes products damaged while being on the store shelves, there is a very low amount discarded because the products are too old to be sold. **Retailers' cosmetic guidelines** on potatoes may lead to rejections of potatoes before entering stores and the organisation of the shop shelves might also play a role (Agreste, 2012 ; Jeannequin et al., 2015). Regarding the transformed processed potato (e.g. frozen, canned), the loss at this distribution stage is minimal (0.5%) mainly thanks to the long lifetime of the products (INCOME Consulting - AK2C, 2016).

It is noted that table potatoes have declining market in the UK and have been partly replaced by frozen potato products: chips etc., which have far lower wastage rates.



Potatoes and tomatoes
Foodservice & household food waste drivers
Preparation techniques – peeling / cutting
Lack of appropriate storage
Misinterpretation of date labels
Hygiene regulations (preventing reheating food) [FR]
Overstocking
Loss of cookery skills in preparing / cooking potatoes
Lack of protection/ packaging during transport from retail
High attention to cosmetics, especially in food service
Purchase of bulk packs
Lack of awareness of optimal conditions
Primary production
Processing & packaging
Retail & logistics
Foodservice & household
Waste management (Incineration / AD / EfW / Compost)
Waste & Valorisation stream
Legend: driver families
Technological
Institutional (business)
Institutional (policy)
Social
Inter stage

POTATOES AND TOMATOES: SUMMARY OF FOODSERVICE & HOUSEHOLD STAGE

Within the foodservice and household stage, potatoes/tomatoes have reached their final destination to the end consumer and is very sensitive to perishability.

Consumers are the key driver to food waste generation, notably because of a lack of good storage practices. This is even more symptomatic for tomatoes. The discounts proposed by retailers when products are close to their consumption is also a cause involving food waste.

Since there are not a lot of valorisation streams at the disposal of consumers, the vast majority of loss goes to waste management (incineration, AD, EfW or compost).

POTATOES AND TOMATOES: DESCRIPTION OF FOODSERVICE & HOUSEHOLD STAGE

In Italy, 20% of the tomato supply (183,000 tons in 2012) is used within the hotel, restaurant and catering sectors, while the rest is sold by retailers, mostly to households. It is understood that the proportion is similar across EU member states for vegetables.

The distinction between "potentially avoidable" waste and "avoidable" waste can be made. In the case of **potatoes**, "potentially avoidable waste" refers to the peeling and "avoidable" waste means the potatoes wasted even though they were edible.

Households

Regarding **households**, lack of adapted packaging during transport from retail may cause some waste of **tomatoes** in particular. A first share of waste is due to damages during transport from the supermarket to households; another share is not consumed as it rots due to either unsuitable storage condition. **Storage** at home is a source of concern especially for tomatoes in warmer weather. **Lack of awareness** of optimal storage conditions is therefore a major driver (appropriate storage - light, heat, humidity) which makes fresh products degrade faster.

In addition, leftovers that are not consumed, or are stored for too long, become waste. Consumers may also misinterpret date labels, mistaking "best before" for "use by" dates or forgetting to consume the product on time entirely.

Losses associated with **potatoes** for direct consumption are very diverse: peeling, removing damaged parts, cosmetic standards, especially table scraps left over after a meal (Ministère de l'écologie, 2012). Preparation techniques such as peeling are usually not optimised, which leads to some waste. In France, the estimated waste of potatoes peeled is estimated at 5% of the bought quantities of potatoes (INCOME Consulting - AK2C, 2016). Waste for transformed or processed products is less significant since they have a higher storage life and require less preparation. Differently from potatoes, **tomatoes** are rarely peeled before being consumed, and are consumed mostly raw, or used for obtaining tomato sauce.

Purchase of bulk packs which are often cheaper than the same quantity bought loose. But often the **households** underestimate the quantity in the pack and do not finish it. The packaging of **potatoes** is often proposed by bags of 3, 5 or even 25 kg. Since the price is often more attractive for big quantities, this encourages people to buy these bags even if this involves having leftovers. **In other words, discounted food products at supermarkets, such as "2 for 1" deals often induce loss for households.** Via this type of marketing, consumer are encouraged to purchase more food for less, regardless of their actual need.

In Italy, most tomato waste produced at household level is disposed with organic waste, if recycling is available at municipality level. Some households, especially in rural areas, can use this waste to feed animals, or to produce manure.

Foodservice sector

The **foodservice** sector is prone to **overstocking**, where losses are linked to forecasting and inaccurate estimations of portioning. In addition, some professional practices in the food service sector such as automatic peeling helps people to gain time and facilitate their work but this fosters waste though this is very hard to quantify. In France, in commercial catering, it is estimated that as much as 20% of mass is wasted potato peeling (INCOME Consulting - AK2C, 2016).

In **foodservice**, client requirements on **cosmetics** can be strict, leading to potato rejects, and minimal food waste recovery. Rules on **food safety** and product quality, portions size, client requirements or administrative rigour could be food waste drivers. In France, strict hygiene regulations, preventing reheating food for example, limits the channels of valorisation and may restrict redistribution. When it comes to public catering, food cannot be reheated after already being heated once because of sanitary/health restrictions. Within this scenario, all uneaten cooked food must be disposed of.

4.4 Processed meat & poultry

For the **processed meat and poultry** food category, the following country-specific information is detailed below per value chain step:

Food product category	Countries covered in the study				
	DE	FR	IT	SE	UK
Processed meat & poultry			x		x

4.4.1 Context

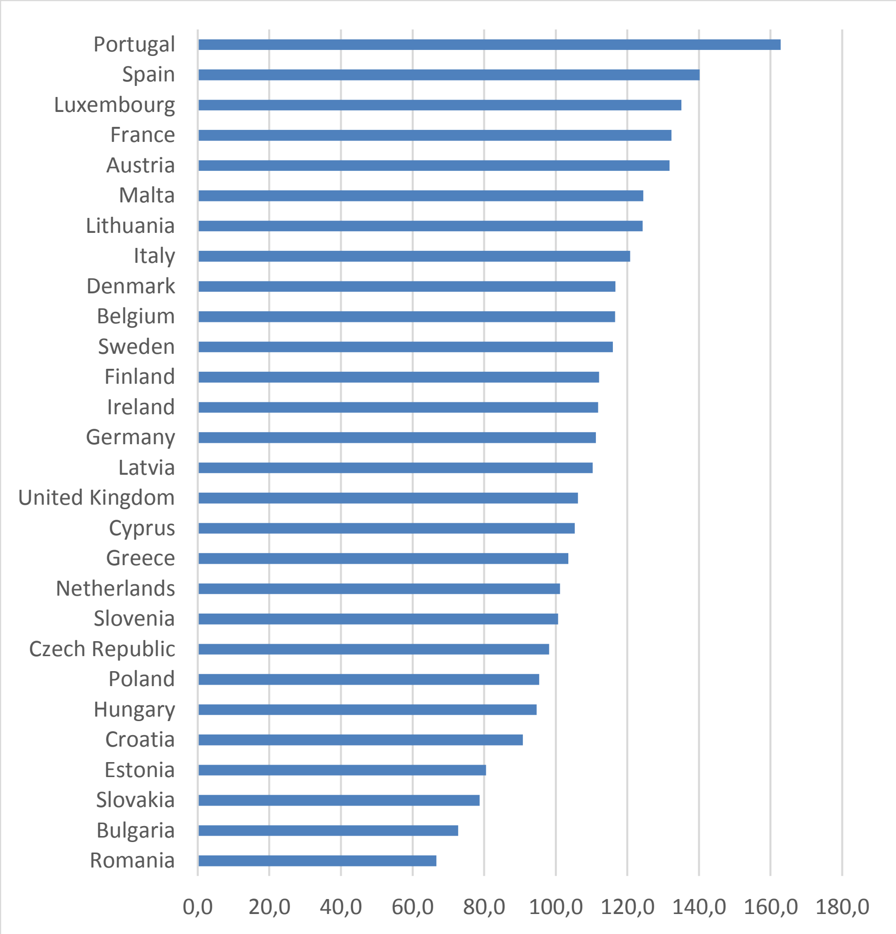
Meat production, including red meat, poultry and fish, across EU-28 amounts to 72 million tonnes. This does not include weight of livestock slaughtered across the EU-28. The sector includes carcase meat, cuts/ fillets, preserved but also processed meat, fish, poultry and inputs to pre-prepared meals. There is therefore a wide variety of products: frozen, chilled, cured meats, etc. Within this study particular attention is paid to chicken, with some details on ham.

The five largest producers of meat in Europe are Germany, France, Italy, Spain and the UK.

Portugal, Spain, Luxembourg, France and Austria are the largest per capita consumers of meat products. There is a significant range between lowest and highest consumers across EU28 (66.6 kg (Romania) per capita to 162.8 kg (Portugal)).

For these system maps two products were analysed: processed meat in the UK and unprocessed poultry meat in Italy.

EU-28 Meat consumption in 2011 (kg per capita (FAOStat)



According to the EFSA Comprehensive Food Consumption Database, poultry is the second most consumed type of meat in Italy: 40.6% of adults had consumed it during the period of reference in 2005-2006, compared to 84.7% for all livestock (EFSA, 2006). In particular, chicken was by far the most consumed type of poultry meat, with 34.7%, compared to 57.5% for beef, 35.1% for veal, and 31.8% for pork. However, the consumption of chicken meat has been increasing during the last decade, while that of the more expensive beef and veal has been decreasing steadily due to the ongoing economic crisis, as well as health and environmental concerns. In 2015, the production of poultry meat was 1,296,400 tons, of which 906,700 tons of chicken (Unaitalia, 2016). Consumption amounted to 19.9 kg per capita, of which 14.4 of chicken – an increase of 3.4 percent compared to the previous year. The sector of poultry is totally self-sufficient: Italy produces 105.5 percent of its consumption, and 99 percent of the chicken comes from inside the country (Unaitalia, 2016).

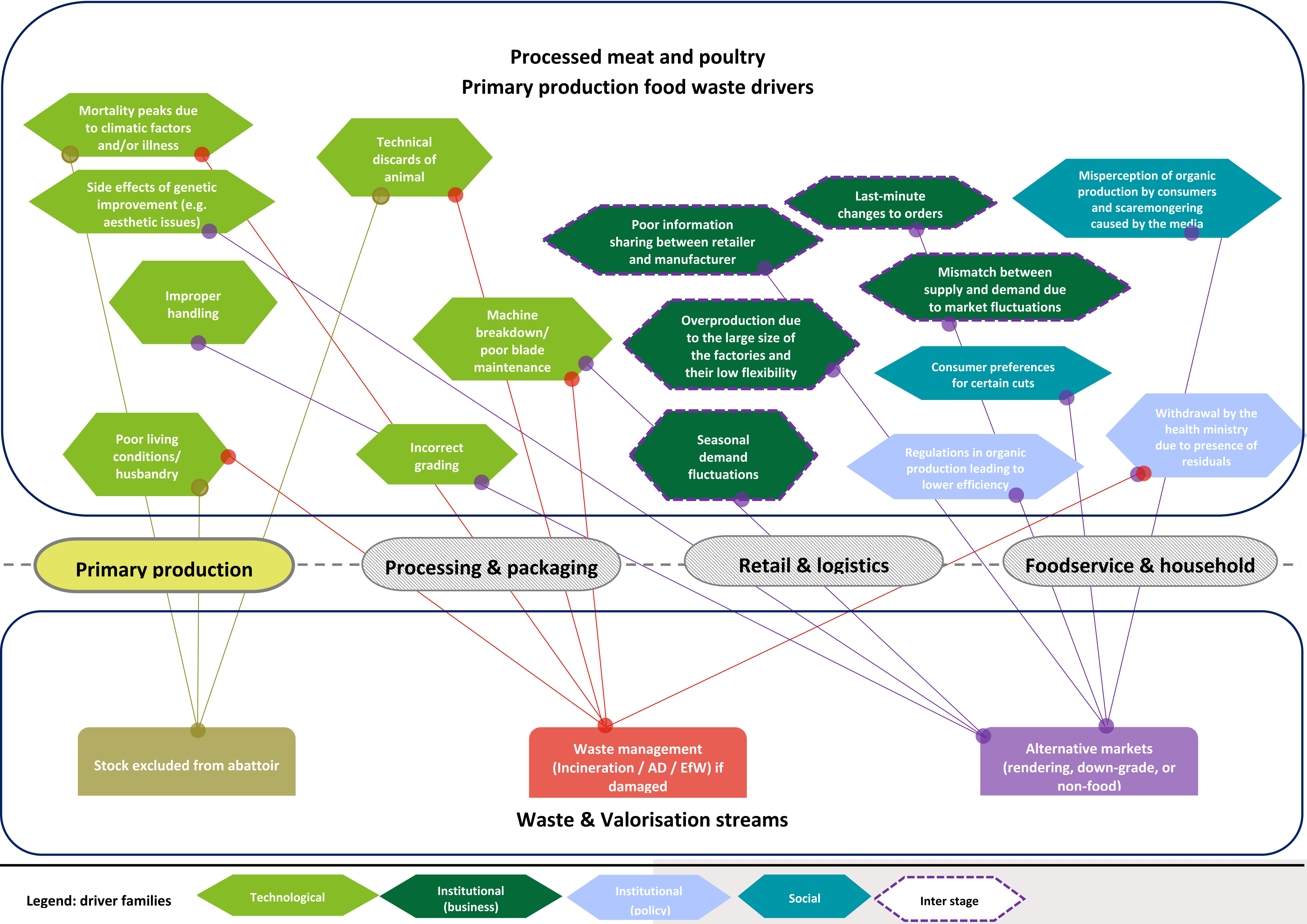
Differently from the cattle and pig supply chains, which are more atomized, for chicken, three large firms (Amadori from Cesena, Aia from Verona, Fileni from Jesi, Marche) represent around 80% of the Italian production. Overall, almost all chicken comes from industrial production: self-consumption covers around 5%. These firms integrate all steps of the supply chain within their activities, ensuring technical efficiency through the presence of specialists (Unibo, 2017).

Chicken products are grouped into five categories: I. entire raw ("deli") chickens; II. raw cuts of chicken (e.g. breast, thighs, wings, drumsticks, etc.); III. processed raw chicken (meat skewers, hamburgers); IV. ready-to-eat chicken (meatloaves, roast, sausages); V. ready-to-eat chicken with the addition of other products (side dishes, vegetables). In Italy, chicken is usually purchased raw, without being processed and without additional ingredients. Hence, categories I and II represent around 60 percent of the total value of sales. According to EFSA (2015), no single prepared chicken product was consumed by more than one percent of consumers. Moreover, the purchase of entire carcasses is less and less frequent: consumers prefer packed cuts (with or without bones). Therefore, the analysis below focuses on categories I and II (slaughtered chicken, either entire or in pieces, eventually deboned), while other categories are mentioned only when by-products are used for chicken preparations. Cockerels and capons are not considered, due to the specific process followed to obtain them.

It is worth noticing that Europe defines three different categories of animal by-products. It goes from Category 1 (very high risk) to Category 3 (low risk). The valorisation options different relatively to the product category and since Category 1 by-products must be destroyed while categories 1 and 2 can be used in composting and biogas plants (after rendering for Category 2).

4.4.2 Processed meat and poultry system maps per sector of the supply chain

The following section covers in detail the drivers that affect the different stages of the supply chain. For each step of the value chain, a dedicated system map provides a zoomed-in illustration of the identified drivers and waste/valorisation streams for each particular step:


Processed meat and poultry
Primary production food waste drivers
Mortality peaks due to climatic factors and/or illness
Technical discards of animal
Side effects of genetic improvement (e.g. aesthetic issues)
Improper handling
Machine breakdown/ poor blade maintenance
Poor information sharing between retailer and manufacturer
Last-minute changes to orders
Misperception of organic production by consumers and scaremongering caused by the media
Mismatch between supply and demand due to market fluctuations
Overproduction due to the large size of the factories and their low flexibility
Consumer preferences for certain cuts
Poor living conditions/ husbandry
Incorrect grading
Seasonal demand fluctuations
Regulations in organic production leading to lower efficiency
Withdrawal by the health ministry due to presence of residuals
Primary production
Processing & packaging
Retail & logistics
Foodservice & household
Stock excluded from abattoir
Waste management (Incineration / AD / EfW) if damaged
Alternative markets (rendering, down-grade, or non-food)
Waste & Valorisation streams
Legend: driver families
Technological
Institutional (business)
Institutional (policy)
Social
Inter stage

PROCESSED MEAT AND POULTRY: SUMMARY OF PRIMARY PRODUCTION STAGE

The major drivers include systemic institutional drivers such as the sharing of information between retail and primary production but also order modifications and cancellations. Key technological drivers, which constitute the majority of drivers are this stage, are technical discards and incorrect grading (quality control), machinery malfunction and poor conditions.

Alternative markets provide important channels for valorization. Animal feed is a major valorization stream following rendering. The other key waste & valorization streams are stock excluded from the abattoir, incineration, anaerobic digestion and energy from waste.

PROCESSED MEAT AND POULTRY: DESCRIPTION OF PRIMARY PRODUCTION STAGE

Even before the animals are sent to the abattoir, some waste appears in the chain. When stock is not healthy enough, or is not suitable, it does not go in the process for human consumption. The complexity for breeders of dealing at the same time with market demand and with their own production process sometimes leads to **overproduction**. **Communication** is a central element but the study has shown that much effort can be done regarding this aspect.

First of all, at primary production level, satisfactory **living conditions**, good animal **husbandry** and veterinary plans are key to ensuring the welfare of animals. Many are not deemed healthy enough to enter the chain.

Improper handling and **hygiene lapses** can swiftly lead to generation of food waste. **Human errors** due to lack of sufficient **training** can also cause **incorrect grading** of meat in quality control. In addition, **machine breakdown** or **poor blade maintenance** can lead to additional quantities of rejected meat.

Technical discards may be associated with the lack of demand for certain parts of the animal. This concerns both demand from secondary markets as well as **consumer preferences**.

Last-minute changes to orders leads to uncertainty for the producer due to the lack of consistent predictable demand. This is combined with **poor information sharing** between retailers, distributers and manufacturers. There are also **seasonal demand fluctuations,** which must be taken into account in the production planning.

As for **chicken** specifically, primary production includes breeding farms (grandparents' and parents'), hatcheries, and broiler growing farms.

Industrial chickens are hybrids which have passed through a long **selection** process aimed at achieving fast growth, low conversion indexes (of animal feed into meat) and, thus, efficient transformation. The genetic industry works at the global-level, with 3-4 multinational houses of selection that provide eggs to all national industries.

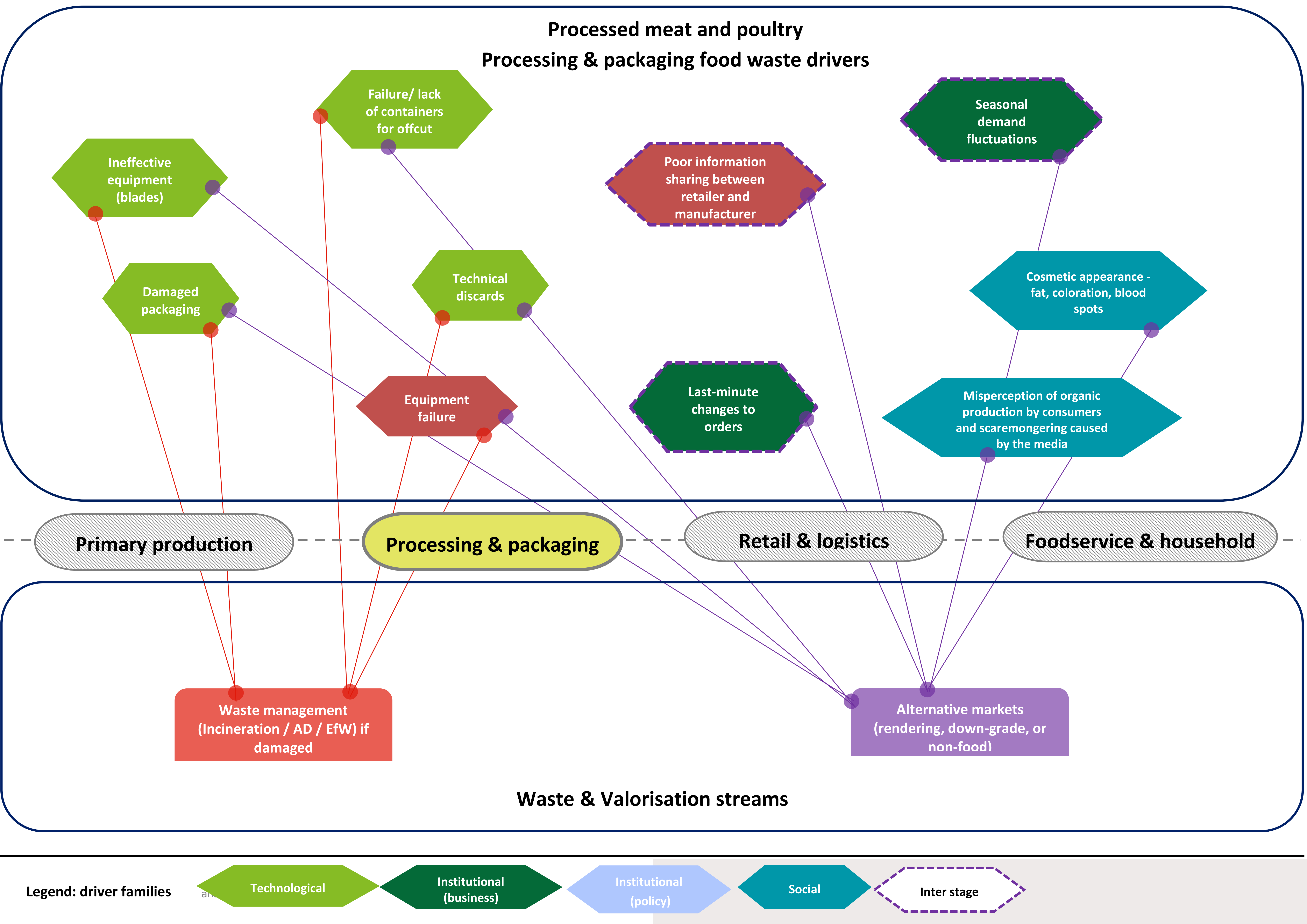
Three typologies of chicken are produced: 1. light (slaughtered at 1.5-1.7 kg, all female); 2. mid-sized (slaughtered at 2.5-2.8 kg, half female and half male); 3.

Heavy (slaughtered at 3.3-3.8 kg, all male). Female chickens are slaughtered younger because, after they reach a weight of 2.5-2.8 kg, all feed they eat is converted into fat rather than into muscular mass.

Parents' breeding farms buy eggs (or one-day chicks) from the houses of selection. Parents are a very small number, because each of them produces about 140 eggs; therefore, the mortality within this phase is not very high. Small and infertile eggs are discarded before being incubated and transferred to firms that **make egg products** (pasta, pasteurised eggs, cakes, etc.), thus preventing food waste. Italian consumers eat around 220 eggs per capita a year, of which 60 percent fresh, and 40 percent within other products: most of the latter come from this phase of the chicken supply chain.

A second waste flow is generated during the hatchery phase: infertile eggs and dead embryos are transferred to the rendering section of the factory (Rendering is the cooking or processing of ABP with heating to at least 133° C for at least 10 minutes at a pressure of at least 3 bars to product protein meals and tallow), where they are autoclaved and dried out to produce protein-based flours. These flours are used for feeding fish in fish farms, or pets (before the outburst of the mad cow disease, they were used to feed animals aimed at human consumption). A third waste flow is due to **mortality** within **broiler growing farms**, accounting for 3-4 percent of all chickens apart from the case of rare events, such as heat peaks. Dead chickens are disposed as special waste (i.e., sent to **incineration**).

Thanks to **genetic improvements**, the efficiency of chicken farms improved considerably. In the fifties, 2.0 kg of weight were reached after around 100 days, and the conversion rate of feed into meat was 4-5; today 40 days are enough, and the conversion rate is about 1.5-1.6. As a side-effect of genetic selection, chicken breast can present some visual anomalies: in this case the meat is downgraded, i.e. processed to make different products, or sent to the rendering section of the firm. However, producers can be penalized (in terms of price, or rejection of the product) in case of anomalies; therefore, they have an interest in minimizing them through constant research.


Processed meat and poultry
Processing & packaging food waste drivers
Failure/ lack of containers for offcut
Ineffective equipment (blades)
Poor information sharing between retailer and manufacturer
Seasonal demand fluctuations
Damaged packaging
Technical discards
Cosmetic appearance - fat, coloration, blood spots
Equipment failure
Last-minute changes to orders
Misperception of organic production by consumers and scaremongering caused by the media
Primary production
Processing & packaging
Retail & logistics
Foodservice & household
Waste management (Incineration / AD / EfW) if damaged
Alternative markets (rendering, down-grade, or non-food)
Waste & Valorisation streams
Legend: driver families
Technological
Institutional (business)
Institutional (policy)
Social
Inter stage

PROCESSED MEAT AND POULTRY: SUMMARY OF PROCESSING & PACKAGING STAGE

The processing & packaging stage includes the systemic drivers found in the primary production stage, notably **asymmetry of information** and **order modifications**. Ineffective equipment due to maintenance and investment inadequacies, technical discards as cuts are increasingly refined and damaged packaging are principal technological drivers at this stage.

As in the primary production stage, alternative markets provide important channels for valorisation following rendering for example. The other waste & valorisation streams are incineration, anaerobic digestion and energy from waste.

PROCESSED MEAT AND POULTRY: DESCRIPTION OF PROCESSING & PACKAGING STAGE

The processing and packaging stage is affected by technical issues such as **equipment and machinery failure**. This may affect the meat directly (non-functioning blades due to poor maintenance) causing rejects or case damage to packaging, leading to unsellable products.

Further **technical discards** can be generated at the processing stage as cuts are refined. There may not be a sufficient system for collecting offcuts, which hence become waste rather than be processed in secondary markets. This may simply be due to a lack of containers. Bill of materials (BOM) ends are sections of meat that are at either end of the meat BOM. For example, they are too small to slice into. 'BOM ends' cause significant waste within the ham slicing stage as the meat is held at the BOM ends by grips slices too small for use cause more than 30% loss. In a similar manner, over-trimming of meat in the butchery plant can result in high quality cuts not being fully used.

During site visits in the UK, the main material flows identified as waste and by-product streams included the following elements: floor waste (meat that had fallen from conveyors, from cutting machine breakdowns, trimmings in the butchery plant accidentally dropped); meat/ animal tissue for which no alternative market was available, sent to rendering; animal fats/ oils recovered from DAF (Dissolve Air Flotation) plants; sludge from pre-treatment plant containing meat particles from washing processes; bones, sent to rendering; and QA rejects on the slicing line, not within retailer specifications (to down-grade markets)

The problem of **last-minute order changes** also affects the processing and packaging stage. The lack of certainty and inflexibility of production leads to the generation of waste. Similarly, the lack of information sharing between actors across the supply chain contributes to the generation of waste. The processing and packaging actors are also struck by seasonal demand fluctuations.

Cosmetic expectations limit the acceptable standards of products. Attention is paid to far, coloration and blood spots for instance. Non-compliant meat may be sent to secondary markets or to waste streams. In addition, in the UK, a significant issue observed is the prevalence of **Quality Assurance (QA) down-grades** within the meat slicing plant. Out-grading criteria included in particular, the fat content, the general appearance and the shape of the product. The high loss rates on some lines (up to 40%) are due to over-stringent retailer specifications, especially on lines supplying the premium end of the retail market. The trend towards greater standardisation of meat sold in supermarkets inevitably results in rejects due in part to the natural variation in meat.

All potential waste is sent to alternative markets to be valorised, unless the material is dropped and becomes floor waste, in which case it follows a waste stream. High level definitions of food waste are not particularly relevant to the meat processing sector, due to the high value of protein-based foodstuffs and the diversity of down-grade markets that generally prevent a product that is rejected from its intended market from becoming waste. Offcuts, meat shreds, skin, offal and bones: all have alternative markets**. In some cases, alternative markets may have a higher value than the main market** (for example, pork scratchings from skin and membranes used in the cosmetics sector). However, the factors that drive the downgrading of meat products have environmental and wider sustainability implications. These are likely to exceed those associated with fractions that fall within European food waste definitions for the meat processing sector.

During the analysis conducted in the UK, it was observed that site operators are required to segregate meat waste according to the requirements of risk categories set by the Animal by-product (ABP) Regulations. Use for animal feed is therefore an option.

Raw cuts of chicken do not undergo any type of processing. However, chickens are cleaned, graded, slaughtered and cut. These operations can be implemented by either the producer, or a specialized slaughterhouse; cuts are then packed.

The chicken supply chain is very concentrated and, thus, coordinated: in Italy, three firms cover around 80% of the production, internalizing all activities, including the slaughtering of chickens. Therefore, these operations take place within the same firm where the chickens are bred, eventually within a specialized plant.

Light chickens are sold whole while middle-sized and heavy chickens are sold cut, due to their excessive dimensions. While heavy chickens from industrial production are slaughtered after around 50 days, the minimum age to slaughter **biological chickens** is 81 days. After eliminating blood, plumage, offal, entrails, necks and heads, chickens reach between 66 and 70 percent of their initial weight (e.g. the weight of the busts of light chickens is 1.0 kg, down from 1.5 kg). As for the parts removed, liver, muscular stomach and heart are sold for human consumption in Italy, but this depends on the cultural habits of the countries.

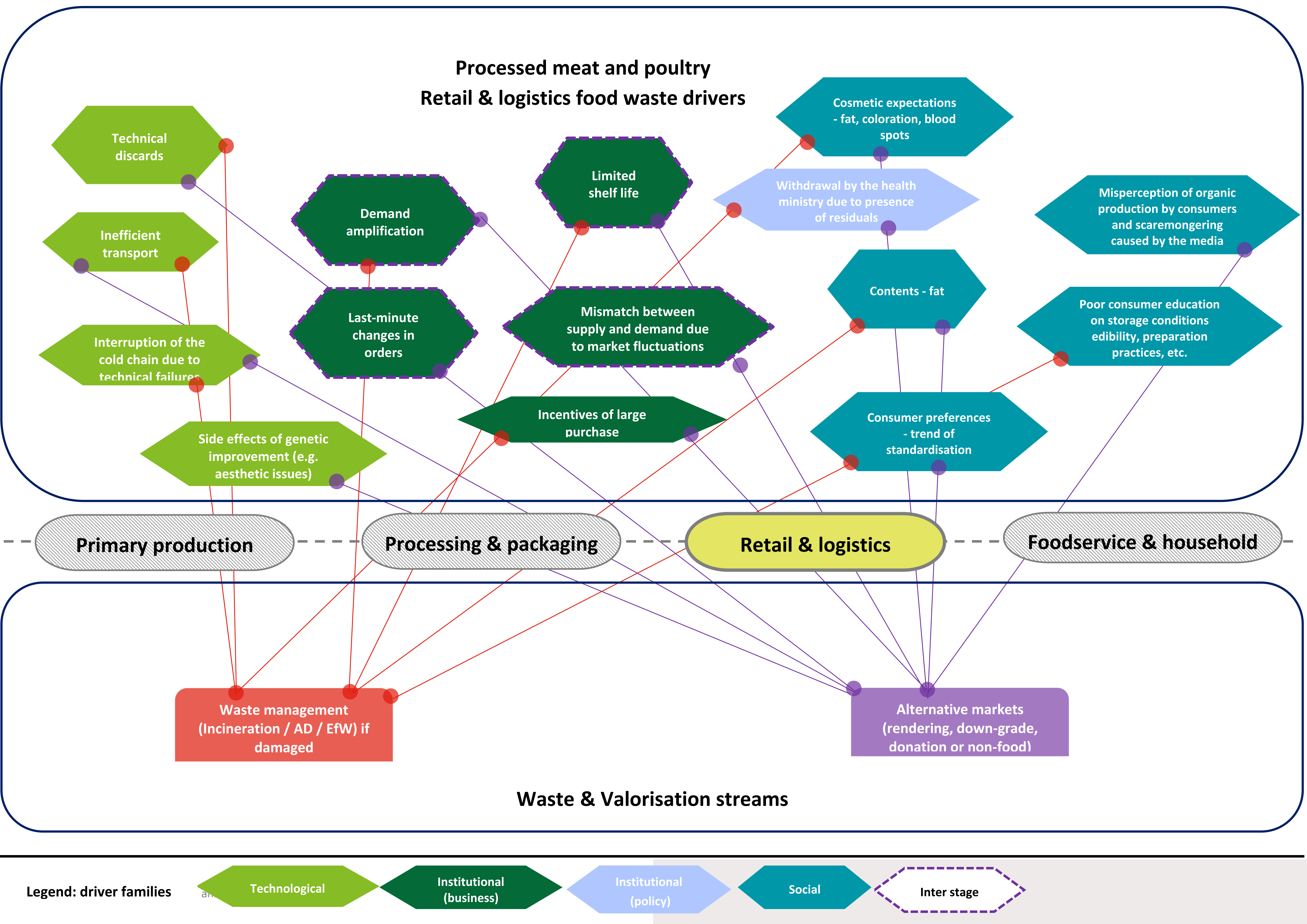
The remaining parts are sent to the **rendering** section of the factory, where they are autoclaved and dried out to produce protein-based flours. Blood is very valuable in terms of nutritional content; the plumage is also very nutritive, although it needs to undergo treatment to eliminate anti-nutritional factors, like sulphur amino acids and chitin. Even the fat surrounding the entrails is used for animal nutrition. As a result, **almost no waste is generated in these phases.**

A relevant by-product of chicken slaughterhouses is represented by the water used to wash the animals (around 20 litres per animal). Considering that

Aia and Amadori (two of the largest chicken firms in Italy) slaughters 150 million and 120 million chickens a year respectively, the size of this waste emerges clearly. The disposal of water represents an important cost, as it needs to be purified. A good practice has recently emerged: Amadori opened a “green plant”, where the organic part of the water is recovered to produce biogas, while the water is made drinkable.

Chickens’ back and carina are not sold as separate cuts. They are squeezed at high pressures to produce mechanically deboned meat. Due to the presence of iron and fats, this meat is highly unstable. Therefore, it must be consumed within 24 hours, or frozen. It is generally used to make products like sausages, where the meat cannot be directly seen by consumers.

During **rare events**, like the avian influenza (2000 and 2006), **large market fluctuations** in the demand of meat were observed. In these cases, the slaughtering of animals continues at the same speed, but they are usually frozen until the market settles.


Processed meat and poultry
Retail & logistics food waste drivers
Technical discards
Inefficient transport
Interruption of the cold chain due to technical failures
Side effects of genetic improvement (e.g. aesthetic issues)
Demand amplification
Last-minute changes in orders
Limited shelf life
Mismatch between supply and demand due to market fluctuations
Incentives of large purchase
Cosmetic expectations - fat, coloration, blood spots
Withdrawal by the health ministry due to presence of residuals
Contents - fat
Consumer preferences - trend of standardisation
Misperception of organic production by consumers and scaremongering caused by the media
Poor consumer education on storage conditions edibility, preparation practices, etc.
Primary production
Processing & packaging
Retail & logistics
Foodservice & household
Waste management (Incineration / AD / EfW) if damaged
Alternative markets (rendering, down-grade, donation or non-food)
Waste & Valorisation streams
Legend: driver families
Technological
Institutional (business)
Institutional (policy)
Social
Inter stage

PROCESSED MEAT AND POULTRY: SUMMARY OF RETAIL & LOGISTICS STAGE

At the retail stage, social drivers alongside institutional drivers are identified as the two principal categories. Social drivers include cosmetic expectations and other preferences of the consumer, heightening specifications. The institutional economic and business management drivers include order modifications and cancellations, limited shelf life of products and instances of demand amplification.

Alternative markets provide important channels for valorization as in the previous stages. The other key waste & valorization streams are incineration, anaerobic digestion and energy from waste.

PROCESSED MEAT AND POULTRY: DESCRIPTION OF RETAIL & LOGISTICS STAGE

Changes to retailer specifications may be made without reference to the production yield. They therefore have implications at the processing stage and the loss in value is not borne by the retailer. If a tightening of the **specification** is made on the basis of **consumer preference** (fat, coloration, blood spots etc.) or from the perspective of market advantage in retail sales, the implications for the manufacturer can be significant. Overall, consumer preferences and the trend of standardization, restrict what is considered satisfactory.

Although this is not a waste driver, it represents a wider issue in relation to supply chain economics and sustainability. If more animals are slaughtered to maintain the same level of final product, further imbalances in carcase utilisation may be exacerbated due to the lower demand or lack of end-markets for cuts and non-carcase meat generated.

Some chilled processed meat products are sensitive to rapid **demand fluctuations** and **late order cancellations**, potentially resulting in further economic losses to the sector. A significant example within the meat processing sector relates to products that are in greater demand for barbecuing during the summer months. As with other **highly seasonal demand fluctuations**, forecasting and information sharing are important aspects of retailer and manufacturer efforts to reduce inefficiencies and waste.

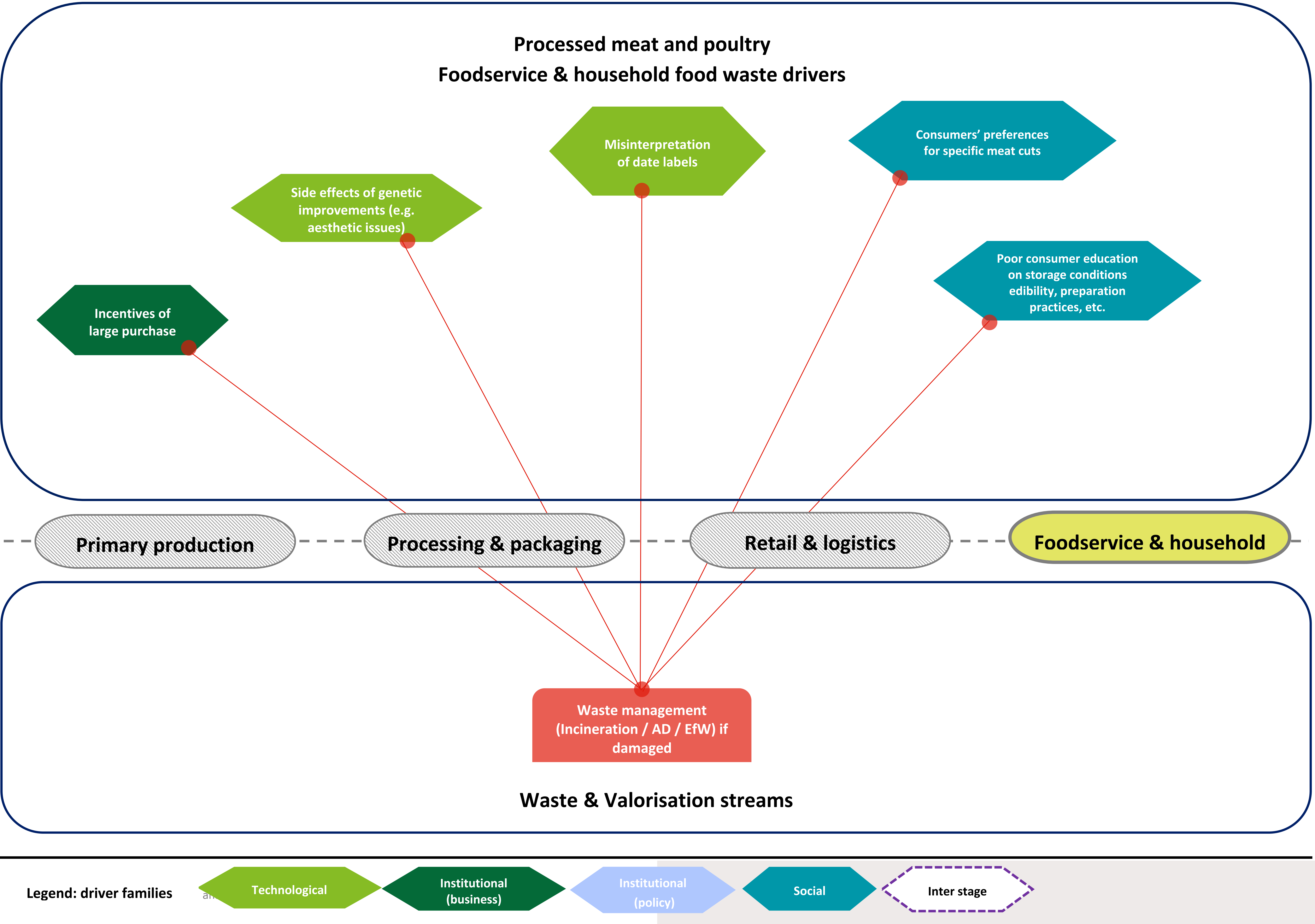
Technical discards occur yet again as meat cuts are further refined. In Italy, people usually buy raw chicken (study conducted specifically on this product) and very scarcely processed poultry. This means that the quantity of meat wasted at the processing stage is smaller than in countries with a different operating mode but higher within the household stage instead.

Consumers may misinterpret **date labels**, mistaking "best before" for "use by" dates, or simply forget to consume the product on time. Overall, many meat products have a **limited shelf life**.

As for Chickens, logistics includes the transport of live animals from the producer to the slaughterhouses (often internalized by the firm), and of carcasses and cuts from the slaughterhouses to the retailers. Waste in the wholesale and logistics phase is negligible. In Italy, **mortality during transport** is **low**, with a rate of around 0.2% - 0.5% of all animals transported: in this case, they are transferred to the rendering section of the factory, where they are used to produce protein-based flours.

Once chicken meat reaches the selling point, if no problems in the cold chain were observed, it is displayed to consumers until some days before the end of its shelf-life. Shelf-life is around 9-10 days; therefore, products are usually withdrawn after around 8 days. Indeed, it is **difficult to sell** them **in the last days of their shelf-life.** Actual procedures vary depending on the agreement between producers and retailers.

As for the management of **unsold meat**, the products belonging to categories I and II which are still within their shelf-life are either withdrawn by producers or sent to the **gastronomy** section of the supermarket, and used to prepare cooked food for human nutrition. Those beyond their expiry date are transferred to the rendering section of the producing firm. Due to the presence of additional foodstuffs, whose quality and origin needs to be certified using more complex procedures, the products belonging to categories III, IV and V are sent to *ad hoc* firms. They may then be cooked and used for **human nutrition**, e.g. within canteens.



Processed meat and poultry
Foodservice & household food waste drivers
Misinterpretation of date labels
Consumers' preferences for specific meat cuts
Side effects of genetic improvements (e.g. aesthetic issues)
Poor consumer education on storage conditions edibility, preparation practices, etc.
Incentives of large purchase
Primary production
Processing & packaging
Retail & logistics
Foodservice & household
Waste management (Incineration / AD / EfW) if damaged
Waste & Valorisation streams
Legend: driver families
Technological
Institutional (business)
Institutional (policy)
Social
Inter stage

PROCESSED MEAT AND POULTRY: SUMMARY OF FOODSERVICE & HOUSEHOLD STAGE

The focus of the study on this stage is chicken.

At the food service & household waste stage, drivers are relatively less numerous but remain diverse, covering three driver categories. A key technological driver is the presentation and misinterpretation of dates for the use of a product, business and social driver categories. Social drivers include consumer preferences and specifications as well as awareness of optimum storage conditions. The principal business driver is based around the attractiveness of incentives for consumers or food service providers to make large potentially unsuitable purchases.

Alternative markets are not considered a major stream at this stage even for food service actors. The key waste & valorization streams are deemed to be incineration, anaerobic digestion and energy from waste organised by the relevant municipal authority.

PROCESSED MEAT AND POULTRY: DESCRIPTION OF FOODSERVICE & HOUSEHOLD STAGE

The food service and household sector of the supply chain includes restaurants, hotels, catering services, public institutions (hospitals, schools, etc.), as well as households.

It is worth noting that raw cuts of chicken undergo a preparation process. **Chicken** is a very **flexible product**. It is easy to cook and, thanks to its aromatic neutrality, can be used in many different dishes. During the last decades, consumers' purchasing habits have changed (e.g. they prefer chicken cuts rather than entire chickens). However, chicken producers could easily **redirect parts for which there is less demand** to other uses, including the preparation of processed products. If the lack of demand is temporary, slaughtered chickens are simply frozen. The ongoing economic crisis generated a **substitution effect of red meat** with "traditional" **chicken** meat, due to the lower price of the latter, as well as the lack of ethical, religious, nutritional, or sanitary barriers. Hence, the chicken industry has kept having a good performance.

The consumption phase was not extensively enquired. However, once purchased, the raw cuts of chicken are likely to overcome a preparation process that includes the eventual elimination of some parts (e.g., the skin, the fat and the bones), and the cooking. These same parts may be discarded (or, as for bones, *are* discarded) also after the meal. If the municipality implements the separate collection of waste, these parts are disposed as organic waste. Some families could use them to feed pets.

4.5 Prepared meals (sandwiches)

For **prepared meals (sandwiches)** food category, the following country-specific information is detailed below per value chain step:

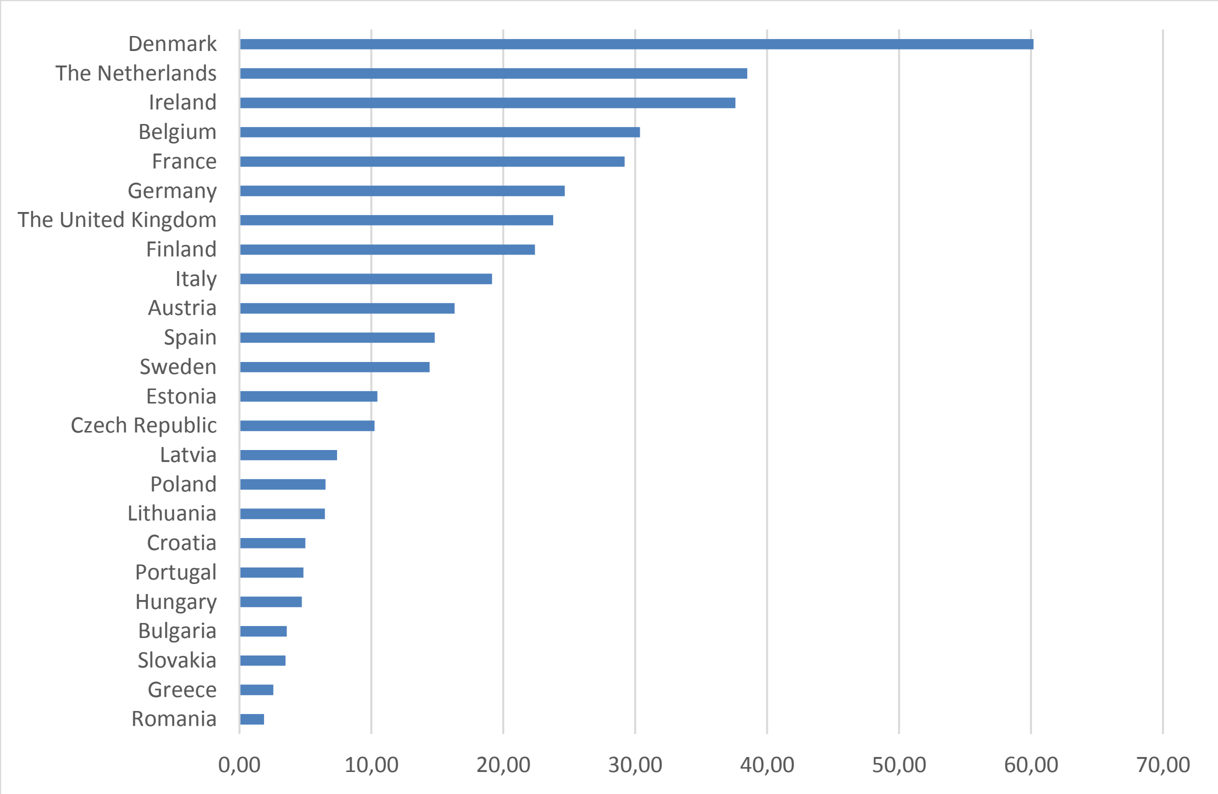
Food product category	Countries covered in the study				
	DE	FR	IT	SE	UK
Prepared meals (sandwiches)					x

4.5.1 Context

The pre-prepared meal manufacturing sector is very diverse and includes a wide range of products and EU-28 amounts to 9.5 Mt of production across EU (Eurostat, 2012). The sector produces meat, poultry dishes and fish dishes (including fish and chips); vegetable dishes; frozen or otherwise preserved pizza; fresh (i.e. uncooked) pizza; and sandwiches. These products in turn draw from a wide variety of ingredients from across primary producers and from other sections of food manufacturing.

For the purposes of our study we focus our analysis on sandwiches as a common prepared meal in the UK, which sits just above average in terms of production per capita as illustrated by the graph below. The production of prepared meals per capita is diverse across Europe. Denmark produces about 20 times more as Romania and stands out as the largest producer out of EU member states. The three largest producers are Denmark, the Netherlands and Ireland.

EU-28 Pre-prepared meal production in 2012, kg per capita (Eurostat, 2012)

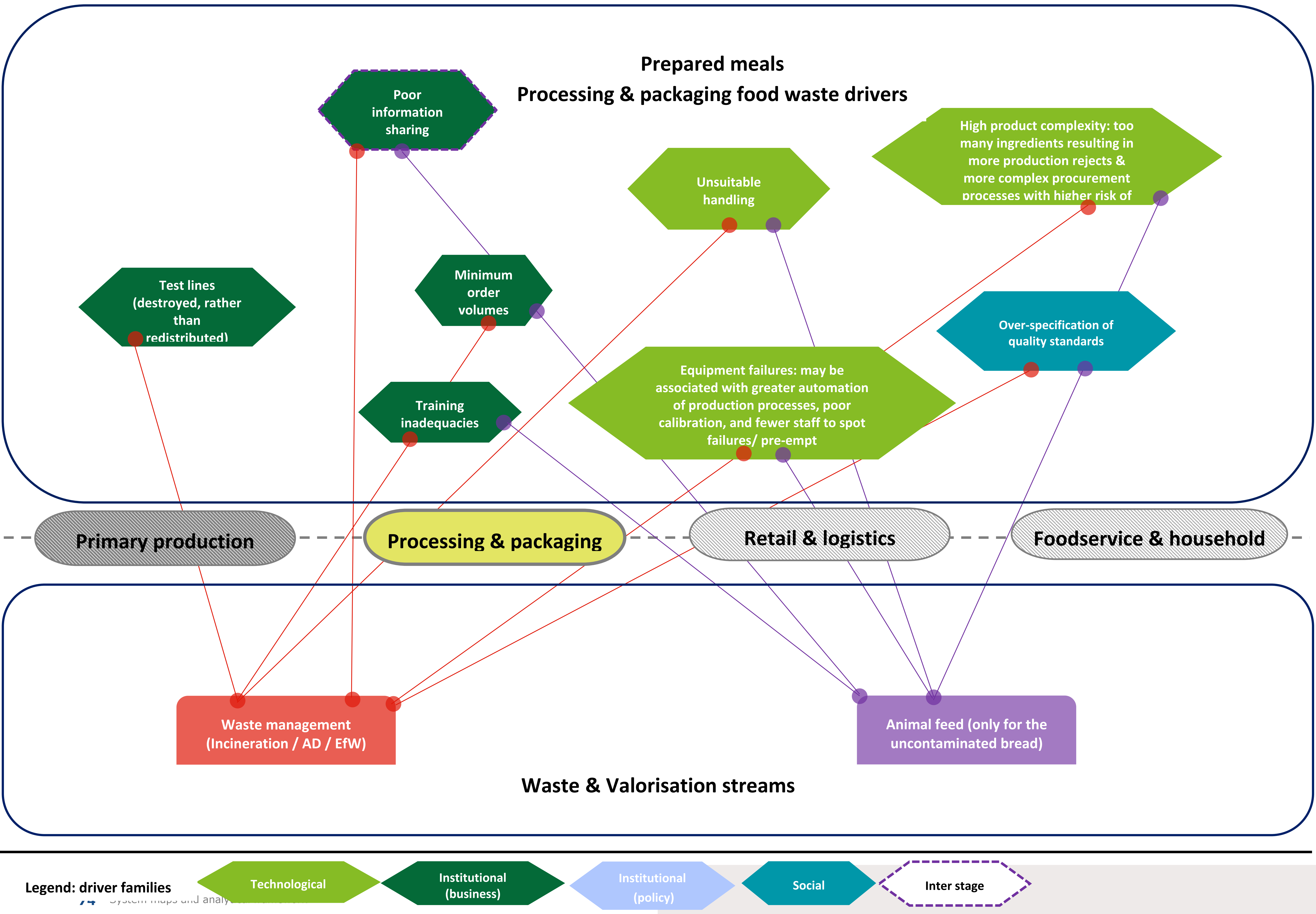


4.5.2 Prepared meals map per sector of the supply chain

The following section covers in detail the drivers that affect the different stages of the supply chain. For each step of the value chain, a dedicated system map provides a zoomed-in illustration of the identified drivers and waste/valorisation streams for each particular step:

PRIMARY PRODUCTION

Attention was not given to this stage of the supply chain for this product group due to the diversity of raw materials used in prepared meals (See sections on bread, dairy, tomatoes and meat for more information on this stage for these ingredients).


Prepared meals
Processing & packaging food waste drivers
Poor information sharing
High product complexity: too many ingredients resulting in more production rejects & more complex procurement processes with higher risk of
Unsuitable handling
Test lines (destroyed, rather than redistributed)
Minimum order volumes
Over-specification of quality standards
Equipment failures: may be associated with greater automation of production processes, poor calibration, and fewer staff to spot failures/ pre-empt
Training inadequacies
Primary production
Processing & packaging
Retail & logistics
Foodservice & household
Waste management (Incineration / AD / EfW)
Animal feed (only for the uncontaminated bread)
Waste & Valorisation streams
Legend: driver families
Technological
Institutional (business)
Institutional (policy)
Social
Inter stage

PREPARED MEALS: SUMMARY OF PROCESSING & PACKAGING STAGE

The drivers identified are mainly institutional business drivers, including systemic drivers such as minimum order volumes and a lack of information sharing between supply chain actors but also drivers that are more specific to the processing & packaging stage, including training inadequacies and test lines. The technological drivers identified include equipment failures, high product complexity and unsuitable handling in processing and packaging. Another systemic driver reaching upstream at the processing & packaging stage is the social driver, over-specification of quality standards.

Uncontaminated bread is sent for use as animal feed. Otherwise the waste management streams may be incineration, anaerobic digestion, or energy from waste.

PREPARED MEALS: DESCRIPTION OF PROCESSING & PACKAGING STAGE

Food waste is not identified as an issue within the operational and commercial teams of actors in the processing and packaging stage as waste levels are already factored into the yields and margins for individual products.

Sandwiches often have **high product complexity** due to the number of different ingredients that are used in the final product. Some pre-prepared meal manufacturers may handle more than 2,000 ingredients. During the product design stage, if overly-complex ingredient lists are used there is greater potential for food waste to occur. This is as a result of missing ingredients resulting in more production rejects as well as contributing to more **complex procurement processes** which entail a higher risk of waste. Simplification of product specifications can result in food waste reduction. For instance, avoidance of multiple grades of mayonnaise within a single product.

Waste observed during a site visit in the UK included: the centres of cucumbers, the ends of cheeses from grating, bacon fat (intercepted from wash water), tomato juice (investigations are currently underway as to whether this could be used in dips).

On a related note, for certain ingredients there may be **minimum order volumes** for product ingredients. If storage is inadequate, orders cannot be aligned with the production plan and the quantities of stock of each ingredient are not matched food waste may be generated.

A critical part of the production plan is the use of **test lines** as a preliminary stage of processing & packaging. The products generated from these test lines are destroyed rather than being redistributed as they may be commercially sensitive, hence contributing to food waste generation.

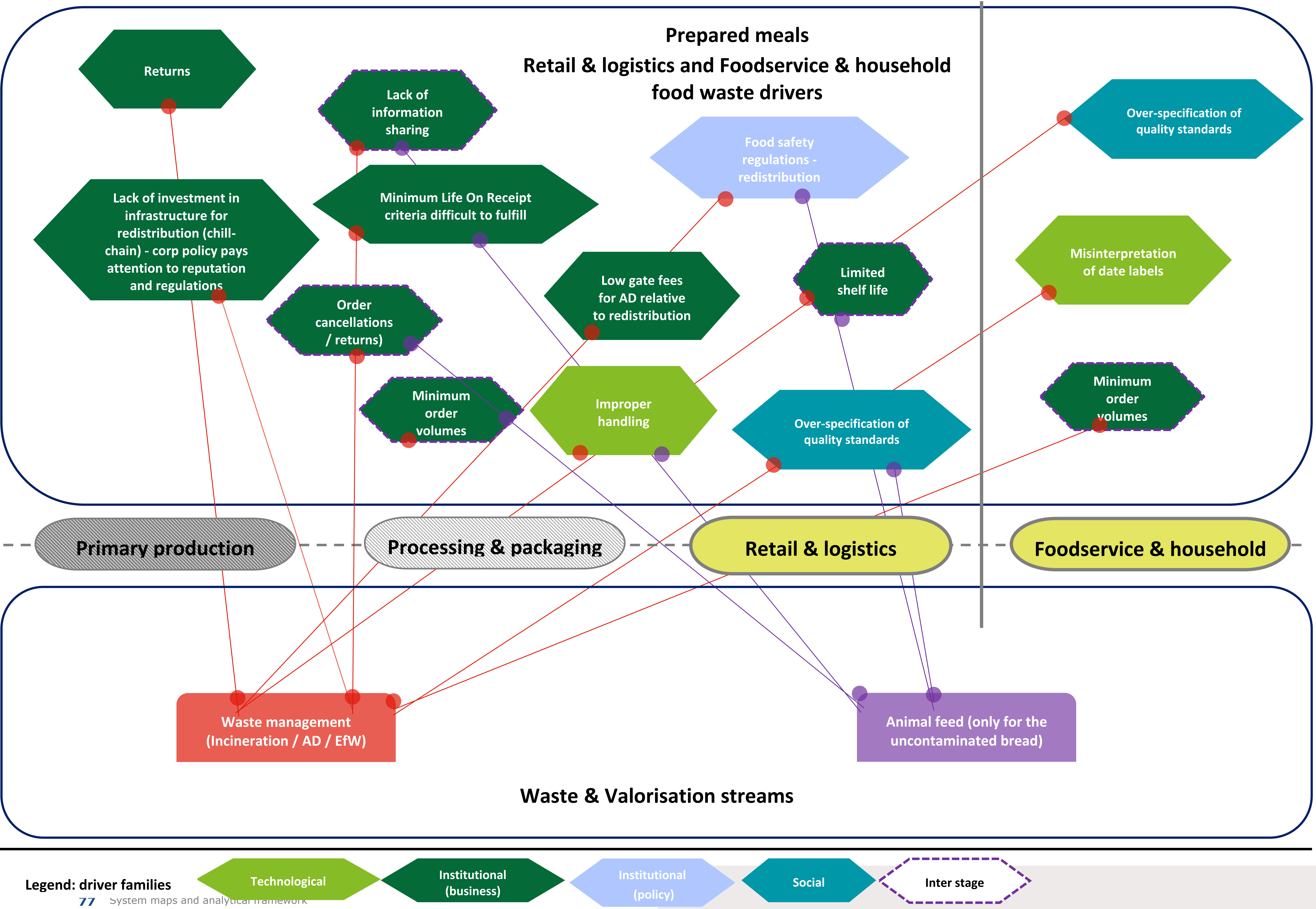
In addition to voluntary business decisions, there are other factors, contributing to waste at the processing and packaging stage, over which the company may have less control. **Equipment and machinery failure**s combined with **human error** including **inadequate handling** are key groups of drivers of food waste.

Sandwich making, as with other food and drink business sectors, has invested in more **automated production** but few sandwich products lend themselves to fully automated production lines. Where automation has occurred, such as with machinery for placing chicken portions in sandwiches, the full costs of food waste associated with **breakdowns** and **poor calibration** are often not fully considered. Although business decisions to inform such capital investments focus on savings on labour costs, without detailed mapping of food waste by individual unit process, the unintended consequences may not be fully understood.

Equipment failures may therefore be associated with automation of production processes, poor calibration, and **fewer staff** to spot or pre-empt system failures. Inadequate handling of produce due to **lack of training** may also lead to food waste. Training may also impact on quality control and an excessive quantity of items selected as rejects. An over-specification of quality standards may be enhanced at this stage, causing unnecessary rejects of otherwise satisfactory products.

Other factors relating to **technological issues** were identified. Product 'give-away' may relate to poor calibration of weighing equipment. Although this is not technically a food waste, over-portioning in sandwiches reduces profitability. Lack of recovery of fats and greases (FOGS) from waste water sludge due to plant cleaning are also a point which could be improved. Although wash water undergoes pre-treatment before discharge, technologies to extract fats, oils and greases may vary in their effectiveness.

In the UK, uncontaminated bread is sent for use as animal feed i.e. crusts, bread that falls off the production line, bread that is too dry or that does not meet QA requirements. Contamination of bread to animal feed may result in skips being returned from the feed processing site. Ideally any contamination is identified on site before the materials dispatched.



Prepared meals
Retail & logistics and Foodservice & household food waste drivers
Returns
Lack of information sharing
Lack of investment in infrastructure for redistribution (chill-chain) - corp policy pays attention to reputation and regulations
Minimum Life On Receipt criteria difficult to fulfill
Food safety regulations - redistribution
Over-specification of quality standards
Order cancellations / returns)
Low gate fees for AD relative to redistribution
Limited shelf life
Misinterpretation of date labels
Minimum order volumes
Improper handling
Over-specification of quality standards
Minimum order volumes
Primary production
Processing & packaging
Retail & logistics
Foodservice & household
Waste management (Incineration / AD / EfW)
Animal feed (only for the uncontaminated bread)
Waste & Valorisation streams
Legend: driver families
Technological
Institutional (business)
Institutional (policy)
Social
Inter stage

PREPARED MEALS: SUMMARY OF RETAIL & LOGISTICS AND FOODSERVICE & HOUSEHOLD STAGE

Drivers in these final stages are predominantly industrial business drivers. Some of the key drivers identified include systemic drivers such as minimum order volumes, lack of information sharing, order modifications, cancellations and returns.

As in the previous stage, uncontaminated bread is sent for use as animal feed. Otherwise the waste management streams may be incineration, anaerobic digestion, or energy from waste. There is low investment in infrastructure for redistribution channels, relatively low gate fees for AD and there are strict food safety regulations, which restrict the potential for redistribution and favour.

PREPARED MEALS: DESCRIPTION OF RETAIL & LOGISTICS AND FOODSERVICE & HOUSEHOLD STAGE

Improper handling of products in transit or on the shop floor by staff or by customers may cause some waste. There is also a trend in **over-specification of quality standards and expectations** of customers reinforced by **instore quality control**, leading to additional waste.

A driver identified in the processing and packing stage may also affect the retail stage. Certain wholesale or processing & packaging actors may require **minimum order volumes**, which may not be adapted to demand, contributing directly to the problem of **overstocking**. The **limited shelf-life of products** combined with overstocking leads to food waste. When m**inimum life on receipt** criteria are set too high they may become difficult to fulfil and put the manufacturer under pressure to undertake smaller production batches and deliver products more frequently to retail customers.

Regarding **waste and valorisation streams, low gate fees for AD relative to costs of redistribution make this a preferred option.** There is therefore a need for policies to incentivize redistribution. Legislative complexity and lack of understanding related to diversion to animal feed may also limit food business' willingness to segregate foods suit for use in animal feed. In addition, there may be a lack of investment in infrastructure for redistribution, which requires a chill-chain.

Chilled products are more difficult to redistribute safely due to the requirement to maintain the chill-chain and concerns over the food safety implications. Producers of food surplus perceive food redistribution to be an unacceptable risk to brand integrity (with much of the output labelled with retailer branding). The redistribution sector requires investment in adequate infrastructure to redistribute chilled products. Unless these barriers are addressed, pre-prepared chilled foods will continue to be sent to AD rather than made available for redistribution.

As aforementioned in the previous stage, **consumers’ expectations** may be reinforced by over-specification causing further rejection of products at the household and foodservice stage.

The waste of sandwiches at household level is not considered to be significant. On the other hand, a number of factors lead to waste in the food service industry in particular.

Minimum order volumes may affect food service providers, leading to over-stocking or unsuitable portioning. In addition, **it was identified that further regulation may be needed** to address the practice of **late cancellation** and **reduction of orders**, which may increase uncertainty for producers and distributers in addition to potentially directly causing waste generation from unsold products (however there is a risk of increasing the quantity of unwanted products and waste at retail stage).

It was found that in the UK, returns are handled by the retailers and no returns are received back at the production site, which limits the systemic nature of this driver.

Finally, supply chain initiatives, such as sustainability standards set by retailers, need to be linked to include more granular/ transparent food waste reporting to encourage efforts to reduce food waste.

5 Analytical overview

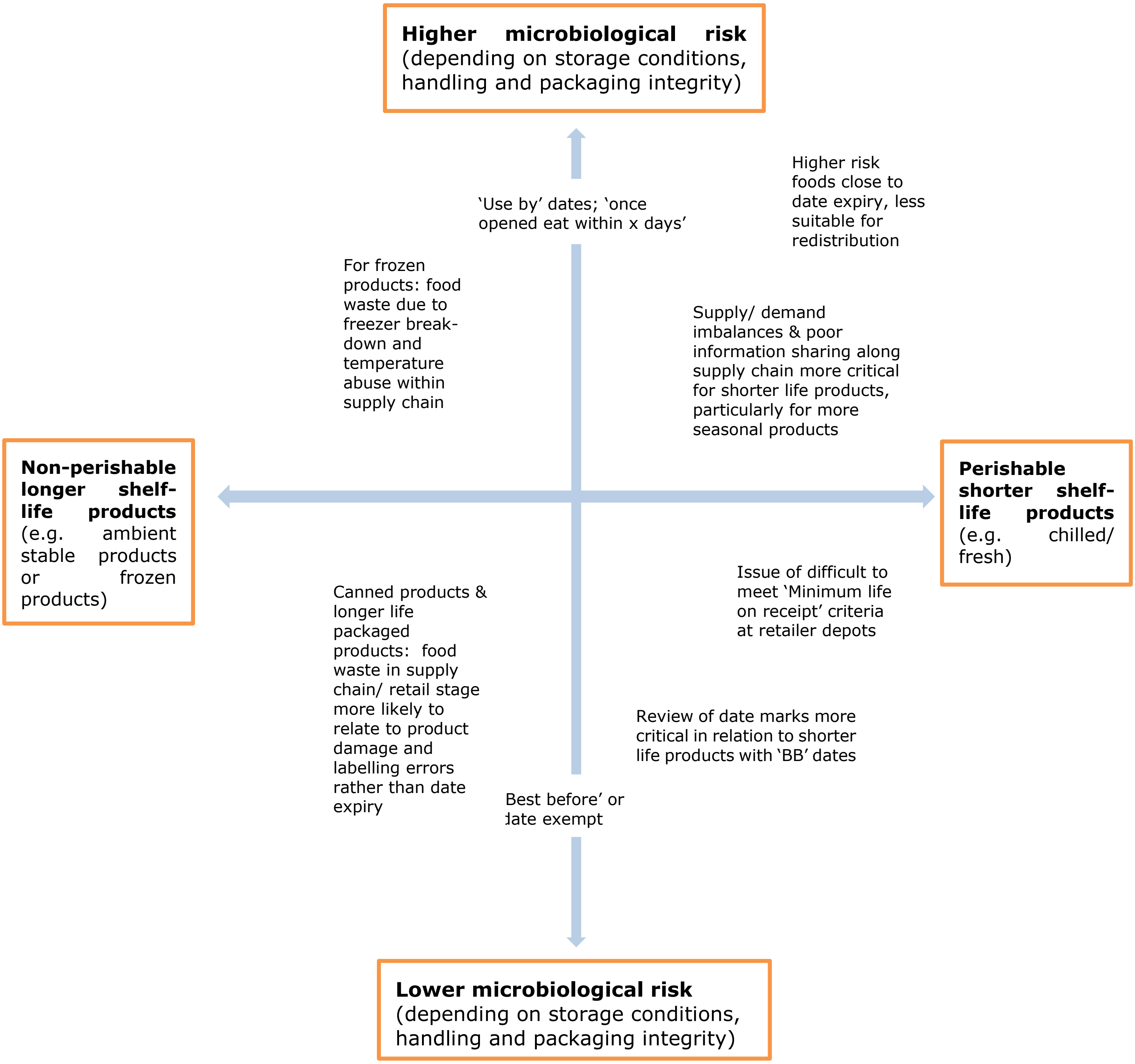
The top-down analysis, on which the FUSIONS policy research was based, had already identified the majority of drivers indicated in this report by using a sector by sector approach. Although this is an effective mean of identifying the most visible drivers, it cannot be used to readily identify the systemic drivers that operate along supply chains and across sectors to induce food surpluses and increase food waste.

The bottom-up approach to mapping food waste drivers was developed to shed light on systemic drivers as well as to set existing knowledge from the FUSIONS study within the context of food businesses and their behaviours. In addition, as different food products have different waste profiles along the supply chain, the approach was used to explore the drivers specific to particular food products from the more generic drivers identified by the top-down analysis. This was achieved through the detailed system maps generated for five contrasting product types that were investigated along their supply chains.

The main findings of the bottom-up approach are illustrated in the diagrams below in relation to the key dimensions of:

- Food safety, risk and food temperature
- Supply chain complexity and level of cooperation

MAPPING OF FOOD WASTE DRIVERS TO FOOD RISK AND FOOD TEMPERATURE/ PERISHABILITY DIMENSIONS:



One main finding using the bottom-up system mapping is that the type and impact of food waste drivers depend on **the level of perishability and microbiological risk** of food products. For example, less perishable food products such as frozen and canned products are more likely to be wasted because of product damage and labelling errors than date expiry, or because of freezer break down and temperature abuse. A part of the waste associated to less perishable food products could be addressed by "best before" dates exemptions which is currently under investigation in a European study led by DG SANTE.

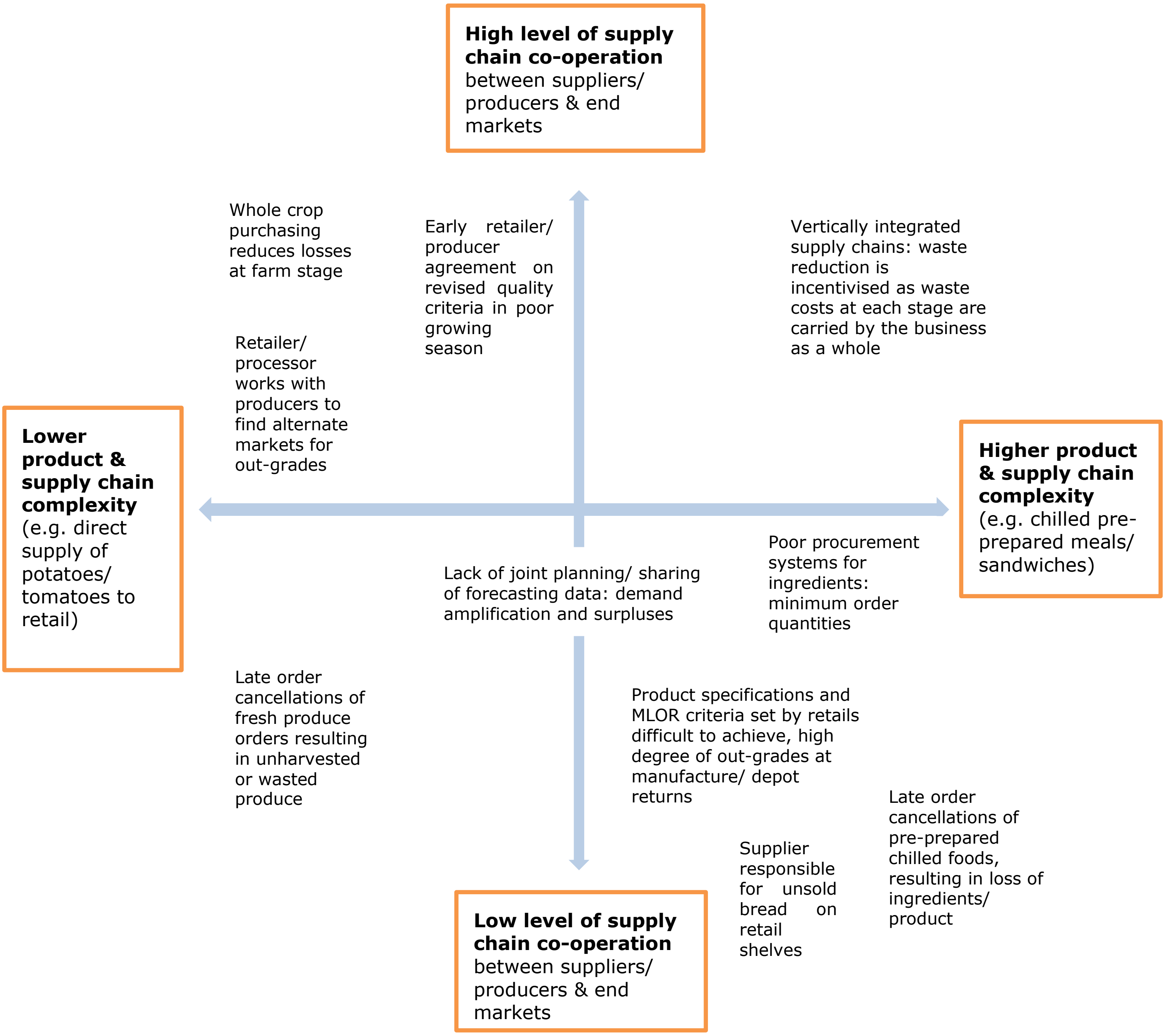
More perishable and higher risk food products are more likely to be wasted when approaching the "best before" date and are less suitable for redistribution. The product system maps showed that for some perishable products, although the most quoted driver is the expiry of the "best before" date, very often there are other drivers behind such as shelf **over-stocking** in the retail sector. This was indeed the case for industrial bread which is very often over-stocked for the purpose of having full-shelves (including extended opening hours). This requirement raises the chances of a product not to be picked by a customer before its expiry date.

More perishable products are more often wasted because of **supply and demand imbalances** and **poor information sharing** along supply chain. Indeed, the mapping exercise showed that the **supply and demand imbalance** is an important driver in the food supply chain. However the factors behind this imbalance are complex and include forecasting errors, over-optimistic projections for increased product demand associated with retail promotional offers. Forecasting practices are often too complex and fail in linking consumer sales, production scheduling and farmers. An increase in demand results in each step in the chain making adjustments that accumulate within the upstream food chain.

The analysis also showed that supply and demand is imbalanced by the **lack of data sharing** and **asymmetry of information** along the supply chain to the extent that this phenomenon may not be widely acknowledged or fully measured. These drivers are more critical for shorter life products, particularly for more seasonal products and for products with higher perishability and microbiological risk. The introduction of integrated whole supply chain key performance measures that involve retailers, logistics, suppliers and farmers working together would be a step towards addressing this issue.

More perishable products are also likely to be more wasted because of difficulties in meeting very strict criteria such as **'Minimum life on receipt' (MLOR) criteria** at retailer depots. The bottom-up analysis illustrated that, in some cases, the over rigorous MLOR criteria, allows retailers to return products to supplier or the warehouses of their third party logistics providers if the criteria is not met. For example, the WRAP study "Reducing food waste by extending product life" identified MLOR for bread as 86% of product life for bread delivered to convenience stores (WRAP, 2015). Although these criteria guarantee greater remaining life for the product in store and at home, it may also result in smaller production batches and more frequent delivery to retailers, and loss of economies of scale within baking batches.

Supply chain complexity and level of cooperation



The second main finding using the bottom-up system mapping is that the type and impact of food waste drivers depend also on **the complexity of the product (and supply chain) and on the level of cooperation between actors across the value chain**.

The lack of joint planning and **sharing of forecasting data** increases demand and food surpluses for products with both low and high complexity. **Late order cancellations** of fresh produce orders results in unharvested food and in upstream waste in the supply chain if demand is not replaced. The risk of waste because of late order cancellations is higher for chilled products such as processed meat or dairy. In order to reduce both demand amplification and late modification of orders by retailers, closer co-operation on ordering systems and planning is a way forward. If actors across the supply chain cooperated more, whole crop purchasing could reduce losses at farm stage.

Strict **quality specifications** combined with **poor staff training** lead to grading errors and thus food waste. Site visits and interviews with business operators indicated that over-stringent retailer specifications are responsible of 40% of the food waste at the meat slicing plat stage. In order to better investigate the extent to which quality specifications is a food waste driver, “value stream mapping” approaches are needed to analyse the root causes of quality rejects at all stages. Food waste could be reduced thanks to better cooperation between retailer/processor and producers to find alternate markets for out-grades or thanks to early retailer/ producer agreement on revised quality criteria in poor growing season.

Another driver identified by the bottom-up system mapping and related to business behaviour is the **minimum order quantities criteria** set by the suppliers especially for ingredients. Chilled pre-prepared meals/ sandwiches are more impacted by this driver than products which are less complex (potatoes and tomatoes). This criteria was present both for bread and pre-prepared meals and can be reduced by systematic review of the ingredient procurement system with a view to streamlining ingredients-related processes and reducing non-production waste.

The system maps also illustrated that **unclear responsibilities** of who owns the waste lead stress on the value chain and to higher risk for food waste generation. For example, in Germany, retailers can return the unsold industrial bread to their suppliers unlike France and the UK. Retailers do not have any incentive to calibrate the orders and return less bread to the suppliers as food waste and surplus is not managed by them. Because of these unclear responsibilities on which actor owns waste or surplus at each stage, data representation of food wasted per step of the value chain may not depict an accurate picture of the current situation.

6 References

Agricol1, "Les processus de transformation des pommes de terre", http://www.agricole1.com/les-processus-de-transformation-des-pommes-de-terre (accessed February 16 2016)

AIBI, « AIBI Bread Market Report 2013", January 2015

Andersson, Martin. "Manager Farming, Orkla Foods Sverige Ab." (25 Januari 2017).

Andrae, Lisa. "Manager, Swedish Potato Growers Association (Potatisodlarna)." (17 January 2017).

Anna-Karin Modin-Edman, pers. comm., January 10, 2017.

Avitalia (ed. by). 2012. 'Tracciabilità delle carni di pollame lungo la filiera avicola'. In ISMEA, https://goo.gl/OAijOd (accessed January 25, 2017).

Bardby, Bengt. "Purchase and Sales, Ab Ka Lundblad Frukt Och Grönt." (9 January 2017).

Baumgardt, Sandra, und Thomas Schmidt. „Environmental impacts and abatement costs of food waste reduction: the case of bread". In Putting LCA into Practise, 2016. http://www.lcafood2016.org/wp-content/uploads/2016/10/LCA2016_BookOfAbstracts.pdf#886.

Bengtsson, J., and J. Seddon. 2013. 'Cradle to Retailer or Quick Service Restaurant Gate Life Cycle Assessment of Chicken Products in Australia'. Journal of Cleaner Production 41 (February): 291-300.

Buurman R., Velghe J. (CRIOC), "Les supermarchés et le gaspillage alimentaire.", 2013, http://www.iufn.org/wp-content/uploads/2014/01/CRIOC-2013-Les-supermarchés-et-le-gaspillage-alimentaire.pdf (accessed February 16 2017)

Canali, Massimo, Karin Osergren, et al. "Establishing a common framework for food waste definition and identifying its drivers." Establishing a common framework for food waste definition and identifying its drivers. August 2014. Accessed March 28, 2017. http://www.eu-fusions.org/index.php/publications/265-establishing-a-common-framework-for-food-waste-definition-and-identifying-its-drivers

Castellani, V., Sala, S., and L. Benini. 2017. 'Hotspots Analysis and Critical Interpretation of Food Life Cycle Assessment Studies for Selecting Eco-Innovation Options and for Policy Support'. Journal of Cleaner Production 140, Part 2 (January): 556-68.

Cellura, M., Ardente, F., and S. Longo. 2012. 'From the LCA of Food Products to the Environmental Assessment of Protected Crops Districts: A Case-Study in the South of Italy'. Journal of Environmental Management 93 (1): 194–208.

Cellura, M., Longo, S., and M. Mistretta. 2012. 'Life Cycle Assessment (LCA) of Protected Crops: An Italian Case Study'. Journal of Cleaner Production 28 (June): 56–62.

Cesari, V., Zucali, M., Sandrucci, A., Tamburini, A., Bava, L., and I. Toschi. 2017. 'Environmental Impact Assessment of an Italian Vertically Integrated Broiler System through a Life Cycle Approach'. Journal of Cleaner Production 143 (February): 904-11.

CIWM (2016) Tesco And Branston Tackle Supply Chain Potato Waste, posted 20th October 2016, Available: http://ciwm-journal.co.uk/tesco-branston-tackle-supply-chain-potato-waste/

Del Borghi, A., Gallo, M., Strazza, C., and M. Del Borghi. 2014. 'An Evaluation of Environmental Sustainability in the Food Industry through Life Cycle Assessment: The Case Study of Tomato Products Supply Chain'. Journal of Cleaner Production 78 (September): 121–30.

EBLEX (2014) The Use of Animal By-products: The improving opportunities to add value to the beef and sheep slaughtering sectors,: http://beefandlamb.ahdb.org.uk/wp/wp-content/uploads/2016/07/74318-5th-Quarter-Use-and-Flow-Final-Report-130514.pdf

EFSA (2015) 'The EFSA Comprehensive Food Consumption Database'. Accessible at: https://www.efsa.europa.eu/en/food-consumption/comprehensive-database (Accessed 22 December 2016).

EFSA (2006) 'The EFSA Comprehensive Food Consumption Database'. available at: https://www.efsa.europa.eu/en/food-consumption/comprehensive-database (Accessed 22 December 2016).

Envall, Mary. "Environment & Quality Manager at Estrella Ab." (19 January 2017).

Eriksson, Mattias, and Ingrid Strid. "Livsmedelssvinn I Butiksledet - En Studie Av Butikssvinn I Sex Livsmedelsbutiker." (2011).

Eriksson, Mattias. "Researcher, Swedish University of Agricultural Sciences." (9 january 2017 2017).

EU Regulation (EC) No 178/2002 on general principles and requirements of food law as well as the FAO/WHO Codex Alimentarus Commission on food safety (ALINORM 04/27/33A) Article 3: EU Regulation No 178-2002: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2002:031:0001:0024:EN:PDF & FAO/WHO Codex 04/27/33A: http://www.codexalimentarius.org/input/download/report/618/al0433ae.pdf#page=46

European Commission, "Commission Regulation (EU) No 142/2011 implementing Regulation (EC) No 1069/2009 of the European Parliament and of the Council laying down health rules as regards animal by-products and derived products not intended for human consumption and implementing Council Directive 97/78/EC as regards certain samples and items exempt from veterinary checks at the border under that Directive Text with EEA relevance", 2011. Available at: http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:32011R0142

European Parliament, Council of the European Union, "regulation (EC) No 183/2005 laying down requirements for feed hygiene", 2005. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2005:035:0001:0022:EN:PDF

Eurostat (2012) Manufactured goods, Prodcom – Statistics by Product, available at: http://ec.europa.eu/eurostat/web/prodcom

Eurostat (2015) Manufactured goods, Prodcom – Statistics by Product, available at: http://ec.europa.eu/eurostat/web/prodcom

FAOSTAT (2011) Food and Agriculture Data, Food and Agriculture Organization of the United Nations, available at: http://www.fao.org/faostat/en/#home

FEFAC (2012) Feed Use of Former Foodstuffs converting food into food, {Online}, Available: http://ec.europa.eu/dgs/health_food-safety/dgs_consultations/docs/ag/summary_ahac_05102012_2_fefac_en.pdf

France Nature Environnement "Du gaspillage à tous les étages.", May 2016, https://ged.fne.asso.fr/silverpeas/LinkFile/Key/1cd9d8f4-47cd-431c-be6e-758cdd895aa8/dossier-thematique-fne-gaspillage-alimentaire-actualisation-mai2016.pdf (accessed February 15 2017)

Franke, Ulrika, Elin Einarson, Niels Andrésen, Erik Svanes, Hanna Hartikainen, and Lisbeth Mogensen. "Kartläggning Av Matsvinnet I Primärproduktionen." (2013).

Franke, Ulrika, Hanna Hartikainen, Lisbeth Mogensen, and Erik Svanes. "Food Losses and Waste in Primary Production - Data Collection in the Nordic Countries." (2016).

Fredrik Javensköl, pers. comm., January 20, 2017.

FUSIONS. „Drivers of current food waste generation, threats of future increase and opportunities for reduction", 2014. http://www.eu-fusions.org/index.php/download?download=111:drivers-of-current-food-waste-generation-threats-of-future-increase-and-opportunities-for-reduction.Gira, "Bake-off Bakery Markets in Europe", July 2016

Göbel, Christine, Petra Teitscheid, Guido Ritter, Antonia Blumenthal, Silke Friedrich, Tanja Frick, Lisa Grotstollen, u. a. „Verringerung von Lebensmittelabfällen – Identifikation von Ursachen und Handlungsoptionen in Nordrhein-Westfalen". Studie für den Runden Tisch „Neue Wertschätzung von Lebensmitteln" des Ministeriums für Klimaschutz, Umwelt, Landwirtschaft, Naturund Verbraucherschutz des Landes Nordrhein-Westfalen. Münster: Fachhochschule Münster Institut für Nachhaltige Ernährung und Ernährungswirtschaft – iSuN; Verbraucher-zentrale Nordrhein-Westfalen; Trifolium - Beratungsgesellschaft mbH, 2012.

Gorwitz N."Loi Macron : le Sénat oblige les supermarchés à donner leurs invendus alimentaires.", Public Sénat, 10, April, 2015, https://www.publicsenat.fr/lcp/politique/loi-macron-senat-oblige-supermarches-donner-invendus-alimentaires-876896 (accessed February 16 2017)

Gupta J et al., 2013; Weimer D. L. et al., 2010.

Gustavsson, Jenny. "The Climate Change Impact of Retail Waste from Horticultural Products." (2010).

Hartikainen, Hanna. "Researcher, Luke." (25 January 2017).

INCOME Consulting - AK2C - 2016 - "Pertes et gaspillages alimentaires : l'état des lieux et leur gestion par étapes de la chaîne alimentaire.", May 2016, Report, https://centre.ademe.fr/sites/default/files/files/Accueil/pertes-gaspillages-alimentaires-etat-lieux-gestion-rapport.pdf (accessed February 15 2017)

INRA "Leviers pour réduire les pertes agricoles et alimentaires: comprendre, quantifier et analyser.", Novembre 2015, https://www6.inra.fr/ciag/content/download/5737/43339/file/CIAG34-4-Juin.pdf (accessed February 15 2017)

Interview with Lidl. Salon d'Agriculture, Paris. 2017

ISMEA (ed. by) 2012. 'Pomodoro da mensa: L'evoluzione del consumo in Italia'. In: https://goo.gl/NR8aOZ. Accessed 9 January 2017.

ISMEA (ed. by). 2016. 'Conserve di pomodoro: Calano acquisti di passate, pelati e polpe. Bene i sughi pronti'. In: https://goo.gl/fqntWP. Accessed 9 January 2017.

Jeannequin B., Plénet D., Carlin F., Chauvin J.-E., Dosba F., "Pertes alimentaires dans les filières fruits, légumes et pomme de terre.", 2015 Innovations Agronomiques 48, 59-77, http://www6.inra.fr/ciag/Revue/Volumes-publies-en-2015/Volume-48-Decembre-2015 (accessed February 15 2017)

Jepsen, Dirk, Annette Vollmer, Ulrike Eberle, Jacob Fels, und Thomas Schomerus. „Entwicklung von Instrumenten zur Vermeidung von Lebensmittelabfällen". Ökopol, corsus, ZNU, Leuphana Universität im Auftrag des BMUB, 2014. https://www.umweltbundesamt.de/sites/default/files/medien/378/dokumente/zusammenfassung_entwicklung_von_instrumenten_zur_vermeidung_von_lebensmitteabfaellen_0.pdf.

Juin H., "Les pertes alimentaires dans la filière Céréales.", 2015 Innovations Agronomiques 48, 79-96, http://www6.inra.fr/ciag/Revue/Volumes-publies-en-2015/Volume-48-Decembre-2015 (accessed February 15 2017)

Kranert, M., G. Hafner, J. Barabosz, H. Schuller, D. Leverenz, Kölbig, Schneider, S. Lebersorger, und S. Scherhaufer. „Ermittlung der weggeworfenen Lebensmittelmengen und Vorschläge zur

Verminderung der Wegwerfrate bei Lebensmitteln in Deutschland‟. Stuttgart: Universität Stuttgart, Institut für Siedlungswasserbau, Wassergüte- und Abfallwirtschaft, Lehrstuhl für Abfall-wirtschaft und Abluft Universität für Bodenkultur Wien, Institut für Abfallwirt-schaft, 2012.

Lavelli, V. 2013. ‘High-Warranty Traceability System in the Poultry Meat Supply Chain: A Medium-Sized Enterprise Case Study’. Food Control 33(1): 148-56.

Lyckeby Starch. "Så Tillverkas Potatisstärkelse " https://www.lyckeby.com/om-stärkelse-och-fiber/så-tillverkas-potatisstärkelse.

Manning, L., Baines, R., and S. Chadd. 2008. ‘Benchmarking the Poultry Meat Supply Chain’. Benchmarking: An International Journal 15(2): 148-65.

Mattsson, Kristina. "Vi Slänger Frukt Och Grönsaker I Onödan – Varför?". (2014).

Ministère de l'agriculture "Pertes et gaspillages alimentaires.", November 2011, http://agriculture.gouv.fr/file/pertes-gaspillagesrapport270112cle02c35dpdf (accessed February 16 2017)

Ministère de l'agriculture, ministère de l'économie "Les innovations technologiques, leviers de réduction du gaspillage dans le secteur agroalimentaire: enjeux pour les consommateurs et pour les entreprises.", November 2014, http://www.entreprises.gouv.fr/files/files/directions_services/etudes-et-statistiques/prospective/agroalimentaire/2014-11-rapport-Pipame-gaspillage-alimentaire.pdf (accessed February 16 2017)

Ministère de l'écologie, "Réduction du gaspillage alimentaire État des lieux et pistes d’action.", November 2012, http://www.doc-developpement-durable.org/file/programmes-de-sensibilisations/developpement-durable/Rapport_final_gaspillage_alimentaire_nov2012.pdf (accessed February 17 2017)

Møller, Hanne, Therese Hagtvedt, Nina Lødrup, Jens Kirk Andersen, Pernille Lundquist Madsen, Mads Werge, Ane Kirstine Aare, et al. "Food Waste and Date Labelling- Issues Affecting the Durability." 2016.

Östergren, Karin, Gustavsson Jenny, et al. "FUSIONS Definitional Framework for Food Waste." FUSIONS Definitional Framework for Food Waste. July 2014. http://www.eu-fusions.org/phocadownload/Publications/FUSIONS%20Definitional%20Framework%20for%20Food%20Waste%202014.pdf.

Pålsson, Joakim. "Ceo, Lpm Potatis Ab." (11 January 2017).

Piras, S., De Menna, F. and M. Vittuari. 2017. ‘Interview with a manager of the Fruit and Vegetable Wholesale Market of Bologna’. (22 Febraury 2017).

Piras, S., De Menna, F. and M. Vittuari. 2017. ‘Interview with an expert of the chicken supply chain from the University of Bologna’. (1 March 2017).

Riggi, E., and Avola, G. 2010. ‘Quantification of the Waste Stream from Fresh Tomato Packinghouses and Its Fluctuations: Implications for Waste Management Planning’. Resources, Conservation and Recycling 54 (7): 436–41.

Riggi, E., and G. Avola. 2008. ‘Fresh Tomato Packinghouses Waste as High Added-Value Biosource’. Resources, Conservation and Recycling 53 (1–2): 96–106.

Ritter, Guido, Petra Teitscheid, Lena Heitkönig, Silke Friedrich, Esther Müller, Fara Flügge, Julia Bergmann, u. a. „Endbericht zur Studie ‚Reduktion von Lebensmittelabfällen bei Brot und Backwaren – Entwicklung eines Konzepts für Handel, Handwerk und Verbraucher‘“. Münster: iSuN Institut für Nachhaltige Ernährung und Ernährungswirtschaft, 2015.

Ritter, Guido. 2017. Telephone interview with Prof. Dr. oec.troph. Guido Ritter, Fachbereich Oecotrophologie / Facility Management.

Rossi, L., and S. Piccinini. 2017. ‘Sottoprodotti agroindustriali, un potenziale da sfruttare’. In: https://goo.gl/i5RguU. Accessed 9 January 2017.

Sebbane M., Costa-Migeon S. "Gaspillage alimentaire en restauration d'entreprise: une analyse qualitative des normes personnelles et sociales.", 2015, 19 p., https://hal.archives-ouvertes.fr/hal-01165737v2/document (accessed February 16 2017)

Stenmarck et al. 2016

Tesco (2014) Tesco 25 food waste hotspots, {Online}, Available: https://www.tescoplc.com/files/pdf/responsibility/food_waste_hotspots.pdf

The Institute of Grocery Distribution (un-dated) Case study: Arla - Remedial solutions that will reduce waste, {Online}, Available:https://www.igd.com/Research/Supply-chain/Waste-prevention-guide-2/Six-to-fix-to-prevent-waste/Process/Arla---Remedial-solutions-that-will-reduce-waste/

Törnquist, Marie. "Marknadsöversikt, Potatis Till Mat Och Stärkelseproduktion 2015." (2015).

Unaitalia (2016) ‘Avicoltura, crescono produzione (+2,8%) e consumi (+1,7%) – E’ boom del pollo (+3,9%)’, Una italia, 3 February available at: https://www.unaitalia.com/avicoltura-crescono-produzione-28-e-consumi-17-e-boom-del-pollo-39/, 3 February (Accessed February 16th, 2017).

Unibo (2017) Interview with University of Bologna professor, 2017

United Kingdom Department for Environment, Food & Rural Affairs and Animal and Plant Health Agency (2014) Guidance for the animal by-product industry, {Online}, Available: https://www.gov.uk/guidance/supplying-and-using-animal-by-products-as-farm-animal-feed

United Kingdom, Department for Environment Food & Rural Affairs (2014), Using leftover milk and milk products as farm animal feed {Online}, Available:https://www.gov.uk/guidance/using-leftover-milk-and-milk-products-as-farm-animal-feed

United Kingdom, Department for Environment Food & Rural Affairs (2015), Usage of milk by dairies in England & Wales – October 2015, 10th December 2015;

Waskow, Frank. „Lebensmittelabfällen im Konsumbereich (in und außer Haus)". gehalten auf der AbfallvermeidungsDialog: Vermeidung von Lebensmittelabfällen, Berlin, 2015.

WRAP (2011) Resource Maps for Fresh Meat across Retail and Wholesale Supply Chains: http://www.wrap.org.uk/content/resource-maps-fresh-meat

WRAP (2011) Resource Maps for fruit and vegetables, {Online}, Available: http://www.wrap.org.uk/content/resource-maps-fruit-and-vegetables

WRAP (2013) Co-operative food potato whole chain resource efficiency project: http://www.wrap.org.uk/sites/files/wrap/Increasing%20Profitability%20in%20the%20Potato%20Supply%20Chain.pdf

WRAP (2015) Reducing food waste by extending product life {Online}, Available: http://www.wrap.org.uk/sites/files/wrap/Product%20Life%20Report%20Final_0.pdf

WRAP (2015) whole chain resource efficiency reviews, {Online}, Available: http://www.wrap.org.uk/content/whole-chain-resource-efficiency

7 Annex

Country specific system maps with their explanation

7.1 Bread

7.1.1 France

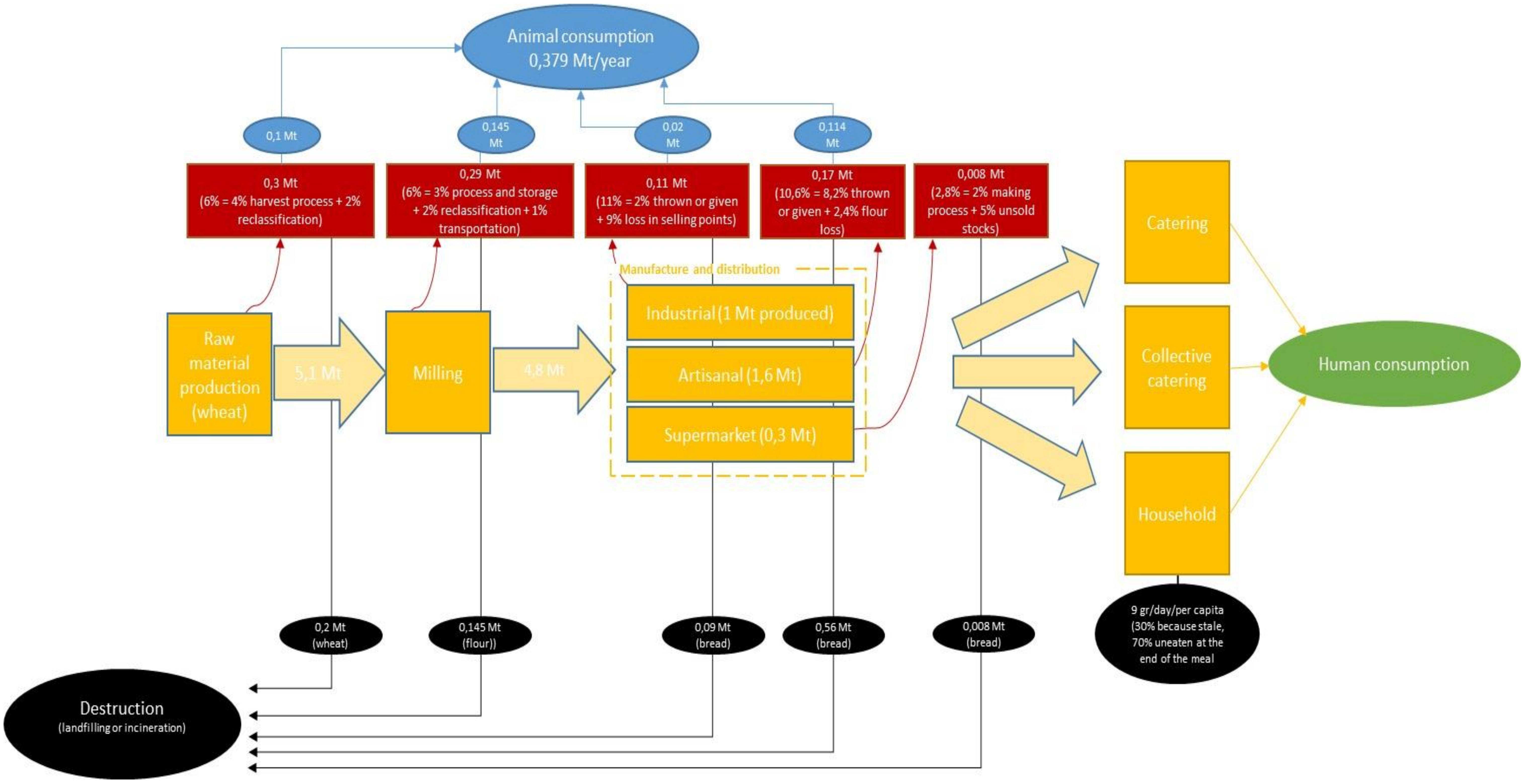


Figure 2: Bottom-up system map: Bread (France)

7.1.2 Germany

The Germany product map for bread was started at the product intake stage to focus on the impact of the bread/baked good value chain, as it is not possible from existing data to pinpoint what waste/drivers at the primary production stage are specific to the bread/baked goods value chain. Establishing this causal link is first possible at the ingredient intake stage based on available data.

The research conducted bases heavily on analyses done in Nordrhein-Westfalen, a province of Germany (Göbel u. a. 2012; Ritter u. a. 2015). As the structure of the food industry with relation to bread and baked goods does not feature major differences across Germany, these analyses were taken to be relevant on the national level.

The map can be accessed here: https://mm.tt/835925018?t=4E6Tp4fzt2

7.1.3 United Kingdom

The main stages of production processes from ingredient through to final product despatch are shown in the middle of the map. Boxes in the upper half are drivers (brown/ diamonds relate to internal business practices and staff factors; green triangles are technology factors; light blue diamonds are whole supply chain issues), the lower half of the map indicate waste types linked to disposal/ treatment routes. Flags are different types of food waste, colours have no meanings.

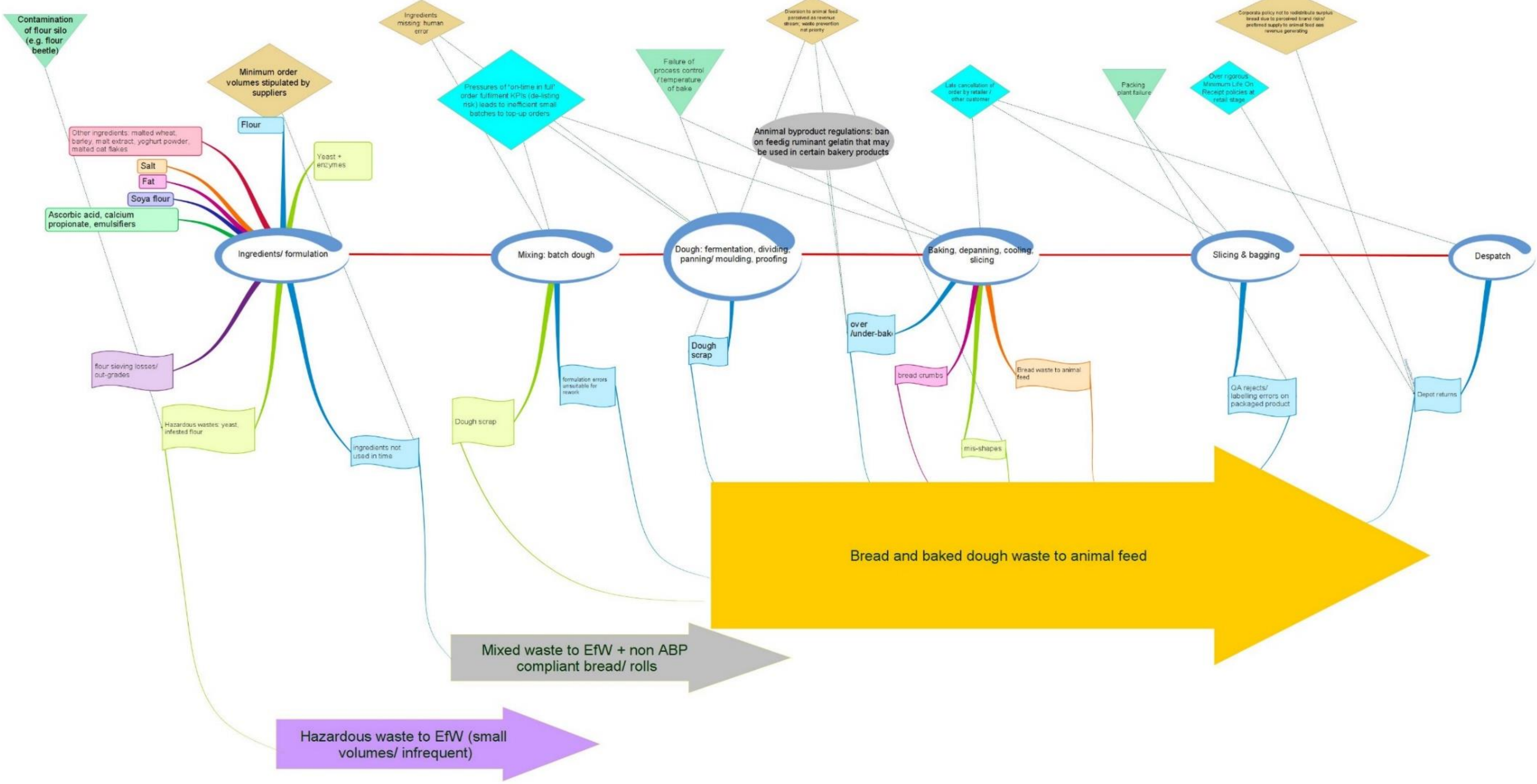


Figure 3: Bottom-up system map: Bakery (UK)

7.2 Dairy

7.2.1 Sweden

Diamond boxes are drivers, connected with waste types, flags. Blue lines are food flows through the value chains. Flags are different types of food waste, colours have no meanings. Below are common waste management options.

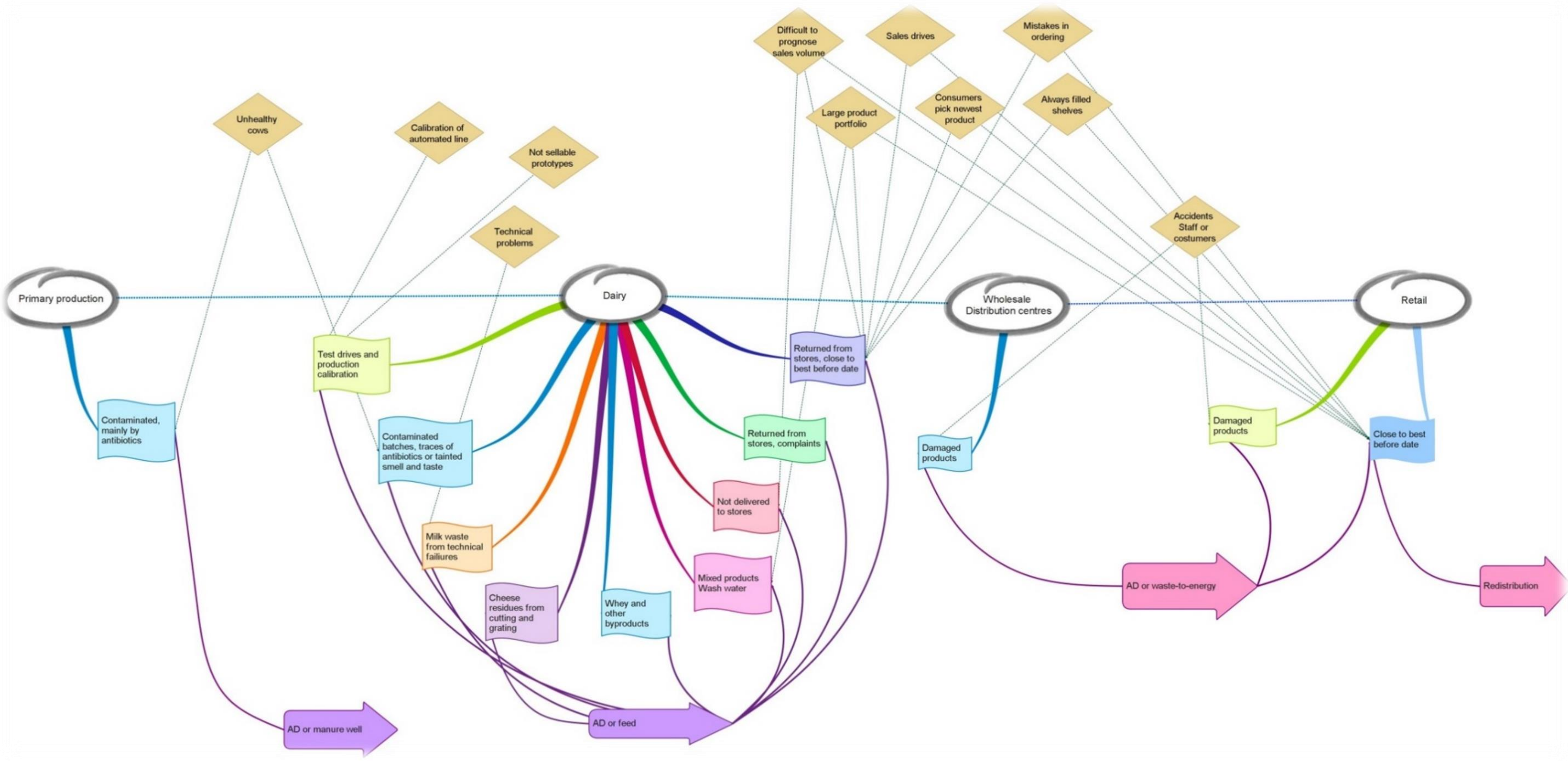


Figure 4: Bottom-up system map (Sweden)

7.2.2 United Kingdom

7.2.3 United Kingdom

The main stages of production processes from ingredient through to final product despatch are shown in the middle of the map. Boxes in the upper half are drivers (brown/ diamonds relate to internal business practices and staff factors; green triangles are technology factors; light blue diamonds are whole supply chain issues), the lower half of the map indicate waste types linked to disposal/ treatment routes. Flags are different types of food waste, colours have no meanings.

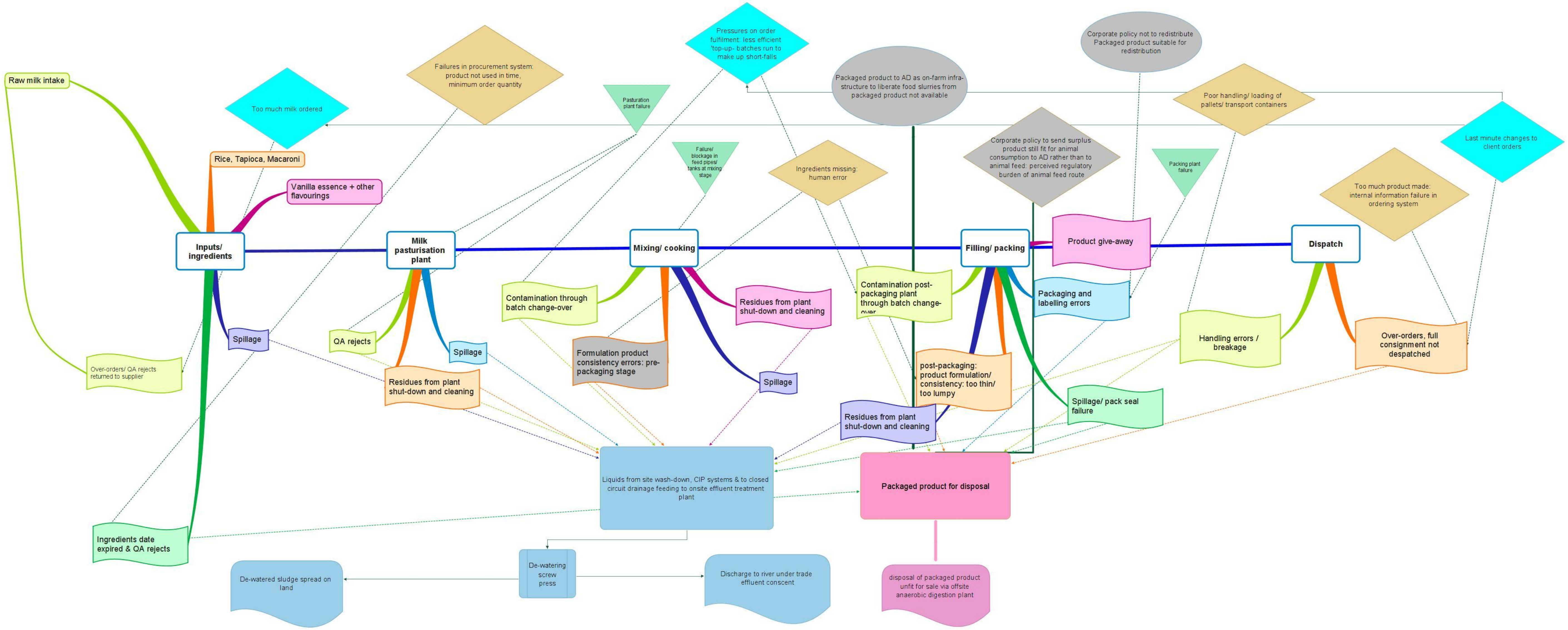


Figure 5: Bottom-up system map: Dairy (UK)

7.3 Potatoes and tomatoes

7.3.1 France

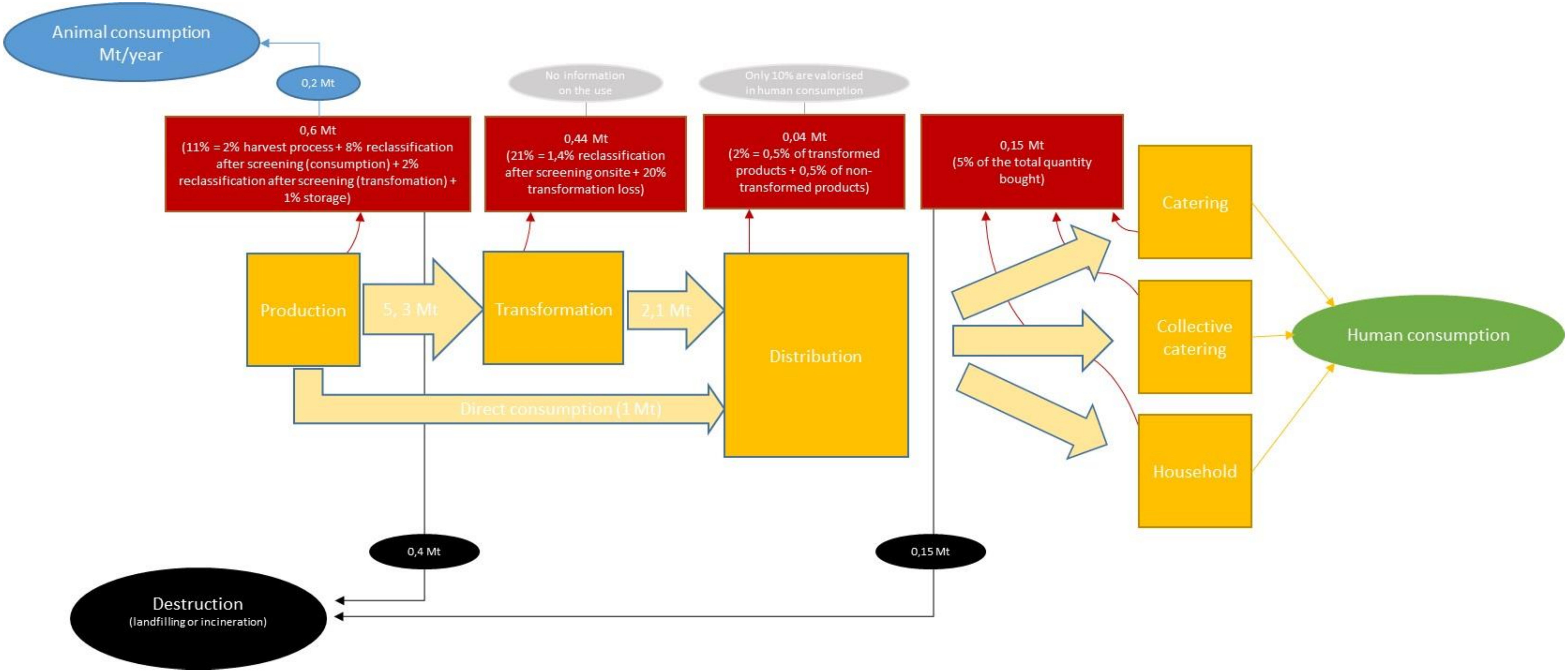


Figure 6: Bottom-up system map: potatoes (France)

7.3.2 Sweden

The value chain differs between regions and products and also the processing industry utilizes side flows hence interconnecting the different actors. Diamond boxes are drivers, connected with waste types, flags. Blue lines are food flows through the value chains. Flags are different types of food waste, colours have no meanings. Below are common waste management options.

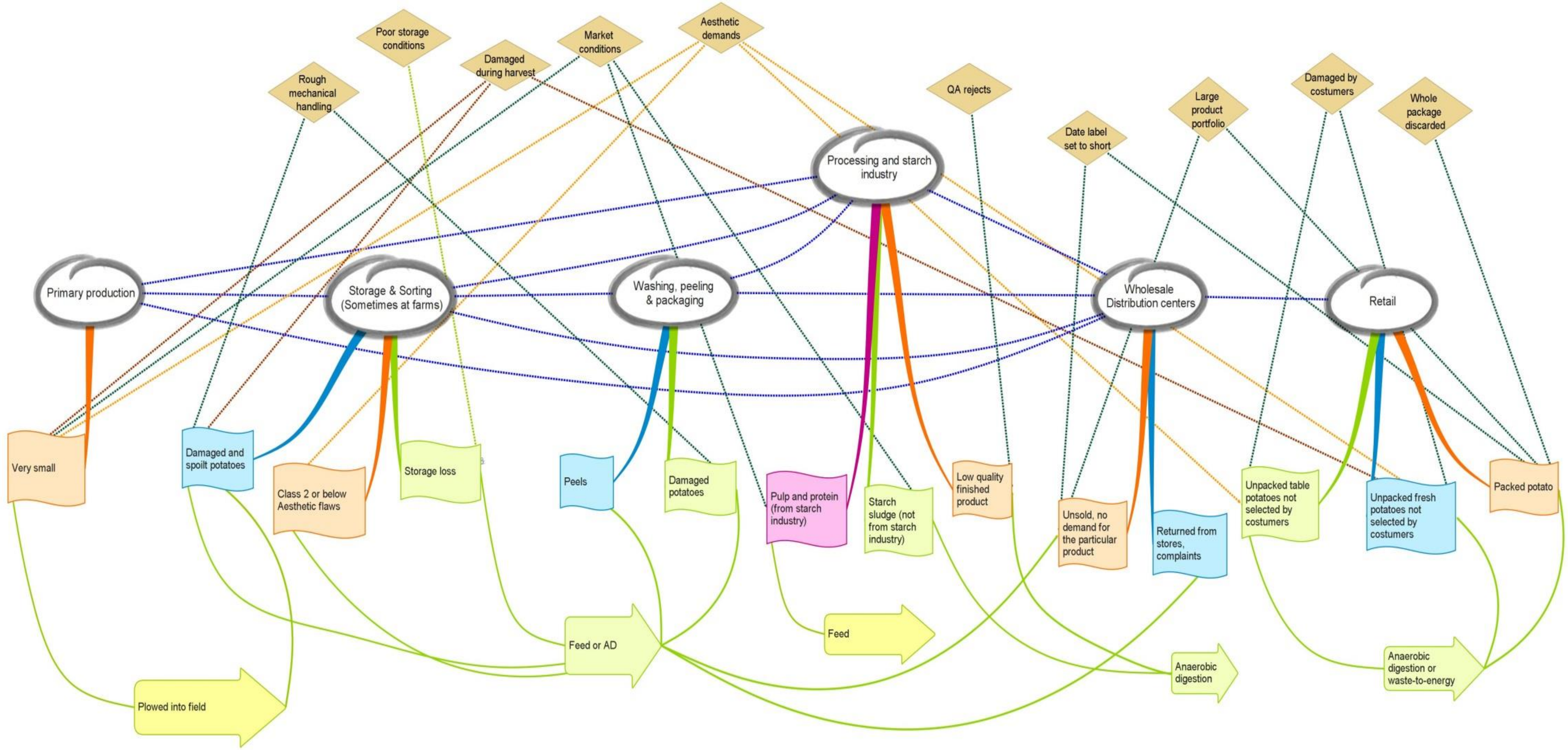


Figure 7: Bottom-up system map: potatoes (Sweden)

7.3.3 United Kingdom

The main stages from farm through to final product despatch are shown in the middle of the map. Boxes in the upper half are drivers (brown/ diamonds relate to internal business practices and staff factors; green triangles are technology factors; light blue diamonds are whole supply chain issues), the lower half of the map indicate waste types linked to disposal/ treatment routes and alternative markets for down-graded meat. Flags are different types of food waste, colours have no meanings.

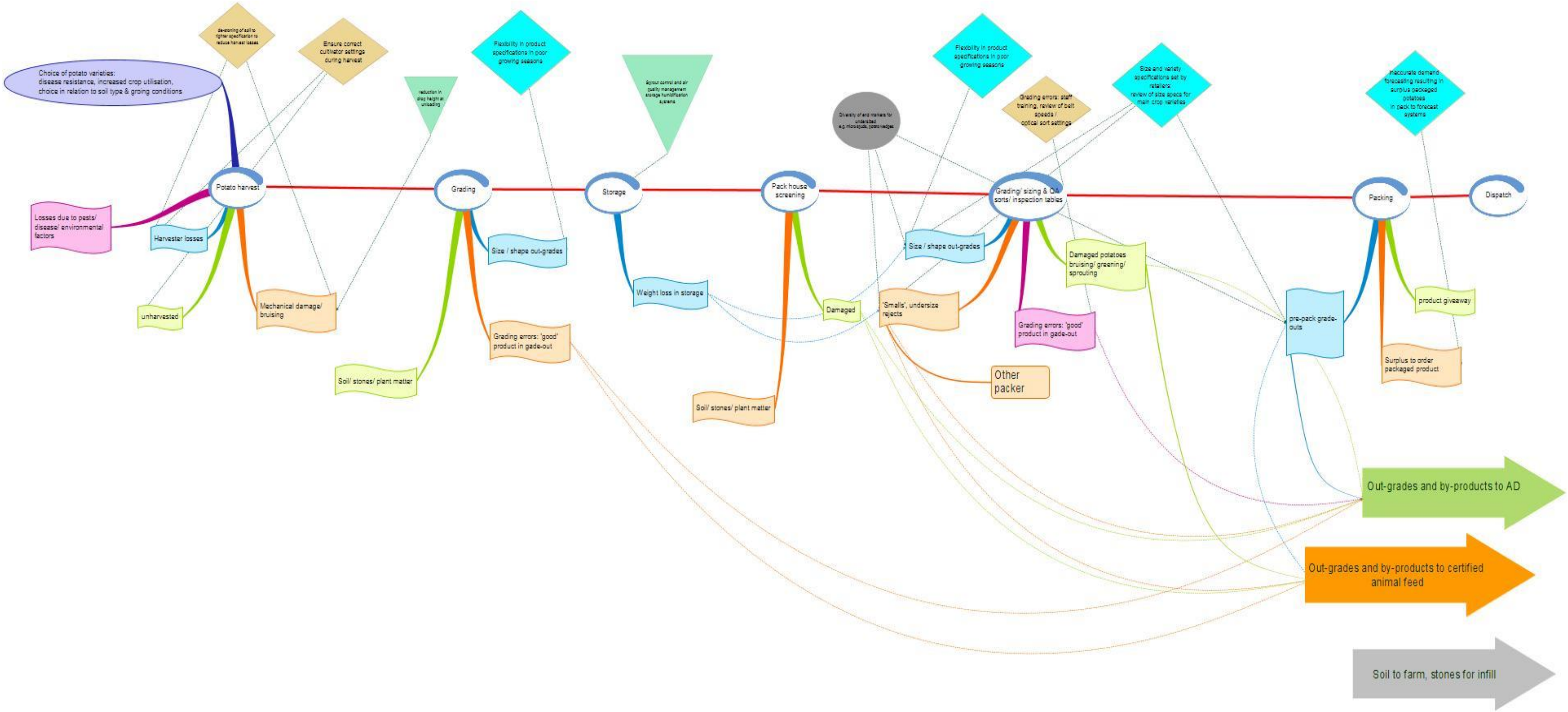
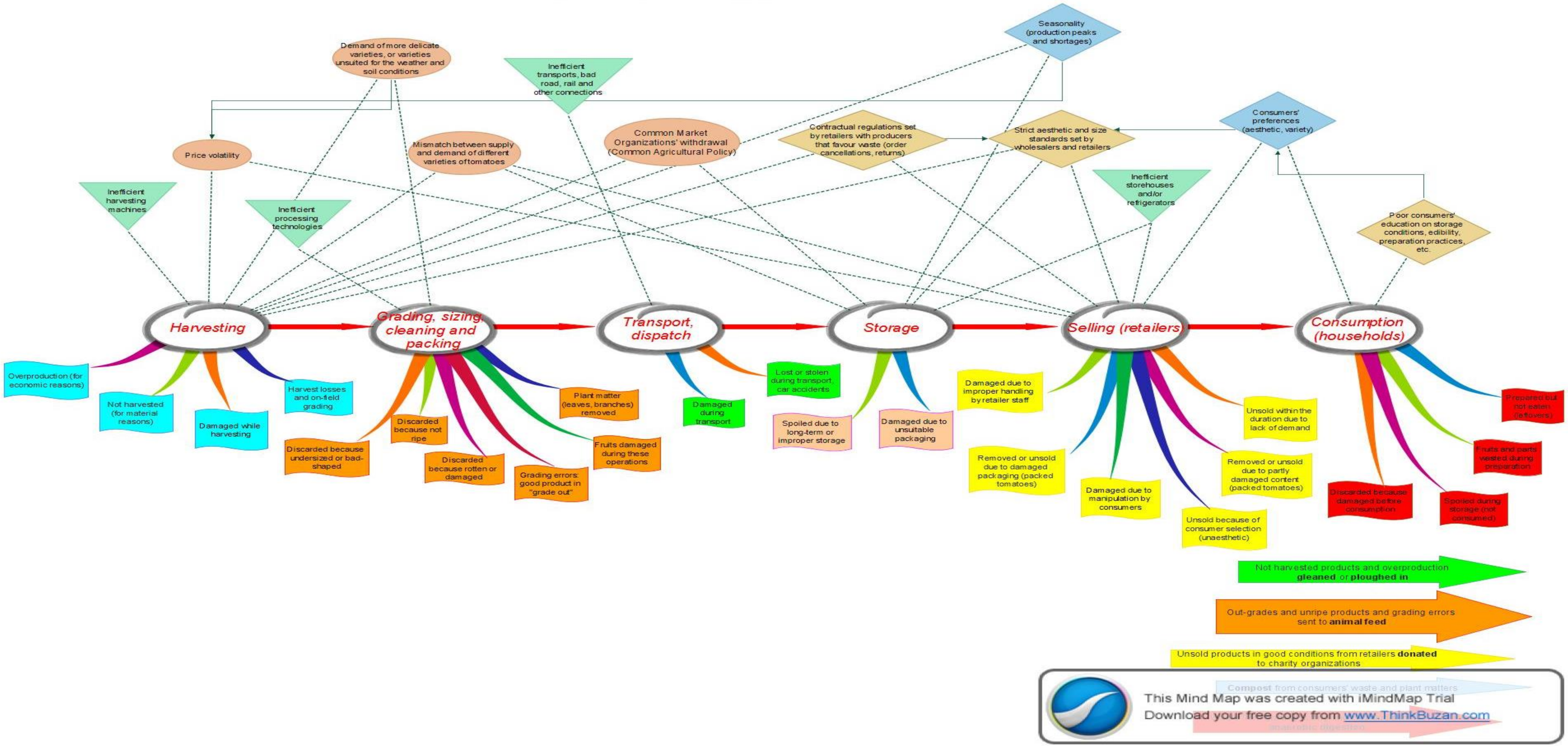


Figure 8: Bottom-up system map: potatoes (UK)

7.3.4 Italy

The supply chain of fresh tomatoes is relatively simple, as tomatoes do not undergo processing; nevertheless, waste flows along it can be relevant. Flags indicate different waste flows/causes, arrows represent their destinations. The boxes above are drivers: business policies (light brown), technological (green), market-related (rose), and supply chain-related



(blue).

Figure 9: Bottom-up system map: Tomatoes (Italy)

7.4 Meat

7.4.1 Italy

A key issue to be solved as for the supply chain of chicken meat concerns its delimitation. Indeed, based on literature, it starts from the grandparent breeder farm, followed by the parent breeder farm and the hatchery. Since all losses during these phases can be ascribed to the process of producing meat – eggs are not aimed at being consumed – the stages of the supply chain may be grouped as follows: 1) Primary production: breeder farm, hatchery and broiler growing farm; 2) Processing and packing: slaughterhouse, grading, cleaning and preparation; 3) Wholesale and logistics: storage (frosting, defrosting, etc.) and transport; 4) Retail: traditional (small-scale) and large-scale, secondary packaging, eventual cutting; 5) Food services and households. Blue-edged boxes are waste flows, red ones destinations.

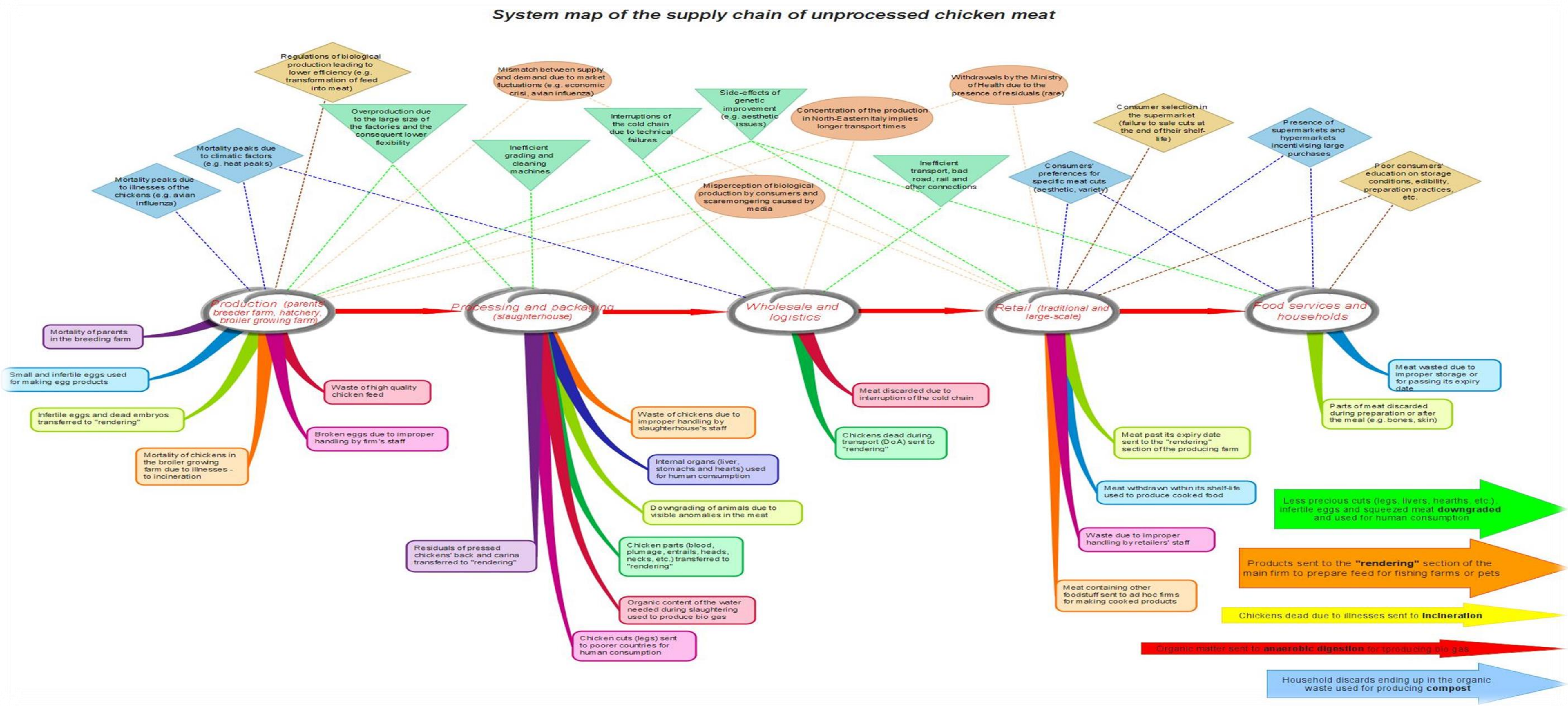


Figure 10: Bottom-up system map: Poultry meat (Italy)

7.4.2 United Kingdom

The main stages of production processes from farm, abattoir, to meat processing plan through to final product despatch are shown in the middle of the map. Boxes in the upper half are drivers (brown/ diamonds relate to internal business practices and staff factors; green triangles are technology factors; light blue diamonds are whole supply chain issues), the lower half of the map indicate waste types linked to disposal/ treatment routes and alternative markets for down-graded meat. Flags are different types of food waste, colours have no meanings.

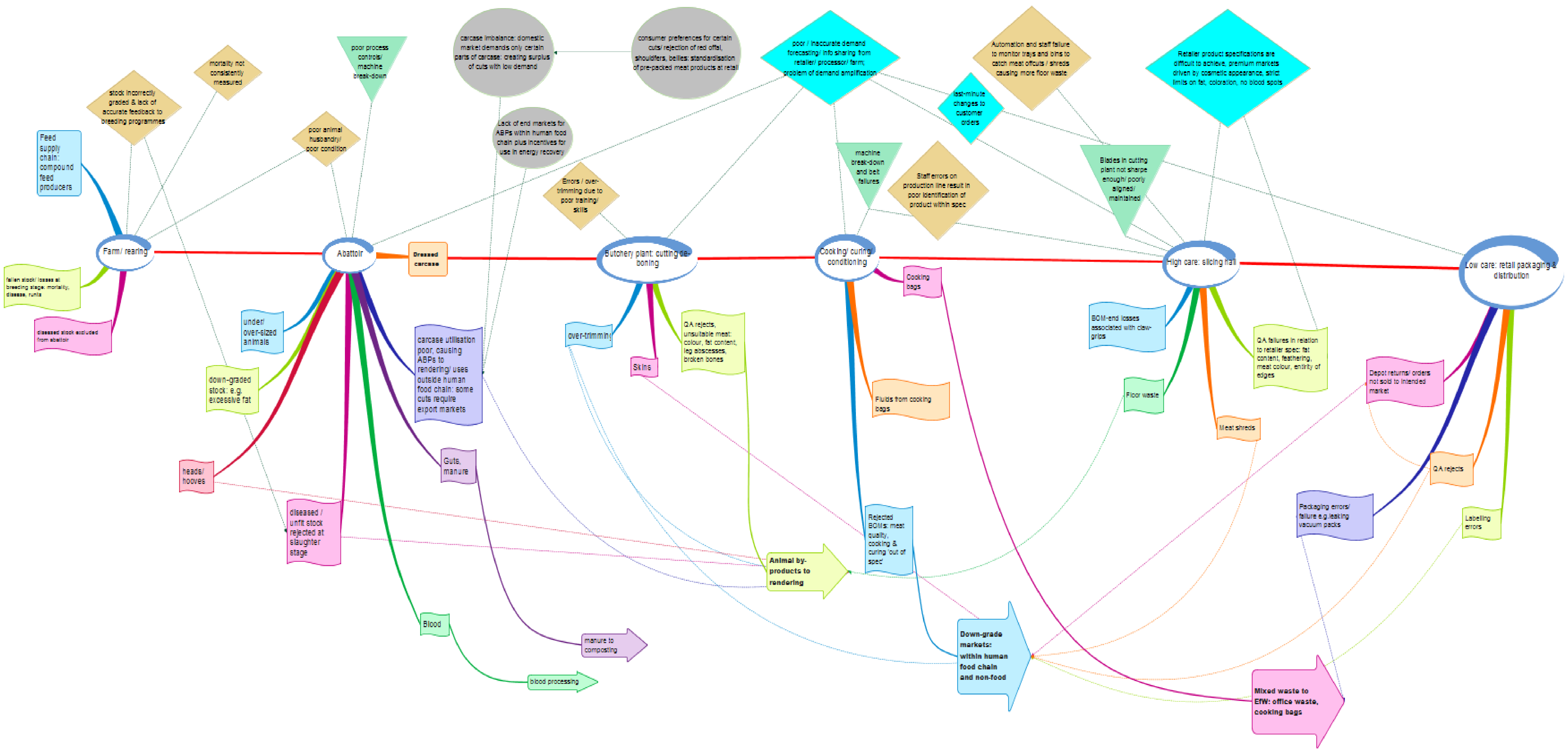


Figure 11: Bottom-up system map: processed meat product manufacture (UK)

7.5 Prepared meals (sandwiches)

7.5.1 United Kingdom

The main stages of production processes from ingredient through to final product despatch are shown in the middle of the map. Boxes in the upper half are drivers (brown/ diamonds relate to internal business practices and staff factors; green triangles are technology factors; light blue diamonds are whole supply chain issues), the lower half of the map indicate waste types linked to disposal/ treatment routes and alternative markets for down-graded meat. Flags are different types of food waste, colours have no meanings.

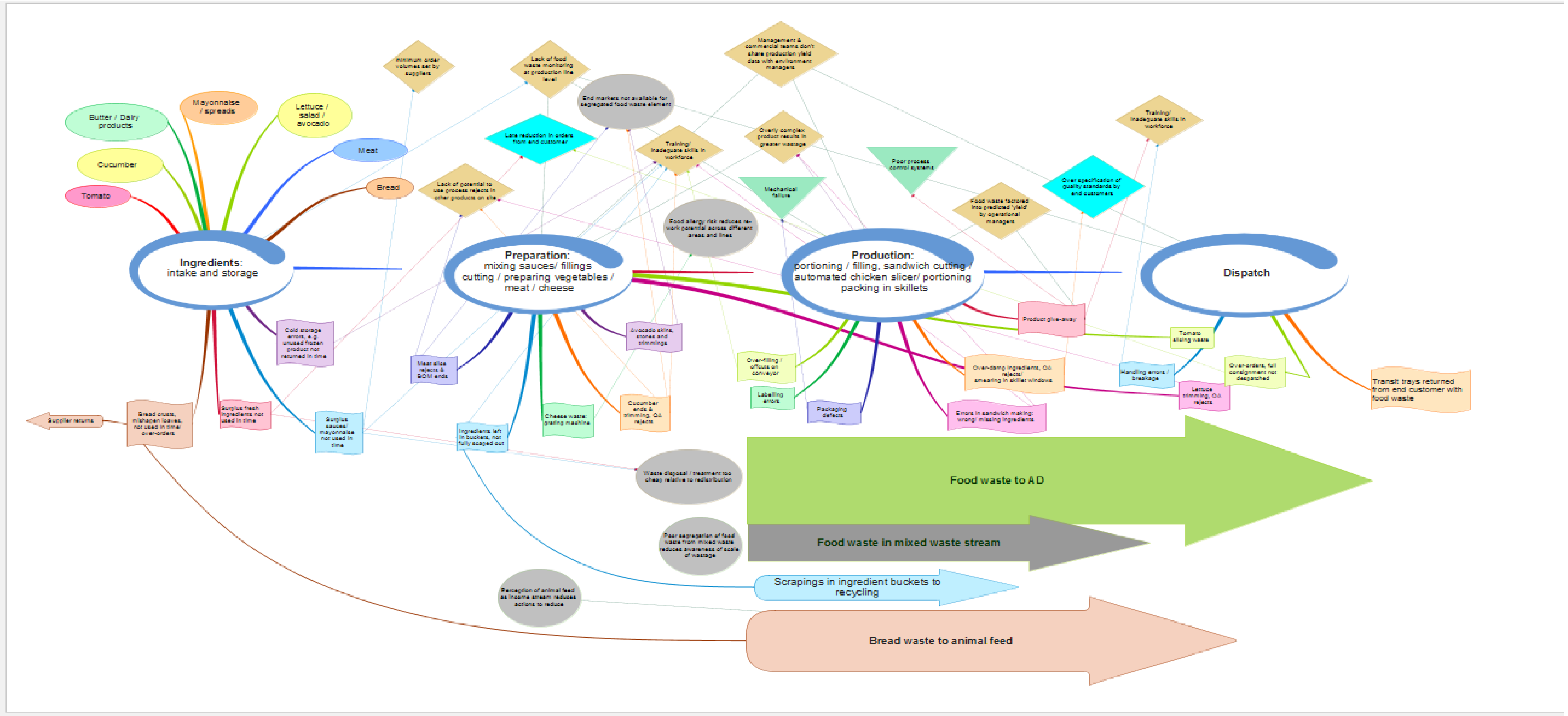


Figure 12: Bottom-up system map: PREPARED MEALS –SANDWICHES (UK)