European Commission

JRC TECHNICAL REPORT

Building a balancing system for food waste accounting at National Level

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2021

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EUR 30685 EN

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EU Science Hub
https://ec.europa.eu/jrc

JRC124446

EUR 30685 EN

PDF	ISBN 978-92-76-37275-2	ISSN 1831-9424	doi:10.2760/316306
Print	ISBN 978-92-76-37828-0	ISSN 1018-5593	doi:10.2760/1669

Luxembourg: Publications Office of the European Union, 2021

How to cite this report: De Laurentiis, V., Caldeira, C., Sala, S., *Building a balancing system for food waste accounting at National Level*, EUR 30685 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-37275-2, doi:10.2760/316306, JRC124446

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Acknowledgements

This report is a deliverable of the Administrative Arrangements between European Commission Joint Research Centre and DG ESTAT, contract n° 2019.0037. The authors of this report would like to thank Eurostat for the coefficients reflecting the food waste amount in waste statistics, to Cristina Re (DG-Estat) and Eduard Hans-Hauser (DG-Estat) for the support in the development of this study, and the European Potato Processors' Association (EUPPA) for providing data used in this work.

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Abstract

The Waste Framework Directive (2008/98/EC) establishes an annual reporting obligation for MS on food waste generation as of reference year 2020. The common methodology is defined in the Commission delegated decision (EU) 2019/1597 and the reporting format in the Commission implementing decision (EU) 2019/2000. Member States (MSs) will be obliged to report data on food waste quantification for the reference year 2020 by the 30th of June 2022. However, EU countries are at different levels of development and implementation of national strategies for food waste quantification. Hence, there is the need to develop a harmonized modelling system that enables the estimation of food waste generated by MSs and to assess the amounts reported by each country. This report presents a model (version 1.0) that intends to fill this gap. The model quantifies food waste at each stage of the food supply chain: primary production, processing and manufacturing, retail and distribution, food services, and household consumption. The food groups for which food waste is accounted for are: sugar beet, cereals, fruit, vegetables, potatoes, oilseeds, meat, fish, eggs, and dairy. Beyond estimating food waste generation, the model estimates: food losses (i.e. not harvested or ploughed in crops, and animal mortality during transport to slaughterhouse and rejected at slaughter), by-products (i.e. surplus food used as animal feed and for non-food uses), and food consumed, which is compared with the results of nutritional surveys to perform a plausibility check of the results of the model. Thanks to the model, food waste generated by each EU MS for the years 2000 to 2017 is estimated. Results per stage of the food supply chain are useful to identify hotspots across both stages of the food supply chain (FSC) and across food groups. For all the countries, the consumption stage was identified as the major contributor to the total amount of food waste generated. Regarding the food group contributing the most to the total amount, this varies from country to country and from stage to stage. In the development of the study, some limitations and potential improvement areas of the model have been identified. These include an update of country-specific coefficients (when data is available), improving the modelling of food waste and by-products generated at the processing stage by obtaining data from food processing industries (e.g. via manufacturing associations), and exploring the possibility of using dynamic food waste coefficients to capture changes in food waste generation patterns as a result of behaviour changes.

1 Introduction

Food waste has been gaining attention in the last years and policies are being put in place to contribute to the reduction thereof. An important step taken to fight food waste at international level was the definition of Sustainable Development Goal (SDG) target 12.3: ‘by 2030 halve per capita global food waste at the retail and consumer levels, and reduce food losses along production and supply chains including post-harvest losses’. The target was set under the SDG 12 – Responsible Consumption and Production. Besides committing to achieve the SDG 12.3 target, the European Commission (EC) has identified food waste as one of the priority areas of the European Circular Economy Action Plan (European Commission, 2015). The commitment of the EC in targeting food waste was reiterated in the New Circular Economy Plan (European Commission, 2020a) and in the recently released Farm To Fork strategy (European Commission, 2020b) presenting the commitment to halving per capita food waste at retail and consumer levels by 2030 (SDG Target 12.3) and foreseeing the definition of a baseline and binding targets to reduce food waste across the EU.

The first challenge to overcome in the path towards food waste reduction is food waste quantification. Up to now, studies quantifying food waste have been developed using different approaches and data sources, mainly relying on secondary data, resulting in high uncertainties in the existing global food losses and waste database (Xue et al., 2017). Xue et al. (2017), reviewed 202 publications which reported food loss and waste data for 84 countries and 52 individual years from 1933 to 2014, highlighting a high variability of the results. Corrado & Sala (2018) analysed studies developed at global scale and EU level, showing significant discrepancies in the results, due to different quantification approaches and data sources. Methodological differences limit the comparability of the results and the monitoring of food waste generation overtime. Such discrepancy was also pointed out in the review of studies quantifying food waste at Member State (MS) level done by the European Commission Joint Research Centre (EC-JRC) (Caldeira et al., 2019a). This study could not reach a conclusion on whether the figures reported were different due to variability among countries in terms of food waste generation profiles, or due to the use of different food waste definitions, system boundaries, and different measurement methods.

The amendment to Directive 2008/98/EC on Waste (European Parliament and of the Council, 2018) obliges European Union (EU) Member States (MSs) to monitor the generation of food waste along the food supply chain (FSC) and to take measures to limit its generation. To contribute to the harmonization of food waste quantification in the EU, the EC has published a delegated act establishing a common methodology and minimum quality requirements for the uniform measurement of food waste generated in MSs (European Commission, 2019a). Data should be reported according to what is established in the implementing decision (European Commission, 2019b) laying down a format for reporting of data on food waste and for submission of the quality check report as aid down in Directive 2008/98/EC. MSs have to report by 30/06/2022 food waste data referring to the year 2020. As mentioned in the Farm to fork Strategy, using the new food waste measurement methodology and the data expected from MS in 2022, the Commission will set a baseline and propose legally binding targets to reduce food waste across the EU (European Commission, 2020b).

Currently, a part of the reporting countries is going to send data on food waste on a voluntary basis, following the former reporting scheme (food waste plug-in reporting[1]) or the new one (defined according to the aforementioned delegated and implementing decisions). In general, all the MSs are currently adapting or developing national strategies for food waste quantification. It is crucial to reach a harmonized approach to allow a comparison of the reported amounts so to have a common baseline for countries.

[1] the “food waste plug-in” is an initiative launched by Eurostat in 2012 to explore how food waste estimations could be made based on data gathered within the data collection framework defined by the Waste Statistics Regulation

In this context, the JRC has investigated potential approaches to develop a model for the estimation of food waste in the EU at MS level, based on data currently available, adopting a consistent approach across countries, and enabling the assessment of temporal trends. Built on existing review studies (Caldeira et al., 2019b; Corrado & Sala, 2018; Xue et al., 2017), the most referred studies developed at EU level were classified according to the modelling approaches adopted, as presented in Figure 1.

Figure 1. Food waste accounting approaches at EU level in the reviewed studies.

Studies classified under *Approach A* apply food waste coefficients to food production statistics to estimate the amount of food waste generated (Bräutigam et al., 2014; FAO, 2011a; Porter et al., 2016; Vanham et al., 2015). These studies used the FAO food balance sheets (FBS) (FAO, 2020) as source of data for food supply combined with food waste coefficients taken from different sources. Falling under this approach are also the studies developed (Kemna et al., 2017) and Caldeira et al., (2019b) adopted the approach described above, using a combination of production statistics and waste coefficients, but in addition developed their studies under the theoretical framework of Material Flow Analysis (MFA)[2]. Other studies that adopted an MFA-based modelling approach are: the work by Beretta et al., (2013), Courtonne et al. (2015), and Xue et al., (2019). These studies were focused on specific case studies : Beretta et al. (2013) accounted for food waste in Switzerland; Courtonne et al. (2015) performed an MFA of the cereal supply chain in France and quantified losses at the farm and during grain storage, and residues from transformation industries; and Xue et al. (2019) mapped the dry matter mass and energy balance of the meat (including beef, pork, and poultry) supply chain in Germany, including waste.

Studies classified under *Approach B* determine food waste applying coefficients to waste statistics. Monier et al. (2010) and (Eurostat, 2017) used data from EU waste statistics reported by each Member State and collected by Eurostat, following the European Waste Classification for statistical purposes (EWC-Stat). In this classification, food waste is not reported separately, but is included to different extents in a number of waste categories together with other bio-waste streams. To overcome this issue, Monier et al. (2010) refined or substituted Eurostat figures with national data, where available and of sufficient quality (therefore complementing approach B with approach C, in Figure 1).

Under *Approach C* is the estimation of food waste at EU level based on the results of food waste accounting studies conducted at MS level was the approach followed in the FUSIONS[3] project (FUSIONS, 2016a). To this end, data compliant with the FUSIONS framework were collected from some European MSs and upscaled to the European level. The selection included only studies aligned to the FUSIONS food waste definition and adopting a robust methodology, and in some cases the results of the national studies were adapted to ensure their consistency with the FUSIONS definition (FUSIONS, 2014, 2016b). The total food waste generated at EU level was then calculated by normalising the food waste reported

[2] 'systematic assessment of the flows and stocks of materials within a system defined in space and time' (Brunner & Rechberger, 2004)

[3] FUSIONS (Food Use for Social Innovation by Optimising Waste Prevention Strategies) was an EU-funded project carried out from 2007 to 2012 on the estimation of food waste generation in the EU.

by a selection of countries (for which the accounting studies were deemed of sufficient quality), with normalisation factors tailored to the stage of the FSC considered (e.g. calculating the food waste per person at consumption stages or the food waste per produced amount at manufacturing), and then upscaling such values at EU level e.g. total EU population or total EU production of processed food. The low number of studies used in the upscaling procedure causes uncertainty of the results, as data were only obtained for up to a quarter of MSs, depending on the stage of the FSC. According to the authors, this factor alone explained most of the uncertainty of the results (FUSIONS, 2016a).

In addition to this review, the JRC evaluated the current availability of data at MS level, and proposed to further develop the model developed at EU level in Caldeira et al. (2019b) and deriving it at MS level (Caldeira et al., 2020). This report presents a detailed description of the further developments done to allow the quantification of food waste at MS level (section 2). Results obtained by the model (version 1.0) are illustrated for the year 2016 and are presented in section 3. Concluding remarks are then presented in section 4.

2 Modelling food waste accounting

The starting point of this study is the model presented in Caldeira et al. (2019b), which was developed to account food waste in the EU28 for the year 2011. The model was further developed to account for food waste in the EU Member States. An analysis focused on the results of the model for three MSs was recently published in Caldeira et al. (2021).

The model is built on the principle of material flow analysis (MFA), estimating the flow of food across the FSC up to consumption. It combines statistical information on the production of crops and animal products, their trade and uses (e.g. non-food uses), and on the production and trade of processed food products, with food waste coefficients and technical coefficients taken from the literature to estimate food waste at each stage of the FSC.

A number of updates were done in the process of deriving the model at MS level, namely:

i) the model was modified to adjust for a different availability of data at MS level. In other words, as in some cases data is only available at EU aggregated level and not for all MSs, alternative calculation methods and data sources had to be used.

ii) the food waste definition was adjusted to be in line with the EU food waste definition (as explained in section 2.1).

iii) the modelling of the amounts of fruit and vegetables distributed fresh, and the amounts of potatoes entering the manufacturing stages was updated with data sources (EUPPA, 2020; Freshfel, 2019) providing data at MS level.

The following sections present the scope of the model (Section 2.1), a detailed explanation of methodology developed to quantify food waste along the FSC (Section 2.2), and the data filling procedures and cut-off rules adopted (section 2.3). A second approach to quantify food waste based on waste statistics is presented in section 2.4. However, this approach was only used to estimate food waste at EU level.

2.1 Scope of the study

The model quantifies **food waste at each stage of the food supply chain** - primary production (PP), processing and manufacturing (P&M), retail and distribution (R&D), food services, and household consumption. The food groups for which food waste is accounted for are: sugar beet, cereals, fruit, vegetables, potatoes, oilseeds, meat, fish, eggs, and dairy.

The food waste definition used in Caldeira et al. (2019b) was adjusted to be in line with the EU food waste definition, which influenced the estimation of food waste at primary production. In Caldeira et al. (2019b), the definition of food waste proposed by FUSIONS is adopted, including crops left in field or ploughed-in and mortality of animals ready for slaughter (e.g. transported to slaughter or rejected at slaughter) in the accounting of food waste. Instead, the EU legislation excludes these streams from its food waste definition. According to EU legislation food waste is defined as:

"*all food as defined in Article 2 of Regulation (EC) No 178/2002 of the European Parliament and of the Council (European Parliament and Council, 2002) that has become waste"* (European Parliament and of the Council, 2018). The definition of 'food' laid down in Regulation (EC) No 178/2002 encompasses food as a whole, along the entire food supply chain from production until consumption. Food also includes inedible parts, where those were not separated from the edible parts when the food was produced, such as bones attached to meat destined for human consumption. Hence, food waste can comprise items that include parts of food intended to be ingested and parts of food not intended to be ingested. 'Waste' means any substance or object which the holder discards or intends or is required to discard (European Parliament and Council, 2008).

According to Article 2 of Regulation (EC) No 178/2002 of the European Parliament and of the Council, food shall not include feed, live animals unless they are prepared for placing on the market for human consumption and plants prior to harvesting (European Parliament and Council, 2002). Therefore, crops ploughed in or left on field and mortality of animals ready for slaughter were excluded from the definition of food waste used in this work.

Nevertheless, for completeness, it was decided to present separately these streams, defined in this report as **food losses**, from the remaining amounts of food waste generated at primary production. Therefore, in the case of meat, food waste is generated from the slaughtering stage onwards, hence at processing, distribution and consumption stages only, while food losses are generated at primary production.

Beyond estimating food waste generation, the model estimates the **by-products** (i.e. surplus food used as animal feed and for non-food uses such as the production of biobased materials) generated at primary production and processing and manufacturing. A further output of the model is the **amount of each food group consumed** at household and food services level (estimated separately). The total amount consumed is compared with the results of nutritional surveys to perform a plausibility check of the results of the model.

In this exercise, **food drained as or with wastewaters** and the **amounts of food waste retained for home composting**, are not accounted for separately from the remaining stream of food waste due to lack of data and of robust methodological approaches to do so.

Based on data availability, the model can be run for all years between 2002 and 2017, and results can be obtained for the EU27 Member States.

2.2 Detailed methodology of the material flow analysis

The aim of this section is to provide all information needed to replicate the model (version 1.0). To that end a detailed description of the underlying methodology of the updated model at each stage of the food supply chain is provided in the following sections: primary production in section 2.2.1, processing and manufacturing in section 2.2.2, and retail and distribution, and consumption in section 2.2.3. For clarity, when necessary, the methodology is presented distinguishing between food groups. An overview of the model developed is provided in Figure 2. This representation is valid for all food groups except for meat and fish. The modelling of the meat food group is illustrated in Figure 3 and explained in detail in subsections 2.2.1.3 and 2.2.2.8. The fish food group was also modelled differently from the other food groups, due to data availability at primary production and processing and manufacturing stages, as illustrated in Figure 4. A detailed explanation of the differences between the modelling of fish waste and the other food groups are provided in subsections 2.2.1.3 (for primary production) and 2.2.2.9 (for processing and manufacturing).

Along the section the reader is often referred to further information stored in Annex 1 and Annex 2. Annex 1 contains the full list of coefficients (technical coefficients and food waste coefficients) used by the model with their respective data source. In subsection 2.2.2 schemes are provided to illustrate the modelling of the processing stage, where the coefficients used are identified with coefficient codes that are then repeated in the tables of Annex 1.

The tables providing the coefficients used are built to enable the future addition of country-specific coefficients, in case of more studies becoming available. Currently, the following criteria is adopted to select which coefficient to use for a specific country (country A):

- if available, the coefficient from country A is used, otherwise
- if available, a coefficient valid for the EU, otherwise
- if available, a coefficient calculated as the average of the coefficients from other countries (B, C, etc.), otherwise
- a proxy coefficient from a study conducted in a non-EU country or from expert estimation.

Annex 2 contains the full list of databases used, and for each the items extracted with their name (e.g. barley), code in the respective data source (e.g. 2513), and the elements extracted (e.g. production, imports). In addition, when alternative data sources are used by the model (i.e. a second data source is used in case of missing data in the first data source), the correspondence between the product codes from the two data sources are provided in Annex 2.

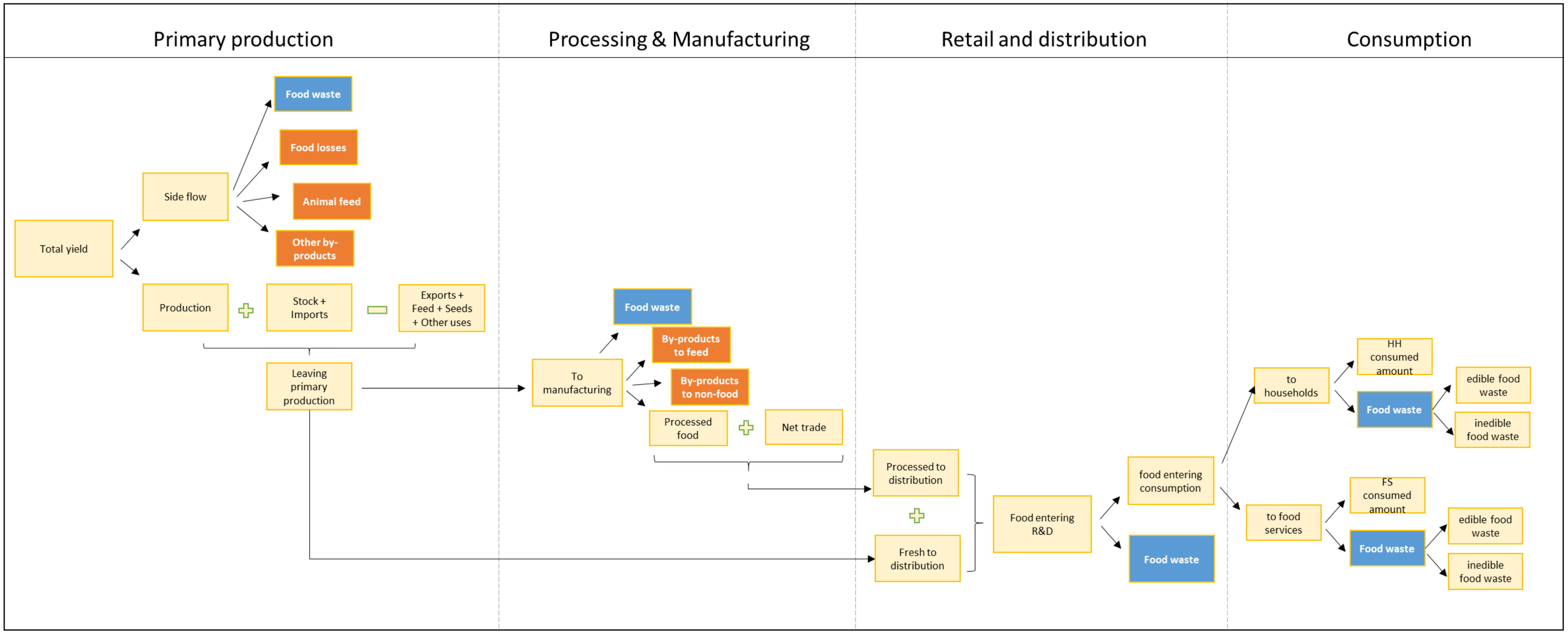

Figure 2. Conceptual scheme of the model developed, valid for all food groups except for meat and fish. Trade data at primary production is taken from FAO trade and referring to primary commodities only. All items expressed in their real weight[4].

[4] This is the weight of a product in the form in which it is produced or traded, as opposed to the primary equivalent weight (i.e. the amount of primary commodity input that would be required to produce a given amount of derived product output) or live weight equivalent (i.e. the live weight of an animal needed to produce a given amount of a derived product).

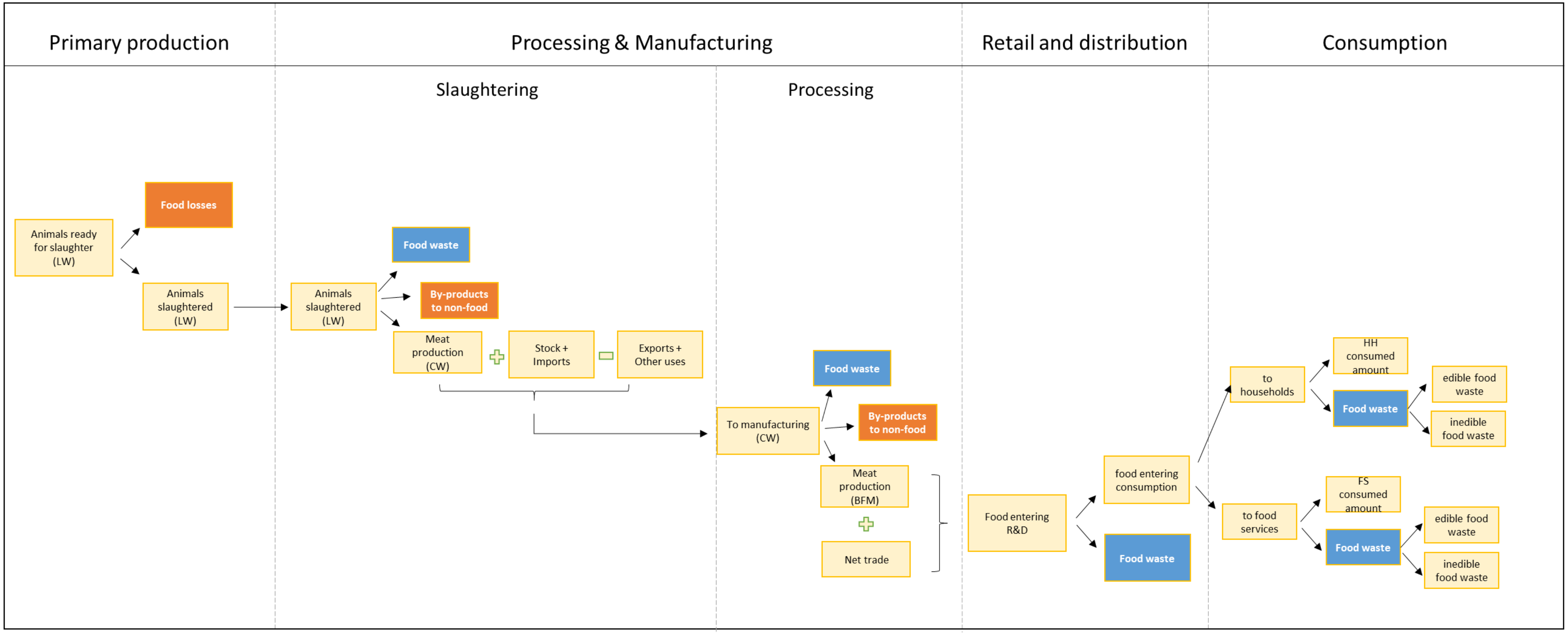

Figure 3. Conceptual scheme of the model developed for the meat food group. More details are provided in Section 2.2.1.3 (primary production) and Section 2.2.2.8 (processing and manufacturing). LW = live weight, CW = carcass weight, BFM = bone free meat.

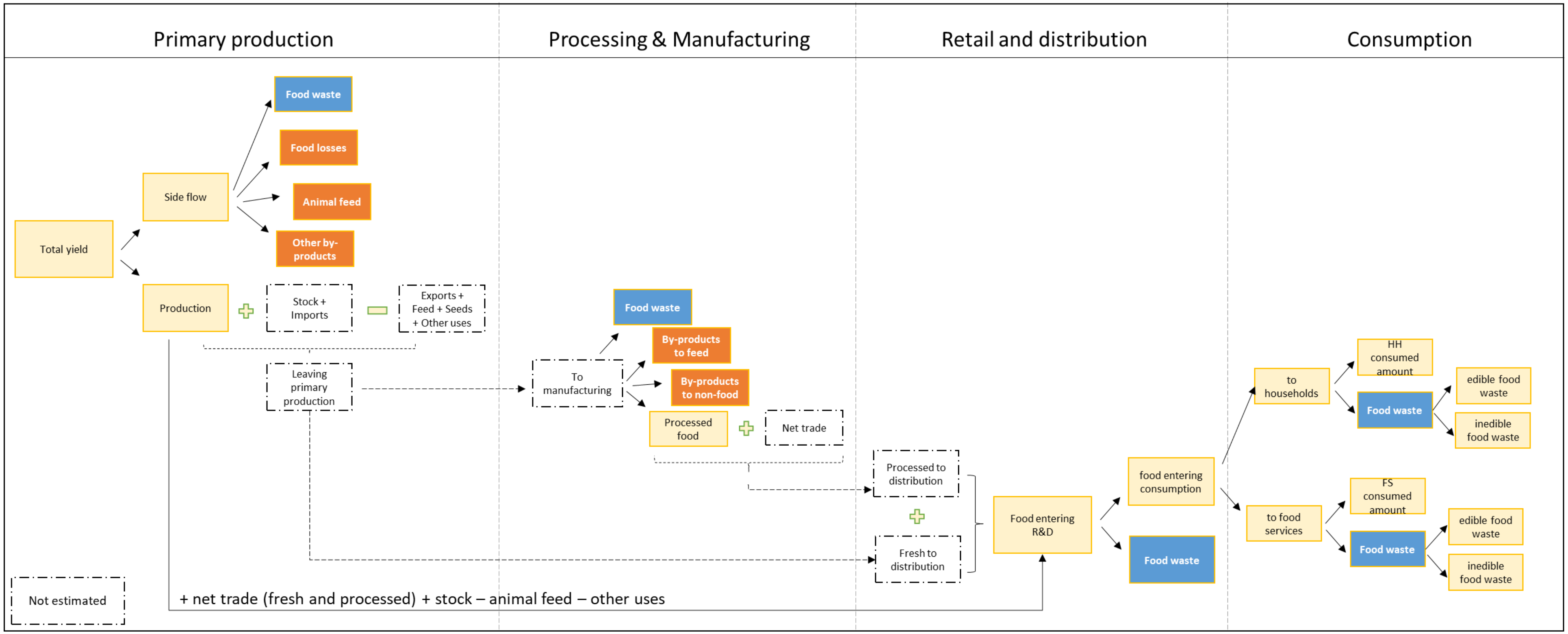

Figure 4. Conceptual scheme of the model developed for the fish food group. Trade data is taken from FAO CBS/FBS and refers to primary commodities and processed products expressed in live weight equivalent (more details are provided in Section 2.2.1.3). The manufacturing stage is modelled in isolation from the other stages and the amount of fresh fish entering the manufacturing stage ("to manufacturing" box) is not quantified (more details are provided in Section 2.2.2.9). At primary production, retail and distribution, and consumption, items are expressed in live weight equivalent[5], while at processing and manufacturing items are expressed considering their real weight.

[5] As opposed to real weight (footnote 4).

2.2.1 Primary production (PP)

The amount of crops and livestock products produced yearly in each MS is taken from FAOSTAT, specifically from the commodity balance sheets (CBS) for the years 2002-2013 and from the new food balance sheets (FBS) for the years 2014-2017[6]. Additionally, live animals slaughtered in the EU are extracted from FAOSTAT livestock primary database. The crops and animal products included in each food group at this stage of the FSC are presented in Table 1. The detailed list of all the crops and animal products included at this stage, identified with their specific code in the source database, is provided in Annex 2, tables A2.1, A2.2, A2.3 and A2.4, for food items identified by FSC stage PP.

Table 1. List of crops and animal products included in each food group at primary production.

Food group	Crops and animal products included at primary production (from FAO classification)
Sugar beet	Sugar beet
Oilcrops	Olives; sunflower seed; rape and mustard seed; soybean; cotton seed
Fruit	Apples; bananas; citrus, other; dates; fruits, other; grapefruit; grapes; lemons, limes; oranges, mandarines; pineapple; plantains
Vegetables	Onions; tomatoes; vegetables, other; beans; peas; pulses, other
Potatoes	Potatoes; sweet potatoes
Cereals	Wheat; barley; rye; maize; oats; rice[7]; other cereals
Dairy	Milk
Eggs	Eggs
Meat	Bovine; sheep; pig; poultry
Fish	Cephalopods; crustaceans; demersal fish; freshwater fish; marine fish; other molluscs; other pelagic fish

2.2.1.1 Plant based food groups: Sugar beet, Fruit, Vegetables, Potatoes, Cereals

A three-stepped approach was followed to calculate the food waste at primary production of plant-based food groups and the amounts of each entering the following stage of the supply chain (i.e. processing and distribution stages). These steps include: 1) the calculation of the amount of each crop produced for food purposes; 2) the calculation of food waste at primary production, and 3) the calculation of the amount of each crop leaving primary production (as illustrated in Figure 2). A detailed explanation of each step follows.

[6] Beyond the different temporal coverage, the main difference between the two databases are that the new food balance sheets provide additional information compared to the commodity balance sheets (e.g. per capita food supply quantity, protein supply quantity), which are not used by the model. For the purpose of this model the two databases are therefore considered equivalent.

[7] Rice is considered at this stage as "paddy equivalent". As in the FBS it is only reported as "milled equivalent", this was converted into "paddy equivalent" by dividing it by a coefficient equal to 0.6 taken from (FAO, 2003) (see Annex 2, Table A2.1).

Step 1: calculation of the amount of each crop produced for food purposes

The CBS and the FBS provide information on the supply and uses of **crops** expressed in commodity primary equivalent (i.e. the amount of primary commodity input that would be required to produce a given amount of derived product output (GSARS, 2017)). Table 2 provides an example of this information for the item: "wheat and products". The domestic supply quantity (DSQ) is calculated as production plus imports plus stock variation minus exports (items highlighted in orange in Table 2). In this table, imports and exports quantities refer to trade flows of wheat and of wheat-derived products (e.g. flour) measured in primary equivalent (i.e. amounts of wheat necessary to produce the imported quantity of flour). The DSQ is then distributed amongst the following uses: feed, seeds, losses, processing, food supply quantity, other uses (items highlighted in green in Table 2). The reader is referred to FAO, (2001) for a detailed overview of the elements included in the FBS/CBS. The information extracted from the CBS and FBS for this exercise is the following: production amount, stock variation, domestic supply quantity, feed, seeds and other uses. The last three items are then used to calculate the share of feed (S_f), seeds (S_s), and other uses (S_o) of the domestic supply quantity, according to the following equations:

$$S_f = \frac{Feed}{DSQ}\ [\%] \qquad [1]$$

$$S_s = \frac{Seeds}{DSQ}\ [\%] \qquad [2]$$

$$S_o = \frac{Other\ uses}{DSQ}\ [\%] \qquad [3]$$

Table 2. Example of commodity balance sheets (FAOSTAT), for the item "wheat and products", EU28, year 2013. All quantities are expressed in commodity primary equivalent.

Element	**Value [Mt]**
Production	144.4
Import Quantity	41.3
Stock Variation	2.3
Export Quantity	66.8
Domestic supply quantity	121.4
Feed	46.6
Seeds	5.3
Losses	3.2
Processing	4.9
Food supply quantity (tonnes)	53.4
Other uses	8.0

According to the definition of food waste, the calculation of food waste generated at primary production should only refer to the portion of harvested crops destined for human consumption. However, this information is not provided directly from the CBS/FBS. Hence, the amount of each crop harvested destined for food production (Pf) was calculated as follows:

$$P_f = P - (P \times s_f + P \times s_s + P \times s_o) \qquad [4]$$

Where P is the production from CBS/FBS, and s_f, s_s and s_o are calculated by means of equations 1, 2, and 3.

The underlying assumption is that the relative share of the considered uses (food, feed, seeds, and other uses) of the domestic supply quantity, which includes imported goods and excludes exported goods, as provided by the CBS/FBS, can be taken as a proxy of the relative share of uses of the crops produced in the region considered. In other words, the amounts that are used for feed, seeds, and other uses, according to the FBS/CBS include the imported quantity of each crop and exclude the exported quantity, the assumption taken here is that the relative share of each use, prior to trade, can be considered the same.

The elements "processing" and "losses" (Table 2) are not considered in this calculation. This is because under "processing" are reported the quantities of a crop processed for food purposes but entering a different commodity item group (e.g. "beverages, fermented" made of wheat). The element "losses" provides an estimation of waste and losses taking place between the level at which primary production is recorded and the household level (excluded) (FAO, 2001). As the aim of this calculation is to obtain the total quantity of a certain crop available at primary production to be used for food purposes, it is not necessary to subtract these two quantities.

Step 2: calculation of food waste at primary production

In this second step, food waste at primary production is calculated by combining the amount of each crop harvested to be used for food production (P_f) with coefficients taken from the literature. Additionally, the following elements are derived:

- Food losses (defined in this work as crops left on fields and ploughed in)
- Surplus food used as animal feed (in addition to the amount used as animal feed as reported by FAOSTAT in the FBS/CBS)
- Other by-products (surplus food at primary production used for other uses)

As the production amounts reported in the FBS/CBS do not include waste and losses at primary production, the "total yield" (i.e. the total crop ready for harvest) is calculated from the produced amount (Pf), by using a coefficient (PP01) as illustrated in equation 5 and Figure 5. This coefficient defined "side flow coefficient" (from Hartikainen et al., (2018)) represents the share of the total crop ready for harvest that is either wasted, lost, transformed in animal feed or in other by-products. Then, each component (food waste, food losses, animal feed, other by-products) is calculated from the total yield, using coefficients derived from the literature, following equations 6 to 9.

The calculation of food waste, food losses, animal feed and by-products are illustrated in equations 5 to 9.

$$Total\ yield = \frac{P_f}{(1-PP01)} \quad [5]$$

$$Food\ waste = \frac{P_f}{(1-PP01)} \times PP02 \quad [6]$$

$$Animal\ feed = \frac{P_f}{(1-PP01)} \times PP03 \quad [7]$$

$$Food\ losses = \frac{P_f}{(1-PP01)} \times PP04 \quad [8]$$

$$Other\ by-products = \frac{P_f}{(1-PP01)} \times PP05 \quad [9]$$

Where:

PP01 = side flow coefficient, equal to PP02 + PP03 + PP04 + PP05

PP02 = food waste coefficient

PP03 = animal feed coefficient

PP04 = food loss coefficient

PP05 = other by-products coefficient

The coefficients used and their data sources are provided in Annex 1, table A1.1 for each food group.

The first two steps of this procedure are illustrated by Figure 5.

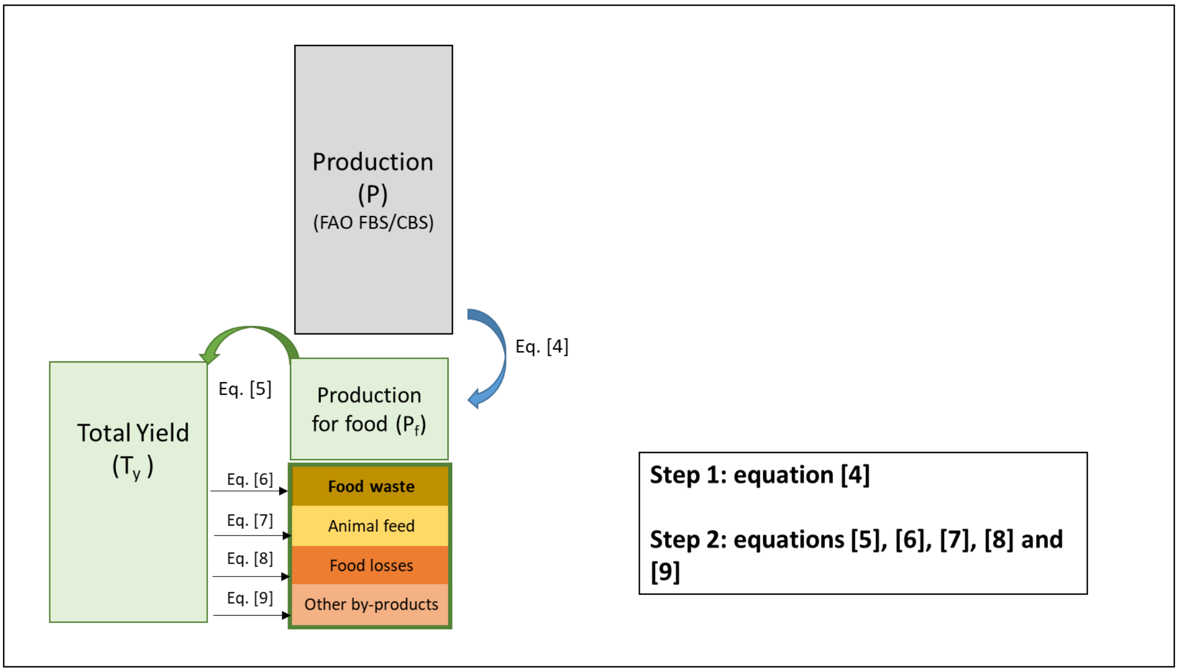

Figure 5. Visual representation of the calculation procedure to derive the amount of each crop produced for food, and the related food waste, animal feed, food losses and other by-products.

<u>Step 3: calculation of the amount of each crop leaving primary production</u>

Import and export quantities from the CBS/FBS present primary commodities together with processed products expressed in primary equivalent. Instead, the FAO trade database, reports imports and exports of primary and processed commodities separately (where the latter are expressed in their real weight and not in primary equivalent weight). An example of FAO trade statistics is provided in Table 3. It is possible to see, comparing Table 2 and Table 3, that imports and exports of wheat in the EU28 in 2013 were significantly lower than those of "wheat and products", as it can be expected that most of the quantity of "wheat and products" imported refers in fact to processed products.

Table 3. Example of FAO trade statistics (FAOSTAT) for the item "wheat", EU28 (excluding intra EU trade), year 2013.

Element	Value [Mt]
Import Quantity	3.9
Export Quantity	25.1

As the model developed distinguishes between food waste generated at primary production and food waste generated at processing and manufacturing, it is important to know how much of each crop is imported and exported in its unprocessed state (e.g. wheat), in order to calculate the amount of primary commodities leaving primary production to enter the processing and manufacturing stage and/or to enter directly the distribution stage to be distributed as fresh (this is the case only for certain food products such as fruit and vegetables) (as illustrated in Figure 2).

This calculation is performed as follows.

First, an "alternative domestic supply quantity" – DSQ*, is calculated following the same rationale of the domestic supply quantity from the CBS/FBS: as the sum of production quantity, stock variation, and net trade (imports minus exports). The reason for defining it as "alternative" is that, in this case, a different source is used for trade data: instead of extracting trade data from the CBS/FBS, FAO trade statistics are used to extract trade data, as they provide this information for primary commodities only.

Equation 10 illustrates the calculation of the alternative domestic supply quantity (DSQ*).

$DSQ^* = P + S + I - E$ [10]

Where P is the production (taken from CBS/FBS), S is the stock variation (taken from CBS/FBS), I and E are respectively imports and exports (taken from FAO trade).

Annex 2, Table A2.3 provides the list of codes for which data was extracted from FAO trade statistics. As the two databases use a different classification system, a mapping table is provided in Annex 2, Table A2.10, that links item codes in FAO CBS/FBS with item codes in FAO trade. This table is an input to the model.

The following equations (11 – 13) are then applied to calculate the portion of the DSQ* used for animal feed, seeds and other uses.

$$Feed^* = DSQ^* \times s_f \qquad [11]$$

$$Seeds^* = DSQ^* \times s_s \qquad [12]$$

$$Other\ uses^* = DSQ^* \times s_o \qquad [13]$$

Finally, the amount of crops leaving the primary production stage (Lpp), and therefore available for processing and fresh distribution, is calculated as follows.

$$Lpp = DSQ^* - Feed^* - Seeds^* - Other\ uses^* \qquad [14]$$

The underlying assumption of this calculation is that the share of different uses is the same for the domestic supply calculated considering only raw commodities (DSQ*) and considering both raw and processed commodities (DSQ). This is a critical assumption, and might cause either underestimations or overestimations of the amounts leaving primary production, depending on how the actual distribution of uses of primary commodities is compared to the distribution of primary and processed commodities. For the same reasons presented under "Step 1", and as the aim of equation 14 is to obtain the total quantity of a certain crop entering the processing stage for food purposes, the elements "processing" and "losses" from Table 2 are not considered.

The total animal feed generated at primary production is then calculated as the sum of two components: the animal feed calculated from equation 7 (as a share of the side flow) and animal feed calculated from equation 11 (based on CBS/FBS). Similarly, the item "other uses" calculated from equation 13 (based on CBS/FBS) is added to the quantity of "other by-products" calculated from equation 9 (as share of the side flow) to obtain the total amount of each crop at primary production destined to non-food uses.

For all plant based food groups, excluded oilcrops, the three steps presented above are applied directly to each crop included (presented in Table 1) to calculate:

- the amount of each crop used for food purposes,
- the related food waste, food losses, animal feed and other by-products generated at primary production, and
- the amount of each crop leaving the primary production stage and available for processing and fresh distribution.

2.2.1.2 Plant based food groups: Oilcrops

The model was modified in the case of oilcrops to account for the significant non-food uses typical of this group of commodities. The modified version of the three steps presented above is reported here.

<u>Step 1: calculation of the amount of oilcrops produced for food purposes</u>

While for olive oil, the entire harvest is intended to be used for food purposes, the remaining oilcrops are used both for food production and biofuels production. The calculation on the amount of each crop used for food purposes, necessary to estimate the food waste and food losses in the food supply chain, is based on the share of vegetable oils used as biofuels in the EU in 2016 ($OC1_i$), provided by Transport and Environment (2016) for the following vegetable oils: soybean oil, rapeseed oil, sunflower oil, palm oil, and other oil. Based on these shares, the amount of each oilcrop produced for food production is calculated by adapting equation 4 as follows:

$$P_f = \sum_{i=1}^{5}\left[P_i - \left(P_i \times s_{fi} + P_i \times s_{si} + P_i \times s_{oi}\right)\right] \times (OC1_i) \qquad [15]$$

Where: $OC1_i$ is the share of vegetable oil used as food per type of oil (provided in Table 4), P_i is the produced amount of each oil (i), s_{fi}, s_{si}, s_{oi} are calculated following equations 1-3 for each oilcrop (i).

Figure 2 is also valid for oilcrops, if equation [4] is replaced by equation [15].

Table 4. Share of different oils used as biofuels in the EU in 2016 (Transport and Environment, 2017).

Oil type	Share for biofuel	Share for food (OC1)
Olive oil	0%	100%
Rapeseed oil	60%	40%
Sunflower oil	4%	96%
Soybean oil	27%	73%
Vegetable oil (generic)	44%	66%

Step 2: calculation of food waste at primary production

Food waste, food losses, animal feed and other by-products are then calculated for the quantity of oilcrops used for food consumption (P_f) using the coefficients reported in Annex 1, Table A1.1, by means of equations 5 to 9.

Step 3: calculation of the amount of each oilcrop entering the processing and distribution stages

The amount of each oilcrop leaving primary production is then calculated by adapting equation 14 as follows:

$$Lpp_i = (DSQ_i^* - Feed_i^* - Seeds_i^* - Other\ uses_i^*) \times (OC1_i) \qquad [16]$$

Where DSQ_i^*, $Feed_i^*$, $Seeds_i^*$, and $Other\ uses_i^*$ are calculated for each oilcrop (i) by means of equations 10, 11, 12 and 13 respectively.

The total amount of oilcrops leaving primary production is then calculated as presented in equation 17.

$$Lpp = \sum_{i=1}^{5} Lpp_i \qquad [17]$$

2.2.1.3 Animal based food groups: Dairy, Eggs, Meat, and Fish

As for **animal products**, the modelling of milk and eggs follows the same approach presented for crops. The only differences are that in the case of milk the element "seeds" is equal to zero, while for eggs the element "feed" is equal to zero, whereas the element "seeds" accounts for eggs used for hatching. Instead, the modelling of fish and meat at primary production presents substantial differences to the other food groups. This is presented in detail below.

Meat

As specified in section 2.1, in this work, primary production of the meat supply chain includes the activities taking place up to slaughtering, the latter being excluded as considered part of the processing stage. According to the EU legislation (European Parliament and Council, 2002) live animals are not considered to be food, therefore at this stage no food waste is produced. However, there are losses caused by mortality of the animals ready for slaughter, both during transport to slaughterhouse and rejects at slaughterhouse, which are here quantified and classified under food losses (as mentioned in Section 2.1).

Food losses at primary production are calculated by applying food loss coefficients to the live weight of livestock slaughtered in each country (Pf). This is calculated from the number of animals slaughtered (Hi), as extracted from FAOSTAT livestock primary database (see Annex 2, Table 2.4), and the average weight of each species at slaughter (PP06), extracted for each country from the GLEAMi website[8], as illustrated by equation 18.

$P_f = \sum_i H_i \times PP06_i$ [18]

Where:

H_i are the number of heads of each species (i) slaughtered in the country considered

$PP06_i$ is the average weight at slaughter of species (i) in the country considered

The full list of average weights at slaughter considered is provided in Annex 1, Table A1.1.

The calculation of food losses is done following equation [7]; however, for this food group the side flow coefficient and the food losses coefficient are the same (i.e. the full side flow is considered a food loss, PP01 = PP04), as illustrated in Figure 3. The coefficients used are provided in Annex 1, Table A1.1.

The amount of meat leaving primary production corresponds to the total live weight of livestock slaughtered in each country (Pf).

Fish

The CBS and the FBS provide information on the supply and uses of fish expressed in live weight equivalent. The following information is extracted from the FBS/CBS: production, imports, exports, animal feed and other uses. The same procedure presented for plant-based food groups (**step 1**) is then applied to calculate the amount of fish produced for food purposes (Pf), by means of equation 4.

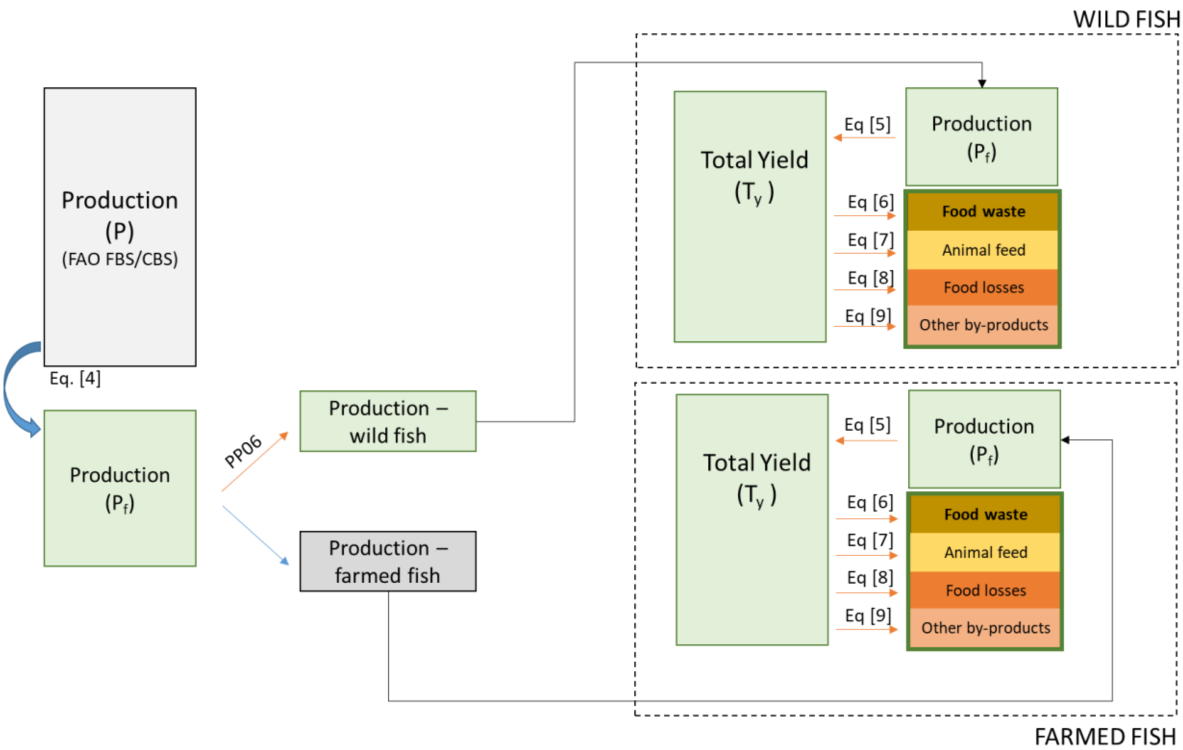

Figure 6. Visual representation of the calculation procedure to derive the amount of fish produced for food, and the related food waste, animal feed, food losses and other by-products.

[8] http://gleami.org/

Then, as illustrated by Figure 6, a distinction is made between farmed fish and wild caught fish. This is because food waste coefficients at primary production from the literature study consulted are provided separately for wild fish and farmed fish. As such information is not provided in FAOSTAT, the distinction is made considering the share of wild and farmed fish provided by EUMOFA (2018) for fish fished in the EU by species type. The table with the coefficients used is provided in Annex 1, Table A1.1 (coefficients PP06 for fish).

Food waste and by-products (in this case only animal feed) generated at primary production (i.e. fishing of wild and farmed fish) are then calculated by applying coefficients taken from the literature to the Pf, as illustrated in equations 5, 6, 7 and 8, following **step 2** of the procedure presented for plant-based food groups. The coefficients used are provided in Annex 1, Table A1.1. It is possible to see that not all coefficients are provided (PP01 and PP02 only for wild fish, and PP01 and PP03 only for farmed fish), as according to the source consulted (ADEME, 2016), the entire side flow generated from wild fish is wasted (by-catches thrown back in sea), while the entire side flow generated from farmed fish is used as animal feed. Therefore, in the model, food waste at primary production for this food group is only related to wild fish. It should be noted that the study used to estimate waste of wild fish (i.e. ADEME, 2016) is based on data collected in 2013. Between 2015 and 2019, European vessels were required to gradually eliminate the practice of discarding back to sea unwanted catches, through the introduction of the landing obligation introduced by the new Common Fisheries Policy (European Parliament and of the Council, 2013). Therefore, this coefficient is expected to be overestimating food waste generation for the years following 2015.

The calculation of the amount of fish entering the processing and distribution stages (**step 3**) is significantly different to what was presented for the other food groups (as reported in Figure 4). The reason for this is that, unlike the other food groups, it is not possible to distinguish between trade of fresh and processed fish products, as part of the processing already takes place at sea (gutting, freezing) and trade statistics report together raw and processed fish products. For this reason, it is not possible to quantify the amount of fish leaving the primary production stage and entering the processing stage, instead, based on FAOSTAT data, it is only possible to quantify directly the amount of fish entering the distribution stage, expressed in live weight equivalent.

The amount of fish entering the distribution stage is therefore calculated directly from the CBS/FBS as:

$$\textit{Fish entering distribution} = P + I + S - E - O - A \quad [19]$$

Where

P = production

I = import

S = stock variation

E = export

O = other uses

A = animal feed

Although it is not possible to quantify the amount of fresh fish entering the processing and manufacturing stage, an estimation of food waste generated at P&M is performed, as presented in section 2.2.2.9.

2.2.2 Processing and manufacturing (P&M)

Of the stages considered, the processing and manufacturing stage is the most complex to model due to the large number of transformations that take place to derive processed food products from crops and animal products that leave the primary production stage. For this reason, this is also the stage where the modelling approach varies substantially across the different food groups. A detailed description of the model per food groups is provided in the sub-sections below.

An assumption common to several food groups is that, due to lack of data, inefficiencies of the processing stage causing food waste and by-products are often not considered (this is not the case for potatoes and cereals, where some information on the efficiency of transformation processes could be retrieved). When this is the case, and inefficiencies are not accounted for, food waste and by-products are estimated considering the inedible component of different commodities. This implies that the food waste and by-products generated at processing are most likely underestimated.

Furthermore, it is expected that at this stage of the FSC, the use of side streams from food processing activities for several purposes (e.g. animal feed production, production of biomaterials, other non-food uses) is a common practice, as a way to maximise profit and reduce costs related to waste treatment operations. In this case, following the definition adopted in this work, residues would be classified as by-products. However, it is quite challenging to estimate the relative share of by-products and of waste generated by the different food manufacturing sectors, due to a lack of statistical data providing this information. For this reason, the amount of food waste estimated at this stage is affected by the assumptions made on what share of the residues generated will become a by-product, and might consequently be both, underestimated or overestimated.

The main inputs of the modelling approach adopted at this stage are statistical data on production and trade of processed food products taken from a range of databases from Eurostat, FAOSTAT and EUMOFA[9] websites (i.e. FBS, CBS, Prodcom, APRO, FAO trade, COMEXT, EUMOFA) and coefficients taken from the technical literature. Annex 2 provides for each source of data the full list of items extracted at this stage (identified with FSC stage P&M), in Tables A2.1, A2.2, A2.3, A2.5, A2.6, A2.7, A2.8 and A2.9. Additionally, the full list of coefficients used in the calculations at P&M is provided in Annex 1, Table A1.2.

In some cases, in order to deal with data gaps in the Prodcom database for trade of processed products, an alternative option from where to extract the data is provided. In other words, if no data is available from the first data source (Prodcom), a second data source can be used in replacement (FAO trade). To this end, a mapping between the item codes of the two different data sources is provided as input to the model and can be found in Annex 2 Table A2.11.

2.2.2.1 Sugar beet

The entire flow of sugar beet leaving the primary production stage, calculated from equation 14 (section 2.2.1) is assumed to enter to processing and manufacturing stage (i.e. no sugar beet entering the distribution stage as such). Figure 7 illustrates the modelling approach adopted for this commodity. From the amount of sugar beet entering the processing stage, it is assumed that when processed into sugar 78% of the initial weight is water leaving the system (i.e. due to evaporation) – (coefficient SU2 in Figure 7).

Waste and by-products are then calculated by means of mass balance, as the difference between the quantity of sugar beet entering the processing stage, the water evaporating and the amount of refined sugar produced. The latter is taken from the CBS for all years until 2013, where it is provided under the classification "Sugar, refined equivalent". As the FBS do not provide such information, for all years after 2014, the value of production of "Sugar, raw equivalent" is extracted from the FBS, and a coefficient of 92% is used to calculate the equivalent quantity of refined sugar (coefficient taken from FAO, (2003)).

Waste and by-products are then differentiated by means of coefficients. All coefficients are provided in Annex 1, Table A1.2.

[9] https://www.eumofa.eu/web/eumofa

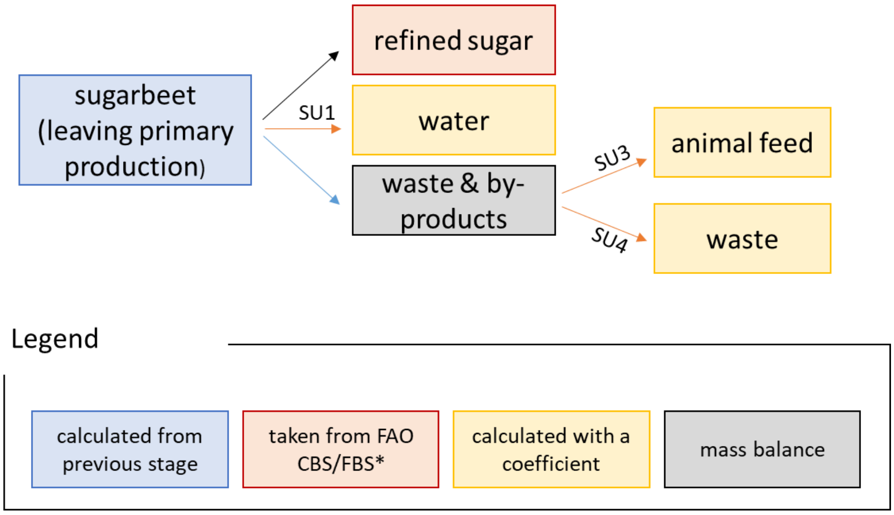

Figure 7. Modelling of the processing stage of sugar beet into refined sugar. * the amount of refined sugar is taken from CBS until 2013. As the FBS does not provide this information, for the years after 2013 refined sugar is estimated by multiplying the quantity of raw sugar equivalent by a coefficient SU2 (SU2 = 92%).

Trade data of processed sugar is taken from FAO trade statistics considering both "Refined sugar" and "Sugar raw centrifugal" (this is an intermediate product that is further processed to become refined sugar). After converting the latter into its refined equivalent quantity (using a coefficient of 92%), total imports and exports are calculated by adding together refined sugar and raw sugar converted into refined equivalent.

This information is then used to calculate the amount of refined sugar entering the distribution phase (E_d), identified as "Processed to distribution" in Figure 2, according to the following equation.

$$Ed = P + S + I - E - O \qquad [20]$$

Where:

P = production of refined sugar (taken from CBS/FBS)

S = stock variation of refined sugar (taken from CBS/FBS)

I = total imports of refined sugar and raw sugar converted in refined equivalent (taken from FAO trade)

E = total exports of refined sugar and raw sugar converted in refined equivalent (taken from FAO trade)

O = other uses (taken from CBS/FBS)

2.2.2.2 Oilcrops

The following products are modelled at this stage: preserved olives, olive oil, rapeseed and mustardseed oil, soybean oil, sunflowerseed oil, cottonseed oil. The amount of oilcrops leaving primary production to enter the processing stage for food production is calculated as presented in section 2.2.1 (equations 16 and 17). Similarly to sugar beet, no oilcrops are assumed to enter the distribution phase in their unprocessed state. The modelling of waste and by-products at the processing stage varies according to oil type.

For rapeseed and mustard seed oil, soybean oil, sunflower seed oil, and cotton seed oil, the amount of each vegetable oil produced (P_i) is taken from the FAO CBS/FBS and multiplied by a specific coefficient (coefficients $OC1_i$ in Table 4) to derive the amount produced for food purposes ($P_{f,i}$).

$$P_{f,i} = P_i\,(CBS/FBS) \times OC1_i \qquad [21]$$

Then, as illustrated in Figure 8, the cake generated at processing and manufacturing is calculated by means of mass balance by subtracting from the amount of each oilcrop entering the processing stage (calculated following equation 16) the amount of vegetable oil produced for food purposes. As can be seen from the coefficients provided in Annex 1, currently the model assumes that all the cake generated is used as animal feed (in other words OC3 is equal to 100% and OC2 is equal to 0%). According to the model, the processing of vegetable oils for the above mentioned oilcrops does not generate food waste.

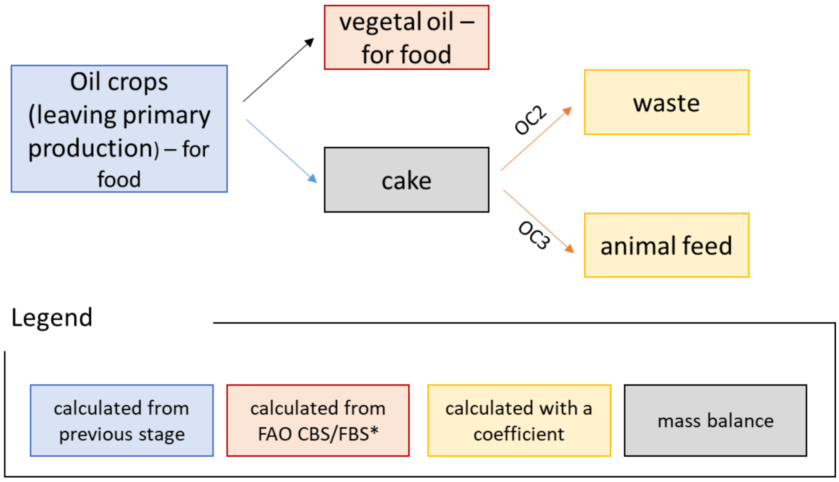

Figure 8. Modelling of the processing stage of oil crops (rapeseed and mustard seed, soybean, sunflower seed, and cotton seed) into vegetable oils. * Calculated as: amount reported in CBS/FBS x OC1 (Table 4).

The procedure for olives is illustrated by Figure 9. The amount of preserved olives produced is extracted from Prodcom. Then, from the total olives leaving primary production (calculated following equation 16 in section 2.2.1) the preserved olives are subtracted, providing the amount of olives transformed into olive oil. Coefficients derived from (Consejería de Agricultura y Pesca, 2015) are used to estimate from this quantity:

- the olive oil produced (including both olive oil and olive pomace oil),
- the amount of pomace and olive pits resulting from the extraction of olive oil and a subsequent extraction of olive pomace oil and
- the wastewater generated.

Waste and by-products are then calculated from the quantity of pomace and olive pits, following (Consejería de Agricultura y Pesca, 2015). All coefficients used are provided in Annex 1, Table A1.2.

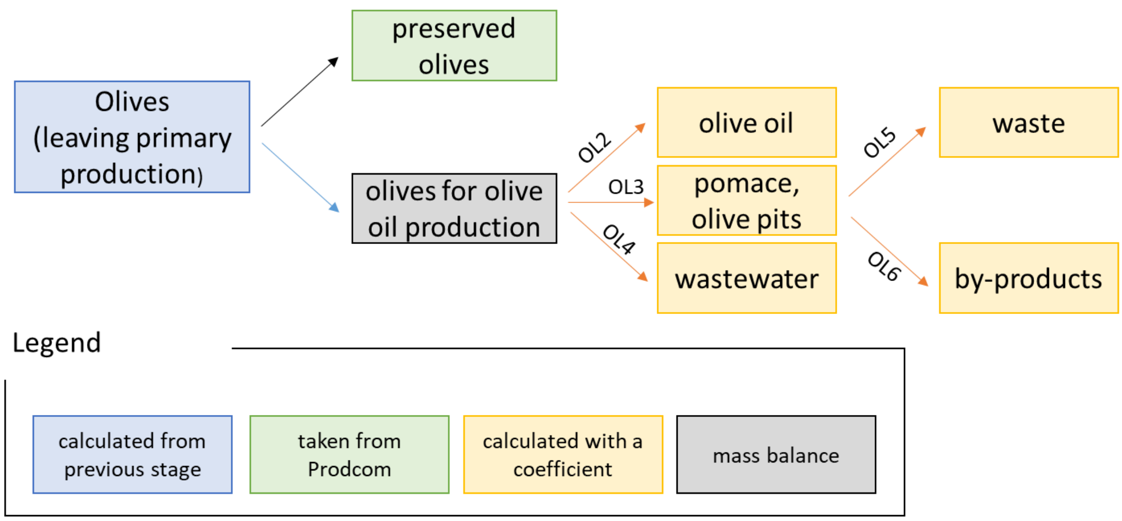

Figure 9. Modelling of the processing stage of olives into processed olives and olive oil.

Finally, the amount of processed olives, and vegetable oils (including olive oil) entering the distribution phase ("Processed to distribution" in Figure 2) is calculated by adding to the amount produced for food the net trade of each product. Net trade is calculated as imports minus export taken from FAO trade statistics. At this stage, in addition to the vegetable oils considered above, also the net trade of palm oil is taken into account. This is because, according to FAOSTAT, palm oil is not produced in EU MSs but is imported from extra EU countries.

For all vegetable oils (thus including palm oil), only the share of the net trade used for food is considered, to this end the coefficients $OC1_i$ from Table 4 are applied.

2.2.2.3 Potatoes

The amount of potatoes leaving primary production is calculated by means of equation 14.

Data on processed potato products at Member State level is affected by several gaps due to confidentiality issues. This affects the availability of processed potato products in the Prodcom database for several countries. Furthermore, there is no statistical information on the amount of fresh potatoes entering the manufacturing stage, nor on the amount of fresh potatoes distributed as such. For this reason, an alternative approach to the one adopted at EU level in Caldeira et al., (2019b) was adopted in this update of the model.

Based on data provided by EUPPA, (2020) on the amount of potatoes used by the manufacturing sector to derive processed potato products and the mass of final products produced in the main EU producing countries (i.e. Belgium, the Netherlands, France and Germany), and on the amount of potatoes leaving primary production in each MS, it was possible to estimate three coefficients used in the model:

- the percentage of the amount leaving primary production that enters the P&M stage for the 4 main producing countries (P01 in Figure 10, equal to 62%)
- the percentage of the amount leaving primary production that enters the P&M stage in the remaining countries (P01 in Figure 10, equal to 18%)
- the average ratio between the final potato products and the raw potatoes entering the P&M stage (P02 in Figure 10, equal to 51%)

Based on these coefficients, it is possible to calculate for each country: the amount of potatoes entering the P&M stage ("to manufacturing" in Figure 2), the amount of processed potato products leaving the manufacturing stage ("processed food" in Figure 2), and the amount of fresh potatoes entering the distribution phase ("fresh to distribution" in Figure 2). The latter element is calculated by performing a mass balance, subtracting from the potatoes available for processing and distribution the ones used by the manufacturing industry, as illustrated in Figure 10.

This approach was selected even though it is a coarse approximation of what happens in reality (as even between the four main producing countries the share of potatoes directed to manufacturing is quite variable), based on considerations on data availability and in order to protect data confidentiality.

Waste and by-products generated at the processing stage are then derived from the amount of potatoes processed, as illustrated in Figure 10. All the coefficients used to model the processing of potatoes, reported in Annex 1, Table A1.2, were derived from the information provided by EUPPA, (2020).

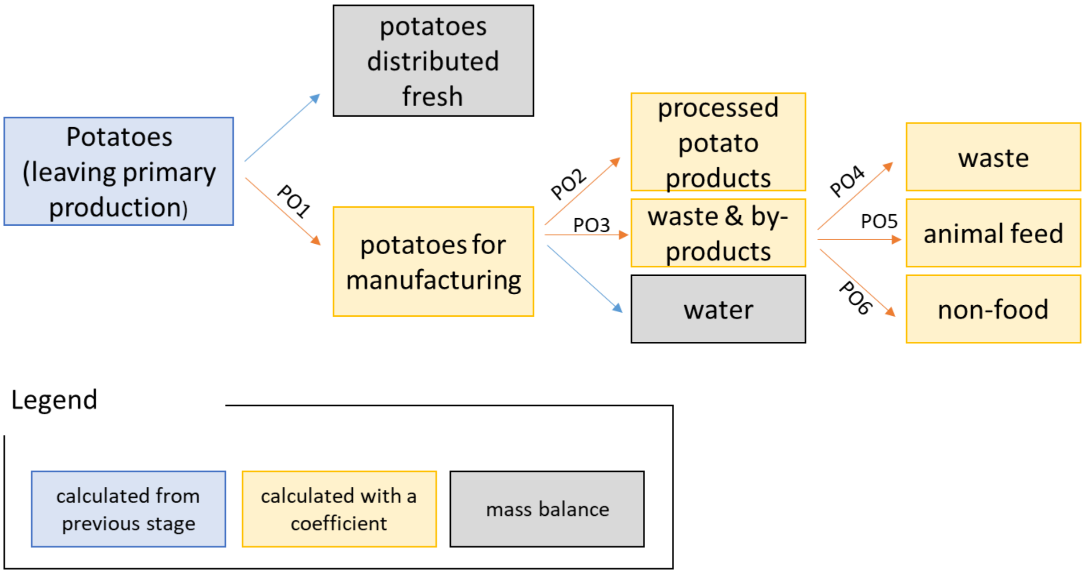

Figure 10. Modelling of the processing stage of potatoes.

The net trade of processed potato products was then derived from Prodcom (see Annex 2, Table 2.5). Finally, the total flow of potatoes and products entering the distribution phase was calculated by adding together the potatoes entering the distribution stage as fresh, the processed potato products produced and the net trade of processed potato products (as illustrated in Figure 2).

2.2.2.4 Fruit & Vegetables

Food groups fruit and vegetables at P&M were modelled in the same way and are therefore described together in this section.

Of the amount of fruit and vegetables leaving primary production, calculated by means of equation 14, a part will directly be distributed fresh, and the rest will be processed into wine and other fruit-based products (e.g. juice, jams) or vegetable-based products (e.g. tomato sauce). The modelling of fruit and vegetables at this stage is illustrated respectively in Figure 11 and Figure 12.

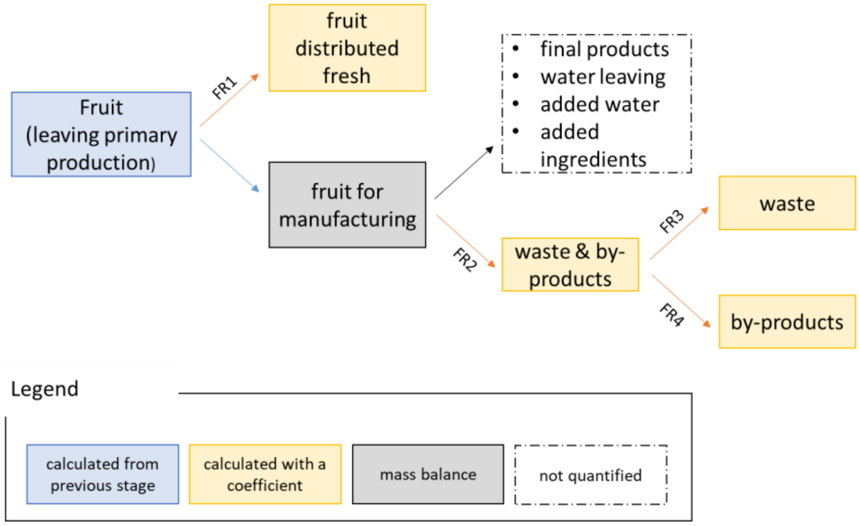

Figure 11. Modelling of the processing and manufacturing stage of fruit.

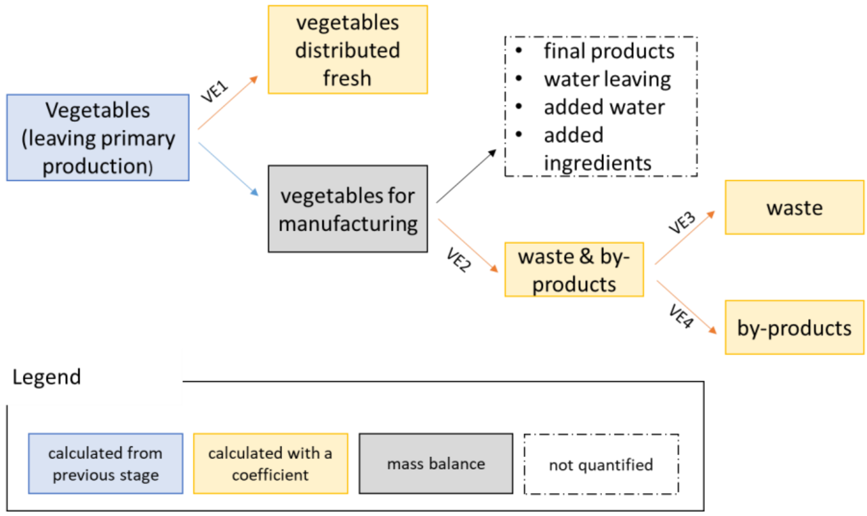

Figure 12. Modelling of the processing and manufacturing stage of vegetables.

As there is no official statistics on the amount of fruit/vegetables distributed fresh, nor on the amount fruit/vegetables entering the manufacturing stage, the share of each flow in the different MSs needed to be estimated.

Information provided in Freshfel (2019) on the amount of fruit/vegetables consumed fresh in the MSs in 2017 was used to perform this estimation. From the quantities of fresh fruit/vegetables consumed per capita, the total amount of fresh fruit/vegetables distributed was calculated for each country. Then this quantity was divided by the amount of fruit/vegetables leaving primary production in 2017, calculated by means of equation 14, to calculate two coefficients (FR1 in Figure 11, and VE1 in Figure 12) for each country that represents the share of fruit/vegetables leaving primary production to be distributed fresh. As this information is only available for the year 2017 (fresh fruit/vegetables consumed from (Freshfel, 2019)), these coefficients are considered static and are applied to all years. In one case (fresh fruit to distribution coefficient calculated for Lithuania), this process yielded a coefficient larger than 1 and the coefficient was assumed to be equal to 1 (meaning that no fruit is considered to be processed in that country). This is reasonable in countries that are not producing significant amounts of fruit at primary production, that are more likely to import directly the processed fruit products (e.g. wine, or juice) rather than importing the raw materials to produce domestically processed fruit products). The coefficient FR1 calculated for each country are provided in Annex 1, Table A1.2.

The amount of fruit/vegetables used at P&M is then calculated by performing a mass balance as the amount leaving primary production minus the amount distributed fresh.

To estimate the food waste generated when producing processed fruit/vegetables products, the amount of fruit/vegetables used at manufacturing is multiplied by coefficients (FR2 and VE2), equal to the average inedible component of fruit/vegetables according to De Laurentiis et al., (2018). The waste and by-products derived from this quantity are obtained by means of coefficients taken from (Kemna et al., 2017). All coefficients used are provided in Annex 1, Table A1.2.

As can be seen from Figure 11 and Figure 12, the transformation of fresh fruit/vegetables into the final processed products is not modelled (see items marked as "not quantified") due to: i) the complexity of the different transformations and ii) the lack of data on the amount of each type of fruit/vegetables available for processing (or available for fresh distribution). Instead, the processed fruit/vegetable products produced and traded by each country are extracted from Prodcom with the exception of wine which is taken from FAOSTAT CBS. The imports and exports of processed fruit/vegetable products are taken from FAOSTAT trade statistics in case of data gaps in the Prodcom database (wine is instead taken from FAOSTAT trade by default due to several data gaps found in Prodcom). Then the processed fruit/vegetable products entering the distribution phase are calculated as the sum of production and net trade.

The total amount of fruit/vegetables and fruit/vegetable products entering the distribution phase are then calculated by adding together the fresh fruit/vegetables and processed fruit/vegetable products entering this stage, as illustrated in Figure 2.

2.2.2.5 Cereals

The processing stage of cereals is modelled considering the processing of the following crops: common wheat, durum wheat, barley, maize and rice. The amount of wheat (common plus durum wheat), barley, maize and rice available for processing is calculated as explained in Section 2.2.1 (equation 14). As in FAOSTAT CBS/FBS the distinction between common wheat and durum wheat is not provided, the amount of durum wheat produced is extracted from Eurostat APRO database, and the amount traded from COMEXT. Finally, the amount of durum wheat used for animal feed production and for seeds are estimated as, respectively, 7% and 5% of the amount produced (coefficient derived from the cereal balance sheets for 2015 taken from Eurostat database). Based on this, equation 14 is applied to calculate the amount of durum wheat available for processing. The amount of common wheat available for processing is obtained by subtracting the latter from the flow of wheat available for processing.

The modelling of the processing of cereals into cereal based products is mostly based on the model of the cereal supply chain developed by Courtonne et al. (2015), from which coefficients were derived and applied to the amount of each cereal available for processing. This source provided information on the different uses of cereal crops in France, and on the efficiency of the processes of converting crops into derived products. The distinction between waste and by-products generated was instead based on ADEME (2016). The modelling approach adopted is presented below differentiating by crop type. All coefficients used are provided in Table A1.2 of Annex 1.

Figure 13 illustrates the modelling of the transformation of common wheat into starch and flour, and the transformation of flour into its derived products. Coefficients are used to derive the amount of common wheat used by the starch and glucose industry and the amount processed into flour, then additional coefficients are used to derive the amount of waste and by-products generated in these transformations. Then the flour produced is added to the net trade of flour, and coefficients are used to distinguish between the different uses of flour and the waste and by-products generated.

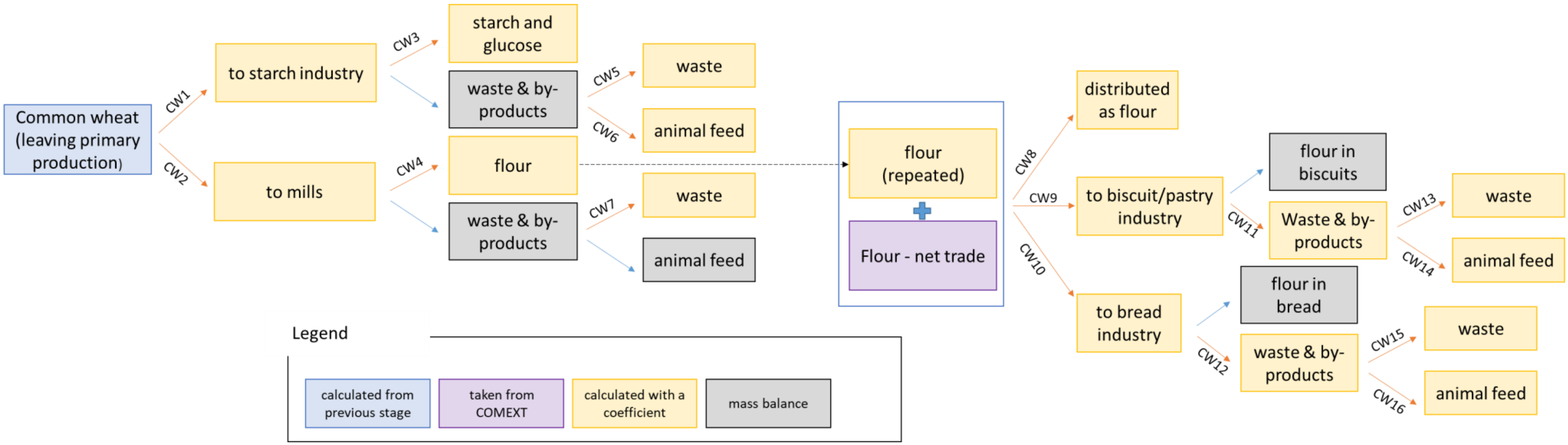

Figure 13. Modelling of processing and manufacturing stage of common wheat.

Figure 14 illustrates the modelling of durum wheat into semolina and then into pasta and couscous. Durum wheat entering the P&M stage is calculated as the sum of the produced amount taken from APRO database (see Annex 2, Table A2.6, plus net trade (from COMEXT, see Annex 2, Table 2.8), minus 5% of production (seeds), minus 7% of production (feed). Coefficients are used to derive the amount of semolina produced, and the waste and by-products are derived by means of mass balance. Then, the semolina produced is added to the net trade of semolina, and the amount of derived pasta and couscous are estimated, together with the waste and by-products generated in the process. The by-products generated are assumed to be used as animal feed, according to ADEME (2016).

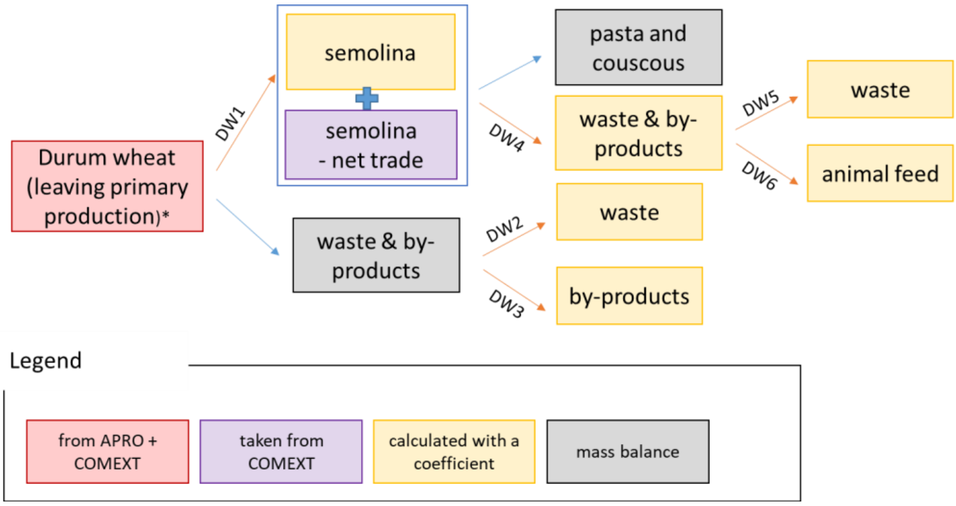

Figure 14. Modelling of durum wheat into pasta and couscous. *calculated from APRO, plus net trade (from COMEXT), minus 7% of production (feed), minus 5% of production (seeds) (respectively DW7 and DW8 in Annex 2, Table A1.2).

Figure 15 illustrates the modelling of maize wheat into starch and glucose. First, the amount of maize used for the production of starch and glucose is derived by means of a coefficient. The remaining amount, calculated with a mass balance, is assumed to be used by the cornmill and canned corn industry. These processes are not modelled further. Coefficients are then used to calculate the final amount of starch and glucose produced, together with the waste and by-products generated in the process. The by-products generated are assumed to be used as animal feed, according to ADEME (2016).

The modelling of rice is presented in Figure 16, coefficients are used to derive the amount milled rice produced and to derive the waste and by-products generated in this process. All by-products are assumed to be used as animal feed.

The modelling of barley is illustrated by Figure 17. In a first transformation, barely is processed into malt. Here, coefficients are used to derive the amount of malt produced, and the amount of waste and by-products, while the water leaving this system is calculated by means of mass balance. The process of transforming malt into beer is not modelled, due to missing data on added water and added ingredients. Therefore, from the quantity of beer produced (derived from Prodcom), using specific coefficients derived from (Roth et al., 2019), the amount of brewer's spent grain generated is estimated (assumed to be used as animal feed) and the amount of waste is obtained.

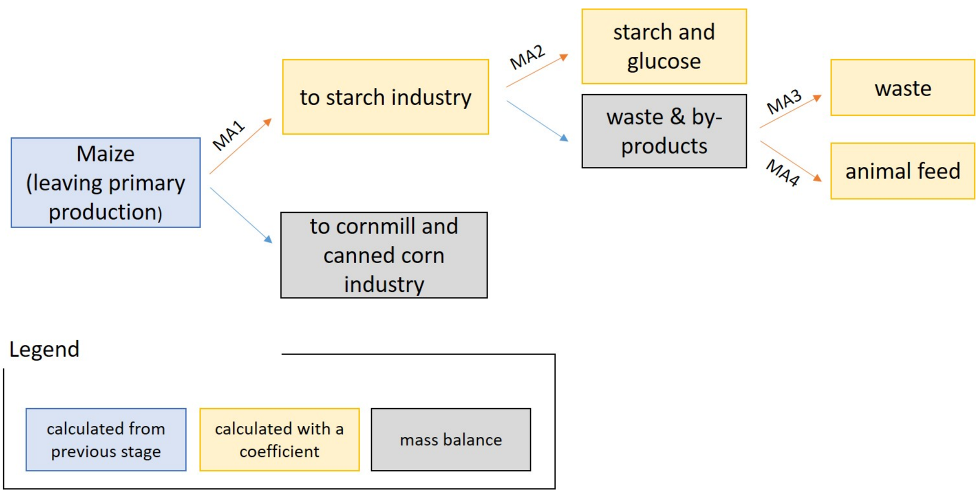

Figure 15. Modelling of maize into starch and glucose, and cornmill and canned corn.

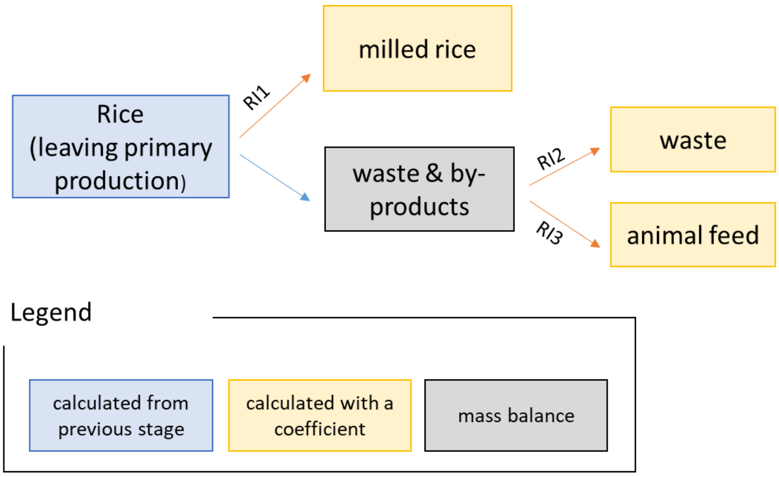

Figure 16. Modelling of rice milling.

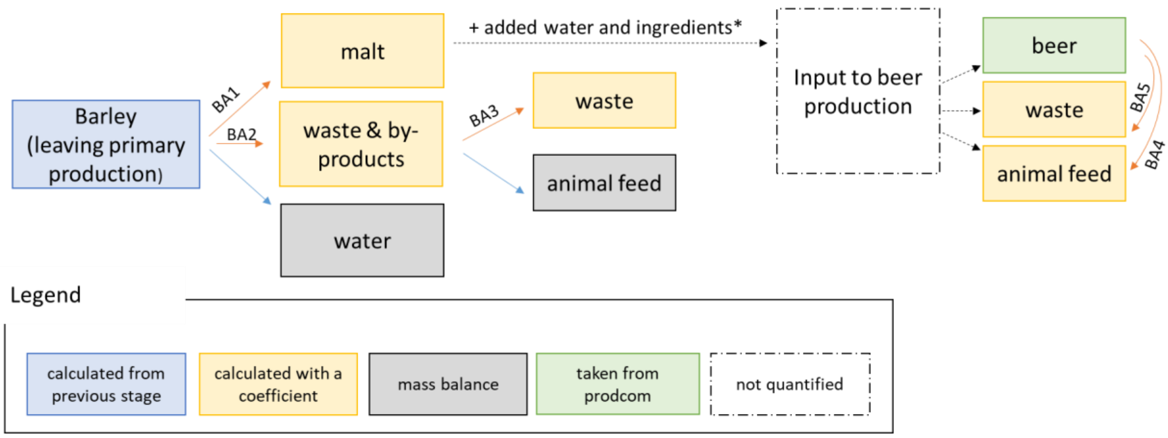

Figure 17. Modelling of barley into beer. * Not estimated.

Finally, the total waste and by-products obtained from the transformation of cereals into processed products are calculated.

To derive the amount of cereal based products entering the distribution phase (as presented in Figure 2) the following procedure is adopted. The amount of flour distributed as such (not used by the food manufacturing sector) is derived from the approach presented above, as illustrated in Figure 13. No information on trade of this product is available, and therefore this element is not considered. For the remaining cereal based products assumed to enter the distribution phase (i.e. bread, pastry, biscuits, pasta, beer, breakfast cereals and rice) information on production and net trade is extracted from Prodcom (see Annex 2, Table 2.5) and added together.

2.2.2.6 Dairy

The processing stage of dairy products is modelled using as input data Eurostat APRO database: specifically considering apro_mk_pobta and apro_mk_farm. These two databases provides for each MS data on whole and skimmed milk utilization to produce dairy products and on the amounts of each product produced in real weight both considering products produced by dairies (apro_mk_pobta) and products produced directly on farms (apro_mk_farm). The following dairy products are included in the model: drinking milk, butter and yellow products, cheese, yogurt, cream, powder and other concentrated milk, casein, buttermilk, milk based drinks, and other fresh products (for more details, see Annex 2, Table A2.7).

It should be noted that in this case the amount of milk leaving primary production (calculated by means of equation 14) is not used to derive the amount entering the P&M stage (conversely to what is reported in Figure 2), which is instead taken directly from the APRO database.

In the model, whey is generated from the production of cheese and caseins taking place at dairies (Figure 18). Whey from cheese production is calculated by using a coefficient taken from (Kemna et al., 2017) multiplied by the amount of milk used to produce cheese, extracted from APRO database. Whey from the production of casein is calculated as the difference between milk (skimmed plus whole) used for caseins production and the amount of caseins produced. From the total whey generated (from caseins and cheese production), a coefficient is applied to calculate the amount that becomes food waste (taken from (Kemna et al., 2017)). Then, whey used for feed is extracted from the APRO database and accounted for as a by-product.

For each dairy product included in the model, the amount produced by dairies is extracted directly from the APRO database.

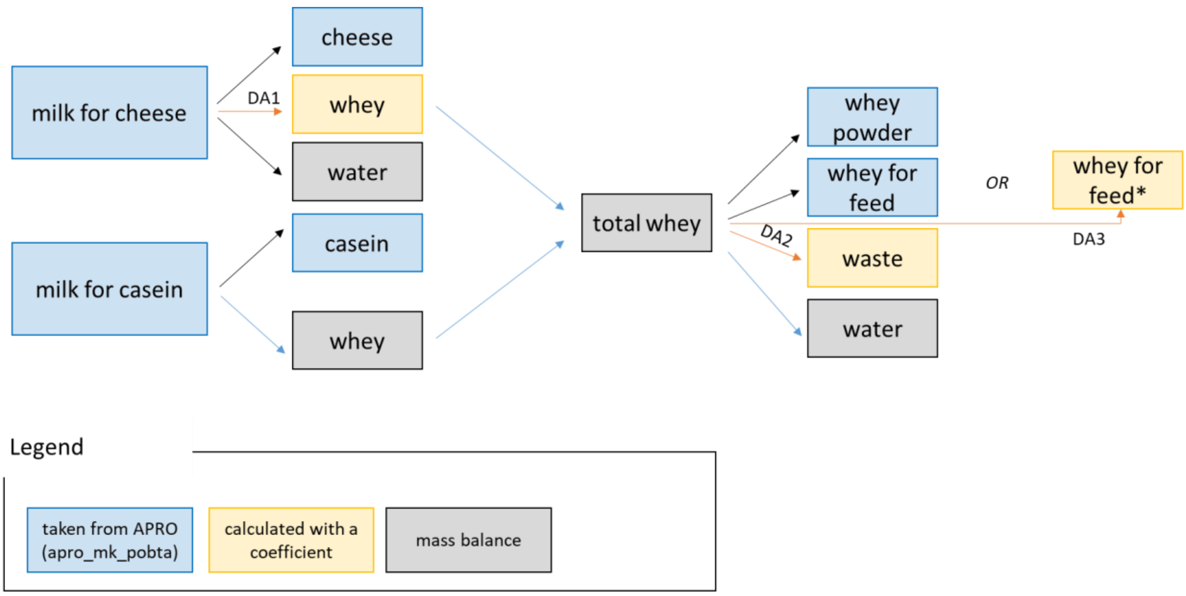

Figure 18. Modelling of milk into cheese and casein products. *in case of missing data in APRO database the whey for feed is calculated from the total whey available by applying a coefficient (DA3).

Regarding the dairy products produced directly at farm level, the following information is extracted from the relevant Eurostat database (apro_mk_farm): the amount of drinking milk, butter, cheese and cream produced on farm. No further assessment is done of waste and by-products generated in the processing of these products, as it is assumed that most residues from these activities would be used as animal feed and they would already be accounted for inside the amount of animal feed extracted from the FBS/CBS, by means of equation 11.

The amount of dairy products entering the distribution phase is derived as the sum of dairy products produced (by dairies and on farm) and net trade of dairy products, extracted from Prodcom database (see Annex 2, Table 2.5).

When using the APRO database, several issues arose due to data gaps. The data gap filling techniques adopted are presented in detail in Section 2.3.

2.2.2.7 Eggs

The amount of eggs leaving primary production is calculated as reported in section 2.2.1 (equation 14). As illustrated by Figure 19, a part of this quantity is distributed fresh while the rest enters the manufacturing stage where it is transformed into processed eggs products (liquid egg, dried egg, and frozen egg) to be sold as such or further used by the food processing industry. The coefficients used to perform this estimation (EG1 and EG2) are provided in Table A1.2 of Annex 1 and derived from (Agra CEAS Consulting, 2008).

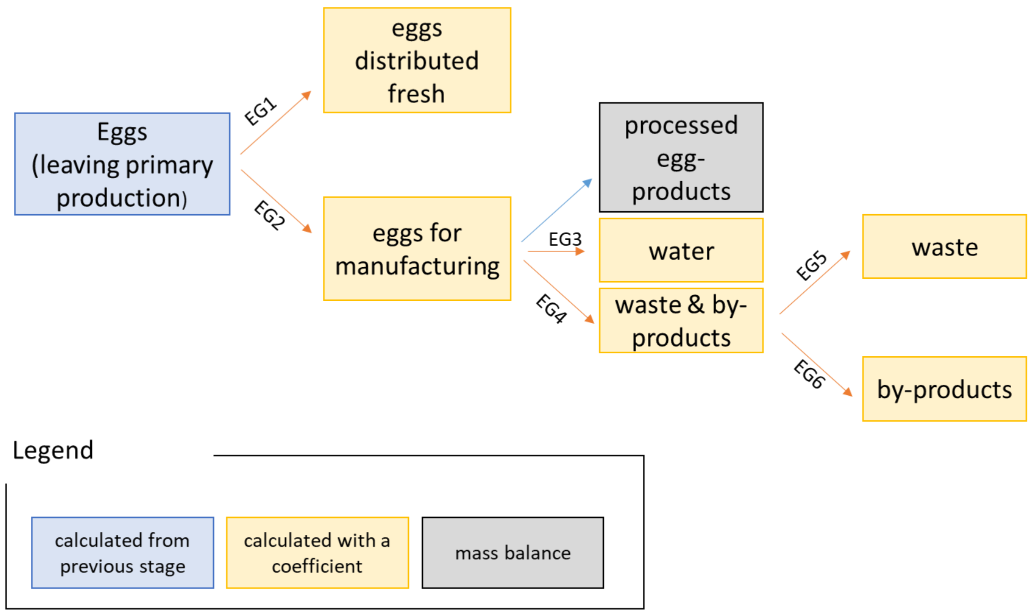

Figure 19. Modelling of processing and manufacturing stage for eggs.

From the quantity entering the manufacturing stage, water evaporated and waste and by-products are calculated by means of coefficients extracted from (Kemna et al., 2017; Rimestad et al., 2017; ROLAND, 1988) (reported in Annex 1, Table A1.2). Hence, the total weight of processed eggs products is calculated through a mass balance, by subtracting from the amount of eggs entering the processing stage, waste, by-products and water leaving the system. This quantity is added to the amount of eggs distributed fresh and to the net trade of processed egg products (extracted from Prodcom, see Annex 2, Table 2.5) to calculate the total amount of eggs and egg products entering the distribution phase (as illustrated in Figure 2).

This is a coarse approximation of what happens in reality, as both fresh and processed egg products are used by the food industry to be incorporated in other processed products (e.g. pasta, biscuits, cakes). Therefore, the flow of egg and egg products entering the distribution phase as such is expected to be lower than the quantity estimated by the model. Nevertheless, due to a lack of data needed to capture the full complexity of this part of the food supply chain, and as this is not expected to affect significantly the estimation of food waste amounts, this approximation was deemed appropriate.

2.2.2.8 Meat

The modelling of the processing stage of meat is divided into two sub-stages: slaughtering (presented in Figure 20) and further processing (presented in Figure 21 for all species excluded poultry and Figure 22 for poultry). An overview of the full model of the meat food group is provided in Figure 3. The amount of meat entering the slaughtering stage (live weight) is calculated as explained in Section 2.2.1 (equation 18). From this quantity, the waste and by products generated at slaughtering are calculated by means of coefficients that provide the share of Category 1 (CAT1), Category 2 (CAT2) and Category 3 (CAT3) residues generated when slaughtering bovine, sheep, pigs and poultry, classified according the level of public and animal health risk and contaminations. Category 1 includes high risk level materials, Category 2 medium level risk material and Category 3 low level of risk (Regulation (EC) No 1069/2009 of the European Parliament and of the Council; European Commission Regulation (EU) No 142/2011). This categorization establishes the reutilization opportunities according to the health risk, reported in Regulation (EC) 1069/2009. Coefficients to derive CAT1, CAT2 and CAT3 materials were taken from (Laraia et al., 2001), and reported in Annex 1, Table A1.2.

Then, wasted amounts (i.e. incinerated) and by-products (i.e. residues used for the productions of biodiesel, fertilizers, feed, pet food) are derived using the coefficients reported in Annex 1, retrieved from (Ferronato et al., 2020).

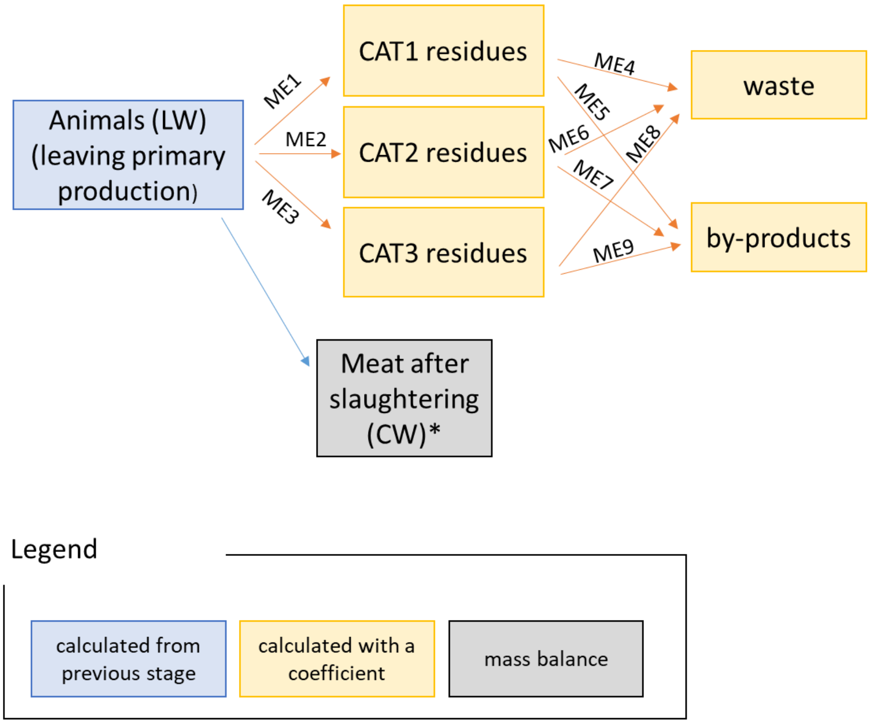

Figure 20. Modelling of meat, all species, slaughtering sub-stage. *This is not linked to the following step (processing) as the amount of meat after slaughtering is taken directly from CBS/FBS. CW: carcass weight, LW: live weight.

The meat available after slaughtering in each country is calculated from FAOSTAT FBS/CBS and FAOSTAT trade, by means of equation 22 for the following meat products: bovine meat, poultry, pig meat, animal fats, edible offals, other meat (see Annex 2 Table A2.2 for the list of items extracted from the two databases). At this point, meat is expressed in terms of carcass weight[10].

$$\text{Meat (CW) after slaughtering} = P + S + I - E - \text{Other uses*} \qquad [22]$$

[10] The definition of carcass weight varies across species. For more details see: https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Carcass_weight

Where:

P = production (taken from CBS/FBS)

S = stock variation (taken from CBS/FBS)

I = imports (taken from FAO trade)

E = exports (taken from FAO trade)

The term Other uses* is calculated from the value of "Other uses" reported in the FBS/CBS as explained in Section 2.2.1, following equations [3], [10] and [13].

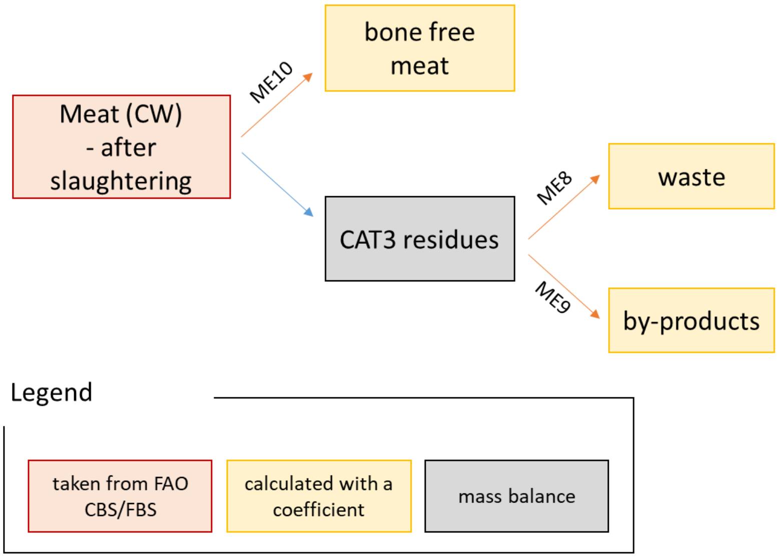

Figure 21. Modelling of the processing stage for bovine, sheep and goat, and pork meat.

For all species excluded poultry, as illustrated in Figure 21, the bone-free-meat (BFM) equivalent is calculated, by multiplying the amount of meat available after slaughtering with a coefficient reporting the ratio between BFM and carcass weight for the relative species (ME10). To assign a coefficient to the item "other meat", the coefficient for sheep was used as a proxy. Instead, for both edible offals and animal fats, a coefficient equal to 1 was used (i.e. assuming the amounts reported in the CBS of these two items are entirely edible). These coefficients are taken from Russo et al. (2013) and reported in Annex 1, table A1.2.

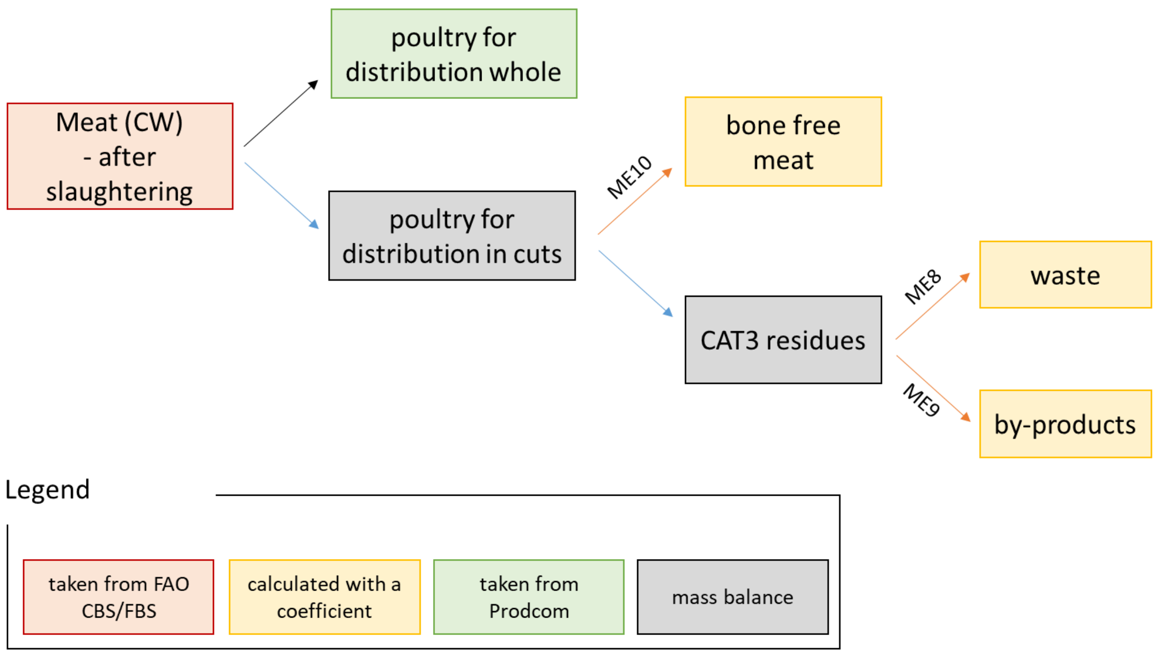

Figure 22. Modelling of the processing stage for poultry meat.

In the case of poultry, an additional step is necessary to account for the portion of poultry which is distributed and sold as whole (and therefore should not be converted into BFM at this stage). The amount of poultry distributed as whole is taken from Prodcom (see Annex 2, Table 2.5), and the amount distributed in cuts is calculated by means of mass balance. The latter, is then converted into BFM using the coefficient ME10 specific for poultry, retrieved from Russo et al. (2013).

The residues generated at this stage are then obtained by subtracting from the meat expressed in carcass weight the resulting bone-free-meat. All of these residues are assumed to be CAT3, according to (Ferronato et al., 2020). The same coefficients presented for the other species are used to derive the amount of waste and by-products generated.

Finally, the total meat products entering the distribution stage (as illustrated in Figure 3) are calculated as the sum of: BFM equivalent for each meat product considered (including the portion of poultry meat distributed in cuts), poultry distributed as whole, and net trade of processed meat products (taken from COMEXT, see Annex 2, Table A2.8).

2.2.2.9 Fish

As mentioned in Section 2.2.1.3, it is not possible to estimate the flow of fish entering the processing stage based on statistical data available. Therefore, unlike the other food groups, the amount of waste and by-products generated at this stage is not calculated from the amount of fish entering this stage, but through an alternative approach here presented, and the P&M stage is modelled in isolation from the remaining stages (as shown in Figure 4).

Firstly, the produced amount of total fish products is taken from EUMOFA for the EU and each MS (see Annex 2, Table 2.9).

According to Jackson & Newton (2016), the EU fish processing activities taking place between 2009 and 2013 generated on average 0.67 Mt of food waste and 1.5 Mt of fish meal and fish oil (classified as by-products) per year. In the same period of time, the average amount of processed fish products produced in the EU was equal to 3.74 Mt. Based on this, two coefficients were calculated and are provided in Annex 1, Table A1.2. The first, FI1, is equal to the ratio between food waste generated and the amount of processed fish products produced in the EU, while the second, FI2, is equal to the ratio between by-products generated and the amount of processed fish products produced in the EU. These two coefficients are then used to calculate food waste and by-products generated by each MS based on the produced amount of fish products, as presented in Figure 23.

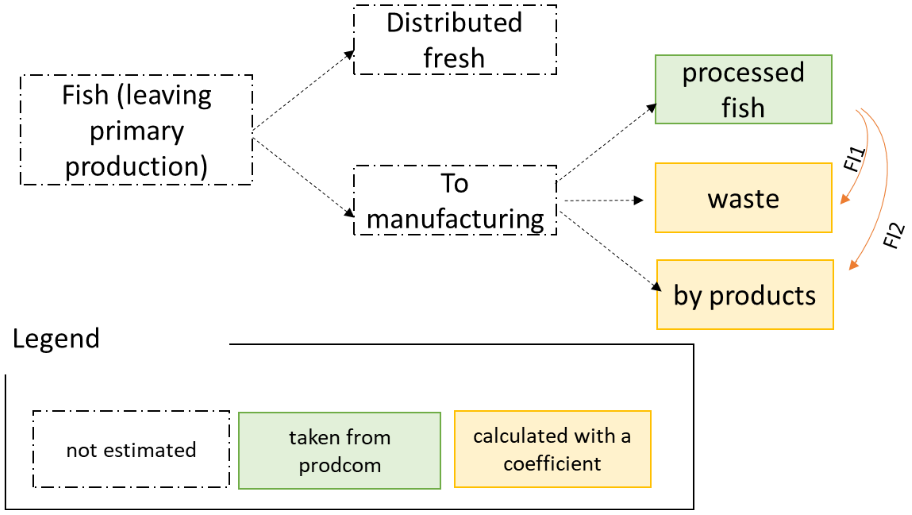

Figure 23. Modelling of the P&M stage of fish.

The amount of fish entering the distribution phase is calculated as detailed in section 2.2.1.3 based on FAOSTAT data and expressed in live weight equivalent. The consequence of this assumption is that food waste generated from the distribution and consumption stage of fish might be overestimated as the mass of fish entering these stages in the model is larger than the real mass of fish. This is because part of the inedible components that are discarded at the processing stage (and accounted for as food waste and by-products at this stage) would be considered to enter the distribution phase due to the methodological choice of assessing the flow of fish in live weight equivalent.

2.2.3 Retail and distribution (R&D), consumption in household, and consumption in food services

The modelling of the remaining three stages of the supply chain (i.e. distribution and retail, consumption in household, and consumption in food services) is illustrated by Figure 24.

The amount of food entering the R&D stage is calculated for each food group, as presented in Section 2.2.2. Then, by means of product-specific food waste coefficients, food waste generated at this stage is calculated, and the food entering the consumption stage is obtained through a mass balance.

This quantity is then divided between the food consumed in household and in food services, by means of coefficients. When possible, such coefficients are product and/or country specific, in all other cases, average coefficients are used (coefficients identified with RDC02 – household- and RDC03 – food services - in Annex 1, Table A1.3). Food waste generated at consumption stage is then calculated using food waste coefficients that are specific of the product and of the FSC stage (different coefficients are used for household and food services). The eaten amount of each food group is then calculated by means of mass balances, by subtracting food waste generated from the quantities entering the consumption stage.

Furthermore, coefficients providing the edible waste are applied to derive the amount of food waste that is edible, and by means of mass balances the inedible food waste. All coefficients used, taken from the food waste literature, are provided in Annex 1, Table A1.3.

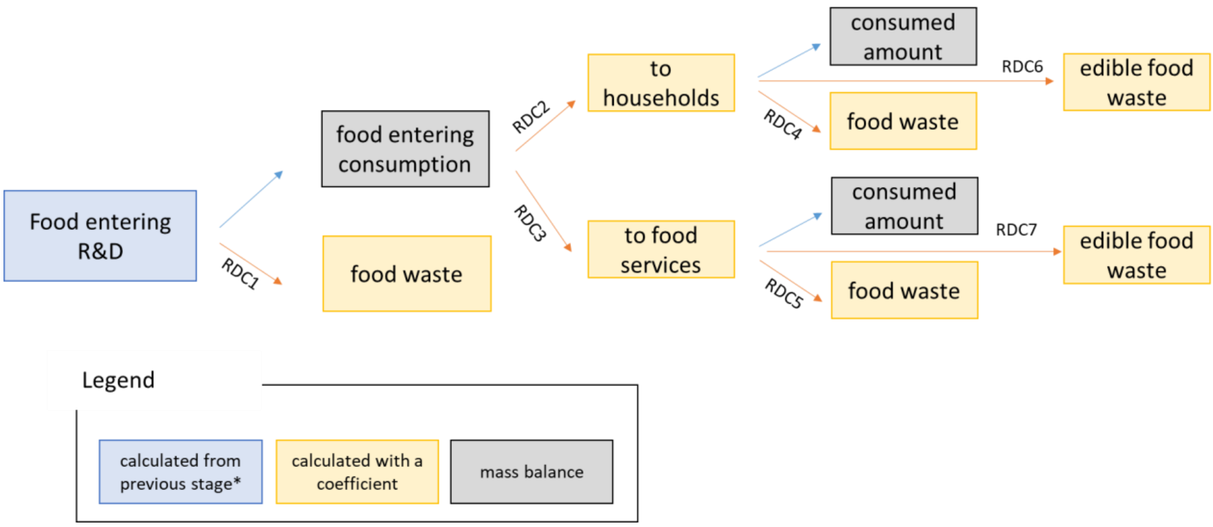

Figure 24. Modelling of retail and distribution and consumption stages. *This calculation varies across food groups, for details see Section 2.2.2.

2.3 Data gap filling procedures and cut-offs

In the development of the model, issues related to several food groups arose due to data gaps in the data sources consulted. Hereunder, the main issues are reported.

Prodcom database: Data gaps in production and trade data.

The list of products for which production and trade data is extracted from the Prodcom database in the model, is available in Annex 2, Table A2.5.

When extracting production and trade data from the Prodcom database at Member State level for these products, data gaps were found in some cases (for instance in the case of fruit juices). Therefore, alternative data sources were investigated to use in case of data gaps. To this end, data was taken from FAO trade when a correspondence could be made between the product classification in Prodcom and FAO trade (this was the case for fruit juices, dried fruit, canned tomatoes and preserved mushrooms). The mapping between the two classifications is provided in Annex 2, Table A2.11.

In the case of processed meat products, due to several data gaps in trade information provided by the Prodcom database, it was decided to use instead COMEXT database at a higher level of aggregation (less affected by confidentiality issues). Instead, as no alternative data sources were found to retrieve the production quantities of processed products presented in table A2.5, the assumption made in case of data gaps in Prodcom was that the production was equal to zero.

In the case of potatoes, due to several data gaps, an alternative modelling approach at processing and manufacturing was adopted, not relying on the Prodcom database at this stage. In the calculation of potatoes (fresh and processed) entering the distribution phase, the amount of processed potato product produced was estimated using coefficients, and the Prodcom database was only used to derive the net trade of processed potato products (see Section 2.2.2 for more details).

Every time a data gap is found in the Prodcom database, and no alternative source of data is available, missing values are replaced by zeros in the model. This presents two main consequences.

1) When data from the Prodcom database is affecting the calculation of food waste at processing (which is the case for whole poultry, beer and processed olives), missing data might cause an under/overestimation of food waste (specifically food waste at P&M would be overestimated in case of missing production data of whole poultry and processed olives, and underestimated in case of missing production data of beer).

2) In all the other cases, data from Prodcom is affecting only the amount of food estimated from the distribution phase onwards. In these cases, there are three possibilities:

    a. if both production and trade data are missing, the amounts entering the distribution phase will be zero, hence, it will be underestimated;

    b. if production data are missing, and trade data are available, the amounts entering the distribution phase will be underestimated, and the value will be positive in case the country is a net importer and negative in case the country is a net exporter of that product;

    c. if production data are available and trade data are missing, in case the country is a net importer the amount entering the distribution phase will be underestimated, in case the country is a net exporter it will be overestimated.

    When this calculation let to a negative value (case b with net exporting countries), a cut-off was applied and the value was set equal to zero.

An under/overestimation of the amounts of food entering the distribution phase translates into an under/overestimation of: food waste generated at distribution, food waste generated at (household and food service) consumption, and eaten amounts.

APRO milk database

Another database affected by several data gaps is the APRO_MK database, used to model the processing and manufacturing stage of dairy products. In this case, as no alternative source was found, and as this source of data was necessary to estimate waste and by-products generated by processing dairy products, a specific data-gap-filling procedure was developed:

- In case of missing values of utilization of whole milk for the production of cheese, these quantities were estimated from the amounts of cheese obtained by multiplying them by a coefficient equal to 5.4.
- In case of missing values of utilization of skimmed milk for the production of cheese, these quantities were estimated from the amounts of cheese obtained by multiplying them by a coefficient equal to 1.8.
- In case of missing values of utilization of skimmed milk for the production of caseins, these quantities were estimated from the amounts of caseins obtained by multiplying them by a coefficient equal to 32.9.

These three coefficients were obtained from the relationship between input milk and produced products at EU level, where no data gaps were found.

- In case of missing data on the amounts of whey products used for feed, these were estimated as 24% of the amount of whey quantified from the production of cheese and caseins (as illustrated in Figure 18).
- In case of missing data on "raw milk delivered to dairies", this value was taken from the amount of milk leaving primary production, calculated at the previous step.

To fill-in data gaps on the amounts of dairy products produced, the following approach was adopted:

1) The total EU production of dairy products for the year 2011 was calculated as the sum of the quantities of dairy products produced in all the MSs for which data was available
2) the total amount of raw milk delivered to dairies in the EU for the year 2011 was calculated as the sum of this amount for all MSs for which data was available

3) the ratio between the quantity of each dairy product produced in the EU and the total raw milk delivered to dairies was calculated
4) all data gaps were filled by applying the same ratio to the amount of raw milk delivered to dairies in each country.

To give an example, no information is provided in the APRO database of the amount of cheese produced in Ireland in 2011. At EU level the total amount of milk delivered to dairies is 139.9 Mt and the total amount of cheese produced is 8.8 Mt. It is important to highlight that the latter quantity is an underestimation, as three countries (i.e. Ireland, Malta and Luxembourg) did not report this value. From these two values it is possible to calculate that the ratio between the cheese produced in the EU and the raw milk delivered to dairies is 0.06. Therefore, the amount of cheese produced in Ireland is calculated by multiplying by this coefficient (0.06) the amount of raw milk delivered to dairies (5.5 Mt), yielding a value of 0.35 Mt.

2.4 Food waste estimation based on waste statistics

In this approach, food waste was quantified for the different stages of the food supply chain for specific NACE (Nomenclature statistique des Activités économiques dans la Communauté Européenne) activities (those expected to generate food waste). The correspondence between the NACE activities considered and the stages of the food supply chain is the following:

- primary production corresponds to NACE activity A: Agriculture, forestry and fishing;
- processing and manufacturing corresponds to NACE activities C10-C12: Manufacture of food products; beverages and tobacco products;
- retail and food services correspond to NACE activities G-U_X_G4677: Services (except wholesale of waste and scrap);
- households correspond to NACE activity EP_HH: Households.

The main underlying data source used in this type of studies are the EU waste statistics, reported by each Member State and collected by Eurostat based on EU Commission regulation on waste statistics (No. 2150/2002) (European Commission, 2012). The waste statistics were reported in "Generation of waste by waste category, hazard and NACE Rev. 2 activity" (Eurostat, 2014). Data are provided for all economic sectors (following the NACE classification of activities) and for households.
As the waste statistics do not explicitly report food waste, the following European Waste Catalogue for Statistics (EWC-Stat) codes potentially containing food waste were identified in Eurostat (2014):

- Animal and mixed food waste (EWC-Stat W091);
- Vegetal waste (EWC-Stat W092);
- Household and similar wastes (EWC-Stat W101).

The calculations of the total amount of food waste per country is obtained by means of equation 1.

$$FW_{MS} = \sum_i (\beta_{091} * W_{091,\, i} + \beta_{092} * W_{092,\, i} + \beta_{101} * W_{101,\, i}) \qquad [23]$$

for $i = NACE\ activities\ A, C10 - C12, G - U_{X_{G4677}}, EP\_HH$

Where:

FW_{MS}	Total amount of food waste in each country (MS)
β_{091}	Coefficient expressing the share of food waste in waste code W091
$W_{091,\, i}$	Waste Amounts reported under waste code W091 by NACE activity i
β_{092}	Coefficient expressing the share of food waste in waste code W092

$W_{092,\,i}$ Waste Amounts reported under waste code W092 by NACE activity i

β_{101} Coefficient expressing the share of food waste in waste code W101

$W_{101,\,i}$ Waste Amounts reported under waste code W101 by NACE activity i

In the model, the coefficient expressing the share of food waste in waste code W091 (β_{091}) is equal to 0.95 whilst the coefficient expressing the share of food waste in waste code W092 (β_{092}) is equal to 0.49. Instead, a coefficient equal to 0.20 was used as a default coefficient for the share of waste in household waste. The share of food waste in waste code W101 (β_{101}) results from 0.25 multiplied by the household waste plus street cleaning residues and waste from markets, all divided by W101. These coefficients were obtained from Eurostat (2020) as share of food waste in the EWC categories based on data reported by MSs. It is important to highlight that these coefficients were determined to be used at EU level and differences in the coefficients are observed at MS level. Country specific coefficients cannot be used due to data confidentiality. Moreover, not all MS have provided information that allowed to calculate country specific coefficients. Therefore, this approach was used to estimate food waste at EU level. It is important to highlight that very likely the coefficients β_{091} and β_{092} would be different depending on the NACE activity under which the waste is reported. However, due to lack of data, coefficients β_{091} and β_{092} are assumed not to vary across NACE activities (i.e. all stages of the food chain).
A comparison between the results of this approach based on waste statistics and the results of the model (based on MFA) presented in this report, is provided in Section 3.3.

3 Food waste estimates

This section presents an overview of the results obtained from the model (version 1.0) (Section 3.1), a plausibility check of the results of the model performed by comparing one of its outputs (i.e. the eaten amount) with food consumption data (Section 3.2), and a comparison between the results obtained with the two methodological approaches presented in this report (Section 3.3). It concludes by providing a discussion of potential refinements of the model, and related data needs (Section 3.5). It is important to highlight that the model is affected by uncertainty mostly related to the data gaps, to the inherent uncertainty of the underlying statistical data used, and to the assumptions made in the modelling stage to overcome missing data on food waste percentages for different MSs. **Therefore, MSs should not use the data provided by this model to replace their quantification, which should be instead done according the delegated act** (European Commission, 2019a).

3.1 Overview of the results obtained

The model, implemented in R[11] (version 4.0.3), produces a range of outputs. For each EU MS, and for the years 2000-2017, it generates:

- Food waste by stage of the FSC and by food group (absolute terms)
- Per capita food waste by food group for the following stages of the FSC: retail and distribution, household consumption, food services consumption
- Food losses, by-products to animal feed and by-products to non-food at primary production (for each food group)
- By-products to animal feed and by-products to non-food at processing and manufacturing (for each food group)
- Consumed amount of each food group at household level
- Consumed amount of each food group at food services level

Beyond providing all the information above in a table (an extract is provided in Annex 3), a number of tables and charts are automatically generated by the model. Some examples are provided below, for the year 2016, and, in some cases, for a selected country. Annex 4 shows the tables and charts generated by the model for each MS for the year 2016.

Table 5 reports the total amounts of food waste estimated for the year 2016, per stage of the supply chain in the MSs. Table 6 shows the per capita amounts of food waste generated at the last three stages of the FSC: retail and distribution, household consumption, food services consumption. According to the model, on average, in 2016 EU citizens wasted between 9 and 19 kg of food at retail level, between 58 and 163 kg at household level and between 13 and 31 at food services level. It should be highlighted that, as most of the food waste coefficients used are the same for all MSs, the variations shown in Table 6 across MSs are mostly related to the quantities and typologies of food entering the retail and distribution phase as estimated by the model.

[11] https://www.R-project.org/

Table 5. Food waste generated (in Kt) in 2016 in EU MSs by stage of the food supply chain

Country	Primary Production	Processing & Manufacturing	Retail & Distribution	Household Consumption	Food services Consumption
Austria	98	205	112	837	175
Belgium	190	338	164	1586	313
Bulgaria	93	101	81	598	121
Croatia	161	162	61	519	105
Cyprus	21	14	10	83	17
Czech Republic	58	167	127	859	190
Denmark	237	159	111	929	176
Estonia	31	21	14	101	22
Finland	80	102	62	420	93
France	1086	2394	755	5465	1101
Germany	665	1305	993	7546	1546
Greece	418	389	120	995	202
Hungary	190	282	117	893	181
Ireland	100	247	60	461	85
Italy	1911	1786	1008	8481	1661
Latvia	56	46	24	190	39
Lithuania	70	56	39	278	60
Luxembourg	2	6	6	47	10
Malta	8	5	5	39	8
Netherlands	641	527	255	1848	378
Poland	678	989	572	4402	889
Portugal	310	374	185	1425	299
Romania	392	638	240	1791	362
Slovakia	27	55	47	315	69
Slovenia	20	23	20	165	30
Spain	2480	2041	825	6629	1360
Sweden	118	121	99	754	167

Table 6. Per capita food waste generation (kg per capita) in 2016 in EU MSs at retail and distribution and consumption stages

Country	Retail & Distribution	Household Consumption	Food services Consumption
Austria	13	96	20
Belgium	15	140	28
Bulgaria	11	84	17
Croatia	15	124	25
Cyprus	12	97	20
Czech Republic	12	81	18
Denmark	19	163	31
Estonia	11	77	16
Finland	11	77	17
France	11	82	17
Germany	12	92	19
Greece	11	92	19
Hungary	12	91	18
Ireland	13	98	18
Italy	17	140	27
Latvia	12	97	20
Lithuania	14	96	21
Luxembourg	10	82	17
Malta	11	89	18
Netherlands	15	109	22
Poland	15	116	23
Portugal	18	138	29
Romania	12	91	18
Slovakia	9	58	13
Slovenia	10	80	15
Spain	18	143	29
Sweden	10	77	17

A visualisation of the food waste generated for each food group per stage of the FSC is provided in Figure 25 for the example of Austria in 2016. This visualisation is particularly useful to identify hotpots across both stages of the FSC and across food groups. It is possible to see that in this case, and in line with Table 5 and with the findings presented in Caldeira et al. (2019b), the stage of the supply chain responsible for most of the food waste is the consumption stage.

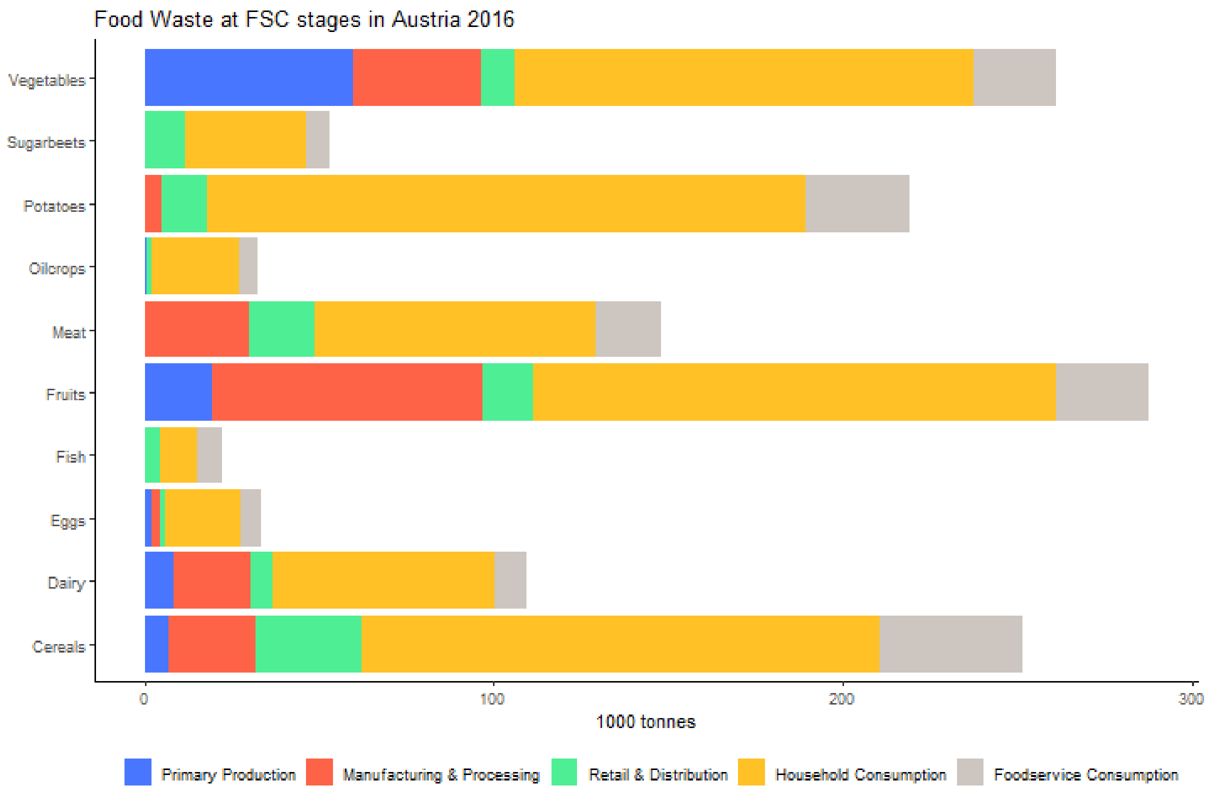

Figure 25. Food waste generated in Austria in 2016, across stages of the food supply chain and food groups

Additionally, Figure 26 shows the generation of food waste through time, as estimated for Austria between 2000 and 2017. The yearly estimations do not present significant variations, which is to be expected as the coefficients used to estimate food waste are static, and changes in food waste generation are only linked to changes in production and trade statistics. Given that the population in Austria did not change significantly during this timeframe, no abrupt changes in food available for distribution is expected between subsequent years, meaning that no abrupt changes are expected in the quantities of food produced and traded (unless a variation in production is compensated with a variation in net trade and vice versa). In some cases, abrupt changes between years can be explained by production and/or trade data no longer being reported for some products (for confidentiality reasons) or vice versa (data no longer confidential being reported from a certain year onwards).

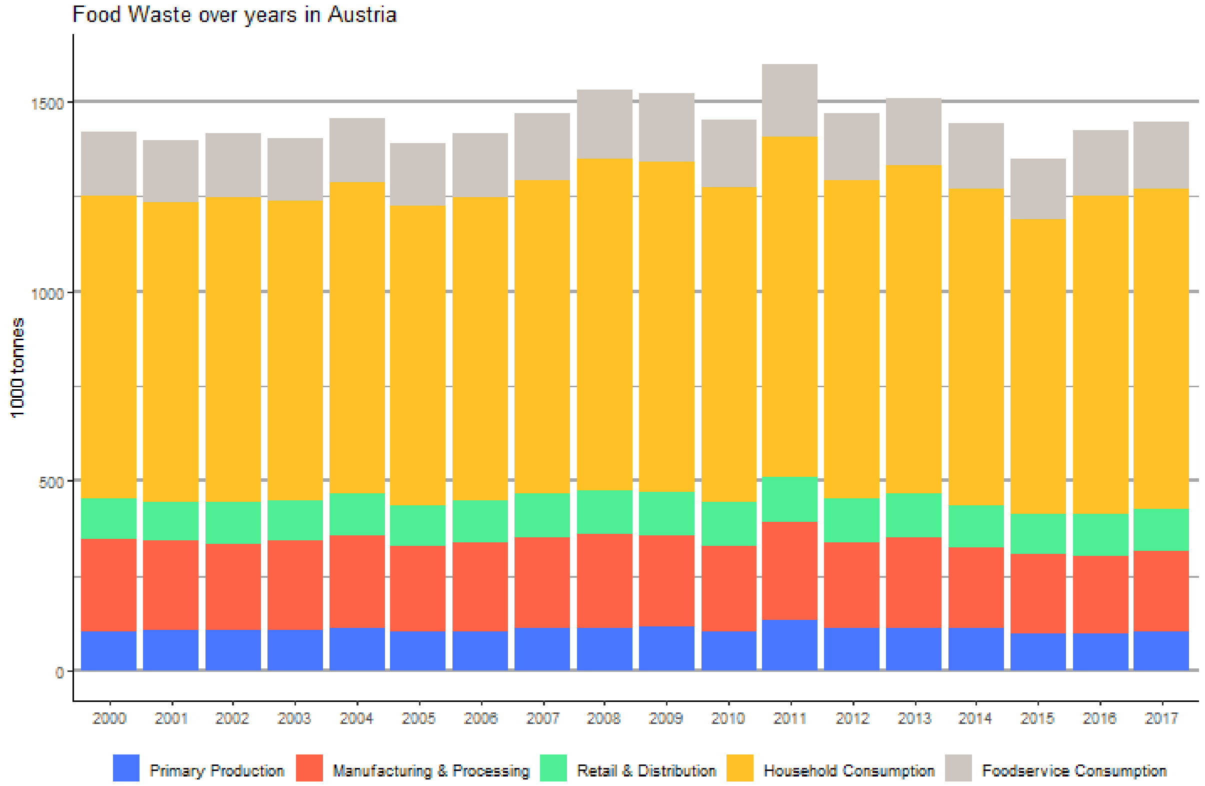

Figure 26. Estimations of food waste generation in Austria in between 2000 and 2017, across stages of the food supply chain

Table 7 presents for the same selection of country and year (Austria, 2016), the food losses at primary production and the amount of each commodity used for animal feed and non-food purposes at primary production and at processing and manufacturing as estimated by the model.

Table 7. Amounts of each commodity used for animal feed and non-food uses at PP and P&M, and food losses generated at PP estimated for Austria in 2016. All quantities are in kt.

	Primary production			Processing & Manufacturing	
Food category	**Animal feed**	**Non-food**	**Food Losses**	**Animal feed**	**Non-food**
Cereals	4095.5	364.9	57.6	940.6	
Fruit		32.1	27.2	94.5	
Vegetables	83.9	8.7	54.7	36.4	
Potatoes	37.3	134.2	59.9	5.8	0.4
Sugar beet	54.6		54.6	262.3	83.7
Oilcrops	110.9	321.9	5.3	305.3	0.1
Meat			9.9		741.8
Fish	25.3			0.0	
Dairy	765.3			252.8	
Eggs					5.3
Total	5172.7	861.8	269.3	1897.7	831.3

Annex 3 provides a table with the full output of the model. Annex 4 provides for the selected year (2016), Figure 25, 26 and Table 7 for all MSs.

3.2 Comparison with food consumption data

One of the outputs of the model is the food consumed at household and food service level. It is important to highlight that the model was not built with the aim of modelling food consumption, as consumption surveys are considered to be more appropriate to this end, as they collect information directly at product level and do not rely on the numerous assumptions that were taken in developing this model on the transformations taking place at the processing and manufacturing stage. Nevertheless, the consumed amounts are a crucial output of the model as they enable to perform a plausibility check of its outputs (i.e. verifying if value is in the expected range given by the hypothesis and preconditions known by the analyst), by comparing them with estimates of food consumption provided by dietary surveys obtained from EFSA (2015). This comparison is performed for the year 2012, as this is the year for which the largest amount of national dietary surveys could be found.

This comparison is affected by some limitations of dietary surveys, namely: dietary surveys are notably underestimating the amounts of food consumed (due to desirability bias people tend to under report their food intake), they are only available for a handful of countries and few years, and are not directly comparable between each other (in some cases weight is referred to cooked food, in others to raw food). Additionally, due to some simplifications of the model at the processing and manufacturing stage (e.g. the fact that the use of sugar or vegetable oils by different food processing industries is not modelled), in some cases, the amount of a certain food type consumed according to the model includes also the amount of that food item consumed in the form of ingredient (e.g. sugar in confectionary), that, instead, would be reported separately in dietary surveys.

With all these limitations in mind, it is interesting to see that, with some exceptions that can be explained using the above presented rationale (e.g. for sugar and vegetable oil consumptions), the amounts consumed according to the model in 2012 in Austria, are within the same order of magnitude from those reported by the nutritional survey from EFSA (2015), as illustrated by Figure 27. A table presenting this comparison for all the countries for which a dietary survey was available is provided in Annex 4. It should be highlighted that, when a dietary survey was not available for the chosen year, the one from the closest year was selected.

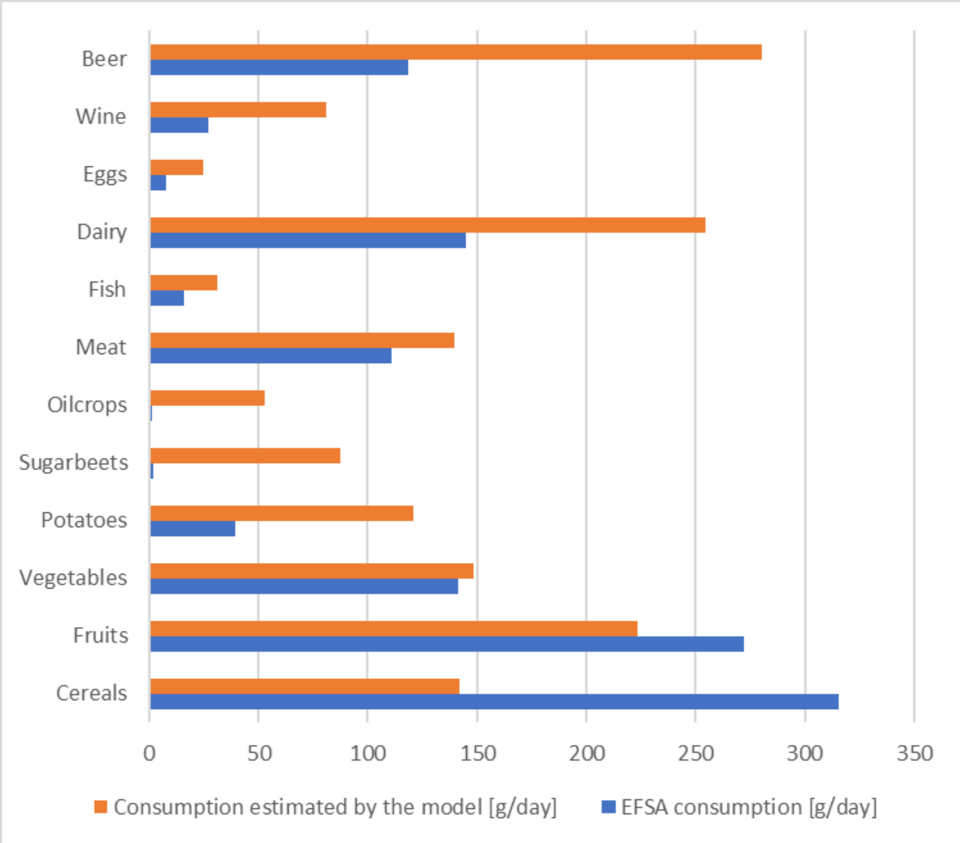

Figure 27. Comparison between amounts of food consumed estimated from the model and consumption amounts reported by EFSA, for Austria in 2012.

In the case of potatoes, the model yielded in four countries (Austria, Belgium, Denmark, Germany) consumed amounts that were more than twice the amount reported in EFSA, (2015). This can be explained considering that, due to a significant lack of statistical data on the production of processed potato products (for confidentiality reasons) and to the lack of statistical data on fresh potatoes distributed, some assumptions had to be taken to estimate the quantity of potatoes used in MSs by the processing industry. As a consequence, this quantity might be underestimated/overestimated causing an overestimation/underestimation of the potatoes distributed fresh. In terms of food waste quantification, this means that in certain countries the waste of potatoes at processing will be underestimated and the waste at consumption overestimated, and in other countries vice versa.

3.3 Comparison with food waste voluntarily reported by Member States

Values of food waste voluntary reported by Luxembourg for the year 2018 were compared with the food waste amounts estimated by the model for the year 2016 (as the underlying data necessary to derive results for the year 2018 was not available) for the same country, as illustrated in Figure 28. It is possible to see that the results of the model are lower than those reported for all stages of the supply chain in the case of Luxembourg. In addition, the model was compared with provisional confidential data provided by another country. In this case, the food waste amounts estimated by the model were higher than those reported from that country at all stages. This suggests that the model is not systematically under- or over-estimating food waste amounts. In addition, the distribution of food waste generation across the stages of the supply chain appears to be well captured by the model.

It is expected that, when more MSs will report the result of food waste measurement exercises, it will be possible to further compare the output of the model and identify potential areas for refinement.

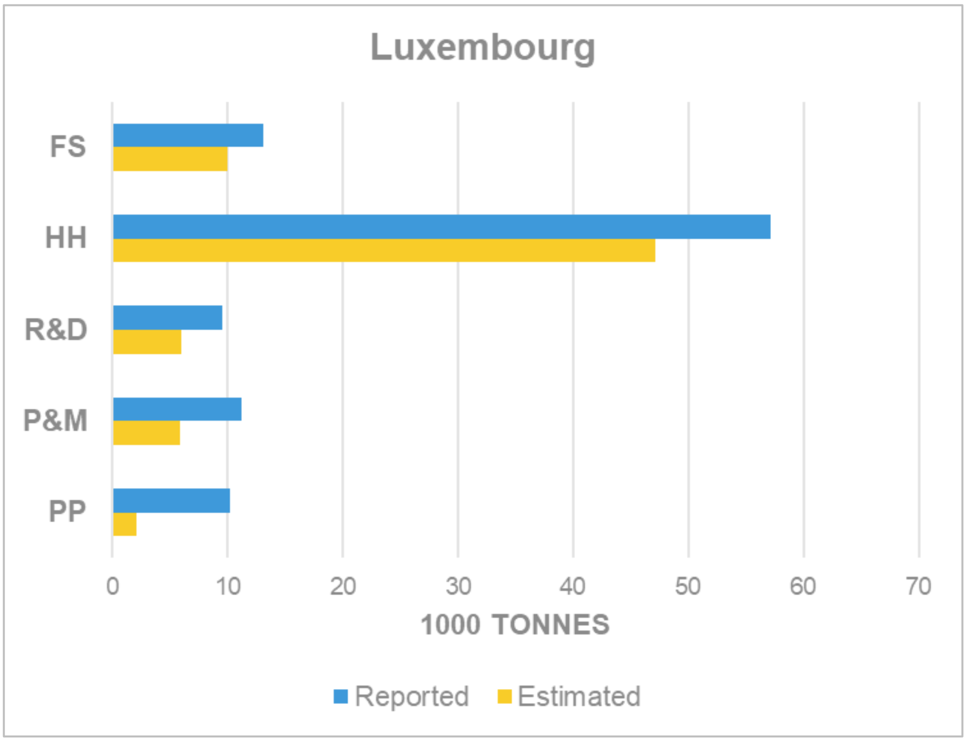

Figure 28. Comparison between food waste values voluntarily reported by Luxembourg (referring to 2018) and food waste values estimated by the model (referring to 2016) across the supply chain. PP: primary production; P&M: Processing and manufacturing; R&D: Retail and distribution; HH: households; FS: food services.

3.4 Comparison with food waste estimates obtained from waste statistics

The approach to estimate food waste from waste statistics was applied at EU27 level rather than at MS level. This is because, as explained in Section 2.4, not all countries reported data that allowed to determine coefficients to be used to estimate food waste from waste statistics, aside the fact that for those that did, data is confidential at MS level.

Table 8 and Figure 29 show the comparison between the results obtained with the two approaches for the estimation of food waste generated in the EU27 in 2016 (the first based on MFA and the second using data from waste statistics). The disaggregation of food waste by stage of the supply chain is based on the correspondence between NACE activities and stages of the FSC, as presented in Section 2.4. As explained in section 2.4, with the second approach it is not possible to distinguish between food services and retail stages (all accounted under NACE activity G-U_X_G4677), therefore these two stages are presented together in Table 8 and with different shades of the same colour in Figure 29 for the results of the first approach. . The disaggregation of the results obtained from the waste statistics per stage of the FSC was obtained assuming that the coefficients expressing the share of food waste in waste codes W91, W92, and W101 do not to vary across NACE activities (i.e. all stages of the food chain). This disaggregation was performed by the JRC and is not present in the plug-in exercise.

It is possible to see that at both household and processing and manufacturing stages, the results differ by less than 20%, while at retail and food services they show a 28% difference. The most significant difference is found at the primary production, where the waste statistics approach estimates a food waste amount that is 72% lower compared to the one estimated by the MFA approach. This can be explained considering that a part of the waste flows generated at primary production are disposed of on-site, e.g. via composting, incineration, anaerobic digestion. Therefore, none of these quantities are reported as waste generated in the waste statistics. Instead, the lower value estimated by the waste statistics approach compared to the MFA approach at household level could be explained considering that the MFA approach estimates food waste generated regardless its destination, this includes also food waste disposed of via the sink, home composted or fed to pets, while the waste statistics approach does not include such destinations. In some countries these destinations resulted to be a significant component of household food waste generation. For instance, according to Flemish Food Supply Chain Platform for Food Loss (2018), 45% of food waste generated in Flemish households between 2016 and 2018 was either composted or fed to pets. Irrespectively of the approach taken, the dominant role of food waste at consumption is observable using both methods (Figure 29).

Table 8. Comparison between the results of food waste generated in the EU27 in 2016 obtained with two modelling approaches presented. *Δ* indicates the relative difference between the results of the second approach and those of the first approach. All values are in Mt.

	Primary Production	**Processing & Manufacturing**	**Retail and Food services**	**Household Consumption**
MFA (first approach)	10.1	12.6	15.8	47.7
Waste statistics (second approach)	2.9	13.3	11.4	39.2
Δ	-72%	6%	-28%	-18%

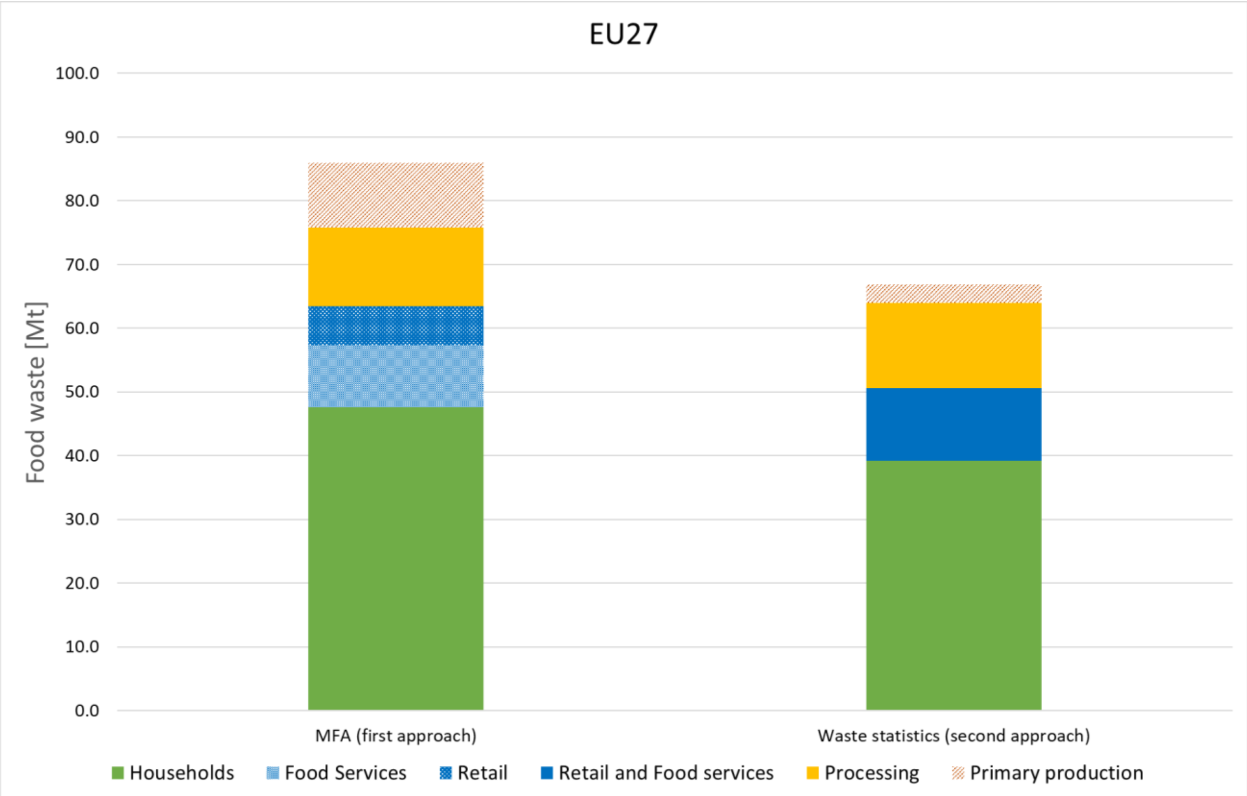

Figure 29. Comparison between the results of food waste generated in the EU27 in 2016 obtained with the two modelling approaches presented.

3.5 Future developments

This section discusses potential future refinements of the model. Some of these would rely of the availability of additional data sources, which could potentially improve the robustness of the model. These are briefly presented in this section.

As presented in Section 2.2.2 data provided by EUPPA (the European Potato Processors' Association) were used to refine the modelling of the processing stage for the potato food group. These data enabled to estimate the amount of raw potatoes entering the manufacturing stage, the amount of processed potato products produced and the amount of waste and by-products generated at this stage. A similar approach could be applied to other food groups, by collecting data from trade associations to refine the modelling of the processing stage and improve the estimation of waste and by-products generated therein.

At primary production, retail and distribution and consumption stages food waste is calculated by means of coefficients taken from the scientific literature and technical reports. In most cases these coefficients were provided at national level and were available only for one or few countries and used as proxies for the remaining MSs. To improve the robustness of the model, and better capture differences in practices and behaviours causing food waste across countries, it would be ideal to collect food waste coefficients at food product level and for each stage of the supply chain, across all MSs. In addition, country-specific and product-specific food losses coefficients could be collected from the literature or through surveys, to improve the modelling of food losses in the model.

A third potential data source to consider for future refinements of the model are market research databases. These databases provide information at national level on products purchased at retail level and by food services in terms of mass. The access to such information could prove beneficial for the model as it could enable to:

- improve the differentiation between the flows of food entering the food service sector and the household sector, by performing this assessment taking into account differences across countries and across different food products
- improve the estimation of the flows of fresh products (e.g. fruit, vegetables, potatoes) entering the distribution phase, as no official statistical data sources are providing this information.

Other potential future refinement of the model could include:

- the expansion of the list of products included in each food group, based on data availability, to ensure a better coverage of the food system
- the use of country specific food waste coefficients by stage of the FSC and food group, collected by means of surveys
- the use of country specific food loss coefficients by food group at primary production, collected by means of surveys
- the disaggregation between edible and inedible food waste at all stages of the FSC
- the inclusion of dynamic food waste coefficients to better capture changes in food waste generation patterns as a result of behavioural changes.

4 Conclusions

This report presents a model developed to quantify food waste at Member State level. Having as a starting point the study developed by Caldeira et al. (2019b) that quantified food waste at EU level, this model was tailored to each Member State. A number of updates were done in the process of deriving the model at MS level to refine the model and to adjust for a different availability of data at MS level. The updates mostly concerned the modelling of the primary production and manufacturing stages. Detailed information on the updated model and on the underlying data used by the model is presented in this report. **The model provides estimates of food waste generated by Member States. These estimates should by no means be used by Member States to replace food waste measurements, but only to perform plausibility checks of the values reported.**

The model quantifies food waste at each stage of the food supply chain - primary production, processing and manufacturing, retail and distribution, and consumption (both in food services and households). The food groups for which food waste is accounted for are: sugar beet, cereals, fruit, vegetables, potatoes, oilseeds, meat, fish, eggs, and dairy. Beyond estimating food waste generation, the model estimates: food losses (i.e. not harvested or ploughed in crops, and animal mortality during transport to slaughterhouse and rejected at slaughter), by-products (i.e. surplus food used as animal feed and for non-food uses), and food consumed, which is compared with the results of nutritional surveys to perform a plausibility check of the results of the model.

Food waste generated by each EU MS for the years 2000 to 2017 was obtained. In general, the yearly estimations do not present significant variations. This is because the coefficients used to estimate food waste are static, and changes in food waste generation are only linked to changes in production and trade statistics. Another limitation associated with the coefficients used in the model is the fact that some of them are not country specific. Currently, very limited country-specific food waste data exists that allows the use of country-specific coefficients. This situation is expected to change in the next years and the model will be constantly updated to make use of the most updated available data.

Results per stage of the food supply chain are useful to identify hotpots across both stages of the FSC and across food groups. For all the countries, the consumption stage was identified as the major contributor to the total amount of food waste for all countries. The contribution of different food groups to the total food waste generated varies from country to country and from stage to stage.

A second approach to quantify food waste based on waste statistics was presented and used to estimate food waste at EU level. The comparison of results (the ones derived from waste statistics with those obtained with the developed model) shows high discrepancies in the amounts obtained for the primary production stage. Such discrepancies are very likely caused by an underreporting of waste collected by waste statistics as waste flows generated in this stage can be treated on site (e.g. incineration of residues for energy production, anaerobic digestion) and might, therefore, not be reported.

Although the model presents some limitations, these have been identified and several points of improvement were defined to be further developed. As abovementioned, a critical point of improvement is the use of country-specific coefficients. Additionally, modelling of food waste and by-products generated at the processing stage can be improved by obtaining data from food processing industries (e.g. via manufacturing associations). Another point worth to explore is the possibility of using dynamic food waste coefficients to capture changes in food waste generation patterns in result of behaviour changes.

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List of abbreviations

BFM	Bone free meat
CBS	Commodity balance sheet
CW	Carcass weight
DG	Directorate General
DSQ	Domestic supply quantity
EC	European Commission
EU	European Union
EUMOFA	European Market Observatory for Fisheries and Aquaculture Products
EUPPA	European Potato Processors' Association
FAO	Food and Agriculture Organization
FBS	Food balance sheet
FSC	Food supply chain
FS	Food services
FUSIONS	Food Use for Social Innovation by Optimising Waste Prevention Strategies
HH	Households
JRC	Joint Research Centre
LW	Live weight
LoW	List of wastes
MFA	Material flow analysis
MS	Member State
NACE	Nomenclature statistique des Activités économiques dans la Communauté Européenne
PP	Primary production
P&M	Processing and manufacturing
R&D	Retail and distribution
SDG	Sustainable Development Goal

List of definitions

Bone-free-meat – Weight of meat products ready for human consumption.

By-products - surplus food used as animal feed and for non-food uses.

Carcass weight – Weight of livestock animals after slaughter and removal of certain parts. The definition of carcass weight varies across species. For more details see:https://ec.europa.eu/eurostat/statistics explained/index.php/Glossary:Carcass_weight

Commodity balance sheets – FAOSTAT statistical database providing for a list of commodities their sources of supply (i.e. production, import and stock variation) and utilisation (i.e. export, feed, seeds, other uses, losses, processing, food supply).

Commodity primary equivalent - the amount of primary commodity input that would be required to produce a given amount of derived product output (e.g. the amount of wheat necessary to produce a certain quantity of flour).

Domestic supply quantity – element of the CBS, calculated as production plus imports and stock variation minus exports.

Food – defined in Regulation 178/2002 as *"food as a whole, along the entire food supply chain from production until consumption. Food also includes inedible parts, where those were not separated from the edible parts when the food was produced, such as bones attached to meat destined for human consumption."* Feed, live animals (unless they are prepared for placing on the market for human consumption) and plants prior to harvesting are excluded from the definition of food.

Food balance sheets – as commodity balance sheets but providing additional information (e.g. per capita food supply quantity, protein supply quantity).

Food losses – Food crops left on field and ploughed in, mortality of the animals ready for slaughter, both during transport to slaughterhouse and rejects at slaughterhouse.

Food supply quantity – element of the CBS, calculated as domestic supply quantity minus feed, seeds, losses, processing and other uses.

Food waste – All food (defined according to Regulation 178/2002), including both edible and inedible parts, that has become waste (defined according to Directive 2008/98/EC).

Food waste coefficient – coefficient taken from the scientific and technical literature providing, at a certain stage of the food supply chain, the share of food waste generated of the amount entering that stage of the supply chain.

Live weight equivalent - the live weight of an animal (fish or livestock) needed to produce a given amount of a derived animal product (e.g. fish fillets).

Processed commodity – any food presenting a degree of processing.

Raw commodity – any food in its raw or natural state, presenting no degree of processing.

Side flow - portion of crops ready for harvest/animals ready for slaughter that is either wasted, lost, transformed in animal feed or in other by-products.

Technical coefficient – coefficient taken from the technical literature used to estimate the quantity of the considered flow from the quantity of a related flow (e.g. pomace and pits generated in the production of olive oil from the amount of olives processed).

Waste – defined in Directive 2008/98/EC as "*any substance or object which the holder discards or intends or is required to discard"*.

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Annex 1. Coefficients used in the model and respective data sources

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Annex 3. Food waste estimates resulting from the model version 1.0

Download

Annex 4. Visualisation of the estimates as output of the model version 1.0 for the year 2016 for all MSs

Annex 4

Visualisation of the estimates as output of the model version 1.0 for the year 2016 for all MSs

Food supply chain stages:
PP = Primary Production
P&M = Processing and Manufacturing
R&D = Retail and Distribution
HH Cons = Household consumption
FS Cons = Foodservice consumption

Austria

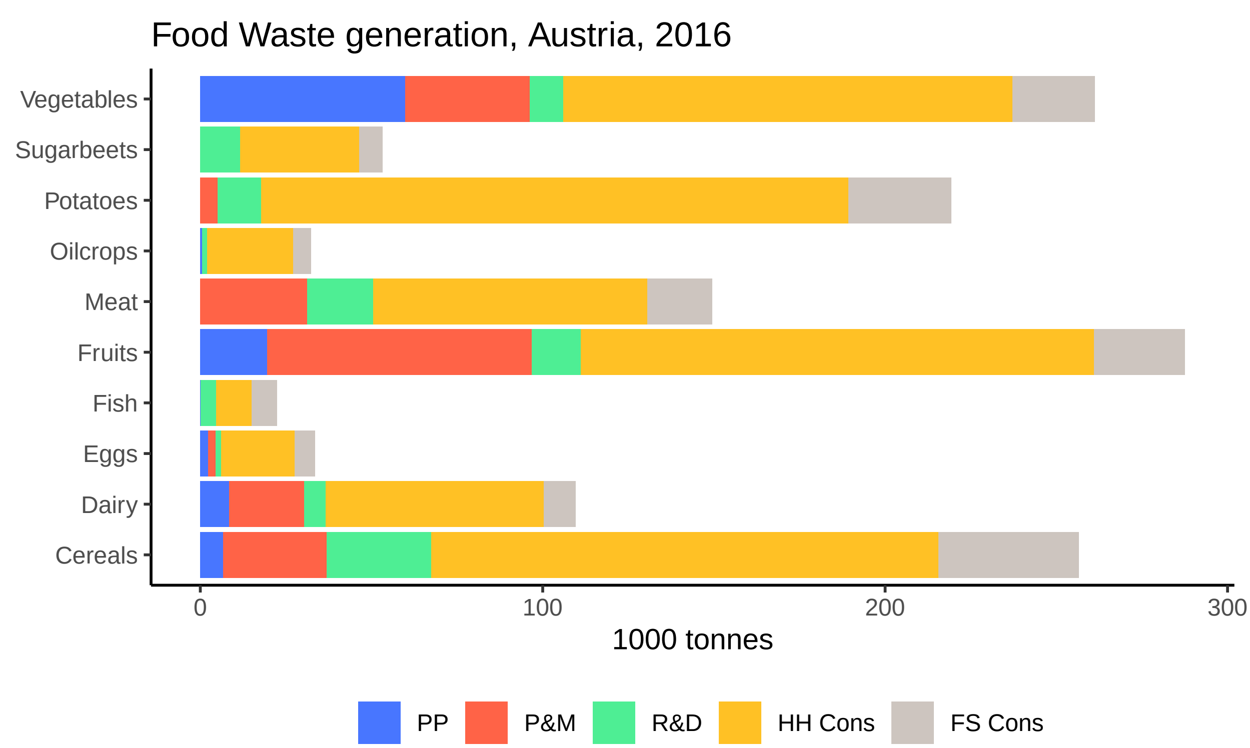


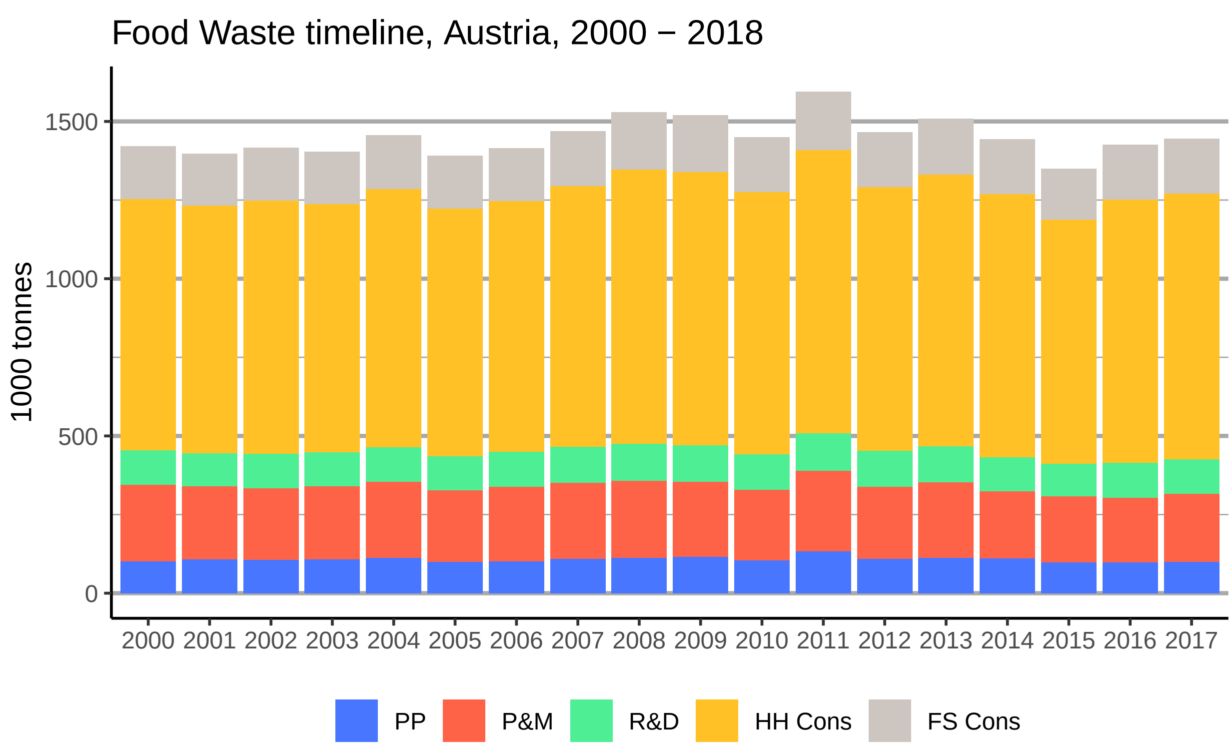
Table 1: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	4095.53	364.88	57.64	940.6	NA
Fruits	NA	32.07	27.19	94.51	NA
Vegetables	83.87	8.66	54.74	36.43	NA

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Potatoes	37.27	134.24	59.88	5.79	0.39
Sugarbeets	54.65	NA	54.65	262.3	83.72
Oilcrops	110.86	321.92	5.26	305.3	0.1
Meat	NA	NA	9.91	NA	741.84
Fish	25.26	NA	NA	0	NA
Dairy	765.29	NA	NA	252.78	NA
Eggs	NA	NA	NA	NA	5.28
Total	5172.73	861.76	269.28	1897.72	831.33

Table 2: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	3.5	17.0	4.7
Fruits	1.6	17.2	3.0
Vegetables	1.1	15.1	2.8
Potatoes	1.5	19.7	3.5
Sugarbeets	1.3	4.0	0.8
Oilcrops	0.2	2.9	0.6
Meat	2.2	9.2	2.2
Fish	0.5	1.2	0.8
Dairy	0.7	7.3	1.1
Eggs	0.2	2.5	0.7
Total	12.8	96.2	20.1



Belgium

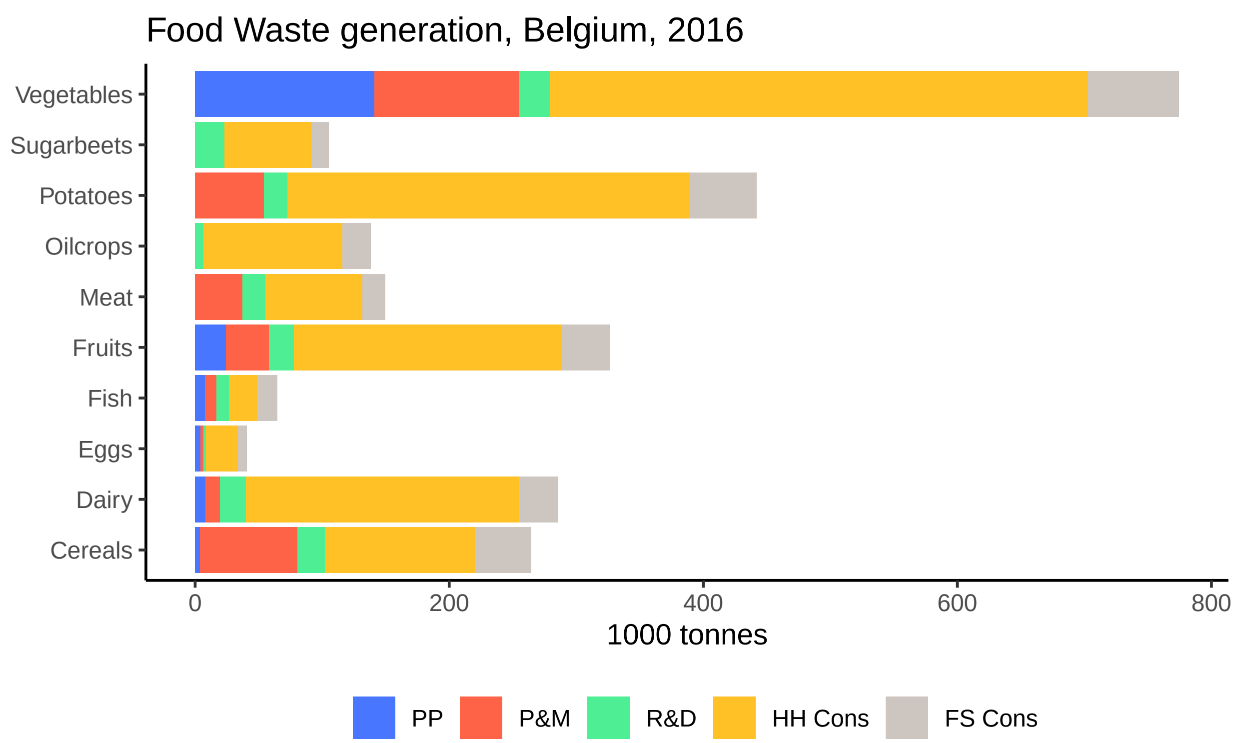


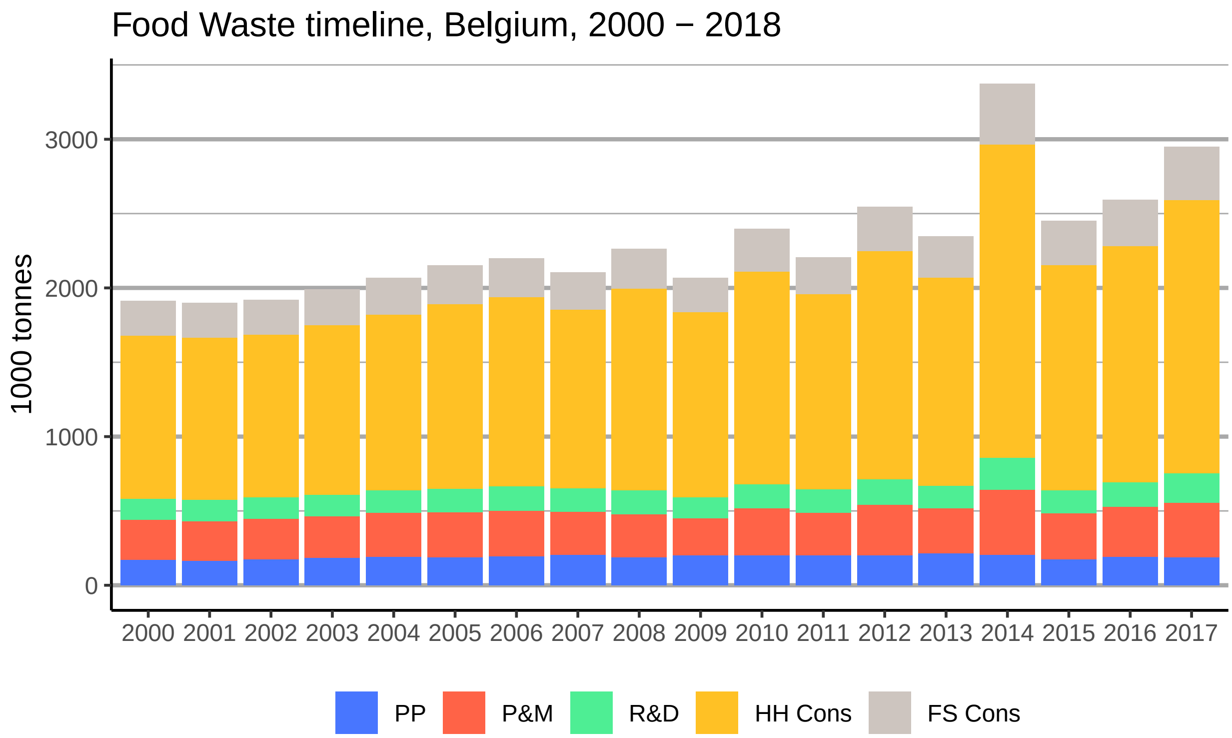
Table 3: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	2967.31	1149.07	27.26	1638.66	NA
Fruits	0.98	49.1	44.63	41.05	NA
Vegetables	496.41	28.3	141.17	113.69	NA
Potatoes	1585.15	116.6	192.53	61.9	4.21
Sugarbeets	62.05	8.5	62.05	217.39	0
Oilcrops	579.69	994.9	0.92	398.76	0
Meat	NA	NA	20.24	NA	1005.96
Fish	20.08	NA	NA	19.96	NA
Dairy	1430.35	6.36	NA	116.85	NA
Eggs	NA	NA	NA	NA	6.02
Total	7142.01	2352.82	488.8	2608.25	1016.18

Table 4: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	1.9	10.4	3.9
Fruits	1.8	18.7	3.3
Vegetables	2.1	37.5	6.3
Potatoes	1.6	28.0	4.6
Sugarbeets	2.0	6.1	1.2

	R&D	HH Cons	FS Cons
Oilcrops	0.6	9.7	2.0
Meat	1.6	6.7	1.6
Fish	0.8	2.0	1.4
Dairy	1.8	19.0	2.7
Eggs	0.2	2.2	0.6
Total	14.5	140.3	27.7



Bulgaria

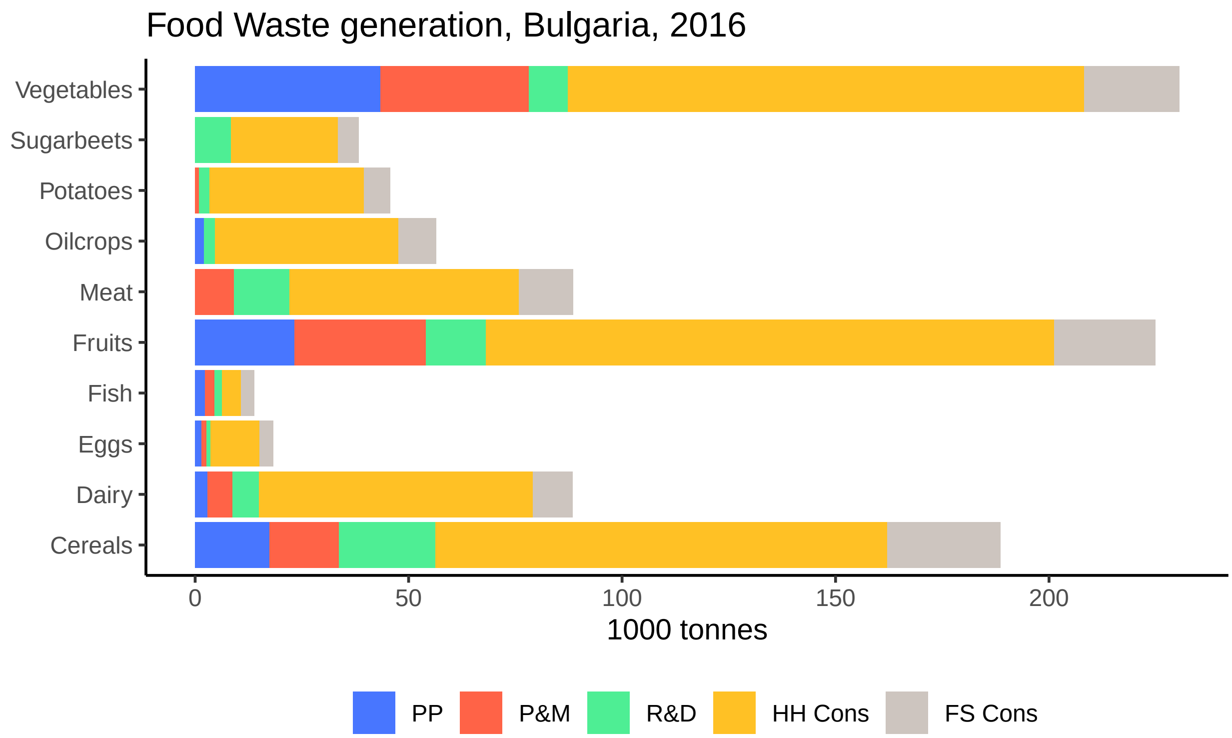


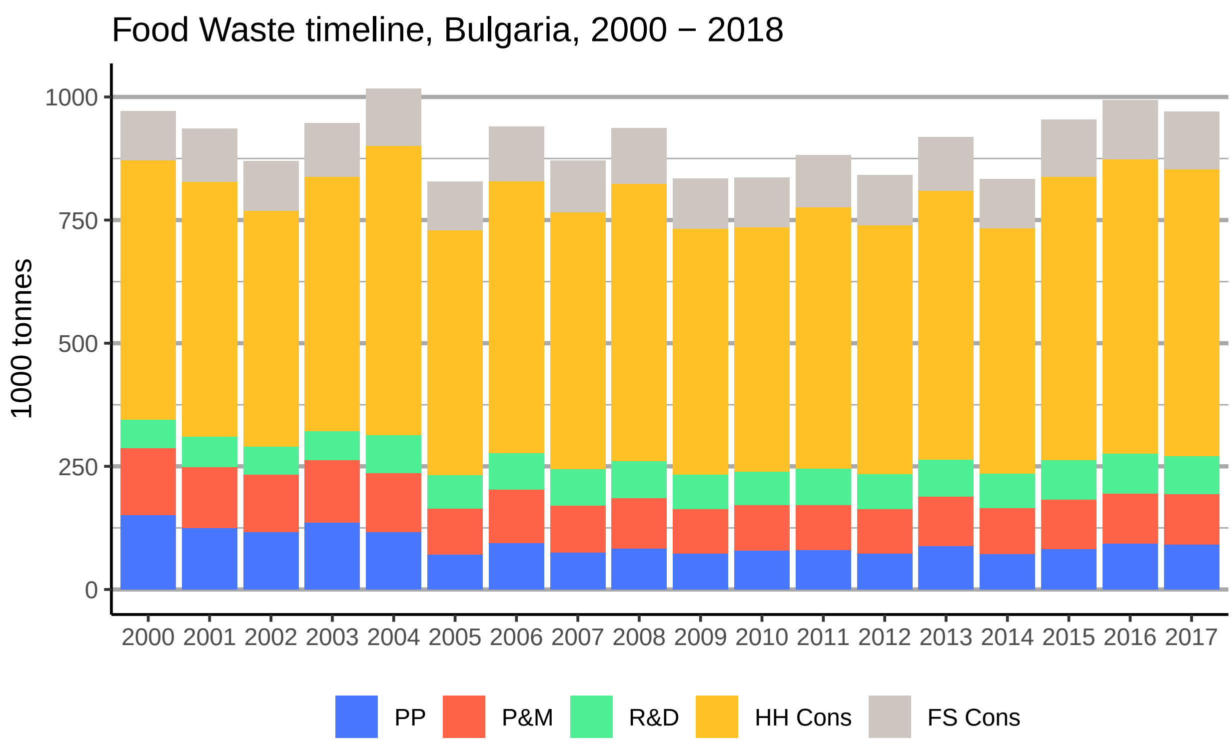
Table 5: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	677.71	305.91	137.42	455.98	NA
Fruits	NA	31.7	24.8	37.76	NA
Vegetables	179.62	11.09	41.88	34.86	NA
Potatoes	6.47	5.57	11.32	1.12	0.08
Sugarbeets	NA	NA	0	0	0
Oilcrops	82.02	47.75	18.72	738.65	0.31
Meat	NA	NA	2.98	NA	246.53
Fish	12.25	NA	NA	4.86	NA
Dairy	172.28	24.7	NA	357	NA
Eggs	NA	NA	NA	NA	2.79
Total	1130.34	426.73	237.13	1630.23	249.71

Table 6: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	3.2	14.8	3.7
Fruits	2.0	18.6	3.3
Vegetables	1.3	16.9	3.1
Potatoes	0.3	5.0	0.9
Sugarbeets	1.2	3.5	0.7

	R&D	HH Cons	FS Cons
Oilcrops	0.4	6.0	1.2
Meat	1.8	7.5	1.8
Fish	0.3	0.6	0.4
Dairy	0.9	9.0	1.3
Eggs	0.1	1.6	0.4
Total	11.3	83.6	16.9



Croatia

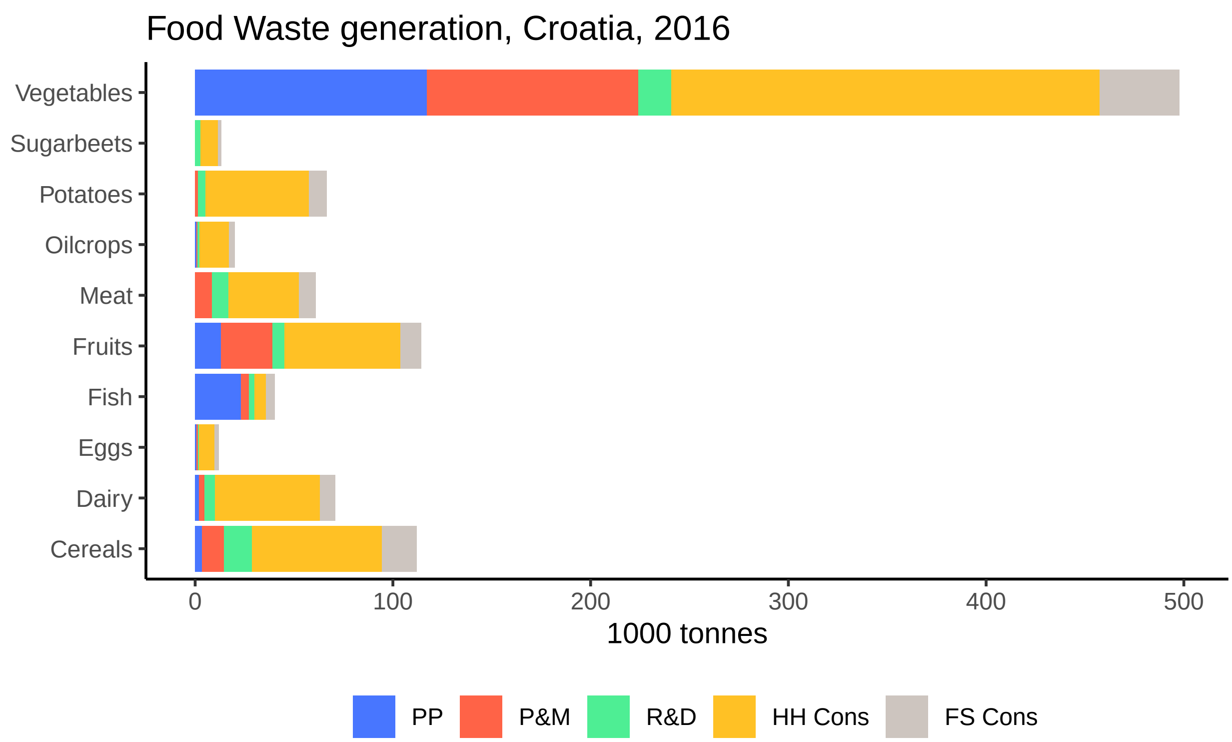


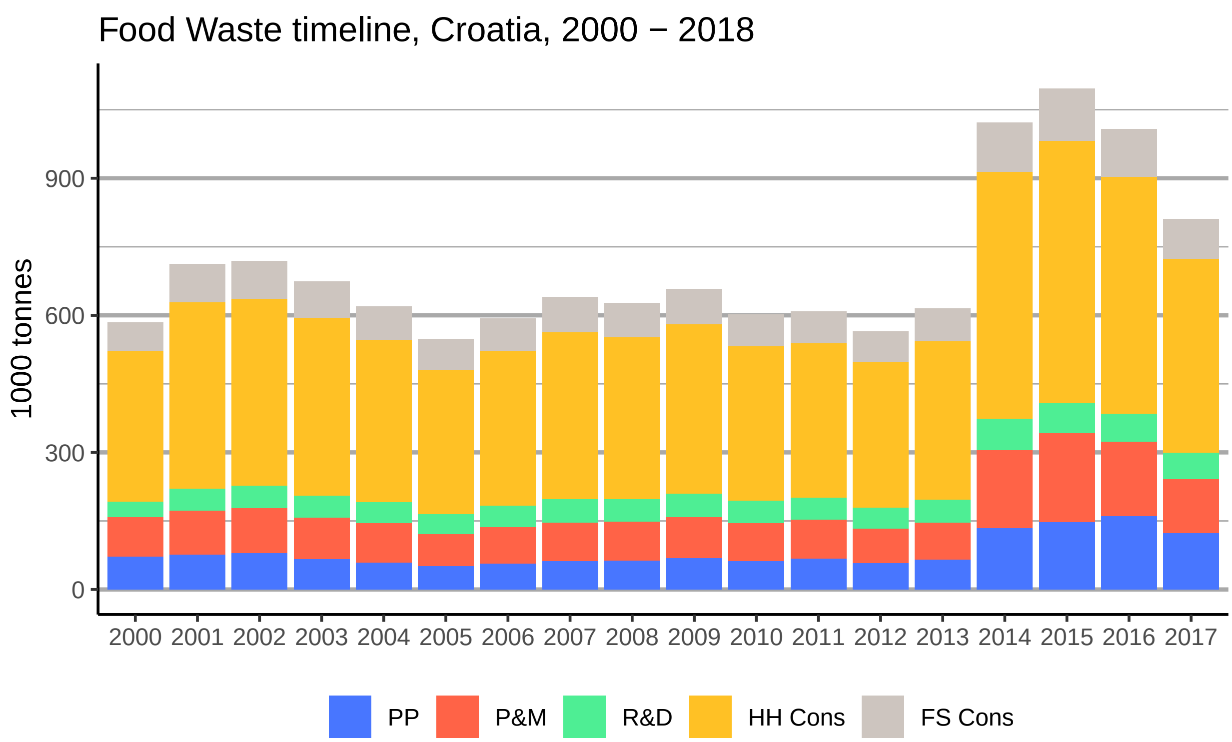
Table 7: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	1983.49	5.76	27.6	266.34	NA
Fruits	NA	19.6	15.97	31.75	NA
Vegetables	127.09	17.62	133.05	106.75	NA
Potatoes	10.88	6.88	16.63	1.71	0.12
Sugarbeets	18.09	NA	18.09	111.4	0
Oilcrops	6.02	73.76	5.97	112.97	9.12
Meat	NA	NA	3.29	NA	235.01
Fish	3.17	NA	NA	9.29	NA
Dairy	16.34	NA	NA	97.47	NA
Eggs	NA	NA	NA	NA	1.83
Total	2165.08	123.61	220.6	737.68	246.08

Table 8: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	3.4	15.7	4.2
Fruits	1.4	14.0	2.5
Vegetables	4.0	51.6	9.6
Potatoes	0.9	12.4	2.2
Sugarbeets	0.7	2.1	0.4

	R&D	HH Cons	FS Cons
Oilcrops	0.2	3.5	0.7
Meat	2.0	8.4	2.0
Fish	0.6	1.4	1.0
Dairy	1.2	12.7	1.8
Eggs	0.1	1.8	0.5
Total	14.6	123.8	25.0



Cyprus

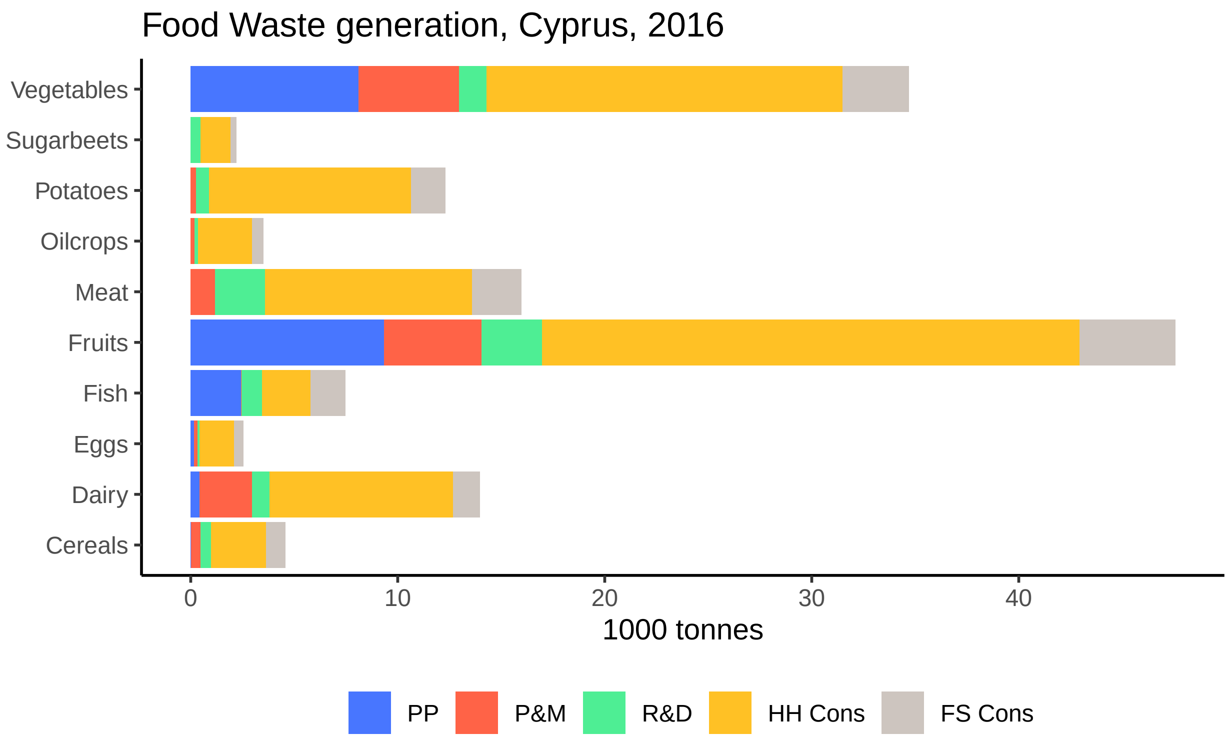


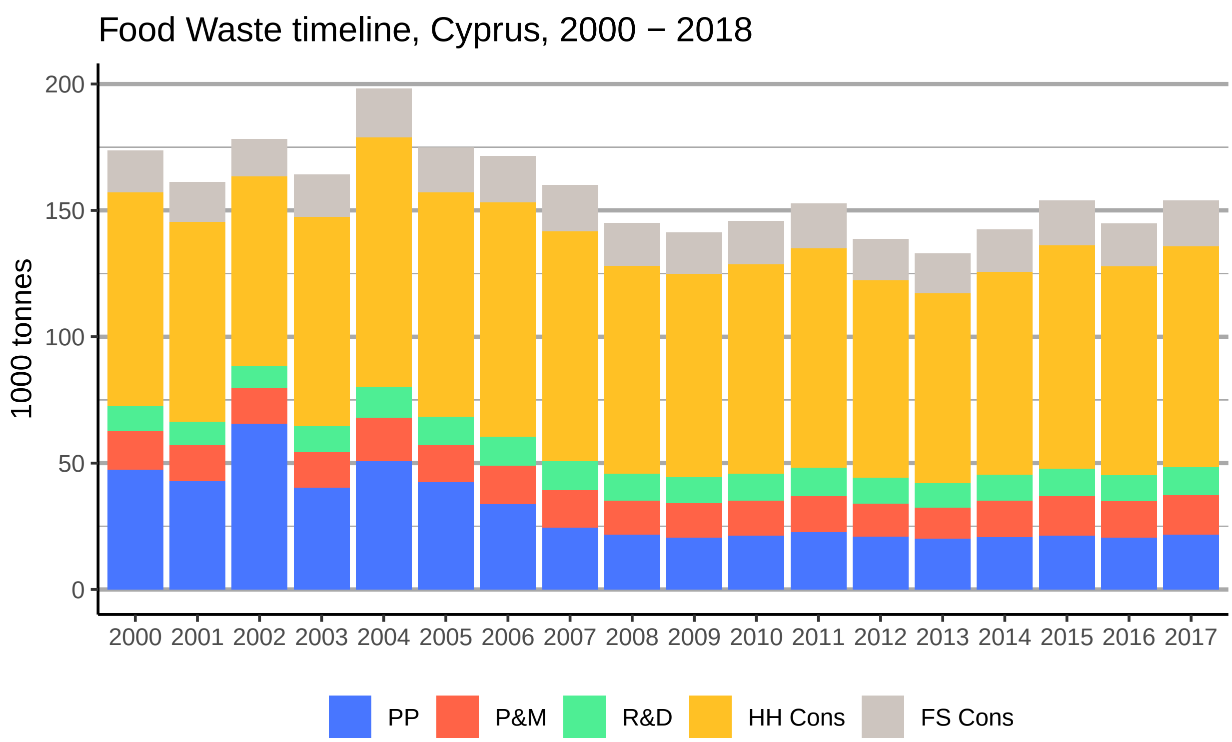
Table 9: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	386.98	20.23	0.11	19.17	NA
Fruits	NA	11.19	7.12	5.73	NA
Vegetables	11.2	2.46	8.23	4.84	NA
Potatoes	4.25	3.07	9.22	0.29	0.02
Sugarbeets	NA	NA	0	0	0.92
Oilcrops	1.77	0.01	0	0.3	3.11
Meat	NA	NA	0.82	NA	64.2
Fish	7.02	NA	NA	0	NA
Dairy	58.8	37.02	NA	0	NA
Eggs	NA	NA	NA	NA	0.36
Total	470.02	73.98	25.49	30.33	68.61

Table 10: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	0.6	3.1	1.1
Fruits	3.5	30.6	5.4
Vegetables	1.6	20.3	3.8
Potatoes	0.8	11.5	2.0
Sugarbeets	0.6	1.7	0.3

	R&D	HH Cons	FS Cons
Oilcrops	0.2	3.1	0.6
Meat	2.8	11.8	2.8
Fish	1.2	2.8	2.0
Dairy	1.0	10.4	1.5
Eggs	0.1	1.9	0.5
Total	12.3	97.3	20.1



Czech Republic

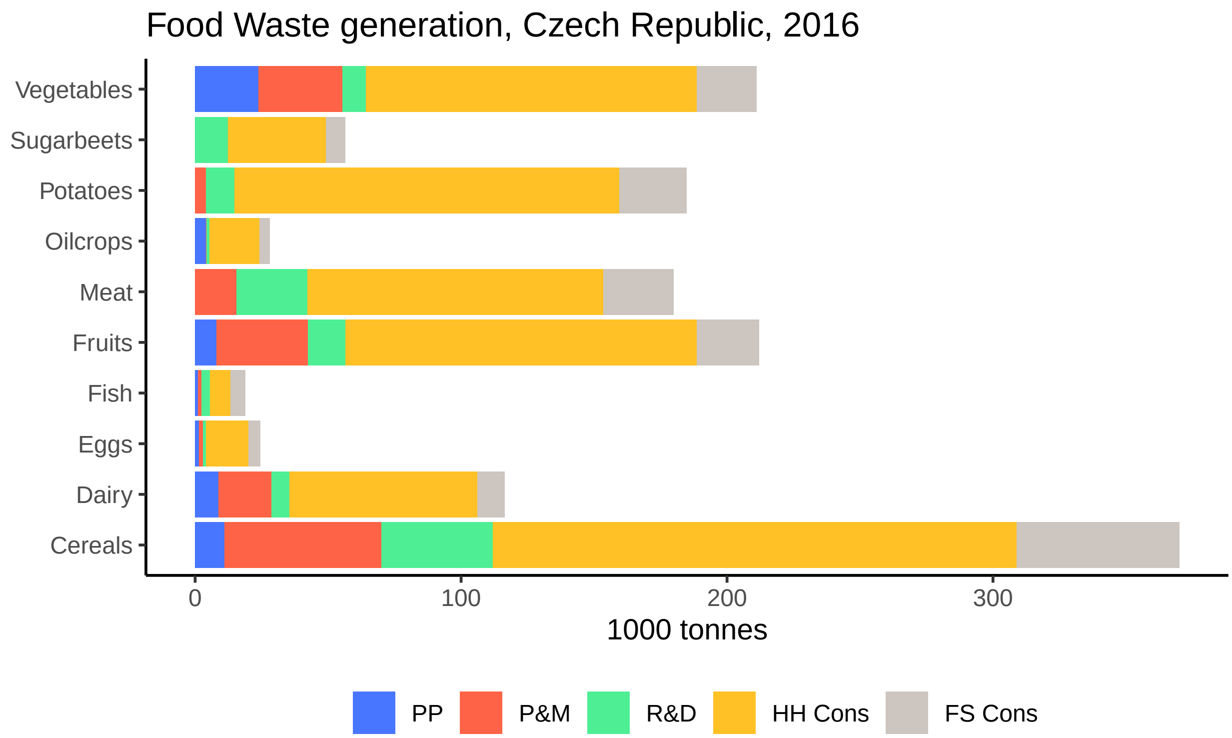


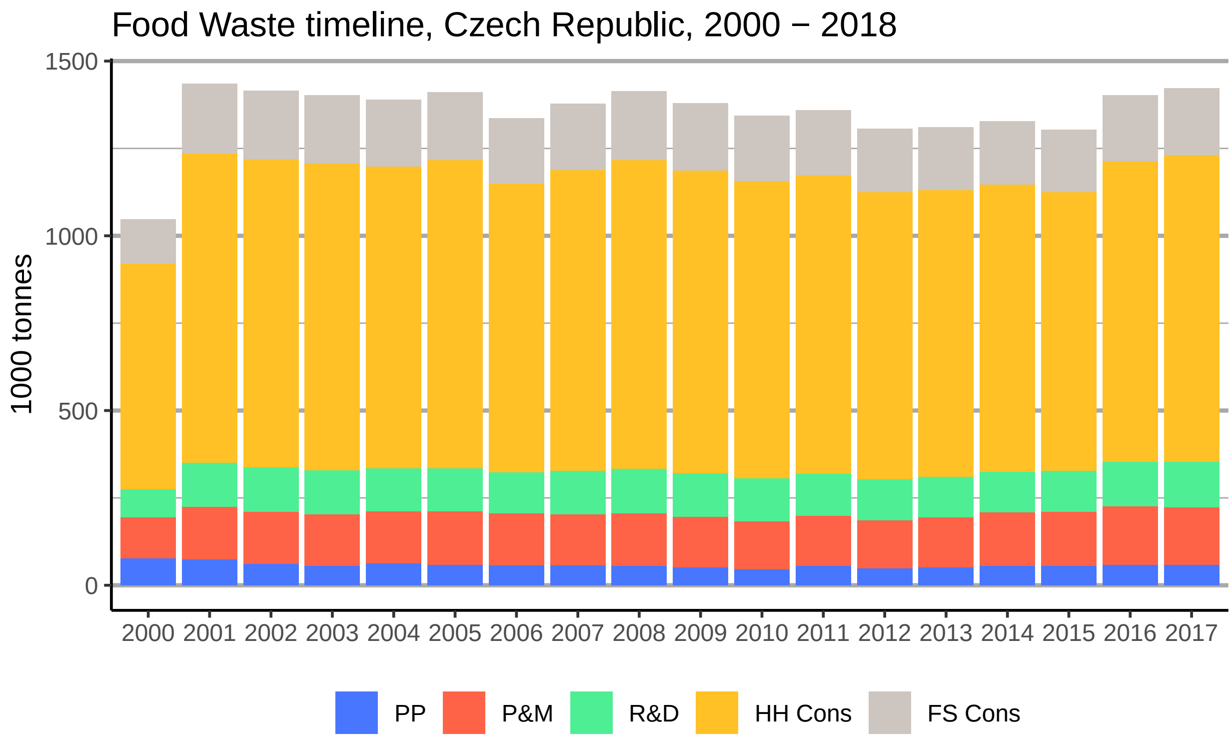
Table 11: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	2720.64	271.69	90.68	1094.96	NA
Fruits	NA	20.18	19.37	41.95	NA
Vegetables	36.42	3.1	23.82	31.45	NA
Potatoes	156.25	17.15	51.45	4.8	0.33
Sugarbeets	732.94	NA	53.65	207.11	0
Oilcrops	51.98	728.34	37.89	431.23	0.02
Meat	NA	NA	5.53	NA	525.58
Fish	30.55	NA	NA	2.8	NA
Dairy	53.2	73.42	NA	318.29	NA
Eggs	NA	NA	NA	NA	3.44
Total	3781.97	1113.87	282.39	2132.6	529.37

Table 12: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	4.0	18.6	5.8
Fruits	1.3	12.5	2.2
Vegetables	0.8	11.8	2.1
Potatoes	1.0	13.7	2.4
Sugarbeets	1.2	3.5	0.7

	R&D	HH Cons	FS Cons
Oilcrops	0.1	1.8	0.4
Meat	2.5	10.6	2.5
Fish	0.3	0.7	0.5
Dairy	0.7	6.7	1.0
Eggs	0.1	1.5	0.4
Total	12.1	81.4	18.0



Denmark

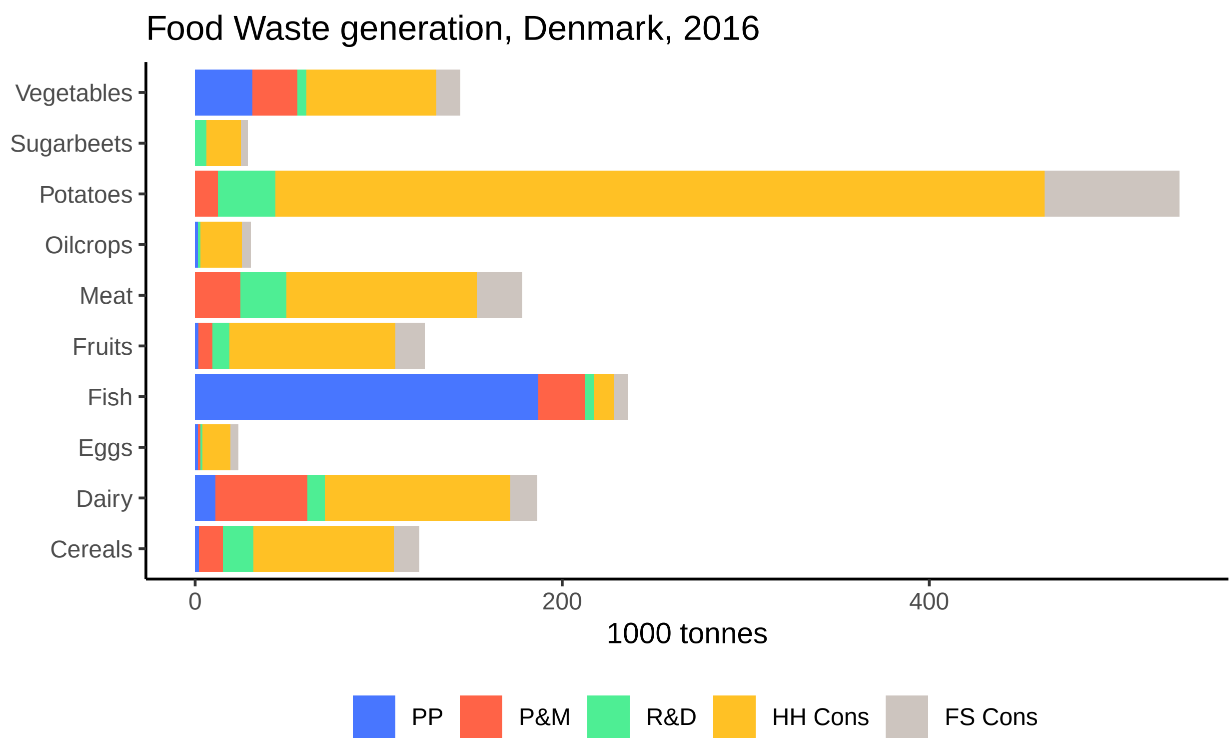


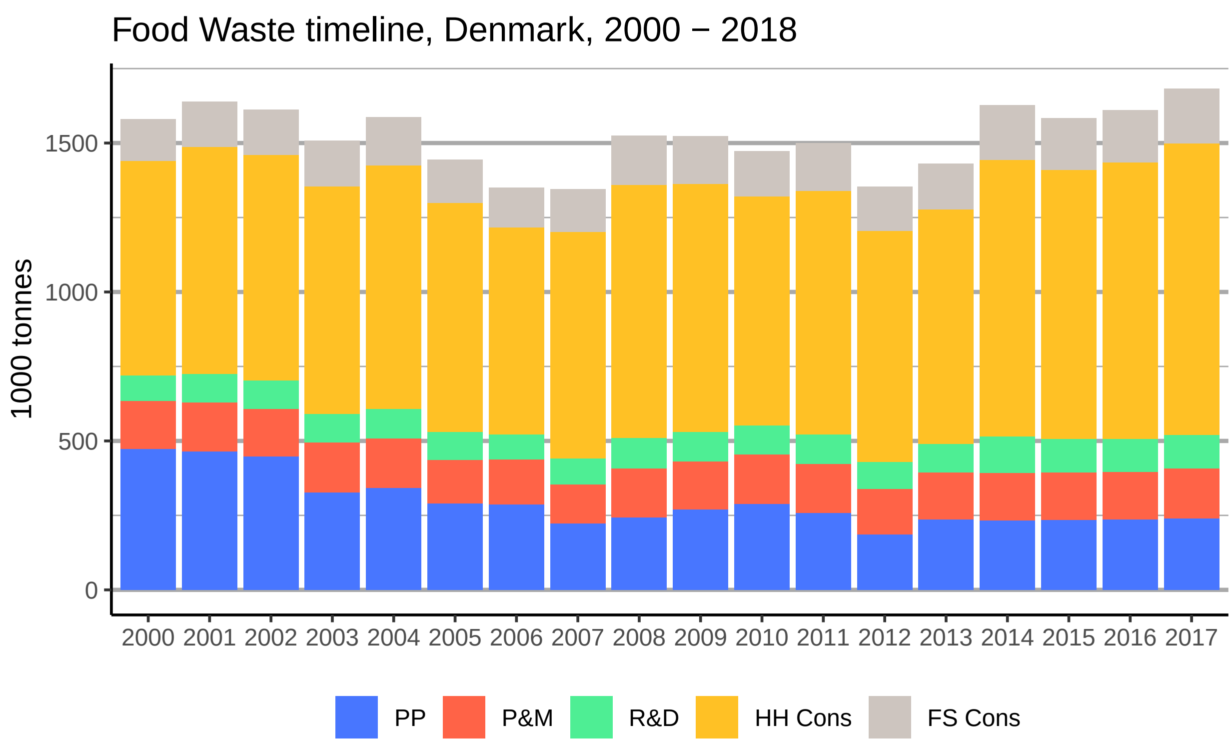
Table 13: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	6413.94	26.69	32.1	221.65	NA
Fruits	NA	5.25	5.17	9.37	NA
Vegetables	72.54	1.32	33.92	24.5	NA
Potatoes	76.78	58.87	176.6	14.19	0.96
Sugarbeets	36.34	NA	36.34	116.88	24.84
Oilcrops	21.71	240.07	14.1	65.22	0.04
Meat	NA	NA	19.74	NA	1214.98
Fish	100	28	NA	56.86	NA
Dairy	1552.17	187.74	NA	0	NA
Eggs	NA	NA	NA	NA	3.35
Total	8273.47	547.94	317.98	508.67	1244.18

Table 14: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	2.9	13.4	2.4
Fruits	1.6	15.8	2.8
Vegetables	0.9	12.4	2.2
Potatoes	5.5	73.4	12.9
Sugarbeets	1.1	3.3	0.6

	R&D	HH Cons	FS Cons
Oilcrops	0.2	4.0	0.8
Meat	4.4	18.2	4.3
Fish	0.8	1.9	1.4
Dairy	1.7	17.7	2.5
Eggs	0.2	2.7	0.7
Total	19.4	162.7	30.8



Estonia

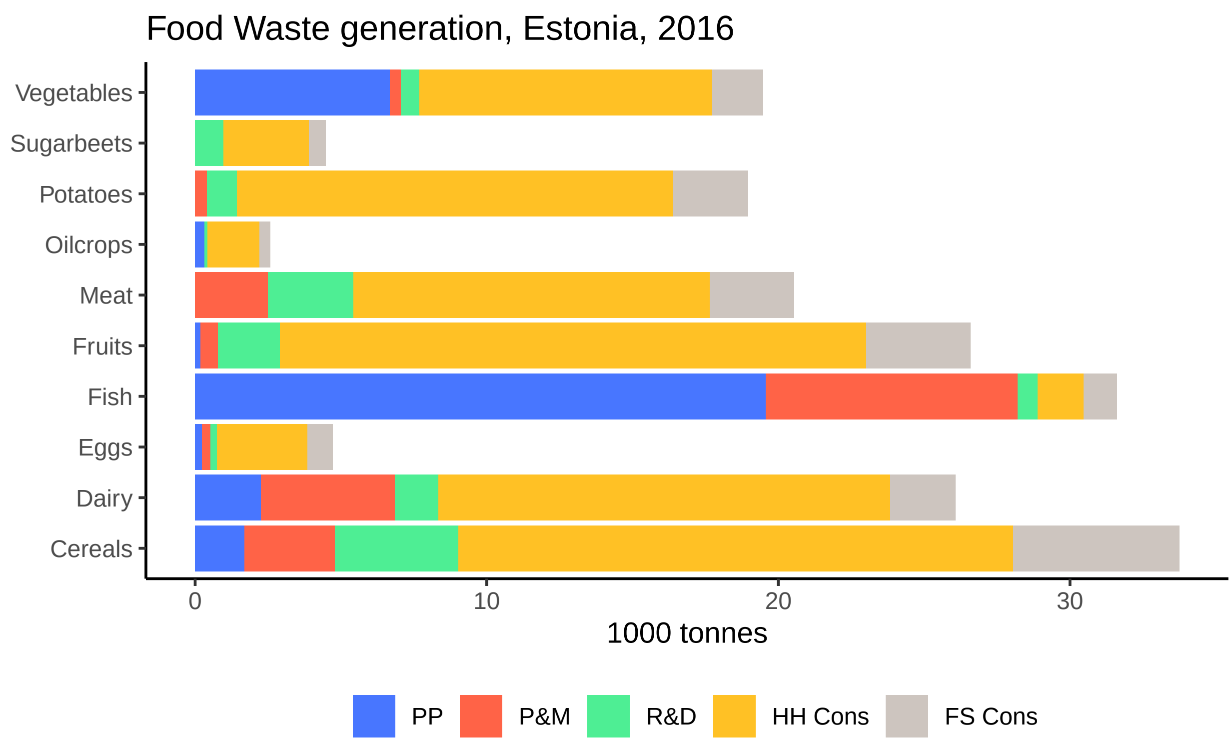


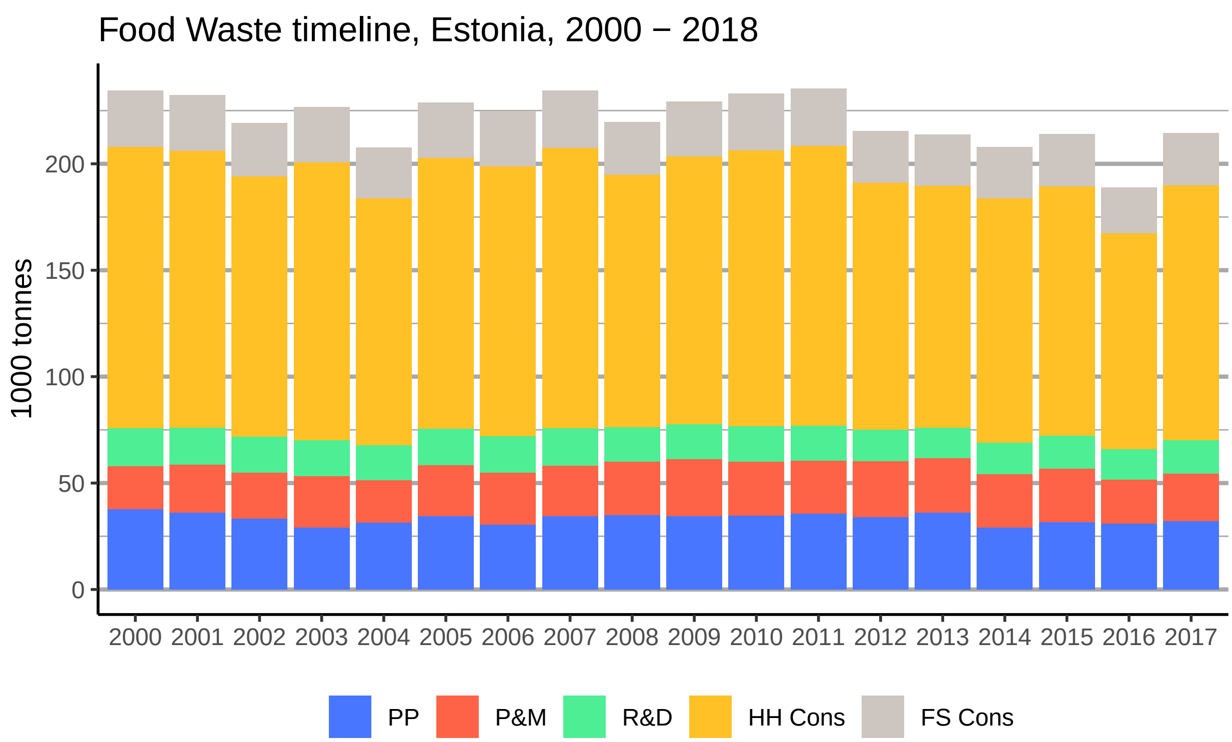
Table 15: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	105.96	9.48	14.35	32.08	NA
Fruits	NA	0.64	0.65	0.73	NA
Vegetables	31.28	0.76	7.4	0.39	NA
Potatoes	9.8	2.37	7.11	0.47	0.03
Sugarbeets	NA	NA	0	0.04	0
Oilcrops	1.48	27.65	2.9	0.27	0
Meat	NA	NA	0.88	NA	82.47
Fish	1.13	NA	NA	19.36	NA
Dairy	28.79	NA	NA	48.48	NA
Eggs	NA	NA	NA	NA	0.69
Total	178.45	40.91	33.29	101.82	83.19

Table 16: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	3.2	14.5	4.3
Fruits	1.6	15.3	2.7
Vegetables	0.5	7.6	1.3
Potatoes	0.8	11.4	2.0
Sugarbeets	0.7	2.2	0.4

	R&D	HH Cons	FS Cons
Oilcrops	0.1	1.4	0.3
Meat	2.2	9.3	2.2
Fish	0.5	1.2	0.9
Dairy	1.1	11.8	1.7
Eggs	0.2	2.4	0.7
Total	11.0	76.9	16.4



Finland

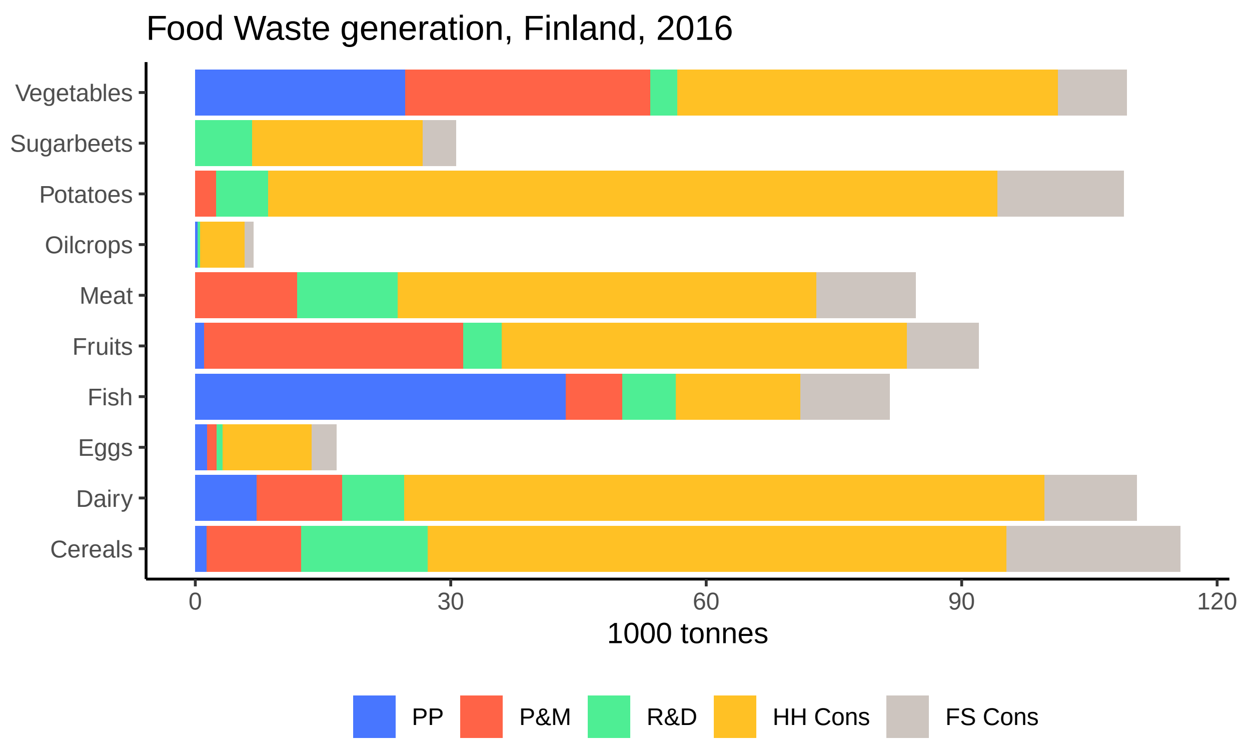


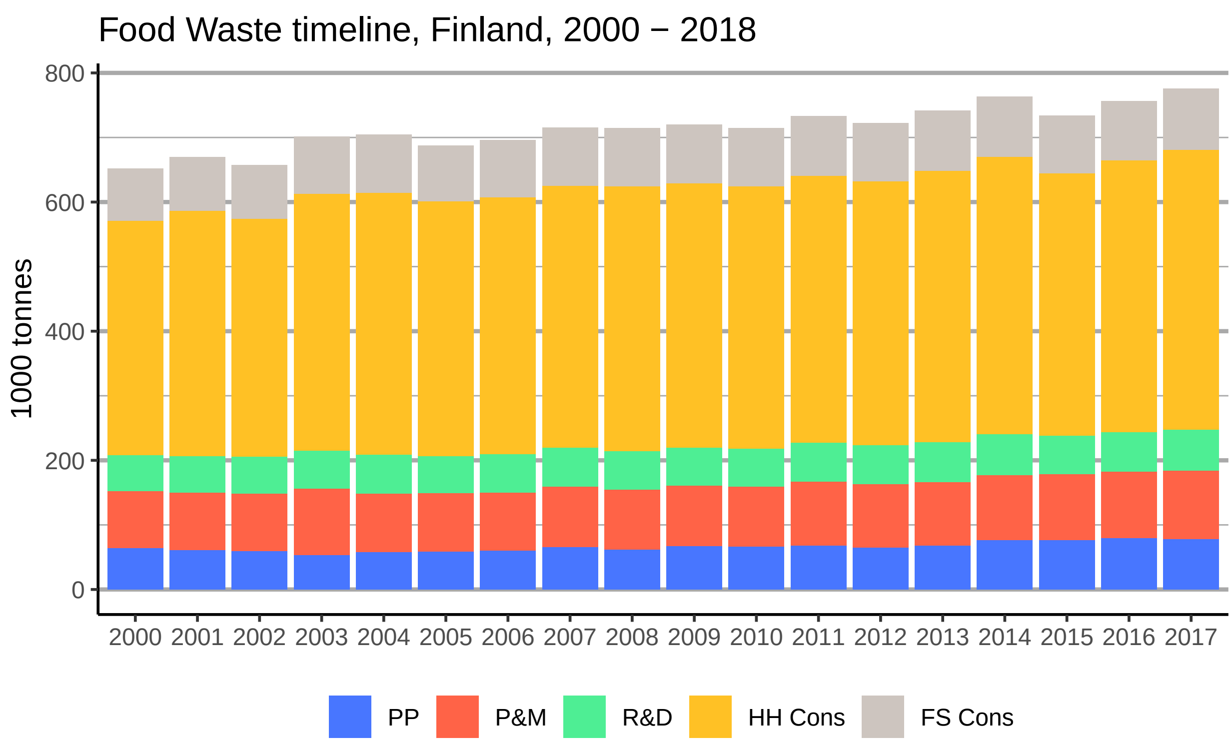
Table 17: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	1604.85	87.64	22.01	154.73	NA
Fruits	NA	1.77	1.52	37.17	NA
Vegetables	30.75	2.5	26.28	28.76	NA
Potatoes	11.91	188.09	35.73	2.79	0.19
Sugarbeets	6.71	NA	6.71	24.64	9.2
Oilcrops	NA	102	2.67	73.77	0
Meat	NA	NA	4.26	NA	328.35
Fish	95.28	NA	NA	14.83	NA
Dairy	24.44	14.95	NA	105.89	NA
Eggs	NA	NA	NA	NA	2.56
Total	1773.94	396.96	99.19	442.57	340.3

Table 18: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	2.7	12.4	3.7
Fruits	0.8	8.7	1.5
Vegetables	0.6	8.2	1.5
Potatoes	1.1	15.6	2.7
Sugarbeets	1.2	3.6	0.7

	R&D	HH Cons	FS Cons
Oilcrops	0.0	0.9	0.2
Meat	2.1	9.0	2.1
Fish	1.1	2.7	1.9
Dairy	1.3	13.7	2.0
Eggs	0.1	1.9	0.5
Total	11.3	76.6	16.9



France

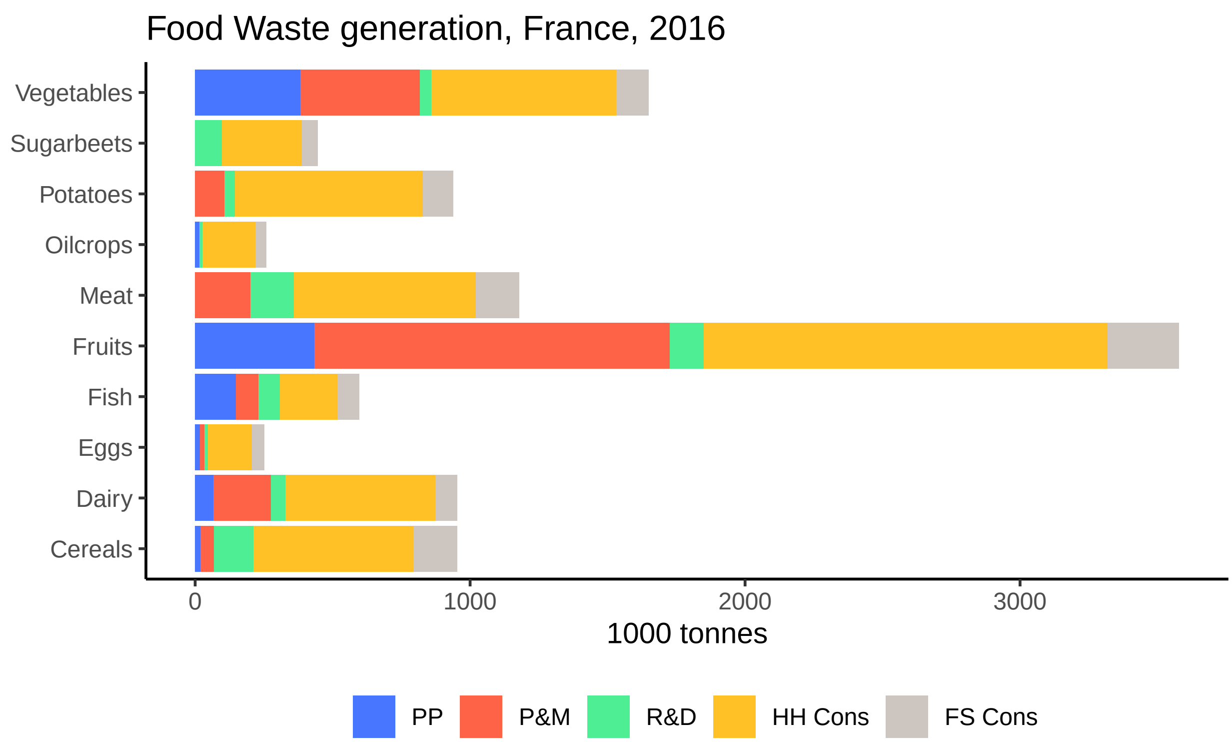


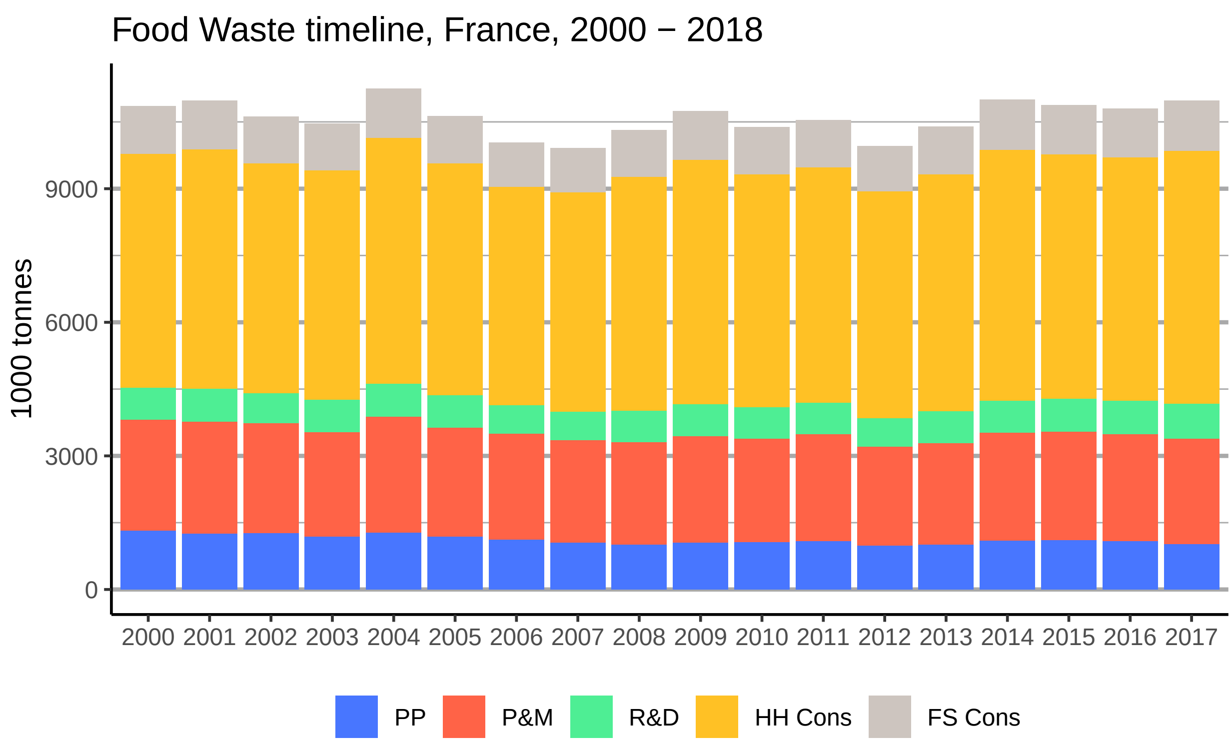
Table 19: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	9378.91	1905.68	789.3	1499.51	NA
Fruits	NA	673.99	559.43	1579.48	NA
Vegetables	468.72	92.65	261.33	434.65	NA
Potatoes	629.53	460.31	542.96	123.3	8.38
Sugarbeets	506.33	1830.99	506.33	2895.76	0
Oilcrops	166.08	2903.69	141.01	2497.99	3.69
Meat	NA	NA	62.21	NA	4475.07
Fish	90.67	NA	NA	183.15	NA
Dairy	4212.81	NA	NA	0	NA
Eggs	NA	8.19	NA	NA	38.47
Total	15453.04	7875.51	2862.57	9213.85	4525.62

Table 20: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	2.1	8.7	2.4
Fruits	1.9	22.0	3.9
Vegetables	0.6	10.1	1.8
Potatoes	0.6	10.3	1.7
Sugarbeets	1.5	4.4	0.9

	R&D	HH Cons	FS Cons
Oilcrops	0.2	2.9	0.6
Meat	2.4	9.9	2.4
Fish	1.2	3.1	1.2
Dairy	0.8	8.2	1.2
Eggs	0.2	2.4	0.7
Total	11.3	82.0	16.5



Germany

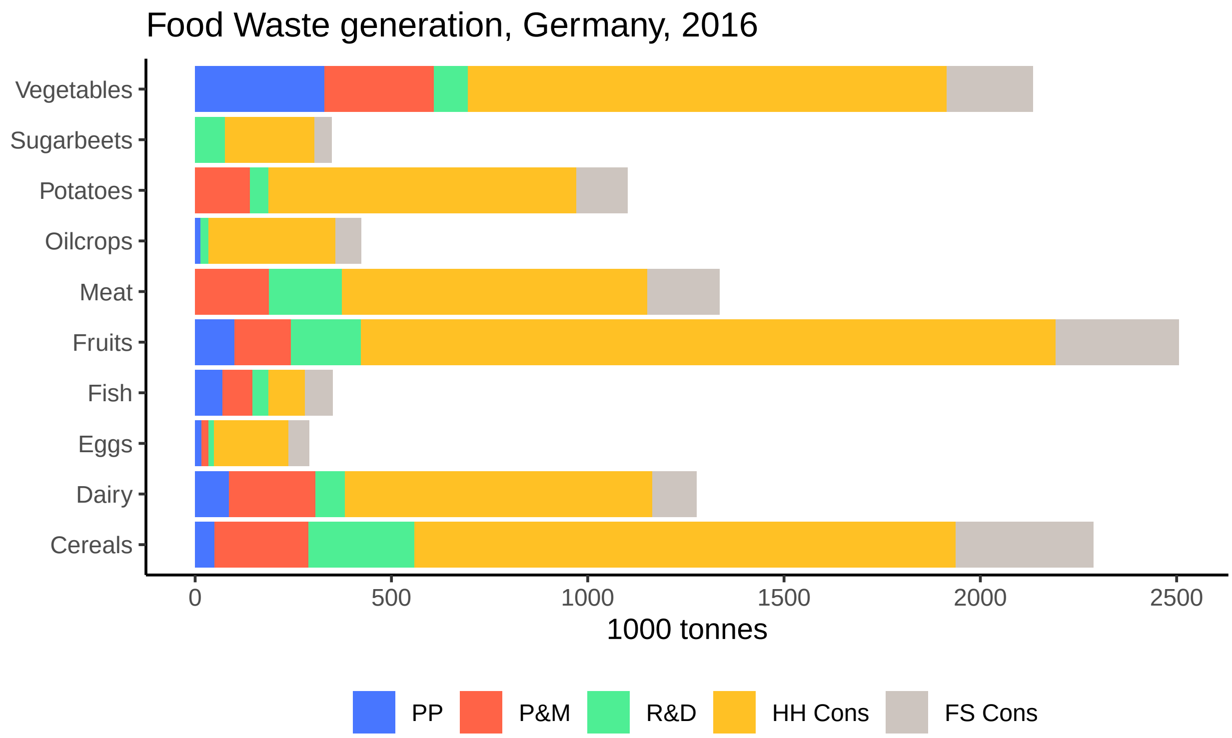


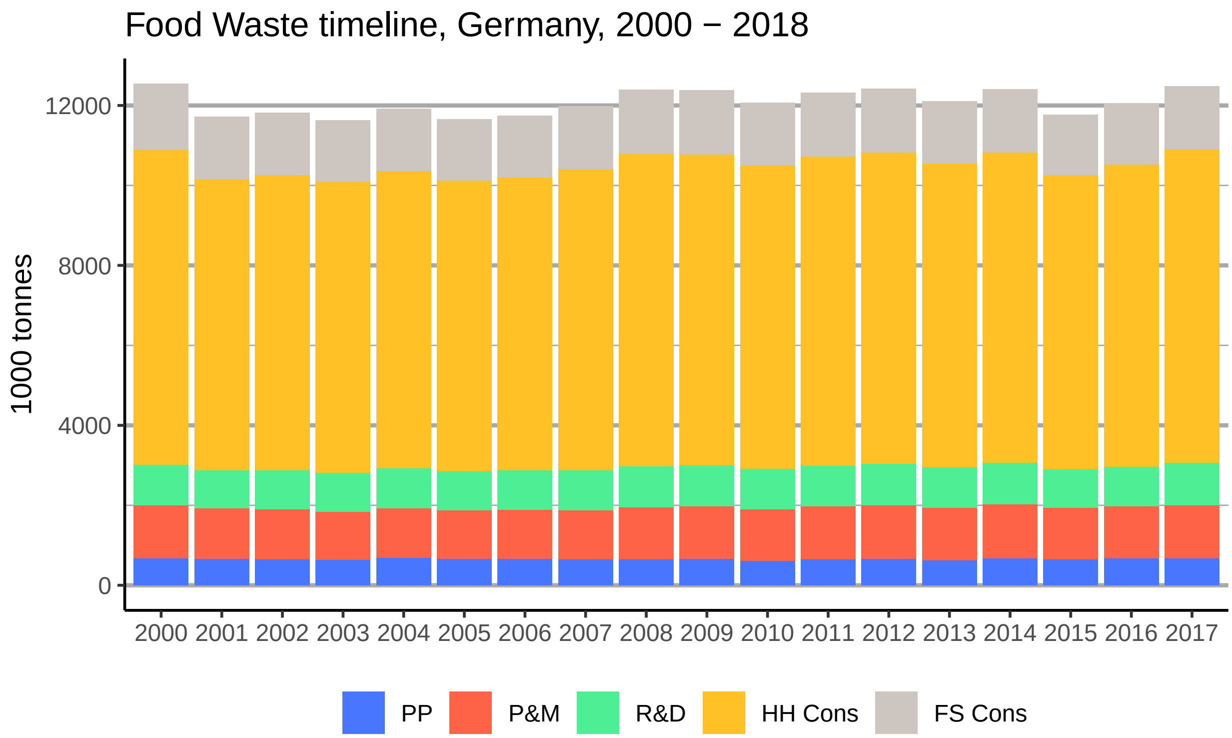
Table 21: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	25316.95	1131.97	402.91	4436.37	NA
Fruits	NA	207.04	189.48	175.6	NA
Vegetables	773.68	43.52	339.33	279.04	NA
Potatoes	403.68	1979.59	771.04	159.54	10.84
Sugarbeets	2197.59	NA	390.53	2095.72	388.24
Oilcrops	254.49	6159.49	130.07	3544.1	0.51
Meat	NA	NA	85.1	NA	6359.23
Fish	13.02	NA	NA	170.97	NA
Dairy	3434.8	764.5	NA	2469.79	NA
Eggs	NA	NA	NA	NA	43.6
Total	32394.22	10286.09	2308.45	13331.12	6802.42

Table 22: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	3.3	16.8	4.3
Fruits	2.2	21.6	3.8
Vegetables	1.1	14.8	2.7
Potatoes	0.6	9.6	1.6
Sugarbeets	0.9	2.8	0.5

	R&D	HH Cons	FS Cons
Oilcrops	0.2	3.9	0.8
Meat	2.3	9.5	2.2
Fish	0.5	1.1	0.9
Dairy	0.9	9.5	1.4
Eggs	0.2	2.3	0.6
Total	12.1	91.8	18.8



Greece

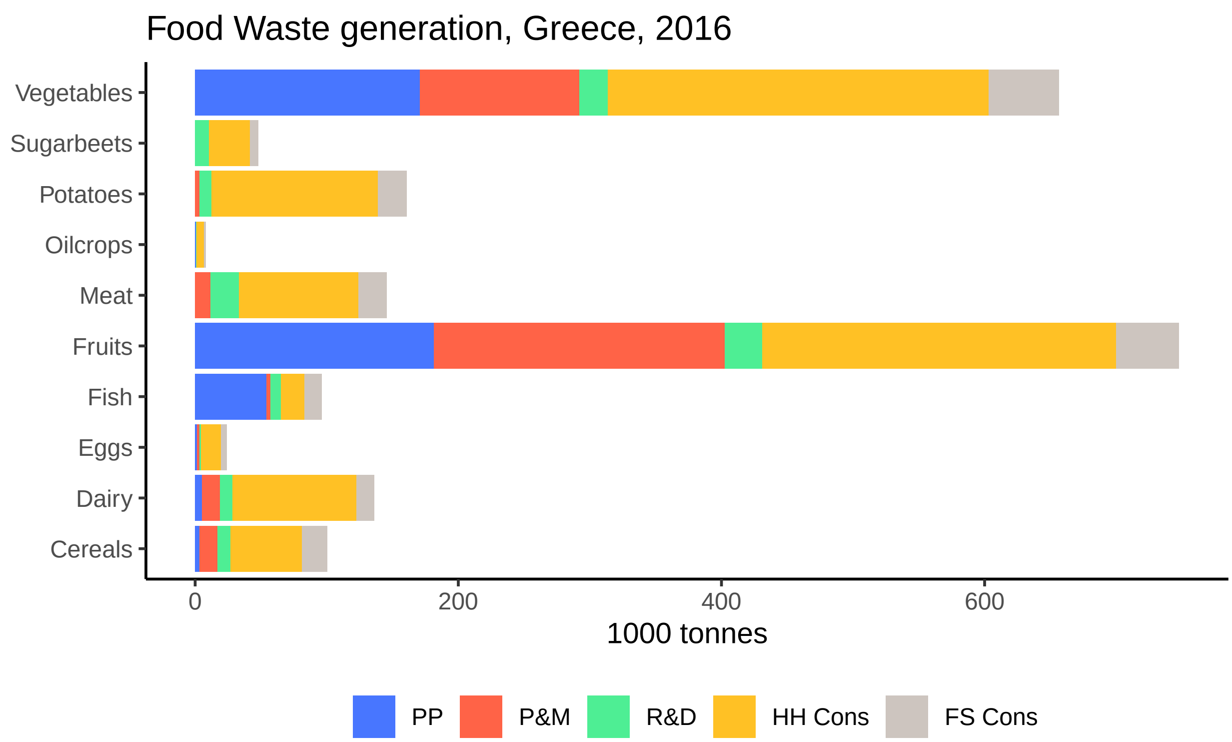


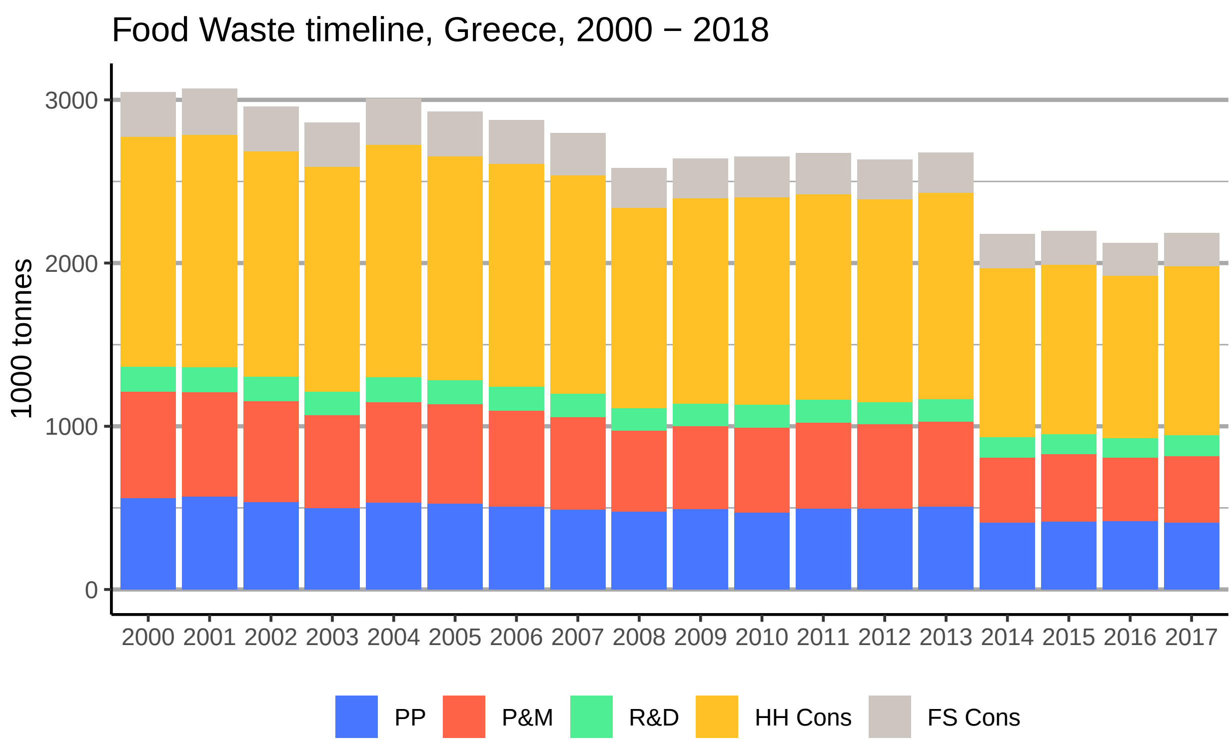
Table 23: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	2881.43	254	26.91	569.04	NA
Fruits	19.53	313.23	184.02	269.8	NA
Vegetables	740.41	106.09	142.75	120.95	NA
Potatoes	52.32	23.87	41.47	4.01	0.27
Sugarbeets	41.29	NA	4.28	25.99	7.36
Oilcrops	6.88	201.01	6.28	363.3	0
Meat	NA	NA	6.31	NA	452.33
Fish	361.07	NA	NA	7.09	NA
Dairy	175.1	31.48	NA	0	NA
Eggs	NA	0.95	NA	NA	3.72
Total	4278.02	930.63	412.02	1360.19	463.68

Table 24: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	0.9	5.0	1.8
Fruits	2.7	24.9	4.4
Vegetables	2.0	26.8	5.0
Potatoes	0.8	11.7	2.0
Sugarbeets	1.0	2.9	0.6

	R&D	HH Cons	FS Cons
Oilcrops	0.0	0.6	0.1
Meat	2.0	8.4	2.0
Fish	0.7	1.7	1.2
Dairy	0.8	8.8	1.3
Eggs	0.1	1.4	0.4
Total	11.2	92.2	18.7



Hungary

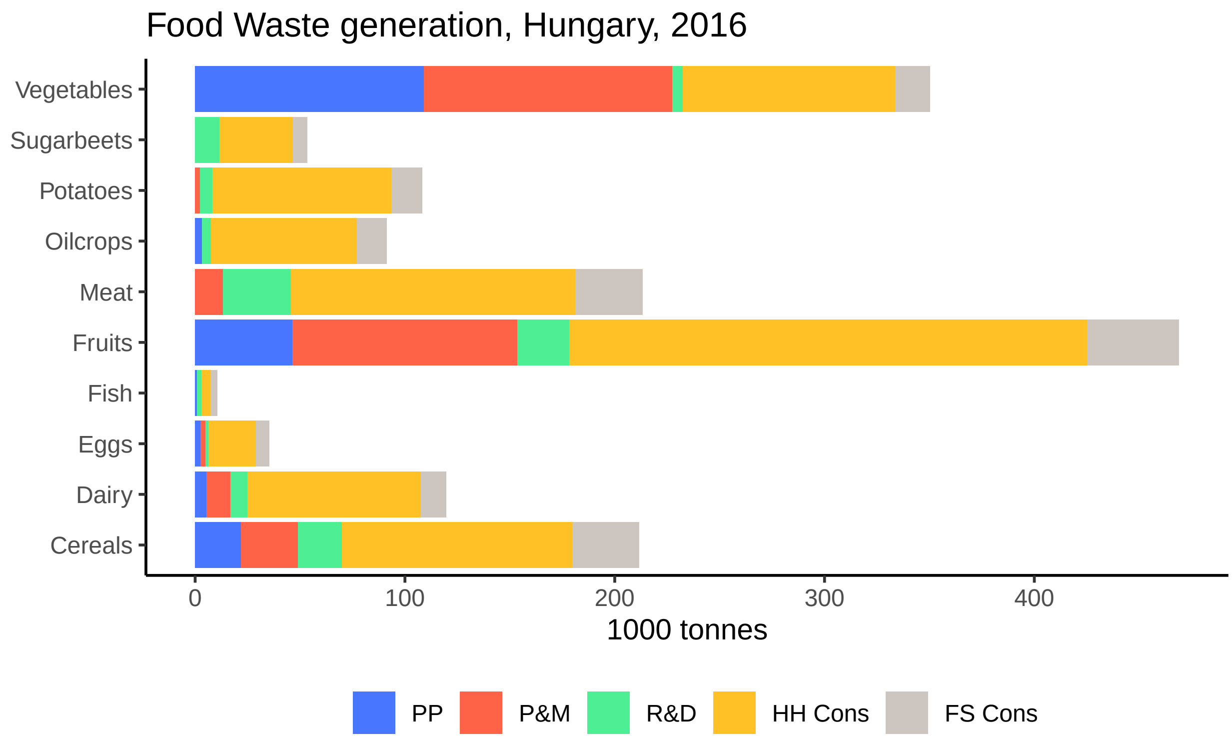


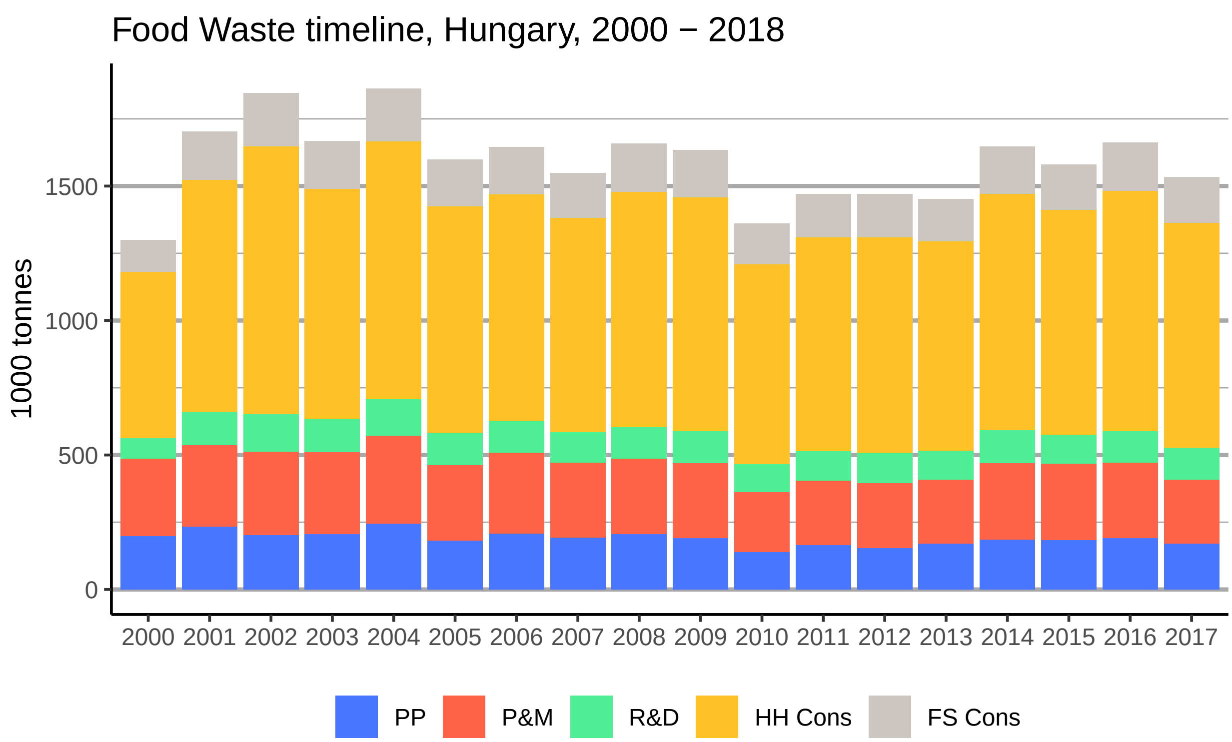
Table 25: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	8282.56	116.78	186.87	1559.47	NA
Fruits	4.9	100.57	89.11	131	NA
Vegetables	316.92	21.05	113.81	118.32	NA
Potatoes	19.16	56.66	34.02	2.69	0.18
Sugarbeets	15.52	108.95	15.52	72.02	0
Oilcrops	112.02	363.74	30.47	1148.78	0
Meat	NA	NA	8.83	NA	681.73
Fish	11.36	NA	NA	0.05	NA
Dairy	130.81	NA	NA	267.77	NA
Eggs	NA	NA	NA	NA	5.4
Total	8893.24	767.74	478.63	3300.11	687.31

Table 26: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	2.1	11.2	3.2
Fruits	2.5	25.1	4.5
Vegetables	0.5	10.3	1.7
Potatoes	0.6	8.7	1.5
Sugarbeets	1.2	3.5	0.7

	R&D	HH Cons	FS Cons
Oilcrops	0.4	7.1	1.4
Meat	3.3	13.8	3.3
Fish	0.2	0.5	0.3
Dairy	0.8	8.4	1.2
Eggs	0.2	2.3	0.6
Total	11.9	90.8	18.4



Ireland

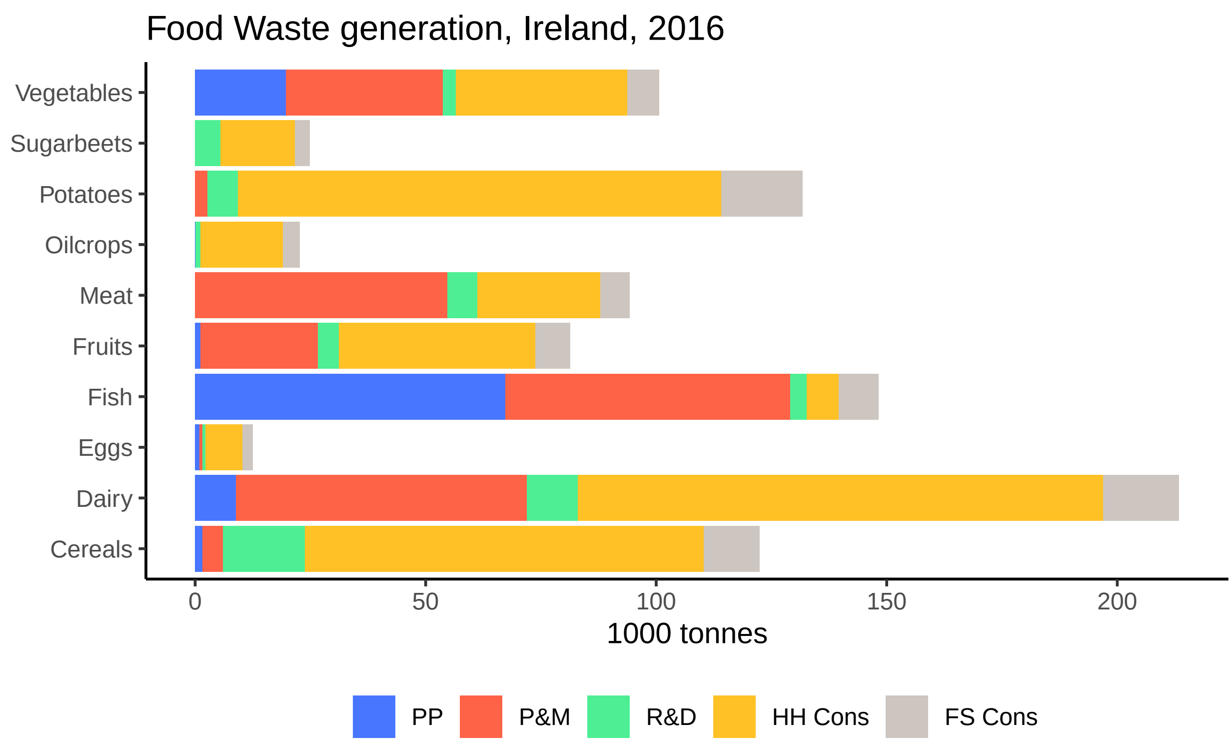


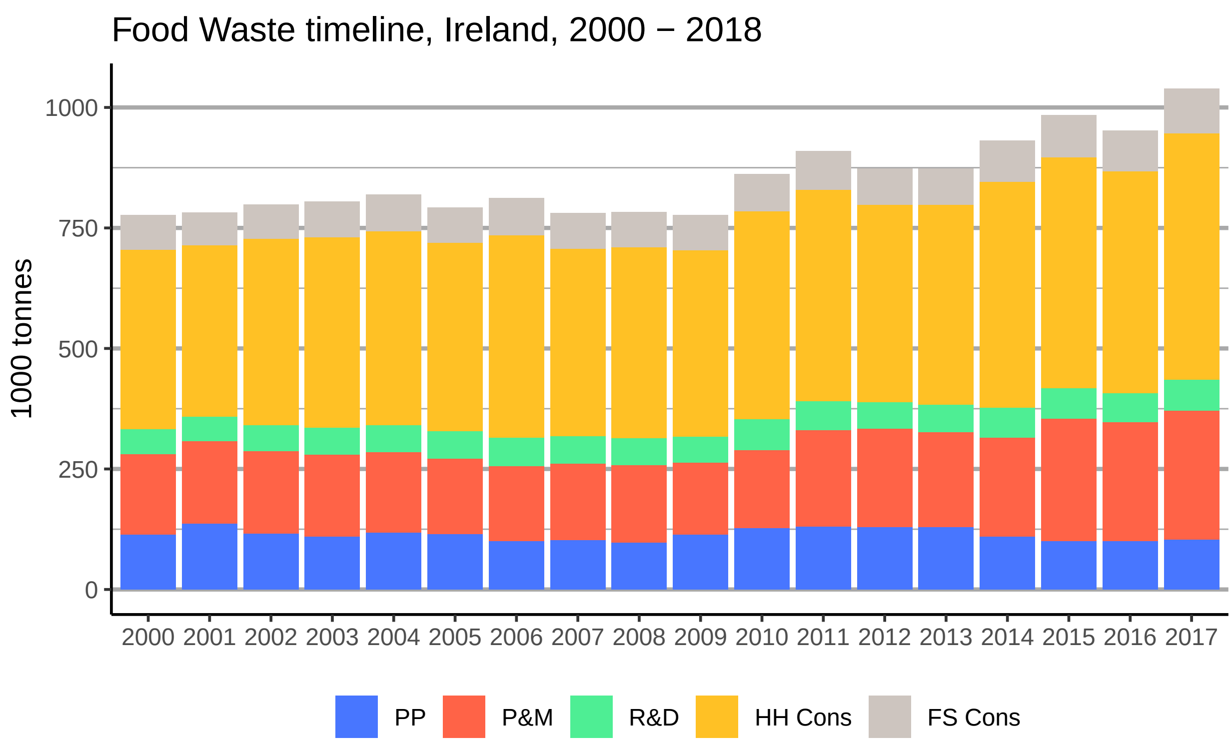
Table 27: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	2898.3	18.89	13.4	135.28	NA
Fruits	NA	3.34	3.25	31.01	NA
Vegetables	89.09	2.77	21.47	34.05	NA
Potatoes	20.54	24.91	32.29	3.04	0.21
Sugarbeets	1.11	NA	1.11	6.8	0
Oilcrops	7.39	21.55	0.97	24.65	0.02
Meat	NA	NA	12.4	NA	725.09
Fish	7.29	NA	NA	138.54	NA
Dairy	2313.13	2057.08	NA	0	NA
Eggs	NA	NA	NA	NA	1.72
Total	5336.85	2128.54	84.89	373.37	727.03

Table 28: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	3.8	18.3	2.6
Fruits	1.0	9.0	1.6
Vegetables	0.6	7.9	1.4
Potatoes	1.4	22.2	3.7
Sugarbeets	1.1	3.4	0.7

	R&D	HH Cons	FS Cons
Oilcrops	0.2	3.8	0.8
Meat	1.4	5.7	1.3
Fish	0.8	1.5	1.8
Dairy	2.3	24.1	3.5
Eggs	0.1	1.7	0.5
Total	12.7	97.5	17.9



Italy

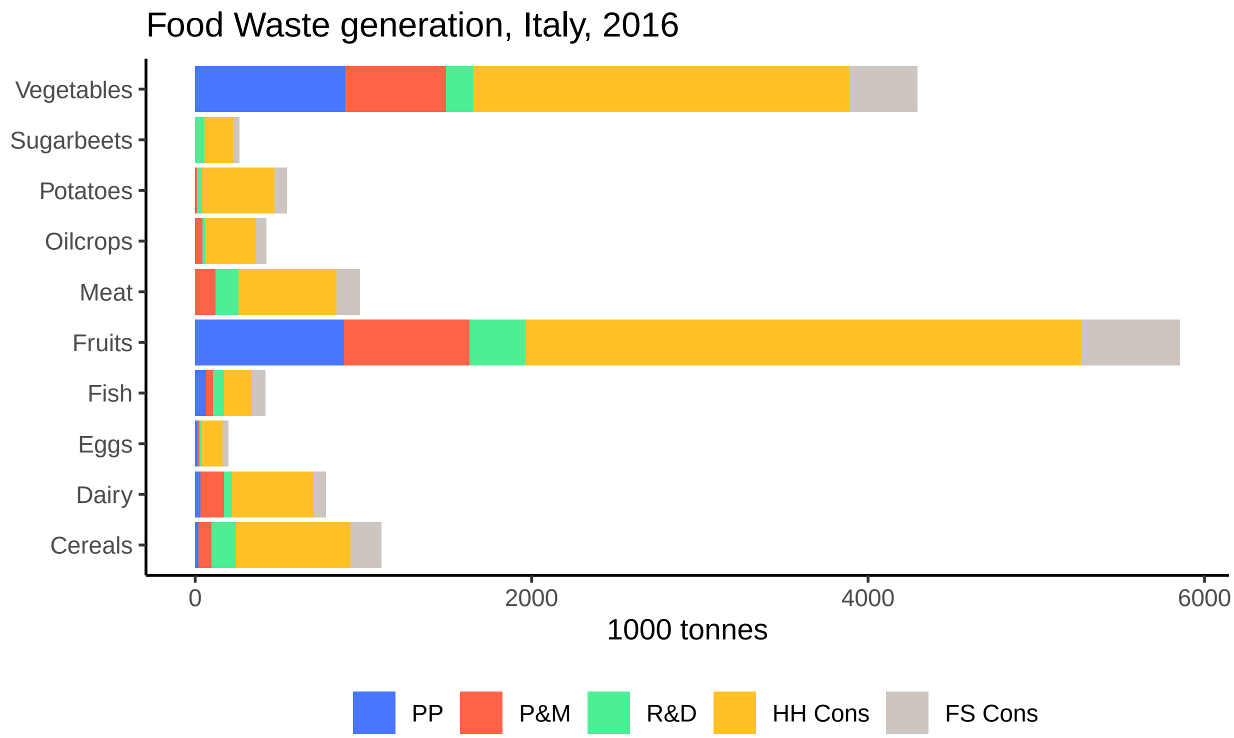


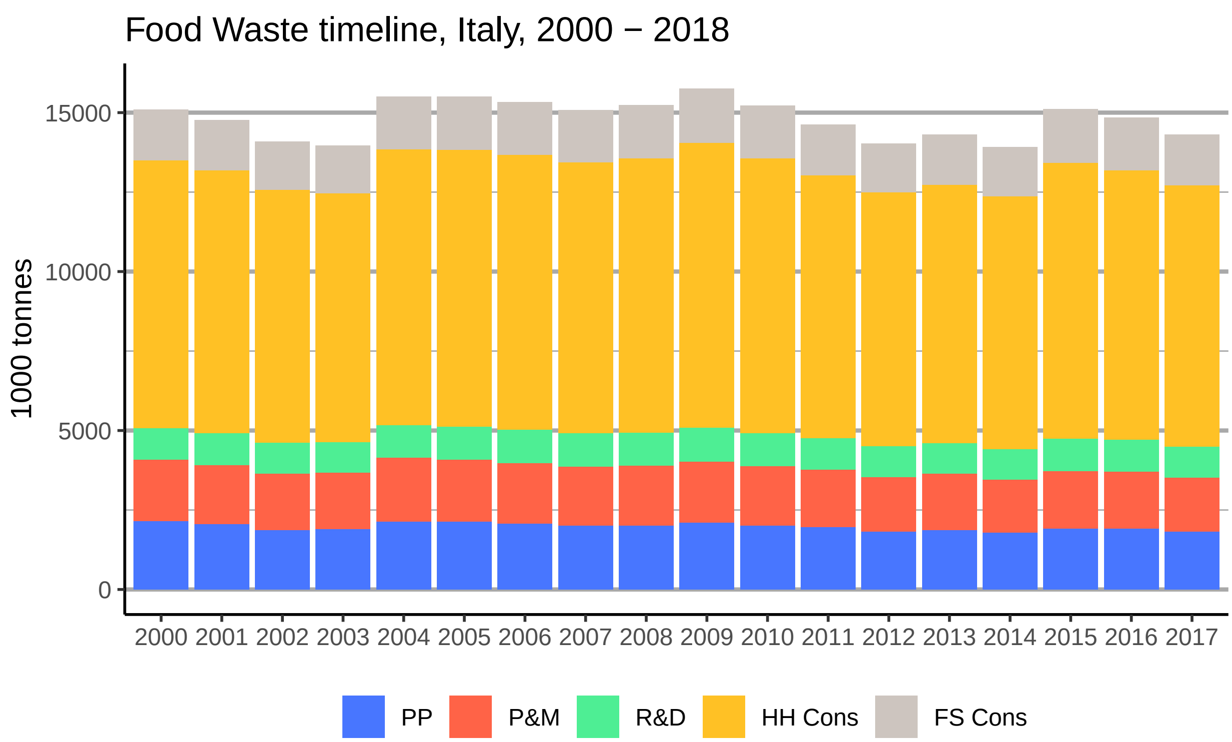
Table 29: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	14387	504.65	153.34	4389.08	NA
Fruits	NA	1277.02	1018.8	910.54	NA
Vegetables	1195.03	361.12	672.6	600.7	NA
Potatoes	75.41	69.82	125.7	13.29	0.9
Sugarbeets	36.08	NA	31.57	221.27	0
Oilcrops	187.03	782.65	14.41	1980.95	634.63
Meat	NA	NA	39.57	NA	3196.11
Fish	220.78	NA	NA	89.85	NA
Dairy	687.47	273.98	NA	2656.42	NA
Eggs	NA	NA	NA	NA	30.53
Total	16788.8	3269.24	2056	10862.1	3862.17

Table 30: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	2.5	11.2	3.0
Fruits	5.5	54.4	9.7
Vegetables	2.6	36.9	6.7
Potatoes	0.5	7.1	1.2
Sugarbeets	0.9	2.8	0.6

	R&D	HH Cons	FS Cons
Oilcrops	0.3	5.0	1.0
Meat	2.3	9.6	2.3
Fish	1.1	2.8	1.3
Dairy	0.8	8.0	1.2
Eggs	0.1	2.1	0.6
Total	16.6	139.8	27.4



Latvia

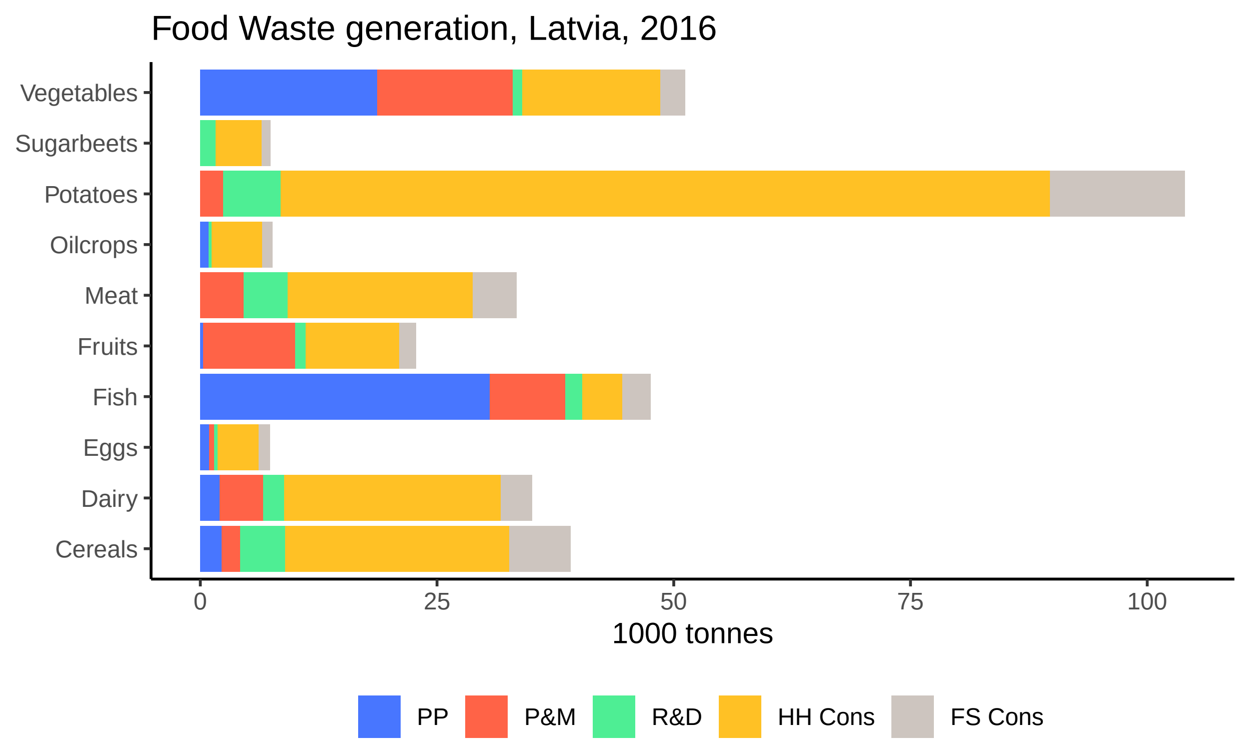


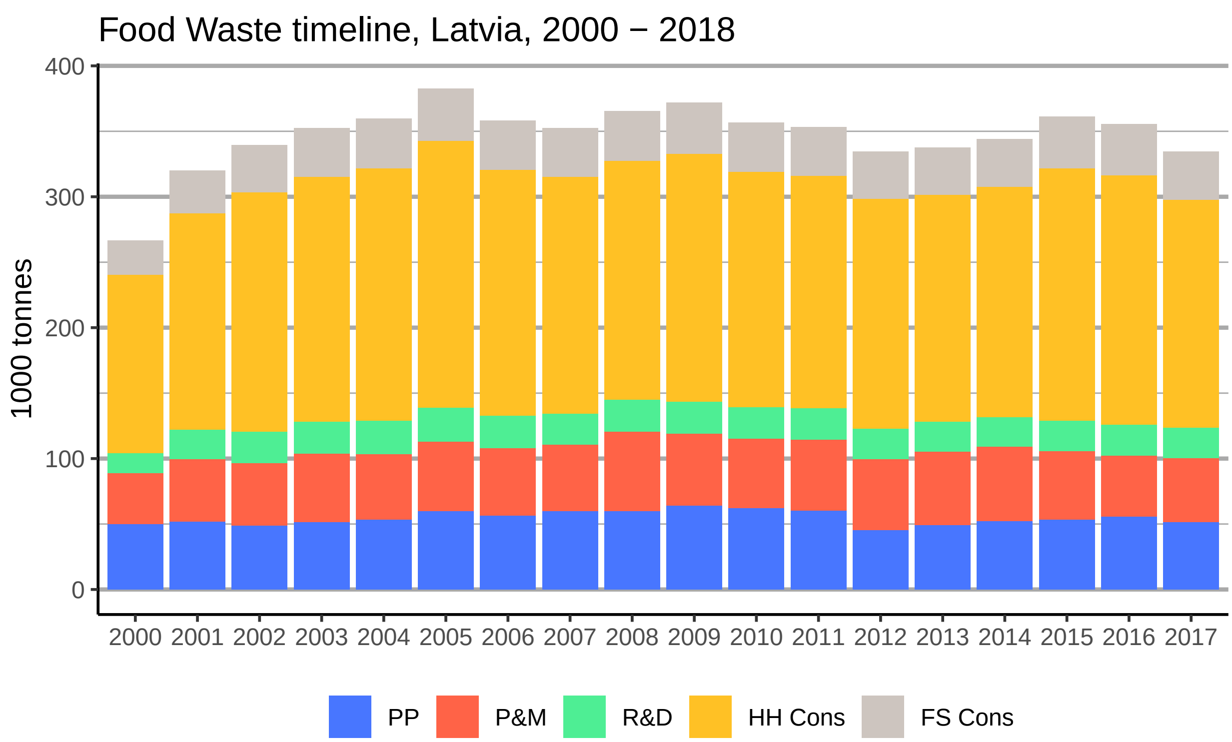
Table 31: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	437.12	52.31	18.19	37.9	NA
Fruits	NA	1.21	1.26	11.89	NA
Vegetables	106.43	2.42	20.17	14.32	NA
Potatoes	59.06	31.7	30.31	2.76	0.19
Sugarbeets	NA	NA	0	0	0
Oilcrops	NA	72.74	8.04	28.27	0.01
Meat	NA	NA	1.19	NA	105.17
Fish	2.53	NA	NA	18.01	NA
Dairy	261.26	NA	NA	48.83	NA
Eggs	NA	NA	NA	NA	1.33
Total	866.39	160.38	79.17	161.98	106.69

Table 32: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	2.4	12.0	3.3
Fruits	0.6	5.0	0.9
Vegetables	0.5	7.4	1.3
Potatoes	3.1	41.3	7.2
Sugarbeets	0.8	2.5	0.5

	R&D	HH Cons	FS Cons
Oilcrops	0.2	2.7	0.6
Meat	2.4	9.9	2.4
Fish	0.9	2.1	1.5
Dairy	1.1	11.6	1.7
Eggs	0.2	2.2	0.6
Total	12.1	96.7	19.9



Lithuania

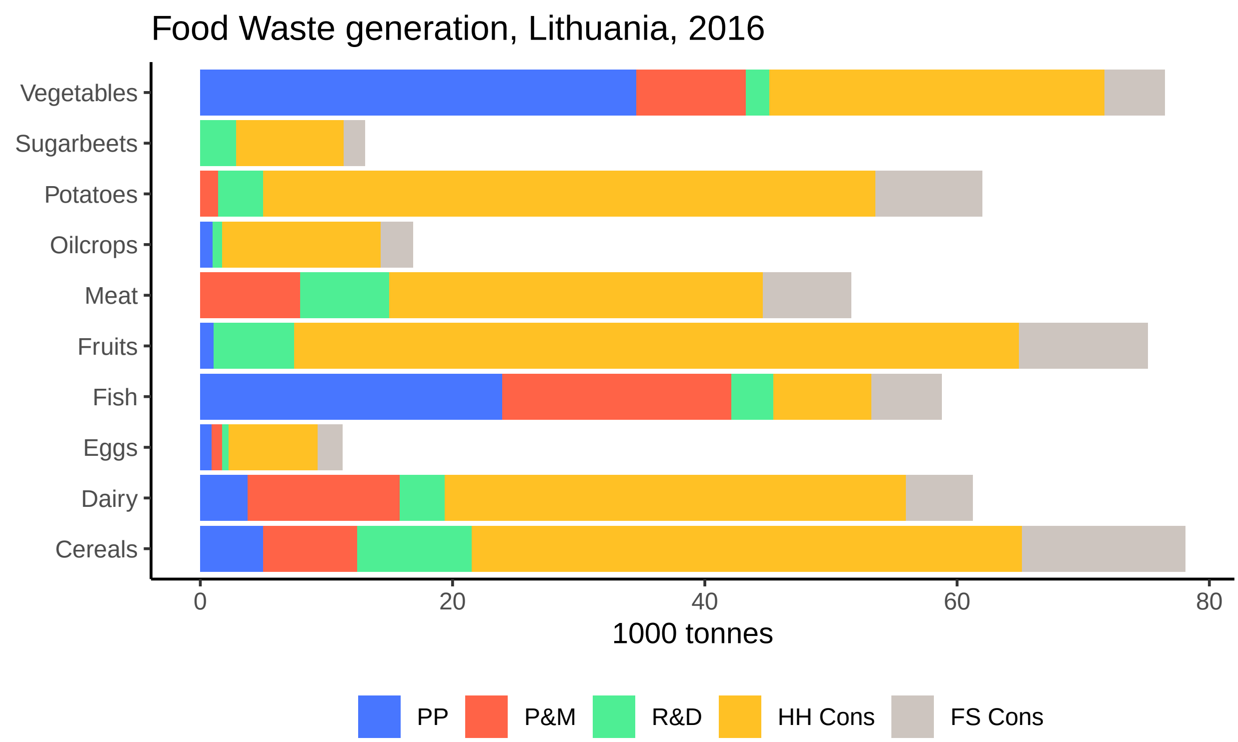


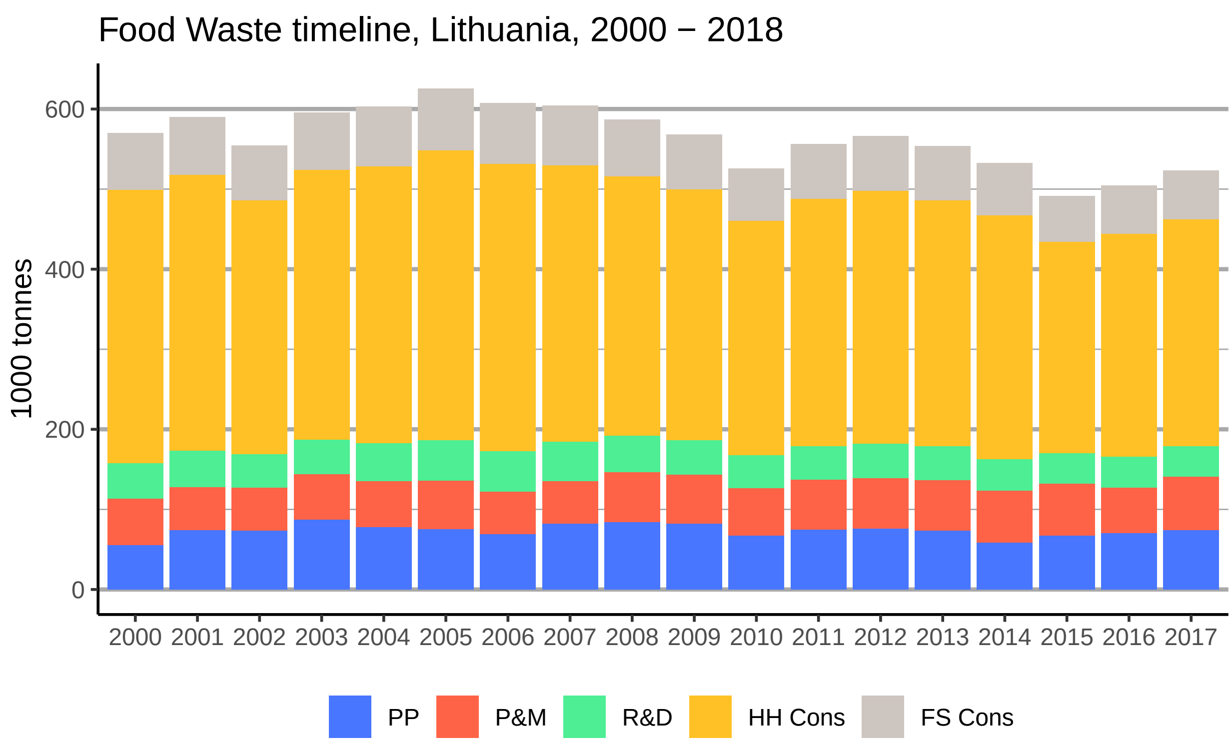
Table 33: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	1086.77	62.23	37.82	87.84	NA
Fruits	4.01	6.57	7.15	0	NA
Vegetables	155.21	2.68	28.79	8.68	NA
Potatoes	71.22	7.2	21.59	1.62	0.11
Sugarbeets	17.7	NA	14.39	72.81	1.84
Oilcrops	31.32	115.6	8.85	50.34	0
Meat	NA	NA	2.67	NA	194.85
Fish	28.36	NA	NA	40.69	NA
Dairy	463.52	NA	NA	127.36	NA
Eggs	NA	NA	NA	NA	1.89
Total	1858.12	194.28	121.26	389.34	198.69

Table 34: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	3.2	15.1	4.5
Fruits	2.2	19.9	3.5
Vegetables	0.6	9.2	1.6
Potatoes	1.2	16.8	2.9
Sugarbeets	1.0	3.0	0.6

	R&D	HH Cons	FS Cons
Oilcrops	0.3	4.4	0.9
Meat	2.5	10.2	2.4
Fish	1.2	2.7	1.9
Dairy	1.2	12.7	1.8
Eggs	0.2	2.5	0.7
Total	13.5	96.4	20.9



Luxembourg

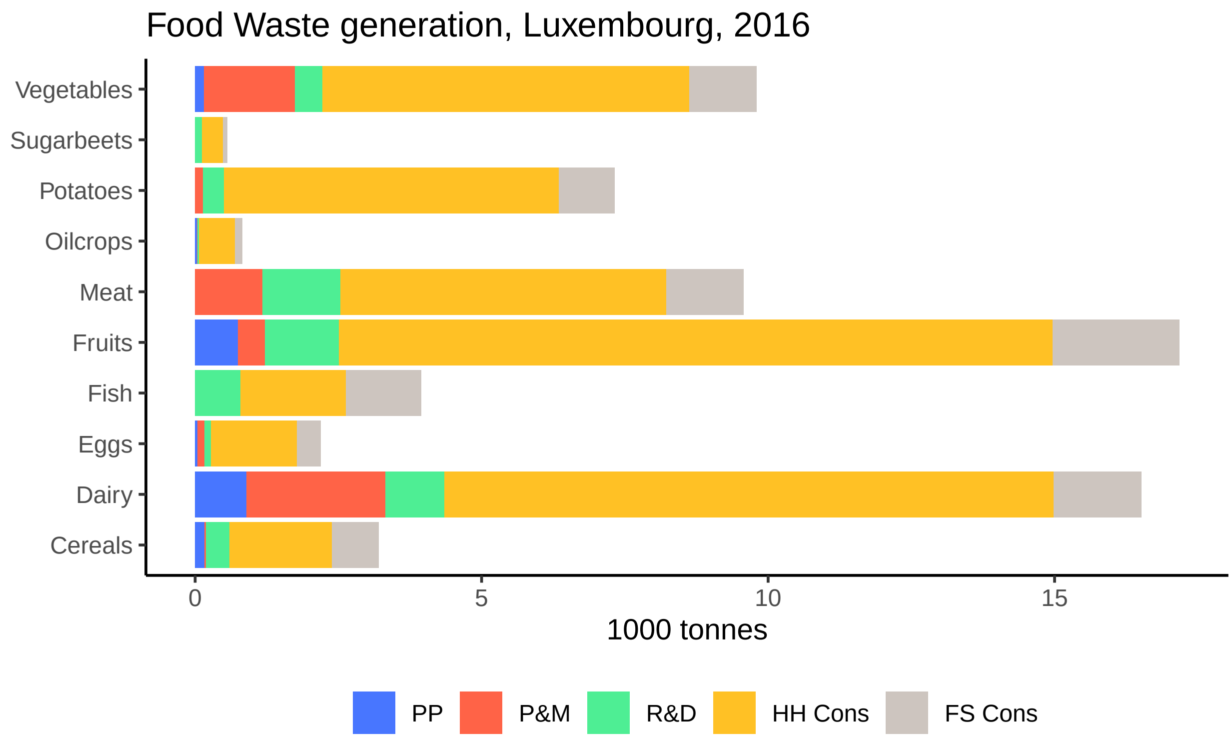


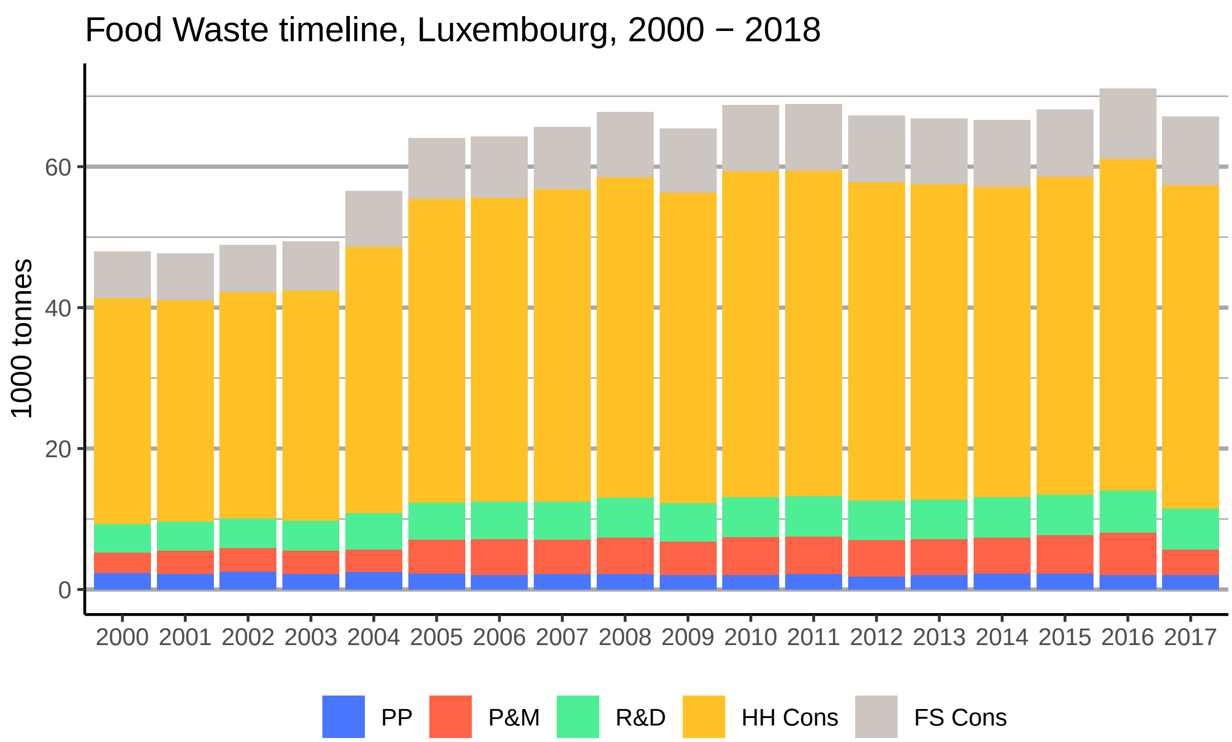
Table 35: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	108.38	2.52	1.36	11.68	NA
Fruits	NA	1.06	0.85	0.58	NA
Vegetables	1.23	0.02	0.18	1.59	NA
Potatoes	1.36	0.56	1.67	0.16	0.01
Sugarbeets	NA	NA	0	0.01	0
Oilcrops	NA	0.07	0.31	0.52	0.05
Meat	NA	NA	0.28	NA	28.6
Fish	NA	NA	NA	0	NA
Dairy	43.85	NA	NA	25.63	NA
Eggs	NA	NA	NA	NA	0.29
Total	154.83	4.23	4.66	40.17	28.95

Table 36: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	0.7	3.1	1.4
Fruits	2.2	21.6	3.8
Vegetables	0.8	11.1	2.0
Potatoes	0.6	10.1	1.7
Sugarbeets	0.2	0.6	0.1

	R&D	HH Cons	FS Cons
Oilcrops	0.1	1.1	0.2
Meat	2.4	9.9	2.3
Fish	1.4	3.2	2.3
Dairy	1.8	18.4	2.7
Eggs	0.2	2.6	0.7
Total	10.4	81.8	17.3



Malta

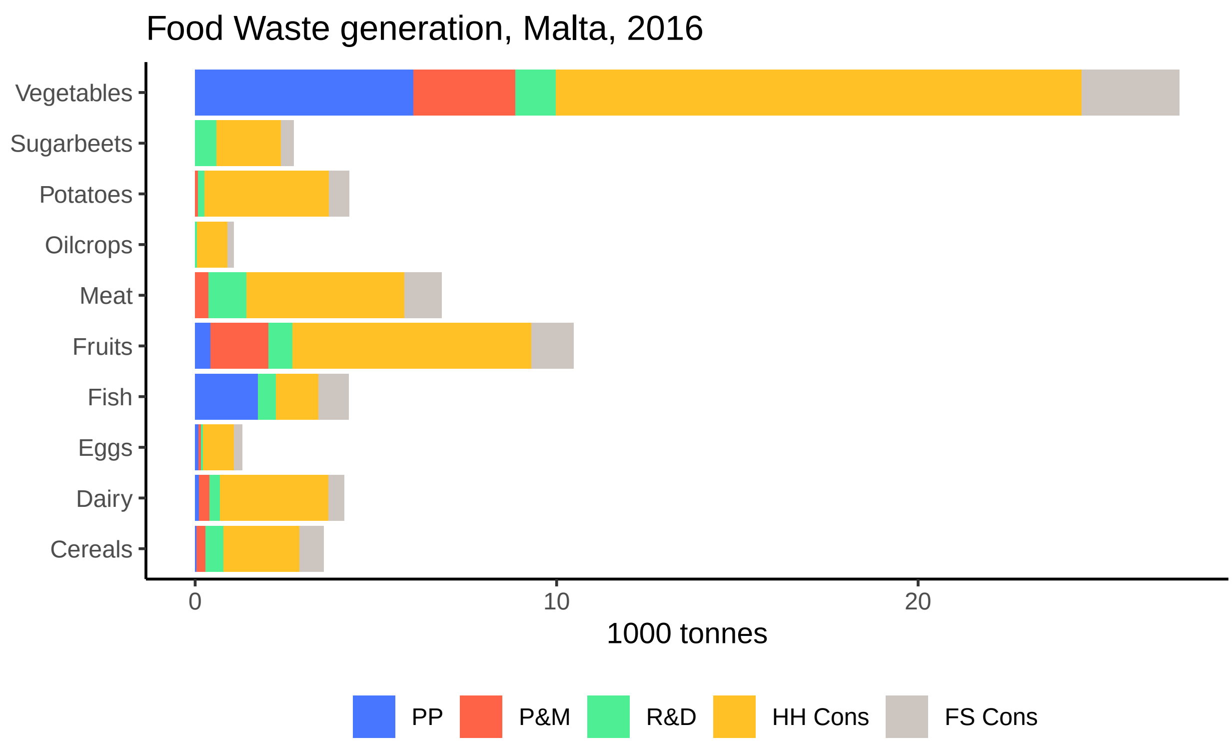


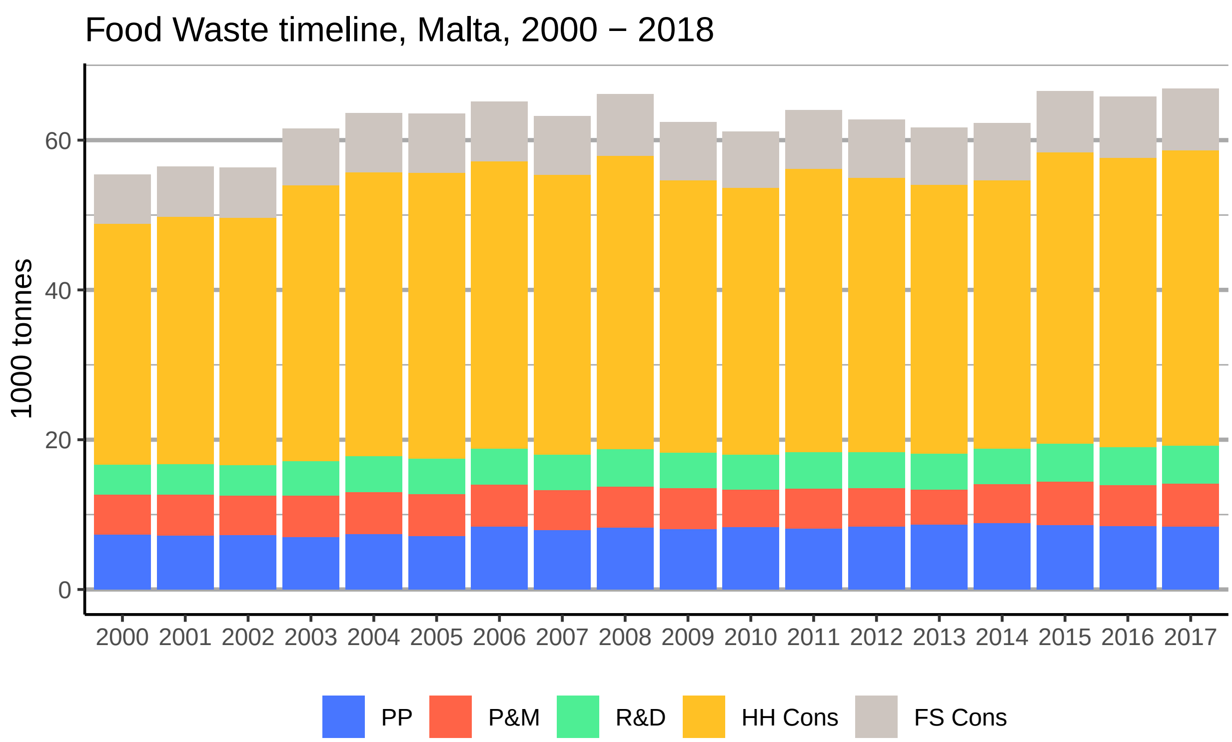
Table 37: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	54.25	8.83	0.31	8.03	NA
Fruits	NA	1.17	0.38	1.95	NA
Vegetables	4.72	8.02	5.94	2.81	NA
Potatoes	0.22	0.88	0.65	0.08	0.01
Sugarbeets	NA	NA	0	0	11.04
Oilcrops	NA	0.04	0	0.11	0.02
Meat	NA	NA	0.12	NA	13.96
Fish	15.04	NA	NA	0	NA
Dairy	2.42	7.83	NA	0	NA
Eggs	NA	0.9	NA	NA	0.19
Total	76.64	27.68	7.4	12.99	25.22

Table 38: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	1.1	4.7	1.5
Fruits	1.5	14.7	2.6
Vegetables	2.5	32.3	6.0
Potatoes	0.4	7.7	1.2
Sugarbeets	1.3	4.0	0.8

	R&D	HH Cons	FS Cons
Oilcrops	0.1	1.9	0.4
Meat	2.3	9.7	2.3
Fish	1.1	2.6	1.9
Dairy	0.7	6.7	1.0
Eggs	0.1	1.9	0.5
Total	11.2	85.9	18.1



Netherlands

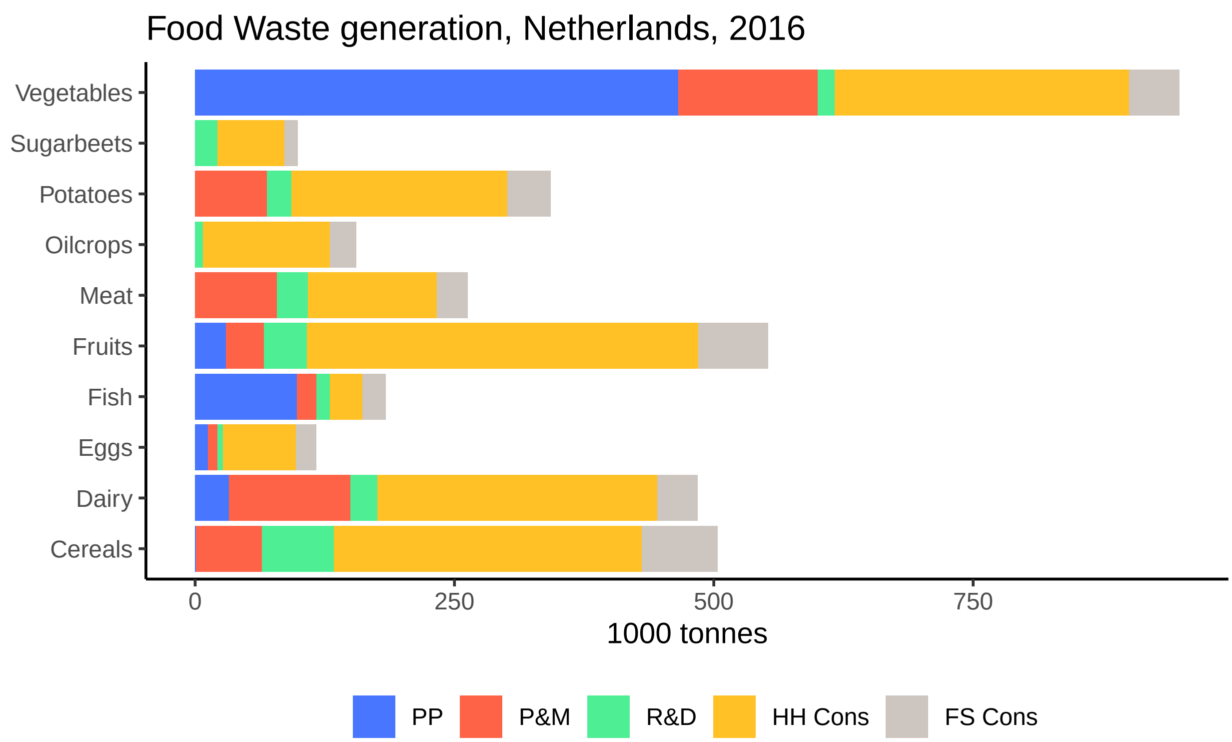


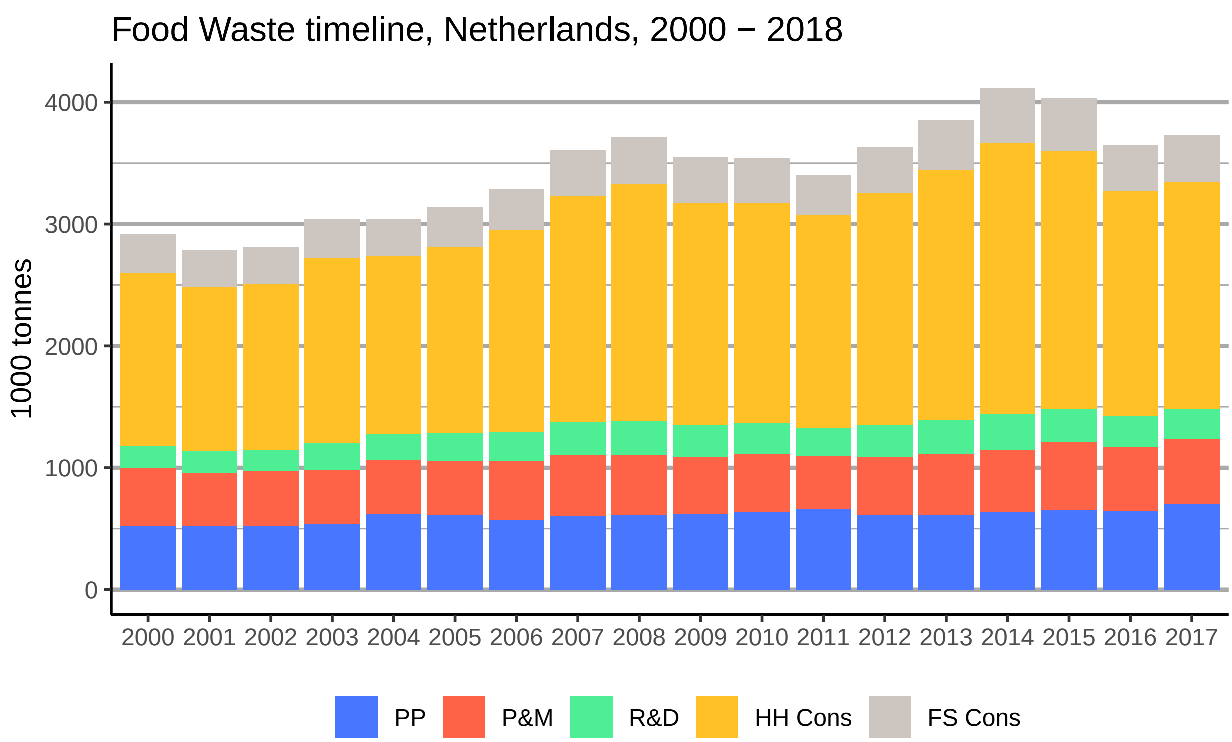
Table 39: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	7524.73	1582.75	7.49	909.06	NA
Fruits	NA	62.32	57.26	44.72	NA
Vegetables	309.32	83.26	389.27	134	NA
Potatoes	1065.2	1084.39	356.77	79.37	5.39
Sugarbeets	85.08	NA	85.08	279.6	134.32
Oilcrops	66.95	937.31	0.13	2124.45	0
Meat	NA	NA	35.2	NA	1819.23
Fish	117.81	114	NA	41.77	NA
Dairy	3751.52	NA	NA	0	NA
Eggs	NA	NA	NA	NA	20.34
Total	12920.61	3864.03	931.21	3612.98	1979.28

Table 40: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	4.1	17.5	4.3
Fruits	2.5	22.2	4.0
Vegetables	1.0	16.7	2.9
Potatoes	1.4	12.2	2.5
Sugarbeets	1.3	3.8	0.7

	R&D	HH Cons	FS Cons
Oilcrops	0.4	7.2	1.5
Meat	1.8	7.3	1.7
Fish	0.8	1.8	1.3
Dairy	1.5	15.9	2.3
Eggs	0.3	4.2	1.1
Total	15.0	108.8	22.3



Poland

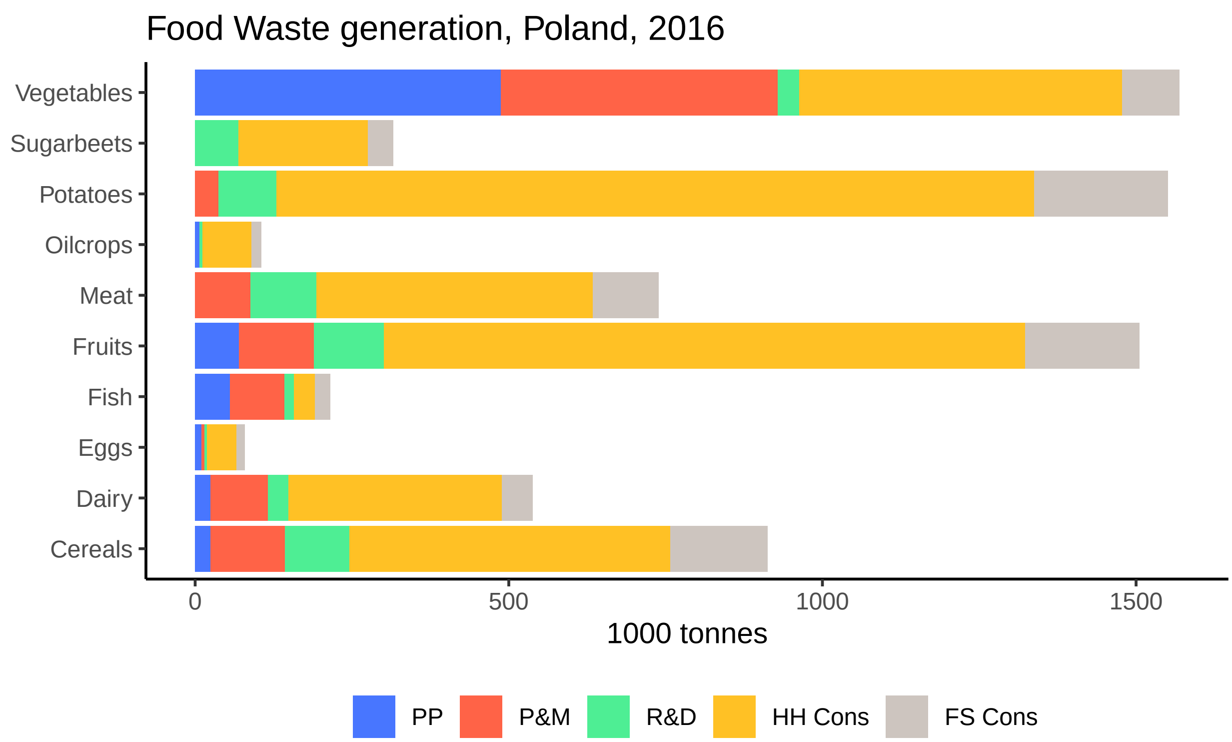


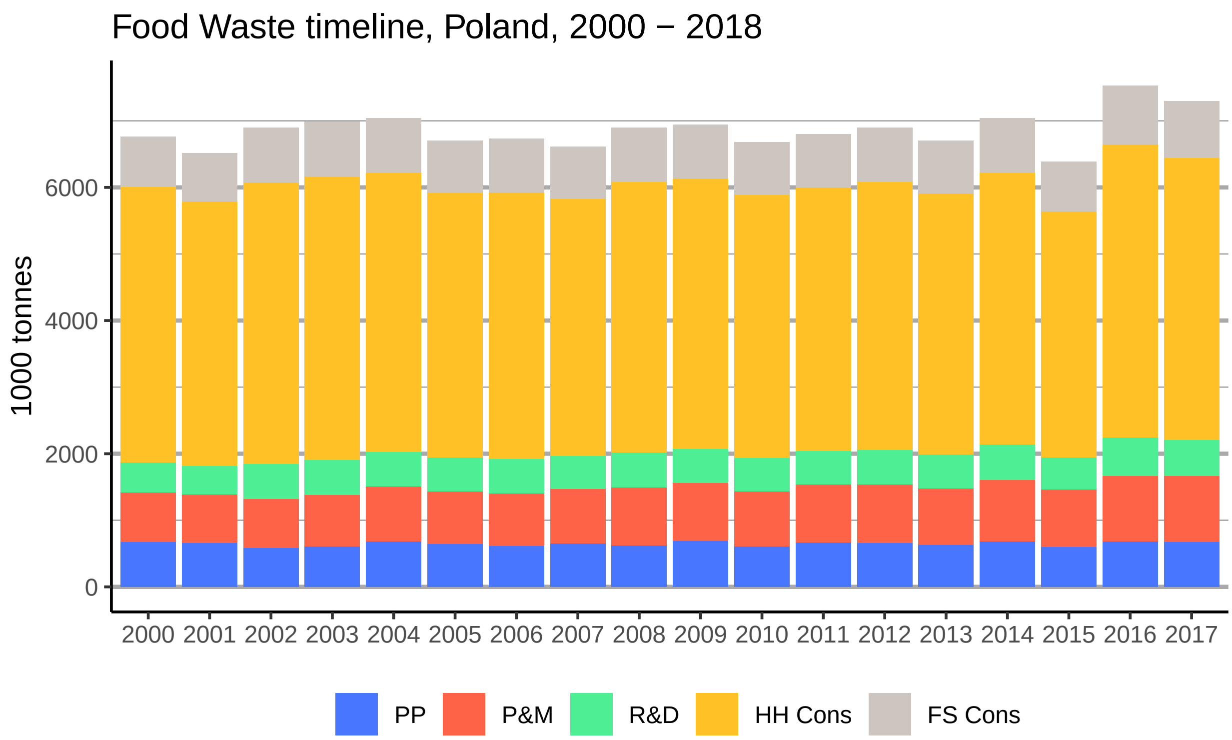
Table 41: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	16444.05	836.92	213.28	2177.58	NA
Fruits	NA	385.8	415.56	146.4	NA
Vegetables	706.3	93.65	473.55	441.35	NA
Potatoes	3046.94	219.54	516.56	42.17	2.87
Sugarbeets	209.13	NA	209.13	890.55	0
Oilcrops	NA	1472.82	61.37	613.84	0.91
Meat	NA	NA	43.71	NA	2939.21
Fish	73.55	NA	NA	195.85	NA
Dairy	3230.43	1774.73	NA	1111.2	NA
Eggs	NA	NA	NA	NA	12.65
Total	23710.41	4783.46	1933.16	5618.95	2955.63

Table 42: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	2.7	13.5	4.1
Fruits	2.9	26.9	4.8
Vegetables	0.9	13.6	2.4
Potatoes	2.5	31.8	5.6
Sugarbeets	1.8	5.4	1.1

	R&D	HH Cons	FS Cons
Oilcrops	0.1	2.0	0.4
Meat	2.8	11.6	2.8
Fish	0.4	0.9	0.6
Dairy	0.9	8.9	1.3
Eggs	0.1	1.2	0.3
Total	15.1	115.9	23.4



Portugal

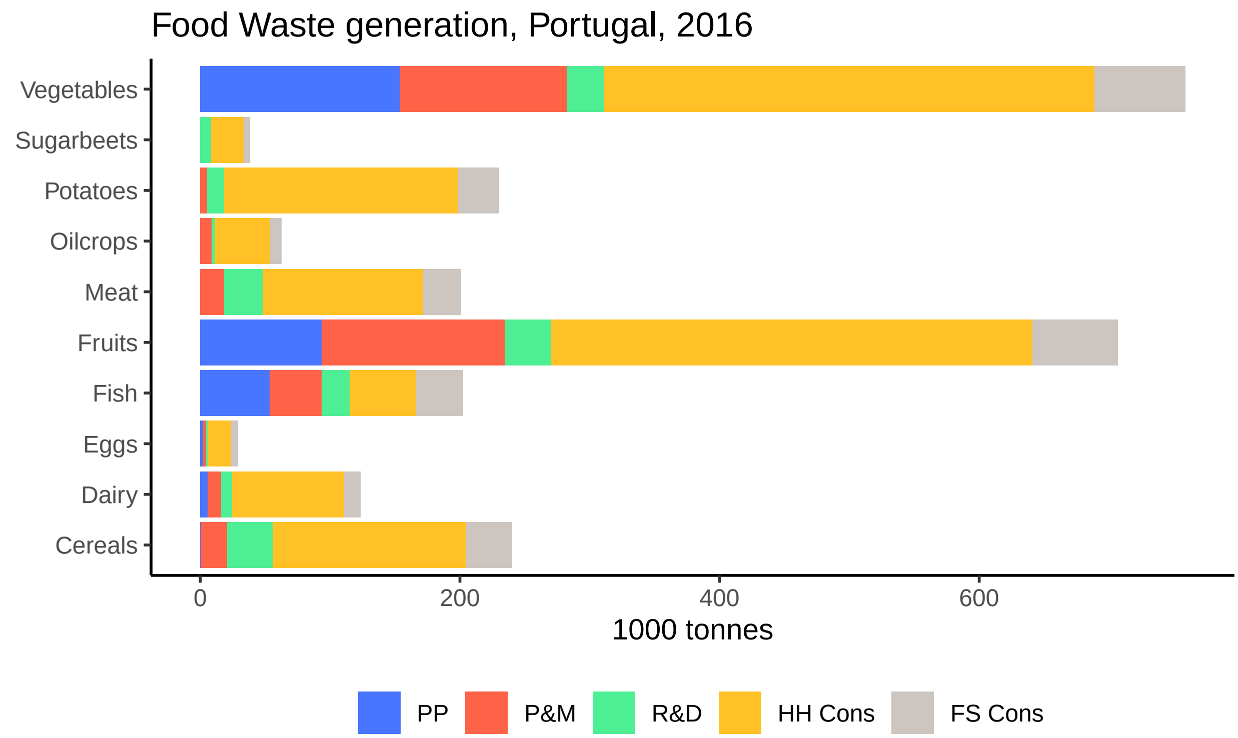


Table 43: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

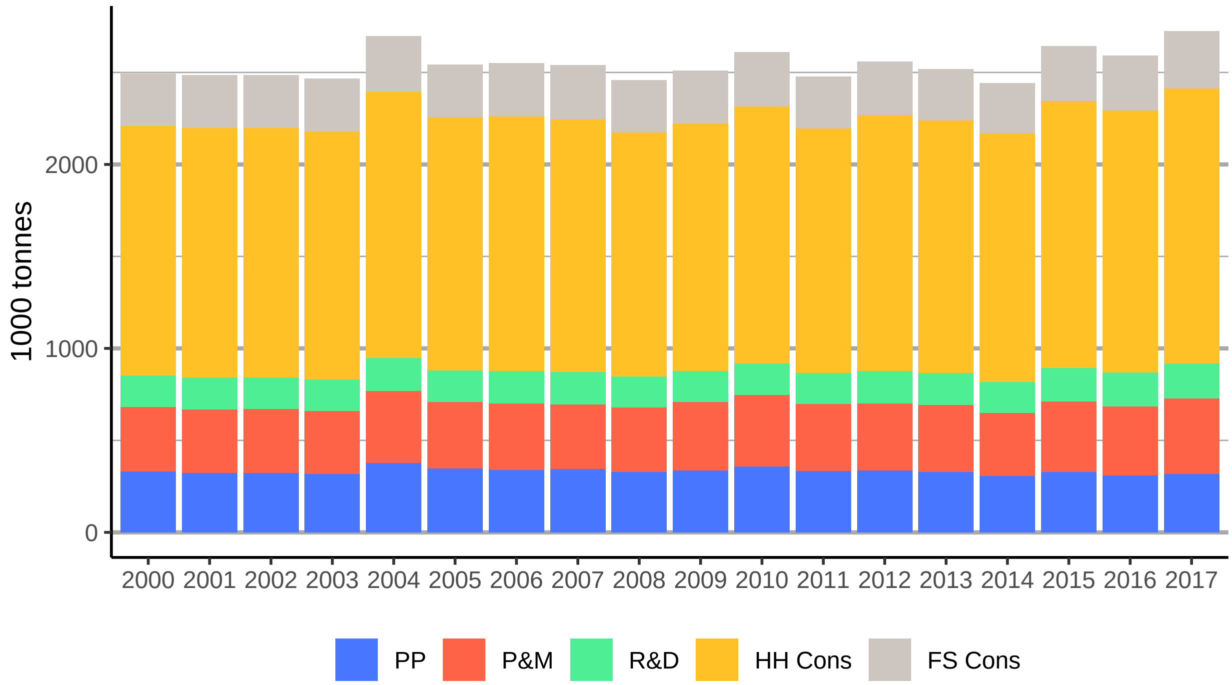
	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	3176.83	76	4.11	574.66	NA
Fruits	0.88	126.72	101.01	172.23	NA
Vegetables	97.13	83.64	83.9	128.31	NA
Potatoes	63.27	45.16	37.65	5.92	0.4
Sugarbeets	0.17	NA	0.17	0.58	11.96
Oilcrops	35.06	361.49	0.05	579.78	138.91
Meat	NA	NA	11.23	NA	683.84
Fish	2.79	NA	NA	89.57	NA
Dairy	59	95.29	NA	109.26	NA
Eggs	NA	NA	NA	NA	4.58
Total	3435.13	788.3	238.11	1660.3	839.68

Table 44: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	3.4	14.4	3.4
Fruits	3.5	35.8	6.3
Vegetables	2.8	36.5	6.8
Potatoes	1.3	17.5	3.0
Sugarbeets	0.8	2.4	0.5

	R&D	HH Cons	FS Cons
Oilcrops	0.2	4.1	0.8
Meat	2.9	11.9	2.8
Fish	2.1	4.9	3.5
Dairy	0.8	8.4	1.2
Eggs	0.1	1.8	0.5
Total	17.9	137.8	28.9

Food Waste timeline, Portugal, 2000 − 2018



Romania

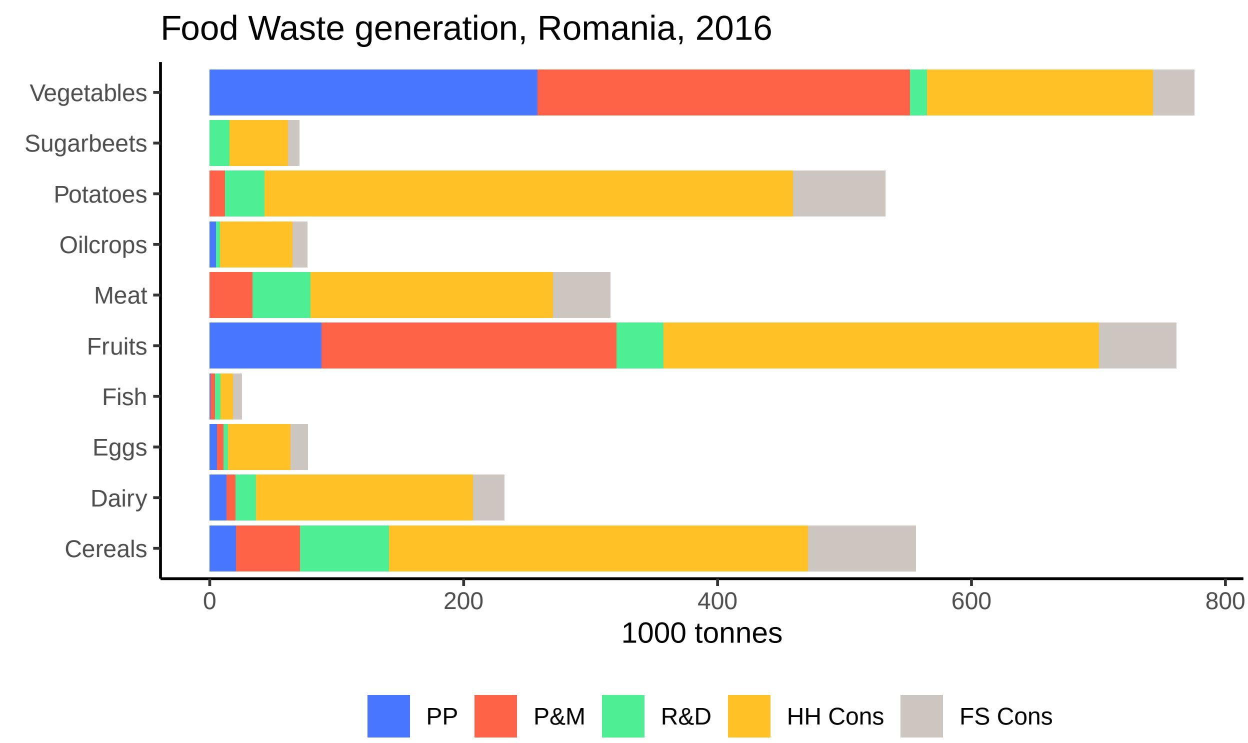


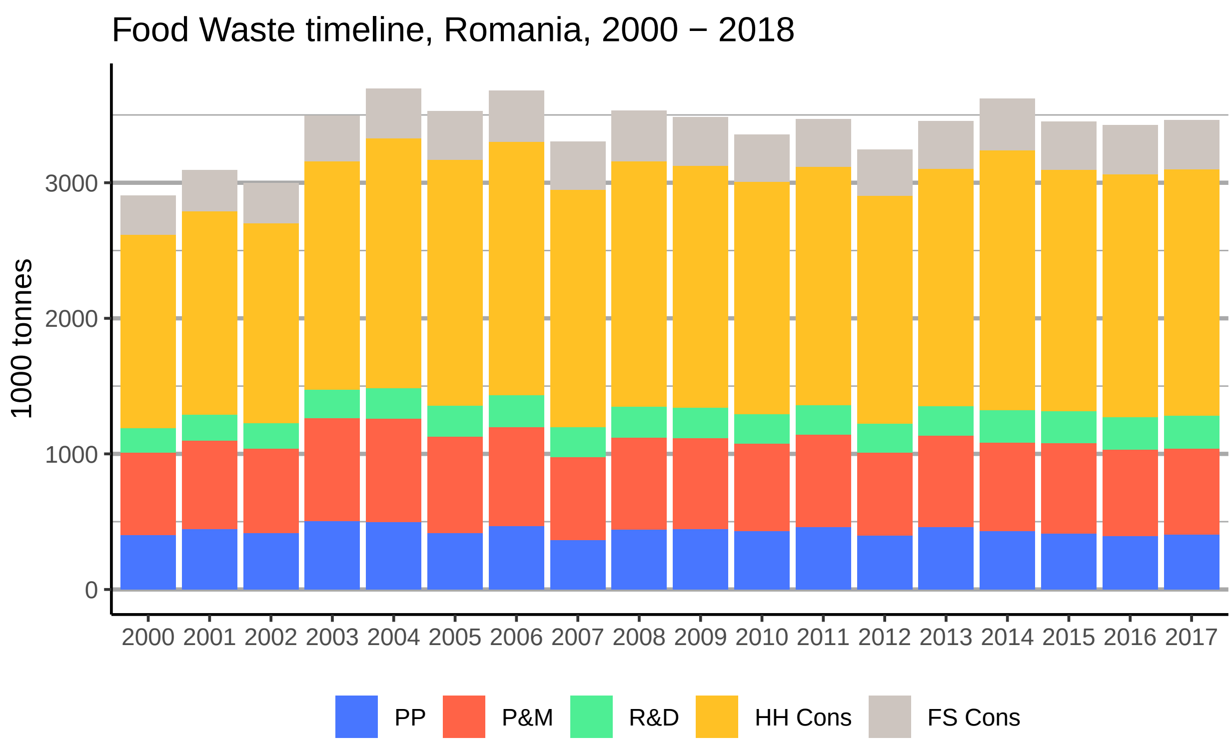
Table 45: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	9099.77	726.11	163.35	1127.01	NA
Fruits	89.37	200.31	117.86	283.92	NA
Vegetables	323.45	56.27	244.07	293.5	NA
Potatoes	211.88	156.09	183.17	13.97	0.95
Sugarbeets	55.7	NA	15.02	74.81	0
Oilcrops	12.62	91.36	44.55	791.38	0.17
Meat	NA	NA	14.49	NA	1025.75
Fish	13.96	2	NA	7.96	NA
Dairy	166.61	NA	NA	22.12	NA
Eggs	NA	17.6	NA	NA	11.95
Total	9973.35	1249.73	782.51	2614.69	1038.83

Table 46: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	3.6	16.7	4.3
Fruits	1.9	17.4	3.1
Vegetables	0.7	9.0	1.6
Potatoes	1.6	21.1	3.7
Sugarbeets	0.8	2.3	0.5

	R&D	HH Cons	FS Cons
Oilcrops	0.2	2.9	0.6
Meat	2.3	9.7	2.3
Fish	0.2	0.5	0.3
Dairy	0.8	8.6	1.2
Eggs	0.2	2.5	0.7
Total	12.2	90.7	18.3



Slovakia

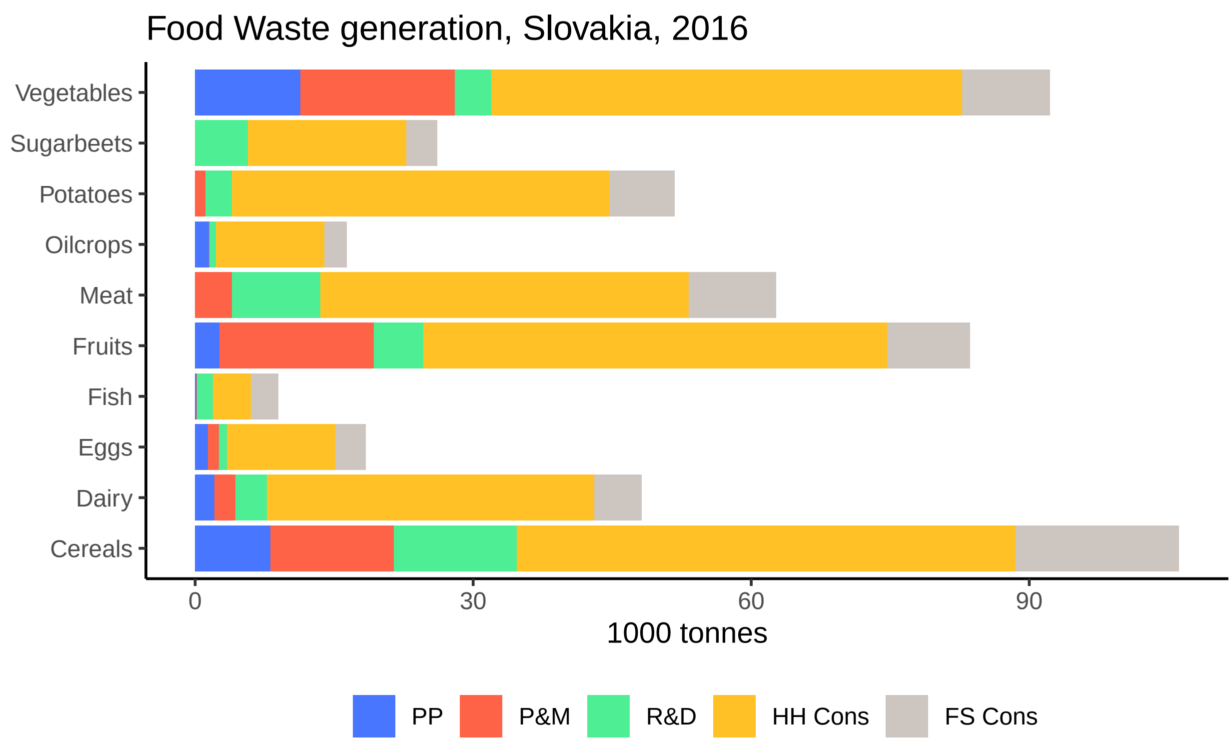


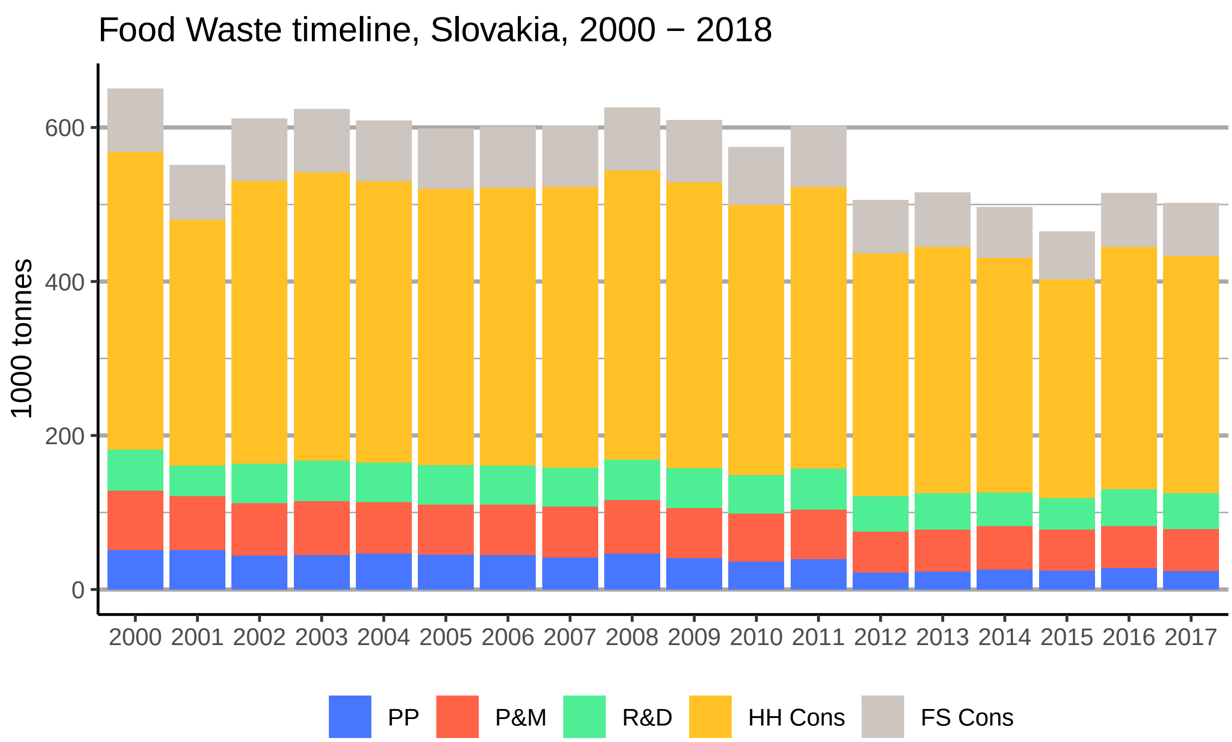
Table 47: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	1397.65	307.61	66.54	462.43	NA
Fruits	NA	4.9	4.35	20.39	NA
Vegetables	18.09	1.91	10.06	16.63	NA
Potatoes	6.09	5.47	16.42	1.3	0.09
Sugarbeets	23.3	NA	23.3	123.9	0
Oilcrops	5.04	249.19	13.83	251.68	0.02
Meat	NA	NA	1.51	NA	159.21
Fish	1.26	NA	NA	0	NA
Dairy	227.3	20.47	NA	23.82	NA
Eggs	NA	NA	NA	NA	2.65
Total	1678.72	589.55	136.01	900.14	161.96

Table 48: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	2.4	9.9	3.2
Fruits	1.0	9.2	1.6
Vegetables	0.7	9.4	1.8
Potatoes	0.5	7.5	1.3
Sugarbeets	1.0	3.1	0.6

	R&D	HH Cons	FS Cons
Oilcrops	0.1	2.2	0.4
Meat	1.8	7.3	1.7
Fish	0.3	0.8	0.5
Dairy	0.6	6.5	0.9
Eggs	0.2	2.2	0.6
Total	8.7	58.1	12.8



Slovenia

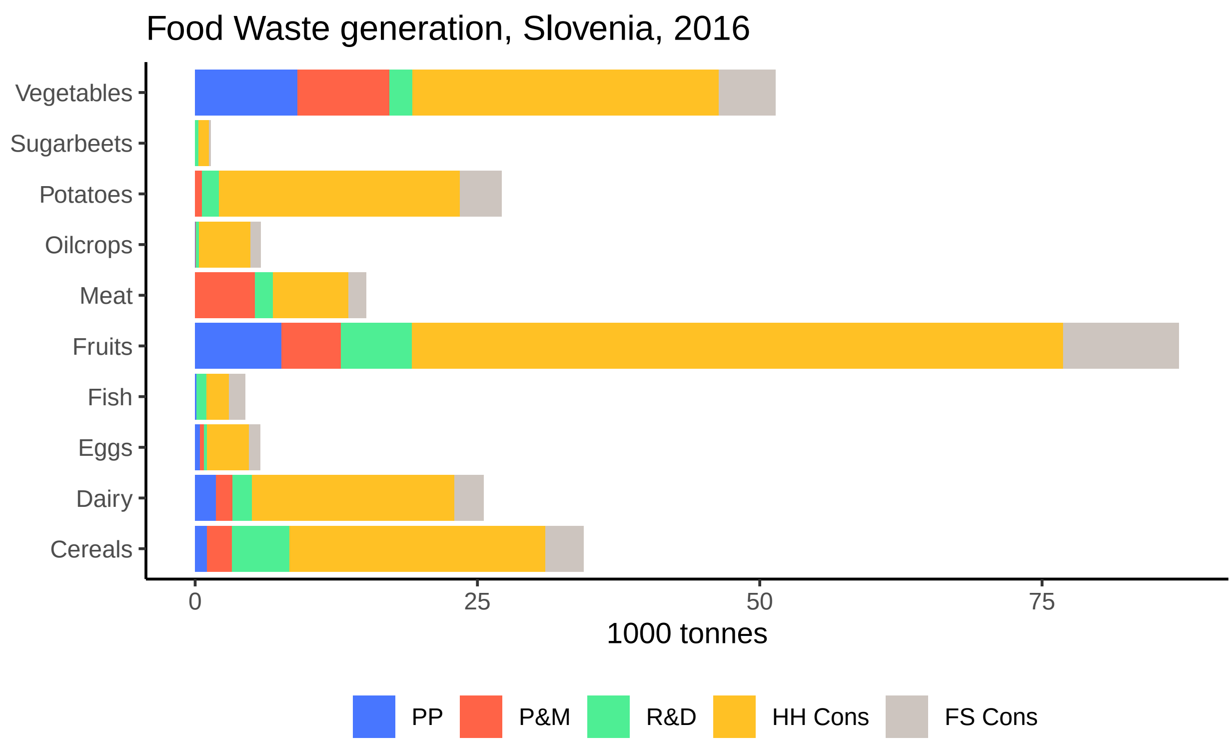


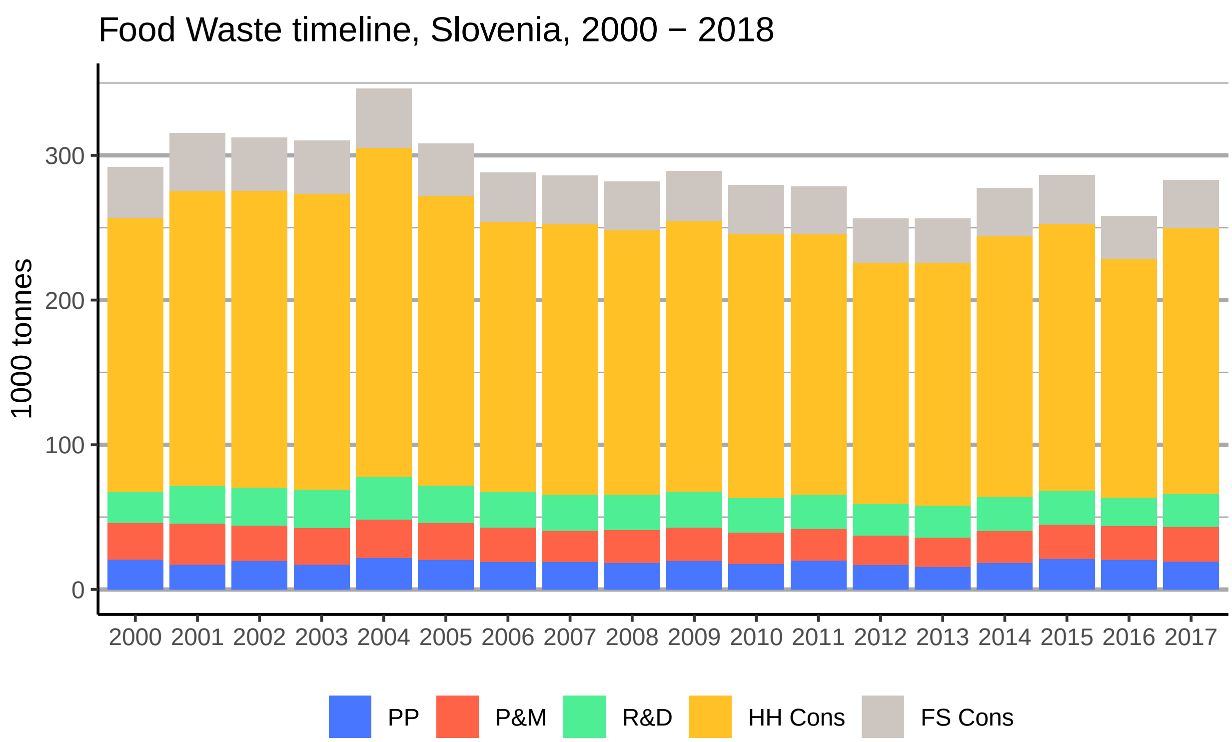
Table 49: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	321.12	15.41	9.23	115.14	NA
Fruits	NA	14.21	12.6	6.44	NA
Vegetables	6.2	1.48	9.24	8.12	NA
Potatoes	11.57	2.36	7.09	0.68	0.05
Sugarbeets	0.73	NA	0	0	8.28
Oilcrops	NA	0.22	0.32	2.09	0.62
Meat	NA	NA	1.71	NA	131.25
Fish	1.12	NA	NA	0	NA
Dairy	20.7	NA	NA	15.28	NA
Eggs	NA	NA	NA	NA	0.84
Total	361.43	33.68	40.2	147.74	141.04

Table 50: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	2.5	11.0	1.6
Fruits	3.0	28.0	5.0
Vegetables	1.0	13.1	2.4
Potatoes	0.7	10.3	1.8
Sugarbeets	0.1	0.4	0.1

	R&D	HH Cons	FS Cons
Oilcrops	0.1	2.2	0.4
Meat	0.8	3.2	0.8
Fish	0.4	1.0	0.7
Dairy	0.8	8.7	1.2
Eggs	0.1	1.8	0.5
Total	9.7	79.7	14.6



Spain

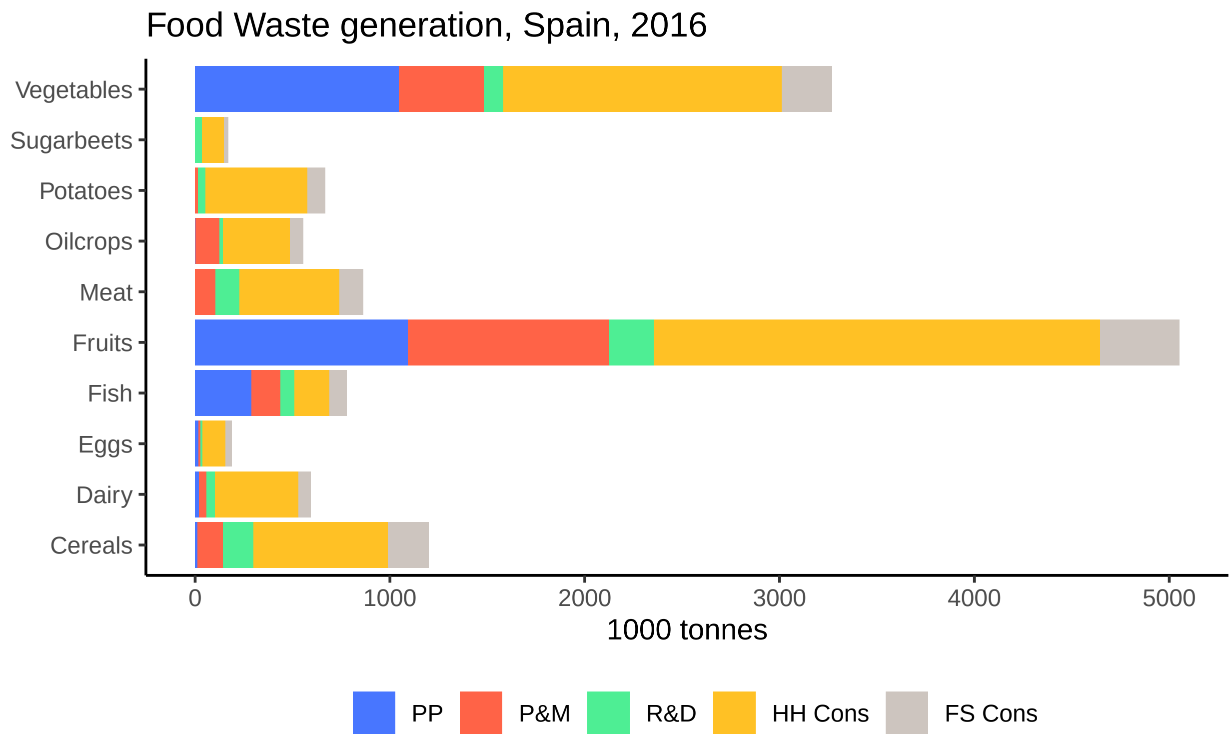


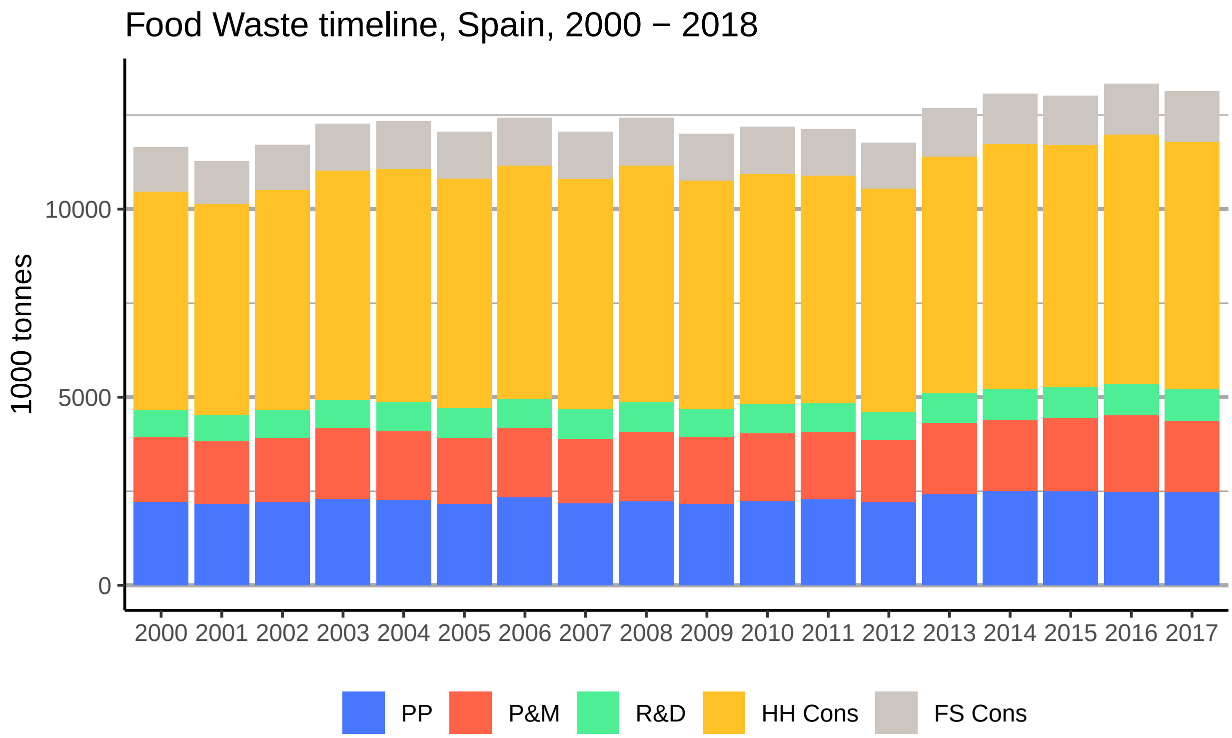
Table 51: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	29714.76	1232.88	109.21	3419.42	NA
Fruits	14.49	1696.62	941.52	1265.02	NA
Vegetables	1455.24	315.24	871.51	435.04	NA
Potatoes	169.18	380.5	183.3	16.89	1.15
Sugarbeets	46.61	NA	46.61	187.32	11.04
Oilcrops	256.21	1080.31	8.89	2709.98	1929.96
Meat	NA	NA	67.45	NA	4087.81
Fish	139.53	1	NA	330.89	NA
Dairy	895	439.85	NA	1097.52	NA
Eggs	NA	NA	NA	NA	29.61
Total	32691.01	5146.39	2228.49	9462.08	6059.56

Table 52: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	3.4	14.9	4.5
Fruits	4.9	49.3	8.8
Vegetables	2.2	30.7	5.6
Potatoes	0.8	11.3	2.0
Sugarbeets	0.8	2.4	0.5

	R&D	HH Cons	FS Cons
Oilcrops	0.4	7.4	1.5
Meat	2.6	11.1	2.6
Fish	1.5	3.9	1.9
Dairy	0.9	9.3	1.3
Eggs	0.2	2.6	0.7
Total	17.8	142.7	29.3



Sweden

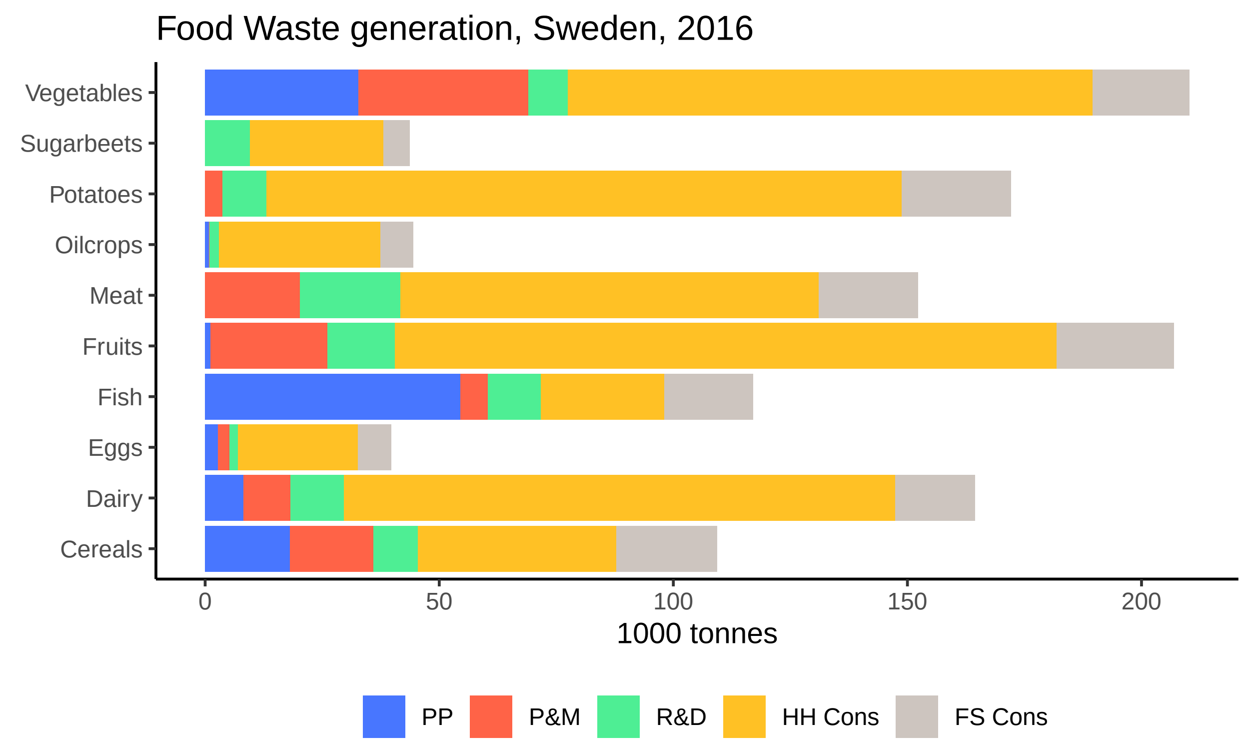


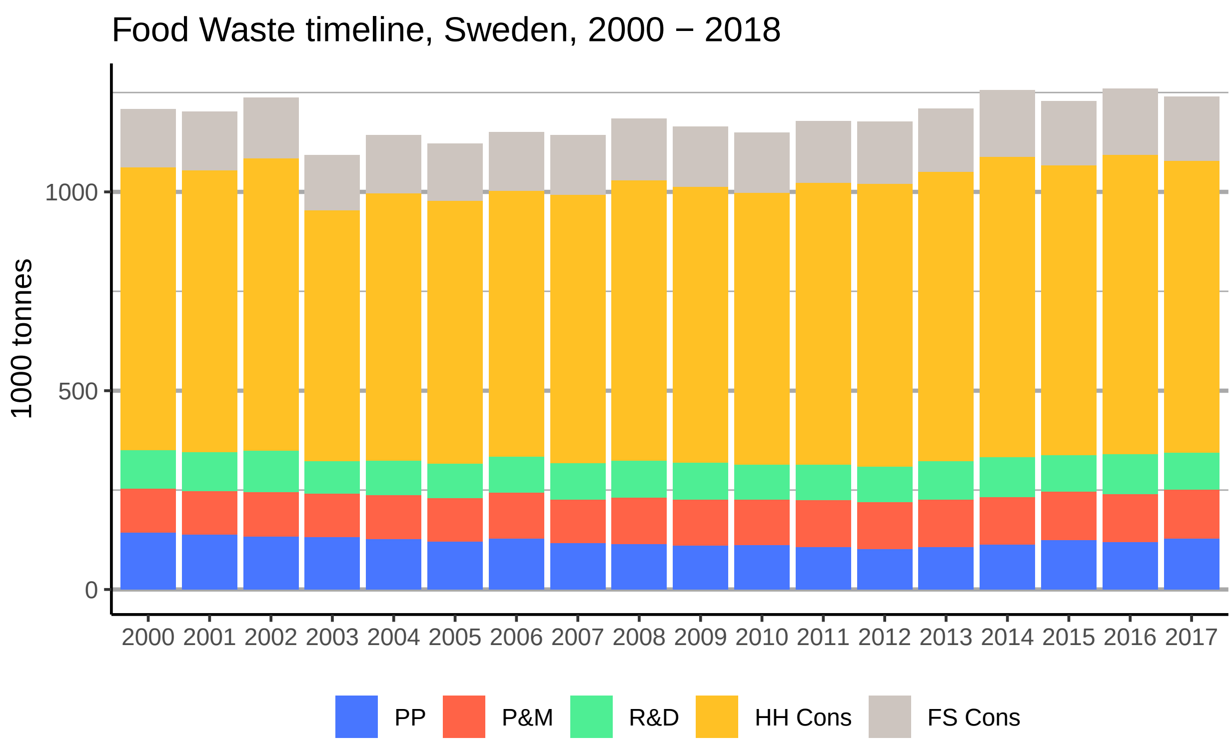
Table 53: Amount of each commodity used for animal feed and non-food uses at PP and PM, and food losses generated at PP.

	PP Animal feed	PP Non-food	PP Losses	P&M Animal feed	P&M Non-food
Cereals	2576.13	63.15	11.74	393.01	NA
Fruits	NA	3.52	3.54	30.52	NA
Vegetables	171.97	9.64	39.37	36.29	NA
Potatoes	64.35	265.31	52.66	4.25	0.29
Sugarbeets	133.81	NA	29.12	78.53	15.64
Oilcrops	7.9	162.94	7.39	83.39	0.85
Meat	NA	NA	6.1	NA	533.02
Fish	81.86	NA	NA	13.06	NA
Dairy	118.41	0.92	NA	316.4	NA
Eggs	NA	NA	NA	NA	5.62
Total	3154.42	505.49	149.92	955.45	555.42

Table 54: Per capita food waste generated at RD, HH Cons and FS Cons. Values expressed in kg person-1 year-1.

	R&D	HH Cons	FS Cons
Cereals	1.0	4.3	2.2
Fruits	1.5	14.3	2.5
Vegetables	0.9	11.4	2.1
Potatoes	0.9	13.8	2.4
Sugarbeets	1.0	2.9	0.6

	R&D	HH Cons	FS Cons
Oilcrops	0.2	3.5	0.7
Meat	2.2	9.1	2.1
Fish	1.1	2.7	1.9
Dairy	1.2	12.0	1.7
Eggs	0.2	2.6	0.7
Total	10.1	76.5	17.0



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doi:10.2760/316306

ISBN 978-92-76-37275-2