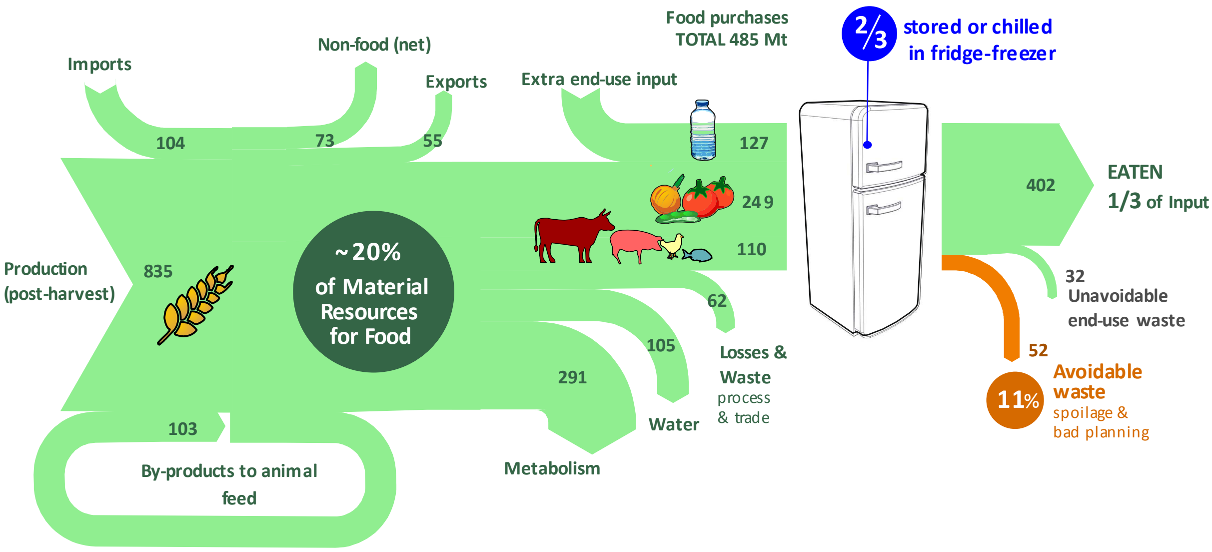
European Commission

Complementary research household refrigeration

Preparatory/review study on Commission Regulation (EC) No. 643/2009 and Commission Delegated Regulation (EU) No. 1060/2010 – complementary research on

Optimal food storage conditions in refrigeration appliances



FINAL REPORT

VHK for the European Commission

In collaboration with Oakdene Hollins

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The information and views set out in this study are those of the author(s) and do not necessarily reflect the official opinion of the European Commission

Energy

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Glossary

ADEME	l'Agence de l'environnement et de la maitrise de l''energie (French Environment and Energy Management Agency)
AMRCR	Asociatia Marilor Retele Comerciale din Romania (the Association for Large Commercial Networks in Romania)
aw	water activity
'best-before' date	the recommended last consumption date, informs about the physical condition and organoleptic quality, can be consumed after this date but may no longer be at its best quality
CA	Controlled Atmosphere
CBS	Centraal Bureau voor Statistiek (Statistics Netherlands)
CCFRA	Campden and Chorleywood Food Research Association
CDC	Centers for Disease Control and Prevention
CECED	European Committee of Domestic Equipment Manufacturers
CREM	Bureau voor duurzame ontwikkeling, Amsterdam
DMC	Domestic Material Consumption (measures the total amount of materials directly used by an economy and is defined as the annual quantity of raw materials extracted from the domestic territory, plus all physical imports minus all physical exports)
ECFF	European Chilled Food Federation
EFSA	the European Food Safety Authority
ErP	Energy-related Products
EUFIC	European Food Information Council
EUMOFA	European Market Observatory for Fisheries and Aquaculture Products
FAO	the Food and Agriculture Organisation of the United Nations
FAOSTAT	FAO statistical data on food and agriculture for over 245 countries and territories from 1961 to the most recent year available
FBO	Food Business Operator
FBS	Food Balance Sheets of the Food and Agriculture Organisation
FEFAC	the European Feed Manufacturers' Federation
FoodFlow	the overall diagram containing the main food flows of the EU
FSAI	Food Safety Authority of Ireland
FUSIONS	Food Use for Social Innovation by Optimizing Waste Prevention Strategies
HACCP	Hazard Analysis and Critical Control Points
IEC	International Electrotechnical Commission
IFR	Institute of Food Research
ISWA	International Solid Waste Association
kt	Kilo tonnes, 1 kt = 1000 metric tonnes
MAP	Modified Atmosphere Packaging
MJ	Mega Joules (Net Calorific Value, unless specified differently)
Mt	Mega tonnes, 1 Mt = 1 000 000 metric tonnes=10^9 kg
Mtoe	Mega ton oil equivalent, 1 Mtoe=4.1868 x 10^4 TJ= 41.868 x 10^9 MJ
NGO	Non-governmental Organisation
OECD	the Organisation for Economic Co-operation and Development
OVAM	Public Waste Agency of Flanders

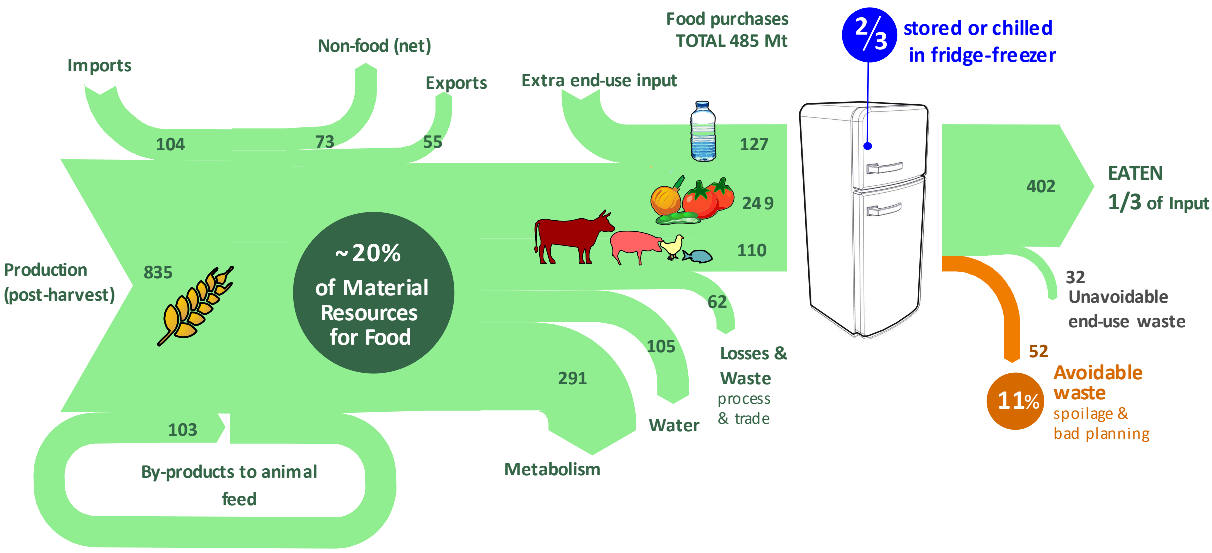
pH	numeric scale to specify the acidity
RH	relative humidity
RIVM	Rijksinstituut voor Volksgezondheid en Milieu (National Institute for Public Health)
RSE	Raw Sugar Equivalent
RTE	Ready to eat foods
shelf life	the period of time for which a product remains safe and meets its quality specifications under expected storage and use conditions
SIK	the Swedish Institute for Food and Biotechnology
SMP	Skimmed Milk Powder
UCO	Used Cooking Oil, a.k.a. RVO (Recycled Vegetable Oil)
UHT	Ultra-High Temperature
'use-by' date	the last consumption date, informs about microbiological safety, should not be consumed after this date
VTEC	verocytotoxigenic Eschericia coli
WFD	Waste Framework Directive
WFLO	World Food Logistics Organisation
WHO	World Health Organisation
WMP	Whole Milk Powder
WP	Whey Powder
WRAP	the UK waste and Resources Action Programme
WRI	World Resource Institute
WWF	World Wildlife Fund

Executive summary

The preparatory review-study on the Ecodesign and Energy Labelling of household refrigeration (VHK, March 2016) identified opportunities where refrigeration appliances can make a valuable contribution to fighting food waste, which is an important component of the European Commission's 'circular economy' package.
This complementary study explores the size of the problem, optimal storage conditions for prolonged food shelf-life, the quantitative balance between avoiding food waste through better refrigeration and the possible increase of energy use of the refrigeration appliances, and possible policy measures to reach the appropriate balance between the two.

As this study shows, food production 'from farm to fork' constitutes almost 20 weight percent of the EU's Domestic Material Consumption (DMC), comparable --in weight-- to the DMC of all energy carriers. End-users, i.e. private households and food services, waste 18% of those resources. Of this end-use waste, 60% (11% of the total end-use waste) is due to food spoilage and bad planning and thus avoidable. This study aims --as much as current incomplete data allow-- to give a comprehensive overview of food flows in the EU to give policy makers a correct starting point for a conservation strategy and lay a sound basis for further analysis.

Refrigeration appliances store two-thirds of the food and drinks prior to consumption and waste disposal. They play a major role in preventing food spoilage and could possibly contribute to better planning if they were designed more adequately.

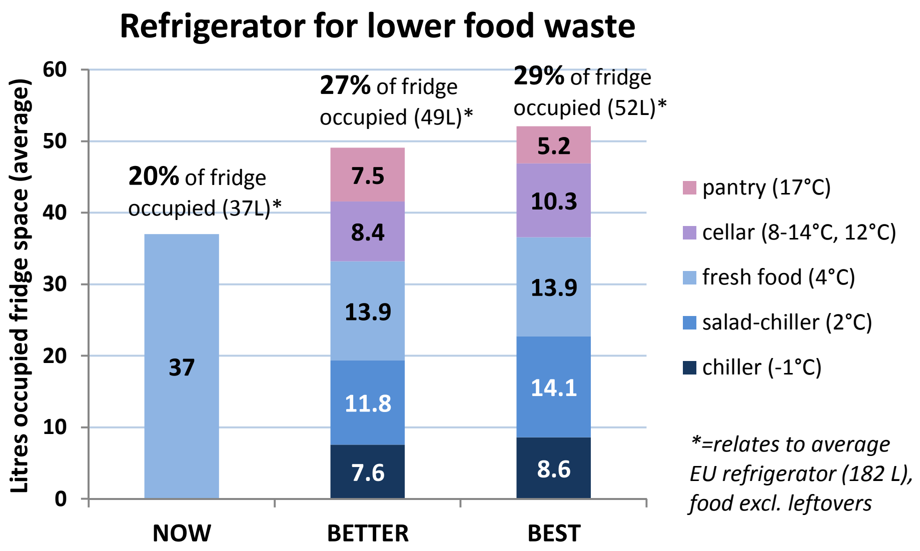


Simplified EU food flow diagram (more detailed inside the report)

Currently, over 85% of refrigeration appliances offer --apart from a freezer compartment-- only a single fresh food compartment at a temperature of +4°C. For about half of the fresh food (and drinks) this is either too warm or too cold for best fresh food preservation. The presence of a chiller (-1°C) and a 'cellar' compartment (8-14°C) could increase the shelf-life, in days, with on average a factor 3 or 4. For certain foodstuffs like fresh meat, that required large resources to produce, the shelf life could be prolonged from 3 to 20 days by using a chiller instead of the usual fresh food temperature.

An appropriately designed refrigeration appliance is an important condition to realise much longer shelf-life, but it is not the only condition for end-users to change their behaviour. The current food labelling practice of suppliers setting 'use-by' dates based on a worst-case scenario is the reported reason of large part of the avoidable food waste, at least for some (animal-origin) foodstuffs. If a strategy of less food waste through better refrigerated preservation is to be successful for these products, appropriate lateral measures are strongly recommended.

Preliminary calculations from EU food flows and findings on optimised storage conditions, show that --purely based on the occupied storage space of relevant foodstuffs and 'all other factors being equal'-- the ideal food-conserving refrigerator with extra cellar and chiller compartments would consume at least 20% more electricity than today's reference. The total volume is slightly bigger and the average temperature is slightly lower.



Comparison of occupied space (in L) and storage temperatures for current, 'better' and 'best' refrigerator in terms of food storage

Having said that, 'all other factors' need not be equal. At the moment, the average refrigeration appliance is --even when taking into account peak usage twice as high as average-- at least a factor two oversized. On average, the foodstuffs -including sufficient extra space for effective cooling-- occupy only one quarter of the refrigerated space available. Secondly, the preparatory study showed that for household refrigerators there is still a significant technical saving potential of up to 30-40% and an economic saving potential of 18-20%. This means that a future food-saving appliance would not use more in an absolute sense, but it would save less. Thirdly, the existence of several different temperature compartments ranging from -1°C to +17°C creates new energy saving possibilities, e.g. from cascading and re-use of 'waste cold' from defrosting.

Nonetheless, even when not considering these three factors, it would be enough --in terms of mass and energy equivalent-- to save 2% on end-use food waste, i.e. 9% instead of 11% avoidable waste, to compensate for a 20% higher energy use of the refrigerator.

This confirms that there is a solid basis for policy makers to allow multi-door correction factor for refrigeration appliances in Ecodesign and Energy Labelling. At least this would no longer penalize the multi-door appliances, with e.g. inherently larger door-leakage energy losses than a single-door refrigerator, in Ecodesign and Energy Label rating.

Secondly, harmonisation at EU-level of (parts of) setting 'use-by' dates is recommended. For instance, comparable to today's food labelling for frozen products, the use-by dates could differentiate between storage at +4°C (normal refrigerator) and -1°C.

Last but not least, information campaigns raising consumer-awareness are important. When linked to proper use of the (relatively new) cold storage facilities and the benefits of not only less food waste but also healthier and tastier food, it is believed that such campaigns could be more successful then campaigns to change wasteful behaviour in general.

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1 Introduction

1.1 Scope

The preparatory review-study on the Ecodesign and Energy Labelling of household refrigeration (VHK, March 2016) identified opportunities where refrigeration appliances can make a valuable contribution to fighting food waste. EU households throw away a significant part of the food purchased, with over half of that food waste being avoidable. Fighting food waste is an important component of the 'circular economy' package in the 7th Environmental Action Plan.

Refrigeration appliances can help in food planning and logistics, but above all they can create the right storage conditions to prolong the life of food (prevent food decay) and enable re-use of leftovers. Currently, most household refrigerators offer only one fresh-food temperature, nominally +4°C, which is often too warm or too cold for specific foodstuffs and drinks. Ideally, apart from the freezing at -18°C, ideally there should be 3 or 4 refrigerator temperatures/atmospheres: a 0°C meat/fish chiller, a 2°C salad chiller, a 4°C dairy and meat-cuts fridge, a 8-12°C cellar for most fruit, 'fruity' vegetables and beverages. Over 60% of EU dwellings do not have a cellar and, apart from offering the best temperature, a higher-temperature cellar compartment cutting down on the volume of lower-temperature compartments also offers an opportunity for saving refrigeration energy. Also, the presence of a higher temperature cellar or pantry increases the opportunities for energy saving by capturing the 'waste-cold' from low-temperature compartments and defrosting ('cascading' of heat/cold). The cascading of temperatures in one appliance offers interesting possibilities for energy cascades and thus further savings.

Rough estimates in the preparatory review-study claim that, although they might be slightly bigger, future refrigerators can be better for healthier, tastier food and save on energy. If only 10% of food waste can be avoided the annual savings on energy resources invested in food would be substantially higher than the total annual electricity consumption of the household refrigerator.

Realising the transition to better food preservation at lower energy use is a considerable challenge. It entails raising awareness, promoting the right refrigeration products to come on the market, stimulating consumers to use these products correctly, convince food authorities to take the improved new practice into account in food safety, etc. It is therefore important to get the facts straight from the start:

- What and how much foodstuffs are involved at EU level?
- What are the optimal storage conditions?
- What could better refrigeration technology contribute. This includes lowering EU energy use because of less food waste? and,
- What could be possible measures that policy makers may take to enhance the process?

These are the subjects of this study.

1.2 Approach

The study will be conducted by VHK, assisted by Oakdene Hollins. VITO is contract manager. VHK is a technical specialist with a long track-record in ecodesign and household refrigeration. Oakdene Hollins specialises in conservation of materials resources and has been responsible for many studies for the UK Waste & Resources Action Programme (WRAP) on the topic of food waste. The start date of the 7-month project is the 27th of June 2016 and a final report is foreseen in January 2017.

The main activity for this exploratory study will be desk-research, possibly complemented by bilateral consultation of experts at the end of the project. Project-tasks include assessments of:

1. Food mass flows relevant for household refrigeration (flow-diagrams including consumption and waste);
2. Optimal storage conditions (temperature, humidity and relevant (bio)chemical ambient);
3. Relevant EU and international legislation on household food storage conditions;
4. Current storage conditions in cold appliances offered on the market (e.g. from CECED database);
5. Possible policy options under Ecodesign and Energy Labelling, including an estimate of the order of magnitude of expected savings in the short- and long term.

1.3 Possible results

Task 1: Food mass flows
Task 1 is expected to be the most labour-intensive by far. Preliminary research shows that information will be fragmented and incomplete. In the wake of the awareness-raising 2011 FAO-study, several countries and research institutes have started to focus on the food waste problem[1], but, as confirmed by the recent FUSIONS project[2], there is still a considerable way to go in mapping the EU's local food and food-waste habits.

Nonetheless, the aim is to come to a workable dataset on food mass flows that can serve as an input for policy decisions. Furthermore, the EU food flow diagram will give policy makers an idea of the size of the problem and will help set priorities.

Task 2: Optimal storage conditions
The highest gain is expected in differentiation in fresh food conservation, rather than possible optimisation of frozen food storage conditions. Once the first dataset is robust enough, there will be a selection by relevance for refrigerated storage (storage at 17°C or lower). This means that non-perishable foodstuffs and items that are optimally stored at ambient indoor conditions (18-22°C, 50% RH [3]) will be excluded. This will be done in task 2. The foodstuffs will be clustered to groups with similar storage conditions. The compartment temperatures and other defined conditions in the household refrigeration regulations, amended by the definitions in the new IEC 62552:2015 standard, can be a first yardstick. Most relevant will be the distinction between 'pantry' (17°C), 'cellar' (8-12°C), 'refrigerator' (4°C) and 'chiller'. Following the discussions during the review study it is proposed to split the 'chiller' definition in two types: a 'meat/fish' chiller with instantaneous temperature Ti of $-3 \leq Ti \leq +2$°C and an average test temperature Ta of 0°C and a 'salad' chiller with instantaneous temperature Ti of $0 < Ti \leq +3$°C and an average test temperature Ta of 2°C. Apart from the above, a distinction could be made between foodstuffs that can be stored at ambient conditions but are best served chilled (e.g. soft-drinks, beer).

[1] In the Netherlands there are studies by the Netherlands Voedingscentrum, Wageningen University and CREM. In Germany, the ISWA, University of Stuttgart, is active in the field. At EU level JRC Ispra has looked into the state of play of food waste and possibilities for improvement.
[2] www.eu-fusions.org
[3] RH=Relative Humidity

Task 3: Legislation
Task 3 looks at legal barriers to longer storage periods. Specifically, the 'use by' or 'best before' dates that are displayed on the packaging of many foodstuffs are a strong deterrent in that respect. Recent research by Oakdene Hollins identified that the procedure to assess these dates is based on relatively conservative estimates of typical storage conditions and storage periods. Amongst others, it is assumed that the typical storage temperature in a household refrigerator is based on an actual setting of 7°C instead of the nominal setting of 4°C (according to the new IEC refrigerator standard). To make optimal use of improved storage conditions in the future, it would be desirable that they are considered or at least become more flexible (e.g. using indicators with thermal ink, or displaying a range of dates depending on storage conditions).

Task 4: Current storage conditions
In Task 4 the CECED database offers the basis to assess the current lay-out, size and storage temperatures of household refrigeration appliances offered on the market. The 2014 database contains over 18 000 models, with their characteristics, currently on sale in the EU. Also in Task 4, the study team will make a brief inventory of the actual storage temperature for countries where such information is available.

Task 5: Possible policy options
As mentioned, Task 5 will give suggestions for policy options and the order of magnitude of related savings. Suggested policy options to reduce food waste through better storage will distinguish between short-term, with a focus on review of Ecodesign measures for refrigeration appliances, and long-term options, which may also relate to specific barriers for taking maximum advantage of better storage conditions such as the 'best before' and 'use by' dates mentioned above.

Short-term policy decisions may relate to specific provisions in ecodesign measures on household refrigeration that is currently under review, for example promoting more differentiation in storage conditions through specific allowances, bonus-malus measures, etc. Medium- and long term measures may reach further than the strict ecodesign scope, e.g. technology procurement, incentives and promotion, review of current policy on 'use by' dates, etc.

1.4 Study team

The study is conducted by VHK in collaboration with Oakdene Hollins. VHK is the author of the preparatory review study on household refrigeration and a specialist in Ecodesign related mass-flow and energy accounting. Expertise from the latter was applied to the analysis of food flows in Task 1. Apart from that, VHK has also recently acquired expertise in the field of life sciences to undertake the assessment of optimal storage conditions. Oakdene Hollins is a specialist in food waste related research and has been the contractor for many of the food-waste research studies commissioned by UK WRAP. Oakdene Hollins has made an assessment of the legal barriers to longer storage periods in Task 3 and has assisted VHK in the general review. Task 4 takes on board the findings of the preparatory review study as regards the design and storage conditions offered on the EU market and tries to take it one step further, i.e. estimating how designs with more appropriate storage conditions would look like in terms of compartment volumes and storage temperatures.
Task 5 on policy options sums up the main findings of the study and makes suggestions for policy action to promote less food waste through better refrigeration (eco) design.

2 Methodology and data sources (Task 1)

2.1 Introduction

This research is complementary to the preparatory review study on household refrigeration appliances. The inventory of food consumption and food waste flows is thus not a goal in itself, but the research is to provide meaningful results in the context of improved design of these appliances in terms of optimal food storage conditions.

On the other hand, the data availability is such that a considerable effort by the authors is required to assess even an order of magnitude of the food flows involved. Results on food waste are widely diverging due to differences in scope, approach and knowledge of the authors. There are definition-problems, but also inherent accounting problems, e.g. on the water content of various foodstuffs in various stages. There are only a handful of primary sources, i.e. where authors actually performed 'field-work' in generating food waste data. Sample sizes for this field work are generally small and participants may not always be unbiased. In that sense, compared to e.g. energy accounting, food chain accounting appears to be in its infancy.

There are numerous awareness-raising secondary sources, i.e. where authors that put together new data based on quick desk-research, but transparency is often lacking and consistency checks are impossible or require substantial effort.

Examples of consistency checks include

- Household food waste is the difference between the food intake (eaten) and the food purchased by households. If it isn't, there must be a reason, either in the definitions, e.g. where the food intake relates to both consumption at home and out-of-home, or in the quality of the various surveys.
- Total food waste from end-users includes both waste at home and at food services. Ignoring that fact may lead to a wrong impression on consumer food waste behaviour.
- Food waste of households is the sum of at least 3 components: solid waste going to waste collection, (semi-)liquid waste discarded through the sewer, own composting and pet food. For mass accounting, it is also necessary to take into account water evaporation from the foodstuff (not added tap-water) during cooking. Note that food waste through the sewer is significant.
- Solid household food waste is the sum of the food fraction in organic waste with other fractions being garden waste and undefined, and the food fraction in the mixed waste fraction. Garden waste can be up to 60% to 70% of the total organic waste and the mixed fraction includes a sizeable amount of organic food waste (kitchen & garden waste). The size of these fractions has to be taken into account and can differ considerably between Member States and even regions (e.g. rural versus urban).
- The quantity of solid household food waste can be assessed 'top-down', i.e. from taking the sorting analysis of waste streams one step further to find a distinction between kitchen waste and other organic waste, or 'bottom-up' from specific food waste diaries and weighing with end-users. Both approaches should, within margins, have similar findings.

There are considerable differences between data sources on volume and nature of food waste in the EU. Differences can stem from:

- the method of data retrieval (e.g. dairies, garbage analysis, municipal waste statistics, interviews),
- representativeness (population size, year),
- 'product' scope (liquid and solid waste or only solids; amount reported as cooked or raw; avoidable waste only or also including unavoidable food waste like peels or bones; allowances for non-food waste e.g. garden waste), geographical scope (EU, national, local),
- type of consumers (with or without non-residential food preparation; waste only or the full food life cycle; consistency with consumption data and purchase data),
- data analysis (statistical methods used, assumptions, shortcuts), etc.

It is impossible within this complementary study to solve all the food accounting problems, but at the very least the study team aims to present figures within a ±20% reliability range and as much as possible consistent with existing EU data.

2.2 Methodology Task 1

2.2.1 Scope

The objective is to present a complete representation of the EU food flows that will give policy makers insight into the size of the problem and provide sufficient details to serve as a basis for further analysis of refrigerated foodstuffs.

2.2.2 Accounting principles

The food flow accounting will use the following accounting principles:

- Accounting unit will be, with the exception of crop imports, the real weight of the mass flows at the respective weights for the various stages of the food chain.[4]
- Accounting will use a closed system, i.e. in- and outputs will be clearly identified and must add up. Internal recycling flows will be shown e.g. of animal feed. All values will be transparent. Where information is not available or ambiguous the study team will make an estimate.
- For crops, the starting point is the available mass from the EU net harvest production and crop imports, minus quantities for seeds. Pre-harvest losses will be excluded. Crop imports will be considered in raw materials equivalent, thus taking into account resource loss in the country of origin.
- For meat products, the first input (production and imports) is expressed in net carcass weight for meat and ex-slaughterhouse weight of offals, fats and by-products. For fish and other seafood the first input is expressed in live weight of catches. Eggs are those collected minus eggs used for hatching. The starting point for dairy products is the volume of raw milk delivered to the dairy industry minus own-use of milk by farms. This means that mortality of animals, broken eggs during production and collection, fish catches thrown back at sea, etc. are excluded.
- The outputs of the system are End-use, Exports (of crop and food products separately), Non-food industry (of vegetal and animal inputs separately) and Waste (process waste from the main food flows, avoidable and non-avoidable end-use waste).

[4] Note that this is different from the FAO statistics that use raw material equivalent for all flows.

- To show the size of the impacts from waste at the end-used phase, the 10 main food flows will be traced from harvest or slaughterhouse to end-use. Additional flows are waste and animal feed as well as water; only where it is necessary for consistency. The number of stages (and nodes) in the foodflow will be as limited as possible (6 stages). The objective is to show these main flows in a single (Sankey) flow diagram, with more detailed flow-diagrams and explanations in the report.
- To create a useable basis for mass accounting in refrigeration accounting, the main food flows will be split into appropriate subgroups at end-use stage. Other small food flows and beverages, not traced from the origin, will be added at end-use stage.
- Material flows that are not explicitly taken into account in the food flow accounting are irrigation and drinking water, mineral fertilizers, organic manure, pesticides and energy carriers. These flows will be discussed elsewhere in this study.
- In as much as possible, the data will be checked for consistency with available and official EU-statistics that relate to the EU food supply chain.

As regards the water content of foodstuffs in the various stages of processing, this study will follow Eurostat-conventions as much as possible, i.e. where available. A selection of water content data is given in Annex I.

2.2.3 Definitions

The following definitions are given by the FUSIONS definitional framework[5].

Food: *Food means any substance or product, whether processed, partially processed or unprocessed, intended to be, or reasonably expected to be eaten by humans. 'Food' includes any substance, including water, intentionally incorporated into food during its manufacture, preparation or treatment.*

Food supply chain: *The food supply chain is the connected series of activities used to produce, process, distribute and consume food.*

Food waste: *Fractions of "food and inedible parts of food removed from the food supply chain" to be recovered or disposed (including - composted, crops ploughed in/not harvested, anaerobic digestion, bioenergy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea).*

Note that, also according to FUSIONS and FAO handbooks, the above does not mean that animal feed is considered as 'waste'. Under the definitions of Waste Framework Directive 2008/98/EC[6], animal feed from milling residues, oilcake, peels, etc. is a 'by-product'.

According to the same Directive, currently being reviewed, several types of food waste cease to be 'waste' when used to produce energy, e.g. in incineration of waste with heat recovery at >65% energy efficiency (e.g. in power plants or district heating plants) or possibly in the future when producing biogas through anaerobic digestion (fermentation) co-producing compost. Also hazardous/ infectious animal by-products, after proper pre-treatment (heated to 130°C etc.), can be used as solid fuel in power plants.[7]

[5] FUSIONS, *Estimate of European Food Waste Levels*, 31 March 2016.
FUSIONS "Food Use for Social Innovation by Optimising Waste Prevention Strategies", involving 21 partners from 13 countries, was an FP7 project running from Aug. 2012-July 2016 www.eu-fusions.org

[6] DIRECTIVE 2008/98/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 November 2008 on waste and repealing certain Directives, OJ L 312, 22.11.2008, p.3.

[7] Categories 1, 2 and 3 as defined in Regulation (EC) No 1774/2002 of the European Parliament and of the Council of 3 October 2002 laying down health rules concerning animal by-products not intended for human consumption, *OJ L 273, 10.10.2002, p. 1–95.* Category 1 and 2 are potentially hazardous/infectious animal by-

Nonetheless, for the sake of this analysis all foodstuffs that are being incinerated, landfilled, treated in a biogas or composting plant, flushed down the drain, fed to household pets from leftovers and composted at home will be identified as leaving the food supply chain and thus 'food waste'.

For the end-use phase of the food supply chain the following definitions are used:

<u>Unavoidable food waste:</u> *Parts of food waste considered unfit for human consumption by the intended user. This includes fruit and vegetable peels and pits, animal bones, egg shells, etc. For mass accounting also water evaporated from foodstuffs during cooking (excluding added tap water) is classified as 'unavoidable'. Note that small fractions of 'partially avoidable' food waste are defined by some sources, e.g. certain fruit or vegetable fruit peels that some will eat and others don't. They will be treated as 'unavoidable'.*

<u>Avoidable food waste:</u> *Whole or part of food waste considered fit for human consumption by the intended user. This includes foodstuffs that are, or that the user considers, spoiled (past 'use-by' or 'best before' date or otherwise judged 'off' by the user), stale (bread, beer, carbonated drinks), contaminated (e.g. with animal blood), bought by mistake, spills, cuts from food preparation, left untouched (e.g. in self-service buffet), leftovers from partially but not completely eaten meals.*

Also, the analysis will make an initial assessment of flows that end up in freezer, refrigerator and cupboard. Foods bought frozen will be partitioned to the freezer. Foods that are dry, canned or otherwise preserved for a life of at least a month are partitioned to the cupboard. Fresh dairy products are partitioned to the refrigerator.

For the remaining fresh products an estimate is made. Fresh meat and fish products will be partitioned between refrigerator and freezer. Fresh roots and tubers (potatoes, onions, carrots, etc.) are assumed to go to be stored at ambient temperature (basket, cupboard, cellar), as well as hard fruits (apples, pears, oranges, etc.). Soft fruit and the remaining fresh vegetables are assumed to go to the refrigerator. Opened long-life products will also be in the refrigerator.

This first estimate is a working hypothesis, to be refined at a later stage if more specific information is available on the average refrigerator content. It is certainly not a reflection of the ideal storage conditions for the various foodstuffs. This will be the subject of Task 2.

2.2.4 Geographical and time scope

Ideally, food flows should be established at the level of individual Member States and then averaged for the EU. It is generally assumed that there are large differences in food consumption and food waste based on local eating cultures, habits, waste collection systems, etc. Furthermore, most primary data sources on food waste relate to, and use specific information of, individual Member States. On the other hand, especially as robust and representative information on food waste is scarce, it might well be that the country-specific information does not reflect so much the local habits, but more the quality and completeness of the individual studies.

In a preliminary analysis, the study team has tried to establish country-specific figures from two main sources, i.e. the FAO Food Balance Sheets and the EFSA Comprehensive European Food Consumption database. These are fairly accessible, although the EFSA data

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products, requiring (co-) incineration, possibly after special pre-treatment, and are under no circumstance allowed to enter the food/feed supply chain.

require elaboration, and they are believed to be fairly reliable in their field. The results of this preliminary assessment is given in the following chapter.

As regards the timeframe, the most recent data collections, reported in the period 2013-2016, stem from the period 2010-2013. Thus, as a single reference, they can be assumed to be representative for the year 2012.

2.3 Data sources

FAO
The most cited data source in the context of food waste is the FAO, the Food and Agricultural Organisation of the United Nations. The FAO has a large statistical department (FAOSTAT) that collects and elaborates local, national and supra-national (EU, OECD) statistics to provide policy support in the field of fighting world hunger and the food self-sufficiency of countries. The most important FAO database for this study is the collection of Food Balance Sheets (FBS), which show production, trade and use of foodstuffs per country. The unique advantage of the FAO FBS is the global consistency of data, i.e. all inputs and outputs of trade between countries are linked, so in principle it is possible to take into account the 'Rücksack' of resources used in the country of origin of e.g. an imported good. FAOSTAT spends considerable resources to retrieve and analyse the best available data-sources per country, e.g. mainly Eurostat and national statistics in the EU, but signals that there are still considerable uncertainties in its data. The FAO uses raw material mass equivalent to analyse the availability of foodstuffs up to an aggregate fraction of 'edible foodstuffs', without specifying the form in which these foodstuffs are processed, sold and finally consumed or thrown away. FAO and Eurostat data are thus similar for primary production and trade of crops and animal inputs, but may diverge for imports and exports. Also, the public FAO database is too aggregated and linear (i.e. regarding animal feed) to use in downstream operations. Subjects like food waste are treated by special studies, such as the much cited study by SIK[8] (Gustavsson 2011) that raised global awareness on food waste, stating that '*one-third of our food is thrown away*'.

As an illustration of the above, Annex I gives the FAO Food Balance Sheet for the EU-28 MS in 2011.

Eurostat
The European Union has various policy interests regarding the EU food flows and Eurostat publishes many statistics to serve the various policy objectives including

- self-sufficiency and trade (food balances and statistics on crop and animal production, imports and exports);
- income of farmers and depletion of resources (rules on milk/sugar/fish/etc. quota, with specific statistics);
- economics of the EU food processing industry, food wholesale and –retail (business statistics);
- affordability and pricing of foodstuffs for households (budget analysis, food as part of the inflation 'basket', etc.);
- environmental aspects of agriculture (greenhouse gas, acidification and eutrophication emissions, material resources use, waste, etc.);
- conservation of material resources and waste reduction.

[8] SIK, The Swedish Institute for Food and Biotechnology. http://www.eatforum.org/partner/sik-the-swedish-institute-for-food-and-biotechnology/

Most of these statistics, with the exception of the monetary values, use the actual weight of the goods produced, traded, transported or processed. Especially regarding agricultural production the Eurostat has made considerable effort in scrutinising and harmonising the data of national statistics offices, especially where quota are involved. For trade data and business data from the processing industry Eurostat depends on national data that may not always be very accurate. For reasons of protecting confidentiality of individual company data or for other reasons, data are missing or are reported with years of delay. Furthermore, there may be administrative errors due to misclassification as a result of ambiguous product-definitions, calculation errors, etc. This is one of the reasons why it is not unusual that business and trade data deviate substantially from sector data of industry associations (e.g. collected from their members) or data from commercial market research institutes.

Eurostat's analysis of consumer food purchases are usually incomplete, i.e. only a selection of foodstuffs is involved, and they are based on consumer-panel surveys where there may be limitations as regards their representativeness for the whole population.

Industry associations
Especially with regard food processing, the statistics from industry associations, especially where collected from their members, can be useful. These statistics may be limited and have some bias, e.g. they often tend to be exaggerated for various reasons[9], but they do have the advantage that they are made up by specialists of the sector and thus tend to be coherent and plausible in view of the processes involved. At EU-level there are at least 30 associations, most of them members of the overarching FoodDrink Europe. Some associations show their own production figures collected from members or summaries of Eurostat.

Nutrition surveys
A special kind of data source are nutrition surveys, typically by Member State food and health institutions and collected at EU level in the database of EFSA (European Food Safety Authority). Their scope is to establish the dietary habits of citizens in view of especially health, but assuming that data are reliable they should be complementary to food waste and food consumption data and are thus potentially relevant here.

The set-up of nutrition surveys is comparable to that of food waste surveys. They typically combine questionnaires and phone-checks with a diary-survey where participants are asked to weigh and register every piece of food before it is consumed. This is an expensive and labour-intensive survey, therefore often limited to a restricted number of participants (a few hundred up to a few thousand) and a restricted period of time. It is prone to errors, e.g. weighting uncooked or unpeeled ingredients, forgetting to subtract leftovers, etc.[10], and possible bias, e.g. a deviation from normal behaviour during the survey-period. Furthermore, most nutrition surveys are primarily interested in health aspects and thus find it useful to specify results not as a total but divided by gender and age group. This means that the data need to be recalculated and aggregated to make them useful for use in food waste studies.

On the other hand, and unlike food waste surveys, many Western European countries have a long tradition in nutrition surveys, meaning that there are statistical time-series and there has been more experience in reducing bias and errors as much as possible. Also sample sizes of field studies, although still limited, can be substantially higher than for

[9] VHK has an experience of over 30 years in collecting, verifying industry association data and has come across these situations. In any case, in VHK's experience companies never underestimate turnovers and deliveries when reporting even anonimously. Furthermore, there may be political reasons why the associations may want to boost their importance.
[10] These are remarks and questions on related blogs, where apparently participants were uncertain.

food waste studies. For these reasons, the nutrition surveys are a unique input that often has been ignored in food waste studies.

Annex I gives an overview of the national surveys that are included in the EFSA-database.

Figure 1 gives an example of the recent (interim) results of an extensive nutrition survey in the Netherlands by RIVM.[11] The diagram summarizes interim results from the first two years (2012-2014) with a sample size of n=2337 persons, distinguishing 19 food groups. More detailed overviews with a few thousand types of food are also available. The survey is spread over 4 years, 2012-2016, with a final target sample size of n=4340 persons in the age of 1-79 years, selected to be representative of the NL population in terms of demographics (gender, age), urbanisation level, education and other characteristics. The survey includes questionnaires, diary surveys, interviews, etc. Apart from food consumption also general health characteristics were investigated.

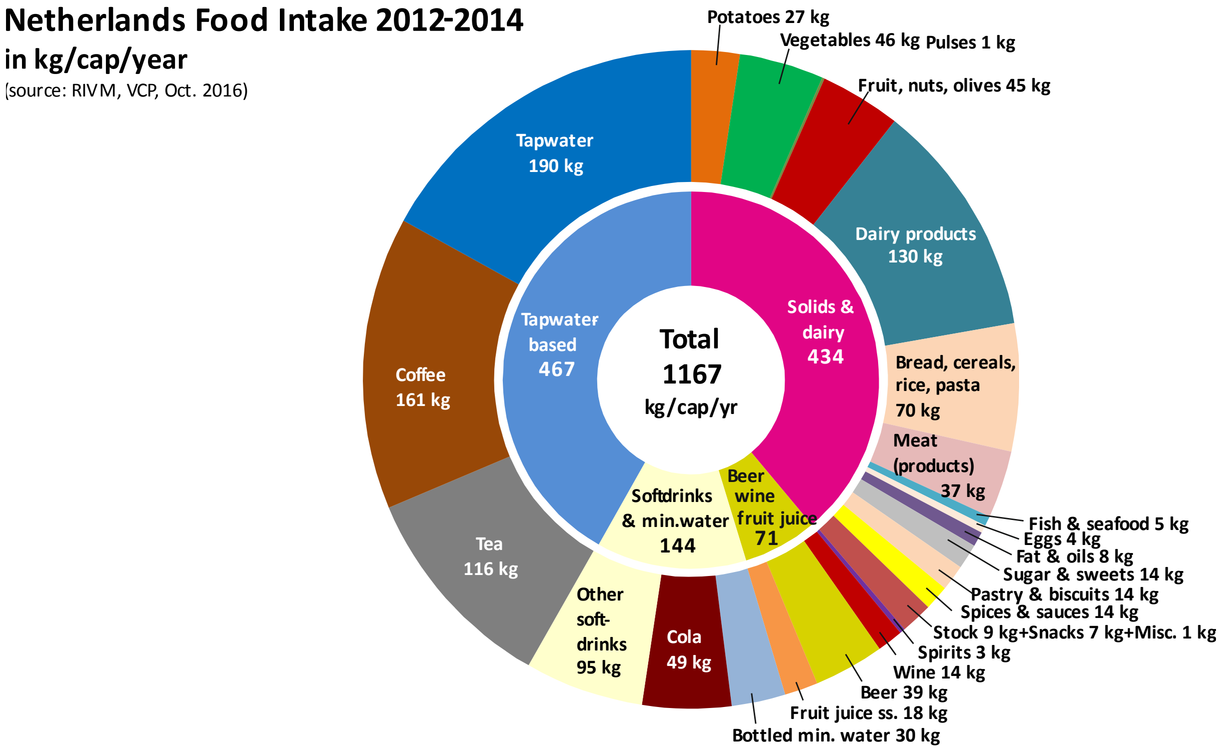

Figure 1. Netherlands Food Intake 2012-2014.
Relates to average annual food intake per capita (in kg/cap/yr), both at home and at food services. (data source: RIVM, VCP,Oct. 2016)

National waste and other statistics

Under the stipulations of the WFD (Waste Framework Directive) and EU targets to reduce landfill, the Member States have an obligation to report to Eurostat on waste fractions. For food waste especially the organic and the mixed fractions are important. Behind these

[11] Rossum, C.T.M. van, et al., The diet of the Dutch, Results of the first two years of the Dutch National Food Consumption Survey 2012-2016, RIVM Letter report 2016-0082, October 2016. National Institute for Public Health and the Environment (Ministry of Health, Welfare and Sport).

reported figures there may or may not be a considerable research that stretches far beyond reporting obligations. It was not possible to make a complete inventory within the timeframe of the study, but at least from sources in the Netherlands (RWS[12]), Flanders-Belgium (OVAM[13]) and Sweden (Avfall Sverige[14]) valuable information is available. For instance, OVAM studies on the food waste in the food services sector are amongst the most detailed in the EU. Also, OVAM has investigated the mixed household waste through sorting analyses of 2000 households, allowing to calculate that part of food waste, and has given a clear split between garden waste and kitchen waste in the organic fraction, allowing to assess that other solid food waste fraction.

Apart from waste statistics, some Member States also produce fairly unique and helpful data. For instance, the UK government Family Food statistics establishes food purchases by households, not just in terms of money (most Member States do) but also in terms of weight. The sample size of the survey is 6000 households.

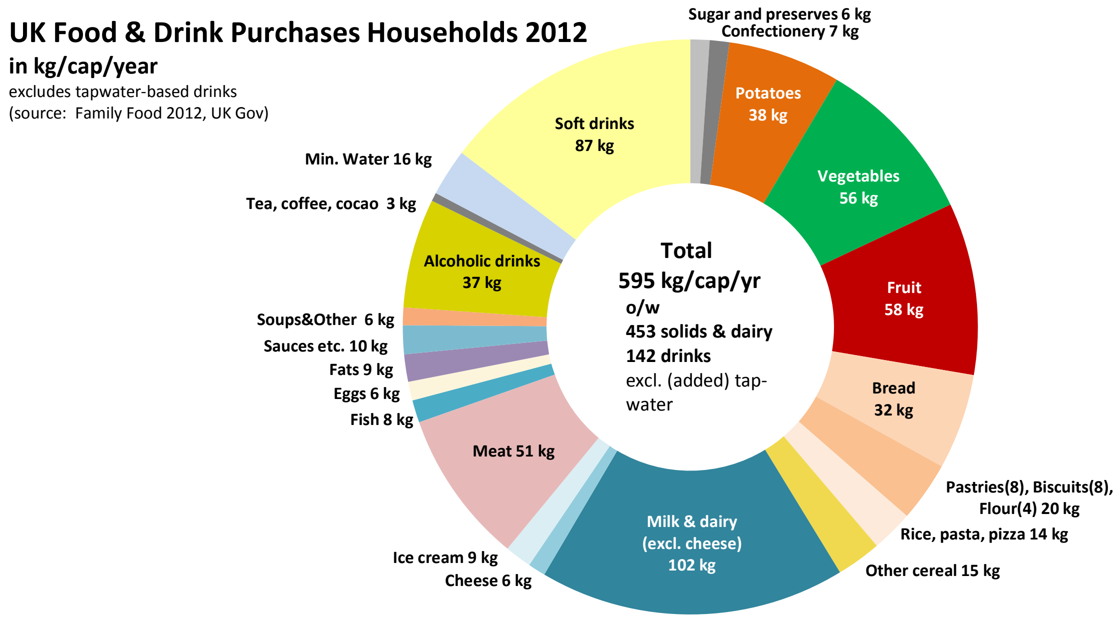

Figure 2. UK Food & Drink Purchases by Households 2012, average in kg/cap/yr. Relates only to purchases for consumption at home and NOT to food & drinks purchased at food services. (source: UK Government, Family Food 2012 statistics, published 2013[15])

[12] Rijkswaterstaat (RWS, Ministry of Infrastructure and the Environment), http://rwsenvironment.eu/subjects/from-waste-resources/
[13] OVAM, de Openbare Vlaamse Afvalstoffenmaatschappij. www.ovam.be
[14] Avfall Sverige- the Swedish Waste Management Association http://www.avfallsverige.se/in-english/
[15] https://www.gov.uk/government/collections/family-food-statistics

Food waste studies

There are many secondary sources on food waste, but only a few primary sources where new field work is done to establish the size and nature of the food waste in households, food services and retail. Food waste in the European processing industry and agricultural sector are often not a part of food waste studies. It is done superficially or not at all, also because especially in food processing there is a definition problem as to what is avoidable ('food waste') and what is not ('food loss'), depending on technology employed.

Most food waste studies relate to solid household waste going to municipal waste collection. Only in recent years also separate surveys were done on liquid or semi-liquid food waste going through the sewer in households. For the volume of food waste ending up on the household compost heap only estimates, not measurements, are available. There are several surveys on solid waste from food services (restaurants, canteens, kitchens in institutions, etc.) and retailers; no research on liquid food waste from food services could be identified. The figure below, derived from a Danish study, illustrates that foodstuffs and drinks discarded through the sewer can be a significant part of the avoidable food waste.

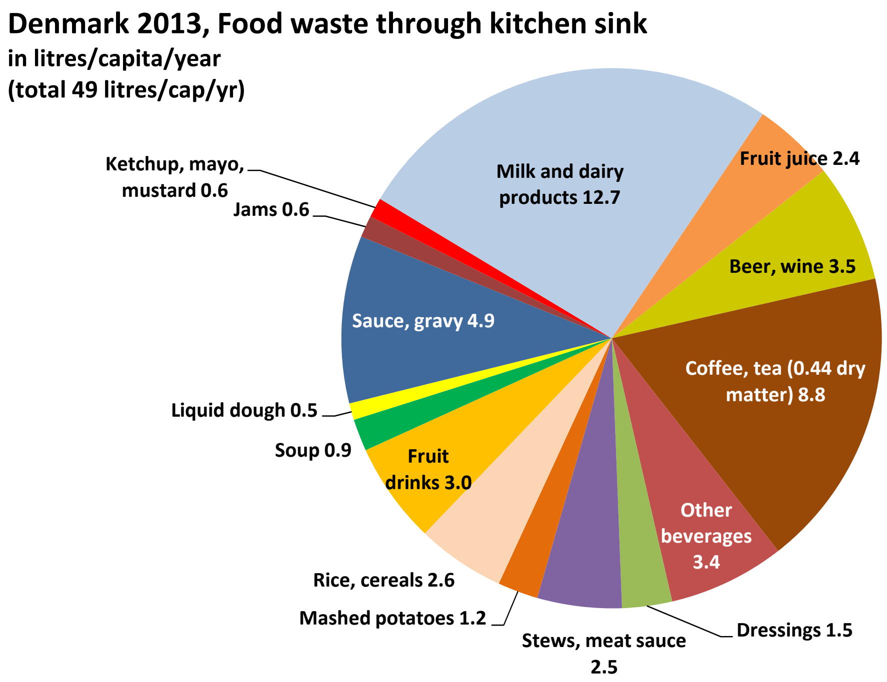

Figure 3. Denmark food waste through kitchen sink in litre/cap/yr.
Total 49 litres/cap/year, equivalent without added tap-water approx. 35 kg/cap/year.
(Added water VHK estimate: Stews/meat sauce 30%; Gravy, jams, rice/pasta 50%; Soup 70%; Coffee & tea 95% added water). Source: Miljøstyrelsen (2014, Danish Ministry of Environment). Survey of 71 households in flats, 2013.

The typical research methods for households include questionnaires, diaries, sorting analysis and interviews. The analysis of food waste may have been done only by diaries, meaning the households were asked to weigh foodstuffs and waste themselves. Sorting analysis may have been done specifically for the food waste and with the consent and therefore also the knowledge of the households. The food waste study may also be an extension of a 'blind' overall household waste sorting, in which case the likelihood of adjusted behaviour ('bias') is lower. For food service establishments and retailers typically a sorting analysis is done for a limited amount of sites, which is then extrapolated to a national total on the basis of weighting of food waste per meal or per employee for the various types.

Sample sizes of the household solid food waste sorting analysis and detailed diary surveys may range from 50 (France ADEME) to 950 (UK WRAP) households. Total food waste estimated from general waste sorting may have higher sample sizes but do not supply details, e.g. Flanders (Belgium) 2000 households. For food waste through the sewer sample sizes are typically less than 100. For waste from retailers and food services the sample size was usually less than 100 establishments.

For Germany and Austria detailed municipal waste sorting of the type that would allow estimating food waste fractions exists but only at local (municipality) or regional level. The national food waste estimates are based on desk research that recalculate existing data from other countries or that pull together data from these local and regional sorting analyses.

For Southern Europe, e.g. Italy and Spain, estimates of national food waste exist, also sometimes produced by the FAO, but usually focus on waste in agriculture and processing and not so much on waste at the retail and end-use level. For Eastern European Member States no food waste estimates could be identified except for Slovenia[16] and Estonia[17].

For this study, specific food waste studies are needed to establish the waste for individual food groups, split up by avoidable and unavoidable fractions.

A preliminary assessment of EU food waste can be found in the next chapter.

[16] Republic of Slovenia Statistical Office, *Hrana med Odpadki (Food Among Waste)*, Nov. 2016 (Slovenian; English version to appear 20.12.2016). Average solid food waste 73 kg/cap/yr (91 in capital, 48 in rural areas), of which 48% households, 19% food services, 9% wholesale and retail, 24% food manufacturing. URL: http://www.stat.si/dokument/9173/hrana_med_odpadki.pdf%20

[17] Republic of Estonia, Ministry of Environment, Food waste study 2014, 2015 [in Estonian] http://www.envir.ee/sites/default/files/news-related-files/toidukao_uuring_seit_2014.pdf
Survey with 100 households and 20 food service establishment. Households waste 54 kg/cap of which 19.45 unavoidable; food services in total 13040 t, which is close to 10 kg/cap (at 1.325 inhabitants).

3 Preliminary food waste analysis

3.1 Introduction

Before entering into a comprehensive assessment of EU food flows, this exploratory chapter investigates the status quo in European food waste reporting. The total EU food waste is the most important figure of Task 1. As mentioned, there is a large divergence between these data and, by analysing different angles and examining different data sources, the study team hopes to build a robust and consistent figure.

The following paragraphs discusses estimates derived from:

- Eurostat waste statistics;
- FAO (edible food fraction in raw material equivalent) versus EFSA (food intake in real weight) on a country basis.
- Secondary sources: Discussion of results and reliability.
- Primary sources: Outcomes and comparison of, i.e. surveys at country level that use sorting analysis, kitchen diaries, interviews to establish food waste.
- Conclusions.

3.2 Eurostat

In the Eurostat waste statistics food waste is a fraction of the mixed household waste ('mixed ordinary waste') and the organic waste ('animal waste and mixed food waste' + 'vegetal waste').

On a voluntary basis, Eurostat requested Member States to estimate the fraction of food waste in the mixed household waste fraction in 2012.[18] 18 Member States gave their assessments, ranging from 21 to 33% (not counting Malta, which is a special case).[19]

Organic waste consists mainly of garden waste and food waste. Flanders (Belgian region with 6.4 million inhabitants) specifies that 38% is food waste[20]. In Germany, the fraction of food waste as part of the organic waste ('Biotonne') is 30% (see figure).[21]

[18] EC Eurostat, Food Waste statistics, Expert group meeting on Food Losses and Food Waste, 22 June 2016. (presentation)
[19] AT 25%, FI 25%, FR 23%, HR 24%, LU 25%, MT 52% (outlier), NL 26%, SE 33%, SI 21%.
[20] OVAM*, Inventarisatie Huishoudelijke Afvalstoffen 2014, 2015*
[21] Krause, P., Oetjen-Dehne, R., Flächendeckender Ausbau der Biotonne in Deutschland, Umwelt- und Energie-Consult GmbH, Berlin, 8.5.2014.

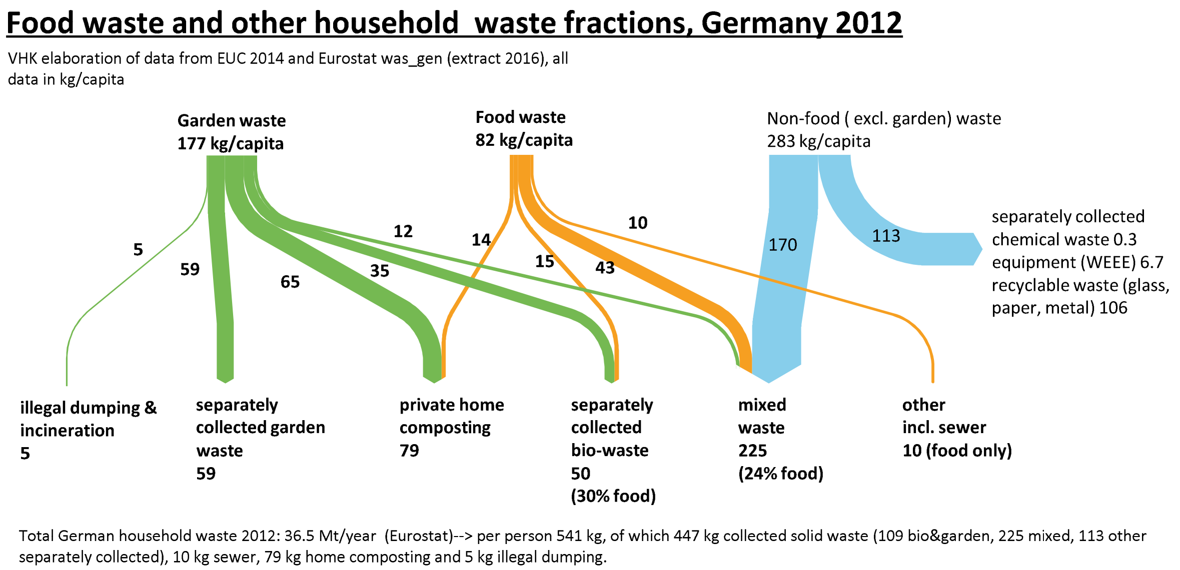

Figure 4. Food waste and other household waste fractions, Germany 2012, in kg/capita.
Source: VHK elaboration of data from EUC[22] , Richter[23] and Eurostat (was_gen database).

On a total of 213.4 Mt household waste collected in 2012, Eurostat finds 137.6 Mt mixed waste and 28.6 Mt of organic waste.[24] For the service sector (except wholesale of waste and scrap)the totals are 36.1 Mt of mixed ordinary waste and 12.6 Mt of organic waste on an overall sector-total of 113.5 Mt. To generate figures at Member State level the organic and mixed waste fractions should NOT be calculated separately since this would reflect the status of separate collection practice in individual countries rather than the food waste.

Assuming a low estimate for the food waste fraction in the mixed waste of 22% and a food waste fraction in organic waste of 35%, the aggregate food waste for households is approximately 40 Mt and for services 12.4 Mt. This comes down to 24% of the total EU organic and mixed fractions for households (40/(137.6+28.6)=24%) and 25% for services (12.4/(36.1+12.6)=25%).

In the graph below, the fraction of 24% was applied to the total of mixed and organic fraction, both for households and services.

[22] Krause, P., Oetjen-Dehne, R., Flächendeckender Ausbau der Biotonne in Deutschland, Umwelt- und Energie-Consult GmbH, Berlin, 8.5.2014.
[23] Richter, F., et al., Grün-Opti: Ist die Erfassung von Grüngut in Deutschland schon optimal?, 10. Biomassenforum 2016.
[24] Eurostat, was_gen database for EU-28 in the year 2012 (extract for 'households' Oct. 2016)

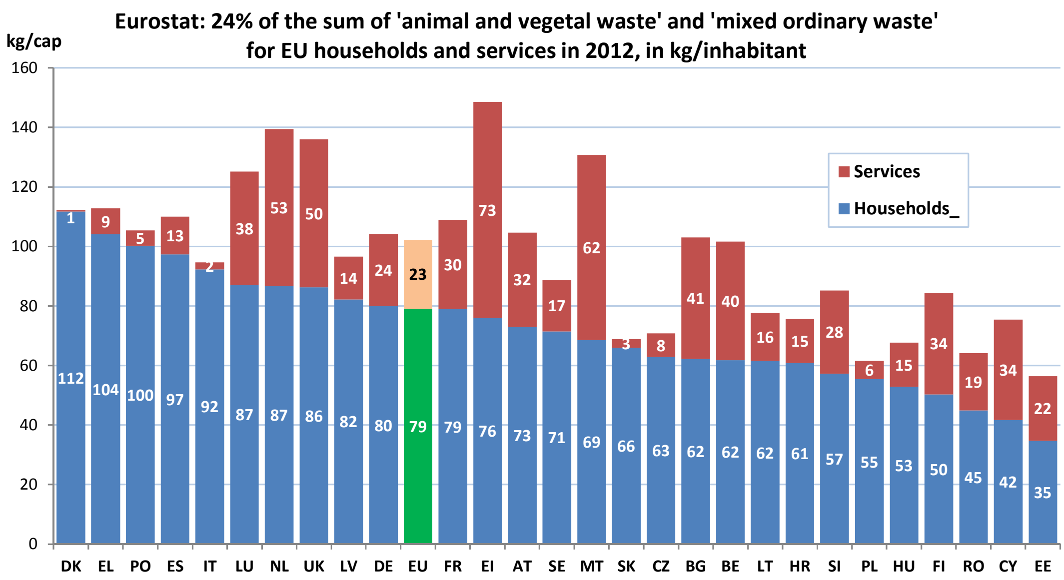

Figure 5. Food waste estimate, using a single multiplier.
Multiplier 24% for the sum of 'animal and vegetal waste' and 'mixed ordinary waste' for EU households and services in 2012, in kg/inhabitant, based on Eurostat (was_gen).

The average EU food waste, i.e. the solids fraction discarded in collected household waste (waste through sewer and food waste through own-composting are not included) thus amounts to 79 kg/inhabitant for households and 23 kg/inhabitant for services. As this is a crude estimate, the accuracy of the EU and country figures for households is estimated at no more than ±15 kg/cap. But within that margin, the figures seem plausible with earlier findings. Specific food waste studies show Danish household food waste to be amongst the highest in the EU. Southern European countries eat more fruit and vegetables, foodstuffs that generate larger quantities of waste. Food waste in larger countries like UK, Germany and France is close the EU average. Finnish and Estonian household food waste is amongst the lowest in the EU according to specific food waste studies.

It is important to realise that Eurostat follows the waste definitions of the WFD (Waste Framework Directive), which means amongst others that waste being incinerated with an energy recovery of at least 65%, e.g. for district heating, is not counted as waste.

This explains the almost zero waste from the services-sector in Denmark and probably also that the Swedish food waste figures are significantly lower than what is found in specific Swedish food waste figures.

Other than that, for the service sector the divergence of calculated figures is much higher than with households. For some countries, e.g. Italy, Spain, Greece and many Eastern European countries, there is probably a problem with the availability/completeness of data. For some smaller countries, like Malta, Ireland, Cyprus, there may be a significant influence of tourists and expats. In Finland, but probably in several Eastern European countries there is the habit to have a hot lunch-meal at work or in school during work/schooldays, with only a home-made sandwich in the evening.

It may be that consumers in some countries eat less or are more frugal than others, but literature shows that there are many other explanations. Countries with smaller households and a larger part of the population living in urban areas tend to have a higher food waste (e.g. Denmark, the Netherlands). Vice versa, in larger households the probability of leftovers and food being thrown away unopened is lower. Also in rural areas, there are many opportunities to divert food waste to animal feed or as input for home-composting, rather than giving the food to the municipal waste collectors. For instance, in a recent food waste study in Slovenia it was found that the food waste volume in the capital Ljubljana (91 kg/capita) was almost twice as high as in the rural areas (48 kg/capita). The overall average (73 kg/capita) does not reveal these large differences.

Overall, the accuracy of this Eurostat-based food waste assessment should not be over-rated, but it does give some consistency with the data found elsewhere in this chapter.

3.3 Country analysis: FAO versus EFSA

In theory, food waste is the difference between food supply and food intake. FAO is the most frequently cited source on food supply. EFSA has the most comprehensive database on food intake. Both sources give data at the level of individual countries, which could make them useful for assessing food waste. The diagram below illustrates the theory.

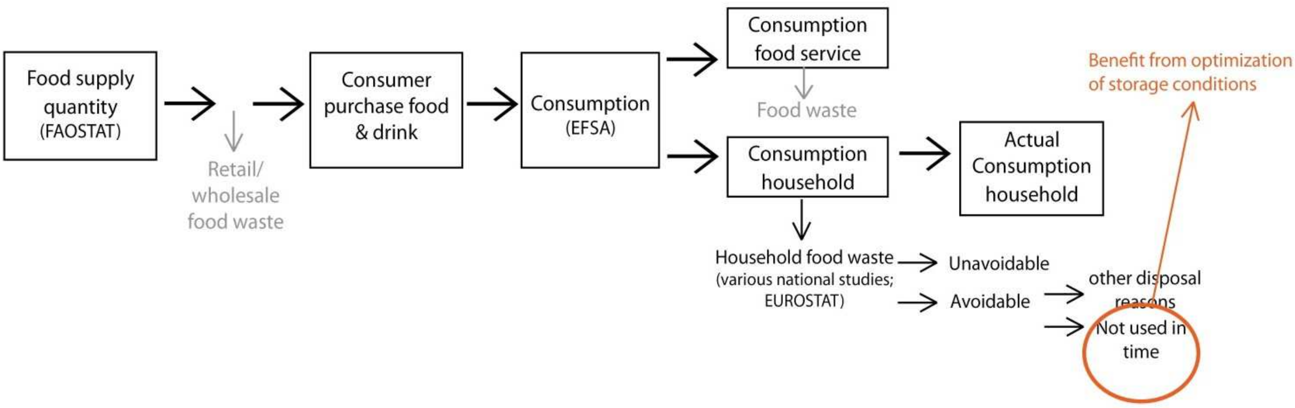

Figure 6. Schematic flow of food & drink products at consumer level.

3.3.1 FAO Food Balance Sheets (FBS)

FAOSTAT Food Balance Sheets (FBS) are a set of data on production, imports, stock variation, export and non-food purposes with which food supply quantities are calculated for a given country. Data originate from 2011 as this is the most recently available year. As an aggregate, the FAO also gives a Food Balance Sheet for the EU-28 (see figure below). The full FBS can be found in Annex I. In total, the FAO calculates that the EU food supply in 2011 amounted to 501 Mt (996 kg/capita).

FBS data contain only standardized items. They are expressed in primary product equivalent, e.g. with the water content, peels, bones, etc. of the raw material.

Also, food data relate to food supply up to the level of input to the food industry. Losses or gains of water, production of waste, recycling of process waste to animal feed, etc. are all NOT included. Furthermore, food waste at the end-use level (consumers and food services) and retail level are not included.

The figure below also illustrates that the FAO FBS accounting is 'open'. A part of the available food input from production and the trade balance goes to Food Manufacturing (mainly for sugar beets, oilcrops, cereals and fruit). A part of the Food Manufacturing then shows up again as Food in the sections of some end-products, i.e. raw sugar (from beets), vegetal oil (from oil crops), beer (from barley but with added water) and wine (from grapes). These parts re-appearing as Food are not an explicit number in the FBS and amount to approximately 65 Mt (VHK estimate). This implies that there is a residual part of 156 Mt (VHK estimate) in Food manufacturing that does not show up as food, but has some unknown destination, probably as animal feed (e.g. oilcake), water being extracted in processing or waste. Note that the 65 Mt is counted twice, i.e. the actual net production is not 996 Mt, but actually 931 Mt (996-65 Mt). Also, note that for beer the FAO FBS counts added tap-water, ca. 30 Mt, as 'production'. This means that actual production is close to 900 Mt/a (1785 kg/capita) of net post-harvest crop plus net carcass weight of animals plus their products (milk, eggs, etc.). Non-alcoholic beverages are not included in the FBS and for coffee, tea and cacao drinks only the dry input is taken into account.

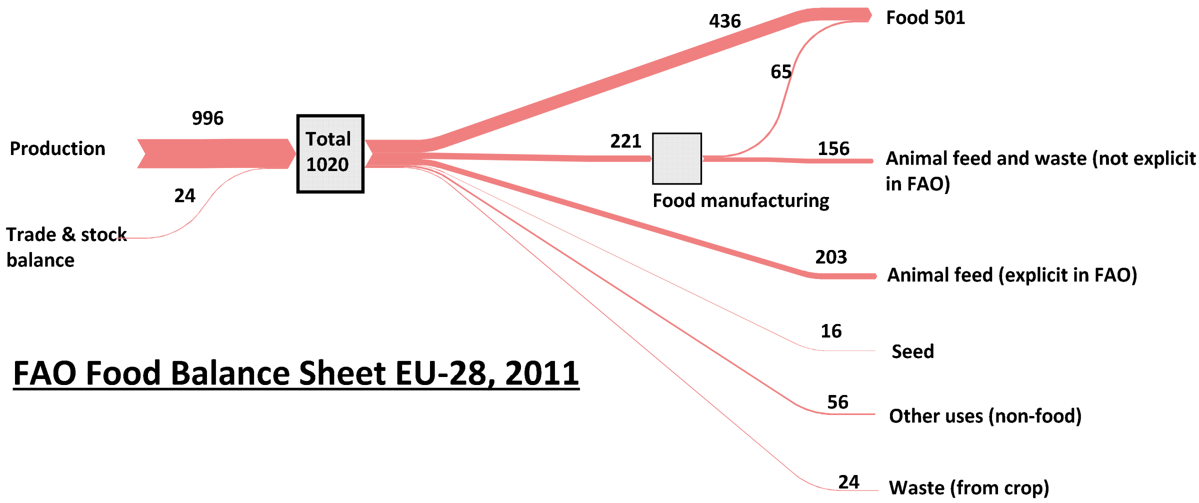

Figure 7. Flow diagram of the FAO Food Balance Sheet for the EU-28 in 2011. (source : VHK on the basis of FAO FBS data)

The figure below gives the FAO FSB 2011 food supply quantity of selected food-groups per Member State 'as is', without any correction for processing losses or inedible fractions. It shows a variation between 480 and 940 kg/capita, with an EU average of slightly more than 750 kg/capita.

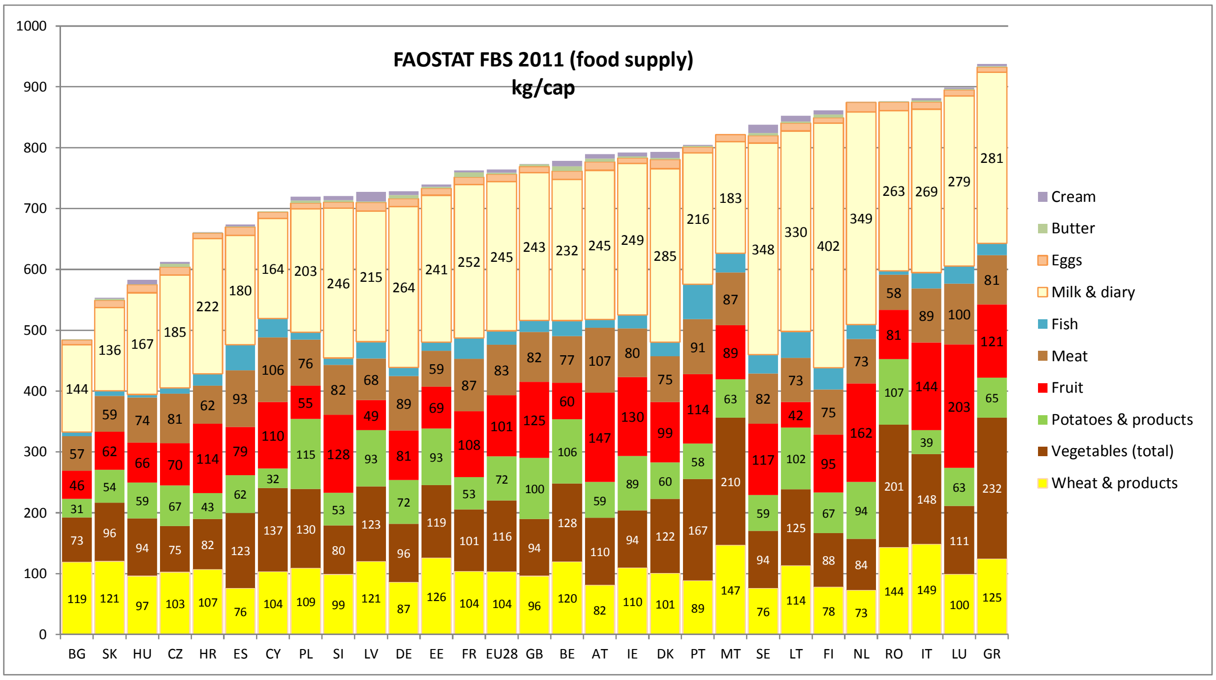

Figure 8. Food supply quantity per member state in 2011 in primary product equivalent (FAOSTAT, 2011)

An advantage of primary product equivalents is that comparisons between food supply quantities of member states are possible because of the equality of the methods used to obtain data, however depending on the reliability of provided data for production, imports, stock variation, export and non-food purposes. Especially non-food purposes data are lacking or insufficient.

A disadvantage is that these data on primary product equivalents are difficult to compare with other databases on food supply or consumption, because they do not reflect the losses and waste from downstream operations to produce the food in the desired shape (processing losses) and deliver them to the appropriate place (wholesale and retail waste). The FAO gives some waste data, but as elaborated in the SIK study is not complete.

3.3.2 EFSA Comprehensive European Food Consumption database

The EFSA food consumption database (as currently available on the EFSA website) consists of numerous national dietary surveys performed in 19 Member States. Consumption data are presented in grams per day and per capita for seven age classes (infants, toddlers, other children, adolescents, adults, elderly and very elderly). EFSA uses the 'FoodEx' hierarchical food classification system containing 21 main food categories that are further divided into subgroups (Annex I). The EFSA database is the only available database containing both country specific and product specific food consumption data so far. An average food consumption per capita presented is calculated from the consumption per age class multiplied by the related share in the country's total population (see Annex I).

EFSA food intake amounts to 631 kg/capita for the EU, excluding water (237 kg/cap.). Of this, there are 46 kg alcoholic beverages (wine, beer, spirits) and 135 kg non-alcoholic beverages (soft drinks, coffee, tea). Without these 181 kg of beverages (excluding milk), the consumption of solids and dairy products (including milk) amounts to 450 kg/capita (e.g. 227 Mt for EU 2011 with 504 million inhabitants).

To be comparable to FAO data, the graph only shows the intake of selected solid foodstuffs and dairy products, i.e. including milk but excluding some of the smaller food flows (sugar, baby food, etc.). The average consumption of these food flows amounts to 380 kg/capita.

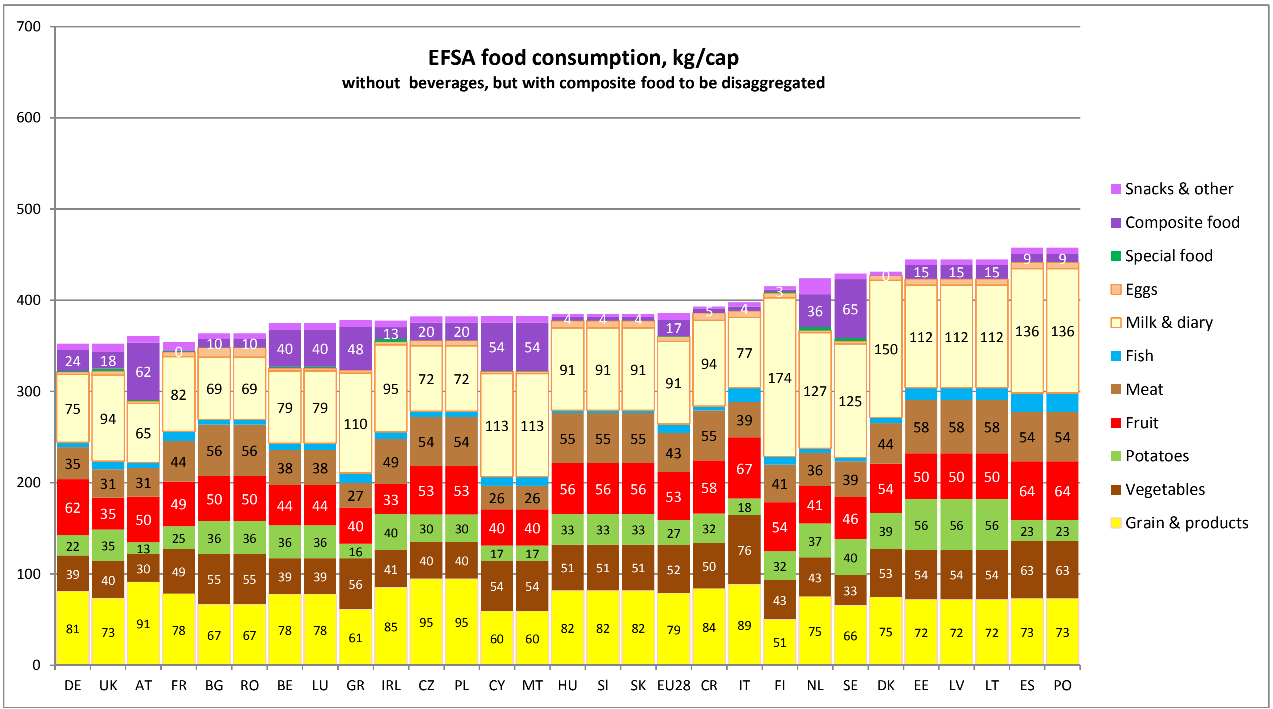

Figure 9. Average annual food consumption excluding beverages, candy, baby food, herbs, animal fats and nuts) (based on EFSA database)

The EFSA database includes 43 dietary surveys with different methodologies or different durations of surveys and performed over various years ranging from 1997-2005. This may cause differences between countries and is therefore less suitable for comparisons between member states. In addition, the numerous surveys use differing nutritional evaluation software which may lead to diverging assignment of foods to the FoodEx food groups (European Nutrition and Health report 2009).

Annex I gives the EFSA data sources per country as well as the population per age class from Eurostat 2011 that was used to aggregate the EFSA data.

Examples of variation in consumption data between Member States:

- The food category 'composite food' is disaggregated for most countries, though some surveys did not or not completely (for example Austria, Sweden). This may underestimate quantities of specific food groups for that country.
- 'Drinking water' and 'soft drinks' had the largest variation between countries. Annual drinking water consumption for example ranges from 30 – 390 kg/cap between member states.

Excluding all drink groups (drinking water, soft drinks, alcoholic beverages and juices) except milk gave a more consistent image of food consumption in EU28. The total remaining food groups have an annual food consumption range of 350 - 450 kg/cap between countries.

3.3.3 Comparison FAO and EFSA

For solid foods and milk, the FAO FBS edible food supply quantity is calculated to be 756 kg/capita and the EFSA database 380 kg/capita (see figure below).

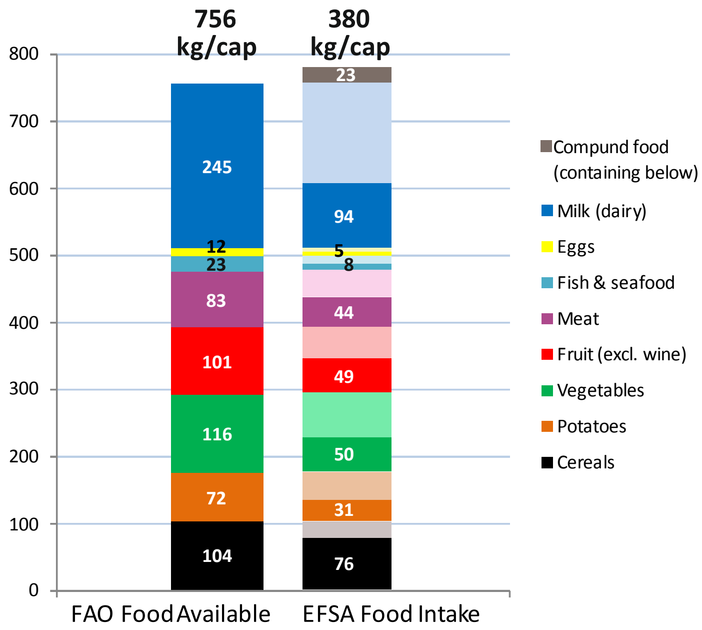

Figure 10. Average food available for EU according to FAO 2011 versus average EU food intake according to EFSA database. (extract 2016, underlying surveys 1993-2010).

Note that the lighter parts in the EFSA column indicate the difference between FAO and EFSA. Also, note that EFSA data cannot be completely disaggregated into the FAO food groups. There is still a small part (23 kg/cap) that consists of compound food (ready meals etc.)

The difference between the two, 376 kg/capita (190 Mt/a) is due to:

- Food manufacturing losses, i.e. not only (avoidable) 'waste' but 'losses' as a result of processing raw materials into a shape desired by the consumers, with part of the by-products being recycled as animal waste;
- Food waste from transport, wholesale and retail
- Food waste from food services (restaurants, canteens and other catering)
- Private household food waste
- General inaccuracy of the two data sources

Especially where the underlying nutrition surveys are old (<2000) and sample size is small or not representative (only certain age groups), the EFSA data can have an error margin of up to ±20%[25]. The FAO data generally adhere to official statistics and suffer from the same uncertainties. The accuracy is estimated at ±10%. The accumulated error margin is in the range of food waste estimates and thus the difference between FAO (food available) and EFSA (food intake) cannot generally be used to estimate country-specific differences in food waste.

Looking at the individual foodstuffs, an additional analysis was made of the differences between FAO and EFSA.

The largest differences occur for milk (FAO, 245 kg/capita) and dairy products (EFSA, 91 kg/capita). FAO uses raw material equivalents and thus does not take into account e.g. that it takes 7-8 kg of milk to produce 1 kg of cheese, that in producing milk powder the milk (or whey) loses some 80-90% in water, etc. As will be shown in the next chapter, these processing steps account for almost half of the weight loss between raw milk (FAO) and intake of dairy products (EFSA). Furthermore, a significant amount of milk powder ends up in compound food and is thus is no longer recognised as a dairy product in a

[25] VHK estimate based on comparison of old and new surveys, e.g. for Lithuania.

nutrition survey. What then remains is food waste, but, as previously discussed, the possible amount of food waste at the end-use is in the order of magnitude of the error-margin.

The figure below gives a comparison between FAO and EFSA data for some other major food flows, i.e. cereals, potatoes, vegetables, fruits (excl. for wine making), meat, fish, eggs and their products. Some countries that had a significant amount of 'outliers', Bulgaria, Romania, Greece, Malta, Croatia, Luxemburg, were omitted from the analysis.
The left y-axis shows, per food group, the FAO data with average, minimum and maximum available food in kg/capita for the EU and 22 Member States. The right y-axis shows the same for the EFSA food intake. The average EU values of FAO and EFSA are aligned.

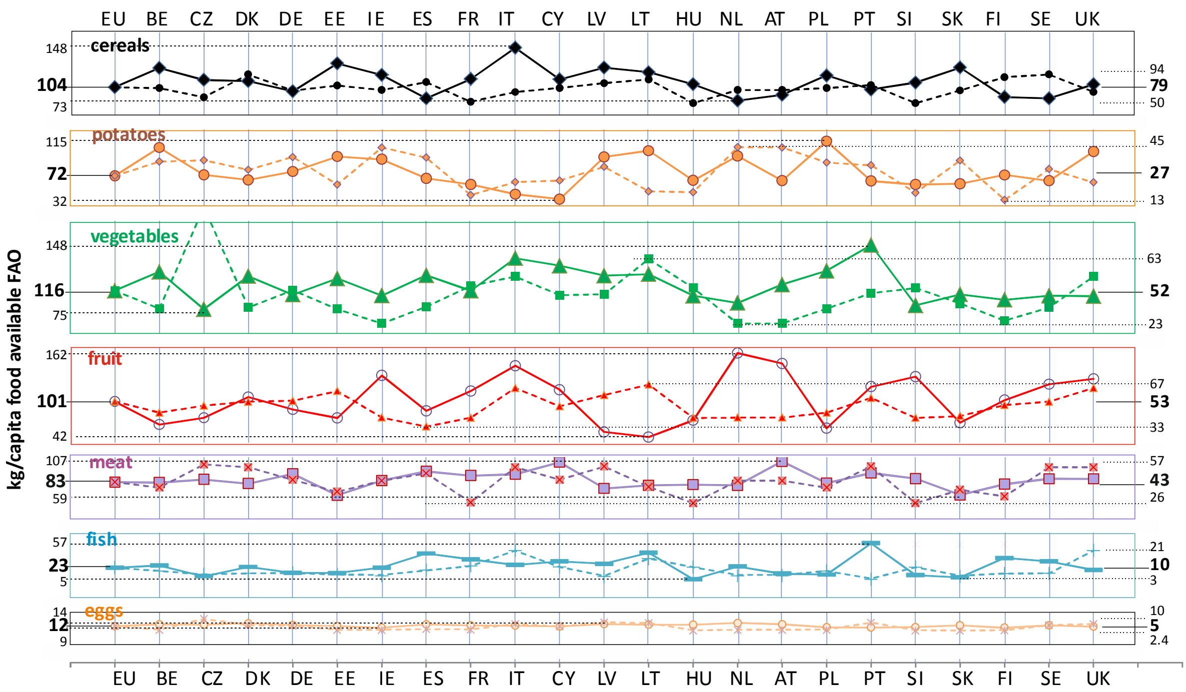

Figure 11. Comparison FAO and EFSA for selected foodstuffs (VHK elaboration). Solid line = FAO, dotted line = EFSA

The main conclusion from the comparison is that the food manufacturing specialties of individual countries are dominant:

- For cereals, Italy has the highest volume available of all, but a lower than average intake. Knowing that Italy produces approximately half of Europe's pasta this is plausible. Dry pasta has a water content that is comparable to that of the raw materials (14-15%), whereas for most other cereal end-products like bread or pastry the weight loss from processing can whole or partly be compensated by a higher water content.
- The FAO data show Poland, Lithuania and Belgium to be the top 3 potato eaters. The difference between FAO and EFSA data for Lithuania can be explained by the fact that the underlying nutrition survey in the EFSA database is old. The latest nutrition survey, not yet introduced in the database, confirms the 2011 FAO data and does show Lithuanians to be avid consumers of potatoes.
- In vegetable processing the weight loss comes from preparation of frozen and canned food as well as e.g. concentrating fresh tomatoes to tomato paste/sauce. Overall, in most countries that the vegetable intake follows the trend of vegetables available.

- The same can be said for the trends in fruit intake, but there are some exceptions. In the Baltic states (EE, LT, LV) the fruit intake is relatively high compared to the fruit available. This could be explained if these countries eat primarily fresh fruit and not so much fruit products and especially not fruit juices. On the other end of the spectrum are countries like Austria (apple juice) and the Netherlands (large imports of concentrates for orange- and other tropical fruit juices).
- The low meat intake of countries like France and possibly also Hungary and Slovenia is difficult to explain; possibly there is an error or bias in the EFSA nutrition survey for these countries. Other than that, for most countries the intake of meat follows the quantity of meat available. This indicates that the average value of 44% loss (77 versus 43 kg/cap) between net carcass weight and final consumption is relatively robust.
- Fish intake is highly dependent on having a sea nearby. Fishing is an important activity in Portugal and Spain. The difference between availability and intake is largest in Portugal, probably due to water loss from dried and salted fish ('bacalhau').
- For eggs there is the unavoidable loss of the shell (11 weight %). Some eggs are especially prepared for the food services and they are an important input in compound food (e.g. pastry, some pasta) and thus no longer recognisable as such in nutrition surveys.

Overall, certain figures from FAO and EFSA are plausible and nutrition surveys can be a useful addition to analyse food flows. However, currently the difference between FAO and EFSA data cannot readily be used to estimate food waste.

3.4 Secondary sources

Secondary sources are studies that do not generate new data through field work, but, as with this study tries to (re)calculate the food waste for the EU from statistics and primary sources (see next section). The study team consulted various secondary sources on food waste, amongst others from SIK (2011 with methodology annex 2013), BIOIS (2012) [26], Vanham (2015), ITAS (2013)[27], Eurostat (2015)[28]and the FUSIONS project (2016) [29]. It is not within the scope of this study to give a review of individual secondary sources; food waste research is relatively recent and it is inevitable that a certain learning process is involved. Nonetheless, several studies were incomplete (i.e. not capturing all waste streams), contained speculative estimates or made wrong assumptions (e.g. that the organic waste stream is a measure for food waste) and this made them unsuitable for our purpose.

The most realistic and comprehensive study is the recent estimate for the EU as a whole by the FUSIONS project. It rightfully does not specify food waste per country or per food group, because reportedly there is insufficient data. Instead, using the inputs of 22 partners, specific food waste studies in 11 countries and a consistency check with Eurostat statistics, it gives an estimate for the EU, as a whole, with appropriate error bars (see table).

[26] BIOIS, 2010, Preparatory study on food waste across EU 27, Technical report 2010 – 054

[27] Priefer, Jörissen and Bräutigam, 2013, Technology options for feeding 10 billion people: Options for cutting food waste, Summary, European Parliament, Science and Technology Options Assessment.

[28] EUROSTAT, 2015, Eurostat project on food waste statistics. Powerpoint presentation, Commission Expert Group meeting on 'Food losses and food waste'. By Hartmut Schrör, Eurostat.

[29] A. Stenmark, C. Jensen, T. Quested and G. Moates, 2016, Estimates of European food waste levels, FUSIONS EU project, Stockholm, Sweden.

Table 1*. FUSIONS study: Estimates of food waste in EU-28 in 2002, includes food and inedible parts associated with food. All values with 95% Confidence Interval*

Sector	Food waste (Mt)	Food waste (kg/capita)	% of total
Primary production	9.1±1.5	18±3	10%
Processing	16.9±12.7	33±25	19%
Wholesale and retail	4.6±1.2	9±2	5%
Food service	10.5±1.5	21±3	12%
Households	46.5±4.4	92±9	53%
of which			
- municipal waste	*35*	*69.2*	*(75%)*
- sewer	*7.8*	*15.4*	*(17%)*
- home compost	*3.8*	*7.4*	*(8%)*
Total food waste	**87.6±13.7**	**173±27**	**100%**

The FUSIONS estimates for food waste volume of households, food services and trade are, although slightly lower, roughly in line with the findings from primary sources in the next section. The figures on primary production and processing should be treated with caution. It is unclear whether they relate to 'food waste' or 'losses' and whether or not there is some valorisation of by-products for animal feed. Especially if FUSIONS intends to describe 'losses' the figures are considerably too low in comparison to waste statistics and in view of known losses from food technologies employed.

3.5 Primary sources

Primary sources are those where the authors have done field work: compositional analysis beyond what is required for WFD, diary surveys, questionnaires, interviews, etc. to estimate the amount of food waste.

There can be considerable differences between data sources on volume and nature of food waste in the EU. Differences can stem from:

- the method of data retrieval (e.g. dairies, garbage analysis, municipal waste statistics, interviews),
- representativeness (population size, year),
- 'product' scope (liquid and solid waste or only solids; amount reported as cooked or raw; avoidable waste only or also including unavoidable food waste like peels or bones; allowances for non-food waste e.g. garden waste), geographical scope (EU, national, local),
- type of consumers (with or without non-residential food preparation; waste only or the full food life cycle; consistency with consumption data and purchase data),
- data analysis (statistical methods used, assumptions, shortcuts), etc.

The most comprehensive and detailed studies on household food waste were made by the UK WRAP (reference years 2010, 2012).[30] The surveys involved food-flow weighting and

[30] WRAP (2012)*, UK Food Waste* and WRAP(2014), *UK food waste – Historical changes and how amounts might be influenced in the future.* Detailed measurement of the weight and types of food and drink waste from approximately 1800 consenting households, a week-long food and drink diary involving 950 households and a synthesis of waste data from more than 80 local authorities.

reporting in 1800 consenting households, a week-long diary survey in 950 households and a synthesis of waste data from 80 local authorities. The results report food waste for 12 main food groups and 45 sub-groups in terms of weight, avoidability, costs and reasons for disposal. Food waste through the sewer was captured through a separate study. Availability of food waste data for other UK-sectors is worse than for households. The 2014 UK WRAP publication complements the detailed work on households with more general data from mainly national statistics to estimate food waste in catering, retail, wholesale and manufacturing.

In Nordic countries fighting food waste is a priority subject. Detailed studies were using compositional analysis of waste bins in combination with questionnaires for a sizeable sample of households. For the aggregation to country-wide data, national waste collection data are used with, at least in a first instance, focus on solid waste only with a limited split in subgroups. In a second instance Sweden[31] and Denmark[32] complemented the work by a separate analysis of food going through the sewer. The (small) fraction that is used for home composting or pet feed is lacking. There are separate Danish and Swedish studies on catering, retail and processing sectors.

Finland's research on food waste is in its early stages and outcomes are divergent from those of the other Nordic countries[33] [34]. Apart from the Finnish households being particularly frugal, another explanation may be that most employees and all school-children have a hot lunch and there is no need for extensive cooking in the evening on work/school days. In that sense the Finnish research on food services and catering is interesting because the volume of food waste is almost as high as the food waste at home. In part, this is also due to the many Finnish self-service buffets, where the number of meals prepared usually exceeds the number of guests.

In Flanders, Belgium (6.4 million inhabitants), the regional government agency OVAM is very active in studies on food waste prevention, often as an extension of the analysis needed to support measures aimed at separate waste collection targets as formulated inn the WFD.[35] In that context, OVAM organises an extensive sorting analyses of mixed and organic household waste with a sample size of 2000 persons. The level of detail is such that at least the total of food waste could be determined with some accuracy, albeit waste from individual food groups was not established. Furthermore, OVAM looked closely at food waste in the catering and restaurant business, finding high amounts of food waste (600 g per meal between kitchen, serving and leftovers) and used cooking oil (UCO). The UCO amounted to 14% of waste from that sector, compared to 28% from other food waste.

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[31] Swedish EPA (2013)*, Swedish Food Waste Volumes 2012.* Household data are derived from elaboration of waste composition data from Avfall Sverige. Sewer data were established from monitoring a (limited) number of households. Data for food services and retail are derived from measured average food waste per employee and then extrapolated.

[32] Miljøstyrelsen(2014, Danish Ministry of Environment)*, Kortlægning af madaffald i servicesektoren (food waste in service sector)* and *Kortlægning af dagrenovation i Danmark (waste in households, waste composition survey 432 households in flats, 113 households in single family homes; separate sewer waste study with 71 households)*

[33] Juha-Matti Katajajuuri (MTT), Food waste and related climate impacts in the Finnish food chain, WASTE ALONG THE SUPPLY CHAIN OECD FOOD CHAIN ANALYSIS NETWORK – 4TH MEETING , 20-21 June 2013 OECD Conference Centre, Paris, France

[34] K. Silvennoinen et al.(2012, MTT), *Food Waste Volume And Composition In The Finnish Supply Chain: Special Focus On Food Service Sector,* Proceedings Venice 2012, Fourth International Symposium on Energy from Biomass and Waste, Cini Foundation, Venice, Italy; 12 - 15 November 2012. Note that Finnish schools give free lunch and one-third of working population eats in the canteen. Sample size 380 households and (30?) food services.

[35] OVAM (2011), *Verzameling van kwantitatieve gegevens van organisch-biologisch afval horeca*; OVAM(2015), *Onderzoek van het voedselverlies bij Vlaamse gezinnen via sorteeranalyse van het huisvuil; OVAM (2015), Sorteeranalyse-onderzoek huisvuil 2013-2014*; OVAM(2015)*, Inventarisatie Huishoudelijke Afvalstoffen 2014.* Elaboration data VHK: Flanders household food waste: 17 kg fraction of mixed hh waste + 43 kg fraction of bio-waste (excl. garden-waste=20%). Flanders food services: 1.1 million meals per day (20.000 establishments x 56 meals) x 0.6 kg waste per meal x 365 days=241 kt/6.4 million inhabitants= 38 kg/cap/yr (=excl. fat and oils 19 kg/cap/yr)

In the Netherlands, the research on food waste is fragmented. The study by Van Westerhoven (CREM 2013) [36] is cited the most, but his methodology diverges from food waste surveys in other countries. Coffee and tea residue (not the liquid itself) are subtracted from the food waste and there is a correction for the water uptake of rice and pasta, but not for the water loss from cooking vegetables, potatoes and meat. Without these corrections the unavoidable solid food loss amounts to 30 kg and the unavoidable losses to 35 kg per capita (total 65 kg/capita). On top of that, he estimates the (avoidable) loss to sewer, home compost heap and pet food to be 15 kg/capita, bringing the total food waste to 80 kg/capita. Total food purchases of solids and dairy products are estimated at 368 kg/capita (less than what the RIVM estimates to be the food intake in a much larger survey). The sample size of the CREM study is 110 households. The study team looked for alternative sources[37]. Rijkswaterstaat is responsible for (separate) waste collection reporting to the central statistics office CBS, which then reports to Eurostat. CBS might retrieve waste data also from other sources. Also, Wageningen University and Research is active in studies on food waste. The study team has made its own estimate, which is slightly higher than that of CREM (see footnote).

The French agency ADEME has recently published a study on food waste for Ministry on Ecology.[38] The study combines a 'quali-quantitative' approach of 512 expert interviews in all sectors (from farmers to consumers) with some small quantitative surveys amongst 50 households and 30 shops as well as a more technical assessment of food losses in various food chains. As such the study is comprehensive, but according to the authors the uncertainties are considerable. Especially the figures on food waste by households are unlikely in light of the overall amount of household waste that France is reporting to Eurostat.

The German government bases its food waste data not on specific surveys but on desk research of other available statistics and other sources recalculated for Germany (ISWA 2012). The ISWA study, in addition to recalculating foreign data for the German situation, did conduct a small survey amongst food manufacturers and caterers to hear what they believe is their food waste. For this reason, although it is predominantly a secondary source, the ISWA-study is still mentioned in this chapter. ISWA made a tentative assessment for Germany of food waste from food services, resulting in 21.4 kg of waste per capita. The ISWA-diagram below gives an overview of the actors involved.

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[36] Westerhoven, M. van, Bepaling voedselverliezen in huishoudelijk afval in nederland, CREM,Oct.2013.

[37] Centraal Bureau voor de Statistiek (2016)*, Gemeentelijke afvalstoffen 1993-2015*; Rijkswaterstaat (2013), *Nederlands Afval In Cijfers* ; Rijkswaterstaat (2015), *Samenstelling van het huishoudelijk restafval, sorteeranalyses 2014*; Jan-Willem Grievink (2011), *Presentation FoodService Instituut Nederland for EFMI Business School*; Mitrovic, S., & Taminiau S., *SUCH A WASTE, Model voor het meten van afvalstromen in het Out of Home segment ..in Nederland*, Dept. Voeding & Diëtiek, 3 Dec. 2011. (includes diary survey 4 restaurants. Avg. waste 0.46 kg/meal). Elaboration data VHK: Household mixed waste (restafval) is 219 kg/cap/yr, of which 32% bio waste (23% kitchen, 6.2% garden, 8.9% undefined)→50 kg food waste. Bio waste is 78 kg/cap/yr, of which assumed 62% garden waste and 38% kitchen/food waste→30 kg food waste. Total household 80 kg/cap/ food waste. Food services: 22% out of home meals (32.3% of food budget) --> 4 million meals/day. Waste per capita: (4 million meals x 365 days x 0.46 kg waste/meal)/16.7 million inhabitants NL→ 40 kg/cap/year food services waste. Note that food waste composition analysis from CREM (2010 and 2013) diverge substantially not only for food waste, possibly due to sample size (110 households), but also for intake and waste NL totals and are not reported here.

[38] ADEME, Pertes et gaspillages alimentaires : l'état des lieux et leur gestion par etapes de la chaine alimentaire, May 2016.

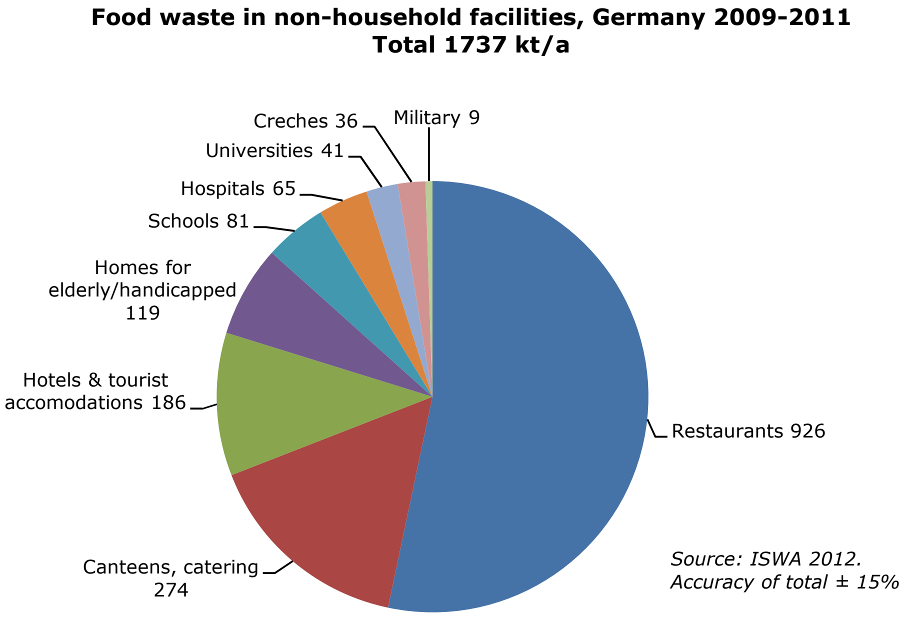


Figure 12. ISWA estimate of food waste in German restaurants and catering. (source: ISWA 2012)

In Austria, the food waste accounting at national level is mainly based on secondary sources and incomplete according to the latest WWF report on the status quo. Results are included in Table 2 for comparison.

The results from above studies are included in Table 2, but there are some other studies that give data per country where not all details on the research-method could be traced.

In 2016, the Slovenian statistical office[39] concluded its first food waste study. It found average solid food waste 73 kg/cap/yr (91 in capital, 48 in rural areas), of which 48% households (35 kg/cap), 19% food services (14 kg/cap), 9% wholesale and retail (7 kg/cap), 24% food manufacturing (17 kg/cap).

In 2014, the Estonian Ministry of Environment commissioned SEI Tallinn to conduct a food waste survey amongst 100 households and 20 food service establishments.[40] Households solid waste was found to be 54 kg/cap, of which 19.45 unavoidable. Food waste with caterers was calculated to be 13040 t for the whole of Estonia, which is close to 10 kg/cap (at 1.325 million inhabitants).

Also in 2014, fifty-two households in Greece filled a daily food waste diary, based on self-weighing, for two weeks each. The results of the diary were then coded, processed and extrapolated to a whole year. The results indicate that Greek households generate

[39] Republic of Slovenia Statistical Office, *Hrana med Odpadki (Food Among Waste)*, Nov. 2016 (Slovenian; English version to appear 20.12.2016). http://www.stat.si/dokument/9173/hrana_med_odpadki.pdf%20
[40] Republic of Estonia, Ministry of Environment, Food waste study 2014, 2015 [in Estonian] http://www.envir.ee/sites/default/files/news-related-files/toidukao_uuring_seit_2014.pdf

approximately 100 kg of food waste per person annually, of which approximately 30 kg is avoidable.[41]

Table 2. Overview of food waste results from primary sources (source: VHK based on misc. sources)

<table>
<tr><th>Country</th><th>UK</th><th>SWEDEN</th><th>DENMARK</th><th>NETHER-LANDS</th><th>FLANDERS (BE)</th><th>FINLAND</th><th>FRANCE</th><th>GERMANY</th><th>AUSTRIA</th></tr>
<tr><td>Source</td><td>WRAP</td><td>Swedish EPA</td><td>Miljø-styrelsen</td><td>CBS, RWS, EFMI</td><td>OVAM</td><td>MTT</td><td>ADEME</td><td>ISWA (Uni Stuttgart)</td><td>misc.</td></tr>
<tr><td>Country population 2012 (million)</td><td>63.50</td><td>9.50</td><td>5.60</td><td>16.70</td><td>6.4</td><td>5.40</td><td>66.40</td><td>81.80</td><td>8.40</td></tr>
<tr><td>Unit</td><td>Kg/cap</td><td>Kg/cap</td><td>Kg/cap</td><td>Kg/cap</td><td>Kg/cap</td><td>Kg/cap</td><td>Kg/cap</td><td>Kg/cap</td><td>Kg/cap</td></tr>
<tr><td><u>Sector</u></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Agriculture and fisheries</td><td>na</td><td>na</td><td>na</td><td>na</td><td></td><td>na</td><td>48</td><td>na</td><td>na</td></tr>
<tr><td>Industry</td><td>61</td><td>18</td><td>na</td><td>na</td><td></td><td>40</td><td>32</td><td>23</td><td>na</td></tr>
<tr><td>Wholesale</td><td rowspan="2">3</td><td rowspan="2">7</td><td>1</td><td rowspan="2">na</td><td></td><td rowspan="2">13</td><td rowspan="2">21</td><td rowspan="2">7</td><td rowspan="2">13</td></tr>
<tr><td>Retail</td><td>30</td><td></td></tr>
<tr><td>Hotels</td><td rowspan="4">14</td><td rowspan="2">15</td><td>2</td><td rowspan="4">40</td><td rowspan="4">38</td><td rowspan="2">7</td><td rowspan="4">21</td><td rowspan="4">23</td><td rowspan="4">33</td></tr>
<tr><td>Restaurants</td><td>11</td></tr>
<tr><td>Institutions</td><td rowspan="2">6</td><td>5</td><td rowspan="2">8</td></tr>
<tr><td>Canteens</td><td>3</td></tr>
<tr><td>Households solids & dairy</td><td>74</td><td>81</td><td>83</td><td>80</td><td>60</td><td>26</td><td>29</td><td>62</td><td>44</td></tr>
<tr><td>Households sewer</td><td>25</td><td>24</td><td>35</td><td>12</td><td>na</td><td>na</td><td>na</td><td>20</td><td>na</td></tr>
<tr><td>Hh. compost & pets</td><td>11</td><td>na</td><td>na</td><td>na</td><td>na</td><td>na</td><td>na</td><td>7</td><td>na</td></tr>
<tr><td>Households subtotal</td><td>110</td><td>105</td><td>118</td><td>92</td><td>60</td><td>26</td><td>29</td><td>89</td><td>44</td></tr>
<tr><td>TOTAL</td><td>196</td><td>151</td><td>170</td><td>86</td><td>98</td><td>94</td><td>150</td><td>142</td><td>90</td></tr>
<tr><td>Organic waste households</td><td>74</td><td>53</td><td>91</td><td>106</td><td>363</td><td>31</td><td>56</td><td>111</td><td>105</td></tr>
<tr><td>Mixed waste households</td><td>282</td><td>242</td><td>371</td><td>255</td><td>149</td><td>178</td><td>266</td><td>222</td><td>198</td></tr>
<tr><td>Total Org. + Mix househ.</td><td>357</td><td>295</td><td>462</td><td>360</td><td>512</td><td>209</td><td>322</td><td>333</td><td>303</td></tr>
<tr><td>(Org+Mix) % of total</td><td>82%</td><td>67%</td><td>69%</td><td>68%</td><td>na</td><td>65%</td><td>71%</td><td>75%</td><td>63%</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Organic waste services</td><td>42</td><td>37</td><td>0</td><td>74</td><td>37</td><td>37</td><td>39</td><td>28</td><td>85</td></tr>
<tr><td>Mixed waste services</td><td>163</td><td>35</td><td>9</td><td>144</td><td>127</td><td>105</td><td>85</td><td>74</td><td>46</td></tr>
<tr><td>Total Org. + Mix services</td><td>205</td><td>72</td><td>9</td><td>218</td><td>164</td><td>142</td><td>124</td><td>102</td><td>131</td></tr>
</table>

According to data supplied by the Romanian Ministry of Agriculture, national food waste amounts to 2.2 Mt (110 kg/capita at 20 million inhabitants). Of this, 49% is discarded by households, 37% by the food industry, 7% by retailers, 5% by public food services and 2% by the agricultural sector. It is not clear how these data were estimated. Foodstuffs thrown away the most are leftovers (26%), bread & pastries (21% of purchase), vegetables (19%) and fruit (16%). Main motives, according to AMRCR are 'not consumed in time/ spoilage' (26%), 'too much served' (21%) and 'excess shopping' (14%).[42]

In March 2009, Polish Radio reported on around 4 Mt of food waste in Poland (over 100 kg/cap at 38.5 million inhabitants). Studies conducted for the Federation of Polish Food Banks[43] reportedly show that 79% of Poles is aware of a significant amount of food wasted and 30% admitted to throwing away food that could still be used. Further background on

[41] Abeliotis, K., et al., Estimation of household food waste generation in Greece, paper at Conference: IHWM – Crete 2014 - 4th International Conference on Industrial and Hazardous Waste Management, At Chania, Crete, Greece, Volume: Proceedings.

[42] Ministerului Agriculturii şi Dezvoltării Rurale (MADR) and
InfoCons study for Asociaţia Marilor Reţele Comerciale din România (AMRCR)
at http://www.adihadean.ro/2016/01/food-waste-romania/

[43] http://www.bankizywnosci.pl/

the surveys and figures is not given.[44] More recent estimates of food waste for Poland are coming from EU-studies.

Although in the press there are figures of 5.1 Mt of food waste in Italy, no primary source could be identified, nor to which actors are thought to be responsible of that waste. Segré and Falasconi (2011) presented figures that do not come from surveys but are a subtraction of INRAN 2005-2006 nutrition survey figures, measuring food intake, from the FAO 'available food fraction' in its Food Balance Sheet for Italy. As mentioned previously, this method of establishing 'food waste' is questionable as it involves large part of unavoidable losses (not 'waste') in food manufacturing. In 2013 Sergé organised a questionnaire amongst households asking which food fraction they discard most frequently (and why). This survey gave trends but no quantitative data.

According to a Portuguese publication, the Portuguese food waste amounts to over 1 Mt (almost 100 kg/capita at 10.5 million inhabitants), of which 332 kt in agricultural production, 77 kt in the food industry, 298 kt in distribution and 324 kt at the consumer.[45] No study details are given.

The Spanish Ministry of Agriculture MAGRAM made an inventory of food waste/loss in agriculture and food processing with quantitative information. Also, a large series of interviews on food waste was conducted with all actors in the food chain.[46] This gives an insight in trends, but is of limited use for food flow accounting. For household waste, there is a 2013 study by consumer association HISPACOOP that mentions an average food waste of 1.3 kg per week (76 kg/year) per household. At 2.7 persons per household this means 28 kg/capita. For Spain, this would result in 1.5 Mt of (solid) food waste for households.[47] The HISPACOOP survey uses (online) kitchen diary surveys with a panel of 413 households and a questionnaire with 3454 participants. Foodstuff volume discarded amounts to 19.3 % for bread & pastry, 16.9% for fruit and vegetables, 13.3% for dairy products (including milk), 13.2% for pasta, 7.4% for beverages (incl. beer, wine, soft drinks), 5.9% for meat, 5.7% for leftovers and between 3 and 5% for the rest.

For other Member States, no specific food waste studies could be identified. Hungary is working with Germany, Spain and the UK in the EU-Refresh platform[48], so quantitative data can be expected in the coming years. The Czech Republic, Slovakia, Lithuania and Latvia are aware of the food waste problem, but no national studies could be found, within the limited context of this study, that quantify the problem. In these countries, if food waste is mentioned it is taken from the 2010 BIOIS study, which only looked at Eurostat's organic waste fractions.

[44] http://www2.polskieradio.pl/eo/print.aspx?iid=105347
[45] Study: PERDA (Perdes alimentares anuals), cited in http://www.caritas.pt/site/lisboa/index.php/destaques-principais/665-2016-ano-de-combate-ao-desperdicio-alimentar
[46] MAGRAM, Barómetro del Clima de Confianza del Sector Agroalimentario -- MONOGRÁFICO Desperdicio Alimentario, Ministerio de Agricultura, Alimentacio Y Medio Ambiente,2012
[47] HISPACOOP, Estudio sobre el desperdicio de alimentos en los hogares, December 2012. [see also http://www.mapama.gob.es/es/alimentacion/temas/estrategia-mas-alimento-menos-desperdicio/Definiciones_cifras.aspx]
[48] http://eu-refresh.org

3.6 Conclusions on total food waste

3.6.1 Households

Municipal waste
Based on primary sources, the solid (municipal) household waste varies between 83 kg (Denmark) and 26 kg (Finland), based on the primary sources. In general, the solid food waste volume is highest in Northern and Western parts of the EU (SE, DK, NL, DE, UK) and lowest in the Southern and Western European parts. Due to the uncertainties of the individual studies it is difficult to make an exact population-weighted average, but it appears that the average of 69.2 kg/capita of the FUSIONS study is correct.

Waste through the sewer
The number of studies on household food waste flushed down the sewer are limited and were done mainly for the North-Western part of the EU. Quantities vary between 12 and 35 kg per capita. The 15.4 kg/capita of the FUSIONS study could be correct, considering that no studies for the Southern and Eastern parts of the EU are available on the subject.

Food waste to home composting and pet feed
As regards the share of household food waste going to home composting and illegal dumping, there are only some indicative figures for the UK (11 kg/capita) and Germany (sources mention 7-14 kg/capita, the lowest value is included in the table). Nonetheless, the 7.4 kg/capita of the FUSIONS project seems low. Anecdotal information from e.g. Denmark and Slovenia suggests that in rural areas and/or for single family houses (i.e. with gardens) the food waste is considerably lower than in urban areas and apartment buildings. A very likely explanation is that larger parts of food waste go to home composting and pet or farm animal feed rather than to municipal waste collectors.

Also in Flanders (Belgium), where some municipalities now have started to charge not just for the mixed waste but also for the separate collection of organic waste, OVAM found that part of the organic waste now seems to be 'disappearing' from the municipal waste stream. It is proposed to double the FUSIONS estimate to around 15 kg/capita.

In total, it means that according to the sources studied, the EU household waste amounts to 100 kg/capita (±10 kg).

Note that this excludes the effect of the balance between water-uptake by cooking rice and pasta and water evaporated when cooking vegetables, potatoes, meat and fish.
Furthermore, most food waste studies do <u>not</u> consider the waste of used cooking oil, soft drinks and bottled water. Also the waste from the so-called small flows (see paragraph 4.14) is only partially taken into account. These will be added in the final estimation of food waste in paragraph 4.16 (see also paragraph 3.9).

3.6.2 Food services

All primary sources on food waste only deal with solid food waste, not with waste through the sewer. Also, the separate collection of used cooking oils and fats (UCO), which can be quite substantial in countries like e.g. Belgium, is not classified as food waste. Other possible waste streams are not captured.

It is difficult to determine the waste from restaurants, canteens and caterers in public institutions (school, hospitals) through a sorting analysis. Waste collection is often in the hands of separate contractors (Van Gansewinkel, Shack, Veolia) and there are some restaurant chains like McDonalds that have their own 'Green Trucks'.

This means that reliable data can only come from interviews, diaries and analysis of garbage mix 'on the spot', i.e. through specific surveys. Primary sources show food waste volumes of 14-15 kg (UK, FI) to 40 kg (NL, BE) per capita. Considering that, with the exception of Finland, on average only 20-22% of the hot meals is consumed in food service facilities it implies that the waste level per meal is <u>at least</u> 50% higher than at home. In part this is due to many canteens and some restaurants being self-service, multiple menu set-up where much food that has been prepared has to be thrown away if there is no demand. Aggregated to a national scale, these 'serving losses' are responsible for at least a third of the service food losses. The kitchen preparation losses and the leftovers also each constitute one-third.

The FUSIONS estimate of 21.4 kg/capita for food service solid food waste is thus certainly not too high and is probably higher. To be complete, probably some 4 kg must be added for sewer losses, bringing the total to 25 kg/capita (±5 kg). Note that this is without the loss of used cooking oil and other possible routes to waste disposal.

As for households, waste of used cooking oil, soft drinks and bottled water by food services will be added in the final estimation of food waste in paragraph 4.16.

3.7 Wholesale and retail

Primary source estimates of food waste in retail and wholesale, whereby the latter is considered negligible, vary between 3 kg (UK) and 31 kg (DK) per capita. The average of the seven primary sources is 14 kg/capita. The FUSIONS project estimates 9 (±2) kg/capita, which would be rather on the low side. As a rounded figure this study proposes retail food waste of 10 (±5) kg per capita.

Note that statistics on retail food waste will probably change drastically in the coming years. France recently adopted legislation requiring retailers to give food that is still edible but possibly past its (internal or publicised) 'sell-by' date to charity. Romania has announced that it will do the same by the end of 2016. Italy has adopted a law that removes the legal barriers for retailers giving away foodstuffs to charity that are past their 'sell-by' date or that do not conform to certain standardised formats.

3.8 Food industry and agriculture

Some primary sources, usually with a focus on end-use food waste, also give figures for 'food waste' in the food industry or even agricultural waste. These figures vary between 18 kg (SE) and 61 kg (UK) per capita.

None of these figures is based on actual measurement by the authors. Furthermore, there is a definition problem between what is 'food loss' and what proportion of food loss is 'food waste', i.e. the reasonably avoidable part of food loss. The UK numbers are based on UK statistics and most likely refer to 'food loss'. The lower numbers in the other countries are mostly based on interviews with manufacturers on what they consider avoidable, i.e. 'food waste' from e.g. start-up losses, production lines breaking down, cleaning of machinery, food wasted in trucks, errors in storage conditions causing spoilage, etc. The highest amount of food waste in the processing industry, assigned to retailers or both industry and retailers, comes from the production of bread which many retailers send back after one day on the shelf.

In this study, the choice between "loss" and "waste" is not so relevant. For the food flow diagram in the next chapter the food loss is most important; if 'waste' occurs at the level of food industry it will not be directly influenced by better or worse professional or household refrigeration.

3.9 Food waste per food group

Not all primary sources give food waste per food group and not all at the same level of detail. The most detailed and thus most cited assessment comes from the UK WRAP studies[49], which will also here be used as a basis for the solid food waste.

Table 3 . UK WRAP Food Waste 2012 versus UK Food Purchases (2012 Family Food statistics), total and avoidable waste per food group

Food group	Purchases (kt)	Total waste (kt)	Waste % of purchases	Total avoidable waste (kt)	Avoidable waste % of purchases
Bakery	**2268**	**558**	**25%**	**446**	**20%**
Standard bread	1400	460	33%	350	25%
Speciality bread	631	49	8%	48	8%
Other	238	49	21%	48	20%
Meat and fish	**3741**	**566**	**15%**	**301**	**8%**
Pork / ham / bacon	657	140	21%	99	15%
Fish and shellfish	475	35	7%	29	6%
Beef	446	56	13%	34	8%
Poultry (chicken / turkey /duck)	828	280	34%	110	13%
Other	1334	55	4%	29	2%
Dairy and eggs	**7033**	**478**	**7%**	**419**	**6%**
Milk	5204	290	6%	290	6%
Cheese	376	34	9%	34	9%
Yoghurt / yoghurt drink	644	54	8%	51	8%
Egg	396	82	21%	23	6%
Other	413	18	4%	21	5%
Staple foods	**1707**	**154**	**9%**	**154**	**9%**
Rice	304	40	13%	40	13%
Pasta	565	34	6%	34	6%
Breakfast cereal	495	70	14%	70	14%
Other	343	10	3%	10	3%
Fresh fruit	**2457**	**911**	**37%**	**350**	**14%**
Banana	707	310	44%	67	9%
Soft / berry fruit	515	51	10%	44	9%
Apple	446	110	25%	59	13%
Other	789	440	56%	180	23%
Fresh vegetables and salads	**3834**	**1636**	**43%**	**811**	**21%**
Cucumber	139	42	30%	33	24%
Lettuce	109	52	48%	44	40%
Carrot	334	140	42%	73	22%
Tomato	281	49	17%	45	16%
Onion	360	130	36%	55	15%
Leafy salad	63	23	37%	21	33%
Potato	1578	730	46%	320	20%
Other	971	470	48%	220	23%
Processed fruit, vegetables and salads	**2239**	**195**	**9%**	**195**	**9%**
Potato	812	85	10%	85	10%
Other	1426	110	8%	110	8%

[49] WRAP, 2013a, Household food and drink waste in the United Kingdom 2012. By T. Quested, R. Ingle and A. Parry. The Waste and Resources Action Programme, UK.

Table 3. Continued

Food group	Purchases (kt)	Total waste (kt)	% of purchases	Total avoidable waste (kt)	% of purchases
Confectionery and snacks					
Sweet biscuits	528	19	4%	19	4%
Savoury snacks	416	23	6%	22	5%
Other	0	20		20	
Drinks	**8730**	**1248**	**14%**	**711**	**8%**
Fruit juice and smoothies	941	120	13%	120	13%
Tea waste	86	550		73	85%
Squash	0	38		38	
Carbonated soft drink	5392	230	4%	230	4%
Other	2311	310	13%	250	11%
Condiments, sauces, herbs & spices	0				
Cook in sauce	0	42		42	
Gravy	0	12		12	
Other	0	85		83	
Cakes and desserts	**604**	**72**	**12%**	**72**	**12%**
Cakes / gateau / doughnuts / pastries	492	86	17%	86	17%
Other	112	72	64%	72	64%
Pre-prepared meals (store bought)*	**759**	**115**	**15%**	**115**	**15%**
Other (including home- made meals, oils & fats)	**588**	**790**	**134%**	**350**	**60%**
Total in Mt	**37362**	**7000**	**18.7%**	**4200**	**11.2%**
Total in kg/capita (*1000/63.5 M)	**588**	**110**		**66**	

The amendments applied to fine-tune and complement these data for the EU:

Dairy products waste in the Netherlands (10%) and Denmark (8-10%) was higher than the 6% indicated above for the UK. A figure of 9% will be assumed.

Beer and wine are missing in the UK list, but were found to show 7% (avoidable) waste in other publications. (see Annex III)

Use and waste from vegetal oil (incl. margarine) is not explicitly included in the list above. For oil used in deep fat frying of French fries, snacks, etc. a study by Ecofys[50] mentions a total of 3.6 Mt of Used Cooking Oil (UCO) discarded by households (1.7 Mt), gastronomy and the food industry. Assuming that industrial frying takes up 0.6 Mt, this leaves 3 Mt as waste for households and gastronomy. With approximately half of vegetal oil used for deep fat frying (4 Mt), the related waste is thus 75% for that.

The other half (4 Mt) of vegetal oil is used as dressing, assumed 25%, and for lower temperature baking and frying, also assumed at 25%. The latter may be used also as an ingredient for gravy. Also, taking into the high waste fraction for e.g. salad, it is assumed that for both fractions there will be a 25% waste. In aggregate, for vegetal oil this means a waste percentage of 50% of purchases, of which 90% (45% of purchases) will be unavoidable and 10% (5% of purchases) may be due to overdosing and is thus avoidable.

Margarine is also used as a sandwich spread, with relatively little waste. Thus, for margarine a total waste fraction of 30% of purchases will be assumed, of which 15% (5% of purchases) will be termed ‘avoidable’.

50 ECOFYS, Trends in the UCO Market, 2013 for the UK Dept. of Transport

It is not documented whether the UK WRAP waste data are corrected for cooking (weight) losses. In general, for the weight increase of cooking pasta (factor 2) and rice (factor 3) the correction is standard procedure. The weight loss of cooking meat, fish and vegetables is usually not taken into account and some correction of (unavoidable) waste is assumed. Assumptions are:

- For meat and fish, it is assumed that 50% of waste is from cooked leftovers, for which a correction of 20% is assumed. Overall, this means that waste from meat and fish is 10% higher than what is indicated in the table.
- For fresh vegetables, it is assumed that half are eaten raw (leafy vegetables and half of fruity vegetables) and the other half is cooked (roots, tubers, brassicas, half of fruity vegetables). Of these cooked vegetables, it is assumed that half is wasted in preparation and half are cooked leftovers, to which a correction of approximately 30% would apply. Overall this means that the waste of the fresh vegetable group will be 7.5% higher than what is indicated in the table.

4 Main food flows

4.1 Presentation of the flow diagram

4.1.1 Introduction

The objective of the EU FoodFlow diagram is to show the main food flows in the EU, firstly to illustrate the size of the food waste problem and secondly to make an inventory of foodstuffs and beverages for refrigeration. In doing so, an attempt was made to arrive at a closed mass-based accounting system. This means that inputs and outputs of the food system should match.

To build a complete food system from incomplete data an iterative approach was used, alternating between 'top-down' figures and 'bottom-up' aggregates of detailed flows. To report on the final result of such a process a 'top down' approach is chosen, starting out with a complete, yet streamlined flow diagram in this paragraph and then filling in the detailed background in the subsequent paragraphs. The overall diagram will always be referred to as 'FoodFlows'.

The main instrument to construct FoodFlows and most of the underlying detailed analyses is a so-called Sankey diagram, i.e. a graphical representation based on its own or Excel-linked data where the arrow-widths represent the size of the mass-flow (in Mt) and the nodes help to check whether in- and outputs are in balance.

4.1.2 System boundaries and accounting

The system relates to the EU 2011/2012 data, including extra-EU trade.

The food system starts, as does the FAO, with the raw material equivalent (RME) mass of the crop imports, crop exports and crop production. For crop imports and –exports this means that the 'Rücksack' of material resources spent/saved in the country of origin/destination is taken into account. For practical reasons[51], the forage input is given in dry hay equivalent (humidity 20%). If it were given in the original weight of forage feed (grass, green fodder, etc.) the humidity would be higher (close to 65%) and thus more than 3 times higher.

However, after this initial phase, all flows relate to real mass. For practical reasons, i.e. to keep the balance, the import and export of processed food into the EU is thus also in real mass. This may give rise to a small over/underestimation of the total materials input, but given that the extra-EU trade is small and reasonably balanced, the error is considered negligible.

The mass of the crops relates to post-harvest production, i.e. it does not include (pre-) harvest losses. The production of seed material is shown (in brackets) but excluded from the initial figure.

The farm animal products (meat, milk, eggs) are not separate inputs, but are modelled as the result of the animal feed input. For accounting purposes –not necessarily biologically correct-- the difference between feed inputs and animal product outputs is defined as 'metabolism' (faeces, urine, gas, body heat, growth/maintenance, movement, etc.) and not

[51] The original data of 233 Mt stem from FEFAC; there is some uncertainty as regards the exact humidity content there, but there is little uncertainty as regards the multiplier to arrive at the original weight. A second practical reason is that a mass flow of 757 Mt would dwarf all other mass flows.

further specified. The exception is fish & seafood, predominantly caught in the wild, that is treated as a separate input.

The initial meat production is given in net carcass weight ex slaughterhouse, meaning it does not include mortality of live animals, nor does it include possible slaughter for own use. Flows of non-food by-products (hides, bones, non-edible fat etc.) are expressed in real mass.

Eggs are usually counted as numbers and then multiplied by egg-weight (typically 60 g/egg), with (pre-) collection losses not counted. Eggs for hatchery (to 'produce' laying hens) are not part of initial egg input (comparable with 'seed' for crops), nor possible own use by farmers.

Milk production is the mass delivered to the dairy industry. Raw milk set apart for on-farm milk consumption (e.g. for making cheese, cream, etc. but also possible own consumption) is thus not included (but still shown in brackets).

In the flow diagram, only a dozen main food flows are traced 'from farm to fork'. Minor food flows and non-alcoholic beverages are added only in the end-use phase. These are separate inputs.

Various processes influence the water content of the foodstuffs. In most cases, these are small quantities and are implicitly included in the waste streams. Only where there is a very large water extraction (i.e. in producing raw sugar, in cheese and milk powder) or large addition of tap water (i.e. for beer making) these flows are added explicitly. The balance of these 3 water extractions/additions is an explicit input/output.

The system boundaries on the output side, apart from exports, are the non-food industry (vegetal and animal), waste streams and end-use. Note that waste from the non-food industry that is used for animal feed (e.g. oilcake from biofuel production) or definitely classified as waste is included in the system.

There is one recycling flow, i.e. by-products from downstream processes that are (re)used as input for animal feed. These by-products are first combined with waste in one flow and then split. The recycling of by-products adds to the gross material input, but is excluded from the net material input.

There are several flows that are NOT in the considered food flow diagram because they are not relevant for the scope of assessing refrigerator content. These 'missing flows' include 62 Gt of irrigation water, 2 Gt of drinking/ cleaning water from the public grid, 19 Mt of fertiliser, 12-14 Mt of organic manure (from animal faeces), 0.2 Mt of pesticides and 283 Mtoe (Million tonnes of oil equivalent) of gross energy input. [52] These flows will be discussed in Chapter 5 on Impacts.

As mentioned, also the pre-harvest waste and, for farm animals, the mortality of live animals are also not taken into account.

[52] Sources include: VHK, MEErP, Part 2, 2011 (for irrigation and drinking water). BIOIS 2010 and Eurostat agricultural statistics (for manure, fertiliser, pesticides). The energy input, calculated by VHK on the basis of [VHK, Ecodesign Impact Accounting, 2016] will be discussed in the next chapter.

4.1.3 Aggregates

The table below is the result of the food flow analysis and the basis for the FoodFlow diagram. It shows for EU 2011-‘12 the main flows from import and production until food intake.

Table 4. FoodFlow EU 2011-’12 by main flows

Stage	**Sugar beets**	**Oilcrops & nuts**	**Potatoes**	**Vegetables**	**Fruit**	**Cereals**	**Forage**	**By-products** (incl. non-food out)					**TOTAL**
Crop import	0	18	1	4	18	17	0	25					83
production (+recycled)	125	46	56	63	61	251	233	103					938
production & import	***125***	***64***	***57***	***67***	***79***	***268***	***233***	***128***					***1021***
Post-harvest & partitioning													
Water XL	-88												-88
Waste & by-products			-7	-7	-11			-33					-58
—o/w by-products			*-3.5*	*-3.5*	*-5.5*			*-25*					*-38*
—o/w waste			*-3.5*	*-3.5*	*-5.5*			*-8*					*-21*
Export1			-7			-33							-40
Veg. Non-food	-7	-30	-5			-30							-72
compound feed						-87		-88					-175
own cereal feed						-51							-51
bought straight feed								-38					-38
forage feed							-233						-233
Total feed						*-138*	*-233*	*-126*					*-497*
Remains for food	***30***	***34***	***38***	***60***	***68***	***67***							***296***
Processing & animal products							**Meat**	**Fish**	**Milk**	**Eggs**			
Metabolism (fed animals vs feed)							-249		-27	-15			-291
Animal products from feed							59		140	7			206
Animal products from catch								6					6
Import2	7	9						5					21
Non food	-5	-9					-14		-4	-2			-34
Waste & By-products	-6	-20	-10	-6	-16	-15		-2					-75
—o/w By-products	*-2.0*	*-13.4*	*-6.7*	*-3.0*	*-7.0*	*-10.1*		*-1.3*					*-44*
—o/w Waste	*-4.0*	*-6.6*	*-3.3*	*-3.0*	*-9.0*	*-4.9*		*-0.7*					*-31*
subtotal	**20**	**14**	**28**	**54**	**52**	**52**	**42**	**7**	**136**	**4**			
Animal products & retail													
Water XL						38			-45				-7
Export2	-6						-3	-2	-3	-1	**Soft drinks**	**Small flows**	-15
Waste & By-products	-3					-6	-10		-21				-35
—o/w by-products	*-1.5*					*-4.8*	*-5*		*-10*				*-17.3*
—o/w waste	*-1.5*					*-1.2*	*-5*		*-11*				*-17.7*
subtotal	**17**	**14**	**28**	**54**	**52**	**84**	**32**	**7**	**67**	**4**			**359**
End-use phase													
Purchase	17	14	28	54	52	84	32	7	67	4	106	20.2	485
Intake	16	9	17	35	40	74	25	6	61	3	98	16	402
Waste	1.0	4.9	10.8	19.1	12.3	10.1	6.9	0.5	5.5	0.7	7.9	3.9	84
—o/w Unavoidable	*0.2*	*4.1*	*5.7*	*9.1*	*6.2*	*0.0*	*3.3*	*0.1*	*0.5*	*0.4*	*0.0*	*2.4*	*32*
—o/w Avoidable	*0.9*	*0.8*	*5.1*	*9.9*	*6.1*	*10.1*	*3.6*	*0.4*	*5.1*	*0.2*	*7.9*	*1.5*	*52*

For a detailed table of the foodstuffs in the end-use phase see paragraph 4.14.

To check the validity of the accounting, the following table gives the totals per phase. Apart from a small rounding effect, it shows that ‘sources’ and ‘sinks’ are in balance.

Table 5. FoodFlow balance, sources and sinks.

SOURCES	***Mt***	***SINKS***	***Mt***
Total imports	104	Total byproducts process	-103
Total production from crop + fish	1070	Total waste process & retail	-71
Total non-food byproducts&waste	33	Total non-food input	-106
TOTAL SOURCES (gross)	**1207**	Total exports	-55
		Total water XL	-95
		Metabolism	-291
		End-use waste	-84
		Intake	-402
		TOTAL SINKS (gross)	**-1207**
Total without recycling of by-products (103 Mt lower production) ***TOTAL SOURCES (net)***	**1104**	*Total without recycling of by-products (103 Mt by-products sink removed)* ***TOTAL SINKS (net)***	**1104**
Total net EU Domestic Material Input with forage at original weight (750 Mt) instead of dry hay equivalent (233 Mt). On the side of the sinks, the 'Metabolism' will increase accordingly			
TOTAL SOURCES (net, real)	**1621**	***TOTAL SOURCES (net, real)***	**1621**

The gross balance total amounts to slightly over 1.2 Gt. Without the recycling of by-products to animal feed, an action that does not require resources from outside the system, the net total becomes 1.1 Gt.

The forage feed is given in dry hay equivalent; there is no documentation on the issue, but it is estimated from analogy with USDA-figures that the given 233 Mt of dry hay equivalent is equal to 750 Mt of original feedstuffs (grass, green maize, etc.). See also Annex II for the water content of feedstuffs. When increasing 'forage' as a source, the 'metabolism' as a sink will increase with same amount.

Eurostat gives a total EU Domestic Materials Consumption (DMC) of 7.3 Gt, of which *biomass minus wood* (=food related crops) amounts to 1.44 Gt or almost 20%. Considering that some inputs like soft drinks and bottled water consist almost completely of added water (not considered a part of DMC). The Eurostat value is in line with this study's estimate (deviation <10%).

The 20% of EU Material Resources for food production is a very large number. Half of the EU Material Resources go to minerals (for construction), 23% to fuel and 4% to metal ores. The material resources inputs for the Ecodesign-regulated energy-related products (40 Mt) constitute 0.5% of the EU's Domestic Materials Consumption.[53] *As a result, even a very small saving on food waste is very likely to outweigh material resources efforts needed to improve household, professional and commercial refrigeration.*

The figure below gives a simple version of the FoodFlow diagram to introduce the principle and the main values.

[53] VHK, Ecodesign Impact Accounting – Special Material Resources, 2016.

FoodFlows & Refrigeration

Aggregated, EU 2011-'12, in Mt

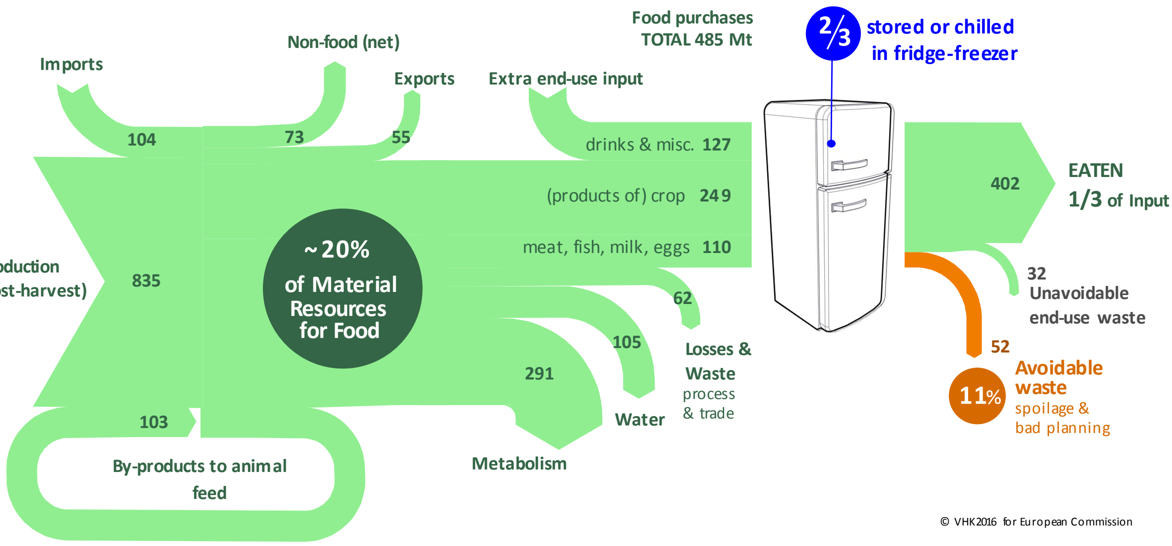
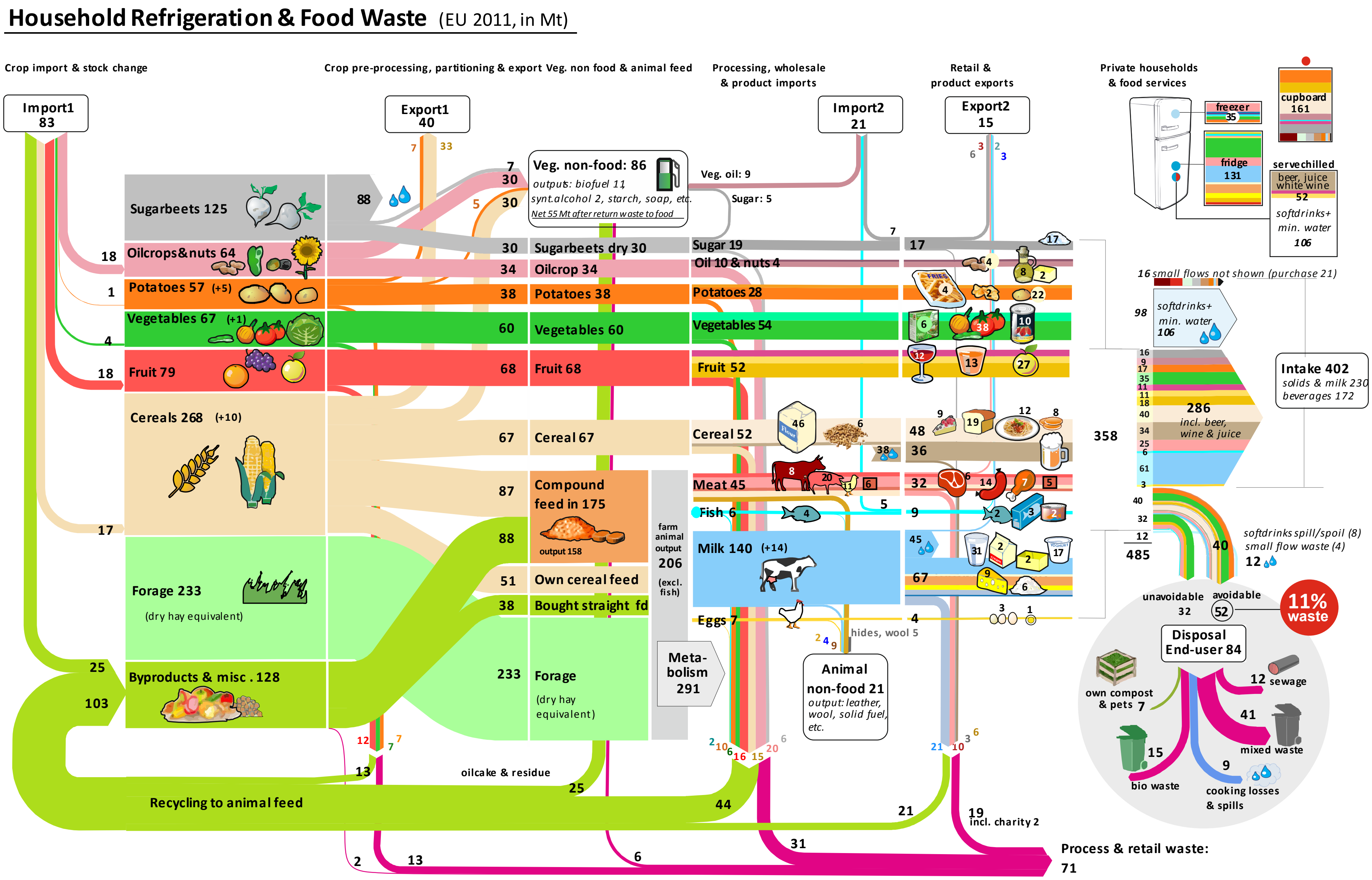


Figure 13. Simplified EU food flow diagram

A more detailed, but still one page FoodFlow diagram is given hereafter.



The diagram contains main feed and food flows. Flows <0.5 Mt are not shown and thus rounded figures will not always match. Pre-harvest & pre-slaughter waste is excluded. Flows of softdrinks (ca. 50), bottled mineral waters (56) and some non-perishable small flows (*cacao 5, sauce & spices 4, salt 3, sweeteners 2.5, coffee 2.2, spirits 1.4, babyfood 1.1, vinegar, tea 0.4, etc.*) are only listed at end-use. „Vegetables“ includes pulses (beans, peas, etc.). „Oilcrops“ includes treenuts. „Fish“ includes crustaceans and molusks. Output used for seeds or own use is in brackets. Consumption off tapwater is not included in the end-use. Irrigation water (62 Gt), other farm water use (2 Gt), fertiliser (19 Mt), manure (12 Mt), pesticide (0.2), energy (283 Mtoe) are also not included here Mt.
Source: VHK based on elaboration of data from FAO, Eurostat, EFSA, food waste studies by WRAP, ISWA, CREM and others. Copyright VHK 2016 for the European Commission

Figure 14. EU FoodFlows (2011-‘12, in Mt)

4.2 Sugar beets

Sugar beets are by far the most important raw material in the EU.[54] According to the FAO, the net EU harvest of sugar beets was 125 Mt[55]. After harvest, where the beet leaves are left on the land, the crop is washed, sliced and sugar extracted by diffusion. Milk of lime is added to the raw juice and carbonated in several stages to purify it[56]. Water (88 Mt) is evaporated by boiling the syrup under a vacuum. The syrup is then cooled and seeded with sugar crystals. The white sugar that crystallizes out can be separated in a centrifuge and dried. It requires no further refining.

The beets contain 22-24% of dry matter with 17.3% sugar content.[57] Processing results in around 15% (raw) sugar with 5% molasses and 2% beet pulp as by-product. The molasses by-product, containing around 50% sugar, can be further processed to extract raw sugar or, possibly in combination with the beet pulp, can be processed for the production of mainly (bio)ethanol in the non-food industry[58]. The flow-diagram shows that 30 Mt of dry matter results in 19 Mt raw sugar, 5 Mt input in the vegetable non-food industry and 6 Mt of residue that goes to 4-5 Mt animal feed and 1-2 Mt waste.

The raw sugar is then refined to 17 Mt white sugar for food purposes.[59] A small part of the refined sugar is bought as table sugar by households. UK surveys show that added sugar, i.e. sugar added during processing, is found for 25% in soft drinks (40% for teenagers), 25% from table sugar/ sweets/chocolate/jams, 8% from milk products, 22% from cereals/cakes/biscuits, 8% from alcohol, 12% from other sources. [3][60]

These proportions can vary considerably per country. For instance, chocolate consumption in countries like Germany, UK and Switzerland is around 10 kg/capita/year, whereas in Southern European countries it is less than half.[61] On average, the refined sugar consumption was around 34 kg/capita/year in 2011.

The flow diagram on imports and exports of sugar is a simplification. In reality, the accounting is more complex because of the 2007 EU Sugar Reform that limits total EU production quotas for food purposes to 13.5 Mt of white sugar equivalent which amounts to 14.7 Mt in raw sugar equivalent (RSE). EU sugar processors in Member States have four options to market sugar produced out-of-quota: export (but this is limited to 1.5 Mt RSE due to WTO agreements), disposal for non-food purposes (ethanol, fermentation), disposal on the EU-market at a heavy penalty/levy or carry-over in stock. In 2011, the latter option resulted in 3.6 Mt of RSE production going to the stock. At the same time, the EU imported 3 Mt of raw sugar and 1.2 Mt of white sugar from outside the EU.

This means that the stockpile, imports and exports of raw sugar more or less compensate each other and thus, for the sake of complicity one of these have been taken into

[54] Production of sugar cane is negligible, although there are a few refineries of imported sugar cane in the EU (ca. 1.4 Mt)

[55] The sugar sector reported a harvest of 151 Mt of sugar beets for the EU-27 in 2011 (CEFS, Sugar Statistics 2011, Comité Europeen des Fabricants de Sucre, www.cefs.org) from 1.5 million hectares (yield 10.6 t/ha).

[56] Carbonatation is a chemical reaction in which calcium hydroxide reacts with carbon dioxide and forms insoluble calcium carbonate. The target is a large particle that naturally settles rapidly to leave a clear juice.

[57] CEFS, Sugar Statistics 2011, Comite Europeen Des Fabricants De Sucre, www.cefs.org.

[58] Molasses can also be used in the fermentation industry to help in the production of yeast. Relatively these are small quantities and not shown in the flow-diagram

[59] Conversion factor 1/1.087. Source: USDA, EU-28 Sugar Annual Report, 2016.

[60] source: How much sugar do we eat? By Christine Jeavans BBC News, 26 June 2014 (based on data from the UK National Diet and Nutrition Survey 2008-12) http://www.bbc.com/news/health-27941325

[61] Compare e.g.: http://group.candyking.com/en/about-candyking/market-overview/ or Zucker in Zahlen/Quarks & Co/08.12.2015. http://www1.wdr.de/fernsehen/quarks/sendungen/zucker-zuckerinzahlen100.html

account.[62]

4.3 Oil crops & Nuts

Oil crops include rapeseed (colza), olives, sunflower, mustard seed, soybeans, groundnuts (peanuts), coconuts (including copra), palm kernels and cotton seeds. Tree-nuts include almonds, Brazil nuts, cashews, chestnuts, filberts/hazelnuts, macadamia nuts, pecans, pistachios, pine nuts, Shea nuts and walnuts. They are eaten as snacks or as an ingredient in compound food preparations (e.g. ice-cream, chocolate).

The EU produced 43 Mt of oil crops and 0.8 Mt of tree nuts in 2011. Some 18 Mt of oil crops (mainly soy) and 1.5 Mt of tree nuts were imported; exports are insignificant. Around 3% of oil crops (1.9 Mt) is used directly for food after removing the shells or pits, i.e. a part of peanuts (0.4 Mt), olives (0.8) and coconuts (0.4). In the diagram these are classified, together with the tree nuts, as 'nuts' and amount to 4 Mt. The oil crops for oil available in the EU amount to 60 Mt in 2011 and in aggregate there were 64 Mt of oil crops & nuts available for consumption/processing.

Roughly half of the oil crops go to the food-industry and the other half goes to non-food industry, in both cases to produce vegetable oils with oilcake as an important animal feed by-product.

Processing oil crops results for most types in 40 wt. % oil and 58% oilcake (weight percent). Olives and soybeans have a lower oil-yield of around 18-20% (first pressing). The oilcake has a high protein- content and is valuable as (mainly) animal feed. Processing of oil crops produces little waste; even the olive pits are valued as biofuel-input (14-19 MJ/kg) for gasification or co-combustion.[63]

Vegetable oil for food is consumed raw (e.g. olive oil), as cooking oil (sunflower, colza, etc.) or as an ingredient for e.g. margarine (2 Mt), peanut butter, miscellaneous compound foodstuffs. Non-food applications are biofuel ('biodiesel'), soap (palm oil), etc.

Imports of vegetable oil (mainly soy) amounted to 9 Mt of vegetable oil, mainly for the non-food industry; vegetable oil exports were in the order of 1 Mt, with a relatively large share of olive oil.

Around 30 Mt oil crops went to non-food applications to produce 10 Mt of oil (mainly biodiesel)[64] and 15-20 Mt of oilcake (animal feed). The other 30 Mt of oil crops went to food applications to produce around 10 Mt of vegetable oil equivalent (oil 8, margarine 2) and 4 Mt of 'nuts' (2.3 Mt tree nuts and 1.9 Mt of directly edible oil crops such as peanuts, coconuts and olives).

The oilcake by-product of both food and non-food industry goes to animal feed. Processing oil crops results for most types in 40 wt. % oil and 58% oilcake (weight percent). Olives and soya beans have a lower oil-yield of around 18-20% (first pressing). The oilcake has a high protein-content and is valuable as) animal feed. In total, it is estimated that the 60 Mt of oil crops had a yield of 15-20 Mt of oil and 35-40 Mt of oilcake, with an estimated 1 Mt (1-2%) as actual processing waste. EU-imports of oilcake, the by-product of vegetable oil processing, are significant at 25 Mt.

Around 1 Mt of this Used Cooking Oil (UCO, a.k.a. 'RVO', Recycled Vegetable Oil) is recycled to the non-food industry for biodiesel (90%) or oleo-chemicals (10%, e.g. soap, candles). The main sources of recycled UCO are the frying shop industries, catering

[62] CEFS, Sugar Statistics 2011, Comite Europeen Des Fabricants De Sucre, www.cefs.org.
[63] MoRE, Market of Olive Residue for Energy, WP4 report, Dec. 2008 www.moreintelligentenergy.eu
[64] See also: FEDIOL, *Food, Feed and Fuels -- A Deeper Look*, 2012-'13, www.fediol.eu

establishments and small restaurants or bars. Ecofys estimated the theoretical potential of UCO for the EU at 3.6 Mt/year from gastronomy, households (1.7 Mt) and food industry[65]. Ecofys also estimated that 60% of household UCO (i.e. 1 Mt) was improperly being disposed of, mainly by flushing it through the drains (and often blocking sewers).

4.4 Potatoes

There is generally consensus that in 2011 the EU harvested 62 Mt of potatoes, of which 5 Mt for seeds, in 2011. Including imports of 0.5 Mt[66] this means that 57 Mt of potatoes was available for exports and various uses. Exports took up 7 Mt. The starch production, consumed 7 Mt of potatoes to produce 1.4 Mt of starch. Around 70% of that starch (5 Mt potato equivalent) went to non-food applications e.g. paper making and the remaining starch was used in food manufacturing (2 Mt potato equivalent that we partitioned to 'small flows' (e.g. confectionary) that only appears in the main flow diagram as end-use.

The most important potato products are 4.4 Mt of frozen (pre-cooked) French fries, 2.3 crisps and similar preparations as well as 0.3 Mt of dried potatoes. The FAO mentions a conversion efficiency of 28% from potatoes to French fries. This is a global figure and it is assumed that efficiency for the EU will be around 33% for French fries and 25% for crisps. This means that French fries production took up some 13 Mt of potatoes and crisp production around 9 Mt. Apart from that, 22 Mt of fresh potatoes was consumed by end-users. From these figures, it results that 43 Mt of potatoes was needed to produce 28 Mt of end-product. This means some 15-16 Mt of water (evaporated from cooking), animal feed (from peels etc.) and waste was lost. We partitioned these quantities to pre-processing (7 Mt) and processing (9 Mt).

4.5 Vegetables

Eurostat crop statistics[67] splits *'fresh vegetables'* in

- *'brassicas'*, i.e. cauliflower & broccoli, Brussels sprouts, white/red/savoy cabbage and 'other' (kohlrabi and Chines cabbage),
- *'leafy and stalky vegetables'*, i.e. leeks, celery, lettuces (grown outdoors or in a greenhouse), endives, spinach, asparagus, chicory (for fresh consumption or processing), artichokes and 'other',
- *'vegetables cultivated for fruit (incl. melons)'*, i.e. tomatoes (fresh or for processing, grown outdoors or in a greenhouse), cucumbers (outdoors or in a greenhouse), gherkins, eggplants/courgettes (incl. marrows)/gourds & pumpkins, melons (muskmelons & watermelons), peppers and 'other'.
- *'root, tuber and bulb vegetables'*, i.e. carrots, onions & shallots, beetroot, celeriac, radishes, garlic and other (turnips, fennels, salsifies & scorzonera).

Fresh pulses are split in fresh peas, fresh beans (French beans and runner beans) and 'other'.

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[65] ECOFYS, Trends in the UCO Market, 2013 for the UK Dept. of Transport

[66] Imports of potato products amounted to 0.47 Mt, mainly as fresh or chilled potatoes (0.38 Mt) and sweet potatoes (0.07 Mt). Source COMEXT data, DG AGRI elaborations for EU-27

[67] Eurostat, Handbook for Annual Crop Statistics, Revision 2015.

The FAO food balance only distinguishes tomatoes (and products), onions and other vegetables. Pulses are split in peas, beans and 'other', as with Eurostat.

The FAO finds an EU 2011 production of 68 Mt of vegetables and 4 Mt of pulses. The quantity needed for seeds is small (1 Mt as a placeholder for all non-potato and non-cereal seeds). Around 4 Mt of vegetables is imported, giving a total of 75 Mt (68+4-1+4).

Exports equal the imports (4 Mt). Furthermore, the FAO finds a vegetable waste of 7.3 Mt and 4.2 Mt destined for animal feed (2.2 Mt vegetables, 2.1 Mt pulses).

The diagram below gives a split of the EU-2011 crop production by type (source Eurostat).

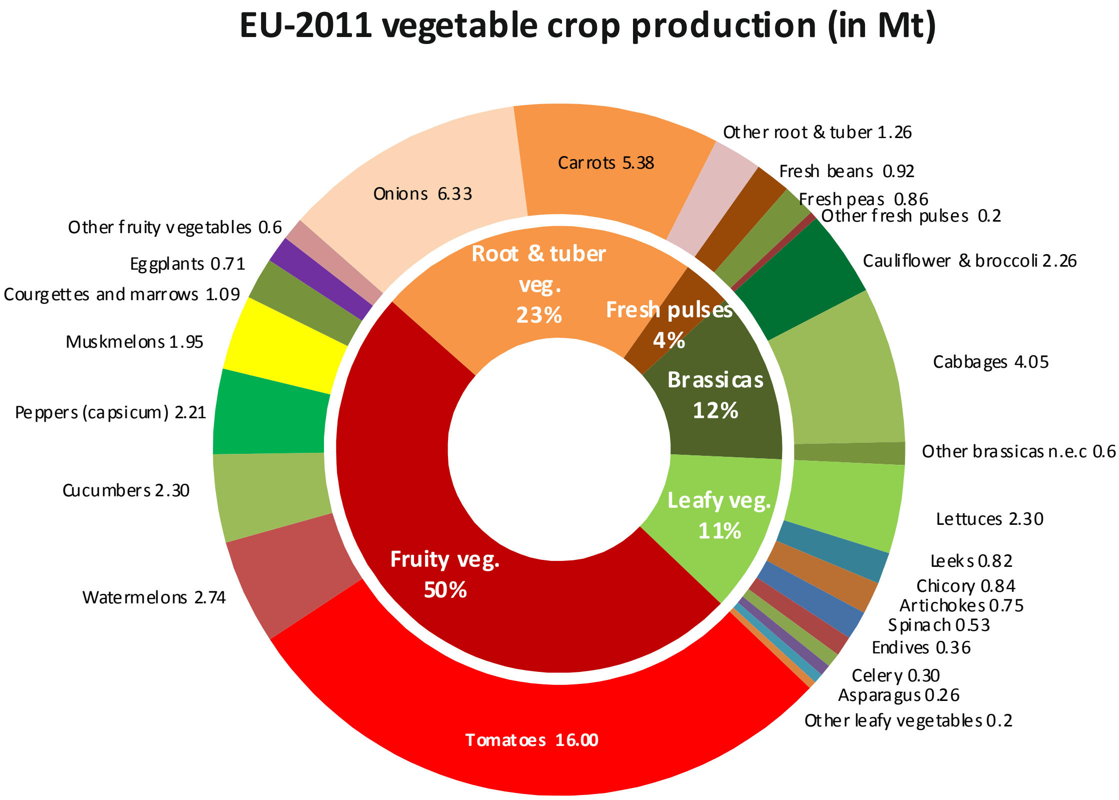

Figure 15. EU-2011 vegetable crop production (in Mt, total 55 Mt) as reported by Eurostat[68]

Note that Eurostat only includes *fresh* pulses, whereas FAO also includes at least a part of *dry* pulses under the header of vegetables (FAO 1.7 Mt, Eurostat 3.1 Mt).

This leaves 60 Mt (58.7 Mt vegetables and 1.5 Mt pulses) for further processing, which is assumed to result in 8 Mt of waste, and results into mainly frozen (6 Mt), fresh (38 Mt) and otherwise preserved (10 Mt, mainly canned) vegetables and pulses. As such there is 54 Mt of vegetables and pulses available for purchase by the end-user.

EFSA-data suggest that on average an EU consumer eats at least 54 kg of vegetables and pulses per capita per year, perhaps a bit more (say 5%) when counting vegetables in EFSA's composite foods. At 504 million EU-inhabitants in 2011 this comes down to a total vegetable intake of 29 Mt. This implies a food waste in the household of 25 Mt or around 45%. A large part of this waste will be unavoidable, not only because of peeling and

[68] Eurostat Crop Statistics 2011 [apro_acs_a], extract 29.10.2016

cutting losses but also because a large part of the food will be cooked (see methodology section).

The main flow diagram is showing only the main flows. The Sankey-diagram and – additionally—the pie-diagram below give more details for the case of tomatoes, which constitute the largest group of vegetables in terms of weight. It shows that from the 15377 kt available at harvest plus imports, 8666 remains for purchase (56%) and eventually 7412 kt (48%) is actually eaten. This is a vegetable that when purchased fresh is typically eaten unpeeled and uncooked (no cooking loss through evaporation).

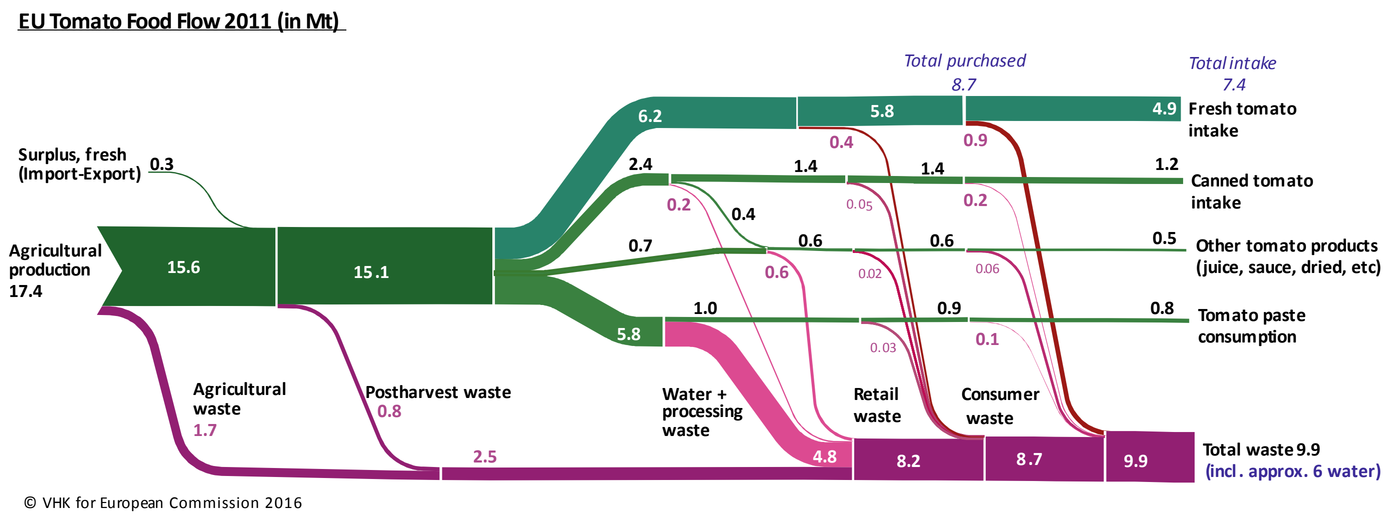

Figure 16. EU-2011 Flow-diagram tomatoes (VHK based on misc. sources)

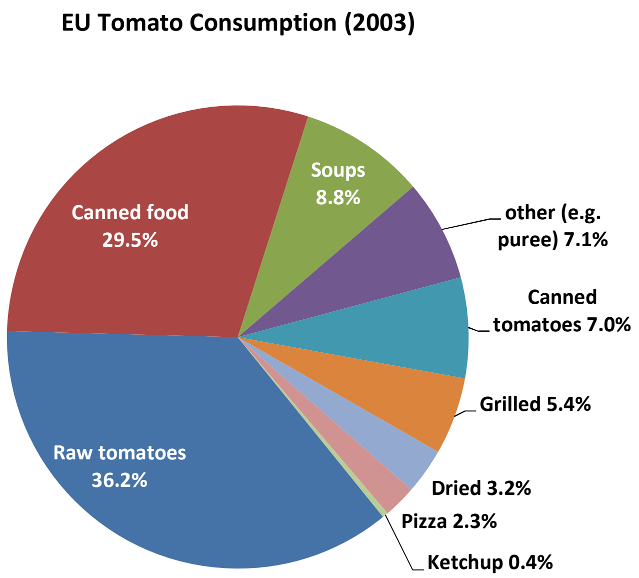

Figure 17. EU Tomato Consumption.
(Source:. R. Re, 2003, *Tomato consumption and plasma lycopene concentration*, European journal of clinical nutrition)

The FAD 2009 handbook Fruit & Vegetables gives some examples of tomato processing, e.g. 5-7 kg tomatoes are needed for 1 kg paste and 0,3-0,4 kg of tomato paste is needed for 1 kg ketchup.

4.6 Fruit

Most of the fruit in the EU is consumed in liquid form, which means that even for such a relatively simple product a great deal of processing is involved with possible errors in mass-accounting. A second problem is that a comparatively large part of the crop input is imported. To allow for efficient transport it is often not imported as fruit crop but as concentrated juice, e.g. of oranges. This means that peeling and pressing has been done in the country of origin. If, as is our case, we want to have a starting point with true raw material equivalent this means that the actual weight of the imported fruit has to be converted.

As the diagram below shows, the largest EU fruit crop (40% of production) is grapes, used mainly (90%) for wine making. Indigenous citrus fruits (oranges, small citrus fruits and lemons) account for 11.6 Mt of EU crop production. Taking into account the equivalent of 6.7 Mt oranges is imported from outside the EU[69], citrus fruits can be considered number two. Pome fruits such as apples (11.8 Mt) and pears (2.8 Mt), mainly indigenous, are number three. In total, the EU crop production amounts to 60 Mt and the imports, expressed in equivalent raw material are estimated at 17-18 Mt. After oranges, bananas (4.4 Mt) are the second largest imported fruit.

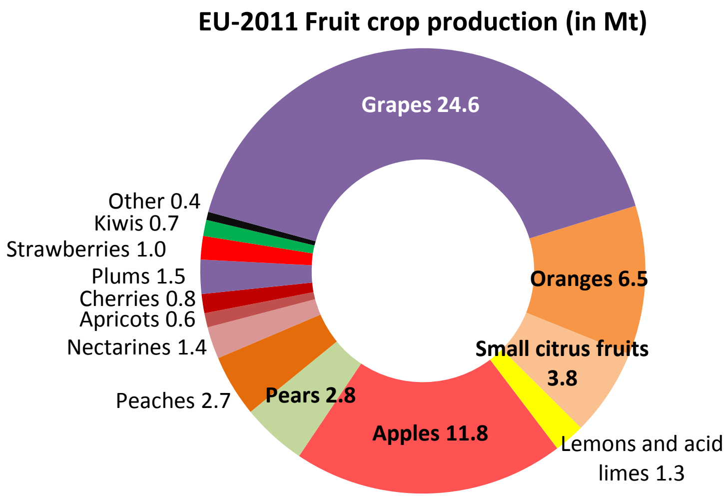

Figure 18. EU-2011 Fruit crop production (in Mt, total 60.1 Mt). Source: Eurostat crop production

This means, taking into account that exports are negligible, that in total 79 Mt are available for EU consumption.

The table below, based on miscellaneous sources, shows the raw material crop equivalent of the various liquid, canned or otherwise preserved and fresh fruit. It turns out (last

[69] 2.8 Mt of not-concentrated juice and 0.8 Mt of concentrated juice (enough to make the equivalent of 3.6 Mt of juice) plus 0.3 Mt waste, but not including peels used for animal feed.

column) that 57 Mt (72%) of the 79 Mt input is used to produce 43.9 Mt of non-alcoholic products, i.e. fruit juices and soft drinks (12 Mt), canned, dried, jam or otherwise preserved fruits (3.5 Mt) and 28.4 of fresh fruit. The other 23 Mt (28%) is used to produce wine for drinking (12 Mt) or for the production of vinegar and spirits (3 Mt).

Table 6. Estimated EU fruit processing 2011 (excl. retail & end-user waste).
Source: VHK on basis of FAO, AIJN, Eurostat

Fruit	**Liquid**	*Crop eq.*	**Canned, dried, jam, etc.***	*Crop eq.*	**Fresh**	**TOTAL Crop eq.**
	Mt	*Mt*	**Mt**	*Mt*	**Mt**	**Mt**
Oranges**	**4.1**	*7.7*	**0.1**	*0.2*	**7.8**	**15.7**
Apples	**2.2**	*3*	**0.7**	*1.4*	**6.3**	**10.7**
Pineapple	**0.4**	*0.8*	**0.3**	*0.6*	**0.1**	**1.5**
Grapes (excl. 22.14 for wine)	**0.5**	*0.7*	**0.3**	*1.8*	**2.0**	**4.5**
Bananas	**0.1**	*0.15*			**4.3**	**4.3**
Peaches	**0.4**	*0.6*	**0.1**	*0.2*	**1.9**	**2.7**
Other fruit (pears, peaches, cherries, etc.)	**4.3**	*6.6*	**2.0**	*5.0*	**6.0**	**17.6**
TOTAL EXCL WINE	**12.0**	***19.6***	**3.5**	***9.2***	**28.4**	**57.0**
Grapes for wine to drink	**12**	*17.0*				**17**
Grapes for other wine use (vinegar, spirits, etc.)*	**3**	*5.0*				**5**
TOTAL INCL WINE	**27.0**	***41.6***	**3.5**	***9.2***	**28.4**	**79.0**
*Animal feed & waste****	*14.6*		*5.7*		*2*	***22.2***

*= Not included in end-use fruit because incorporated in 'small flows'
**=Orange juice: Single strength juice NFC (Not From Concentrate) 1 Mt (80% import), Juice FC (From Concentrate, 100% import) 2.16 Mt, Nectar (avg. 57% concentr.) 0.94 Mt, Softdrink with orange flavour (avg. 11% concentrate) 1.44 Mt.
***= partitioned equally between pre-processing (peel removal) and processing, i.e. each 11 Mt in main flow-diagram

In the main flow diagram, the use of wine for vinegar and spirits is only taken into account in the end-use phase under 'small flows'.

4.7 Cereals (incl. rice)

Crop production and trade

Cereals, including rice, constitute by far the largest group of crops produced in the EU. EU production 2011 is estimated at 290 Mt[70], of which 10 Mt was used for seeds[71]. Imports are 17 Mt[72] and exports 33 Mt, the latter including a 1-2 Mt stock increase. As a result, 264 Mt is available for EU consumption. Of this, 30 Mt went to the non-food industry for the production of biofuel and synthetic alcohol. Around 167 Mt went to animal feed, of which 51 Mt as own cereal from animal farmers, 87 Mt in industrial compound feed and 20 Mt in ceral processing residue and 9 Mt in bought straight feed. This leaves 67 Mt for human food and food products.

Between data sources FAO[73], Eurostat[74] and DG AGRI [75] the differences on quantities of

[70] There are deviations between Eurostat crop statistics (283 Mt), FAO (293 Mt) and EC DG AGRI (287 Mt), mainly due to differences in classification of 'mixtures of grains', 'dual-purpose crops' (feed and food), 'energy crops', 'dry pulses', etc.. The 290 Mt is VHK's best estimate.
[71] Sources: FAO FBS, Eurostat crop statistics
[72] Converting 1 kg flour to 1.3 kg raw cereal equivalent
[73] FAO Food Balance Sheets, region EU-28, year 2011, published 2015.
[74] Eurostat Crop Statistics 2011 [apro_acs_a], extract 29.10.2016.

cereal production as well as use for animal feed and seed are relatively small (±3%).[76]

Deviations in figures for imports and exports are higher (±10%), probably because the FAO uses the weight of 'raw material equivalent' (as VHK proposes), whereas Eurostat uses actual weight, independently whether some processing occurred prior to trade. The split-up between food and non-food applications is not very transparent, probably because the data sources do not elaborate the flow to the full range of end-use applications. E.g. it appears that all starch production and similar is partitioned to non-food, whereas further downstream more than half of starch end-products do end-up in food applications (e.g. sweets). Having said that, there is not enough data to correct for that and thus the existing data (30 Mt for non-food) is used. The accuracy of cereal-volume for human food is estimated at ±5%.

The diagram below gives the annual EU crop production in 2011. Wheat is worldwide 27.1% of the cereals mix but in the EU it is almost half of the cereals production (47%). In other parts of the world maize is more popular (35% of global production).

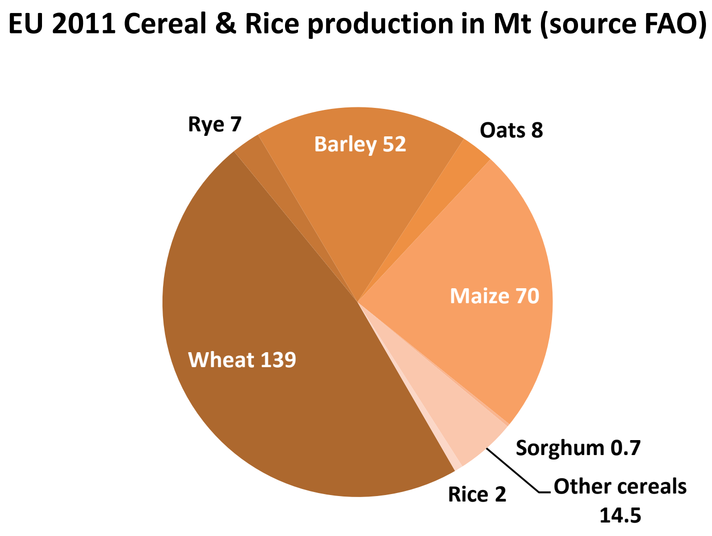

Figure 19. EU 2011 Cereal & Rice production by type, in Mt (source: FAO FBS 2011)
Note that the weight of 'rice' is given in milled equivalent.

<u>*Intermediate products (rice, flour, starch, malt)*</u>

Eurostat's Europroms[77] gives production and trade volumes for the food industry. For intermediary products the following numbers are given:

- For milled rice products an EU production of 2.9 Mt and a trade deficit of 1.3 Mt (1.5 Mt imports, 0.2 Mt exports) are given, leaving 4.2 Mt for EU consumption.
- EU production of flour was 35.4 Mt; after a trade surplus of 1 Mt this leaves 34.4 for EU consumption. EU production of milling residues is 11 Mt.
- Cereal starches (i.e. excl. 1.1 Mt of potato starch), syrups and gluten, etc. show a production of 11.8 Mt with a residue of 4.1 Mt.

[75] European Commission, DG AGRI, Cereal Balance 2011.
[76] There may be some confusion as to the role of 'green maize', This is a maize plant almost exclusively (except perhaps for 'baby maize') cultivated as animal fodder, i.e. it is harvested before maize kernels start to appear. Eurostat crop production mentions a harvest of 241 Mt of green maize in 2011. 'Green maize' is not included in 'cereals'.
[77] Sold production, exports and imports by PRODCOM list (NACE Rev. 2) - annual data [DS-066341]

- The production of malt from barley amounts to 8 Mt, of which 2.2 Mt is exported, leaving 5.8 Mt for EU beer production. The beer production amounts to 38.5 Mt, of which 2.5 Mt is exported. The residue from beer brewing amounts to 5.3 Mt.

All in all, according to Eurostat, the production of primary cereal products and rice amounts to 58 Mt with a (commercial) by-product of 20.4 Mt of production residue. This is in line with FAO 2011 manual for conversion factors, which mentions 70-79% efficiency for the production of flour and malt from cereal, with 18-20% bran as by product (and 1-3% waste).

End products (bread, pastry, biscuits, pasta)

Cereal end products include, according to Europroms, 19.1 Mt of bread, 5 Mt of pastry, 7.8 Mt of biscuits, 4.9 Mt of uncooked pasta, 2-3 Mt of prepared pasta products including ca. 1 Mt of frozen pizza. This gives a total of 39.8 Mt. Imports are small (in total 0.3 Mt). Exports amount to 2 Mt (1.2 Mt pasta & products, 0.6 biscuits, 0.2 other), thus leaving 19 Mt of bread, 7.2 Mt biscuits, 5 Mt pastry, 6.7 Mt of pasta for EU consumption (37.9 Mt in total). To this 4.2 Mt of rice and around 1.2 Mt of breakfast cereals [78] have to be added plus an unknown quantity of flour that is as ingredient in compound food (non-paste ready-meals, pizza, snacks, sausages, etc.). Estimating the latter at roughly 4 Mt, the deliveries to households can be estimated at 47 Mt. Also, taking into account the 8 Mt barley for beer making the total solids content 55 Mt. Significant unknowns include the water content of the various (intermediate and end-products and the split of the starch etc. production between (human) food and non-food.

Starch Europe members[79], representing 95% of EU starch production, process 23.6 million tonnes of EU agricultural materials (8.7 Mt wheat, 8.1 Mt maize 7 Mt potatoes) into 10.7 million tonnes of starch (1.4 Mt potato, 4.2 Mt wheat, 5.1 Maize) in 2015. The EU consumes 9.3 million tonnes of starch (excluding starch by-products totalling around 5 million tonnes), of which 61% in food, 1% in feed and 38% in non-food applications, primarily paper making. Of the 9.3 million tonnes of starch and starch derivatives consumed in the EU, 26% are native starches, 19% modified starches and 55% starch sweeteners. End-uses are confectionery & drinks (31%), other foods 30%, pharma & chemicals 4%, corrugation and paper (29%), other non-food 5% and 1% feed. Gluten is a mixture of proteins found in wheat and related grains, including barley, rye and oat. It is used e.g. in dough and co-produced with starch in relatively small quantities (0.5 Mt on a total of approx. 10 Mt starch in the EU-2011).

There are many routes to starch and related products. The figure below gives an example of a new concentrated process for the production of gluten with a starch slurry and proteins as by-product.[80]

[78] Industry association Ceereal (www.ceereal.eu) mentions an EU production of 1.2 Mt of breakfast cereals.

[79] http://www.starch.eu

[80] A.J. van der Goot et al., Concepts for further sustainable production of foods, Journal of Food Engineering 168 (2016) 42-51.

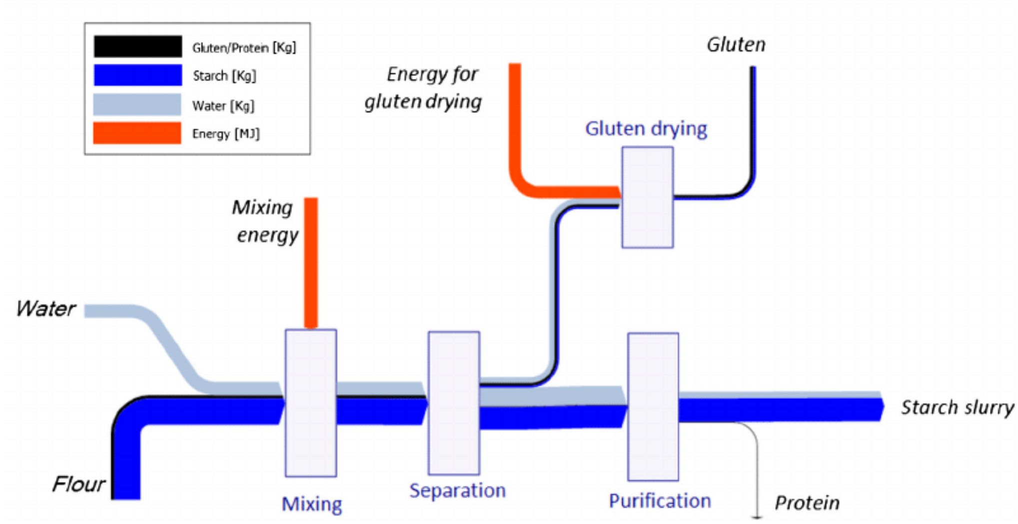

Figure 20. Proposal for a concentrated process for the separation of wheat flour into starch and gluten.
Internal recycle streams are not included. The process uses much less water than a conventional process, thus saving energy and achieving higher output levels. Source: A.J. van der Goot et al. (2016).

Please note that starch end-products, in particular confectionary and drinks, are mostly incorporated in the 'small flows' and part of the main flow diagram only at the end-use phase.

Information of Eurostat was checked against statistics provided by members of industry associations.

The European Floor Millers association[81] gives out figures for their market. They mention that 45 Mt of soft wheat and rye is used to produce 35 Mt of flour (i.e. efficiency 77%). The flour is used in small bakeries (30%, 10.5 Mt), large bakeries (30% 10.5 Mt), bakeries in supermarkets (12%, 4.2 Mt), biscuit & rusk manufacturers (14%, 4.9 Mt), household flour (12%, i.e. 4.2 Mt) and other uses (5%, 1.8 Mt). When translating these figures to end-products it is important to take the humidity rate (HR) and non-cereal ingredients into account. Flour, like grain, has a HR of 13-14%. White bread has a HR of 37%, which means that 1 kg of bread contains 0.75 kg of flour. In other words, 19 Mt of bread contain 14 Mt of flour.

Cake has a HR of 25%, but another 50% comes from non-cereal ingredients (sugar, eggs, milk powder, fat), which means that 1 kg of cake contains 0.25 kg of flour. This means that 5 Mt of pastry contain 1.25 Mt of flour. Biscuits appear in all sorts and shapes, but several recipes require 0.5 kg of flour. This means that 7.8 Mt of biscuits contain 3.9 Mt of flour. In aggregate, the bread, pastry and biscuits sold contain 19.15 Mt of flour. Taking into account a 10-20% loss in manufacturing (source: ISWA) this can be rounded to 23 Mt. To this, 4.2 Mt of household flour and 1.8 Mt for other uses should be added, resulting in 29 Mt of flour. It does means that some 6 Mt of the 35 Mt flour produced by the European Floor millers is unaccounted for.

In that context, it is relevant that Eurostat registers only bread that is actually sold. But at the end of the day, many bakeries take back the bread that has not been sold in the shop. Some bakeries may sell it at half the price the next day, use it to produce new recipes or

[81] http://www.flourmillers.eu/page/facts-figures-flour-milling-industry/

donate to charity (food banks) but ultimately most ends up as animal feed[82] or possibly as biofuel[83]. It is estimated that very little bread ends up in the real waste stream. It is estimated that Dutch bakeries take back 140 million old loafs of bread per year (112 kt). Scaling up this figure to the EU, this means almost 3 Mt of old bread goes to animal feed. In the UK, a study of WRAP for Tesco revealed that half of the bread is never eaten, with 40-50% disposed of in shops and the rest at home. If this is true for the whole of Europe, it means that bakers need to bake 27 Mt of bread to actually sell 19 Mt in shops, i.e. 8 Mt goes into 'old bread'. Assuming a middle value between the Netherlands and the UK, an over-production of 6 Mt makes sense.

The above figures apply to *soft* wheat and rye. For pasta and couscous another wheat, durum wheat (durum semolina), is used. Pasta producers are represented by UNAFPA - Union of Organisations of Manufacturers of Pasta Products of the EU (www.pasta-unafpa.org/), but their statistics add little to what is given by Eurostat.[84]

For pasta production, durum wheat is first mixed with water (30 water: 100 wheat), subsequently extruded and then dried. Arendt et al. [2013] mentions Humidity Rates (HRs) for pasta, i.e. 'fresh' (HR>24%), 'stabilised' (HR<20%), 'dry' (HR<12.5%). Other durum wheat products include couscous, bulgur, etc. [85].

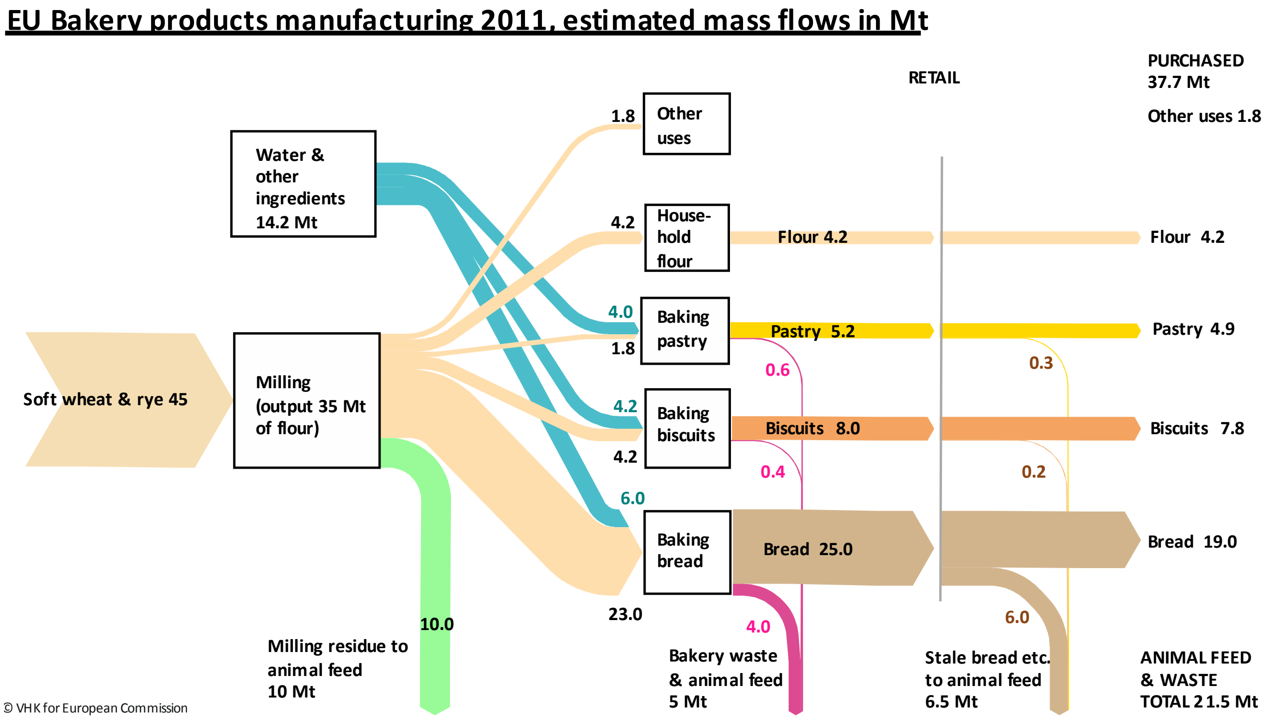

Figure 21. EU Bakery products manufacturing 2011, estimated mass flows in Mt. Source: VHK 2016 elaboration of data from misc. sources.

Compared to the HR of the raw material (wheat HR 14%) there is not a large difference, so

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[82] E.g. in the Netherlands a price of 8 cents per bread (800 g) is paid for stale bread going to animal feed.
[83] Fermentation bioreactors to produce biogas or incineration in special bakery ovens. (source: Trouw, Oud brood is slim te gebruiken, 13 Nov. 2009).
[84] UNAFPA only supplies some data on per capita consumption. According to UNAFPA annual pasta consumption per capita in Italy is 23.5 kg. In the rest of the EU it varies between 1 (Ireland) and 8 (DE, FR) kg.
[85] Arendt, E.K., Zannini, E., Cereal Grains for the Food and Beverage industries, Woodhead Publishing Ltd., 2013.

we can assume that the 7-8 Mt of pasta and pasta products require the input of an equivalent amount of durum wheat. Together with the 35 Mt of flour from soft wheat and rye this gives an estimated 42 Mt of flour produced in the EU.

Note that cereals are also used in the production of spirits. As will be discussed in the section on 'small flows' this application takes up 2-3 Mt of cereals.

Sankey diagrams for food processing are scarce, but Courtonne et al. (2012) have produced a comprehensive Sankey diagram for cereal processing in France 2007/2008.[86] Data in that diagram largely confirm the VHK-estimates in this section.

The figure of 167 Mt of cereals being used as animal feed seems fairly robust between sources. The following paragraph deals specifically with animal feed.

4.8 Animal feed

The following diagrams represent data from the association of European compound feed producers FEFAC. Figure 23 shows the overall sources of animal feed in the EU.

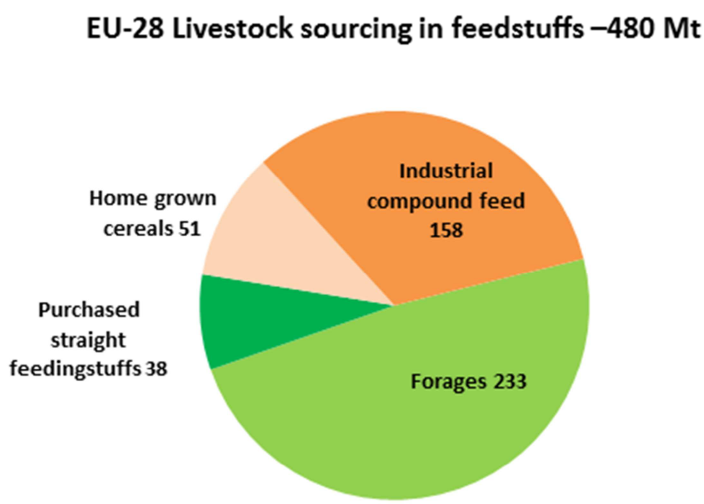

Figure 22. EU Livestock sourcing in feedstuffs 2013. Source: FEFAC 2015.

It is important to note that the forage volume is given in Mt of dry hay equivalent (HR 14-20%[87]). In reality, the green plants have a humidity content ranging from 60% to almost 78%. This means that the original volume of the crop is several times higher. Eurostat's statistics on domestic material consumption (DMC) mention 527 Mt of 'fodder and grazed biomass', 158 Mt of straw and 215 Mt of used crop residues (pre- and post-harvest), bringing the total 'forage' volume to 900 Mt.[88]

The diagram below gives a further split-up of the inputs for the 158 Mt of industrial compound feed.

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[86] J. Courtonne, J. Alapetite, P. Longaretti, D. Dupré, 'Etude des flux de céréales à l'echelle locale: Exemples en Rhône-Alpes, en Isère et dans le SCOT de Grenoble', 2012. http://www.eco-data.fr/dataviz/sankey/sankey_studies/Fili%C3%A8re%20c%C3%A9r%C3%A9ales/article_c%C3%A9r%C3%A9ales.pdf

[87] Depends on the source. US statistics (USDA) use 14% humidity rate, whereas in literature also values of 20% are found.

[88] Eurostat DMC statistics also report 57 Mt of crop residues (e.g. beet leaves) not used for feed.

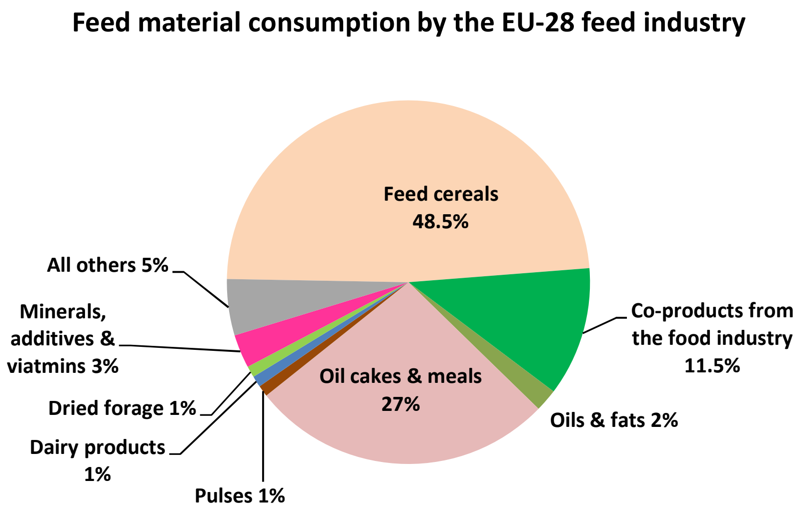

Figure 23. EU feed material consumption by the compound feed industry 2013. Source: FEFAC 2015.

Almost half of the input comes from cereals (48%), 27% comes from (oil)cakes and meals mostly as a by-product of oil crop and grain processing. Likewise, the 11.5% co-products from food and bioethanol industries are also products from oil crop and grain processing.

The FEFAC does not report on waste during compound production. For the time being we assume that it takes 10% more input, i.e. 175 Mt, to produce 158 Mt of compound feed. Largely, this extra 10%, 17 Mt, is considered to be recycled within the industry. As suggested by FEFAC almost half of the input for compound feed, i.e. 87 Mt, comes directly from cereal crop production. The other (more than) half, 88 Mt, comes from by-products of processing of cereals (say 20 Mt), oil crops and other products in the food industry and trade. This brings the cereal share in compound feed to 107 Mt. To this, the 51 Mt own cereal feed cultivation by animal farmers should be added and finally there is a share of cereals in the bought straight feed by farmers, which is set at 9 Mt. This is a rough estimate, but this is the best we can do within the limited resources available.

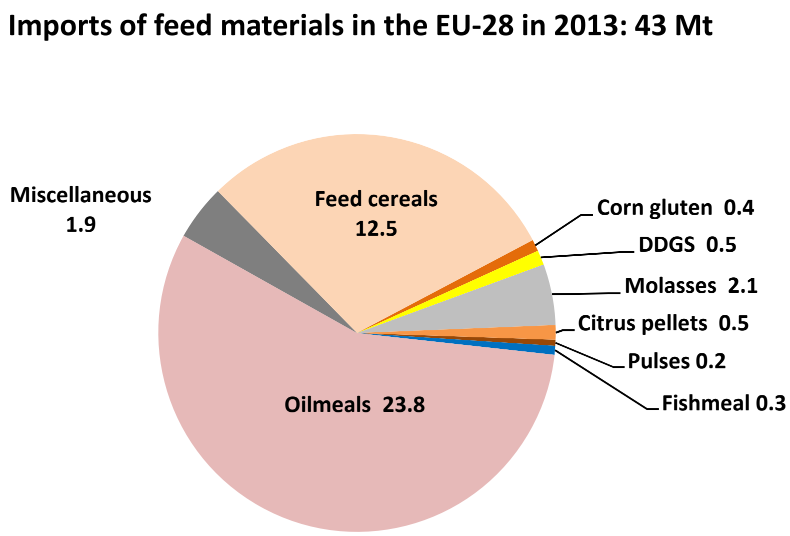

Figure 24. EU imports of feed materials by the compound feed industry 2013. Source: FEFAC 2015.

The diagram below shows the destination of the industrial compound feed by type of animal.

Detailed FEFAC-statistics suggest that at least two-thirds of the compound feed for cattle goes to dairy cows and over one-third of the compound feed for poultry goes to laying hens.

This means that overall more than two-thirds of the total compound feed goes to animals for meat.

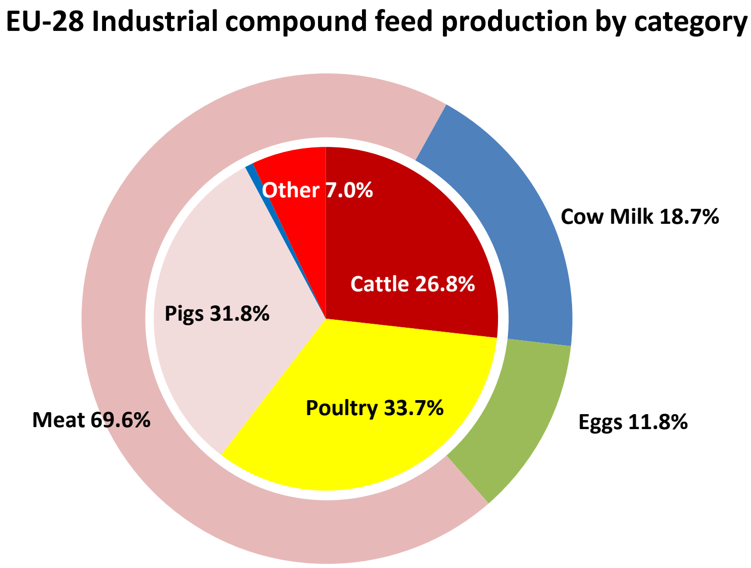

Figure 25. EU industrial compound production and its destination.
Source: FEFAC 2015.

Apart from Eurostat and FEFAC, there are also calculations from food scientists that might help in establishing the actual food flows. For the EU such assessments could not be identified within this limited study. For the US, Shepon et al. (2016)[89] recently published calculated food flows 'from feed to meat'. From the physiological energy and protein flows in that and other studies[90], supplemented with EU-specific data mentioned earlier[91], VHK tried to make an assessment for the EU food flows, which is given in the diagram below.

[89] Shepon, A. , Eshel, G., Noor, E. and Milo, R., Energy and protein feed-to-food conversion efficiencies in the US and potential food security gains from dietary changes, Published 4 October 2016 • © 2016 IOP Publishing Ltd Environmental Research Letters, Volume 11, Number 10
http://iopscience.iop.org/article/10.1088/1748-9326/11/10/105002
[90] Vries, M. de, Boer, I.J.M. de, Comparing environmental impacts for livestock products: A review of life cycle assessments, Animal Production Systems Group, Department of Animal Sciences, Wageningen University, Wageningen, The Netherlands
March 2010 Volume 128, Issues 1-3, Pages 1–11.
[91] Including indication of the pig diet in the EU from Zijlstra 2009: Cereals 48%, Co-product oil seed 25%, Co-product food industry residues 14%, Fats & oils 2%, Misc. 11%.

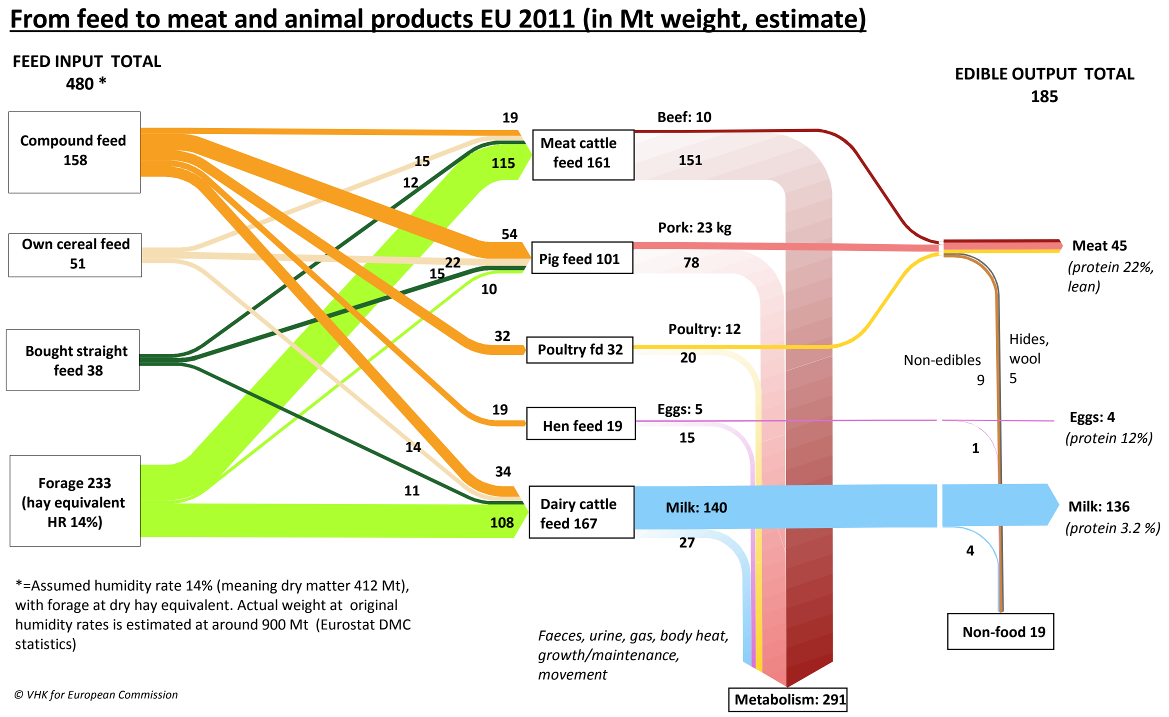

Figure 26. EU 2011 flow from feed to meat and animal products (estimate). Source: VHK elaboration of misc. sources.

The figures in the diagram are an estimate and –very important—it is accounting based on the actual mass of feed and foodstuffs as shown in the EU FoodFlow diagram. For food scientists this is not the most logical way of accounting food flows. In reality, this part of food sciences, is much more interested in the feed-to-food conversion of calories and protein, which may paint a very different picture. Merely as an illustration, the diagram above shows the protein content of (lean) meat, eggs and milk, demonstrating that e.g. meat contains about 6 to 7 times more protein than milk. Shepon et al. (2016) try to demonstrate how a different US meat diet, e.g. partially substituting beef with chicken, can reduce the environmental impact.[92] Other scientists work on reduction of nitrogen (N) and phosphorous (P) reduction in excrements by proposing to adjust the feed mix. Optimisation of the feed-to-food conversion in all its aspects is of paramount importance for dealing with world hunger, self-sufficiency issues, land use, etc.

4.9 Meat

In 2011 the EU animal population for meat consisted of 65 million bovine animals, 148 million pigs, 58 million sheep, 6 million goats and 0.8-1 billion poultry animals. Of this, 25 million bovines, 248 million pigs, 42 million sheep, 4-5 million goats and 7.2 billion poultry were slaughtered in 2011. Note that the above does not include the EU herd for milk and flock of laying hens for eggs.

The EU food flows diagram starts with the carcass weight of the slaughtered bovines (8 Mt), pigs (20 Mt), poultry (11 Mt) and a miscellaneous group (6 Mt) that includes 2 Mt carcass weight from other animals (sheep, goat, horses, etc.), 1 Mt edible offals and 3 Mt of raw animal fat. These are the amounts available after subtracting an export surplus of

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[92] In fact, mainly because the US consumes more meat and twice as much beef as Europeans per capita, the animal feed-input in the US (312 million inhabitants in 2011) is the same as that in the EU-28 (504 million inhabitants in 2011). Per capita this means that the average US inhabitant uses 60% more animal feed than its EU-counterpart.

3 Mt meat products, 1.4 Mt offals and 0.8 Mt of animal fat ('Export2' in the flow diagram). Furthermore, there is a 9 Mt carcass processing output consisting of non-edible raw fat, bones, etc. as well as 5 Mt of hides and wool that go to the non-food industry. The animal non-food industry turns these inputs into leather, wool, etc. Potentially hazardous offals, bones, etc. are boiled and then used as solid fuel in e.g. power plants.

The 45 Mt of carcasses and edible remains are subsequently processed to meat products. In the process, some 10 Mt of bones, fat, etc. is lost to waste, animal feed and moisture. This leaves 35-36 Mt of meat products for purchase by households and food services. These products consist of beef (7-8 Mt), pork (16 Mt), chicken (8 Mt) and 'other products' (5 Mt, including 1.4 Mt of meat based ready meals, bacon, ham, snacks, etc.). The 'other products' may be frozen, canned or otherwise preserved, but the majority of meat is sold fresh (chilled) and may then either be stored fresh in the household or frozen in the home freezer (assumed 50/50).

For the assessment of consumer waste from meat products it is important to consider that the difference between purchased weight and actual meat intake consists not only of bones or fat but also of the water evaporation and other cooking fumes during the preparation.

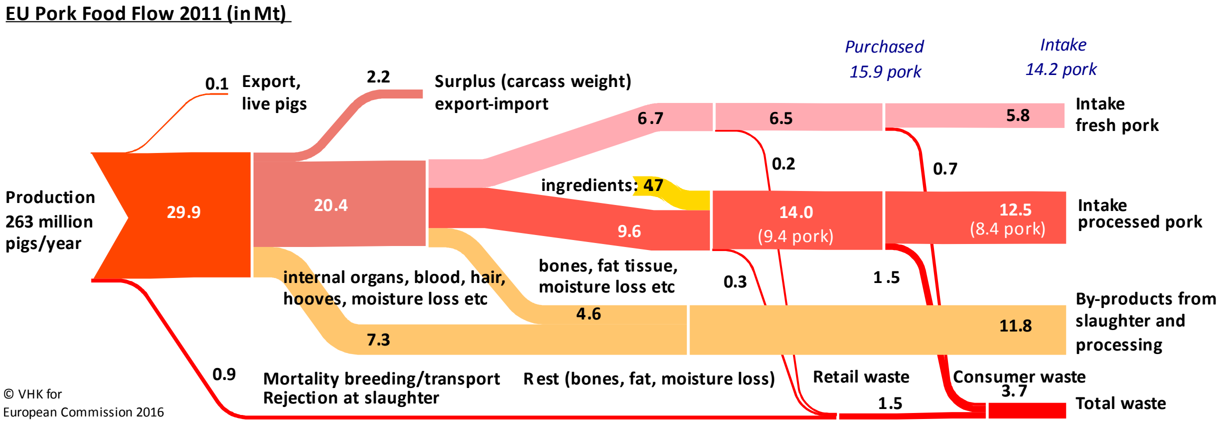


Figure 27. EU Pork Food Flow 2011.
Source: VHK elaboration of Eurostat and sector data.

Figure 27 shows more detail for the production of pork for the EU-2011. Amongst others it shows that there is not only weight loss from processing, but also other non-meat ingredients are added to produce processed pork. These non-meat ingredients, e.g. vegetables and potatoes in ready-meals, are already taken into account elsewhere in the main flow diagram and thus not included in EU-FoodFlows diagram.

Figure 27 also shows that 2.7 Mt, around 17%, is lost as consumer waste through preparation (e.g. cutting away fat or bones, evaporation during cooking), by spoilage or leftovers gone bad.

4.10 Fish

EUMOFA, European Market Observatory for Fisheries and Aquaculture Products, signals 4.2 Mt of EU catches (live weight equivalent) and 1.2 Mt of fish and seafood from aquaculture. Imports amount to 6.8 Mt catches and 1.7 Mt from fish-farms. Exports are 1.8 Mt catches and 0.1 Mt from fish farms. The most important importers are Norway (21% of volume), Iceland and China.

All in all, the apparent consumption amounts to 12 Mt, of which 9.1 from catches and 2.9 from fish farms. The 12 Mt of apparent consumption can also be split in fish (9.2 Mt) and other seafood (molluscs, cephalopods and crustaceans, 2.8 Mt). The diagram gives an overview of apparent annual consumption (in live weight) per capita and per type. The EU average is 23.87 kg/capita.

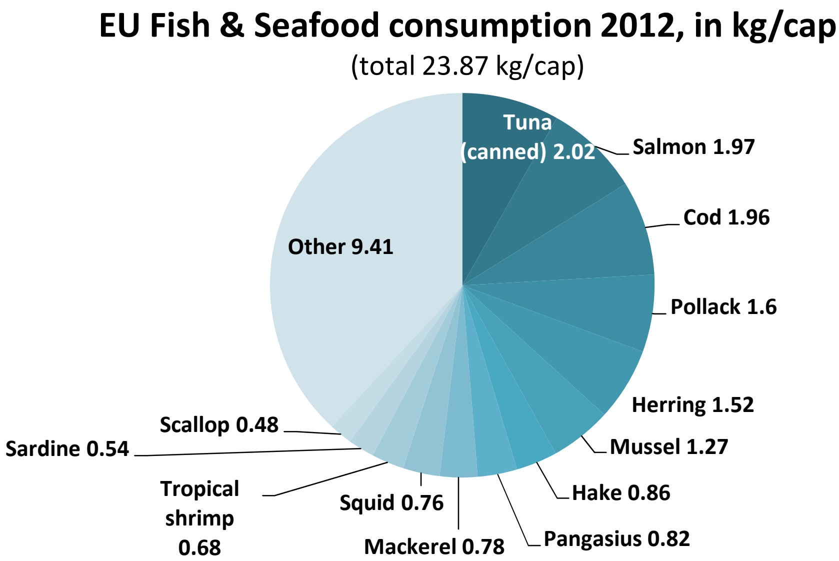


Figure 28. EU Fish & Seafood consumption 2012, in kg per capita (live weight equivalent). Source EUMOFA 2015.

For processed fish products, Eurostat's Europroms statistics suggest an apparent consumption of:

- 1.2 Mt fresh/chilled fish (0.4 Mt fresh fillet, 0.8 Mt battered or otherwise prepared chilled fish),
- 2.4 Mt frozen products (1.8 Mt fish, 0.6 other),
- 2.2 Mt otherwise preserved products (canned, smoked, brined, etc. split in 1.4 Mt fish and 0.8 Mt other).

In total this amounts to 5.8 Mt in fish products.[93]

On top of that, apart from the 1.2 Mt of fresh/chilled fish mentioned above, there is an amount of fresh whole fish (or gutted or filleted on the spot by the retailer). The amount is unknown, but anecdotal information from e.g. Belgium (4.6 kg fresh fish/capita) suggests that at least 1.3 Mt should be added. This would bring the total of fresh fish to 2.5 Mt.
The total fish and seafood consumption thus becomes 7 Mt, which means that --compared to the 12 Mt live weight-- there is waste+animal feed to the amount of 5 Mt. Compared to the official EUMOFA conversion factors, e.g. canned tuna 1.87, smoked salmon 2.1, fresh whole fish 1.00, this makes sense.[94]

[93] Fish-based ready meals are 0.2 Mt, of which probably less than half is fish. This small number is taken in rounding up the total value.
[94] EUMOFA European Market Observatory for Fisheries and Aquaculture Products, ANNEX 8: Conversion factors by CN-8 codes from 2001 to 2016, www.eumofa.eu, Update 2016 (extract Oct. 2016, pdf-file 639 pages, covering 7000-8000 traded fish products)

Europroms signals an apparent consumption of 0.6 Mt fish meal for animal feed and 0.4 Mt inedible fish waste (excluding whalebone, shells, corals etc.), which means that at least a part of this waste has an economical value. Furthermore, from the difference between EU 'catches' of 4.8 Mt (Live weight equivalent) and 'landings' 4.2 Mt (actual weight of fish at the port), it is clear that a part of cleaning has been done at sea.

Almost half of the fish landings are small pelagic fish like herring, mackerel, sardine and anchovis. Another 18% are other marine fish (seabream, monk fish, ray and sharks). Groundfish, e.g. cod, hake and haddock, represent 12% of EU fish landings. The 1.2 Mt from EU aqua-cultural production is largely covered by molluscs (0.6 Mt) and salmon (0.4 Mt). An extra-EU import of 5.4 Mt consists mainly of 1 Mt ground-fish, 0.7 Mt tuna, 0.7 Mt salmon and 0.7 Mt non-food uses. Extra-EU export is 1.7 Mt, of which 0.7 Mt small pelagic fish, 0.3 Mt tuna and 0.3 Mt non-food uses adds to a total 9 Mt for EU consumption. Of this 4,3 Mt is processed and sold as fish products and 4.7 Mt is sold fresh.

According to EUMOFA, and also confirmed by country-specific data on Belgium, 22% of the fish is eaten in restaurants or other foodservice facilities, almost 4% in institutions (homes, etc.) and 74% at home. The UK is the exception, with only 60% of fish meals eaten at home, 35% at foodservices and 5% in institutions.

4.11 Dairy products

In 2011, the EU-28 had 23 million milk-cows with a yield of 154 million tonnes (Mt)/year. In comparison, the contribution of goats and sheep is small. Around 4.5 million milk goats and 25 million milk ewes contributed over 2 Mt each (not shown in the diagram). The yield per cow varies between 3.5 (Romania) and 9.4 (Denmark) tonnes per head. The average yield is 6.7 tonnes per head.

Milk farmers retain 14 Mt for own use, amongst others for on-farm production of dairy products, and deliver 140 Mt of raw milk to the dairy industry. In the dairy industry, the raw milk goes into two major flows: 80 Mt goes into the production of fresh dairy products and 55 Mt goes to cheese making. In addition, there is a relatively small part of the raw milk that is directly used to produce whole milk powder WMP (5 Mt to produce 1.3 WMP).

From the largest flow of 80 Mt of raw milk 17 Mt is used directly, after heat treatment, for whole drinking milk, 59 Mt for the production of butter (2 Mt), cream (2 Mt) and skim milk (55 Mt) through centrifuging the milk, 4 Mt is used for the production of 1.5 Mt of condensed milk. The skim milk is further processed to drinking milk (14 Mt), input for cheese making (14 Mt), skim milk powder SMP (10 Mt to produce 1.6 Mt SMP) and other fresh dairy products (17 Mt). The latter includes yoghurt (9 Mt), low-fat milk (6 Mt mostly as ingredient) and buttermilk (1 Mt).

The 14 Mt of skim milk mentioned above adds on to the 55 Mt flow of whole milk input for cheese making, bringing the total to 69 Mt milk input. Cheese results in 9 Mt of cheese from almost 67 Mt of milk and 0.12 Mt of casein used as auxiliary input from more than 2 Mt of milk. The production results in 17 Mt of water loss (evaporated or to sewage) and 44 Mt of a by-product called whey. The whey is further processed into whey powder WP (20 Mt whey to produce 2 Mt of WP), 10 Mt of liquid whey –concentrated or not—mainly used as animal feed (rearing), 0.6 Mt of the food supplement lactose from 11 Mt of whey, and 1-2 Mt of waste[95].

[95] Note that waste from residue that is removed by cleaning accounts for less than 1 % (0.37% according to ISWA) of total dairy sector throughput. In the diagram 'waste' is only made explicit once, as a placeholder for the many waste streams that actually occur.

All in all, the dairy industry turns 140 Mt of raw milk into almost 80 Mt of marketable products and over 60 Mt of water and waste. The marketable products end up in exports (3 Mt), animal feed & waste (11 Mt) and 66 Mt of deliveries to private households (~75%) and food services (~25%[96]). Of these 66 Mt around 6 Mt is milk powder and condensed milk typically used as an ingredient e.g. for ice cream.

The figure on the next page gives a simplified Sankey-diagram of weight flows. The quantities are an elaboration by the authors from various Eurostat statistics and dairy sector data. Based on the deviations between various sources, the accuracy of the individual flow-data is estimated to be in the order of 10-20% (smaller data have higher margins).

[96] Derived from Eurostat data specifying 75% of milk delivered in packages <2 L and 25% delivered in larger packages.

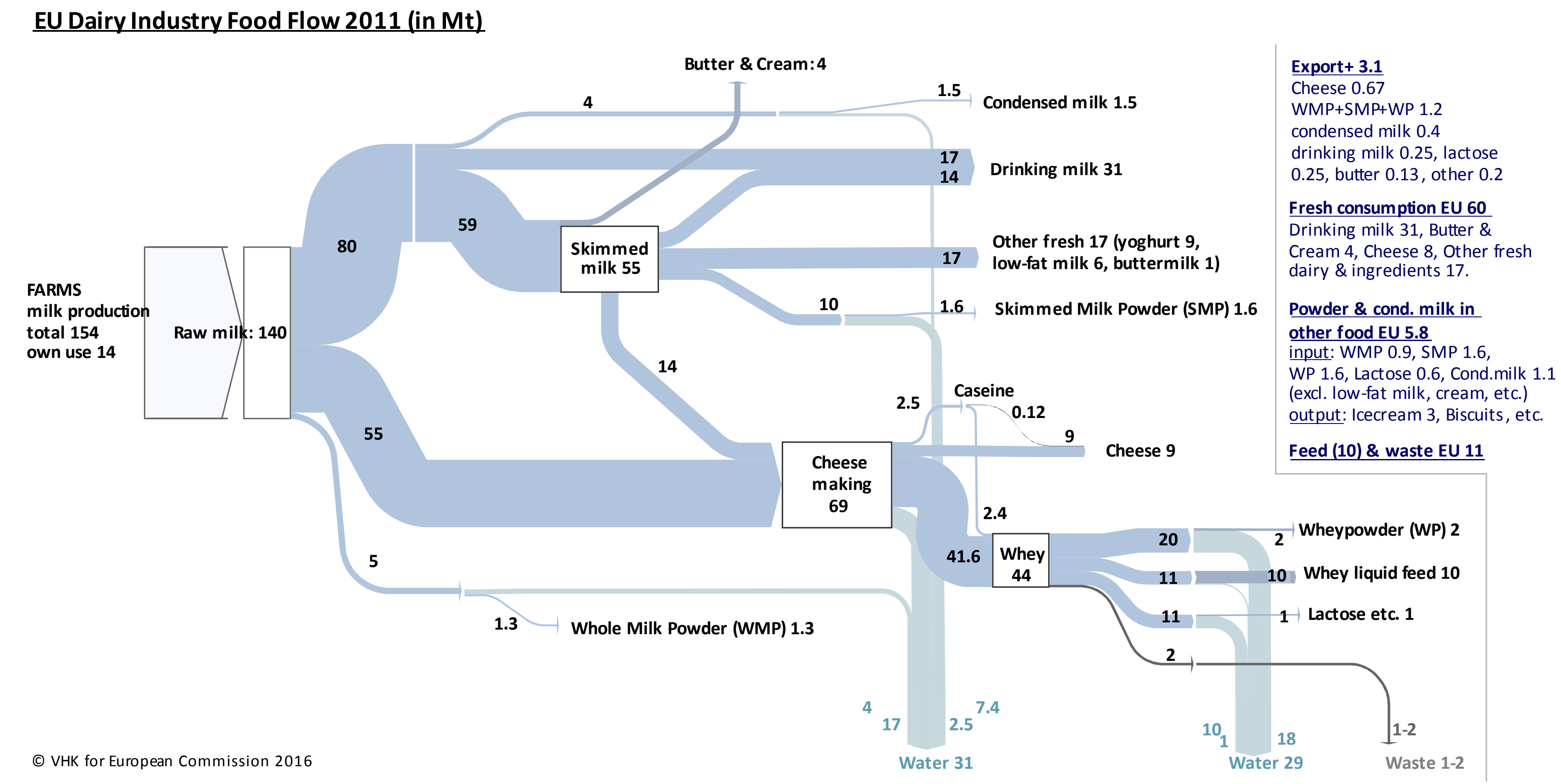


Figure 29. Sankey-diagram of mass flows (in Mt) in the EU 2011 dairy industry.
Source: VHK from elaborated Eurostat data and data from the dairy sector (extract Oct. 2016).

For our purpose it is useful to make a distinction of dairy products by their storage conditions. Most of dairy products are kept in the fridge (+4 degrees C), even though uncut cheese might also be kept in a cellar or another dark place. Ice-cream is of course kept in the freezer (-18°C). Of the 31 Mt of drinking milk, roughly one-third of the drinking milk consumed is 'fresh' (pasteurised for a few minutes at 72 degrees C) and needs to be kept in the fridge. Two-thirds is sterilised milk or UHT milk (Ultra High Temperature, i.e. sterilised for a few seconds at 135 degrees) and can stay outside the fridge when unopened. It is assumed that on average one-third of UHT milk stays in the fridge and two-thirds is kept outside (unopened). UHT-milk is standard (>90%) in most of Southern-Europe and Belgium. Pasteurised milk is more than 80% of the drinking milk consumed in Northern Europe, the UK and the Netherlands.

4.12 Eggs

In the year 2011, almost 0.5 billion laying hens produced 7.6 Mt of eggs (approx.125 billion eggs), of which 0.3 Mt went to waste before being collected and 0.9 Mt were used as eggs for hatching. Of the 6.4 Mt eggs remaining (starting point in the FoodFlow diagram), 0.26 Mt constitute an export surplus and 0.25 Mt are wasted in post-harvest handling. This means 5.9 Mt of eggs were available for EU consumption, of which

- 0.5 Mt went to the non-food industry (casein),
- 3.5 Mt were sold as table eggs and
- Over 1.9 Mt are processed to become liquid (1.2Mt), dried (0.06 Mt) and frozen (0.02) egg products, losing 0.25 Mt of water, 0.6 Mt of shells and 0.4 Mt in processing and distribution waste along the way.

The consumer and food services sector waste, including the shells, is estimated at a total of 0.7 Mt. This results in an actual intake of 2.78 Mt of table eggs in households, which comes down –at an average weight 61 g/egg to a total of 46 billion eggs, or rather 1.7 table eggs per capita per week. The rest of the eggs (1.2 Mt) is consumed as ingredient in other foodstuffs and adds another 0.8 egg per capita per week. The Sankey diagram below gives an overview.

EU Egg production and supply chain (1000 tonnes)

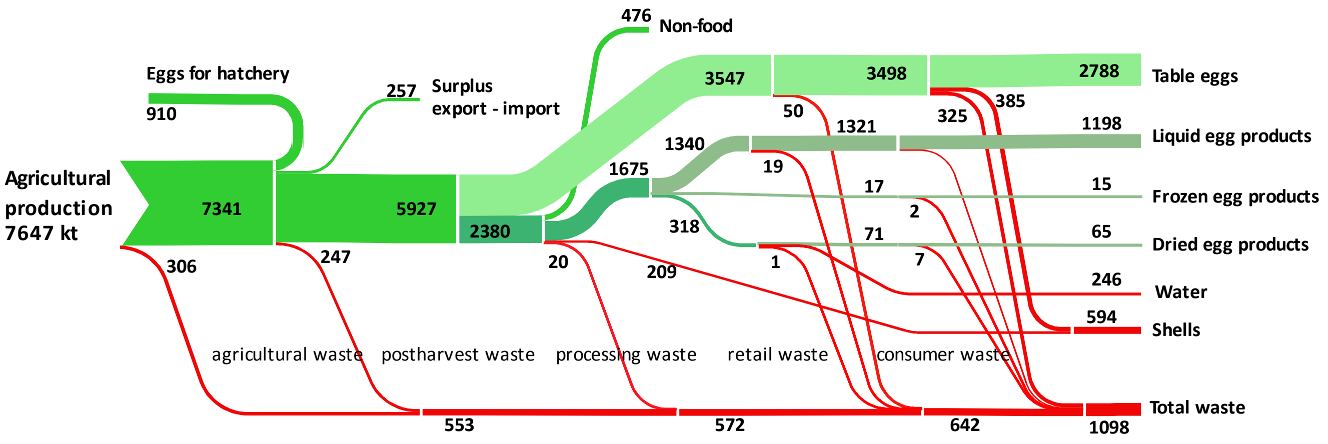


Figure 30. EU egg food flow 2011 (in 000 tonnes).
Source: VHK elaboration of Eurostat and sector data.

4.13 Post-harvest and process waste

At the bottom of the EU FoodFlow diagram there are two major flows that are fed by what is discarded in the primary processes.

From right to left there is a flow of residues that are recycled to animal feed. These are the oilcakes from vegetable oil production, milling residues from flour production, stale bread returning from the shops, etc. They are not-hazardous and rich enough in nutrients to be fit as feed. In small quantities (<5%) this flow also contains vitamins and other supplements that are expressly produced to serve as animal feed. The size of this recycling flow, estimated at 103 Mt, is mainly derived from the inputs for the compound industry and the bought straight foodstuffs as presented by FEFAC, also taking into account the 25 Mt of imported oilcake. Given that we are trying to make a closed account, the size of this flow, often ignored in other publications, is more or less accurately established.

From left to right there is a flow of real waste. The size of this flow is composed of

- Post-harvest agricultural waste (13 Mt plus an estimated 2 Mt waste from recycling process waste to animal feed);
- waste from the vegetable non-food industry: 6 Mt of residue that could not be recycled to animal feed or that slipped into the sewage when cleaning the equipment;
- waste from food manufacturing: 25 Mt of solid and liquid waste from, at that point in the process, over 500 Mt raw material input and much of this will be unavoidable (peels, bones, cleaning residue, etc.);
- waste from retail and trade, including waste from processing animal products (milk & eggs) and meat: 15 Mt.

In total this waste stream is calculated to amount to 66 Mt. This value is calculated purely from adding the individual processes that feed into that waste stream. There is not enough information to specify whether that waste stream is solid (registers as 'waste') or liquid (spilled into the sewage) and certainly not enough insight whether the individual products in this flow really qualify as 'waste' in accordance with the latest legal definitions of 'waste' in the Waste Directive.

However, a plausibility check with the EU waste generation statistics sector can be done. In that sense, it is reassuring that Eurostat waste_gen statistics identify 40 Mt of waste from the agricultural sector and 48 Mt of waste from the food industry.

The diagrams below give details of those waste streams. EU waste statistics and the definitions of waste are 'work in progress'. Also, it has to be considered that the EU FoodFlow diagram does not take into account pre-harvest wastes (including mortality of animals), whereas Eurostat presumably does. On the other hand, the EU FoodFlow diagram does take into account a part of the losses from the wholesale and retail sector and this is not included in the diagrams below.

It is outside the scope of the resources available for this assignment to go to the bottom of this, but it is reassuring that Eurostat waste streams show an order of magnitude that is in line with what could be established from the sum of individual waste streams.

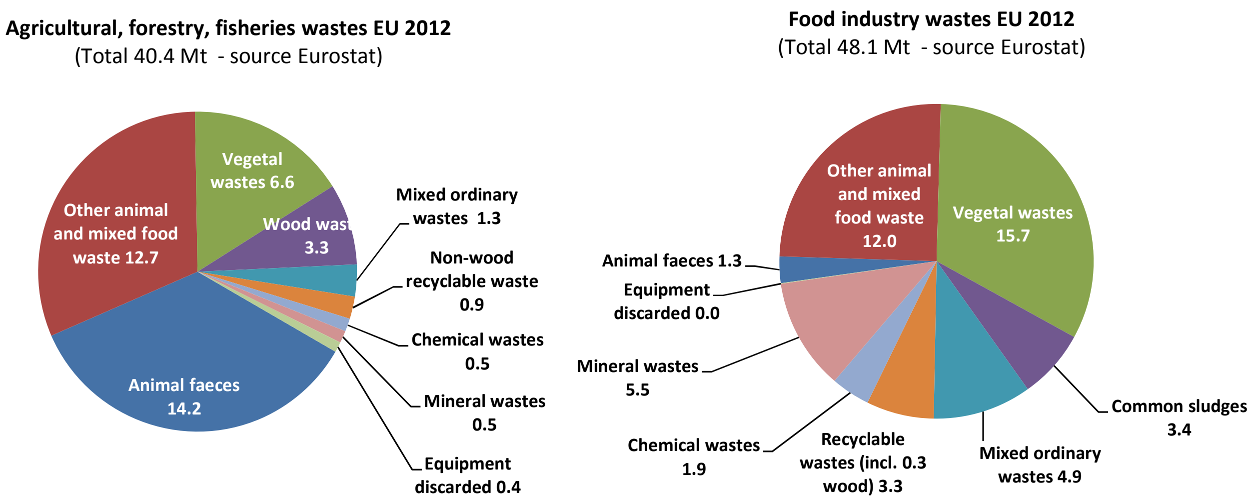


Figure 31. EU 2012 total waste flows of the agricultural sector (left) and food industry (right), according to Eurostat env_wasgen (extract Oct. 2016).

The overall conclusion is that the recycled feed and waste streams are plausible. Of the total 165 Mt being discarded by the primary processes in the EU FoodFlow diagram around 60 weight % is being recycled to (mainly) animal feed and 40% goes to waste.

4.14 Small flows, bottled water and soft drinks

For practical reasons the aggregate EU FoodFlow diagram is limited to main food flows. This means that some food flows that are small in size or in impact (e.g. bottled water and soft drinks) are only added to that diagram in the final end-use and waste phase.

These flows include:

- Bottled water 56 Mt
- Soft drinks 50 Mt
- Cacao 5 Mt
- Sweets 2.5 Mt
- Coffee 2.2 Mt
- Sauces & spices 4 Mt
- Salt 3 Mt
- Spirits 1.4 Mt
- Baby food 1.1 Mt
- Vinegar 1 Mt
- Tea 0.4 Mt

In total, bottled water and soft drinks are 106 Mt, of which 5 Mt is estimated to be wasted by the end-user. The other small flows represent a consumption of 21 Mt, of which 4 Mt is estimated to be wasted by the end-user.

This paragraph gives some background details on these 'small flows'.

4.14.1 Bottled water and soft drinks

Eurostat distinguishes unsweetened waters (56.2 Mt production, 1.5 Mt export, 0.1 import, apparent consumption 54.8 Mt) and soft-drinks. The latter are divided in 'waters with added sugar, other sweetening matter or flavoured' (36.2 Mt production, 0.4 Mt imports, 1.1 exports), other 'non-alcoholic beverages not containing milk fat' (15 Mt production, 0.6 exports, 0.1 imports) and 'non-alcoholic beverages containing milk fat' (production 1.2 Mt, 0.1 Mt exports). Overall these soft-drinks represent 52.4 Mt EU production, 1 Mt imports, 2.9 Mt exports and thus an apparent consumption of 50.5 Mt.

4.14.2 Cacao and products, sweets

The FAO mentions 4.3 Mt of cacao bean imports. Data from Eurostat Europroms on EU 2011 production of cacao-based products are given below. The same source mentions exports of (mainly) chocolate end-product amount to 0.5 Mt. The average consumption of chocolate end-products in the EU is thus 3.1 Mt or 6.2 kg/capita.

Table 7 . Cacao-based products, manufacturered in the EU 2011
(based on imports of 4387 kt cocao beans). Source: Eurostat Europroms NACE 2.0 (extract 2016)

Cacao ingredients	**kt**	**Chocolate intermediaries Packings >2 kg, (cacao butter %)**	**kt**	**Chocolate end-products**	**kt**
Paste	377	bars/liquids/powder (>18%)	836	Filled blocks (cream, liqueur)	769
Butter, fat & oil	600	milk crumbs (>18%)	18	Blocks with added cereal, fruit or nuts	419
Powder, no sugar	601	flavoured coating (>18%)	155	Other blocks	503
Powder, with sugar	196	food preparations (<18%)	136	Chocolates (incl. pralines) with alcohol	90
	1773	food products with cocoa	172	Other chocolates	418
			1317	Filled confectionary	364
				Other confectionary	269
				Sandwich spread	510
				Cacao for beverages	166
				White chocolate	122
					3630

Making chocolate-based products often involves compound production. The Sankey diagram illustrates a (fictitious) production process for candy bars.

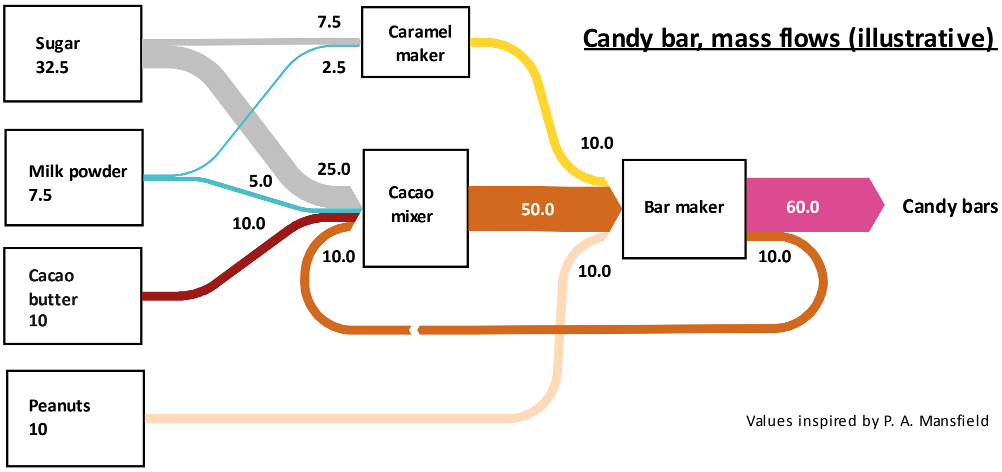


Figure 32. Fictitious example of the production of a candy bar
Illustration of the complexity of mass-accounting in the chocolate and sweets industry (data taken from P.A. Mansfield).

As regards sweets (sugar confectionary, chewing gum, gum jellies, etc.), Eurostat reports a production of 2.7 Mt with 0.1 Mt imports and 0.2 Mt exports. The apparent EU consumption is thus 2.6 Mt. The main inputs for sweets are sugar and starch.

4.14.3 Coffee and tea

The FAO reports imports of 4.6 Mt of coffee beans and exports of 2.2 Mt. Apparent consumption is thus 2.4 Mt of coffee. This makes the Europeans the largest coffee-consumers in the world with a market share of 31%. At around 6 g per cup, almost independent on the size of the cup, 400 billion cups of coffee per year are consumed in the EU (2008), i.e. 2.2 cups per capita per day (4.8 kg of ground coffee per year). Over half of the coffee comes from drip filter machines, where it is known that on average the last 25-30% is thrown away. [97] The rest comes from portioned espresso or filter pad coffeemakers, i.e. with virtually no coffee waste but possibly with some extra packaging (capsules, pads). The figure below gives the consumption per EU-Member State.

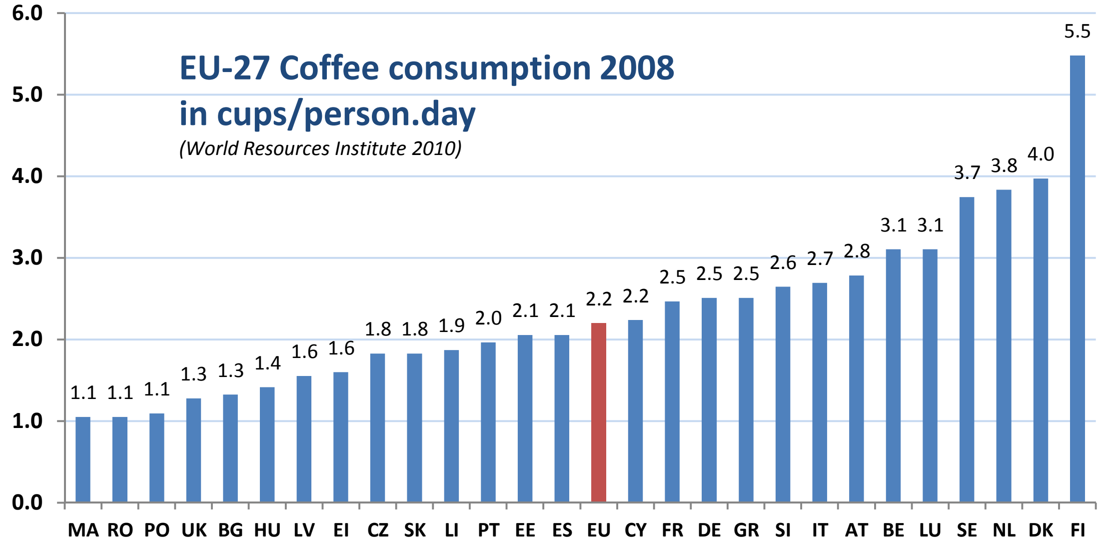


Figure 33. **Coffee consumption EU-27 in 2008**,
Note: 1 cup (liquid 45 cl espresso or 125-150 cl filter coffee) represents 7 g of grounded toasted coffee dry (source: WRI in EC 2012[98].

For tea, the EU has 0.44 Mt imports and 0.16 exports. This means that close to 0.3 Mt of tea is consumed, i.e. 0.6 kg per capita per year.

In the accounting, only the dry matter of coffee and tea is counted as waste. Added tap-water is in principle excluded, although some studies also take the coffee drip mass, with some 20-30% residual tap water included[99], as a basis for accounting. It can be assumed that all coffee residue from portioned coffee machines is unavoidable. For drip filter coffee 70% can be classified as unavoidable (assuming 30% is thrown away). The latter is also confirmed in the Danish and Swedish analysis of food waste through the sewer, which includes large quantities of coffee (see Chapter 3).

4.14.4 Spirits

According to the industry association Spirits Europe the European spirits consumption amounted to 2.5 Mt. Main inputs are cereals (2-3 Mt) and wine (1 Mt). The table below gives an overview of consumption per type.

[97] EC, Commission Working Document on possible Ecodesign and EU Energy Label measures for Domestic Coffee Machines, EC with VHK assist, Brussels, 18.11.2012
[98] Ibid 98
[99] VHK estimate based on the CREM 2013, which finds 11 kg/capita of coffee (and tea) drap in the food waste of the Netherlands, whereas statistically it should be no more than 8-9 kg/capita.

Table 8. European spirits consumption 2011.
Source: Spirits Europe (www.spirits.eu)

	Mt*	Notes on input
Flavoured spirits	0.814	
Vodka	0.675	0.73 Mt grain +0.06 Mt molasses and 0.08 Mt potatoes
Whisky	0.411	0.64 Mt barley, 0.65 Mt wheat & maize
Brandy	0.256	0.624 Mt good wine for cognac + 0.3 Mt for brandy
Rum	0.188	
Gin/Genever	0.106	
Tequila	0.013	
Other Spirits & Cane	0.080	
TOTAL	**2.542**	

*assuming 1 t=1000 L

Eurostat Europroms specifies a production of 1.9 Mt of spirits. Imports are 0.14 Mt and exports 0.6 Mt (of which whisky 0.26 Mt, vodka 0.1 Mt and brandy/cognac 0.1 Mt), The apparent consumption in the EU would thus amount to 1.4 Mt in 2011.

4.14.5 Sauces and spices

Tomato ketchup 1.4 Mt, Vinegar (50% wine, 50% other) 1.1 Mt, Mustard 0.3 Mt and other sauces 2.8 Mt. Imports and exports are small (<0.2 Mt each). The 'other sauces' probably include mayonnaise (70-80% vegetable oil plus eggs), BBQ sauces, etc.

The EU produces 3.1 Mt of salt. With imports of 0.5 Mt and exports of 0.3 Mt the apparent consumption of salt in the EU is 3.3 Mt.

The FAO reports 143 kt production of spices, of which 83 kt pimento and 60 kt other spices. Around 95 kt pepper, 57 kt pimento and 177 kt other spices are imported. Eurostat Europroms gives no data on spices.

4.14.6 Baby food

Eurostat reports a production of 656 kt of homogenised preparations, typically used for infants, with negligible imports and 44 kt of exports. This leaves an apparent consumption of 616 kt, 80% of which in small pots <250 grammes.

Eurostat reports a production of 799 kt of other food preparations for infants, probably milk powder preparations, with exports of 279 kt and 5 kt imports. This leaves an apparent consumption of 525 kt of these other infant preparations.

In total, the baby-food production amounts to 1.4 Mt and consumption amounts to 1.1 Mt.

4.15 Non-food

The non-food industry applications are divided in vegetal non-food and animal product non-food. Vegetal non-food includes the production of biodiesel (mainly from colza), starch for non-food applications such as paper and cardboard production (mainly from potatoes and cereals), alcohol from e.g. maize and other cereals, additives for soap (e.g. palm oil), pharmaceuticals, sugar as additive for e.g. gypsum-boards. Ethanol is used extensively as a solvent in the manufacture of varnishes and perfumes; as a preservative for biological specimens; in the preparation of essences and flavourings; in many medicines and drugs; as a disinfectant and in tinctures (e.g., tincture of iodine); and as a fuel and gasoline additive.

The flow-diagram only shows inputs. Some output values, e.g. 11 Mt for biofuels, are mentioned only as an illustration, but the numbers are not complete.

The animal products non-food industry includes by-products of meat production such as hides (for leather), wool, etc. Furthermore, the conversion of bones and inedible fats to solid fuels

4.16 End-use and waste

End-use and waste were discussed in Chapter 3. Food services represent around 20% of the end-use, in terms of food served (in kg), and around 26% of the solid food waste (25 kg/cap). Private households purchase 80% of total food and are responsible for 74% of the total collected solid food waste (70 kg/cap. Solid food waste).

For households, the waste through sewer (15 kg/cap.) and non-collected waste (15 kg/cap., e.g. home composting) are known and bring the household totals to 100 kg/cap. For the food services, there are no data for these streams, but –taking proportional values—and extra 10 kg/cap is assumed, bringing the food service food waste total to 35 kg/cap. As mentioned in par. 3.6 and 3.9, the food waste studies did not (fully) take into account the waste of used cooking oil (4.6 Mt or 9 kg per capita per year), waste of soft drinks and bottled water (7.92 Mt or 15.7 kg/cap/yr) and a part of the so-called small flows (3.92 Mt or 7.8 kg/cap/yr). Taking into account also these previously omitted flows The total end-use food waste is estimated at 167 kg/capita or 84 Mt for the EU (504 million inhabitants). This relates to all food, excluding added tap-water.

According to the EFSA database, the EU average food intake is 631 kg/capita, both from households and services. Adding 135 kg wasted, this results in food purchases of 766 kg/capita, of which food waste would thus be 18%. The UK has statistics of food purchases by private households, i.e. not by food services, and arrive at a figure of 595 kg/capita. If this is 80% of the total, it means that food purchases would be 743 kg/capita. And again, the 135 kg/capita constitute almost 18%. Assuming that households purchase 74% of the total food, food purchases would be 804 kg/capita and 135 kg/capita constitutes 17%. These are the margins that can reasonably be expected.

As mentioned in paragraph 3.9, the avoidable solid waste will amount to 60% of total and unavoidable waste is 40%. Including also sewer losses, the avoidable amount will be closer to 70% and the unavoidable loss closer to 30%. In other words, the avoidable fraction of end-use food waste will be 40-50 Mt (11-12% of purchases) and the unavoidable fraction 20-30 Mt (7-8% of purchases).

For the flow diagram, the waste per food group was calculated, following Table 3 in paragraph 3.9. For a coherent mass flow accounting the water loss from cooking certain vegetables (average 30%), potatoes (10%), meat & fish (15-20%) and the water gain from cooking rice (factor 3) and pasta (factor 2.5) will be added as 'unavoidable loss'. Annex I gives more details on various foodstuffs.

The table below gives the percentages applied and food wasted in Mt per food group.

Table 9. Food waste per food group EU 2011-'12

Foodstuff	Pur-chase	Waste in % of purchase			Waste in Mt				Intake
		Total	Avoidable	Not in time	Total	Unavoi-dable	Avoidable	Not in time	
Mt or % purchase	*Mt*	*%*	*%*	*%*	*Mt*	*Mt*	*Mt*	*Mt*	*Mt*
Sugar	17	6%	5%	1.9%	1.02	0.17	0.85	0.32	16.0
Vegetal Oil	8	50%	5%	3%	4.00	3.60	0.40	0.20	4.0
Margarine	2	30%	5%	3%	0.60	0.50	0.10	0.05	1.4
Nuts	4	8%	8%		0.32	-	0.32		3.7
Potatoes fresh	22	46%	20%	10.0%	10.12	5.72	4.40	2.20	11.9
Potatoes (mainly chips) frozen	4	13%	13%	0.5%	0.52	-	0.52	0.02	3.5
Potato crisps etc.	2	8%	8%	0.5%	0.16	-	0.16	0.01	1.8
Vegetables fresh	38	46%	22%	21.0%	17.48	9.12	8.36	7.98	20.5
Vegetables canned/preserved	10	11%	11%	3.3%	1.10	-	1.10	0.33	8.9
Vegetables frozen	6	8%	8%	2.4%	0.48	-	0.48	0.14	5.5
Fruit fresh	27	37%	14%	9.0%	9.99	6.21	3.78	2.43	17.0
Fruit juice & nectar	13	11%	11%	4.8%	1.43	-	1.43	0.62	11.6
Wine (from fruit)	12	7%	7%	2.5%	0.84	-	0.84	0.30	11.2
Cereals: Bread	19	22%	22%	16.3%	4.18	-	4.18	3.10	14.8
Cereals: Pastry & flour	9	17%	17%	11.0%	1.53	-	1.53	0.99	7.5
Cerals: Biscuits	8	4%	4%	2.6%	0.32	-	0.32	0.21	7.7
Cereals: Pasta & rice	12	13%	13%	2.0%	1.56	-	1.56	0.24	10.4
Cereals: Beer (incl. water)	36	7%	7%	2.0%	2.52	-	2.52	0.72	33.5
Meat, Beef	6	14%	8%	2.3%	0.86	0.40	0.46	0.14	5.1
Meat, Pig	14	23%	15%	4.5%	3.22	1.11	2.11	0.63	10.8
Meat, Poultry	7	37%	13%	3.8%	2.59	1.66	0.93	0.27	4.4
Meat, other & edible fats, offals	5	4%	2%	0.7%	0.22	0.11	0.11	0.03	4.8
Fish, fresh	2	7%	6%	1.8%	0.15	0.03	0.12	0.04	1.9
Fish, frozen	3	7%	6%	1.8%	0.22	0.04	0.18	0.05	2.8
Fish, smoked/canned/salted	2	7%	6%	1.8%	0.15	0.03	0.12	0.04	1.9
Dairy, drinking milk	31	9%	9%	4.5%	2.79	-	2.79	1.40	28.2
Dairy, cream	2	5%	4%	3.1%	0.10	0.02	0.08	0.06	1.9
Dairy, butter	2	5%	4%		0.10	0.02	0.08		1.9
Dairy, yoghurt, pudding, other	17	8%	8%	3.1%	1.43	0.08	1.35	0.53	15.6
Dairy, cheese	9	9%	6%	3.1%	0.81	0.27	0.54	0.28	8.2
Dairy, Powder & Condensed	6	5%	4%		0.30	0.06	0.24		5.7
Eggs, table eggs	3	21%	6%	3.1%	0.62	0.45	0.17	0.09	2.4
Eggs, liquid/powder/etc.	1	6%	6%		0.06	-	0.06		0.9
Beverages, soft drinks	50	8%	8%	0.3%	4.00	-	4.00	0.15	46.0
Beverages, bottled water	56	7%	7%	0.3%	3.92	-	3.92	0.17	52.1
Small flows, cacao	5	5%	5%		0.25	-	0.25		4.8
Small flows, sauce & spices	4	10%	10%		0.40	-	0.40		3.6
Small flows, salt	3	5%	5%		0.15	-	0.15		2.9
Small flows, sweeteners	2.5	5%	5%		0.13	-	0.13		2.4
Small flows, coffee	2.2	99%	15%	0.0%	2.20	1.87	0.33		0.0
Small flows, spirits	1.4	5%	5%	2.5%	0.07	-	0.07	0.04	1.3
Small flows, baby food	1.1	7%	7%		0.08	-	0.08		1.0
Small flows, tea	0.6	99%	15%		0.60	0.51	0.09		0.0
Small flows, vinegar	0.4	10%	10%		0.04	-	0.04		0.4
Total	**485**				**84**	**32**	**52**	**23**	**402**
% of purchase	*100%*				*17%*	*7%*	*11%*	*5%*	*83%*

Table 10. Summary food waste by main groups

		Waste in % of purchase			Waste in Mt		Avoidable			Intake
	Purchase	Total	Avoidable	Not in time	Total	Unavoi-dable	Avoidable	Not in time	Other	
	Mt	*%*	*%*	*%*	*Mt*	*Mt*	*Mt*	*Mt*		*Mt*
Sugar	17	6%	5%	1.9%	1.0	0.2	0.9	0.3	0.5	16
Veg. Oils & nuts	14	35%	6%	1.8%	4.9	4.1	0.8	0.3	0.6	9
Potatoes	28	39%	18%	8.0%	10.8	5.7	5.1	2.2	2.9	17
Vegetables	54	35%	18%	15.7%	19.1	9.1	9.9	8.5	1.5	35
Fruit	52	24%	12%	6.5%	12.3	6.2	6.1	3.4	2.7	40
Cereals	84	12%	12%	6.3%	10.1	0.0	10.1	5.3	4.9	74
Meat	32	22%	11%	3.3%	6.9	3.3	3.6	1.1	2.5	25
Fish	7	7%	6%	1.8%	0.5	0.1	0.4	0.1	0.3	6
Dairy	67	8%	8%	3.4%	5.5	0.5	5.1	2.3	2.8	61
Eggs	4	17%	6%	2.3%	0.7	0.4	0.2	0.1	0.1	3
Soft drinks	106	7%	7%	0.3%	7.9	0.0	7.9	0.3	7.6	98
Small flows	20	19%	8%	0.2%	3.9	2.4	1.5	0.0	1.5	16
	485				84	32	52	23		402
	100%				*17%*	*7%*	*11%*	*5%*		*83%*
Kg per capita	*962*				*167*	*63*	*103*	*46*		*795*
'-o/w at home					*125*	*47*	*77*	*35*		
'-o/w food service					*42*	*16*	*26*	*11*		

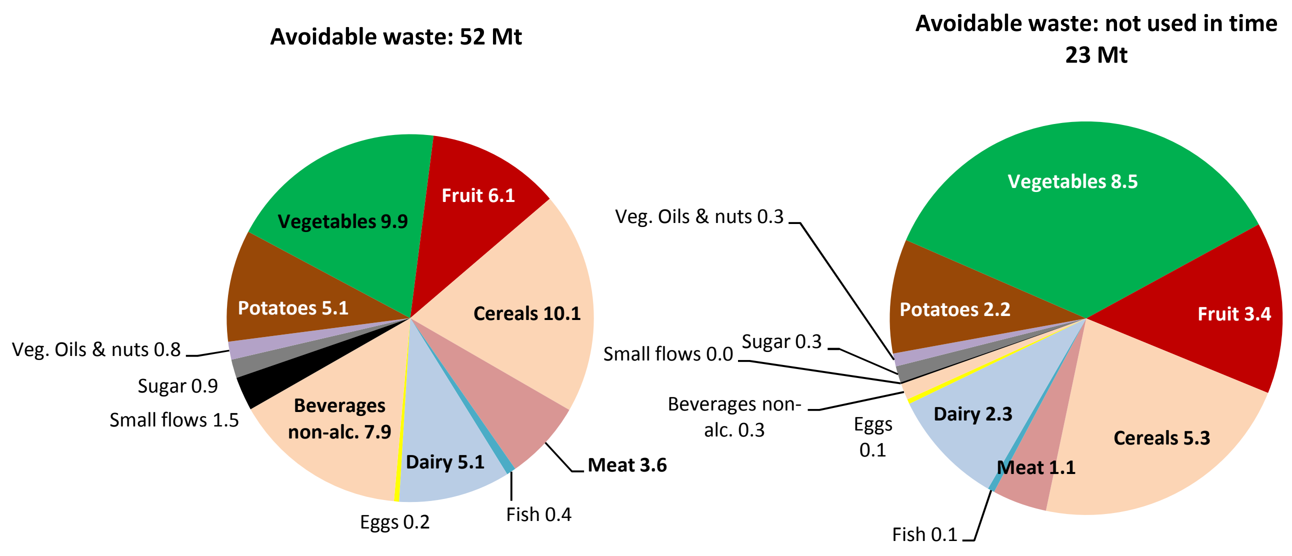


Figure 34. Avoidable waste, total and fraction of avoidable waste 'not used in time'.

4.17 Refrigerated fraction

The FoodFlow diagram gives an estimate that two-thirds, 326 Mt out of 485 Mt food and beverages purchased, is either permanently stored or, for beverages, at least chilled prior to serving. This is an estimate, because, although there are sources that advice on how a refrigeration appliance should be used for various foodstuffs, no comprehensive data could be found on how the refrigerator is used.

The figure below gives the VHK-estimate, based on anecdotal data. It distinguishes items permanently stored in freezer (36 Mt), refrigerator (115 Mt) and at room temperature (161 Mt). Then there is a group of long-life beverages, to be refrigerated when opened and/or served chilled, where it is assumed that two-thirds of the time (or for two-thirds of the total volume) they will be outside the refrigerator and one-third inside.

EU Storage of Food & Beverages

preliminary estimate, in Mt purchases/year

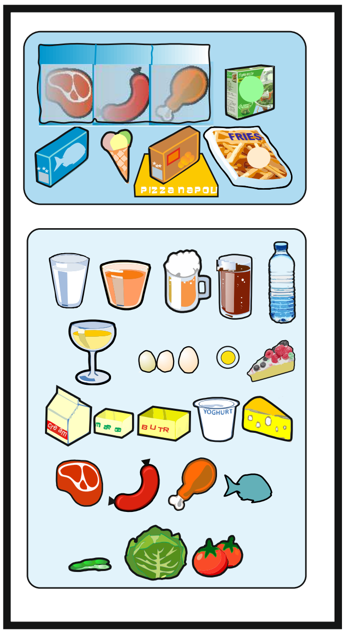
Freezer	
meat	16
ice-cream	3
ready meals	2
fish	3
pizza	1
vegetables	6
fruit	1
potatoes	4
	36

Fridge	
meat	16
fresh milk	12
fish	2
vegetables	31
fresh juice	3
pastry	7
margarine	2
cream	2
butter	2
other diary	17
cheese	9
jam etc.	8
sauces	4.4
	115

33% of chilled drinks	
Milk UHT	6
fruit juice	4
beer	12
white wine	3
soft drinks	17
min. water	18
	60

Total fridge 175.4

Total cold 210



Room temperature	
potatoes fresh	22
potato chips	2.2
vegetables fresh	7
vegetables canned	10
fresh fruit	27
red wine	6
bread/pasta/biscuits	41
oil, nuts	12
canned fish	3
sugar	17
salt	3
chocolate & sweets	5.2
coffee	2.2
tea	0.4
babyfood (homogen.)	1.1
spirits	1.4
vinegar	1
	161

66% of chilled drinks	
Milk UHT	13
fruit juice	4
beer	24
white wine	3
soft drinks	33
min. water	38
	115

Total room temp. 276

Figure 35. Estimated EU storage-practice for food & drinks. (VHK estimate)

Note that the data relate to EU-totals in Mt. In kg per capita per year, as an average of the 504 million EU-28 inhabitants in 2011, the values in Mt should approximately be multiplied by two. This means that e.g. the total purchases 485 Mt translate into 970 kg per capita per year, or 18.6 kg per capita per week.

Per household, counting 213 million households in the EU in 2011, the food and drink purchases amount to 2276 kg per year or 43.8 kg/week.

As mentioned in Chapter 3, consumers are estimated to consume 80% of food at home and 20% through food services. Furthermore, the waste of food services per meal is substantially higher than at home, mainly because not all food prepared is actually ordered (especially in self-service restaurants). There are few surveys, but they all indicate that total food loss is 50% higher per meal than at home. This means that also the ingredients purchased will be not 20% but 30% of the total.

To estimate the actual annual purchases per capita and private household, excluding food services, the numbers have thus to be multiplied by 70%. This means 679 kg/capita/year (13 kg/cap/week) and 1593 kg/household/year (30.6 kg/hh/week).

Assuming that the estimate in figure 35 is correct, 43% (210/485 Mt) of these mass values should end up in the refrigerator. For the average household (30.6 kg/week) this means a mass of ~13 kg/week.

Loading frequency and load-mass per trip

Geppert (2010)[100] investigated, amongst others, the loading frequency and load-mass per shopping trip for a household fridge-freezer. The analysis involved online questionnaires for 1011 participants, equally divided between Germany, Spain, Great Britain and France. Furthermore, an in-home survey was conducted with 100 households consisting of temperature logging, diary surveys and taking pictures of the fridge-freezer content during a period of 2 weeks per household.

Geppert found a median value of 4 to 4.4 shopping trips per week, within a range of 0.5 to 8 trips/week. Young single households indicate significant lower shopping frequencies than respondents of multi-person households and elder single households; differences between countries and other household characteristics are statistically not significant. The median mass of foodstuffs placed in the refrigerator after a shopping trip varies between countries: UK 2.2 kg, Germany 3 kg, France 4.2 kg, Spain 3.3 kg. The average median value is around 3.2 kg. The average maximum (over all trips per household) is 5.7 kg/trip for France. The average minimum is around 1.7 kg/trip for the UK. Spain showed the highest per-household peak values, i.e. between 0.4 and 14.4 kg/trip. Looking at all single values, small amounts up to 3 kg are placed into the refrigerator with a frequency of around 60 %. 30 % of the values are within the range 3 and 10 kg. Nearly 10 % of the values are higher than 10 kg, whereas quantities of more than 16 kg appear with a frequency of 1 %.

The multiplication of median weekly shopping trips (4.2/week) and the median mass stored in the refrigerator (3.2 kg/trip) gives a total of 13.4 kg per week. This is in line with the estimate in the previous section.

Geppert also investigated the average degree that the refrigerator is filled. In the online survey, roughly half of the respondents thought that their refrigerator was *'Sometimes completely full and sometimes less full'*. Some 10% believed their fridge to be completely full most of the time. 32% believed it to be half full and 8% believed it to be usually partially (less than half) full.

[100] Geppert, J., Modelling of domestic refrigerators' energy consumption under real life conditions in Europe, Dr.-Ing. thesis at Rheinischen Friedrich-Wilhelms-Universität Bonn, Institut für Landtechnik (Prof. Dr. rer.nat. Rainer Stamminger), Germany, 2011.

However, a detailed analysis of the in-home survey results showed that at the most 23-28 % of net (inner) volume of the refrigerator is used, even of appliances assessed by respondents as fully filled. Young and elderly single households show the lowest filling degrees. As families become more numerous the filling degree increases. Interestingly, it was found that larger refrigerators have a higher filling degree.

The average actual refrigerator temperature setting is about 4.5 °C, i.e. significantly lower than the 6 or 7°C found in older literature and fairly close to the standard setting (4°C). This subject is further discussed in Task 3 and 4.

Other findings from the Geppert study are:

- The average number of door openings is 11 times per day (78.3% of respondents open the door less than 15 times a day).
- Most respondents answer that they cool down hot leftovers before putting them in the fridge.
- The average minimum kitchen temperature is 17-18°C and the average maximum is 24.5°C. This suggests an overall average of 21°C.

5 Impacts [Task 1]

This chapter describes the impacts of food waste in comparison with refrigeration appliances or even all Ecodesign-regulated ErP (Energy-related Products).[101]

5.1 Material Resources and Waste

The graphs below combine the findings from this study on food with the findings of VHK Ecodesign Impact Accounting for all Ecodesign- and Energy Label regulated Erp (Energy-related Products). The net mass consumed is given at end-use only. The ErP production includes only the direct materials in the product, excluding mining and production waste. Likewise, also the auxiliary and energy use during the use phase are net fractions to which the waste, given in figure 37 should be added. The food quantity represents the mass purchased.

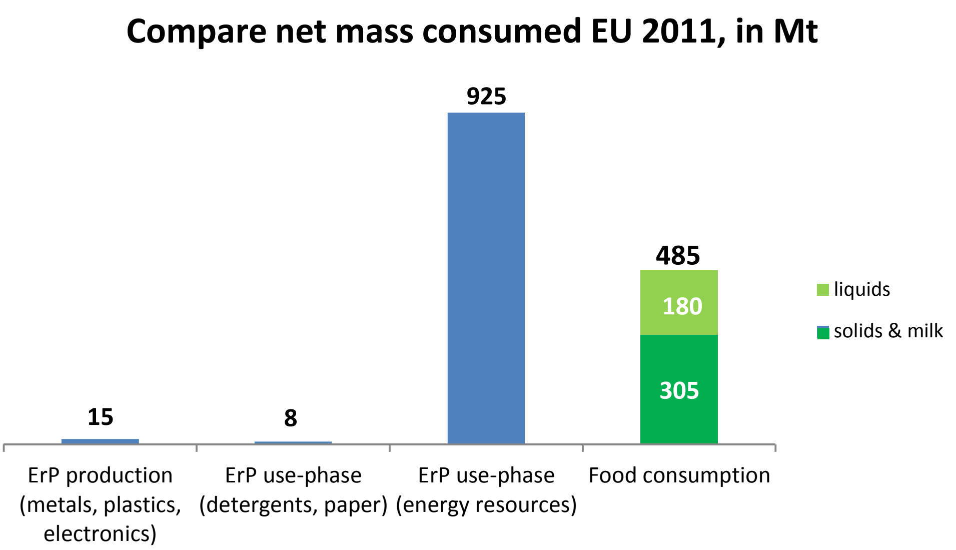


Figure 36. Comparison net mass flows between food consumption and ErP-related mass flows.

[101] Note that preliminary estimates from the inception report were revisited and where necessary corrected.

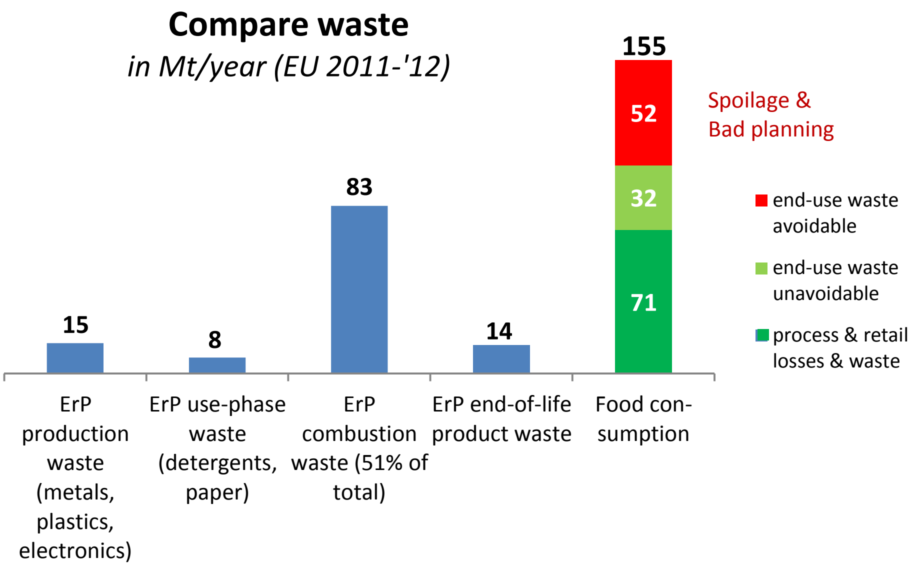


Figure 37. Comparison waste flows between food consumption and ErP-related mass flows.

For regulated ErP the sum of net materials and waste is roughly representative of the domestic material consumption (DMC) related to these products. However, for food products, as is demonstrated in Chapter 4, the accounting is more complex. To produce 485 Mt of food (incl. waste) around 1.44 Gt of inputs is required.

The figure below, elaborated from Eurostat's DMC statistics, gives thus a more complete representation of the relative material resources flows involved.

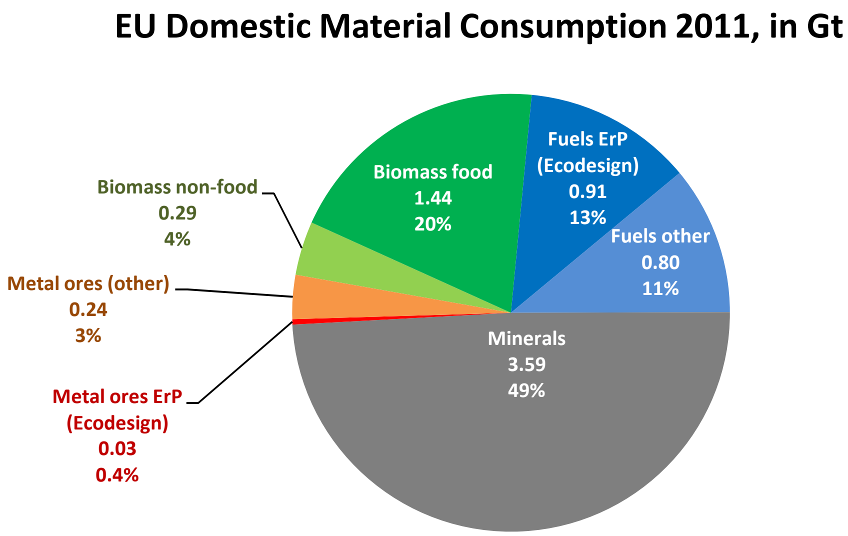


Figure 38. Comparison mass flows between food consumption and ErP-related mass flows (rounding may give deviation in the sum)

For foodstuffs, there is a factor 3 between the material resources consumed and the foodstuffs purchased by the end-user. This implies that every Mt saving on avoidable losses at the end-use translates into 3 Mt reduction of the material resources inputs required.

Furthermore, as mentioned in Chapter 4, the 20% of DMC that the EU sets apart to produce food is very large. It dwarfs non-energy material resources related to ErP (0.4-0.5% of DMC) and strictly on a mass-basis it is in the same order of magnitude of energy resources (13% for ErP + 11% for non-ErP).

5.2 Energy

The energy consumption related to food production and consumption was calculated from the VHK Ecodesign Impact Accounting. It amounts to 283 Mtoe in primary energy consumption, i.e. including the power generation losses.

The graph below gives an overview.

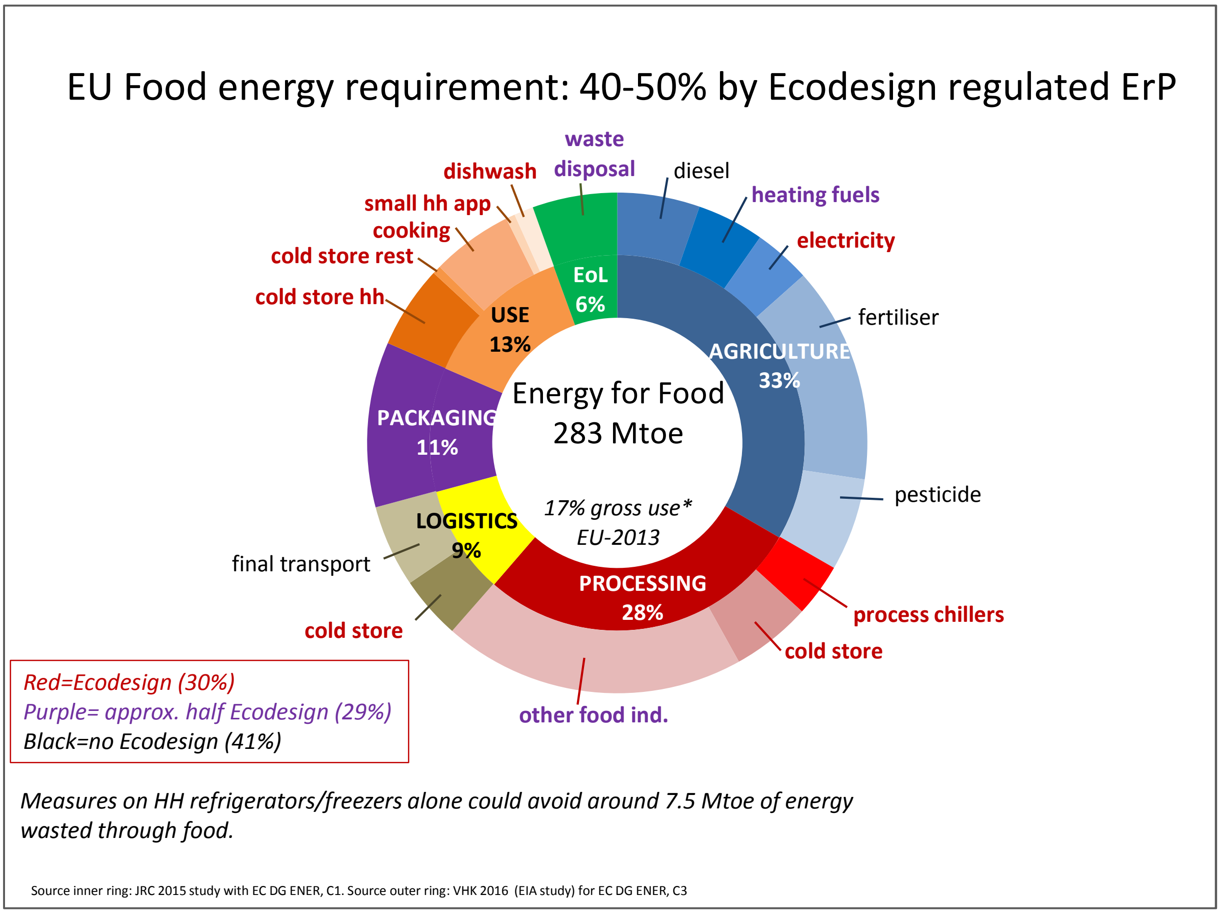


Figure 39. Comparison energy consumption for food production, distribution, consumption and disposal, wholly, partially or not regulated through Ecodesign and possibly Energy Labelling measures. (source: VHK, elaborated from EIA study 2016)

The 283 Mt energy consumption for food means that 17% of EU energy consumption relates to food production.

When comparing this figure of 283 Mtoe for food with the 925 Mtoe for ErP it needs to be considered that almost half (45%) of the energy use for food comes from ErP products and components regulated by Ecodesign and possibly Energy Labelling. How this partitioning was made is indicated in the figure above.

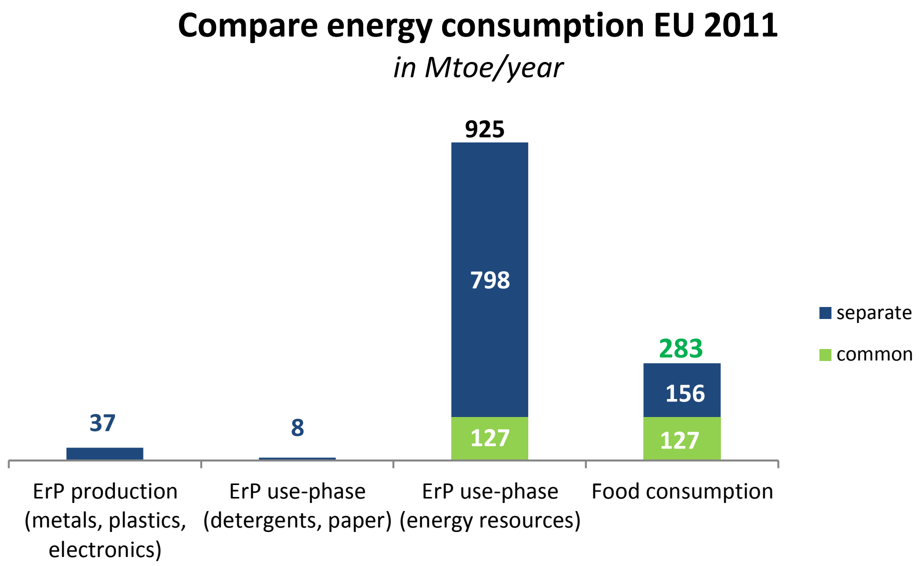


Figure 40. Comparison energy consumption flow between food and ErP-related mass flows

Based on the established mass (485 Mt) and energy flows (283 Mtoe=3291 TWh primary energy) it can be calculated that the average primary energy requirement of all foodstuffs is 6.8 kWh/kg or 24.5 MJ/kg (primary energy).

5.3 Greenhouse gas (GHG) emissions

Agricultural activities in the EU-28 generated 471 Mt CO2 equivalent of direct GHG in 2012, corresponding to about 10.35 % of total greenhouse gas emissions (4548 Mt CO2 equivalent).[102] [103] These emissions are mainly methane (199 Mt) and nitrous dioxide (272). The 10.35% emissions relate to manure management (1.73%), enteric fermentation (3.24%), agricultural soils (5.3%), rice-cultivation (0.05%) and field burning of agricultural residues (0.02%).

The above methane and nitrous dioxide emissions exclude the direct and indirect CO2-emissions from the use of energy resources for food production. In that sense, the 283 Mtoe of energy use for food production translates into 600 Mt CO2 equivalent of GHG-emissions, i.e. another 13% of EU total. In total, it can be estimated that EU food production causes 1070 Mt CO2 equivalent or almost 24% of the EU total.

In comparison, the 970 Mtoe related to production, use and end-of-life of regulated ErP constitute over 2000 Mt CO2 equivalent, which is around 45% of EU-total. Of this, 127 Mtoe or 268 Mt CO2 emissions are shared with the food production.

[102] note that information on land use, land use change and forestry is excluded.
[103] Source: http://ec.europa.eu/eurostat/statistics-explained/index.php/Agriculture_-_greenhouse_gas_emission_statistics

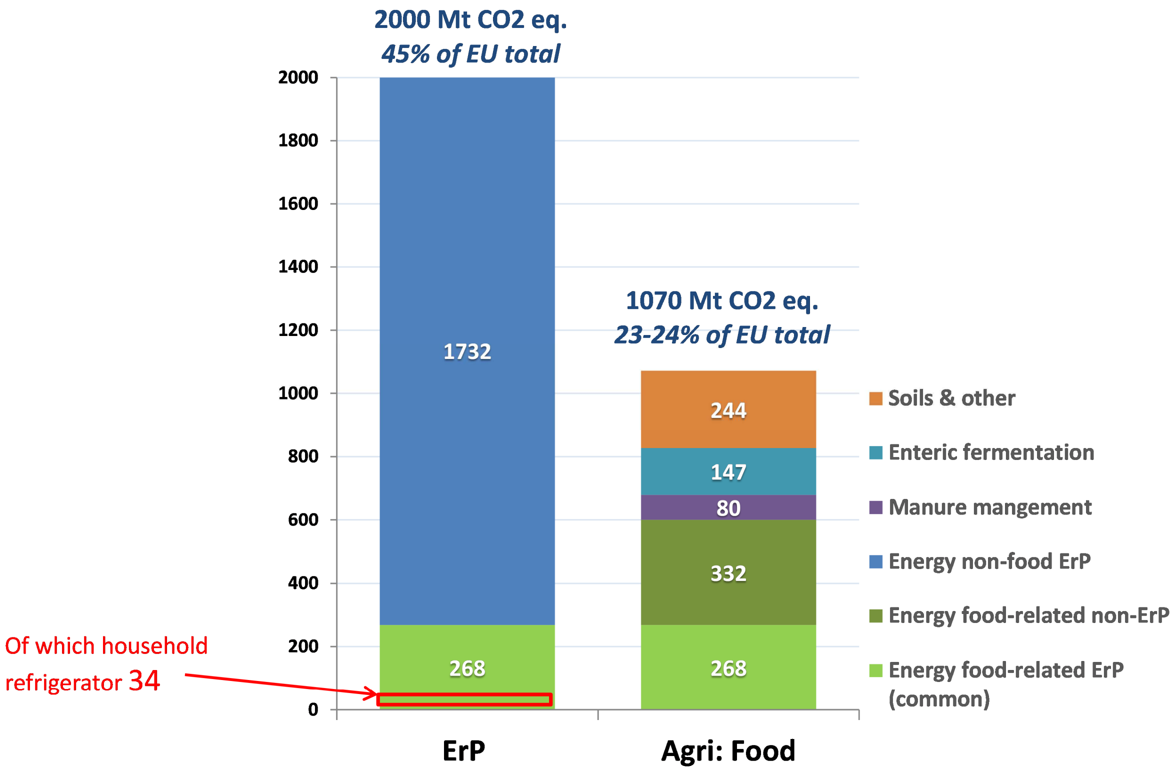


Figure 41. Comparison of greenhouse gas emissions related to regulated ErP and those related to agricultural/food production, distribution and consumption.

5.4 Water

Irrigation water and water from the public grid for the agricultural sector have been analysed in the VHK MEErP-study, Part 2. The irrigation water volume amounts to 62 Gt (62 billion m³), whereas water from the public grid for drinking/cleaning in the agricultural sector was estimated at 2 Gt (2 billion m³). The flow diagram below shows this total of 64 Gt for the agricultural sector to be 27% of the total water abstracted in the EU (237 Gt). However, considering that the cooling water for power plants (100 Gt) is only temporarily used for thermal properties, one could also estimate that almost half of the water abstracted in the EU is to be attributed to the food sector.

For comparison, the water abstraction for production, use and end-of-life of all regulated ErP (status 2016) amounts to 3.7 Gt. This amounts to 1.6% of total EU abstraction or 17 times less than the water abstraction for the agricultural sector.

Note that within the concept of 'water footprint' the above refers strictly to 'blue water'. Globally, according to Hoekstra and Mekonnen[104], blue water is only 12% of the water footprint. The 'water footprint' also includes green water (rain, 78% of total) and grey water (virtual water that would be required to dilute polluted water to acceptable levels, 10% of total).

[104] M. M. Mekonnen and A. Y. Hoekstra, The green, blue and grey water footprint of crops and derived crop products, Hydrol. Earth Syst. Sci., 15, 1577–1600, 2011
www.hydrol-earth-syst-sci.net/15/1577/2011/
doi:10.5194/hess-15-1577-2011

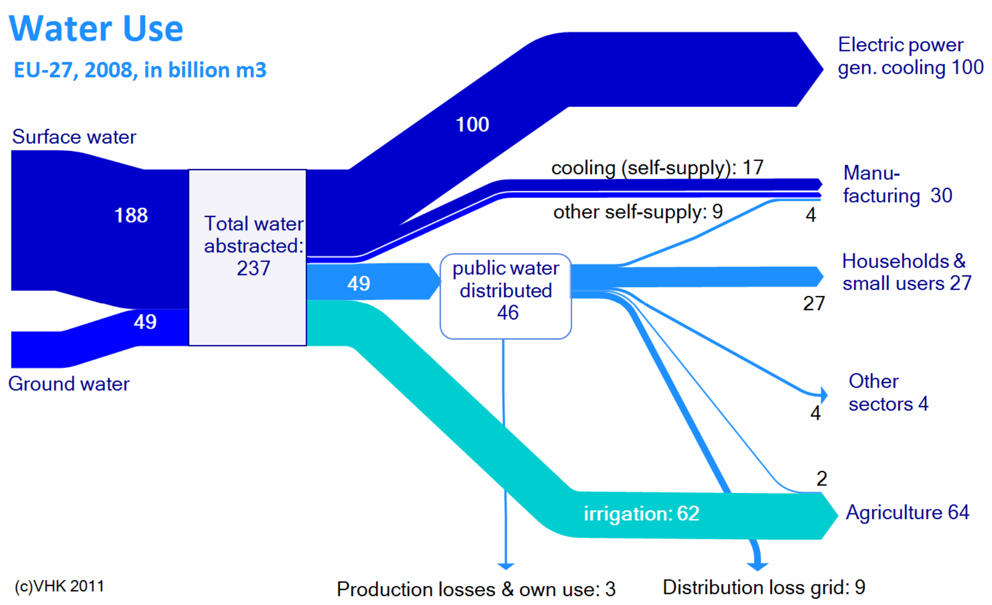


Figure 42. Water abstraction for irrigation, manufacturing industry, energy cooling and public water supply (billion m^3/year) EU-27, 2008 (source: VHK, MEErP, 2011)

Note: The figures are VHK estimates based on Eurostat 2011 Tables ten00002-ten00010. If 2008 country data were not available, figures were taken from the latest previous year or –if no specific country data were found at all—they were estimated from a population weighted share of the EU-average or other sources. Accuracy is estimated at ±10%. Note that 'irrigation' does not include rainwater.

5.5 Monetary impacts

An investigation of monetary impacts was not a priority in this study. Nevertheless, hereafter some figures are presented that should give policy makers a sense of the proportions involved.

According to Eurostat (nama_10_co3_p3 database, COICOP 3 digit), the average person spent 3000 euros on food and beverages (in current prices). At a family size of 2.3 persons per household, this comes down to 6900 euros per year. Of this, the average person spent 2000 euros at home and 1000 euros at catering services. Per household this amounts to 4600 euros and 2300 euros respectively.

Given an avoidable waste of 11%, the average household is throwing away around 500 euros per year in food waste that could be avoided by better planning (50%) and consuming food before it is spoiled (50%). If, for instance and just to give an idea, a better refrigeration appliances reduced the spoilage by half, the average household would save 125 euros per year.

The average person spent 600 euros on energy (electricity, gas and other fuels, excluding transport fuels) and 100 euros on the purchase of household appliances. Per household these figures are 1380 and 230 euros respectively.

The household refrigeration appliances are a part of these figures. According to the preparatory review study (VHK, March 2016)[105], the average household owned 1.4 refrigeration appliances at an average price of 528 euros/unit. Per year, over an average product life of 16 years, this means 33 euros per refrigeration appliance and 46 euros for

[105] VHK and Armines, Preparatory review study household refrigeration appliances, fort he European Commission, March 2016.

the 1.4 refrigeration appliances per household. This is 20% of the appliance purchasing budget. The electricity costs for operating these 1.4 refrigeration appliances is 77 euros per year. This is based on average installed appliances in 2014; for newly bought refrigerators in 2014 the energy costs is 14 euros lower, i.e. 63 euros per year. With new measures, the energy costs of new units may again be some 11-12 euros lower (18-20%) in 5 to 8 years.

In conclusion, the monetary savings from a 2.7% saving on food purchases due to avoided waste are 10 times more than the monetary savings on a 20% more efficient refrigeration appliance.

The table below gives an overview of the Eurostat consumer data for the year 2011.

Table 11. Final consumption expenditure of households by consumption purpose, EU 2011 (COICOP 3 digit) [Eurostat, nama_10_co3_p3 database, extract Dec. 2016]

COICOP class	**per capita**		**per household (2.3 x cap.)**		**Total EU-28**	
	euros/yr		*euros/yr*		*billion euros/yr*	
Food	1 600		3 680		816	
Non-alcoholic beverages	200		460		84	
Alcoholic beverages	200		460		114	
Subtotal food&drinks at home		***2 000***		***4 600***		***1 014***
Catering services	1 000	1 000	2 300	2 300	482	482
Subtotal food&drinks		***3 000***		***6 900***		***1 496***
Electricity, gas and other fuels	600		1 380		319	
Household appliances	100		230		57	
Total energy and appliances		***700***		***1 610***		***376***
Total expenditure		**14 500**		**33 350**		**7 337**

6 Optimal storage conditions [Task 2]

6.1 Introduction

In task two optimal storage conditions for refrigerated food products were investigated. By partitioning foodstuffs to various refrigerator and freezer zones the storage time may be elongated, which gives the consumer more opportunity/time to consume the product. Refrigerator and freezer zones include a pantry (17 °C), cellar (8 to 14°C), wine storage (12°C), fresh storage (4°C), salad chiller (1 to 2°C), meat chiller (-1 to +1°C) and a freezer (-18°C). Current storage conditions are suboptimal and current refrigeration appliances provide limited options for optimal storage of a wide range of products.

Various aspects influence the way food products are optimally stored.

Condition of the food product
'Optimal' storage not only varies per foodstuff but also depends on their condition (ripe, unripe, mechanically damaged, dehydrated or wet, sliced or whole) when it reaches the consumer. Unripe fruit often requires warmer storage temperatures than ripe fruit. Mechanically damaged fruits or vegetables are more susceptible to microbial invasion as the protective skin barrier is broken. Similarly, sliced or cut fruit and vegetables are more susceptible to microbial spoilage and lose quality and nutrients more quickly.

Foodstuffs and ethylene
For fruit and vegetables, the ethylene concentration in the air (emitted by fruits in ripening phase) also significantly impact spoilage and storage time. It can either onset or speed up ripening of other fruits. But it can also cause leaf abscission (the shedding of leafs), leaf yellowing or brown spots in vegetables. Some foodstuffs can therefore better not be stored next to each other.

Not only storage temperature
Foodstuffs lose moisture more quickly in relatively dry environments. This affects the quality and the nutritional value as water soluble vitamins and minerals may be lost. On the other hand, wet foodstuff due to condensation increase the change on microbial growth and turn fruit and vegetables soft. Therefore, the relative humidity – next to storage temperature – is an important extrinsic factor in household food storage to prevent spoilage.

Food safety and regulations
Optimal storage conditions also depend on food safety issues. Food business operators (FBOs) must comply with many food safety regulations, especially regarding food products of animal origin and ready-to-eat foods (RTE foods) like pre-prepared meals, salads and sandwiches. For example, FBOs are required by the Regulation EC 852/2004 on Food Hygiene to base their food safety and food hygiene practices on the Hazard Analysis and Critical Control Points (HACCP) principles. Food containing pathogens causing foodborne illness often do not show visible signs of spoilage (WHO, 2015[106]; Netherlands nutrition centre, 2016[107]) making it harder for consumers to evaluate food quality and safety.

Perishable foods generally are provided with an 'use-by' or 'best-before' date set by the FBO to ensure safety of the product. The FBO is responsible for the product safety and the setting of the expiration date, therefore depending on the FBOs' expertise and business interests. This subject is further elaborated in task 3. Besides the expiration date, the quality and safety of a food product is assessed by the consumers' subjective observation. With organoleptic properties, such as smell,

[106] WHO, 2015, Food safety fact sheet N°399, World Health Organization, Geneva
[107] Netherlands Nutrition Centre (Het Voedingscentrum), 2016, Storage of food fact sheet

appearance and texture the consumer evaluates freshness and quality of a product. The evaluation is therefore dependent on the consumers' background, knowledge and personal preferences.

Stage of processing
'Optimal' storage conditions also depend on the intention and perspective of the actor and the stage of processing, storage and transport of a food product. Long-term storage of foods for long-distance transport from harvest to market, as is the case with exotic fruits, benefit from storage conditions that delay or slow down ripening and respiration processes to maximize the shelf life. Short-term storage at retail strives to maintain visible freshness and quality to meet consumer standards. Finally, after purchase, the consumer is responsible for the transport and storage conditions of his/her food products. Ideally, consumers take into account the use-by dates, ripening process and shelf life of their food products during food planning and preparation. In practice, however, this will not always be the case.

Shopping frequency and household composition
Shopping frequency largely influences the need for proper storage conditions. For example, a household shopping once a week relies on the refrigerator for all their fresh products to maintain quality during a week or more. Households shopping daily (e.g. unemployed or pensioners) are less dependent on household storage conditions. The size of households relate to the degree of leftovers being wasted. Having more eaters will increase the possibility that leftovers are actually consumed. Compared to urban households, households in rural areas will have less leftover waste because they can also use it for animal feed and home composting.

In conclusion, type and condition of the food products, time, final use and consumer expectations for the product to be eaten, are major factors in food storage conditions. Consumer associations and green NGO's tend to focus on consumers that have lots of time for shopping, food preparation and eating. But a large share of households do not have, or do not want to spent much time on shopping and food preparation. Ideally green NGO's and consumer associations should focus their advice on these consumers, since they represent a higher risk of food being wasted (Stakeholder meeting, 2015[108]).

6.2 Approach and sources

The subject of this chapter 'optimal storage conditions for food products' covers a vast field of knowledge. It should be stressed that this study does not aim to give a complete overview of all factors involved in food storage conditions, food safety and food spoilage (food science is indeed a science). This study focusses only on the basics of storage conditions related to the food products that are kept in refrigerator and freezer zones in households.

Sources consulted for this study included sources describing storage conditions in various stages of the food supply chain, amongst which agricultural long-term storage recommendations, storage conditions recommended for fresh food cargo handlers, wholesalers and retailers, and consumer storage recommendations. These sources include scientific publications but also documents and guidelines form public and private advisory bodies, NGO's, and consumer organisations, amongst which EFSA, EUFIC (European Food Information Council), WHO, WFLO (World Food Logistics Organization), CDC (Centers for Disease Control and Prevention), Netherlands Nutrition Centre and Zentrum der Gesundheit.

[108] Stakeholder meeting, 2015, Ecodesign & Labelling Review household refrigeration appliances, minutes of the 1st stakeholder meeting.

The following three paragraphs describe data retrieval (section 6.3), data analysis (section 6.4) and conclusions (section 6.5). The section on data retrieval summarizes the most relevant information that was gathered related to food storage. The information is subdivided into three product groups: 1) Meat, fish and dairy products, 2) Fruit and vegetables, and 3) Bread and pastry. In the data analysis, information and data that were gathered are further analysed. Based on the data that was found a summary is given in terms of 'what food products should go where in the various storage zones' and when and how long they can best be stored. Also, suggestions are made concerning additional parameters that could extent shelf life. The conclusion summarizes what the consequences of suboptimal storage conditions of traditional fridges and freezers are for food waste and for the energy consumption related to higher or lower temperature storage compartments.

6.3 Data retrieval

6.3.1 Meat, fish and dairy

Meat, fish and dairy are potentially hazardous food products because they can cause diseases in humans and animals. Generally, consumers are advised to keep their meat, fish and dairy products stored in the lower (colder) section of the refrigerator. Raw fish and meat can only be stored there if these products are consumed the same day or the day after. If not, raw fish and meat must be kept in the freezer at -18°C where they can be kept for a period of 3 to 6 (sometimes even 12) months. Depending on their type, dairy products can be kept in the refrigerator for a period of 3 to 14 days. To understand the mechanisms causing safety risks and food spoilage this subject is further investigated.

Optimization of storage conditions of meat, fish and dairy aims at the minimisation of food safety risks and the prevention of food spoilage.

Food safety risks in meat, fish and dairy products are predominantly related to foodborne illnesses caused by pathogenic microorganisms such as Salmonella or Campylobacter (EFSA, 2016[109]). Animals often form a source of pathogens and their products can act as a vehicle for pathogen transmission. The amount of pathogens present in the food and the susceptibility of the consumer determine if you get sick. Storage conditions largely affect the possibility and rate of growth for pathogenic bacteria (and other bacteria) present in foods. Therefore, correct storage is essential for both food safety and food spoilage.

Food spoilage is the process of food deterioration in which one or more sensory aspects are affected by physical, chemical or microbial mechanisms making the food unfit or undesirable for human consumption. For example, a change in the colour of meat (browning, chemical mechanism) or milk turning sour (microbial mechanism). Most spoilage microorganisms are not pathogenic (Blackburn, 2006[110]; Netherlands Nutrition Centre, 2016[107]).

Food safety risks relate to possible health hazards present in food causing illness or other harm to the human body, like pathogenic microorganisms such as bacteria, fungi, viruses and parasites, but also chemical (biological toxins, antibiotics, dioxins), physical (bone fragments, metal flakes, glass) and allergenic hazards.

[109] EFSA, Food-borne zoonotic diseases, https://www.efsa.europa.eu/en/topics/topic/foodbornezoonoticdiseases, accessed October 2016.

[110] Blackburn, C., 2006, Chapter 6 Managing microbial food spoilage: an overview, in Food Spoilage Microorganisms, Woodhead Publishing, pages 147-167.

6.3.1.1 Food safety aspects meat, fish & dairy

Pathogenic contamination
Contamination of food occurs through contact with human or animal faeces (manure), ecosystem interaction (bacteria or viruses naturally present in nature), levels of community sanitation and hygiene, or contact with the gastro-intestinal tract of animals during slaughter. Pathogens have many varying pathways for contamination. For shell eggs for example, salmonella contamination can either take place in the infected laying hen before the egg is laid, or through pathogens present on the shell due to contact with contaminated faeces. The chance on Salmonellosis attracting will increase when the pathogen has had the opportunity to grow and achieve high populations in both the yolk and the albumen (Humphry, 1994[111]). Food may be infected by the norovirus during e.g. primary production of shellfish in waters near human sewage outlets, use of animal manure fertilizer or contaminated irrigation water for production of fresh produce, or food handling by infected workers (EUFIC 2014[112]; EFSA 2011[113]). Table 12 shows various food vehicles involved in transmission of the most common pathogens in the EU. Food products of animal origin are among the most important food vehicles.

Table 12. Common food vehicles for pathogenic microorganisms in foodborne outbreaks in the EU. According to EFSA/ECDC 2015[114] annual summary report of 2013 (were available percentages of outbreaks caused by the food vehicle are included). *viruses include: norovirus (>95% of cases), hepatitis A virus, rotavirus, flavivirus

Microorganism		Food vehicle		
Salmonella	2013	Eggs and egg products 44,9%	Sweets & chocolate 10,5%	Pig meat 8,9%
	2014	Eggs and egg products 44%	bakery products 12,9%	Pig meat 9,3%
Campylobacter	2013	Broiler meat 50%	Other poultry meat products 18,8%	Milk 9,4%
	2014	Broiler meat 55,2%	Milk 6,9%	Mixed foods 6,9%
Listeria	2013	RTE products; Crustaceans, shellfish, molluscs	Cheese	Meat and meat products
	2014	Mixed foods	Fish and fishery products	Buffet meals
VTEC	2013	Bovine meat	Vegetables and juices	Cheese
	2014	Milk	Vegetables and juices	Mixed foods
Yersinia	2013	Raw vegetables and salads	Pig meat	Mixed foods
	2014	Unpasteurised milk	Mixed foods	Pig meat
Viruses*	2013	Crustaceans, shellfish, molluscs 40%	Buffet meals 14%	Fruit, berries, juices 11,6%
	2014	Crustaceans, shellfish, molluscs 36,8%	Mixed foods 22,4%	Vegetables and juices 14,5%
Bacillus toxins	2013	Mixed foods 29,6%	Other foods 22,2%	Vegetables and juices 11,1%
	2014	Mixed foods 34,4%	Other foods 28,6%	Cereal products 11,4%
Clostridium toxins	2013	Other foods 21,7%	Mixed foods 20%	Bovine meat 18,3%
	2014	Other foods 19%	Bovine meat 14,3%	Other red meat 11,9%
Staphylococcal toxins	2013	Other foods 26,6%	Mixed foods 19,1%	Vegetables and juices 12,8%
	2014	Mixed foods 29%	Broiler meat 9,7%	Pig meat 9,7%

[111] Humphry, T.J., 1994, Contamination of egg shell and contents with Salmonella enteritidis: a review, International Journal of Food Microbiology 21(1-2): 31-40
[112] European Food Information *Council* (EUFIC), 2014, Viral foodborne illnesses. ***http://www.eufic.org/article/en/artid/Viral-foodborne-illnesses/*** accessed October 2016.
[113] EFSA, 2011, Scientific opinion on an update *on the present knowledge on the occurrence and control of foodborne viruses, EFSA Journal 9(7): 2190.*
[114] EFSA/ECDC, 2015, The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2013, Scientific report of EFSA and ECDC, EFSA Journal 13(1): 3991.

Factors affecting microbiological growth
Because the amount of pathogens present in a food product is a large factor in the occurrence of a foodborne illness (excl viruses), it is essential to understand the factors affecting growth of pathogens and other microorganisms. It is a combination of intrinsic and extrinsic factors that affect the growth of microorganisms. The pH and water activity (a_w) of a food product are two important intrinsic factors. The pH is a scale to express acidity of a product with pH-values higher than 7 considered basic and pH-values lower than 7 considered acidic. The a_w is the ratio of water vapour pressure of the food to the water vapour pressure of pure water under the same conditions; an a_w of 0,1 means extremely dry and an a_w of 1,0 is that of pure water. In practice, it indicates the amount of freely available water in a food product. Bacteria and other microorganisms often need a certain level of available water for survival and/or growth. Many fresh products have a pH and/or a_w favourable for growth of a broad range of microorganisms. Listeria monocytogenes, for example, grows in products with pH 4,3 - 9,4 and a_w >0,92, and has therefore the potential to grow in raw foods (European Commission, 2013[115]; Lawley, 2013a[116]).

Time/temperature conditions and the relative humidity (RH) are extrinsic factors that can greatly affect microbiological survival and growth on food products. The temperature growth range of Listeria monocytogenes lies between -1,5 to 45 °C and is therefore considered a high-risk pathogen for refrigerated and RTE foods. Obviously, the time a microorganism is exposed to a certain temperature also affects the final number of microorganisms present. Table 13 provides an overview of common pathogenic bacteria with corresponding growth characteristics for temperature, pH and aw.

Additionally, dynamic interactions between different microorganisms play a considerate role in which microorganisms gain the upper hand in the food. Dominance of one microorganism may inhibit growth of others, called antagonistic interactions. On the other hand, growth of a microorganism may change the environment as such, favouring conditions for growth of other microorganisms, called synergistic interactions. Altogether, a combination of multiple intrinsic and extrinsic factors such as time, temperature, RH, pH and a_w and dynamic microbiological interactions are what determines survival and possible growth of microorganisms in food. Various microbial growth predicting models like ComBase or Pathogen Modelling Program are designed to predict growth. FBO's may use these predicting models to assess product shelf-life and food safety.

In practice, factors vary throughout the supply chain and are dependent on handling procedures of the various actors in the supply chain, for example variations in temperature during distribution, transport, loading and unloading, and storage at retailer or consumer.

[115] European Commission, 2013, Commission Staff Working Document: Guidance document on Listeria Monocytogenes shelf-life studies for ready-to-eat foods, under Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs, Brussels.
[116] Lawley, 2013a, Listeria factsheet, Food Safety Watch, http://www.foodsafetywatch.org/factsheets/listeria/ Accessed October 2016

Table 13. Pathogenic bacteria and toxin producing bacteria growth characteristics.
(Viruses are not included because they do not grow in foods) (*characteristics for toxin production)

	Temperature °C ***range***	***optimum***	***pH*** ***range***	***optimum***	***Water activity***	***Source***
Salmonella	5 - 50	35 - 37	3,8 – 9,5	7 – 7,5	≥ 0,94	ANSES, 2011b
	5 - 47	35 -37	4,5 – 9,0	6,5 – 7,5	≥ 0,94	Doyle, 1989
	7 - 48		3,7 – 9,5	6,5 – 7,5	≥ 0,94	Lawley, 2013b
	5 - 47	35 - 37	4,2 – 9,5	7,0 – 7,5	≥ 0,94	ICMSF, 1996
Campylobacter	30 - 45	42	4,9 - ?	6,5 – 7,5	≥ 0,98	Lawley, 2013c
	30 - 45	41,5	4,9 – 9,0	6,5 – 7,5	≥ 0,98	ANSES, 2011a
		42 - 45	5,5 – 8,0	6,5 – 7,5		Doyle, 1989
	32 - 45	42 - 45	4,9 – 9,0		≥ 0,98	ICMSF, 1996
E. coli	7,6 – 47,4		4,0 – 8,3		≥ 0,95	Ross et al., 2003
	7 - 46	37	4,0 - ?		≥ 0,95	Lawley, 2013c
	7 - 46	35 - 50	4,4 – 9,0	6,0 – 7,0	≥ 0,95	ICMSF, 1996
Listeria	-1,5 - +45	30 - 37	4,3 – 9,6	6,0 – 8,0	≥ 0,90	Motarjemi et al., 2014
	-1,5 - +45		4,3 – 9,4		≥ 0,92	Lawley, 2013a
	-1,5 - +45	30 - 37	4,0 – 9,6	6,0 – 8,0	≥ 0,90	Ryser & Marth, 2007
	0 - 45	30 - 37	4,4 – 9,4	7	≥ 0,92	ICMSF, 1996
Yersinia		28 - 30	4 - 10	7,6		Motarjemi et al., 2014
	0 - 44	25 - 29	4 - 10			Bhunia, 2008
	-2 - +42	28 - 29	4,2 – 9,0		≥ 0,96	Bari et al., 2011
	-1 - +42	28 - 30	4,2 – 9,6	7,2	≥ 0,97	ICMSF, 1996
Clostridium botulinum* (toxins A, B, E)	10 – 48 (A, B)	35 – 40 (A, B)	4,6 - ? (A, B)		≥ 0,94 (A, B)	Johnson, 2007
	3 – 45 (B, E)	18 – 25 (B, E)	5,0 - ? (B, E)		≥ 0,97 (B, E)	
	10 – 48 (A, B)	35 – 40 (A, B)	4,6 – 9,0 (A,B)	7,0 (B, E)	≥ 0,94 (A, B)	ANSES, 2010
	3 – 45 (B, E)	18 – 25 (B, E)	5,0 – 9,0 (B,E)		≥ 0,97 (B, E)	
	10 – 50 (A)	30 – 40 (A)	4,6 – 8,5		≥ 0,93	ICMSF, 1996
	3 – 45 (E)	25 – 37 (E)				
Staphylococcus aureus*	10 - 45	34 - 40	5 – 9,6	7 - 8	≥ 0,86	ANSES, 2011c
	10 - 48	40 - 45	4 – 9,6	7 - 8	≥ 0,85	FSAI, 2011
	10 - 46	40 - 45	4,6 – 8,5		≥ 0,88	ICMSF, 1996

Foodborne illness: impact on health and occurrence in EU

Common symptoms of foodborne illnesses are diarrhoea, abdominal pain, fever, nausea and in severe cases can cause death. Contaminated food often does not show visible signs of spoilage, making it harder for consumers to evaluate food quality (Netherlands Nutrition Centre, 2016[107]; WHO, 2015[106]; Rawat, 2015[117]; Blackburn 2006[110]). Especially minced meat is a high risk product as contaminated meat may easily spread during grinding. Unlike steaks or sirloins etc, microorganisms can also grow inside hamburgers and other minced meat products. Therefore, consumption of medium to rare hamburgers may increase the risk of foodborne illness as pathogens may not be eliminated due to inadequate heating.

A study by EFSA and ECDC (the European Centre for Disease Prevention and Control) on trends and sources of zoonoses and foodborne outbreaks in 2013[114] registered over 314 000 human cases of foodborne illness and a total of 5196 reported foodborne outbreaks[118] in the EU. The study shows that around 39% of these reported outbreaks

[117] Rawat, S., 2015, Food Spoilage: Microorganisms and their prevention, Asian Journal of Plant Science and Research 5(4): 47-56.

[118] 'food-borne outbreak' means an incidence, observed under given circumstances, of two or more human cases of the same disease and/or infection, or a situation in which the observed number of cases exceeds the expected number and where the cases are linked, or are probably linked, to the same food source (Article 2, Directive 2003/99/EC).

occurred at the household. Another 22% of the foodborne outbreaks occurred in restaurants, café's, hotels and bars. The most confirmed human cases in the EU were caused by Campylobacter (214 779 cases) and Salmonella (82 694 cases), covering 95% of the total confirmed foodborne human cases due to zoonoses[119].

Other pathogens relevant in foods (from both animal and plant origin) are toxin producing bacteria such as Clostridium botulinum and Staphylococcus aureus as well as viral agents such as norovirus, hepatitis A and E, and rotavirus. Table 14 presents the number of foodborne outbreaks and related causative agents from 2011 to 2014 in the EU. From 2012 to 1014 around 30-40% of the foodborne outbreaks were caused by bacteria, another 10-20% were caused by viruses. To compare, in the US from 2009-2012 48% of foodborne outbreaks were caused by the norovirus; another 46% due to pathogenic bacteria and the remaining 6% due to toxins, parasites and other hazards (CDC, 2014[120]). Although both sources might not be fully compatible (differences in reporting methods etc), it may be concluded that viral agents play a larger role in foodborne outbreak in the US than they do in the EU. However, data from previous years (see Table 14) show a growth in the contribution of viruses in the EU. Viruses do not multiply in foods but infectious particles may be present on foods for extended periods of time and are easily spread (EFSA 2011[113]). Storage conditions can therefore not be used to reduce the impact of virus-contaminated food as is the case with bacteria-contaminated food.

Table 14. Number of foodborne outbreaks and the contribution per causative agent in the EU.
(adapted from EFSA/ECDC: The European Union Summary Report on Trends and Sources of Zoonoses, Zoonotic Agents and Food-borne Outbreaks in 2011, 2012, 2013[114], 2014)

	outbreaks	***bacteria***	***viruses***	***toxins***	***parasites***	***other***	***unknown***
2014	***5251***	***31%***	***20%***	***16%***	***0,6%***	***2,7%***	***29%***
2013	***5196***	***34%***	***18%***	***16%***	***0,8%***	***2,5%***	***29%***
2012	***5363***	***41%***	***14%***	***15%***	***0,7%***	***2,6%***	***28%***
2011	***5648***	***39%***	***9,3%***	***13%***	***0,5%***	***2%***	***36%***

There are many food handling and food processing procedures in place to prevent contamination and inactivate or restrain microbial growth to guarantee food safety.

HACCP
European food business operators (FBOs) are required by the Regulation EC 852/2004 on Food Hygiene to base their food safety and food hygiene practices on the Hazard Analysis and Critical Control Points (HACCP) principles. HACCP is a risk management methodology based on seven principles to assess hazards and establish control systems based on critical control points to ensure food safety. Implementation of permanent HACCP procedures are mandatory to ensure safety of the FBO's food products. The principal advantage of the HACCP system is its focus on prevention with systematic process controls rather than relying on end-product testing (European Commission, 2005[121]; FAO and WHO, 2009[122]).

[119] The WHO defines zoonoses as diseases and infections that are naturally transmitted between vertebrate animals and humans.
[120] Centers for Disease Control and Prevention, 2014, Vital Signs: Foodborne Norovirus Outbreaks – Unites States, 2009-2012, by A.J. Hall, M.E. Wikswo, K. Pringle, L.H. Gould, U.D. Parashar. Morbidity and Mortality Weekly Report 63(22): 491-495
[121] European Commission, 2005, Discussion Paper on strategy for setting microbiological criteria for foodstuffs in Community legislation, Health and Consumer Protection Directorate D – Food Safety: production and distribution chain, Brussels
[122] FAO and WHO, 2009, Codex Alimentarius: Food hygiene basic texts, 4th edition, World Health Organization and Food and Agriculture Organization of the United Nations, Rome

Codex Alimentarius
Before HACCP is applied, prerequisite programmes should be implemented and verified such as good hygiene practices, the Codex Alimentarius Codes of Practice and appropriate safety requirements laid down by the Codex Alimentarius Commission (FAO and WHO, 2009[122]). The Codex Alimentarius, also known as the food code, are internationally acknowledged food standards and guidelines for food safety, quality and hygiene. The HACCP system was adopted by the Codex Alimentarius Commission. Nowadays, the Codex contains the most internationally used description of the HACCP system consisting of 7 principles and 12 steps for the logic sequence for application of HACCP. The Codex and particularly the HACCP principles form a basis for EU legislation on food safety and hygiene.
Implementation of both HACCP and Codex Alimentarius codes of practice are the responsibility of the FBO. When requested, the FBO should be able to prove safety of their food products to the authority.

Existing EU legislation
EU legislation on food safety covers a broad range of biological (e.g. bacteria, viruses, parasites) and chemical (e.g. mycotoxins, metals, dioxins, residues of medicines or pesticides) hazards and related public health risks. To name a few: Regulation EC 178/2002 on the General principles and requirements of food law, establishing the EFSA and procedures for food safety; Regulation EC 852/2004 on hygiene of foodstuffs; Regulation EC 2073/2005 on Microbiological criteria for foodstuffs; Regulation EC 2160/2003 on control of Salmonella and other specified foodborne zoonotic agents; Directive 2003/99/EC on the monitoring of zoonoses and zoonotic agents; Council Regulation 315/93/EEC laying down Community procedures for contaminants in food; Regulation EC 396/2005 on the Established maximum residue levels for pesticides in food.

Food spoilage is not mentioned in any of the above legislation documents. According to Blackburn (2006[110]), in the eyes of the consumer and the law there is no clear distinction between spoilage and safety. This is illustrated by Regulation EC 178/2002 on the General principles and requirements of food law: food is unsafe when it is considered to be (a) injurious to health, and (b) unfit for human consumption by contamination, through putrefaction, deterioration or decay.

6.3.1.2 Food spoilage meat, fish and dairy

The previous section discussed food safety aspects, i.e. possible health hazards. Food spoilage, discussed here, deals with the sensory perception (smell, colour, texture, shape) making food unfit or undesirable for human consumption.

Storage conditions of foods also greatly affects food spoilage mechanisms. Although many physical, chemical or microbial mechanisms can cause food spoilage, it is the growth of spoilage microorganisms that most often determines the shelf life of food (Blackburn, 2006[110]). Similar to pathogenic microorganisms the growth of spoilage microorganisms is determined by many intrinsic and extrinsic factors in combination with dynamic microbial interaction (see section 'Factors affecting microbial growth' earlier). A study by EFSA (2016[123]) suggests that spoilage bacteria grow more rapidly on meat carcasses compared to pathogenic bacteria. The spoilage bacteria therefore are more likely to limit the shelf life of meat making it unfit for human consumption. Overall, in today's situation food spoilage agents become more important to control with changing consumers expectations to more fresh or less processed products of high quality with year-round availability and competitive pricing (Blackburn, 2006[110]).

[123] EFSA, 2016, Growth of spoilage bacteria during storage and transport of meat, EFSA Journal 14(6): 4523, Parma, Italy

As mentioned before most spoilage microorganisms are not pathogenic. However, there is a grey area in between food safety and food spoilage (see Table 15). Some spoilage microorganisms may be beneficial in the production process of certain animal products, e.g. lactic acid bacteria in yoghurt or cheeses. Other spoilage microorganisms may produce harmful toxins. The technical university of Denmark has developed a predictive modelling software that combines both food spoilage and food safety issues called the Food Spoilage and Safety Predictor (FSSP).

Food products may be grouped in accordance to their sensitivity to spoilage. Perishable foods have a short shelf life and should be consumed within several days to several weeks, these include meat, fish, milk, eggs, fresh fruits and vegetables. Semi perishable foods have a longer shelf life and remain unspoiled for several months when stored properly, these include flour, dried fruits and several grain products. Non-perishable foods (staple foods) do not spoil unless improperly handled and include sugar, spices, canned food and dried beans. However, non-perishable foods may lose quality over time.

Meat spoilage
Common spoilage consequences for meat products are a brown discolouration and a production of slime, off-odours and off-flavours. Meat browning appears due to oxidation and happens with prolonged exposure to air. Pigments in meat giving it the red colour change in time and brown pigments become more prevalent. As the meat ages, enzymes that maintain the red colour become less active and discolouration occurs faster. Next to oxidation and enzyme reactions, meat spoilage is often caused by microorganisms. Microorganisms break down fats, protein and carbohydrates and produce off-odours, off-flavours and slime. Off-odours are produced by, for example, Pseudomonas bacteria who produce the volatile compound sulphydryl causing an unpleasant smell (Gram et al., 2002[124]). In general, off-odours are detectable to consumers when the bacterial count reaches between 10^7-10^9 CFU/g. Lactic acid bacteria (LAB) are responsible for ropy slime production on vacuum and modified atmosphere packed cooked meat products. This slime formation occasionally happens before passing the use-by date (Iulietto et al., 2014[125]). Next to slime formation, LAB are also responsible for the formation of off-flavours, discolouration and gas formation.

Fish spoilage
There are three basic mechanisms relevant in fish spoilage, these include enzymatic activity, oxidation and microbiological growth. Digestive enzymes naturally present in the fish cause autolysis, or 'self-digestion', resulting in meat softening and loss of blood water containing proteins and fats. This degradation can be slow down through cold storage. Lipid oxidation is another mechanisms with a major contribution to fish spoilage. Under influence of oxygen, lipids are split and form free fatty acids which are responsible for off-flavours known as rancidity. Fatty fish species like herring or mackerel are especially sensitive for lipid oxidation. Microbiological growth and metabolism of bacteria, like Pseudomonas and Shewanella in chilled fish, are a major cause in fish spoilage. These bacteria produce various compounds that create ammonia-like off-flavours and fishy off-odours (Ghaly et al., 2010[126]; Gram et al., 2002[124]).

Dairy spoilage
The two main mechanisms of dairy spoilage are lipid oxidation and microbiological growth and metabolism. Hard cheeses generally get spoiled due to mould growth because low water activity levels do not support bacterial growth. The most common type of mould is Penicillium. Certain Penicillium species (e.g. P. roqueforti) are used for cheese ripening

[124] Gram, L., Ravn, L., Rasch, M., Bruhn, J.B., Christensen, A.B. and Givskov, M., 2002, Food Spoilage – Interactions between food spoilage bacteria, International Journal of Food Microbiology 78(1-2): 79-97
[125] Iulietto, M.F., Sechi, P., Borgogni, E. and Cenci-Goga, B.T., 2015, Meat Spoilage: A critical review of a neglected alteration due to ropy slime producing bacteria, Italian Journal of Animal Science 14(3): 4011
[126] Ghaly, A.E., Dave, D., Budge, S. and Brooks, M.S., 2010, Fish spoilage mechanisms and preservation techniques: review, American Journal of Applied Sciences 7(7): 859-877

and give the cheese a blue veined colour (Roquefort, Stilton, Gorgonzola). Creams and soft cheeses on the other hand are more susceptible to yeasts and bacterial growth (M. Brown, Chilled foods: a comprehensive guide). Yeasts are also play a large role on spoilage of yoghurt and fermented milk products.

Psychrotrophic (cold loving) bacteria are a major factor in spoilage of milk and other dairy products (Ledenbach, 2009, Microbiological spoilage of dairy products). It causes a change in flavour, coagulation of milk proteins, increased free fatty acids causing off-odours and a change in texture (Samarzija et al 2012, Psychrotrophic bacteria and milk quality). The well-known sour flavour of spoiled pasteurized milk is caused by growth of Pseudomonas bacteria (Deeth et al. 2001, Spoilage patterns of skim and whole milks).

Spoilage of table eggs is mainly due to bacterial activity from Alcaligenes, Pseudomonas, Escherichia, Proteus species (Shebuski and Freier, 2009[127]). These spoilage bacteria may cause eggs to rotten and change in colour, odour and viscosity, e.g. green, blue, pink, black, red or colourless rots, and fruity or putrid odours. Occurrence of egg spoilage depends on the level of contamination of the egg shell and the ability of the spoilage bacteria to penetrate the egg shell. Elevated storage temperatures increases the risk of bacterial penetration.

Bacterial spoilage is often not the reason why consumers throw eggs away. More common reasons are the passing of the ‘best-before’ date, the loss of freshness, or a combination of both. The EC Egg Marketing Standards regulation determines a maximum ‘best-before’ date of 28 days from the date of lay. Additionally, eggs must be delivered to the consumer within 21 days after lay, resulting in a minimum consumer storage time of 7 days. The freshness of eggs is determined by physicochemical characteristics, for example the increasing volume of the air chamber due to egg weight loss. In time, the albumen (egg white) loses water vapour and CO_2 through the pores of the shell. The rate of weight loss is temperature and humidity dependant. After 28 days of storage at 5 °C and 80-85% RH the egg lost around 3% of its weight. This percentage is around 3-4 times higher when stored at 22 °C with the same RH-percentage. Similarly, relatively dry environments will increase the rate of weight loss. Increased volume of the air chamber increases the risk of bacterial penetration because the inner shell membrane may break. Finally, a combination of atmospheric temperature, RH and egg shell temperature affects condensation on the shell, increasing the risk of bacterial penetration. A disruption in the cold chain for example may cause condensation on egg shells (EFSA, 2014[128]).

[127] Shebuski, J.R. and Freier, T.A., 2009, Chapter Microbiological spoilage of eggs and egg products, in Compendium of the microbiological spoilage of foods and beverages by W.H. Sperber and M.P. Doyle (eds), Springer Science + Business Media, pp 121-134
[128] EFSA, 2014, Scientific opinion on the public health risks of table eggs due to deterioration and development of pathogens, EFSA Journal 12(7): 3782, Parma, Italy

Table 15. Potential food-related hazards and their consequences for consumers (based on Blackburn, 2006)

	physical	**chemical**	**microbial**
physical *spoilage*	Moisture loss, Damage to secondary packaging Fridge/freezer injury and recrystallisation	Chemical changes leading to physical changes (e.g. increased viscosity, sedimentation, colour change)	Swelling of containers due to gas production by spoilage microbes
"grey area"	Moisture gain in dried foods Damage to primary packaging		Pack damage leading to recontamination
safety	Physical hazards (e.g. metal, glass, plastics)	Explosion of (glass) containers due to gas production from chemical	Explosion of (glass) containers due to gas production by spoilage microbes
chemical *spoilage*		Enzymatic and non-enzymatic reactions (oxidation, lipolysis, browning) and chemical reaction resulting in formation of off-odours, chemical residues (e.g. pesticides, veterinary drugs)	Exogenous microbial enzymes
"grey area"		Long-term exposure to chemical residues	Moulds and mycotoxins Biogenic amines from microbial spoilage
safety		Natural toxins (e.g. scombrotoxin) Food allergens	Toxigenic microorganisms and microbial toxins
microbial *spoilage*			Growth/metabolism of spoilage microorganisms causing organoleptic changes (slime, off-odours, off-flavours, gas, textural changes etc) Psychosomatic reaction after consuming spoilt food
"grey area"			Opportunist pathogens Metabiosis
safety			Infectious and toxicoinfectious pathogens

6.3.2 Fruit and vegetables

Fruits and vegetables are highly perishable products sensitive to a wide range of spoilage mechanisms. Correct storage is therefore necessary to prevent food spoilage and minimize food safety risks. Next to these, the ripening and respiration mechanisms of fruits and vegetables play a large role in storage optimization.

6.3.2.1 Ripening and respiration fruit and vegetables

Fruits and vegetables are living organisms and continue to respire during postharvest life to maintain their internal processes (FAO, 1989[129]). During respiration, the fruit or vegetable loses moisture and stored reserves (starch or sugars). This affects flavour and increases deterioration. The respiration rate can be slowed down by storing fruits and vegetables at lower temperatures. However, in some cases this is not be beneficial for the quality of fruit and vegetables as it affects ripening, loss of flavour and breaks down cell structure in chilling sensitive products.

Fruit ripening processes include a sugar accumulation due to changes in carbohydrate composition, change in colour, flesh softening, aroma production and change in texture. Some of these ripening processes are regulated by the plant hormone ethylene, a gas produced by many types of fruits. The amount of ethylene production varies per fruit variety and depends on the ripening stage of the fruit, the respiration rate and the ambient temperature. Unripe kiwifruit for example produces 0.1-0.5 µl/kg·h ethylene at 20 °C. At the same temperature, ripe kiwifruit produces 50-100 µl/kg·h ethylene (UC Davis, 1996[130]). Peaches stored at 0 °C produce a maximum of 5 µl/kg·h ethylene, when stored at 20 °C ethylene production increases up to 160 µl/kg·h for ripe peaches.

Traditionally, fruits are classified in two types of behaviour related to ethylene production and respiratory pattern. Climacteric fruits can ripen off the tree or plant and show a sharp increase in respiratory rate and ethylene production towards ripening. The sharp increase in ethylene production may take place before or after the respiratory peak. The respiratory rate and levels of produced ethylene vary between fruit varieties. Examples of climacteric fruits are apples, pears and bananas. Non-climacteric fruits ripen while attached to the tree or plant and do not show sharp changes in respiratory rate or ethylene production (Brummell et al., 2010[131]). Non-climacteric fruits include citrus fruits, strawberries and grapes. Recent studies have shown that this classification is less evident than previously reported, with fruits like melons or peppers showing both climacteric and non-climacteric characteristics (Paul et al., 2012[132]).

The amount of ethylene gases emitted by a fruit affect other 'ethylene sensitive' fruits and vegetables. For example, it may initiate the ripening process of other fruits or cause leaf yellowing in vegetables such as broccoli or lettuce. A German insurance company for example advises transport companies not to stow ethylene sensitive fruits or vegetables together with ripe fruits as the whole cargo may enter into climacteric stage or cause leaf yellowing. Very low concentrations of around 0.02% ethylene in air may accelerate ripening by 4 to 10 times (TIS GDV, 2016[133]). Ethylene is also being produced commercially and used in many industrial processes, amongst others to accelerate postharvest ripening of banana, avocado or kiwifruit (Brummell et al., 2010[131]).

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[129] FAO, 1989, Prevention of post-harvest food losses: fruits, vegetables and root crops: a training manual, the Food and Agriculture Organization of the United Nations, Rome

[130] UC Davis, 1996, Produce Fact Sheets: kiwifruit, Postharvest technology, Division of Agriculture and Natural Resources, University of California, http://postharvest.ucdavis.edu/Commodity_Resources/Fact_Sheets/ Accessed November 2016

[131] Brummell, D.A. (ed.), Atkinson, R.G., Burdon, J.N., Patterson, K.J. and Schaffer, R.J., 2010, Chapter 11 Fruit growth, ripening and post-harvest physiology in: Plants in Action edition 2, Australian Society of Plant Scientists, New Zealand Society of Plant Biologists, and New Zealand Institute of Agricultural and Horticultural Science 2010-2016. http://plantsinaction.science.uq.edu.au/content/about

[132] Paul, V., Pandey, R. and Srivastava, G.C., 2012, The fading distinctions between classical patterns of ripening in climacteric and non-climacteric fruit and the ubiquity of ethylene – An overview, Journal of Food Science and Technology 49(1): 1-21

[133] Transport Information Service (TIS), 2002-2016, Cargo loss prevention information from German Marine insurers, GDV Die Deutschen Versicherer, http://www.tis-gdv.de/tis_e/ware/inhaltx.htm#6 Accessed October 2016

6.3.2.2 *Food spoilage fruit and vegetables*

Various forms of fruit and vegetable spoilage include loss of moisture (drying-out), chilling injury, mechanical damage or microbiological growth. A product may dry-out due to a low relative humidity or excessive ventilation. Chilling injury occurs in chilling-sensitive fruits and vegetables when storage temperatures are too low. The product's tissue starts to weaken and causes cellular dysfunction leading to discoloration, surface pitting, water-soaked appearance, loss of flavour or failure to ripen (Wang, 1989[134]). Chilling sensitive products include tropical and subtropical fruits and vegetables like tomatoes, pineapples, mango's and eggplants. Bruises or cuts due to incorrect handling affect the appearance of food products. In case of fruit and vegetables cuts damage the skin layer that protects the plant from invasion of microorganisms (Batt and Tortorello, 2014[135]).

Moulds, yeasts and bacteria are of specific importance in spoilage of fruits and vegetables. The bacterium Erwinia carotovora for example causes soft rot in vegetables (Rawat, 2015[117]). Spoilage fungi like Botrytis cause rot in strawberries and grapes and Penicillium cause blue mould on oranges and tomatoes. Bacteria are of less importance in the spoilage of fruits due to a relatively low pH (Harmayani, 2007[136]). Ripening causes the pH of fruits to increase and protective skin layers to soften, enhancing bacterial and fungal susceptibility (Batt and Tortorello, 2014[135]).

Overall, a lowest safe storage temperature is recommended to reduce microbial growth and respiration rate, but without hampering ripening processes or causing chilling injury. A change in optimal storage temperature is preferred regarding the ripening stage of fruits. Depending on the planned time of consumption, unripe fruit should be stored in a colder or warmer environment. Ripe fruit is best stored at the lowest safe temperature combined with high relative humidity. The latter is important to prevent drying-out causing spoilage characteristics such as a wrinkly skin or loss of vitamins.

Impact on nutritional value

Fruit and vegetables form an important source of vitamins and minerals in the human diet. Suboptimal storage conditions may lead to a substantial loss of vitamins. Especially loss of vitamin C has been broadly researched. Vitamin C losses mainly occur in two ways. First, because vitamin C is water soluble, moisture loss in a fruit or vegetable includes loss of vitamin C. Second, a combination of heat, light and oxygen breaks down vitamin C (Lee and Kader, 2000[137]; Netherlands Nutrition Centre, 2016[107]).

In general, vitamin loss is a natural process related to the storage time and cannot be stopped even in optimal storage conditions. However, studies have shown the rate of vitamin loss is much higher at room temperature than stored in the refrigerator or freezer. Spinach, for example, loses up to 27% of folate (a vitamin B) in 10 hours when stored at room temperature compared to 26% loss over 7 days when stored at 4 degrees (Pandrangi and LaBorde, 2004[138]).

Several consumer advisory bodies recommend blanching and then freezing vegetables to limit most vitamin loss (safefood.eu; Netherlands Nutrition Centre). This is however a time consuming practice to which many consumers might not want to dedicate part of their time. Short storage times up to max five days for fresh fruits and vegetables are

[134] Wang, C.Y., 1989, Chilling injury of fruits and vegetables, Food Reviews International 5(2): 209-236
[135] Batt, C.A., and Tortorello, M.L., 2014, Chapter Spoilage Problems in: Encyclopedia of Food Microbiology second edition, Academic Press, p. 465-481
[136] Harmayani, E., 2007, Microbial Food Spoilage, powerpoint presentation, slides: 38
[137] Lee, S.K and Kader, A.A., 2000, Preharvest and postharvest factors influencing vitamin C content of horticultural crops, Journal of Postharvest Biology and Technology 20: 207-220
[138] Pandrangi, S. and LaBorde, L.F., 2004, Retention of folate, carotenoids, and other quality characteristics in commercially packaged fresh spinach, Journal of Food Science 69(9): C702-C707

recommended to maintain all nutrients before consumption. Peeled and cut fruits and vegetables an increased level of vitamin C loss was monitored.

6.3.2.3 Food safety aspects fruit and vegetables

Food safety risks also play a role in fruit and vegetable storage, but are less relevant as in meat, fish and dairy products. Pathogenic microorganisms that have been found in fresh produce are for example Salmonella, E. coli, Campylobacter, Listeria and the norovirus (FAO, 2009[139]). Due to a relatively low pH, bacterial growth is of less importance in fruits (Harmayani, 2007[136]). Therefore, risks of infection with pathogenic bacteria due to consumption of fruits is less common. These risks increase with increasing pH due to ripening activities.

Table 14 shows the occurrence of foodborne illnesses due to viruses has increased in the last years. Fruits and vegetables may for example be contaminated in the field and transmit infectious particles of the norovirus to humans. Correct storage cannot reduce the change of infection but may prevent transmission of infectious particles to other foodstuffs in the refrigerator. Food preparation practices like careful washing of fruits and vegetables before consumption is often recommended to prevent norovirus infection.

6.3.3 Bread and pastry's

Bread is another perishable product of which quality quickly degrades if not stored properly. There is quite some variation in the storage practices of consumers. Some store bread at room temperature, others store it in the freezer compartment. Two main ways of spoilage are considered in this paragraph: spoilage due to microbial growth and spoilage due to bread staling. Naturally, a wide range of factors are involved in bread spoilage but to keep things clear only the major ones are mentioned below.

Moulds and yeasts growth are often spotted on spoiled bread. Common moulds are Penicillium and Aspergillus, a common spoilage yeast is Saccharomycopsis fibuligera. Consumption of these moulds and yeasts can be harmful to health as mycotoxins or other fungal poisons might be present in the bread. Bacteria are less of a factor due to their need for a high moisture content.

Contamination with moulds or yeasts commonly take place after the baking process. The high temperatures during baking eradicate all microorganisms, although heat-resistant spores might survive the heat. Also, microorganisms might survive when temperatures in the bread centre reaches no higher than 100 degrees. In practice, unsanitary cooling and packing rooms and machines are considered the main contamination route. Spores and microorganisms are commonly present in the air and contaminate the crust of the bread. Spreading only appears during cutting and packing as the crust is not suited for microbiological growth (Haegens, 2013b[140]).

Bread staling is probably the most common form of spoilage in bread. Staling characteristics include an increase of firmness and crumbliness of the crumb, a loss of crust crispiness and a deterioration in flavour. It is often mistaken for 'drying out' but it is actually a biochemical process. Changes in starch is considered the major factor in staling and include changes in crystallinity and the amount of soluble starch. Wheat flour, being the main ingredient of most breads, contains around 70-75% starch. Therefore, most breads are staling sensitive. The storage temperature plays a large role in the speed of staling. For temperatures between 21 and 2 °C the rule applies that the lower the temperature, the more rapidly staling occurs. For temperatures below 2 °C: the lower

[139] FAO, 2009, Horticultural chain management for countries of Asia and the Pacific region: a training package, by S. Kanlayanarat, R. Rolle and A. Acedo Jr, the Food and Agriculture Organization of the United Nations, Rome

[140] Haegens, N., 2013b, Chapter 3.5 The microbiological shelf life of bread in: Bread and the technology of bread production, http://www.classofoods.com/ukindex.html Accessed December 2016

the temperature, the slower staling happens. At -18 degrees staling is almost no factor in bread spoilage (Haegens, 2013a[141]).

Overall, various sources recommend a storage at room temperature for 2-7 days, or when longer storage is preferred, 2-3 months in the freezer compartment. Storage in the refrigerator is discouraged due to an increase rate of staling and loss of flavour. Pastry's containing egg or milk products however should be stored in the refrigerator for a maximum of 3 days.

[141] Haegens, N., 2013a, Chapter 3.3 Staling of bread in: Bread and the technology of bread production, http://www.classofoods.com/ukindex.html Accessed December 2016

6.4 Data analysis

Apart from literature on food safety and food spoilage, various sources on optimal storage conditions were analysed, amongst which sources describing storage conditions in various stages of the food supply chain, agricultural long-term storage recommendations, storage conditions recommended for fresh food cargo handlers, wholesalers and retailers, and consumer storage recommendations.

Obviously, shelf-lives at homes, restaurants and other food services of fresh products are limited. They strongly depend on packaging techniques, on the overall time food products remain in the supply chain including the way they are stored, and finally on the way the food products are stored in homes, restaurants and other food services. The better the packing techniques and storing conditions and the shorter the time spent in the food supply chain, the longer the shelf-life that remains for the professional and home consumers. Prolonged shelf-lives will result in a reduction of food waste due to spoilage and not-used-in-time.

This paragraph only assesses the potential impact of optimal temperature and humidity conditions on the shelf-lives of fresh products at the professional and home consumer.

6.4.1 Optimal storage conditions

Table 15 on expected shelf-lives and related storage conditions (see next page) was compiled on the basis of this analyses. Horizontally the various storage temperature ranges that were found in literature are mentioned, together with a column indicating other relevant controlled atmosphere conditions. Vertically the relevant products groups are listed. Note that the shelf-lives mentioned here, are based on good quality raw material and handled by good commercial practices. It should be noted that storage recommendations for consumers are not always the same and may differ depending on the advisory body. Some advisory bodies have storage guidelines for opened products and products without an expiry date (assuming correct storage conditions before arriving in the home). Other advisory bodies provide general recommended storage times from date of purchase for food products when properly stored under the indicated conditions. Storage recommendations for cargo handlers, wholesalers and retailers show lesser variations, except for the topic 'lowest safe chilling temperature'. Here the recommendations may differ.

The table below is compiled on the basis of a common denominator of the various sources, including:

- Cargo handbook, BMT Surveys Rotterdam BV (www.cargohandbook.com)
- Transport Information Service, Fachinformationen der Deutschen Transport Versicherer
- Hamburg-Süd Reefer Guide,
- University of California, Divisions of Agriculture and Natural Resources, Postharvest Technology, Produce Fact Sheet
- World Food Logistics Organisation, WFLO Commodity Storage Manual, 2010
- Storage guide for consumers, Netherlands Nutrition Centre
- Food Storage Guidelines For Consumers, Food Science and Technology, Virginia Tech
- Richtige Lagerung von Obst und Gemüse, 2016, Zentrum der Gesundheit, Neosmart Consulting AG, Switzerland
- FAO, 2009, Horticultural Chain Management for countries of Asia and the Pacific region

See also Appendices 4 and 5 for the Optimal temperature and relative humidity conditions for Fruits and Vegetables according to various sources. See Annex V concerning Ethylene production and Ethylene sensitivity of fruits and vegetables according to various sources.

Table 16. Expected shelf life of food products after purchase-date
when stored under the specified conditions (indicated in non-italic fonts), and expected storage periods of food products after production or harvest when stored under the specified conditions (indicated in *italic green* fonts)

Temp. range in °C	< -18°	-2.2 to -1.2°	-1 to +1°	0 to 1°	1 to 4°	5 to 10°	10 to 15°	15 to 20°	Other
Expected shelf life	months	days	days	days	days	days	days	days	
Meats									*RH 80-85%*
Raw meat									
Bone-in or boneless, sectioned and formed	6-12	*20-30*			3-5				
Restructured		*20-30*	*20-30*		3-5				
Minced or ground	3-6	*7-15*			1-2				
Pre-cooked meat									
Un-cured	6-12	*60*			2-3				
Cured	6-12	*90-180*	*90*		3-5				
Fish									*RH 90-100%*
Raw lean fish	6				1-2				
Raw fat fish	2-3				1-2				
Smoked fish	1-2				2				
Shrimp	3		*in ice: 3*		1				
Clams, crab, lobster, scallops	3		*3-5*		1				*RH 85-90%*
Oysters					*10-14*				
Dairy products									
Fresh Milk					7-20				
- after opening packaging					3				
Yoghurt, quark	1				14				
- after opening packaging					4				
Cream					3-4				
Butter	6			*30*	30				*RH 70-75%*
Margarine	6-12				90				*RH 40-70%*
Soft cheese (depending on variety)	6			*60-90*	7				*RH: 65%*

Temp. range in °C	< -18°	-2.2 to -1.2°	-1 to +1°	0 to 1°	1 to 4°	5 to 10°	10 to 15°	15 to 20°	Other
Expected shelf life	months	days	days	days	days	days	days	days	
Hard cheese (depending on variety)	6			*90-180*	60-120				*RH: 65-80%*
Eggs									
Eggs in shell	24	*150-180*[1]			21-35	*14-21*[2]			[1)] *RH 85-92%* [2)] *RH 70-80%*
Eggs, hard boiled					7				
Egg yolks covered in water	12				2-4				
Egg whites	12				2-4				
Fruit									
Apples			*60-90*		30			ripening	*RH 90-95%; ethyl. producing & -sensitive; climacteric*
Apricots	12		*7-14*		5			ripening	*RH 90-95%; ethyl. producing & -sensitive; climacteric*
Avocados					5	*28-56*	*14-28*	ripening	*RH 85-90%; ethyl. producing & -sensitive; climacteric*
Bananas, mature green					5		*28*	ripening	*RH 90-95%; ethyl. producing & -sensitive; climacteric*
Berries, Goose- and Currants	12		*7-21*		3				*RH 90-95%;*
Berries, Black- and Raspberries	12		*2-5*		2				*RH 90-95%; ethyl. producing & -sensitive; climacteric*
Cherries			*14*		3				*RH 90-95% low ethyl. sensitive*
Grapes			*60-180*		*60* 7			3-4	*RH 90-95%; low ethyl. sensitive*
Grapefruit					7-14		*42-70*		*RH 85-90%; moderate ethyl. sensitive*
Kiwifruit			*90-180*		7-21			3-7	*RH 90-95%; ethyl. producing & -sensitive; climacteric*
Lemons					7-14	*14-21*			*RH 85-95%; moderate ethyl. sensitive*
Lime					7-14	*42-56*			*RH 85-95%; moderate ethyl. sensitive*
Mangos							*14-21*	ripening	*RH 90-95%; ethyl. producing & -sensitive; climacteric*
Melons (storage time also depends on type)					5	*7-21*			*RH 90-95%; ethyl. producing & -sensitive; climacteric*
Canteloupes					*14-21*	*14-21*			*RH 90-95% ethyl. producing & -sensitive; climacteric*
Watermelons					2-5		*14-21*	1-7 *14-21*	*RH 90-95%; chilling injury <10°C; high ethyl. sensitive*

Nectarines				*28-42*	5				*RH 90-95%; ethyl. producing & -sensitive; climacteric*
Oranges (storage time & temp depends on type)					7-14	*21-42*			*RH 85-90%; moderate ethyl. sensitive*
Peaches (storage time also depends on type)				*14-42*	5			ripening	*RH 90-95%; ethyl. producing & -sensitive; climacteric*
Pears (storage time also depends on type)			*60-180*		5			ripening	*RH 90-95% ; ethyl. producing & -sensitive; climacteric*
Pineapples (storage time also depends on type)					5-7	*14-28*			*RH 85-95%; low ethyl. sensitive*
Strawberries	8-12		*3-8*	*1-7*	1-3			1	*RH 90-95%;*
Temp. range in °C	< -18°	-2.2 to -1.2°	-1 to +1°	0 to 1°	1 to 4°	5 to 10°	10 to 15°	15 to 20°	Other
Expected shelf life	months	days	days	days	days	days	days	days	
Vegetables									
Artichokes				*14-21*	*10*	*5*			*RH 90-95%; low ethyl. sensitive*
Asparagus				*14-21*					*RH 95-99%; moderate ethyl. sensitive; CO_2 contr. atmosphere for max shelf life;*
Beans (Snap, Green and Was beans)	12				1-2	*8-12*			*RH 95-100%; moderate ethyl. sensitive*
Beets, topped	12			*120-180*	14				*RH 98-100%; low ethyl. sensitive*
Beets, bunched	12			*10-14*					
Broccoli	10-15			*14-21*	3-5				*RH 98-100%; high ethyl. sensitive*
Brussels Sprouts	10			*21-35*	3-5				*RH 90-95%; high ethyl. sensitive*
Cabbage, early crop	12-48			*21-42*	7				*RH 98-100%; high ethyl. sensitive*
Cabbage, Chinese	12-48			*60-90*	7				*RH 98-100%; high ethyl. sensitive*
Carrots, mature topped	12			*150-270*	14				*RH 98-100%; low ethyl. sensitive*
Carrots, immature topped	12			*28-42*	14				*RH 98-100%; low ethyl. sensitive*
Carrots, bunched	12			*8-12*	3-5				*RH 95-98%; low ethyl. sensitive*
Cauliflower	12			*14-28*	7				*RH 98-100%; high ethyl. sensitive*
Celery				*30-90*	7				*RH 98-100%; moderate ethyl. sensitive*
Chicory				*14-28*	7				*RH95-100%; high ethyl. sensitive*
Cucumbers					7		*10-14*		*RH 95% ; high ethyl. sensitive*
Eggplant							*7-14*		*RH 90-95%; low ethyl. sensitive*
Endive and escarole				*14-21*	7				*RH 90-95%; moderate ethyl. sensitive*

	Green onions				*30*					*RH 95-100%*
	Kohlrabi with leaves				*14-28*					*RH 90-95%*
	Kohlrabi without leaves				*30-60*					*RH 90-95%*
	Leeks, Green				*60-90*					*RH 90-95%; moderate ethyl. sensitive*
	Lettuce (storage time also depends on lettuce type)				*10-21*	7				*RH 95-100%; high ethyl. sensitive*
	Mushrooms	3			*3-5*	2				*RH 87-92%; moderate ethyl. sensitive*
	Onions (storage time also depends on type)	12			*60-180*	3-5				*RH 65-70%; low ethyl. sensitive*
	Peppers, Bell	12				7	*7-14*			*RH 90-95%, with ventilation; low ethyl. sensitive*
	Potatoes (storage time also depends on type)	12					*30-300*		30-90	*RH 90-95%; moderate ethyl. sensitive*
	Tomatoes (storage time depends on initial ripeness						*Ripe 3-5*	*Pink 7-10*	ripening	*RH 85-90%; ethyl. producing & -sensitive; climacteric*

	Temp. range in °C	< -18°	-2.2 to -1.2°	-1 to +1°	**0** to 1°	1 to 4°	5 to 10°	10 to 15°	15 to 20°	Other
	Expected shelf life	months	days	days	days	days	days	days	days	
Bread and pastry										
	Bread	2-3							2-7	
	Pastry (with milk or egg products)					1-3				

When analysing Table 25 the following remarks can be made for the various food product groups

Meat
The storage-periods of the various kinds of (non-frozen) meat can considerably be extended, when storage temperatures of -2.2 to -1.2 °C can be guaranteed. At these temperatures bacteria growth and deterioration of flavour and colour are minimised. Shelf lives of all kinds of meat can thus be increased from 1 to 3 days to 7 to 30 days, depending on the type of meat. This represents a shelf-live increase by a factor 6 to 7.
But also at temperatures around 0°C (-1 to +1°C) the storage periods of meat commodities can be increased. Exact figures of storage periods at these temperatures were not found, but may be somewhere in between.

Fish
For non-frozen fish products, no information was found that storage periods can considerably be extended at certain storage temperatures, other than freezing < -18°C. Generally, fish is stored in ice, both after catch and after processing. When the fish products are not frozen when purchased, it is best to keep them cold or in ice and eat them within 1 or 2 days at the most. Similar remarks as for meat products can be made here concerning bacteria growth and deterioration.

Dairy products
In this product group the storage periods of cheese can be extended when storage temperature of 0 to 1°C and RH of around 65% can be applied. Especially for soft cheeses, storage periods can be extended to 60 - 90 days (an increase by a factor 10 – 12).

The shelf-life of eggs in shell can considerably be extended when they are stored at temperatures between -2 and -1°C and at higher RH-values (up to 5 – 6 months).

Fruit
Various fruits may benefit from storage temperatures between -1 and 1°C and RH-values between 90-95%. Under these storage conditions shelf-lives may be extended by a factor 2 to 7 (from a couple of days to a couple of weeks) compared to the storage conditions of and average refrigerator (1-4°C). This applies for instance for apples, apricots, berries, cherries and pears. Other fruits like nectarines and peaches can comparably gain storage times when stored under temperatures between 0 and 1 (note: temperature not below 0!) and relative humidity values between 90-95%.

Fruits like lemons, limes, melons, oranges and pineapples have their longest storage times at temperatures between 5 and 10°C and RH- values of 85-95%. Soft fruits like avocados, bananas and mangos are best stored at temperatures between 10 - 15°C with again RH-values of 85-95%.

Ripening temperatures of most fruits are between 15 to 25 °C. When finally ripe, shelf life is limited to one or two days. Attention should be given to the fact that once fruit is ripe, it is also more susceptible to chilling injury when stored at too low temperatures.

In summary, depending on the ripeness of the fruits and the expected time to consumption, the proper storage temperatures can be selected. Humidity values will always have to be high to prevent dehydration. Generally, fruit is harvested when it is mature and not ripe

Special attention must be given to ethylene production and ethylene sensitivity of fruit.
Ethylene can speed up the ripening process, but it can also cause damage to ethylene sensitive fruit and vegetables. In the supply chain, various solutions are used to control

or remove ethylene gas from storage compartments, amongst which ethylene adsorbers (small sachets or tubes, filled with sodium permanganate pellets).

Vegetables

Roughly half of the vegetables[142] have their longest storage periods at storage temperatures between 0 and 1°C (Note: not below 0°C) and -apart from onions- at high RH-values (90-100%). These conditions apply to most cabbages, carrots, beets and leafy vegetables. As mentioned earlier, for longest shelf-lives also onions can best be stored between 0-1°C under relatively dry conditions (RH-values between 65-70%).

Fresh vegetables are living organisms that continue their life processes after harvest. Changes that occur in harvested food include water loss, conversion of starches to sugars and vice versa, flavour changes, colour changes, vitamin gain or loss, sprouting, rooting, softening and decay. To maintain the vegetables as fresh as possible these life-processes need to be slowed down without exterminating the living tissue which would result in gross deterioration and drastic differences in flavour, texture and appearance. This can best be achieved at cold storage (0 - 1°C) and high humidity values.

The other half of vegetables plus the potatoes are better off at somewhat higher storage temperatures: 5 - 10°C for vegetables like beans, bell peppers, potatoes and ripe tomatoes. At 10 - 15°C vegetables like cucumbers, eggplants and pink tomatoes have the longest storage time.

A lot of vegetables are ethylene sensitive and can therefore best not be stored together with ethylene producing fruits.

Bread and Pastry

Bread is best kept at storage conditions of -18 °C and a RH as high as possible (90-100%). With these conditions, bread may reach storage times of 2 to 3 months. When frozen storage is not desired, the best option is to store bread for 2-7 days at 18-20°C at a RH of 65-70%. This gives the lowest change on staling and drying-out. Storage at lower temperatures increases the staling rate and is therefore not advised. Prevention of condensation at 18-20°C is essential as warm and moist conditions favours mould growth. Storage in a paper bag can help preventing this.

Cakes, croissants and similar pastry products have longest storage periods when frozen (-18°C). They can be stored up to 2-4 months. The other option is to store pastries at around 4°C for a maximum of 3 days.

[142] See Chapter 4: 'Fruity vegetables' represent half the mass of vegetables (excl. potatoes) produced and the other leafy/brassica/root etc. vegetables represent the other half. On top of that, the potatoes represent a mass that is over half of that of the vegetable group

6.4.2 Forced fit extended fridge/freezer compartments

Based on the ideal storage conditions described in paragraph 2.4.1, the various food products will now be allocated to temperature compartments of an extended fridge/freezer combination, having the following 6 compartments (as opposed to the traditional fridge/freezer with 2 compartments):

Meat chiller	: -1 to 1°C
Salad chiller	: 1 to 2°C
Fresh compartment	: approximately 4°C
Wine storage	: approximately 12°C
Cellar	: 8 – 14°C
Pantry	: approximately 17°C

Table 17. Allocation of foodstuffs in the extended fridge/freezer combination.

	Meat chiller	Salad chiller	Fresh compart	Wine storage	Cellar	Pantry
	-1 to 1°C	1 to 2°C	4°C	12°C	8 to 14°C	17°C
Meat						
Raw meat	X					
Pre-cooked meat	X					
Fish	X					
Dairy products						
Fresh Milk			X			
Yoghurt			X			
Cream, butter & margarine			X			
Soft cheese (@ RH=65%)		X				
Hard cheese (@ RH=65%)		X				
Eggs	X					
Fruit						
Apples, apricots, berries, cherries, pears (@ RH 90-95%); *apples and pears are ethylene producing and -sensitive*	Max. shelf-life X				Min. shelf-life X	Ripening
Nectarines, peaches (@ RH 90-95%); *ethylene producing and -sensitive*		Max. shelf-life X			Min. shelf-life X	Ripening
Avocados, lemons, limes, melons, oranges, pineapples (@ RH 85-95%); Products are *ethylene prod.& sensitive*			when ripe X		Unripe X	Ripening
Mangos, Bananas (@ RH 85-95%), Products are *ethylene prod.& sensitive*				X	X	Ripening
Watermelons (@ RH 90-95%)						X

Vegetables							
	Asparagus, Beats broccoli, cabbage, carrots cauliflower, celery, chicory, (@ RH 95-100%); products are *ethylene sensitive*		X				
	Artichokes, Endives, green onions, kohlrabi, green leeks, lettuce (@ RH 90-95%); products are *ethylene sensitive*		X				
	Beans (@ RH 95-100%); products are moderately ethylene sensitive					X	
	Onions (@ RH 65-70%); products are moderately ethylene sensitive		X				
	Mushrooms (@ RH 65-70%); product moderate ethylene sensitive			X			
	Bell peppers (@ RH 95-100%, with ventilation)					X	ripening
	Potatoes (@ RH 90-95%); products are moderate e*thylene sensitive*					X	
	Tomatoes (@RH 85-90%; products are very e*thylene sensitive*				When ripe X	Green X	ripening
Bread and Pastry							
	Bread (@ RH 65-70%)						X
	Pastry			X			

6.4.3 Estimations on extension of shelf-life

The average traditional fridge/freezer combinations have a freezer compartment (-18 °C) and a main cooling compartment with maximum temperatures varying between 4 and 7°C. In the lower sections of this cooling compartment, temperatures can be a bit lower than in the upper segments. Vegetables and non- tropical fruit are generally kept is the lowest section of the cooling compartment, and raw meat and fish in the section right above. The upper section is for opened cans and soft drinks. The middle section is for pastry, soup, processed meat products and left overs. The upper sections of the refrigerator door are for butter and cheese, just below are the eggs, little tubes and cans. Lowest compartments in the refrigerator door is for big bottles, milk, yoghurt, etc. In short, the temperature differentiation is limited and range from 1-2 to (depending on the settings) 4 to 7 °C.

Combining this existing situation with the information given in table 15 and table 16, the following estimates on shelf-life extensions related to temperature storage can be made, *provided adequate solutions can be found for the requested RH-values and the ethylene problems*.

Table 18. Estimates on increased shelf-lives [in days] of food products
(It is assumed here that the food products were properly handled and stored in the supply chain until in-home storage

	Traditional (existing) fridge	Fridge with extended temp-compartments	According to optimal storage conditions
	days	*days*	*days*
Meat			
Raw meat	2	10-15	20-30
Pre-cooked/processed meat products	2-5	30 -60	60 - 180
Fish	1	3	3
Dairy products			
Milk, yoghurt, cream, butter	same	same	same
Soft cheese	7	30-40	60-90
Hard cheese	60	60-120	90-180
Eggs	21-35	60-100	150-180
Fruit			
Apples & pears	5-30	60-180	60-180
Apricots, berries, cerries	2-5	7-14	7-14
Nectarines, peaches	5	14-42	14-42
Avocados	5	14-28	28-56
Lemons, limes, oranges	7-14	14-28	14-42
Melons, pineapples	5	7-21	14-28
Grapefruit / mangos	7-14 / 2-5	14-21 / 7-14	42-70 / 14-21
Vegetables			
Bell pepper / beans	7 / 2	7 / 7	7-14 / 8-12
Cucumbers / chicory	7	7-10	10 - 14
Potatoes	30-90	30 - 150	30 - 300
All other vegetables	3-14	14-180	14 - 180
Bread (if not frozen)	_	2-7	2-7

In summary, compared to traditional fridges, the storage times of food products in a fridge with extended temperature compartments (*provided adequate solutions can be found for the requested RH-values and the ethylene problems)* can likely be prolonged significantly, as will be discussed in Chapter 8.

6.5 Conclusions

In this first explorative study, the effect of prolonged shelf-lives on the reduction of food waste can only be roughly estimated. The following line of reasoning is applied to enable a preliminary assessment of the reduction of food waste due to prolonged shelf-lives:

- Only food waste caused by timing problems (not-used-in-time) can benefit from prolonged storage times
- 47% of the total avoidable waste is considered waste because of "not-used-in-time" Of which (WRAP, 2013a, household food and drink waste in the UK 2012):
    - 12% fresh vegetables
    - 7% bakery products
    - 2% meals
    - 6% dairy and egg- products
    - 7% fresh fruit
    - 3% meat and fish
- These products were stored using a traditional refrigerator with one cooling compartment with a max temperature of 4 to 7°C, with shelf-lives corresponding to table 18
- The prolonged shelf-lives are inversely proportional to the multiplication factor of the shelf-lives. For example: a shelf-life that is 2 times longer results in half (1/2) the initial food waste; a shelf-life that is 3 times longer results in one-third (1/3) of the initial food waste.

Table 19. Estimates on food waste reduction due to extended shelf-lives.

Product group	Current Food waste, due to *not-used-in-time* [%]	Reduction factor due to extended shelf-lives [-]	Expected Food waste due to *not-used-in-time* down to [%]
Fresh vegetables	12%	2	6%
Cheese and eggs	3% (est.)	3	1%
Fresh fruit	7%	2	3.5%
Meat and fish	3%	3	1%
Bakery products	7%	1	7%
Total	32%		18.5%

In short, with optimal storage conditions the current food waste due to 'not-used-in-time', in Chapter 4 estimated at 23 Mt/year (EU 2011-2012) can be reduced to almost 60% (13 Mt). Furthermore, it can be expected that there will also be benefits for food waste from leftovers and food prepared or served too much (meals or ingredients not eaten when served) etc. The latter, in Task 1 assessed at a total of 29 Mt/year, is difficult to quantify without additional information, but assuming e.g. a quarter avoided food waste of that fraction some 7-8 Mt would be saved.

In total, the impact of better storage conditions could technically be in the range of 20 Mt/year. This requires not only an improved and properly used refrigeration appliance but also there are legal and other barriers to be expected to realising the full potential. This is the subject of Task 3 in the following chapter.

7 Analysis of Shelf Life in the Refrigerated Food Supply Chain [Task 3]

7.1 Introduction

The European Chilled Food Federation (ECFF) (2006) defines:

- **Chilled foods** as prepared foods that for reasons of safety and/or quality rely on storage at refrigeration temperatures throughout their entire life.
- **Shelf life** is the period of time for which a product remains safe and meets its quality specifications under expected storage and use conditions. The shelf life determines the durability date ('use by' for microbiological safety and stability or 'best before' for physical condition and organoleptic quality).

It must be noted that Article 17 of the General Food Law Regulation (EC) No 178/2002 stresses that it **always** remains the responsibility of the Food Business Operator (FBO) to assure the safety of its products.

The refrigerated food supply chain typically involves the following stages:

- food manufacturing and the transfer of chilled products into distribution;
- transportation of product to an intermediate or regional distribution centre for storage;
- distribution of refrigerated food to the retail store;
- retail display on the supermarket / store shelf; and,
- consumer transport of the refrigerated food home to the domestic fridge.

For the first four stages in this supply chain there are strict guidelines and National and European-wide legislation for such control factors as temperature, storage conditions and usage instructions. For example: in the UK, manufacturers' on-site storage and despatch of chilled prepared food is typically at ≤5°C, and often under 'deep chill'; in France, the chilled food manufacturing industry practice is reported to involve storage at ≤4°C (Institute of Food Research, IFR 2006).

At the retail stage, national legislation across the EU-28 Member States varies significantly in terms of the required retail temperatures. For example, for chilled cooked meat products, dairy desserts, fresh cut produce and soups/sauces, national legislation in France specifies a temperature of ≤4°C, in Belgium it is ≤7°C, and the UK ≤8°C.

The last stage is even less consistent and controlled since it is heavily reliant on consumer behaviour. For example, a French study in 2001/02 (Cemagref/Ania 2004) found that around 90% of yoghurts were kept at <6°C and 66% of meat products were kept at <4°C, and that the weakest link in the chain was the consumer (53% of yoghurts at<6°C, and 25% of meat products at <4°C).

WRAP (2013) reports that one of the largest contributors to the 4.4 million tonnes of avoidable household food waste thrown away each year in the UK is the perishable food that requires, or benefits from, refrigerated storage. The WRAP report states that temperature is the prime factor controlling bacterial growth on foods and hence optimal refrigeration temperatures can:

- minimise food safety risks;
- improve food quality; and,
- reduce waste of refrigerated food.

The IFR 2006 report made reference to the recommendations made in the EU SCOOP Report of 1996 stressing that, at the time of reporting (2006), they were still valid. They include:

- To clearly define the shelf life concept(s) and to agree common definitions at the EU level.
- That the European Commission should consider conducting a survey of food and air temperatures in retail cabinets in the Member States, to indicate the practicability of setting broad or product-specific temperatures across the EU.
- To monitor temperature fluctuations in the chilled food chain from production through to the point where the consumer selects the product.
- That the role that food labelling might have in ensuring that foods are held at the appropriate temperatures and with a satisfactory shelf life should be explored.
- That data relating to the microbial safety of foodstuffs should be collected and presented in a systematic and well-structured format, to aid the dissemination of important information to relevant authorities.

This report investigates two critical control points:

- consumer transport to home of the refrigerated food; and,
- storage in the domestic fridge.

7.2 Consumer transport to home of the refrigerated food

WRAP (2010) analysed the impact of three different scenarios shown in

Table 20. *Please note: The Cemagref/Ania (2004) study observed similar practices in France, with the average time of transportation after purchase of 58 minutes for dairy products, 75 minutes for delicatessen & charcuterie and 66 minutes for pre-packed meat.*

Table 20: Scenarios tested

Scenario	Description	Simulation
1	Storage at 4°C followed by two hours at 20°C before return to the fridge at 4°C.	These conditions could reflect retail display, time spent in a car / transport home during warmer months
2	Storage at 4°C followed by one hour at 20°C and one hour at 10°C before return to the fridge at 4°C.	These conditions reflect retail display, time spent in store, and time spent in a car / transport home during colder months (best case)
3	Storage at 4°C followed by one hour at 20°C and one hour at 30°C before return to the fridge at 4°C.	These conditions would reflect retail display, time spent in store and time spent in car / transport home during warmer months (worst case)

Table 21 shows the results of the WRAP Scenario test, highlighting the significant variations in product temperature that can arise, with many above the 8°C limit discussed above in the upstream supply chain.

Table 21: Food temperature results of the scenario testing using a standard bag

Food product	Temperature measurement	Scenario 1			Scenario 2			Scenario 3		
		A	B	C	A	B	C	A	B	C
Milk	At 2 hrs	12.3	11.9		7.1	7.2		10.7	9.8	
	At 5 hrs	5.7	5.7		5.2	5.2		10.1	9.5	
Lasagne	At 2 hrs	11.1	7.6	9.8	7.4	5.6	6.2	7.3	7.3	11.5
	At 5 hrs	5.5	5.5	5.1	5.2	5.4	4.9	8.3	8.1	7.8
Cream cake	At 2 hrs	11.0	12.7	16.4	9.5	7.6	9.6	11.4	8.3	13.4
	At 5 hrs	5.8	6.4	5.7	6.1	5.4	5.3	10.2	9.2	8.6
Margarine	At 2 hrs	10.7	12.2	13.5	7.6	6.7	7.9	9.3	7.6	11.2
	At 5 hrs	6.0	5.8	5.4	5.6	5.3	4.9	9.1	9.4	9.0
Lettuce	At 2 hrs	9.8	9.0		8.9	7.4		19.1	10.6	
	At 5 hrs	7.5	8.8		7.2	7.6		8.7	11.8	
Sliced ham	At 2 hrs	13.1	15.7		8.4	7.6		18.6	10.1	
	At 5 hrs	5.8	5.4		5.6	5.9		8.5	10.5	
Ambient (probe in bag)	At 2 hrs	13.1			10.7			20.8		
	At 5 hrs	5.4			5.2			6.0		

Key: A = Temperature at the centre of the product (reading 1), B = Temperature at the centre of the product (reading 2), C = Temperature at the edge of the product.

7.3 Storage in the domestic fridge

7.3.1 Fridge temperature

Figure 43 shows the results of a study undertaken on 50 domestic fridges in the UK. The study showed that the average temperature was 6.7°C, with 68% above the recommended maximum temperature of 5°C. The IFR 2006 report states that:

"A figure of 60-70% of domestic refrigerators operating at an average temperature >5°C appears to be relatively common to many studies throughout the world".

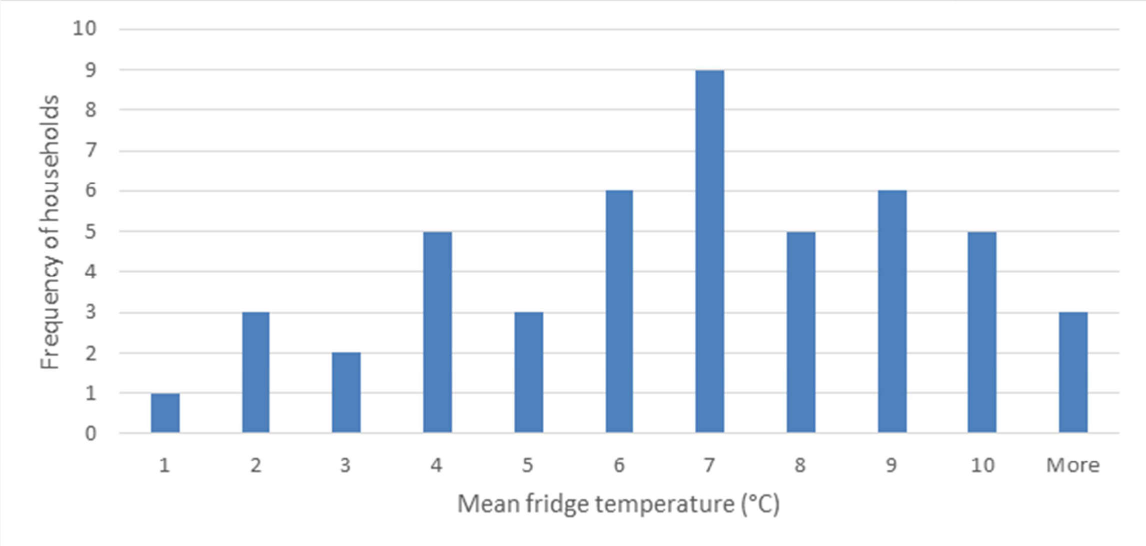


Figure 43: Frequency distribution of mean domestic fridge temperatures (50 fridges) Source: WRAP 2010

From a food safety perspective, Table 22 shows that 6 of the listed 11 micro-organisms have a minimum temperature of between 5°C and 12°C and hence could potentially grow in the fridges with temperatures above the recommended temperature of 5°C.

Table 22: Commonly accepted growth boundaries of pathogenic microorganisms

Microorganism and growth boundary	Minimum temperature (°C)	Commonly associated or implicated foods
Listeria monocytogenes	-0.4	Chilled, ready-to-eat food and long shelf life foods
Bacillus cereus	4	Cooked rice and spices
Campylobacter jejuni	32	Poultry, meat and milk
Clostridium botulinum mesophilic / proteolytic	10-12	Canned, vacuum packed, MAP, jarred
Clostridium botulinum psychrotrophic / non-proteolytic	3.3	Canned, vacuum packed, MAP, jarred
Clostridium perfringens	12	Cooked meat, cooked uncured meat, associated gravy and stocks, casseroles and pea soup
Escherichia coli	7-8	Meat, poultry, milk and vegetable products, sprouting seeds, fenugreek, mustard and rucola, drinking water, unpasteurised apple juice
Salmonella spp.	6	Eggs, poultry, meats, dairy and others, sprouting seeds
Staphylococcus aureus	5.2	Eggs, poultry, meats, dairy, confectionery and others
Vibrio parahaemolyticus	5	Fish and seafood products
Yersinia enterocolitica	-1.3	Fresh meats and milk

Source: Food Safety Authority of Ireland 2011 and ECFF 2006

From a food waste perspective, Table 18 shows the results of a WRAP (2013) study and the impact lowering the fridge temperature can have on storage life. This shows that the storage life can be extended by between 26% and 67% depending on the product.

Table 23: Calculated storage life extensions (days) due to lower fridge temperatures

Product	Days' storage life at 7°C	Days' storage life at 4°C	Difference	
			Days	% extension
Cod	5.1	7.8	2.7	53
Salmon	4.8	7.9	3.1	65
Chicken	5.8	8.7	2.9	50
Pork	4.8	8.0	3.2	67
Salad	7.0	10.4	3.4	49
Broccoli	8.9	11.3	2.4	26
Milk	8.0	11.9	3.9	49

Table 23 to estimate the overall savings potential from extending the shelf life of refrigerated products. Table 24 shows the estimated overall opportunity in the UK to be 71,000 tonnes, with leafy/salad vegetables and milk being the two most significant product categories, accounting for 79% of the total savings.

Table 24: Estimates of annual UK waste reduction due to extended shelf life

Product	Avoidable waste (tonnes)	'Not used in time' (tonnes)	Thrown away: 'going off' (%)	Thrown away: 'going off' (tonnes)	Storage life difference (%)	Potential saving realised (%)	Waste saved (tonnes)
Leafy / salad veg.	270 000	201 000	80	160 800	26.5	75	31 959
Milk	360 000	200 000	50	100 000	48.8	50	24 400
Fresh meat	200 000	130 000	20	26 000	58.3	50	7 579
Bagged salad	36 000	22 000	30	6 600	48.9	50	1 613
Fresh fish	9 600	7 200	20	1 440	58.8	25	212
Root vegetables	51 000	40 500	80	32 400	10	50	1 620
Fruit	99 150	91 300	80	73 040	10	50	3 652
Total	**1 025 750**	**692 000**		**400 280**			**71 035**

Table 25 provides a summary of the estimated value and CO_2e savings associated with the waste savings.

Please note: the WRAP (2013) study used the average emissions conversion factor of 3.8 tonnes of CO_2e per tonne of food produced and did not distinguish between the different food products. It would be envisaged that milk, fresh meat and fresh fish would have a much higher embodied CO_2e than the fruit and vegetable categories and hence the '% of total' column shown for 'estimated CO_2 savings' is inaccurate and only the total CO_2 savings should be considered robust.

Table 25: Value and embodied CO_2e emissions in annual UK waste savings

Product	Waste saved		Estimated value of waste saved			Estimated CO_2 savings		
	Tonnes	% of total	Cost per tonne (£)	(£m)	% of total	Emissions conversion factor (tCO_2/t)	tCO_2 savings	% of total
Leafy / salad veg.	31,959	45	2,590	82.8	51	3.8	121,444	45
Milk	24,400	34	620	15.1	9	3.8	92,720	34
Fresh meat	7,579	11	6,300	47.7	29	3.8	28,800	11
Bagged salad	1,613	2	3,930	6.3	4	3.8	6,129	2
Fresh fish	212	0.3	9,570	2.0	1	3.8	806	0.3
Root vegetables	1,620	2	1,154	1.9	1	3.8	6,156	2
Fruit	3,652	5	1,910	7.0	4	3.8	13,878	5
Total	**71,035**			**162.9**			**269,933**	

Balanced against the savings shown in Table 25 is the cost of the additional energy required to achieve the lower fridge temperature. The *WRAP - Impact of more effective use of fridge and freezer* study (June 2013) estimated this to be an annual cost of £71 million with associated emissions of 321,000 tonnes CO_2e. This therefore suggests that although a significant financial saving of £92 million per annum can be realised, this will come at the cost of an increase in CO_2e emissions of 51,000 tonnes. *Please note: for fridge–freezers with a single thermostat, reducing the temperature of the fridge will have a similar effect on the freezer with the result that the freezer operates at a below-optimum temperature and hence consumes more energy.*

Supporting the suggestion that 4°C is the optimum fridge temperature, the French Decree of 3 April 2002 on domestic fridges required, from 10 September 2002, domestic refrigerators on the French market to have:

- a storage compartment where an average temperature ≤+4°C can be maintained (this area to be identified by a visible, legible and indelible sign); and
- a device to indicate whether the temperature of that compartment is ≤+4°C, complying with certain provisions.

Wider afield, the US Department of Agriculture[143] takes a very risk-averse stance on refrigerator temperature, stating that refrigerators should be set to maintain a temperature of 40°F (4°C) or below and that foods held at temperatures above 40°F for more than 2 hours should not be consumed.

Further studies suggest that optimal temperatures vary with product category, which implies that lowering the temperature of the fridge may actually be detrimental to shelf life for certain food products. Table 26 shows the optimal storage temperatures for a selection of fruits and vegetables and shows a number that are well above 4°C.

[143] http://www.fsis.usda.gov/wps/portal/fsis/topics/food-safety-education/get-answers/food-safety-fact-sheets/safe-food-handling/refrigeration-and-food-safety/ct_index

Table 26: The optimal storage temperature for selected fruit and vegetables

Product	The Engineering ToolBox[144] (°C)	Frontline Services[145] (°C)
Bananas	13-16	13
Cabbage	0	0
Carrots	0	0
Cauliflower	0-2	0
Cucumbers	10-13	10
Eggplant (aubergine)	8-12	10
Grapefruit	13-16	13
Lemons	11-13	10
Lettuce	0	0
Mushrooms	0	0
Onions	0-2	0
Oranges	4-7	5
Potatoes	7-10	
Salad mixes	0-2	
Strawberries	0	0
Tomatoes	13-21	13

ISO 15502:2005 (later reissued as IEC 62552: 2007 and revised as EN 62552:2013) and *Commission Regulation (EC) No 643/2009* of 22 July 2009 implementing *Directive 2005/32/EC of the European Parliament and of the Council with regard to eco-design requirements for household refrigerating appliances* provide details and temperature specifications of the various types of compartments that can form part of domestic refrigerators (Table 27).

Please note: the specifications are identical for the EN 62552:2013 and the Commission Regulation. The IFR 2006 report states that:
"Compliance with these standards (at the time ISO 15502: 2005) would ensure better domestic temperature control of chilled foods, and contribute to microbiological food safety".

[144] http://www.engineeringtoolbox.com/fruits-vegetables-storage-conditions-d_710.html
[145] http://www.frontlineservices.com.au/Frontline_Services/Storage_temperatures_for_fresh_produce.html

Table 27: Domestic refrigeration, definitions of compartments, and storage temperatures

Compartment	Definition	Temperature °C	
		Range	Nominal
Fresh food	Designed for the storage of unfrozen foodstuffs, which may itself be divided into sub-compartments	0 to +8	+4
Cellar	Intended for the storage of particular foodstuffs or beverages at a temperature warmer than that of a fresh-food storage compartment	+8 to +14	+12
Chill	Intended specifically for the storage of highly perishable foodstuffs	-2 to +3	0
Other	A compartment, other than a wine compartment, intended for the storage of particular foodstuffs at a temperature warmer than +14°C	>14	+14
Wine	Exclusively designed either for short-term wine storage to bring wines to the ideal drinking temperature or for long-term wine storage to allow wine to mature.	+5 to +20	+12

7.4 Shelf life determination

The shelf life of a product is the period of time during which the product maintains its microbiological safety and quality. It is calculated using HACCP (Hazard Analysis and Critical Control Points). For food products, such as processed fruit and vegetables (not bagged leafed salads), a 'hazard' is the spoilage of the product which impacts on the quality of the food and food waste.

7.4.1 Legislation on shelf life

Article 9 (1) of *Directive 2000/13/EC* of the European Parliament and of the Council of 20 March 2000 (and Annex X of the *European Regulation (EU) No 1169/2011*) states that:

"Article 9 (1). The date of minimum durability of a foodstuff shall be the date until which the foodstuff retains its specific properties when properly stored.

Article 9 (1) (2). The date shall be preceded by the words:

- *'Best before …' when the date includes an indication of the day,*
- *'Best before end …' in other cases.*

Article 9 (1) (3). The words referred to in paragraph 2 shall be accompanied by:

- *either the date itself, or*
- *a reference to where the date is given on the labelling.*

If need be, these particulars shall be followed by a description of the storage conditions which must be observed if the product is to keep for the specified period.

Article 9 (1) (5). Subject to Community provisions imposing other types of date indication, an indication of the durability date shall not be required for:

- *fresh fruit and vegetables, including potatoes, which have not been peeled, cut or similarly treated. This derogation shall not apply to sprouting seeds and similar products such as legume sprouts."*

Please note: although some food products do not need a shelf life declaration, compliance with relevant food safety criteria is required under European Commission Regulation 2073/2005.

For products, such as meat and fish, a major hazard is the growth of pathogenic organisms which can result in food poisoning.

Article 10 of *Directive 2000/13/EC* of the European Parliament and of the Council of 20 March 2000 states that:

Article 10 (1) (and Article 24 (1) of the European Regulation (EU) No 1169/2011). In the case of foodstuffs which, from the microbiological point of view, are highly perishable and are therefore likely after a short period to constitute an immediate danger to human health, the date of minimum durability shall be replaced by the 'use by' date.

Article 10 (2) (and Annex X of the European Regulation (EU) No 1169/2011). These particulars shall be followed by a description of the storage conditions which must be observed.

7.4.2 Shelf life determination protocols

The ECFF (2006) reports that the determination of safe shelf life may involve the following:

- A review of relevant scientific information, e.g. characteristics of micro-organisms.
- Use of predictive modelling programmes, some of which are publicly available such as ComBase, USDA Pathogen Modelling Programme or Growth Predictor.
- Challenge testing with the relevant pathogens, where predictive modelling does not give sufficient confidence to set a safe shelf life on its own.
- Historical data for similar products.
- Storage trials.

Storage trials are also used in the determination of quality shelf life and involve a product being stored at one or more predetermined temperatures over a specific time-period, that take into account knowledge of the actual chill chain conditions.
The ECFF 2006 report states that:

"*the manufacturer must carefully consider a wide variety of factors and hurdles - including, raw material quality, hygienic processing, temperature, water activity, acidity, modified atmosphere - in determining ways to control microbiological growth and thus prevent spoilage and/or the development of conditions that can lead to food-borne illness. Via the choice and combination of these elements, the manufacturer is able to determine the optimum shelf life for a product and establish conditions for its use that will ensure safe food products for consumers".*

The Food Safety Authority of Ireland (2011) splits the food properties influencing microbial growth, and hence shelf life, into intrinsic and extrinsic properties (Table 28).

Table 28: Food properties influencing microbial growth

Intrinsic properties	Extrinsic properties
Microbiological quality and history of raw materials	Good manufacturing and hygiene practices
Food formulation and composition	Food safety management system, e.g. HACCP
Food assembly and structure	Food processing
pH	Storage temperature
Type of acid present	Gas atmosphere
Water activity (a_w)	Relative humidity
Redox potential	Packaging
Biological structures	Distribution chain
Nutritional content and availability	Consumer practices
Antimicrobial substances	
Microflora – natural occurring or added	

Annex 1 of the Commission *Regulation (EC) No 2073/2005* of 15 November 2005 on Microbiological criteria for foodstuffs details the microbiological criteria that food business operators need to follow, and Annex 2 prescribes the studies that need to be conducted by or on behalf of the food business operators. In particular, this applies to ready-to-eat foods that are able to support the growth of *Listeria monocytogenes*. *Please note: The European Union Reference Laboratory for* Listeria monocytogenes *has produced technical guidance documents on conducting shelf life studies and the latest version can be found at:* https://sites.anses.fr/en/system/files/private/EURL%20Lm_Technical%20Guidance%20Document%20Lm%20shelf-life%20studies_V3_2014-06-06.pdf

From the perspective of temperature on its own, the IFR 2006 report describes the shelf life determination protocols used in France and the UK. The French national protocol for the determination of shelf life of perishable refrigerated foods was published by AFNOR (2003) as shown in Table 29.

Table 29: French shelf life determination protocol in relation to chill chains

Chill chain type	Storage regime
Insufficiently known or controlled, storage temperature believed to be somewhat long at t_1	t_1 for one third of the estimated shelf life t_2 for two thirds of the estimated shelf life
Partially controlled chill chain	t_1 for two thirds of the estimated shelf life t_2 for one third of the estimated shelf life
Totally controlled chill chain	t_1 for the whole of the estimated shelf life

Key: t_1 is the fixed storage temperature by legislation (4°C for chilled prepared foods) or the temperature fixed by the manufacturer; t_2 is a representative temperature of a reasonable breach of the chill chain or a modification of the storage temperature (e.g. in the home). In practice, t_2 is taken to be 8°C, based on the findings of a survey of consumer behaviour carried out in France (Cemegref/Ania, 2004).

Campden and Chorleywood Food Research Association (CCFRA, 2004) have recommended the shelf life evaluation protocol for chilled foods in the UK, as shown in Table 30. The CCFRA protocol notes that the legislation in England, Wales and Northern Ireland is currently 8°C.

Table 30: Recommended UK shelf life evaluation protocol for chilled foods

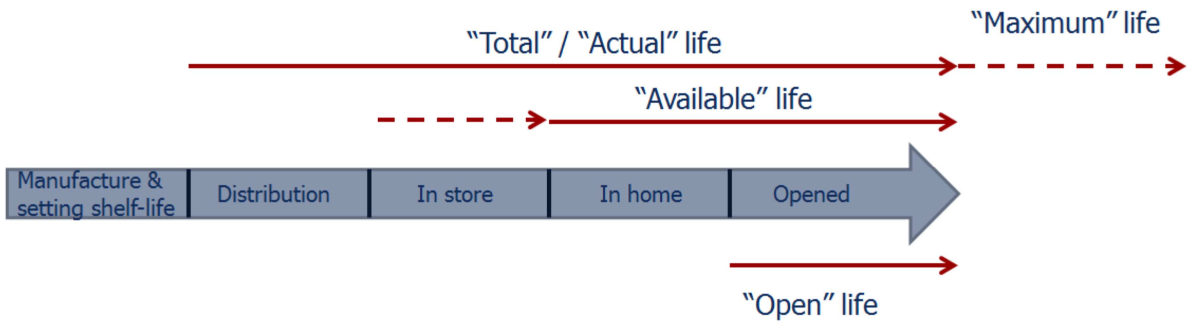
Manufacturing stage		Storage temperature	Time
Under commercial control	In-house storage at manufacturer	5°C or 7°C	To be defined by the manufacturer and / or retailer
	Distribution vehicle storage depot	5°C or 7°C	
	Retail display	5°C or 7°C	
Outside commercial control	Consumer purchase	22°C	2 hours
	Consumer storage	7°C	Remainder of life

The 'Use by' and 'Best before' dates are calculated using the following two elements:

- the results of the shelf life determination tests; and,
- safety margins.

A WRAP study in 2015 found that manufacturers and retailers put in place safety or quality margins ('buffers'), which vary in length, between the specified product life and the maximum life the product stays safe or retains its quality (see Figure 44). This study recommended that, since manufacturers and retailers err on the side of caution when specifying product life, these buffers should be challenged. Of the products included in the WRAP 2015 study, the greatest opportunity was in challenging the product life of potatoes, apples, mincemeat and sliced ham. A published feasibility study (WRAP 2012) which focused on cheese and yoghurt indicated that safety or quality margins can account for as much as 15-25% of the 'maximum life' i.e. the specified product life of the product is 15-25% less than its maximum life. Some retailers also make a short product life part of their 'quality positioning', for example because of 'brand standards' or perceptions of 'freshness' that could be challenged.

Figure 44: WRAP's product life definitions



The Food Safety Authority of Ireland (2011) reports that:

"*the margin of safety should be determined by the food business operator, after examining all reasonably foreseeable conditions of processing, storage, distribution and use. It is not possible to define exact margins of safety for food products, as it will vary between products. However, possible variations in the properties of foods, e.g. pH or temperature during storage, should be taken into consideration when applying the margin of safety*".

The findings from the WRAP 2015 study suggests that this approach is not typically used (in the UK) and instead an arbitrary figure of 15% – 25% is applied as a safety margin across all products - irrespective of whether it is a quality or safety margin.

The WRAP 2015 report also identified the issue of 'open life'. This is a time-period specified, within the date code, which stipulates the period within which a product should be consumed once opened. An important component of open life is that it supersedes other durability coding. This is particularly relevant to products for which food safety is the primary concern. Opening a packaged product increases the safety risk to the product, as it becomes exposed to environmental contaminants. Open life is particularly important in the case of products that are packaged using modified atmosphere, gas-flushed, vacuum-sealed, or contained in a self-regulating atmosphere. In these cases, the atmosphere around the product is artificially controlled to slow the rate of deterioration and prolong the product life. The product will only achieve the desired safety or quality parameters whilst in the modified environment. On opening the packaging, this environment is lost, the benefit that this environment provides is lost, and the deterioration that was arrested whilst sealed re-starts. However, there is relatively little evidence on how open life is set and whether it is set for safety or quality reasons; for example, the open life of products is typically set at two days, but this appears to be an arbitrary figure.

7.5 Barriers to extending product shelf life

Three key barriers to extending product shelf life are:

- consumer behaviour
- current product specific legislation
- product labelling.

7.5.1 Consumer behaviour

The WRAP 2013 report states that for food manufacturers to extend 'use by' dates, a significant improvement in current average domestic fridge temperatures would need to be evidenced. No study is currently planned.

7.5.2 Current product specific legislation

European Commission *Regulation (EC) No 589/2008* of 23 June 2008 laying down detailed rules for implementing Council *Regulation (EC) No 1234/2007* as regards marketing standards for eggs states:

"Article 13. Indication of the date of minimum durability.

The date of minimum durability referred to in Article 3(1)(5) of Directive 2000/13/EC shall be fixed at not more than 28 days after laying. Where the period of laying is indicated, the date of minimum durability shall be determined from the first day of that period."

7.5.3 Product labelling

In addition to the legally required date marks of 'Use by' and 'Best before', retailers can use other dates marks such as 'display until' or 'sell by' which aim to help shop staff with stock control. Such labelling systems have no legal basis and are not aimed at consumers (Defra 2011). Defra (2011) reports that there is evidence from WRAP and general correspondence from consumers that some consumers do not understand the difference between the legally required date marks and those used by food businesses for stock control purposes. WRAP has been running campaigns to reduce the use of such date marks to reduce the quantity of food wasted due to a misunderstanding or misinterpretation of this date mark. However, alternative stock control systems are then needed to ensure the appropriate stock rotation; for example, 'first in first out' principles are adopted to avoid increased food waste at the retail stores. Figures 44, 45 and 46 show examples of fresh produce in UK supermarkets in October 2016 which under European law do not require a durability label but have either a 'display until' or 'best before' date mark for stock control purposes. To highlight the inconsistency in date marking, Figure 45 and 46 show the same food produce with different date marks.

The UK Government has been working with the food industry to see how this confusion might be reduced (Defra 2011).

Figure 45. An example of a fresh produce with a 'best before' date mark

Figure 46. An example of a fresh produce with a 'display until' date mark

Figure 47: A further example of a fresh produce with a 'best before' date mark

7.6 Conclusions

This study highlights the significant discrepancies in the evidence base surrounding the optimum domestic refrigerator temperatures and national legislation across the EU-28 Member States. Numerous studies have campaigned for a 4°C mean temperature for domestic fridges, but other studies and fridge design specifications suggest that the optimum temperature is product-specific and hence a 'catch all' optimum temperature is not appropriate.

As with the conclusions from the IFR 2006 report, we are also in agreement that - even after 20 years - the recommendations made in the EU SCOOP Report of 1996 are still valid, namely:

- To clearly define the shelf life concept(s) and to agree common definitions at an EU level.
- The Commission should consider conducting a survey of food and air temperatures in retail cabinets across the Member States, to indicate the practicability of setting broad or product-specific temperatures across the EU.
- To monitor temperature fluctuations in the chilled food chain from production through to the point where the consumer selects the product.
- The role food labelling might have in ensuring that foods are held at the appropriate temperatures and with a satisfactory shelf life should be explored.
- Data relating to the microbial safety of foodstuffs should be collected and presented in a systematic and well-structured format, to aid the dissemination of important information to relevant authorities.

8 Current Refrigerated Storage Conditions [Task 4]

8.1 Refrigeration appliance volumes and temperatures NOW

The table below gives a straight count of the household Refrigeration appliance combinations on the market in 2014 according to the CECED Database. All volumes are real net volumes. Given the size of the database, with over 18 000 models, it is assumed –as in all preparatory Ecodesign studies on the subject—that the relative frequency and compartment volumes are representative for the EU market.

Table 31. Refrigeration appliance combinations, frequency and compartment volumes (source: CECED Database 2014; definition Tc and rc see text)

Cat.	Combination		Cellar/ Wine Store	Fresh food	Chill	Ice making/ 0*	2*/3*	Food freezer 4*	Total volume	*Equi-valent volume*
		T_c	+12°C	+4°C	+0°C	<0°C	-12°C	-18°C		
		r_c	0.60	1	1.2	1.35	1.8	2.1		
		frequency								
		#	average net volume in L							*eq. L*
Refrigerator										
1	fresh	**2670**		237					237	237
Refrigerator-cellar, cellar and wine store										
2	wine/cellar	**220**	186						186	112
2	wine/cellar+fresh+chill+0*	**1**	132	87	5	20			244	199
	subtotal 221									
*Refrigerator-chiller/0**										
3	fresh+chill	**481**		232	62				294	306
3	fresh+0*	**21**		80		6			86	88
	subtotal 502									
Refrigerators with 1/2/3 compartment*										
4+5+6	fresh+2*/3*	**8**		112			13		125	135
Refrigerator-freezer										
7	fresh+4*	**8615**		213				72	285	364
7	fresh+chill+4*	**1207**		253	26			113	392	522
7	fresh+2*+4*	**615**		333			12	138	483	644
7	fresh+chill+2*+4*	**66**		229	21		10	74	334	428
7	cellar+4*	**2**	126					117	243	321
	subtotal 10505									
Upright freezer										
8	4*	**2766**						203	203	426
8	2*+4*	**95**					8	256	264	552
	subtotal 2861									
Chest freezer										
9	4*	**454**						261	261	548
Multi-use and other										
10	fresh+chill+4*	**802**		196	40			61	297	372
10	fresh+chill+2*+4*	**157**		328	19		15	165	527	724
10	chill	**1**			231				231	277
	subtotal 960									
	Total frequency	**18181**	223	14643	2715	22	941	14779		
	% of total frequency		1.2%	81%	15%	0.1%	5.2%	81%		
	Average comp. volume		**185**	**226**	**36**	**7**	**12**	**110**		
	Average unit volume	**280**							**280**	**379**
	% of unit volume		0.8%	65.1%	1.9%	0.003%	0.2%	31.9%		
	equivalent litres of avg. unit		2	182	5	0	1	89		379
	average *rc* (*Tc*)								1.35 (-3°C)	

The bottom of the table shows some preliminary calculations. Some 81% of the models either has a fresh food compartment or a 4-star freezer compartment or both. The net volume of the average freezer compartment (110 litres) is approximately half that of the fresh food compartment (226 litres).

Translated to the average EU unit, calculated to have a net volume of 280 litres, this means a fresh food volume of 182 litres and a 4-star freezer volume of 89 litres. Together these compartments make up 271 litres, or 97%, of the average unit.

A chiller compartment can be found in 15% of appliances and has an average volume of 36 litres. Translated to the average EU unit this gives an equivalent volume of 5 litres, making up almost 2% of the total. A small (12 litre) 2-star compartment (-12 °C) still occurs in 5.2% of the models. This is remarkable high for this legacy feature and more surprisingly as it seems to occur in combinations that already have a 4-star freezer. A possible explanation is that this 2-star compartment is equipped for ice-making, an activity that might be disruptive for stable temperature conditions in the 4-star freezer.

The cellar/wine storage compartments/appliances occurs only in 1.2% of models. Probably, most of these appliances are wine storage appliances. Also in advertisements the 'cellar' (+12°C) or 'pantry'(+17°C) is practically non-existent in the EU.

The right-most column shows the equivalent volume, i.e. corrected for the compartment design temperature T_c (2nd row from the top) with a factor r_c (3rd row from the top) using the formula $r_c=(T_a - T_c)/20$, where T_a is the ambient temperature of 24°C. For the whole population this equivalent volume is 379 litres. The average r_c is 1.35, which means an average equivalent temperature of —3°C.

Note that calculation of one EU average unit per household is done to accommodate further modelling. In reality, the average household has 1.4 refrigeration appliances. The data suggest that 21% of households has a separate refrigerator plus a separate upright freezer, 4% combines a fridge-freezer with a chest freezer, over 1% combines a fridge-freezer with a wine storage appliance, 15% of households has two fridge-freezers and almost 60% of households own one single refrigeration appliance, i.e. a fridge-freezer.

8.2 Food storage volumes and -temperatures of refrigerator NOW versus BEST

Building on previous tasks an attempt was made to estimate the stored food volumes NOW (2011-2012) versus the stored food volumes that would be BEST from the point of view of the storage conditions, i.e. that would prolong the shelf-life of the foodstuff in the household refrigerator.

For the stored food volumes NOW, the listing of the foodstuffs and their weight in paragraph 4.17 was taken as a basis and translated into weight per week and only for private households (70% of total, i.e. excluding food services). To help translate the weight of these foodstuffs in a stored volume, the typical unit and pack weights (in grams, g) were first established. The specific stored volume, in litres per kg (L/kg), was then estimated, taking into account the weight (at roughly density 1 dm^3/kg), the shape of the outer contour(square, cylindrical or spherical fitting into a square box-like part of the refrigerator), the air inside that shape (e.g. lettuce 'contains' a significant amount of air), a 2-3 cm layer on the outside of the shape to guarantee enough circulation of cold air, extra space on top of the shape that cannot be used because of the shelf on top of the shape.
The purchased food weight (g/week per household) is then multiplied with this volume factor, to find the storage volume that is occupied. Based on the list in paragraph 4.17

the storage temperatures NOW are established. Based on Task 2 (Chapter 5), the 'BEST' storage temperatures, i.e. those that are optimal within the restriction of standard refrigerator temperatures, are indicated. Some additional information on best Relative Humidity and ethylene sensitivity was added. Finally, in the last three columns of the tables presented hereafter, the <u>minimum</u> storage days NOW and under BEST conditions are indicated as well as the resulting prolongation of the shelf-life in the household refrigerator.

The end-result of this exercise, indicated in the end-rows of the tables, is a set of estimated stored food volumes at specific storage temperatures NOW versus a set under BEST conditions.

For instance, the first table below shows, for 15 types of fresh vegetables, an average specific packing volume of 6 litres per kg. The weekly purchases of these vegetables amount to 2402 grams [146] and thus result in 14.46 litres of occupied refrigerator space. In paragraph 4.17 it was assumed that onions and carrots are NOW stored at room temperature (20°C) and the rest in the refrigerator (4°C). At BEST conditions the unripe ('green') fruity vegetables are to be stored in a pantry (17°C) and –once they are ripe—in a cellar compartment (8 to 14°C, reference 12°C).

Table 32. Weekly purchases per private household of vegetables: weight, storage volume- and temperature NOW and under BEST conditions, prolongation of shelf-life

Vegetable	**unit weight**	**units/pack**	**pack weight**	**specific packing volume**	**purchased food weight/week per household**		**storage volume purchased food/ week per hh**		**Storage temperature: NOW**		**BEST unripe**	**BEST ripe or indifferent**		**RH best**	**ethylene sensitive**	**min. days NOW**	**min. days BEST**	**factor longer life**
	g	#	g	L/kg	g/week per hh	%	L/week per hh	%	20°C	4°C	17°C	12°C	2°C					
onion	70	6	420	3	425	17.7%	1.28	9%	20				2	65%	+	5	60	12.0
carrot (mature, topped)	90	10	900	3	362	15.1%	1.08	8%	20				2	90%	+	14	70	5.0
tomato	140	5	700	3	329	13.7%	0.99	7%		4	17	12		90%	+++	3	7	2.3
cabbage	700	1	700	10	272	11.3%	2.72	19%		4			2	90%	++	7	21	3.0
cucumber	400	1	400	3	155	6.4%	0.46	3%		4	17	12		90%	+++	7	10	1.4
lettuce (whole)	360	1	360	25	155	6.4%	3.86	27%		4			2	90%	++	7	10	1.4
pepper, bell	150	3	450	3	149	6.2%	0.45	3%		4	17	12		90%	++	7	11	1.6
muskmelon	500	1	500	5	131	5.5%	0.66	5%		4	17	12		90%	+++	5	7	1.4
cauliflower	640	1	640	10	76	3.2%	0.76	5%		4			2	90%	++	7	14	2.0
broccoli	240	2	480	10	76	3.2%	0.76	5%		4			2	90%	++	3	14	4.7
large courgette	450	4	1800	3	73	3.0%	0.22	2%		4	17	12		90%	+++	7	10	1.4
chicory (piece)	85	5	425	3	56	2.4%	0.17	1%		4			2	90%	++	7	10	1.4
leek	110	5	550	10	55	2.3%	0.55	4%		4			2	90%	++	7	10	1.4
large eggplant	280	1	280	5	48	2.0%	0.24	2%		4	17	12		90%	+++	7	10	1.4
celery (stalk)	40	7	280	10	20	0.8%	0.20	1%		4			2	90%	++	7	14	2.0
celeriac	750	1	750	3	20	0.8%	0.06	0%		4			2	90%	++	7	10	1.4
avg/total				**6.0**	**2402**		**14.46**									**7**	**29**	**4.3**
volume per compartment in L									**2.4**	**12.1**	**1.5**	**1.5**	**11.4**					
potato	90	28	2520	**2**	**1390**	100%	3	100%	20°C		20°C	12°C		90%	+	30	60	2
volume per compartment in L									**3**			**3**						

Note: Where applicable the volume ripe vs. unripe is split 50/50. Does not include vegetables that are normally sold frozen or canned: artichokes (0.75 Mt produced EU, fig. 14), spinach (0.53 Mt), endives (0.36 Mt), asparagus (0.26 Mt), other leafy vegetables (0.2 Mt), other fruity vegetables (0.6 Mt), fresh beans (0.92), fresh peas (0.86 Mt), other fresh pulses (0.2). Also tomato products (take up 11.1 Mt EU produced tomatoes, see fig. 15 and 16), water melon (2.74 Mt), mushrooms (their optimal storage temperature is 4°C) are not included.

The other vegetables (leafy, brassicas, etc.) are best kept in a so-called 'salad-chiller', i.e. as close as possible –but never at or below—the freezing point (reference 2°C). The effect is that on average the vegetables can be kept between a factor 4.3 longer (29

[146](38 Mt fresh vegetables per year for the whole of the EU x 70% for private households, divided by 213 million households x 52 weeks; subsequently multiplied by 1000 to arrive at grams)

instead of 7 days). Without the onions and carrots, the average prolongation is around a factor 2.

The table below gives the calculation for fresh fruit. Overall the effect is a prolongation of shelf-life of a factor 4.8. Without the extremes of apples and pears, the effect would still be a factor 3 on average.

Table 33.Weekly purchases per household of fruit: weight, storage volume- and temperature NOW and under BEST conditions, prolongation of shelf-life

Fruit (packing factor 3 L/kg for all)	**weight**	**units/pack**	**pack weight**	**purchased mass/week per household**		**volume stored**	**Storage temperature** NOW	BEST unripe	BEST ripe or indifferent				**RH best**	**ethylene sensitive**	**ethylene producing**	**min. days NOW**	**min. days BEST**	**longer factor life**
	g	*#*	*g*	*g/week per hh*	*%*	*L/week per hh*	*20°C*	*17°C*	*12°C*	*4°C*	*2°C*	*-1°C*				*days*	*days*	
oranges	150	7	1050	378	22.2%	1.62	20	17		4			90%	++	++	5	14	2.8
apple	120	6	720	305	17.9%	1.31	20	17				-1	90%	++	++	5	60	12
banana (medium)	110	5	550	208	12.2%	0.89	20	17	12				90%	++	++	5	10	2
mandarin	55	10	550	184	10.8%	0.79	20	17		4			90%	++	++	7	14	2
pear	150	6	900	102	6.0%	0.44	20	17				-1	90%	++	++	5	60	12
grape	7	70	490	97	5.7%	0.42	20	17			2		90%	++	++	2	5	2.5
peach (no pit)	140	6	840	92	5.4%	0.39	20	17			2		90%	++	++	5	14	2.8
lemon	90	3	270	73	4.3%	0.31	20	17		4			90%	++	++	7	14	2
plumbs (no pit)	30	15	450	73	4.3%	0.31	20	17			2		90%	++	++	5	14	2.8
nectarine	80	8	640	68	4.0%	0.29	20	17			2		90%	++	++	5	14	2.8
strawberries	40	15	600	48	2.8%	0.21	20	17			2		90%	++	++	1	2	2
cherry (no pit)	5	50	250	39	2.3%	0.17	20	17				-1	90%	++	++	2	7	3.5
apricot (no pit)	50	10	500	29	1.7%	0.12	20	17				-1	90%	++	++	2	7	3.5
pineapple (whole)	900	1	900	5	0.3%	0.02	20	17		4			90%	++	++	5	7	1.4
mango	200	1	200	5	0.3%	0.02	20	17	12				90%	++	++	2	7	3.5
avg/total				**1706**		**7.31**										**5**	**23**	**4.8**
volume per compartment in L							**7.3**	**3.7**	**0.5**	**1.4**	**0.8**	**1.0**						

Note: Where applicable the volume ripe vs. unripe is split 50/50.

The table on the next page gives the results for meat & fish, dairy & eggs, bread & pastry and beverages. For the fresh meat it was assumed in paragraph 4.17 that, because of amongst other the short shelf-life of 2-3 days, half of the purchased meat would be frozen, to be consumed at a later date. With the use of a chiller (-1°C) it is possible to prolong the shelf-life to almost three weeks, instead of 3 days at +4°C.

Most dairy products are NOW stored correctly, i.e. at +4°C. The only exceptions are soft cheese and hard cheese that can benefit, also depending on type, from a lower temperature to extend the storage time. From the viewpoint of resources conservation this is important, because it takes 7 to 8 litres of milk to make 1 kg of cheese and it is thus especially valuable.

For bread, it was assumed that people NOW keep the bread in a bread-box. However, a better method –also for the taste—would be to eat the bread fresh the first day and keep the rest in the freezer (never in the refrigerator).

The storage of especially fresh fruit juice at temperatures around its freezing point (-1 to -3°) can considerably prolong shelf-life. As for the other beverages, the main opportunity is not so much in prolonging shelf-life, but in a (slight) increase of the storage temperature that can improve both the quality/taste and at the same time lower the energy consumption of the refrigerator. With some exceptions (sparkling wine, white beer, light lager beer), 4°C is too cold for beer and wine. Ideal temperatures are around 7-8 °C (chilled craft beer and white wine), 11 °C (heavy stout beer) and 12-13°C (red wine serving temperature, storage temperature for all wines). With a stratified cellar compartment (8-14 °C) this range can be adequately covered. For soft drinks and bottled water there are diverging opinions in literature on the best temperature, ranging from 'as cold as possible' to 'water at body temperature' (37°C, according to Chinese medicine). It is assumed below that carbonated soft drinks and water are to be served at 4°C, whereas flat drinks would be better consumed at 8°C (lower range of the cellar temperatures.

Table 34. Weekly purchases per household of meat & fish, dairy & eggs, bread & pastry, beverages: weight, storage volume- and temperature NOW and under BEST conditions, prolongation of shelf-life

Meat, fish, dairy & eggs, bread & pastry, beverages (packing factor 3 L/kg for all solids, 2.5 L/kg for beverages)	**weight**	**units/pack**	**pack weight**	**purchased mass/week per household**		**volume stored**	**Storage temperature** NOW		BEST				**RH best**	**min. days NOW**	**min. days BEST**	**factor longer life**
	g	*#*	*g*	*g/week per hh*	*%*	*L/week per hh*	*4℃*	*-18℃*	*4℃*	*2℃*	*-1℃*	*-18℃*	*%*	*days*	*days*	
meat & fish																
fresh meat NOW	200	1	200	758	34.3%	2.27	4							3	20	6.7
frozen meat NOW	200	1	200	758	34.3%	2.27		-18						>6 months		1.0
fresh meat BEST	*200*	*1*	*200*	*1137*	*51.4%*	*3.41*					*-1*			*3*	*20*	*6.7*
frozen meat BEST	*200*	*1*	*200*	*379*	*17.1%*	*1.14*						*-18*		*>6 months*		*1.0*
meat products	150	1	150	506	22.9%	1.52	4				-1			5	20	4
fresh fish	200	1	200	190	8.6%	0.57	4				-1			1	3	3
avg/total meat &fish				**2211**		**6.63**								**3.8**	**22.0**	**5.8**
volume per compartment in L							**4.4**	**2.3**	**0.0**	**0.0**	**5.5**	**1.1**				

dairy & eggs	weight *g*	units/pack *#*	pack weight *g*	*g/week per hh*	*%*	*L/week per hh*	NOW *4℃*	NOW *-18℃*	BEST *4℃*	BEST *2℃*	BEST *-1℃*	BEST *-18℃*	RH best *%*	min. days NOW	min. days BEST	factor longer life
milk fresh/ UHTopen	1000	1	1000	1138	35.3%	3.41	4		4					4	4	1
yoghurt, cream	1000	1	1000	948	29.4%	2.84	4		4					4	4	1
butter	250	1	250	126	3.9%	0.38	4		4					30	30	1
soft cheese	100	1	100	253	7.8%	0.76	4			2			65%	7	30	4.3
hard cheese	200	1	200	569	17.6%	1.71	4				-1		65%	60	90	1.5
eggs	60	10	600	190	5.9%	0.57	4		4					7	14	2
avg/total dairy & eggs				**3223**		**9.67**								**15.3**	**22.8**	**1.5**
volume per compartment in L							**9.7**	**0.0**	**6.8**	**0.8**	**2.1**	**0.0**				

bread & pastry	weight	units/pack	pack weight	g/week per hh	%	L/week per hh	**NOW** *20℃*	**NOW** *4℃*	**BEST** *20℃*	**BEST** *4℃*	**BEST** *-18℃*	RH best	min. days NOW	min. days BEST	factor longer life
fresh bread NOW	800	1	800	1201	67.9%	3.60	20					65%	2	2	1
fresh bread BEST	*400*	*1*	*400*	*601*	*34.0%*	*1.80*			*20.0*			*65%*	*2*	*2*	*1*
frozen bread BEST	*400*	*1*	*400*	*600*	*33.9%*	*1.80*					*-18.0*	*65%*	*2*	*60*	*30*
pastry (w eggs/milk)	500	1	500	569	32.1%	1.71		4		4			3	3	1
avg/total dairy & eggs				**1770**		**5.31**							**3.7**	**23.3**	**6.3**
volume per compartment in L							**3.6**	**1.7**	**1.8**	**1.7**	**1.8**				

Beverages	g/week per hh	%	L/week per hh	**NOW** *20℃*	**NOW** *4℃*	**BEST** *20℃*	**BEST** *12℃*	**BEST** *4℃*	**BEST** *-1℃*	min. days NOW	min. days BEST	factor longer life
fresh fruit juice ss	190	1.7%	0.47		4				-1	4	8	2
fruit juice open	253	2.2%	0.63		4				-1	4	8	2
fruit juice unopened	253	2.2%	0.63	20		20				14	28	2
beer (craft) chilled	379	3.4%	0.95		4		12					
beer (lager) chilled	379	3.4%	0.95		4			4				
beer stored	1517	13.5%	3.79	20		20						
white wine sparkling chilled	63	0.6%	0.16		4			4				
white wine chilled	126	1.1%	0.32		4		12					
white wine stored	190	1.7%	0.47	20			12					
red wine	379	3.4%	0.95	20			12					
UHT milk stored	822	7.3%	2.05	20		20						
soft drink sparkle chilled	569	5.1%	1.42		4			4				
soft drink flat chilled	506	4.5%	1.26		4		12					
soft drink stored	2086	18.5%	5.21	20		20						
min. water sparkle chilled	569	5.1%	1.42		4			4				
min. water flat	569	5.1%	1.42		4		12					
min. water stored	2402	21.3%	6.00	20		20						
avg/total dairy & eggs	**11250**		**28**							**0.5**	**0.9**	**2.0**
volume per compartment in L				**19.1**	**9.0**	**17.7**	**5.4**	**3.9**	**1.1**			

The table below summarizes the results of the previous tables and gives an overview of the food and drinks volumes of the refrigerator compartments NOW versus the BEST conditions. The first row gives the compartment temperatures T_c and their respective temperature correction factors r_c. The r_c is also calculated per food group and as a total (blue font), both for NOW and BEST conditions. The table gives the food volumes for the main food groups, in storage litres/week purchased by the average EU private household in 2011-'12. The final rows give the totals for the 'typical refrigerator' as a whole, first in normal litres and then in –the temperature corrected-- equivalent volume V_{eq}. Both in the NOW and BEST accounting there is a small part of the freezer, 2.3 and 2.9 litres respectively, but the rest of the freezer is assumed the same in both situations and thus not taken into account.

Table 35. Comparison volume and equivalent volume of refrigerator NOW and BEST, in storage litres/week purchased per average EU household 2011-'12.

	NOW					BEST								
T_c	20°C	4°C	-18°C			20°C	17°C	12°C	4°C	2°C	-1°C	-18°C		
r_c		1	2.1				0.35	0.60	1	1.1	1.25	2.1		
				Total	avg r_c								**Total**	avg r_c
Vegetables	2.4	12.1		**14.5**	*0.84*		1.5	1.5		11.4			**14.5**	*0.97*
Potatoes	2.8			**2.8**	*0.00*	**0.0**		3.0					**3.0**	*0.60*
Fruit	7.3			**7.3**	*0.00*		3.7	0.5	1.4	0.8	1.0		**7.3**	*0.70*
Meat & fish		4.4	2.3	**6.6**	*1.38*						5.5	1.1	**6.6**	*1.40*
Dairy & eggs		9.7		**9.7**	*1.00*				6.8	0.8	2.1		**9.7**	*1.06*
Bread & pastry	3.6	1.7		**5.3**	*0.32*	1.8			1.7			1.8	**5.3**	*1.03*
Beverages	19.1	9.0		**28.1**	*0.32*	17.7		5.4	3.9	1.1	0.0		**28.1**	*0.30*
TOTAL	**35.2**	**36.8**	**2.3**	**74.4**	*0.56*	**19.5**	**5.2**	**10.3**	**13.9**	**14.1**	**8.6**	**2.9**	**74.4**	*0.73*
o/w refrigerated		*39.1*					*55.0*							
Veq		41.6		**41.6**			54.3						**54.3**	

The result is a refrigerator for 36.8 litres of stored foodstuffs NOW (excl. freezer). Considering an average refrigerator of 182 litres, as assessed in the first paragraph, this comes down to slightly over 20% occupied space. Note that this does not include leftovers, sauces, etc.

The BEST refrigerator features 52 litres of stored foods (excl. freezer), a 40% increase in occupied storage space compared to NOW, but still only 29% of the total space available in today's 182 litre refrigerator. If at weekly peak times (just-after-shopping) the stored food doubles, there would be no problem. At exceptional peaks (e.g. parties) the refrigerator, adequately packed, would be able to hold more than three times the average occupied volume.

The average energy increase for the refrigerator (not the freezer), iterated by the equivalent volume V_{eq}, is 30% more (54.3/41.6-1) for the refrigerator NOW versus the BEST refrigerator.

These are estimates to indicate trends, not to prescribe one single design for all. For instance, many consumers may find the current shelf-lives at room temperature of onions and carrots fairly satisfactory and opt to place them in a well-ventilated pantry (17°C). Potatoes could be kept at room temperature. Apples and pears, once they are ripe, could be placed in an appropriately ventilated cellar compartment (12°C). This would still prolong shelf-life, but not to the extremes of what is calculated above.

The table below calculates the effect of these changes. The increase in occupied space volume is slightly less (33% instead of 40% mainly due to the potatoes). The increase in energy consumption would be 20% (50.1/41.6 – 1) instead of 30%.

Table 36. Comparison volume and equivalent volume of refrigerator NOW and BETTER

	NOW					BETTER								
T_c	*20°C*	*4°C*	*-18°C*			*20°C*	*17°C*	*12°C*	*4°C*	*2°C*	*-1°C*	*-18°C*		
r_c		*1*	*2.1*				*0.35*	*0.60*	*1*	*1.1*	*1.25*	*2.1*		
				Total	***avg rc***								***Total***	***avg rc***
Vegetables	2.4	12.1		**14.5**	**0.84**		3.9	1.5		9.1			**14.5**	**0.85**
Potatoes	2.8			**2.8**	**0.00**	3.0							**3.0**	**0.00**
Fruit	7.3			**7.3**	**0.00**		3.7	1.5	1.4	0.8	0.0		**7.3**	**0.61**
Meat & fish		4.4	2.3	**6.6**	**1.38**						5.5	1.1	**6.6**	**1.40**
Dairy & eggs		9.7		**9.7**	**1.00**				6.8	0.8	2.1		**9.7**	**1.06**
Bread & pastry	3.6	1.7		**5.3**	**0.32**	1.8			1.7			1.8	**5.3**	**1.03**
Beverages	19.1	9.0		**28.1**	**0.32**	17.7		5.4	3.9	1.1	0.0		**28.1**	**0.30**
TOTAL	**35.2**	**36.8**	**2.3**	**74.3**	**0.56**	**22.5**	**7.5**	**8.4**	**13.9**	**11.8**	**7.6**	**2.9**	**74.5**	**0.67**
o/w refrigerated		*39.1*					*52.0*							
V_{eq}		41.6		**41.6**			50.1						**50.1**	

Ignoring the 0.6 litres of difference in freezer space, the graph below gives a comparison of the occupied food space in the refrigerator NOW as well as the BETTER and BEST alternatives.

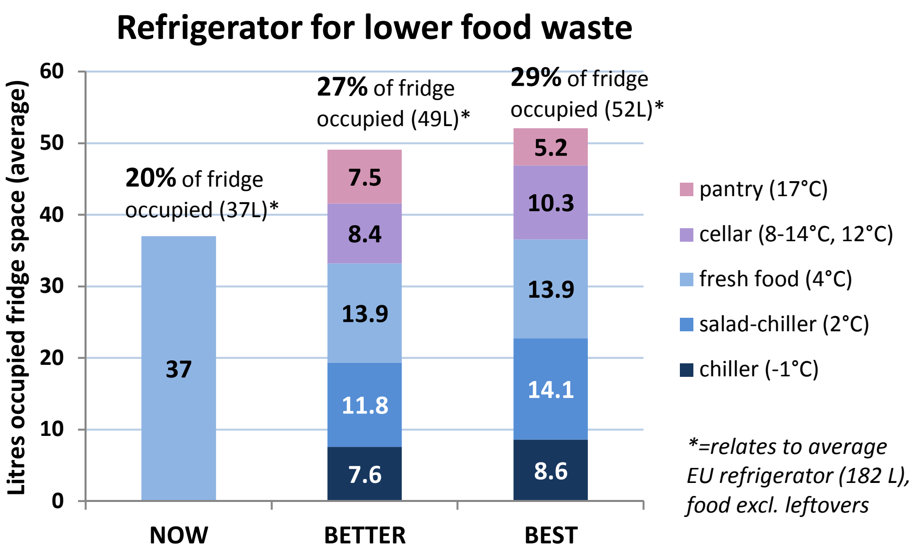


Figure 48. Comparison of occupied space (in L) and storage temperatures for current, 'better' and 'best' refrigerator in terms of food storage

In a practical design, the cellar and pantry compartments could probably be divided internally and have a single door. The same goes for the fresh food and salad chiller compartments. The chiller, carrying the most valuable food resources (meat, fish, hard cheese), would warrant a separate door. Together with the freezer, a compact design would feature 4 outer doors. Instead of a 182-183 L fridge, a 89 L freezer, a 5 L chiller and a 2 L cellar, the BETTER/BEST appliance would have a 95-100 L fridge (incl. salad chiller), a 30 L chiller (-1°C), a 55-60 L cellar (50-66%)+pantry (34-50%) and a 90 L freezer.

The table and graph below give an overview of the prolongation of the shelf-life with the BETTER and BEST alternatives.[147] The BETTER option prolongs shelf-life from an average (minimum days) of 8 days to an average of 18 days. This is an overall factor 2.3, ranging per food group from 1.5 (dairy, due to cheese) to around 6 (meat, fish, bread). For the BEST option, with a better storage for vegetables and fruit, the improved average shelf-life goes up to 23 days, i.e. a factor 3.1.

Table 37. Prolongation of shelf life BETTER and BEST versus NOW

Food group (excl. potatoes)	weight g	NOW min. days	BETTER min days	factor BETTER/ NOW	BETTER min days	factor BEST/ NOW
Vegetables	2402	7	13	1.9	29	4.2
Fruit	1706	5	11	2.2	23	4.8
Meat & Fish	2211	4	22	5.8	22	5.8
Dairy & Eggs	3223	15	23	1.5	23	1.5
Bread & pastry	1770	4	23	6.3	23	6.3
Fresh fruit juice	442	4	8	2.0	8	2.0
Total	**11754**	**7.6**	**18.2**	**2.4**	**23**	**3.1**

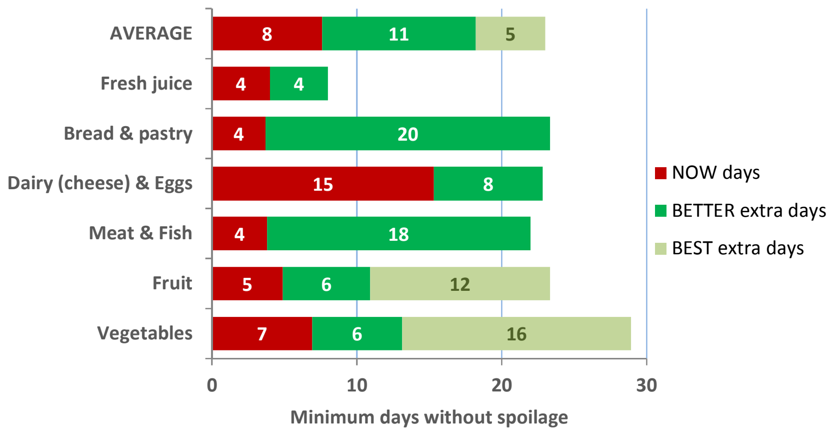


Figure 49. Prolongation of shelf life BETTER and BEST versus NOW.

Note that 'BEST' only applies to optimisation for certain types of fruit (apples, pears) and vegetables (onions, carrots), which already have a long shelf-life. In that sense 'BETTER' is probably the more realistic option.
In 'Dairy' , the storage conditions for cheese can be considerably improved; for fresh milk and other dairy products the current conditions are optimal (NOW=BEST) .

In conclusion and purely based on the occupied storage space of relevant foodstuffs and 'all other factors being equal', the ideal food-conserving refrigerator with extra cellar and chiller compartments would consume at least 20% more electricity than today's reference. On the one hand, it is slightly bigger and on the other hand the average refrigeration temperature over all compartments is lower.

Having said that, 'all other factors' need not be equal: Currently, the average refrigeration appliance is --even when taking into account peak usage twice as high as average-- at least a factor two oversized. On average, the foodstuffs -including sufficient extra space for effective cooling-- occupy only one quarter of the refrigerated space available. Secondly, the preparatory study showed that for household refrigerators there is still a significant technical saving potential of up to 30-40% and an economic saving potential of 18-20%. This means that a future food-saving appliance would not use more

[147] Note that potatoes were excluded here, because the shift to room temperature would give a skewed comparison between BETTER and BEST options.

in an absolute sense, but it would save less. Thirdly, the existence of several different temperature compartments ranging from -1°C to +17°C creates new energy saving possibilities, e.g. from cascading and re-use of 'waste cold' from defrosting.

Nonetheless, even when not considering these three factors, it would be enough --in terms of mass and energy equivalent-- to save 2 percentage points on end-use food waste (10 Mt), i.e. 9% instead of 11% avoidable waste, to compensate for a 20% higher energy use of the refrigerator (i.e. 8 Mtoe).[148]

[148] In terms of energy: 1 Mtoe is 41.87 MJ/kg combustion value. Average energy content of food waste at end-use level is 24.5 MJ/kg (see par. 5.2), but excluding pre-harvest losses and –for leftovers—energy for cooking. Furthermore, the food waste saved has a relatively larger share of meat & fish which have a much higher than average energy content.

9 Policy options [Task 5]

9.1 Conclusions

1. EU food production 'from farm to fork' constitutes almost 20 weight percent of the EU's Domestic Material Consumption (DMC), comparable --in weight-- to the DMC of all energy carriers.

2. End-users, i.e. private households and food services, waste 18% of those resources. Of this end-use waste, 60% (11% of the total end-use waste) is due to food spoilage and bad planning and thus avoidable.

3. Refrigeration appliances store two-thirds of the food and drinks prior to consumption and waste disposal. They play a major role in preventing food spoilage and could possibly contribute to better planning if they were designed more adequately.

4. Currently, over 85% of refrigeration appliances offer --apart from a freezer compartment-- only a single fresh food compartment at a temperature of +4°C. Chiller compartments (-1°C) are present in only 15% of models offered and the share of cellar compartments is negligible.

5. For about half of the fresh food (and drinks) the current single fresh food compartment temperature of 4°C is either too warm or too cold for best fresh food preservation. The presence of a chiller (-1°C) and a 'cellar' compartment (8-14°C) could increase the shelf-life, in days, with on average a factor 3 or 4. For certain foodstuffs like fresh meat, that required large resources to produce, the shelf life could be prolonged from 3 to 20 days by using a chiller instead of the usual fresh food temperature.

6. An appropriately designed refrigeration appliance is an important condition to realise much longer shelf-life, but it is not the only condition for end-users to change their behaviour. The current food labelling practice of suppliers setting 'use-by' dates based on a worst-case scenario is the reported reason of large part of the avoidable food waste, at least for some (animal-origin) foodstuffs. If a strategy of less food waste through better refrigeration is to be successful for these products, appropriate lateral measures are strongly recommended.

7. Preliminary calculations from EU food flows and findings on optimised storage conditions, show that --purely based on the occupied storage space of relevant foodstuffs and 'all other factors being equal'-- the ideal food-conserving refrigerator with extra cellar and chiller compartments would consume at least 20% more electricity than today's reference. On the one hand, it is slightly bigger and on the other hand the average refrigeration temperature over all compartments is lower.
8. Having said that, 'all other factors' need not be equal: At the moment, the average refrigeration appliance is --even when taking into account peak usage twice as high as average-- at least a factor two oversized. On average, the foodstuffs -including sufficient extra space for effective cooling-- occupy only one quarter of the refrigerated space available. Secondly, the preparatory study showed that for household refrigerators there is still a significant technical saving potential of up to 30-40% and an economic saving potential of 18-20%. This means that a future food-saving appliance would not use more in an absolute sense, but it would save less.

Thirdly, the existence of several different temperature compartments ranging from -1°C to +17°C creates new energy saving possibilities, e.g. from cascading and re-use of 'waste cold' from defrosting.

9. Nonetheless, even when not considering these three factors, it would be enough --in terms of mass and energy equivalent-- to save 2% on end-use food waste, i.e. 9% instead of 11% avoidable waste, to compensate for a 20% higher energy use of the refrigerator.

9.2 Recommendations and policy options

1. This study confirms that there is a solid basis for policy makers to allow multi-door correction factor for refrigeration appliances in Ecodesign and Energy Labelling. At least this would no longer penalize the multi-door appliances, with e.g. inherently larger door-leakage energy losses than a single-door refrigerator, in Ecodesign and Energy Label rating.

2. Secondly, harmonisation at EU-level of (parts of) setting 'use-by' dates is recommended. Detailed recommendations are given in Task 3. Additionally, comparable to today's food labelling for frozen products, the use-by dates could differentiate between storage at +4°C (normal refrigerator) and -1°C.

3. Information campaigns raising consumer-awareness are important. When linked to proper use of the (relatively new) cold storage facilities and the benefits of not only less food waste but also healthier and tastier food, it is believed that such campaigns could be more successful then campaigns to change wasteful behaviour in general.

4. This study gives a comprehensive EU mass-flow accounting of foodstuffs to give policy makers a correct starting point for a conservation strategy and lays a sound basis for further analysis in the context of household, professional and possibly commercial refrigeration. Having said that, there are still several interfaces between Ecodesign-regulated appliances and food waste that need to be further analysed before they can be applied in Ecodesign and/or other policy measures:

    a. The focus of this study has been on household refrigeration, but the study has also identified that –per meal—there is higher food waste in professional refrigeration for restaurants and caterers.
    b. For commercial refrigeration, an order of magnitude of food waste has been identified but for possible policy measures more work on the background of this food waste is needed to identify possibilities of food waste reduction through Ecodesign, Energy Labelling or other measures.
    c. When thinking of closing the cold chain, it can be expected that chilled transport-containers will become a (even) more important area and a possible new subject for Ecodesign.
    d. The food industry is an area where Ecodesign-regulated equipment and components are used such as Low- and Medium Temperature (LT and MT) chillers, industrial motors, fans, pumps, air conditioning and High Temperature chillers (e.g. in chocolate factories), etc..

e. In the agricultural sector, irrigation pumps are a large energy-user. Their energy efficiency is Ecodesign-regulated and currently an extended product approach is being elaborated by standardisation committees, but it could well be that a full system approach gives new savings also in terms of the water footprint.

f. As regards food spoilage, this study is limited to traditional preservation techniques, i.e. close to the current concept of a refrigerator, but there may be other –known and new—alternative techniques that can contribute. For instance, beverages that merely need to be served cold bunt not necessarily stored cold, could be cooled 'on the spot' just before drinking. Protective atmospheres that are now applied mainly at the level of packaging (e.g. meat in an oxygen-poor ambient) could also play a role in certain parts of the refrigerator, etc.

g. Packaging and the right portioning size are definitely areas that interact with refrigeration, food waste and packaging waste, etc..

Not all these areas are necessarily relevant for Ecodesign or Energy Labelling measures, although many are or could be, but could include a much larger range of policy instruments.

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Task 1 & 2

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ANNEX I. Food product databases and nomenclature

Featuring: FAOSTAT (nomenclature and EU 2011 data), Eurostat (nomenclature), EFSA (nomenclature and country survey sources)

FAOSTAT Food Balance Sheets commodity list

Table 38. FAOSTAT Food Balance Sheets commodities included

Cereals - Excluding Beer + (Total)
- Wheat and products
- Rice (Milled Equivalent)
- Barley and products
- Maize and products
- Rye and products
- Oats
- Millet and products
- Sorghum and products
- Cereals, Other

Starchy Roots + (Total)
- Cassava and products
- Potatoes and products
- Sweet potatoes
- Yams
- Roots, Other

Sugar Crops + (Total)
- Sugar cane
- Sugar beet

Sugar & Sweeteners + (Total)
- Sugar non-centrifugal
- Sugar (Raw Equivalent)
- Sweeteners, Other
- Honey

Pulses + (Total)
- Beans
- Peas
- Pulses, Other and products

Treenuts + (Total)
- Nuts and products

Oilcrops + (Total)
- Soya beans
- Groundnuts (Shelled Eq)
- Sunflower seed
- Rape and Mustard seed
- Cottonseed
- Coconuts - Incl Copra
- Sesame seed
- Palm kernels
- Olives (including preserved)
- Oil crops, Other

Vegetable Oils + (Total)
- Soya bean Oil
- Groundnut Oil
- Sunflower seed Oil
- Rape and Mustard Oil
- Cottonseed Oil
- Palm kernel Oil
- Palm Oil
- Coconut Oil
- Sesame seed Oil
- Olive Oil
- Rice bran Oil
- Maize Germ Oil
- Oil crops oil, Other

Vegetables + (Total)
- Tomatoes and products
- Onions
- Vegetables, Other

Fruits - Excluding Wine + (Total)
- Oranges, Mandarins
- Lemons, Limes and products
- Grapefruit and products
- Citrus, Other
- Bananas
- Plantains
- Apples and products
- Pineapples and products
- Dates
- Grapes and products (excl wine)
- Fruits, Other

Stimulants + (Total)
- Coffee and products
- Cocoa Beans and products
- Tea (including mate)

Spices + (Total)
- Pepper
- Pimento
- Cloves
- Spices, Other

Alcoholic Beverages + (Total)
- Wine
- Beer
- Beverages, Fermented
- Beverages, Alcoholic
- Alcohol, Non-Food

Meat + (Total)
- Bovine Meat
- Mutton & Goat Meat
- Pigmeat
- Poultry Meat
- Meat, Other

Offals + (Total)
- Offals, Edible

Animal fats + (Total)
- Butter, Ghee
- Cream
- Fats, Animals, Raw
- Fish, Body Oil
- Fish, Liver Oil

Eggs + (Total)
- Eggs

Milk - Excluding Butter + (Total)
- Milk - Excluding Butter

Fish, Seafood + (Total)
- Freshwater Fish
- Demersal Fish
- Pelagic Fish
- Marine Fish, Other
- Crustaceans
- Cephalopods
- Molluscs, Other

Aquatic Products, Other + (Total)
- Meat, Aquatic Mammals
- Aquatic Animals, Others
- Aquatic Plants

Miscellaneous + (Total)
- Infant food
- Miscellaneous

Table 39. FAO Food Balance Sheet EU-28, 2011 (in kt, raw material equivalent)

Note that Imports and Exports relate to both Intra-EU and Extra-EU trade

	Prod.	Import	Stock Var.	Export	Total	Food	Food Manu	Feed	Seed	Waste	Oth. Uses
TOTAL EU-28 (504 inhabitants)	**996 653**	**399 357**	**903**	**376195**	**1 020 645**	**501 150**	**221 420**	**203 332**	**15 908**	**24 017**	**56 094**
Cereals - Excluding Beer	293 091	83 739	1111	99330	278 581	63 367	18 606	167678	9930	6363	12656
Wheat and products	138 770	42073	379	57169	124045	52189	4337	51947	5158	3011	7401
Rice (Milled Equivalent)	2 081	3395	-4	2346	3125	2643	17	290	54	17	104
Barley and products	51 921	11770	3837	18260	49264	546	8105	36916	2458	912	328
Maize and products	70 138	22594	-4112	18268	70348	3764	5504	54699	457	1587	4344
Rye and products	6 910	1153	479	1118	7423	3011	618	3064	450	259	24
Oats	7 970	922	62	1195	7752	875	5	6052	625	191	9
Millet and products	101	109	3	51	163	10		149	3	2	0
Sorghum and products	685	759	-7	117	1316	0		1302	3	4	6
Cereals, Other	14 515	964	474	806	15145	329	20	13259	722	380	440
Starchy Roots	62 383	15 983	-122	18 609	59 639	36 549	2 156	6 499	4 842	4 561	4 737
Cassava and products		327	0	105	225	0	3	89			132
Potatoes and products	62298	15480	-122	18460	59196	36473	2153	6272	4842	4556	4605
Sweet potatoes	54	113	0	33	137	63		70		5	
Yams	2	0		0	2	2			0	0	
Roots, Other	29	63	0	11	79	11		68	0	0	0
Sugar Crops	125 150	825	275	700	125 550	0	118 545	216		54	6 767
Sugar cane	5	0	4	0	8	0	5	0			3
Sugar beet	125145	825	271	700	125542	0	118540	216		54	6764
Sugar & Sweeteners	23 891	17 649	-3407	13335	24792	19327	169	85		10	5197
Sugar (Raw Equivalent)	19045	11499	-3614	8788	18140	16874	150	49		10	1054
Sweeteners, Other	4629	5900	211	4435	6305	2125	0	36			4143
Honey	217	250	-4	112	347	328	19				0
Pulses	3518	1543	45	1206	3899	1491		2069	237	91	0
Beans	144	555	0	134	563	416		111	16	17	0
Peas	1617	554	12	510	1675	652		870	113	39	0
Pulses, Other and products	1757	434	33	562	1661	423		1088	108	35	0
Treenuts	829	2656	5	1117	2377	2369	0			31	8
Nuts and products	829	2656	5	1117	2377	2369	0			31	8
Oilcrops	43 479	31294	906	14359	61314	1903	53 640	4282	317	767	461
Soyabeans	1246	14378	513	2526	13610	87	12521	760	37	203	0
Groundnuts (Shelled Eq)	6	918	2	325	602	445	153	0	1	3	0
Sunflower seed	8534	2995	104	3498	8137	82	6748	1011	75	167	56
Rape and Mustardseed	19306	10175	161	6336	23304	91	20688	2048	154	310	8
Cottonseed	563	194	1	148	610		310	57	39	11	193
Coconuts - Incl Copra		555	5	204	353	350	2	0		0	0
Sesame seed	1	129	0	27	103	30	68	0	0	4	
Palm kernels		0	0	0	0		0	0		0	0
Olives (including preserved)	13391	461	67	636	13283	795	12427			64	0
Oilcrops, Other	432	1489	53	659	1312	23	723	406	11	5	204
Vegetable Oils	17564	23335	139	15360	25669	10196	313	773		6	14925
Soyabean Oil	2296	1689	147	1493	2643	2091	12	22		1	519
Groundnut Oil	65	114	0	48	127	124	0			0	2
Sunflowerseed Oil	2783	2983	10	2307	3467	2291	10			4	1164
Rape and Mustard Oil	8471	3192	0	3224	8437	1831	11	750		0	5843
Cottonseed Oil	48	8	1	7	49	17	0			0	34
Palmkernel Oil	0	881	3	171	711	54	10			0	647
Palm Oil		9059	7	3905	5161	836	26			0	4711
Coconut Oil	0	1607	0	872	735	285	13			0	468
Sesameseed Oil	30	31	0	32	28	25	0	0			2
Olive Oil	2710	1150	-31	1536	2294	2075		0			216
Ricebran Oil	0	0		0	0	0					
Maize Germ Oil	277	192	17	190	295	275	0				20
Oilcrops Oil, Other	884	2429	-15	1575	1722	292	231	1		1	1299
Vegetables	68310	28713	93	28884	68237	58738	8	2210	21	7214	97
Tomatoes and products	16261	8020	5	9142	15146	13918	0	100		1102	26
Onions	6574	1875	0	2697	5751	5125	NaN	2		622	4
Vegetables, Other	45475	18818	88	17045	47340	39695	9	2108	21	5490	67

FAO FBS EU-28 continued

	Prod.	Import	Stock Var.	Export	Total	Food	Food Manu	Feed	Seed	Waste	Oth. Uses
Fruits - Excluding Wine	62043	55748	748	39007	79524	50773	24591	213		3693	397
Oranges, Mandarines	9717	19488	788	13595	16394	15490	21			836	50
Lemons, Limes and products	1313	1199	0	859	1652	1532	NaN			120	5
Grapefruit and products	98	1806	29	866	1065	1041	0			23	0
Citrus, Other	45	224	0	64	206	196	2			1	8
Bananas	386	7002	0	2672	4716	4318	56	5		330	7
Plantains		249	0	52	196	196				0	
Apples and products	11717	7250	-133	6851	11982	9302	1839	122		718	11
Pineapples and products	3	3063	22	1405	1685	1594	0			91	
Dates	4	92	0	22	71	64	0			5	
Grapes and products (excl wine)	25157	4055	0	2717	26499	3831	22139			240	293
Fruits, Other	13603	11320	42	9904	15058	13209	539	86		1329	23
Stimulants	0	9428	11	5470	3956	3919	44			26	2
Coffee and products	0	4601	68	2225	2443	2429	0			26	2
Cocoa Beans and products		4387	-59	3079	1242	1198	44				0
Tea (including mate)	0	440	2	166	271	292				0	0
Spices	143	485	0	246	376	380				3	1
Pepper		95	0	35	58	58					
Pimento	83	114	0	54	140	137				2	
Cloves		2	0	1	1	1					
Spices, Other	60	274	0	156	177	184				1	1
Alcoholic Beverages	61697	16836	1069	21843	57765	51100	2888			153	3625
Wine	16160	6212	950	7743	15579	12384	2888			111	196
Beer	38408	4918	53	7662	35723	35582				39	103
Beverages, Fermented	1269	365	18	623	1030	1027				3	
Beverages, Alcoholic	4216	1684	33	2756	3176	2107					1069
Alcohol, Non-Food	1644	3657	15	3059	2257						2257
Meat	45579	16421	-13	19411	42579	41887	393	0		84	219
Bovine Meat	8059	3213	33	3335	7979	7947	NaN			14	40
Mutton & Goat Meat	1002	372	0	230	1144	1120				4	19
Pigmeat	23374	7775	-20	10444	20684	20489	9			50	137
Poultry Meat	12285	4100	-27	4915	11443	11003	402	0		15	23
Meat, Other	859	961	1	487	1329	1328	5	0		1	
Offals	3057	843	40	2475	1463	1380	0	8		9	81
Animal fats	10039	3946	43	4939	9077	6494	67	383		44	2232
Butter, Ghee	1915	815	8	858	1879	1861		0		0	17
Cream	2351	957	0	1147	2159	2032	0			29	100
Fats, Animals, Raw	5567	1873	35	2702	4765	2563	67	232		15	2032
Fish, Body Oil	203	290	0	228	266	35		146			83
Fish, Liver Oil	3	11	0	4	8	3		5			0
Eggs	6883	1358	3	1489	6757	6088	0	2	559	78	39
Eggs	6883	1358	3	1489	6757	6088	0	2	559	78	39
Milk - Excluding Butter	155527	51385	-403	65945	140564	121839	NaN	14468		830	3928
Milk - Excluding Butter	155527	51385	-403	65945	140564	121839	NaN	14468		830	3928
Fish, Seafood	6679	18411	180	11168	14100	11597		2223	1		278
Aquatic Products, Other	56	174	0	67	163	78					83
Miscellaneous											

EUROSTAT nomenclatures of production and trade statistics

Table 40. Varying nomenclatures of production and trade statistics presented in EUROSTAT.

Production data	Trade data (based on SITC)
Fresh vegetables (incl melons)	*Vegetables, fresh, chilled, frozen or simply preserved, roots, tubers*
Brassicas	
cauliflower and broccoli	
Brussels sprouts	
cabbages	*Cabbage and similar edible brassicas, fresh or chilled*
other	
Leafy and stalked vegetables	
leeks	
celery	
lettuces	*Lettuce and chicory (incl endive), fresh or chilled*
endives	
spinach	
asparagus	
chicory	
artichokes	
other	
Vegetables cultivated for fruits	
tomatoes	*tomatoes, fresh or chilled (extra)*
cucumbers	*cucumber and gherkins, fresh or chilled*
gherkins	
eggplants	
courgettes	
gourds and pumpkins	
musk melons	
watermelons	
pepper, capsicum	
other	
Root, tuber and bulb vegetables	
carrots	*Carrots, turnips, salad beetroot, salsify, celeriac, radishes and similar*
onions	*onions and shallots, fresh or chilled*
beetroot	
celeriac	
radishes	
garlic	*garlic, leeks and other alliaceous vegetables, fresh or chilled*
other	
Fresh pulses	Leguminous vegetables, fresh or chilled
fresh peas	
fresh beans	
Other fresh vegetables	*Other vegetables, fresh or chilled*
Bovine meat	*meat of bovine animals, fresh, chilled or frozen*
Meat of sheep and goats	*meat of sheep, fresh or chilled*
	meat of goat, fresh chilled or frozen
Pig meat	*meat of swine, fresh or chilled*
Poultry meat	*Poultry not cut in pieces, fresh or chilled*
	Poultry cuts and other offal, fresh or chilled

Nomenclature of EFSA Comprehensive European Food Consumption database

Table 41. Nomenclature of EFSA Comprehensive European Food Consumption database, level 1 and 2.

Level 1	Level 2	Level 1	Level 2
Grains and grain-based products		**Animal and vegetable fats and oils**	
	Grains for human consumption		Animal fat
	Grain milling products		Fish oil
	Bread and rolls		Vegetable fat
	Pasta (Raw)		Vegetable oil
	Breakfast cereals		Fats of mixed origin
	Fine bakery wares		Margarine and similar products
Vegetables and vegetable products		**Fruit and vegetable juices**	
	Root vegetables		Fruit juice
	Bulb vegetables		Concentrated fruit juice
	Fruiting vegetables		Fruit nectar
	Brassica vegetables		Mixed fruit juice
	Leaf vegetables		Dehydrated/powdered fruit juice
	Legume vegetables		Vegetable juice
	Stem vegetables (Fresh)		Mixed vegetable juice
	Sugar plants		Mixed fruit and vegetable juice
	Sea weeds	**Non-alcoholic beverages (excepting milk based bev)**	
	Tea and herbs for infusions (Solid)		Soft drinks
	Cocoa beans and cocoa products		Tea (Infusion)
	Coffee beans and coffee products (Solid)		Coffee (Beverage)
	Coffee imitates (Solid)		Coffee imitates beverage
	Vegetable products		Cocoa beverage
	Fungi, cultivated	**Alcoholic beverages**	
	Fungi, wild, edible		Beer and beer-like beverage
Starchy roots and tubers			Wine
	Potatoes and potatoes products		Fortified and liqueur wines (e.g. Vermouth, Sherry
	Other starchy roots and tubers		Wine-like drinks (e.g. Cider, Perry)
Legumes, nuts and oilseeds			Liqueur
	Legumes, beans, green, without pods		Spirits
	Legumes, beans, dried		Alcoholic mixed drinks
	Tree nuts	**Drinking water (water without any additives except**	
	Oilseeds		Tap water
	Other seeds		Well water
Fruit and fruit products			Bottled water
	Citrus fruits		Water ice (for consumption)
	Pome fruits	**Herbs, spices and condiments**	
	Stone fruits		Herbs
	Berries and small fruits		Spices
	Oilfruits		Herb and spice mixtures
	Miscellaneous fruits		Seasoning or extracts
	Dried fruits		Condiment

Jam, marmalade and other fruit spreads

Other fruit products (excluding beverages)

Meat and meat products (including edible offal)

Livestock meat

Poultry

Game mammals

Game birds

Mixed meat

Edible offal, farmed animals

Edible offal, game animals

Preserved meat

Sausages

Meat specialities

Pastes, pâtés and terrines

Meat imitates

Fish and other seafood

Fish meat

Fish products

Fish offal

Crustaceans

Water molluscs

Amphibians, reptiles, snails, insects

Milk and dairy products

Milk and dairy products

Liquid milk

Milk based beverages

Concentrated milk

Whey and whey products (excluding whey cheese)

Cream and cream products

Fermented milk products

Milk derivatives

Cheese

Milk and milk product imitates

Eggs and egg products

Eggs, fresh

Eggs, powder

Sugar and confectionary

Sugars

Sugar substitutes

Chocolate (Cocoa) products

Confectionery (non-chocolate)

Dessert sauces

Molasses and other syrups

Honey

Dressing

Chutney and pickles

Savoury sauces

Flavourings or essences

Baking ingredients

Food for infants and small children

Infant formulae, powder

Follow-on formulae, powder

Cereal-based food for infants and young children

Ready-to-eat meal for infants and young children

Yoghurt, cheese and milk-based dessert for infants

Fruit juice and herbal tea for infants and young children

Infant formulae, liquid

Follow-on formulae, liquid

Products for special nutritional use

Food for weight reduction

Dietary supplements

Food for sports people (labelled as such)

Dietetic food for diabetics (labelled as such)

Medical food (are specially formulated and intende

Composite food (including frozen products)

Cereal-based dishes

Rice-based meals

Potato based dishes

Beans-based meals

Meat-based meals

Fish and seafood based meals

Vegetable-based meals

Egg-based meal (e.g., omelette)

Mushroom-based meals

Ready to eat soups

Prepared salads

Snacks, desserts, and other foods

Snack food

Ices and desserts

Other foods (foods which cannot be included in any

Table 42. Population by age class, % of total population, used for EFSA data conversion (source : EUROSTAT 2016 for EU 2011)

EU Member State	0-14 years Children	15-24 years Adolescent	25-64 years Adults	65-more Elderly
BE	17,0%	12,1%	53,8%	17,1%
BG	13,2%	11,8%	56,5%	18,4%
CZ	14,5%	12,0%	58,0%	15,6%
DK	17,9%	12,5%	52,8%	16,8%
DE	13,4%	11,2%	54,8%	20,6%
EE	15,3%	13,0%	54,2%	17,4%
IRL	21,3%	12,9%	54,4%	11,5%
GR	14,6%	10,9%	55,2%	19,3%
ES	15,0%	10,3%	57,6%	17,1%
FR	18,6%	12,3%	52,4%	16,8%
CR	15,3%	11,8%	55,2%	17,7%
IT	14,1%	10,0%	55,5%	20,5%
CY	16,8%	16,0%	54,5%	12,7%
LV	14,2%	13,4%	54,0%	18,4%
LT	14,9%	14,2%	53,1%	17,9%
LU	17,6%	11,9%	56,6%	13,8%
HU	14,6%	12,3%	56,3%	16,8%
MT	15,0%	13,5%	55,8%	15,7%
NL	17,5%	12,3%	54,8%	15,6%
AT	14,7%	12,2%	55,4%	16,5%
PL	15,3%	13,7%	57,4%	13,6%
PO	15,1%	10,9%	55,3%	18,7%
RO	14,7%	12,2%	55,8%	16,1%
SI	14,2%	11,2%	58,1%	16,5%
SV	15,4%	14,0%	58,0%	12,6%
FI	16,5%	12,3%	53,7%	17,5%
SV	16,6%	13,3%	51,6%	18,5%
UK	17,6%	13,1%	52,9%	16,5%

Table 43. Surveys included in EFSA database.

Use of the Comprehensive Database

Table 1: Dietary surveys included in the EFSA Comprehensive European Food Consumption Database

Country	Name of the dietary survey (Acronym)	Survey period	Geographical level	Age range (years old)	Number of subjects	Method	Replicates	Amount reported[a]	Reference
Austria	ASNS	2005 – 06	National	19 to 65	2,123	24-hour recall	1	as consumed	Elmadfa et al., 2008
Belgium	Regional Flanders	2002 – 03	Regional	2.5 to 6.5	661	Food record	3	mixed	Huybrechts et al., 2008
	Diet National 2004	2004 – 05	National	> 15	3,245	24-hour recall	2	as consumed	De Vriese et al., 2005
Bulgaria	NSFIN	2004	National	> 16	1,204	24-hour recall	1	as raw	Petrova & Angelova, 2006
	NUTRICHILD	2007	National	< 5	1,723	24-hour recall	2	mixed	Petrova et al., 2009
Cyprus	Childhealth	2003	National	11 to 18	303	Food record	3	mixed	Not available
Czech Republic	SISP04	2003 – 04	National	> 4	1,751	24-hour recall	2	as raw	Ruprich et al., 2006
Denmark	Danish Dietary Survey	2000 – 02	National	4 to 75	4,118	Food record	7	as raw[c]	Lyhne et al.2005
Estonia	NDS 1997	1997	National	19 to 64	1,866	24-hour recall	1	mixed	Pomerleau et al., 1999
Finland	FINDIET 2007	2007	National	25 to 74	2,038	48-hour recall	1	as raw[c]	Paturi et al., 2008; Reinivuo et al, 2010
	DIPP	2003 – 06	Regional	1, 3 and 6	1,448	Food record	3	mixed	Räsänen et al., 2006
	STRIP	2000	Regional	7 to 8	250	Food record	4	mixed	Simell et al., 2009
France	INCA2	2005 – 07	National	3 to79	4,079	Food record	7	as consumed	AFSSA, 2009; Lioret et al. 2010; Dubuisson et al. 2010
Germany	DONALD	2006 – 08	Regional	1 to 10	926	Food record	3	mixed	Kroke et al., 2004; Sichert-Hellert and Kersting, 2004
	National Nutrition Survey II	2005 – 07	National	14 to 80	13,926	24-hour recall	2	as consumed	MRI, 2008; Krems et al., 2006
Greece	Regional Crete	2004 – 05	Regional	4 to 6	874	Food record	3	mixed	Linardakis et al., 2008
Hungary	National Repr Surv	2003	National	> 18	1,360	Food record	3	as raw[c]	Rodler et al., 2005
Ireland	NSIFCS	1997 – 99	National	18 to 64	958	Food record	7	as raw	Kiely et al., 2001; Harrington et al., 2001
Italy	INRAN-SCAI 2005–06	2005 – 06	National	> 0.1	3,323	Food record	3	as raw	Leclercq et al., 2009
Latvia	EFSA_TEST	2008	National	7 to 66	2,070	24-hour recall	2	as consumed[b]	Šantare et al., 2008
Netherlands	VCP_kids	2005 – 06	National	2 to 6	1,279	Food record	3	as raw	Ocké et al., 2008
	DNFCS-2003	2003	National	19 to 30	750	24-hour recall	2	as raw	Ocké et al., 2005
Poland	IZZ-FAO-2000	2000	National	1 to 96	4,134	24-hour recall	1	as raw	Sekula et al., 2004; Szponar et al., 2001 and 2003
Slovakia	SK MON 2008	2008	National	19 to 59	2,761	24-hour recall	1	mixed[b]	Not available
Slovenia	CRP-2008	2007 – 08	National	18 to 65	410	24-hour recall	1	as consumed	Gabrijelčič Blenkuš et al. 2009
Spain	enKid	1998 – 00	National	1 to 14	382	24-hour recall	2	mixed	Serra-Majem et al., 2001
	NUT-INK05	2004 – 05	Regional	4 to 18	1,050	24-hour recall	2	mixed	Larrañaga Larrañaga et al., 2006
	AESAN-FIAB	1999 – 2001	National	17 to 60	1,068	Food record	3	as consumed	Requejo et al., 2002
	AESAN	2009	National	18 to 60	418	24-hour recall	2	as consumed	Ortega et al., 2010
Sweden	NFA	2003	National	3 to 18	2,495	24-hour recall	4	as consumed	Enghardt-Barbieri et al., 2006
	RIKSMATEN 1997-98	1997 – 98	National	18 to 74	1,210	Food record	7	as consumed[b]	Becker and Pearson, 2002
United Kingdom	NDNS	2000 – 01	National	19 to 64	1,724	Food record	7	as cooked	Henderson et al 2002

[a] For some of the dietary surveys a different approach from the one listed here has been used to report amounts consumed of specific foods/composite dishes.
[b] Significant proportion of composite dishes were not disaggregated
[c] Most/part of the cereal products (e.g. bread and/or fine bakery ware) were disaggregated to their basic ingredients e.g. flour etc.

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Use of the Comprehensive Database

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Source: *EFSA, 2011, GUIDANCE of EFSA, Use of the EFSA Comprehensive European Food Consumption Database in Exposure Assessment, Parma, Italy*

ANNEX II. Technical look-up tables Task 1

Table 44. Water content feedstuff (Eurostat)

Crop	**Humidity**	**Crop**	**Humidity**
I. Plants harvested green l fresh		II. Plants harvested as silage	
Grass (1. cut)	78 - 85 %	Grass	65%
Grass (2.+ cut)	80 - 84 %	Clover / -grass-mixtures	65%
Clover-grass-mixtures (1. cut)	80 - 85 %	Lucerne / -grass-mixtures	65%
Clover-grass-mixtures (2.+ cut)	82 - 84 %	Barley / wheat	58 - 62 %
Clover (1. cut)	80 - 88 %	Oats	65%
Clover (2.+ cut)	82 - 88 %	Rye	75%
Lucerne-grass-mixtures (1. cut)	80 - 85 %	Field beans	65%
Lucerne-grass-mixtures (2.+ cut)	80 - 83 %	Millet / sorghum / sudan grass	65%
Lucerne (1. cut)	79 - 82 %	Rape and turnip rape	84 - 85 %
Lucerne (2.+ cut)	80 - 82 %	III. Plants harvested as hay	
Barley	76%	Grass	13 - 16 %
Oats	76 - 80 %	Clover / -grass-mixtures	13 - 16 %
Rye	78%	Lucerne / -grass-mixtures	13 - 16 %
Field beans	82%		
Mixed pulses	80 - 88 %		
Sunflower	82%		
Rape and turnip rape	86 - 90 %		

Table 45. Water content crops (Eurostat)

Product	**Standard EU aggregate humidity**	**Product**	**Standard EU aggregate humidity**
Cereals (except rice)	14 %	Soya seed	14 %
Rice	13 %	Linseed (oil flax)	9 %
Dry pulses and protein crops	14 %	Cotton seed	9 %
Rape and turnip rape seeds	9 %	All Plants harvested green	65%
Sunflower seed	9 %		

Table 46. Fat content of some dairy products (misc. sources)

low-fat milk (<0.5% fat),	coffee creamer (12% fat),
butter milk (<1% fat),	cooking cream (a.k.a. single cream 20% fat),
skim milk (1-1.8% fat),	sour cream (20-30% fat),
whole milk (1.8-3.5% fat) etc..	normal ('double') cream (30-40% fat)

Note: The problem with weight-based accounting of milk is the large deviations between data sources. Possible causes are differences in definitions of the product (e.g. is milk with <1% fat or 6-21% fat still 'drinking milk'?), accounting units ('raw milk equivalent' or actual weight), water extraction rates (there is roughly one-third weight loss from various processing processes) , partitioning in multi-product processing (cascade from milk to cheese+whey and then from whey to whey powder, liquid whey, concentrated whey, casein, lactose, etc.).

The evaporation of water and other juices during cooking can be quite substantial as is shown in the table below. When cooking rhubarb or leek half of the weight is lost through evaporation. For most of the brassicas and leafy vegetables one-third is lost in cooking and for all the other vegetables still some 12-15% weight loss comes from cooking.

Table 47. Uncooked food weight in g needed to obtain 100 g of cooked food (median values)

bovine/poultry meat	122	courgette	115
pig meat	115	Parsnip	120
potatoe	91	snow peas	115
pasta	40	pumpkin	140
rice	34	leek	190
endive	164	rhubarb	200
asparagus	120	red cabbage	115
eggplant	115	string beans	100
sweet potato	140	green beans	110
beetroot (pre-cooked)	100	spinach	190
sellery	165	cabbage	140
cauliflower	140	sprouts	120
kale	215	fennel	140
carrot	115	chicory	140
broccoli	140	white cabbage	115
chinese cabbage	165	sauerkraut	115

sources:

R. Smits, het waterbindende vermogen van vlees, Afstudeerscriptie Moleculair koken, Hogeschool van Amsterdam, 2011.

http://www.projectgezond.nl/ongekookt-gekookt-gewicht/

https://www.gezondheidsnet.nl/groente-en-fruit/hoe-kom-je-aan-250-gram-groenten

Note that there may be considerable differences between sources. More sources:

Bognár, A., *Tables on weight yield of food and retention factors of food constituents for the calculation of nutrient composition of cooked foods (dishes)*, Berichte der Bundesforschungsanstalt für Ernährung, Germany, 2002.

Agricultural Handbook No. 102 -- *Food yields summarized by different stages of preparation*, US Dept. of Agriculture (USDA), 1975.

Table 48. Meat & products: Content of water, protein, fat, ash (in percent) and calories (approximate values). Source: FAO

Product	Water	Protein	Fat	Ash	Calories / 100g
FRESH MEAT					
Beef (lean)	75	22.3	1.8	1.2	116
Beef carcass	54.7	16.5	28	0.8	323
Pork (lean)	75.1	22.8	1.2	1	112
Pork carcass	41.1	11.2	47	0.6	472
Veal (lean)	76.4	21.3	0.8	1.2	98
Chicken	75	22.8	0.9	1.2	105
Venison (deer)	75.7	21.4	1.3	1.2	103
Beef fat (subcutaneous)	4	1.5	94	0.1	854
Pork fat (back fat)	7.7	2.9	88.7	0.7	812
PROCESSED MEAT					
Beef, lean, fried	58.4	30.4	9.2		213
Pork, lean, fried	59	27	13		233
Lamb, lean, fried	60.9	28.5	9.5		207
Veal, lean, fried	61.7	31.4	5.6		186
Raw-cooked sausage with coarse lean particles (ham sausage)	68.5	16.4	11.1		170
Raw-cooked sausage finely comminuted, no extender	57.4	13.3	22.8	3.7	277
Raw-cooked sausage (frankfurter type)	63	14	19.8	0.3	240
Precooked-cooked sausage (liver sausage)	45.8	12.1	38.1		395
Liver pate	53.9	16.2	25.6	1.8	307
Gelatinous meat mix (lean)	72.9	18	3.7		110
Raw-fermented sausage (Salami)	33.9	24.8	37.5		444
OTHER FOODSTUFFS					
Milk (pasteurized)	87.6	3.2	3.5		63
Egg (boiled)	74.6	12.1	11.2		158
Bread (rye)	38.5	6.4	1		239
Potatoes (cooked)	78	1.9	0.1		72

URL: http://www.fao.org/docrep/010/ai407e/ai407e03.htm

Table 49. Water content fruits (misc. sources)

Water melon	92%	framboise	87%
strawberry	92%	orange	87%
grapefruit	91%	berries	85%
melon	90%	apples & pears	84%
peach	88%	cherries	84%
Pineapple	87%	banana	74%

ANNEX III. Food waste, selected sources

Table 50. Food waste per food group according to misc. sources

Vanham 2015, table 4	total	avoidable
cereals	17.1%	17.1%
potatoes	25.5%	25.5%
sugar	5-10%	5-10%
pulses	5.0%	4.7%
crop oils	5.0%	4.7%
vegetables	26.2%	20.9%
fruits	25.5%	12.6%
stimulants	5-10%	5-10%
spices	5-10%	5-10%
alcoholic beverages	3-7%	3-7%
meat	14.5%	7.7%
animal fats	5.0%	5.0%
eggs	11.9%	5.1%
milk&yoghurt	7.0%	5.2%
cheese	7.9%	6.0%
cream	5.2%	5.2%
fish	14.5%	7.4%

SIK report 2013	avoidable
cereals	25%
Roots &tubers, fresh	17%
roots& tubers, processed	12%
	–
oilseeds & pulses	4%
vegetables, fresh	19%
vegetables, processed	15%
meat	11%
eggs	8%
milk	7%
fish, fresh	11%
fish, processed	10%

WRAP 2014, product focused report, table 9/10	total	avoidable
bakery	28.0%	23.0%
potato, processed	13.4%	13.4%
confectionary & snacks	5.4%	5.3%
oil & fat	13.0%	3.7%
vegetables, frehs	42.0%	21.0%
vegetables, processed	11.0%	10.0%
fruits, fresh	37.0%	14.0%
fruits, processed	13.0%	12.0%
condiments, sauces, herbs, spices	14.0%	14.0%
meat & fish	15.0%	15.0%
beef	12.6%	7.7%
lamb	12.0%	4.4%
pork	17.6%	12.4%
poultry	34.3%	13.1%
eggs	23.3%	9.0%
dairy & eggs	7.9%	7.1%
cheese	9.0%	9.0%
cream	10.6%	10.6%
milk	7.0%	7.0%
yoghurt	8.8%	8.8%
fish & shellfish	11.8%	9.6%
drink	9.2%	7.5%
soft drinks	7.2%	7.2%
fruit juice	12.0%	12.0%
beer	5.5%	5.5%
wine	5.4%	5.4%
staple foods	7.5%	7.5%
cake & desserts	15.0%	15.0%

WWF Germany 2012, figure 3.2	total waste	avoidable waste
cereals, cereal products	23%	20%
potato, potato products	26%	17%
sugar, sweets	15%	13%
Oils, fats	15%	10%
vegetables, veg products	29%	13%
Fruit, fruit vegetables	29%	13%
meat, meat products	16%	8%
Eggs, egg products	16%	15%
milk, dairy products	14%	13%
fish, fish products	26%	12%

ANNEX IV. Refrigerator compartment temperatures

Table 51. Target temperatures for energy determination by compartment type (IEC 62552-3:2015 Table 1)

Compartment type	Target average air temperature °C
Pantry	17
Wine storage	12
Cellar	12
Fresh food	4
Chill	2
Zero-star	0
One-star	–6
Two-star	–12
Three-star and Four-star	–18

Table 52. Compartment temperatures

°C								
Compartment type								
Fresh food		**Three-star and four-star**	**Two-star**	**One-star**	**Zero-star**	**Chill**	**Cellar**	**Pantry**
T_{1m}, T_{2m}, T_{3m}	T_{ma}	T*** [a]	T** [a]	T* [a]	T_{zma}	T_{cci}	T_{cma}	T_{pma}
$0 \leq T_{1m}, T_{2m}, T_{3m} \leq +8$ average	$\leq +4$ average	≤ -18 [b] maximum	≤ -12 [b] maximum	≤ -6 maximum	≤ 0 average	$-3 \leq T_{cci} \leq +3$ instantaneous	$+2 \leq T_{cma} \leq +14$ average	$+14 \leq T_{pma} \leq +20$ average

[a] The superscripts attached to the symbol T correspond to the **three-star** and **four-star**, **two-star** or **one-star compartment** temperature.

[b] During a **defrost and recovery period**, these **storage temperatures** of **frost-free refrigerating appliances** are permitted to rise by no more than 3 K.

NOTE For definitions of symbols, see 3.7 in IEC 62552-1:—

Following the discussions during the review study it is proposed to split the 'chiller' definition in two types:

- a 'meat/fish' chiller with instantaneous temperature Ti of -3≤Ti≤+2°C and an average test temperature Ta of 0°C;
- a 'salad' chiller with instantaneous temperature Ti of 0<Ti≤+3°C and an average test temperature Ta of 2°C.

The zero, one- and two star compartments are not relevant for storage; it is sufficient to define 'freezing' as a 3 or 4 star condition at -18°C. The freezer condition is mainly relevant for fresh food that, without significant loss of taste, can be stored frozen and quickly thawed before consumption (e.g. bread). Other than that, frozen food is considered to be a different category. Apart from the above, a distinction could be made between foodstuffs that can be stored at ambient conditions but are best served chilled (e.g. soft-drinks, beer).

ANNEX V. Additional tables Task 2

Table 53. Optimal temperature and relative humidity conditions of fruits according to various sources.

	Temperature °C				Relative Humidity (RH) %			
	TIS GVD[149]	Cargo Handbook (BMT Surveys)[150]	Hamburg-Süd reefer guide[151]	UC Davis Postharvest Technology[152]	TIS GVD	Cargo Handbook (BMT Surveys)	Hamburg-Süd reefer guide	UC Davis Postharvest Technology
pineapple	4.5 to 7 ripe 10 to 12 unripe	7 ripe, 10 to 12 unripe	7 to 13	7 to 10 ripe, 10 to 13 unripe	85-90	90	85-90	85-90
apples	1.1 to 4.4	-1 to +4	-1 to 4	0 to 3	90-95	90-95	90-95	90-95
avocado	5 to 8 ripe, 8 to 12 unripe	5 to 12	4 to 13	5 to 13	90	85-95	85-95	90-95
banana	13 to 15	13 to 14	13 to 14.4	13 to 14, 15 to 20 unripe	90-95	85-95	90-95	90-95
pear	0.6 to 1.7	-1 to -0.5	-1.5 to 0	-1 to 0	90-95	90-95	90-95	90-95
clementine	6 to 9	4 to 5	4 to 8	_	85	90	90-95	_
grapefruit	14.4 to 15.6	10 to 15	10 to 15	12 to 14	85-90	90	85-90	90-95
blueberries	-1 to 0	0	-1 to 0	_	90-95	90-95	90-95	_
cherries	0 to 2	-1 to 0	-1 to 0	-0.5 to +0.5	90-95	90-95	90-95	90-95
kiwifruit	0 to 1	-1 to +1	-0.5 to +5	0	90-95	90-95		90-95
lime	8 to 12	9 to 10	8 to 12	10 to 13	85-90	90	85-90	90-95
mandarin	5 to 8	4 to 8	4 to 8	5 to 8	85-90	90	90-95	90-95
mango	10 to 14	8 to 10	8 to 14	10 ripe to 13 unripe	85-90	85-90	85-95	90-95
orange	5 to 10	2 to 7	2 to 10	3 to 8	85-90	90	85-90	90-95
Peaches, nectarines	0 to 1	0	-0.5 to 0	-1 to 0	90	90-95	90-95	90-95
grapes	-1 to 0	-0.5 to 0	-1 to 0	-1 to 0	90-95	90-95	85-95	_
lemons	10 to 14	10 to 14	10 to 14	12 to 14	85-90	90	85-95	90-95
cantaloupe	_	2 to 4	2 to 5	2.2 to 5	_	90-95	90-95	90-95
galia, honeydew	_	8 to 10	9 to 12	7 to 10	_	90-95	90-95	85-90
watermelon	_	10	9 to 12	10 to 15	_	90-95	90-95	85-90
strawberries	_	0	-0.5 to 0	0 to 0.5	_	90-95	90-95	90-95

[149] Transport Information Service, Die Deutschen Versicherer, Cargo loss prevention information from German Marine insurers
[150] Cargo Handbook BMT Surveys Rotterdam BV. www.cargohandbook.com
[151] Hamburg-Süd reefer guide, recommended transport conditions and approximate shelf life of reefer cargo
[152] University of California, Division of Agriculture and Natural Resources, Postharvest technology, Produce fact sheet http://postharvest.ucdavis.edu/Commodity_Resources/Fact_Sheets/

Table 54. Optimal temperature and relative humidity conditions of vegetables according to various sources.

	Temperature °C				Relative Humidity (RH) %			
	TIS GVD	Cargo Handbook (BMT Surveys)	Hamburg-Süd reefer guide	UC Davis Postharvest Technology**Error! Bookmark not defined.**	TIS GVD	Cargo Handbook (BMT Surveys)	Hamburg-Süd reefer guide	UC Davis Postharvest Technology
artichokes	0 to 1	0 to 1	0 to 2	0	90-95	≥95	90-95	≥95
cucumbers	7 to 12	10 to 12	10 to 13	10 to 12.5	90-95	95	90-95	95
carrot	0 to 1	0 to 1	0 to 2	0	95	≥95	90-98	≥98
sweet pepper, paprika	7 to 10	7 to 13	7 to 10	7.5	90-95	90-95	90-95	≥95
asparagus	0.5 to 1	0 to 2	0 to 2	0 to 2	90-95	95	90-98	≥95
tomatoes	8 to 10 ripe, 10 to 12 unripe	8 to 10 ripe, 10 to 15 unripe	7 to 15	7 to 10 ripe, 10 to 15 unripe	80-85	90	65-90	90-95
onions	0 to 4	0	0 to 8	0	75-80	65-75	65-75	65-70
eggplant	_	10 to 12	8 to 12	10 to 12	_	90-95	90-95	90-95
beetroot	_	0 to 1	_	_	_	≥95	_	_
beans (snap and french)	_	5 to 7.5	4 to 7.5	5 to 7.5	_	95	95-98	≥95
broccoli	_	0 to 5	0 to 1	0	_	≥95	90-98	≥95
cabbage	_	0	0 to 2	0	_	≥95	90-98	≥95
cauliflower	_	0 to 1	0 to 1	0	_	≥95	90-98	95-98
celery	_	0 to 1	_	0	_	≥95	_	≥98
chicory	_	0 to 2	_	0	_	≥95	_	≥95
endive	_	0	_	_	_	≥95	_	_
leek	_	0	_	_	_	≥95	_	_
lettuce	_	0	0 to 1	0	_	≥95	90-98	≥95
mushrooms	_	0 to 1	0 to 1	0 to 1.5	_	95	90-98	95-98
spinach	_	0	_	0	_	95-98	_	95-98
potatoes	4 to 12	4 to 10	5 to 10	7	85-90	90-95	85-95	98

Table 55. Ethylene production and sensitivity

	Ethylene production				Ethylene sensitivity		
	TIS GVD	Cargo Handbook	UC Davis Error! Bookmark not defined.		TIS GVD	Cargo Handbook	UC Davis
	µl/kg·h		µl/kg·h	°C			
pineapple	<0.1	low	<0.2	20	low, avoid loading together with citrus fruits	low	low, slightly faster de-greening without influencing internal quality
apples	>100	yes, do not ship with ethylene-sensitive commodities	4-12	0	high	–	can accelerate senescence and loss of firmness
avocado	10-100	high, climacteric, do not ship with ethylene-producing commodities	>100 when ripe	20	high, do not store together with ethylene-producing goods	high	high levels induce avocados to ripen in 3-6 days
banana	1 - 10	moderate, climacteric,	0.2-5 0.3-10	15 20	high, do not store together with ethylene-producing goods	high	most commercial cultivars require exposure to high levels of ethylene to induce ripening
pear	10-100	high, climacteric, do not ship with ethylene-sensitive commodities	0.1-0.5 2-4 5-15 20-100	0 5 10 20	high, do not store together with ethylene-producing goods	high	can be treated with ethylene to ensure uniform ripening within 4-6 days
clementine	0.1-1.0	very low	–	–	none	moderate, do not ship with ethylene-emitting produce	
grapefruit	<0.1	very low	0.1	20	moderate, do not store with elevated ethylene-producing goods	moderate	exposure to ethylene accelerates de-greening and increases susceptibility to decay
blueberries	0.1-1.0	low, climacteric	–	–	low	low	
cherries	<0.1	very low	–	–	low, must not be stored with apples, pears and citruses	low	minimal
kiwifruit	0.1-1.0	low, climacteric	<0.1 (unripe) 0.1-0.5 (unripe) 50-100 (ripe)	0 20 20	high, do not store together with ethylene-producing goods	high, do not ship with ethylene-emitting produce	extremely sensitive, avoid exposure to ethylene during transport and storage
lime	<0.1	very low	–	–	moderate	moderate, do not ship with ethylene emitting produce	ethylene causes de-greening
mandarin	<0.1	very low	–	–	moderate, do not store with elevated ethylene-producing goods	moderate, do not ship with ethylene emitting produce	de-greening by exposure to ethylene. Removal of ethylene from storage reduces decay
mango	1-10	moderate, climacteric	0.1-0.5 0.3-4.0 0.5-8.0	10 15 20	high, do not store together with ethylene producing goods	high	exposure to ethylene results in accelerated and more uniform ripening
orange	<0.1	very low	<0.1	20	moderate, do not store with elevated ethylene-producing goods	moderate, do not ship with ethylene emitting produce	exposure to ethylene may be used for de-greening and may accelerate decay
peaches/nectarines	10-100	high, climacteric	<0.01-5 0.02-10 0.05-50 0.1-160	0 5 10 20	high, do not store together with ethylene-producing goods	high, do not ship with ethylene-generating commodities	exposure to ethylene ripens the fruit more uniformly, does not accelerate ripening
grapes	<0.1	very low	–	–	low	moderate	not very sensitive
lemons	<0.1	very low	–	–	moderate, do not store with elevated ethylene-producing goods	moderate, do not ship with ethylene-producing commodities	exposure to ethylene may be used for de-greening and may accelerate decay

cantaloupe		moderate, climacteric	40-80 (intact fruit) 7-10 (fresh cut)	20 5		high, do not ship with ethylene-producing commodities	moderately sensitive, over-ripening may be a problem during transport and storage
galia, honeydew	1-10	moderate, climacteric	0.5-10 (intact fruit) 14-25 (fresh cut)	20 5	high	high, do not ship with ethylene-producing commodities	ripening with ethylene is no longer a common practice for the California honeydew industry
watermelon	0.1-1.0	moderate	0.1-1.0	20	low	high, do not ship with ethylene-producing commodities	exposure to ethylene will cause unacceptable loss of firmness and quality
strawberries		low	_			low	not sensitive, removal of ethylene from storage air may reduce disease development

	Ethylene production				Ethylene sensitivity		
	TIS GVD	Cargo Handbook	UC Davis		TIS GVD	Cargo Handbook	UC Davis[Error! Bookmark not defined.]
	µl/kg·h		µl/kg·h	°C			
artichokes	<0.1	very low	very low	_	low	low	low sensitivity
cucumbers	0.1-1.0	low	0.1-1.0	20	high, do not store together with ethylene-producing goods	high, ambient ethylene causes rapid yellowing	highly sensitive, causes accelerated yellowing and decay, do not mix with bananas, melons, tomatoes
carrot	<0.1	very low	<0.1	20	low	low	exposure to ethylene induces development of bitter flavour, do not mix with ethylene-producing commodities
sweet peper/paprika	0.1	low	0.1-0.2	10-20	low	low	very low sensitivity
asparagus	<0.1	very low	_	_	moderate	moderate	exposure to ethylene will accelerate lignification (toughening) of asparagus spears
tomatoes	1-10	very low, climacteric	1.2-1.5 4.3-4.9	10 20	high, do not store together with ethylene-producing goods	high	exposure to ethylene will initiate ripening
onions	<0.1	very low	_	_	low, do not load together with apples or pears	low	ethylene exposure may encourage sprouting and growth of decay-causing fungi
eggplant	0.1-1.0	very low	0.1-0.7	12.5	low	moderate	moderate to high sensitivity to ethylene, increases deterioration and browning
beetroot	<0.1	very low	_	_	low	moderate	_
beans (snap and french)	0.1-1.0	low	_	_	moderate	moderate	exposure to ethylene may cause loss of green pigment and increased browning
broccoli	<0.1	very low	very low	_	high	high, floret yellowing	extremely sensitive to ethylene, causes floret yellowing and may reduce shelf-life by 50%
cabbage	<0.1	very low	very low	_	high	high, leaf abscission and leaf yellowing	sensitive to ethylene, causes leaf abscission and leaf yellowing
cauliflower	<0.1	very low	_	_	high	high, leaf yellowing	highly sensitive to ethylene, causes discoloration and accelerated yellowing, do not mix with apples, melons, tomatoes
celery	<0.1	very low	_	_	moderate	moderate	slightly sensitive, exposure to ethylene may cause loss of green colour
chicory	<0.1	very low	<0.1 0.2 0.7	0 10 20	high	high, russet spotting	moderately sensitive, may cause accelerated decay and discoloration of the leafs

endive	<0.1	low	_	_	moderate	low, leaf yellowing	_
leek	<0.1	very low	_	_	moderate	moderate, tissue softening	_
lettuce	0.1-1	low	very low	_	high	high	extremely sensitive to ethylene, causes russet spotting
mushrooms	<0.1	very low	<0.1	20	moderate	moderate, browning of mushroom caps	no significant impact by exposure to ethylene
spinach	<0.1	very low	_	_	high	high, leaf yellowing	highly sensitive to ethylene, may result in accelerated yellowing
potatoes	<0.1	very low	very low	_	moderate, do not store together with elevated ethylene-producing goods, premature sprouting	moderate	high concentrations of ethylene may induce sprouting