European Commission

The European Commission's Knowledge Centre for Bioeconomy

Brief on food waste in the European Union

Key messages

1. According to a recent analysis, 129 Mt of food waste were generated in the EU in 2011. This represents 20% of the food produced. Vegetables, fruit and cereals are the food groups that produce the largest amount of food waste (see section 2).

2. Most food waste is generated during the consumption stage (46%), almost as much as the amounts generated during the primary production (25%) and processing and manufacturing stages (24%) combined. Distribution and retail account for a very small fraction of the food waste generated in the food supply chain (see section 3).

3. The food waste generated at the processing stage has a high valorisation[1] potential, as the food waste streams are present in large, concentrated and homogeneous quantities. Food waste can be transformed into a range of added-value products through several valorisation pathways. The technological and economic feasibility and the environmental impacts of these products need to be comprehensively assessed in order to select the processes and products that enable optimal valorisation of food waste while ensuring sustainability and safety throughout the value chain (see section 4).

4. Actions to tackle food waste require an evaluation framework which includes SMART[2] objectives and Key Performance Indicators to track the achievement of each action's goals and avoid significant trade-offs (see section 5).

[1] Waste valorisation refers to any processing activity aimed at reusing, recycling, or composting waste to yield useful products with an added value (including chemicals, materials, and fuels).
[2] SMART stands for Specific, Measurable, Achievable, Relevant, Time-Bound.

1. What is food waste?

The FUSIONS[3] framework defines food waste as "food and inedible parts of food removed from the food supply chain" that is to be disposed of (e.g. crops ploughed back into the soil, left unharvested or incinerated, food disposed of in sewers or landfill sites, or fish discarded at sea) or used for nutrient recovery or energy generation (e.g. through composting, or anaerobic digestion and other bioenergy pathways) (FUSIONS, 2014[4]).

Inedible parts of food are those parts that are not intended for human consumption, such as bones, rinds, and pits/stones. However, there is no universal definition of the inedible fraction of food waste, which is influenced by a range of variables, including cultural habits (e.g. chicken feet are more commonly consumed in some countries than in others), socio-economic factors, food availability and price, technological advances, international trade, and geography.

Hence, food waste includes parts of food intended to be eaten and parts of food not intended to be eaten (EC, 2019). On the other hand, food waste does not include:

- pre-harvest losses, i.e. losses that occur before the raw material is ready for harvest or slaughter, such as weather-related damage to crops (which is accounted for as agricultural waste);
- by-products[5], i.e. edible or inedible material resulting from food production and processing, such as peels, bones, and scrapings, that are then used for non-food purposes (e.g. cosmetics, glue, pet-food);
- food packaging, such as boxes, wrapping, or plastic containers (although edible packaging would be considered food because it is intended for human consumption).

The FUSIONS' definition of food waste is in line with the official definition adopted by the European Commission[6] (EU, 2018), with the difference being that the latter does not include crops ploughed back into the soil or left unharvested (e.g. crop produce left in the field due to its low economic profitability); see Figure 1.

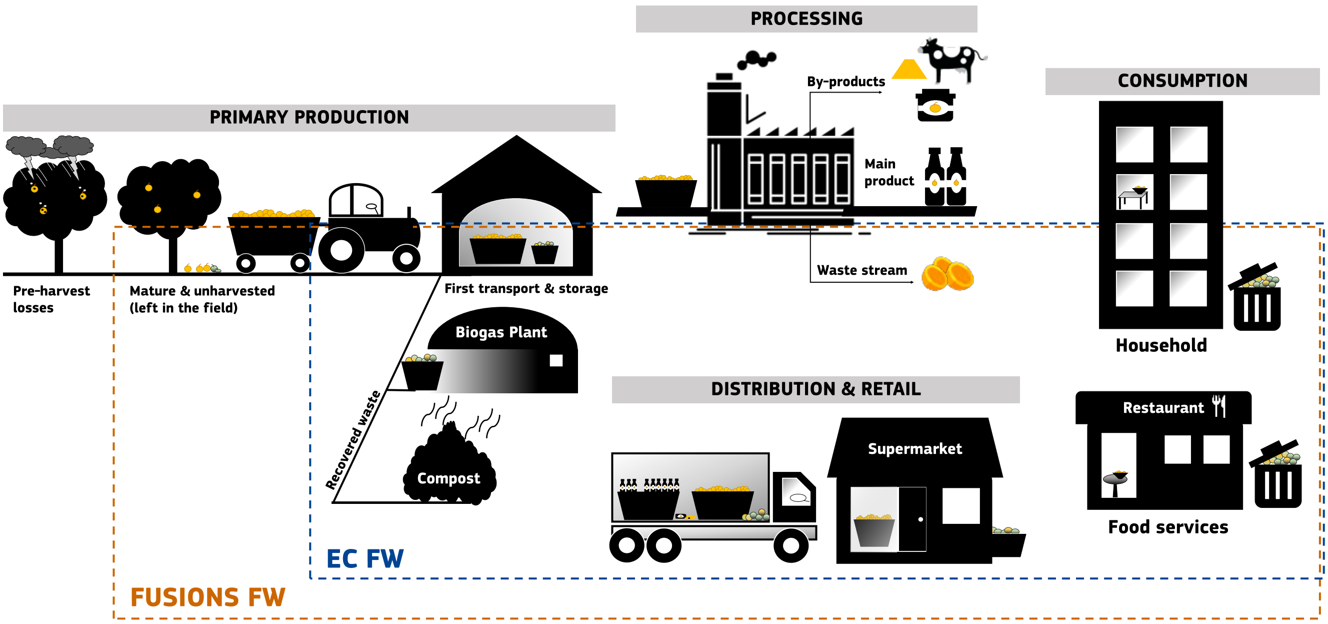


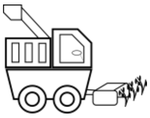
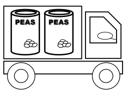
Figure 1. Boundaries of food waste (FW) as defined by FUSIONS (2014)[4] and the EU (2018).

[3] FUSIONS (Food Use for Social Innovation by Optimising Waste Prevention Strategies) was a project that aimed to estimate food waste generation in the EU (https://www.eu-fusions.org/), implemented in 2007-2012 with financial support from the EU's Research and Innovation 7th Framework Programme.
[4] This definition is consistent with the principles of the Food Loss and Waste Standard, a global standard that provides requirements and guidance for quantifying and reporting on food waste (FLW Protocol, 2016). As in Caldeira et al. (2019a), this is the definition used in this brief.
[5] As defined in Directive 2008/98/EC, Article 5(1), i.e. meet the following criteria: further use of the substance or object is certain; the substance or object can be used directly without any further processing other than normal industrial practice; the substance or object is produced as an integral part of a production process; and further use is lawful.
[6] Food waste means all food as defined in Article 2 of Regulation (EC) No 178/2002 (European Parliament and Council, 2002) that has become waste.

As other definitions of food waste are found in the scientific literature, food waste quantification assessments vary with regard to the types of materials covered (e.g. some studies cover only the edible parts of food). Such differences, together with divergences in the system boundaries and the methods used for data collection, hinder a robust quantification of food waste which could be used to develop policies that tackle the issue.

Table 1 presents specific examples of different types of food waste grouped by stage of the food supply chain and large food groups.

Table 1. Possible food waste by stage in the food supply chain. Source: adapted from Corrado et al. (2017).

Stage in food supply chain	**Crops**	**Animals and animal products**
Primary production (incl. first transport and storage) 	Non-harvested edible products Edible products left in the field Edible products harvested but not sold Rotten fruit or vegetables Products damaged by machinery Spilled products Products damaged due to poor handling Products stored in poor conditions	Discarded fish Food lost due to poor storage
Processing 	Issues in processing (e.g. inefficiencies, contamination, etc.) Inedible food waste (e.g. skins, seeds, bones, fruit pomace, etc.) Food damaged by inappropriate packaging	
Distribution 	Food damaged due to lack of cooling/storage facilities Expired food Unsold food Food rejected after quality controls	
Consumption 	Food damaged due to lack of cooling/storage facilities Food not eaten e.g. due to excess, elapsed expiration date, inappropriate packaging, low consumer appeal, and plate waste (i.e. food served but not eaten). Inedible food waste (fruit kernels, bones, etc.)	

2. How much food waste is generated by different food groups in the EU?

According to a Mass Flow Analysis by Caldeira et al. (2019a), around 638 Mt of food commodities were available for human consumption in the EU[7] in 2011[8], generating approximately 129 Mt (fresh weight) of food waste along the whole food supply chain[9] (see Figure 2). Hence, food waste accounts for 20% of food produced. This estimate is significantly higher than that of the FUSIONS project (88 Mt)[10], which was used as a reference for policymaking (e.g. in the Farm to Fork Strategy (EC, 2020)).

Vegetables (24%) and fruit (22%) are the food groups that produce the largest amounts of food waste, followed by cereals (12%), meat (11%) and oil crops (10%). The fish and eggs food groups, which make up the smallest parts of the food supply chain, also generate the lowest quantities of food waste in absolute terms, despite the fact that much of these food groups (50% and 31% respectively) goes to waste (see Figure 3).

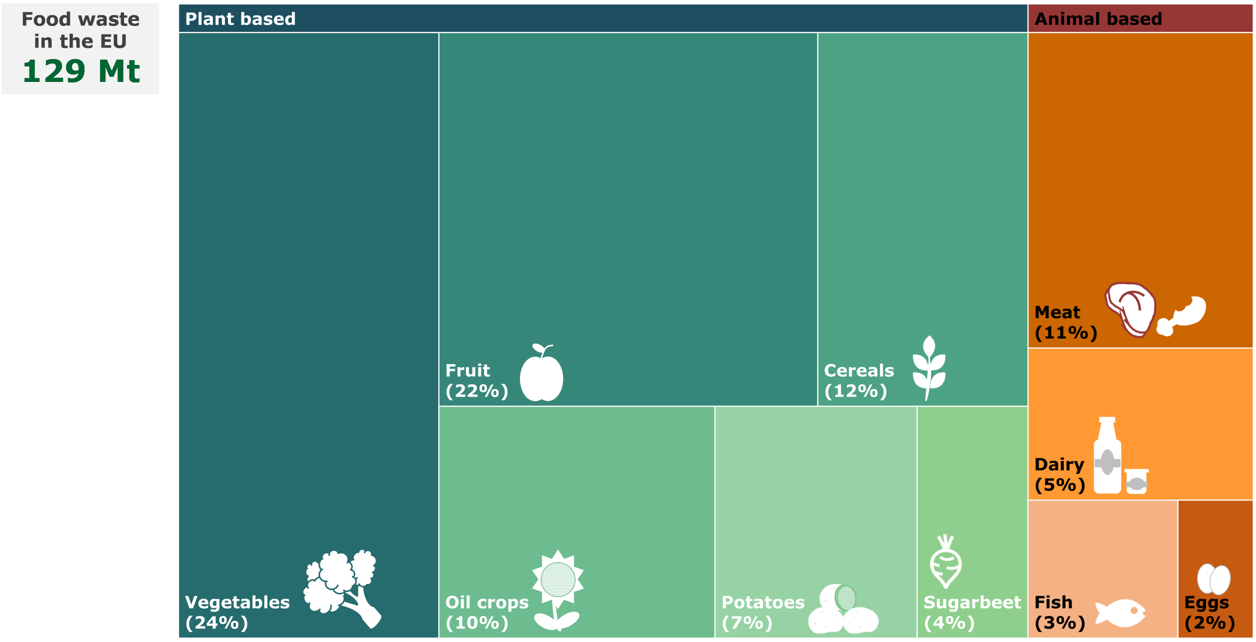


Figure 2: Food waste generated in the EU-28 by food group (2011 data). Mt in fresh weight. Source: Caldeira et al. (2019a).

On the other hand, the food groups that make the largest contributions to the food supply chain (food available) do not produce the largest amounts of food waste. The ratio of food waste to food supplied varies between groups, mainly due to the varying amounts of inedible content and the extent to which each group can be stored before consumption, e.g. cereals (pasta, rice) vs fruit and vegetables (see Figure 3).

[7] European Union comprising the following 28 countries that were Member States of the EU in the reference year (2011): Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and the United Kingdom.

[8] This quantification of food waste builds on the modelling exercise of the Mass Flow Analysis conducted by Kemna et al. (2017) (namely on by-products coefficients), which had 2011 as the reference year. The JRC is currently updating these coefficients and the entire assessment of food waste. This methodology uses a combination of methods (mass balance, coefficients and production statistics) presented in Annex III of Commission Delegated Decision (EU) 2019/1597 (EC, 2019) for the primary production, processing and manufacturing, and retail and distribution stages. Annex III reports methods to be used for the in-depth measurement of food waste.

[9] Annual food waste estimates for the EU range between 119 and 145 Mt due to uncertainties in the coefficients used to estimate the food waste by food group and stage of the supply chain.

[10] Caldeira et al. (2019a) use the FUSIONS' definition and boundaries. However, differences between the two quantifications are observed, mainly at the primary production and manufacturing stages, due to the different approaches followed. Caldeira et al. (2019a) follow a mass balance approach that combines different sources of information with the breakdown into the major EU food groups. FUSIONS uses normalisation factors (based on, e.g., food produced, population and turnover) from a limited number of countries, and upscale the data to the EU level.

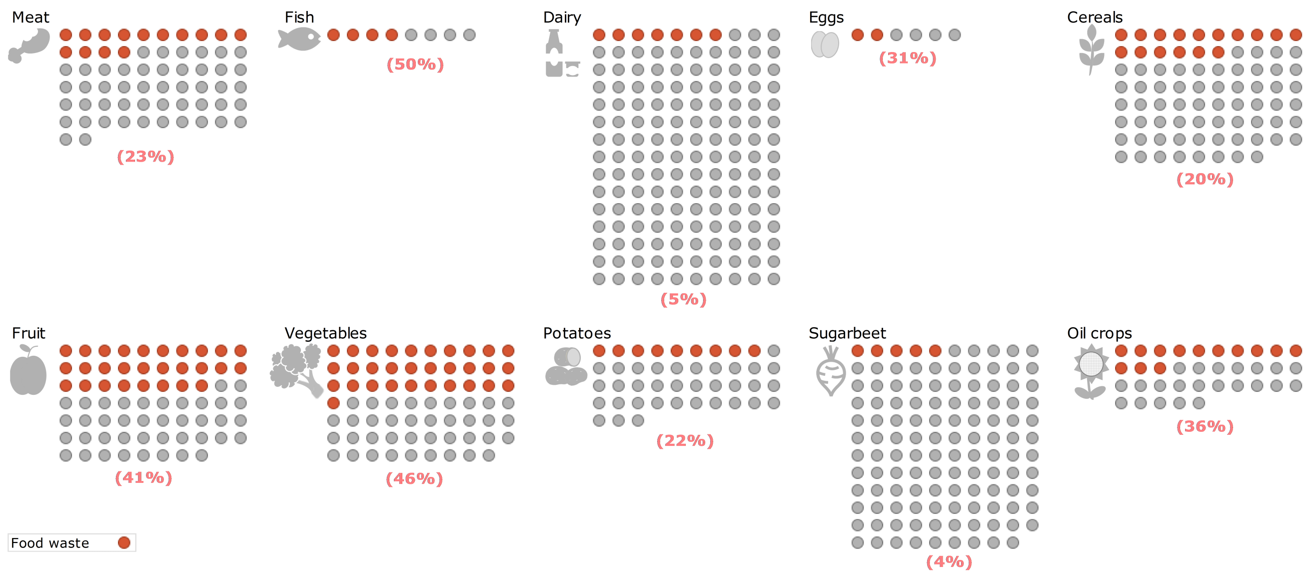


Figure 3. Relationship between food available[11] at the beginning of the food supply chain and food waste along the entire food supply chain, by food group in the EU based on 2011 data. Each dot represents 1 Mt of food; red dots represent the amount wasted. The ratio of Food waste/Food available is given in brackets for each food group. Source: adapted from Caldeira et al. (2019a).

3. How much food waste is generated in each stage of the food supply chain?

The largest amount of food waste is generated during the consumption stage (46%), followed by primary production (25%), and processing and manufacturing (24%). The distribution and retail stages only account for 5% of the food waste generated in the supply chain (see Figure 4).

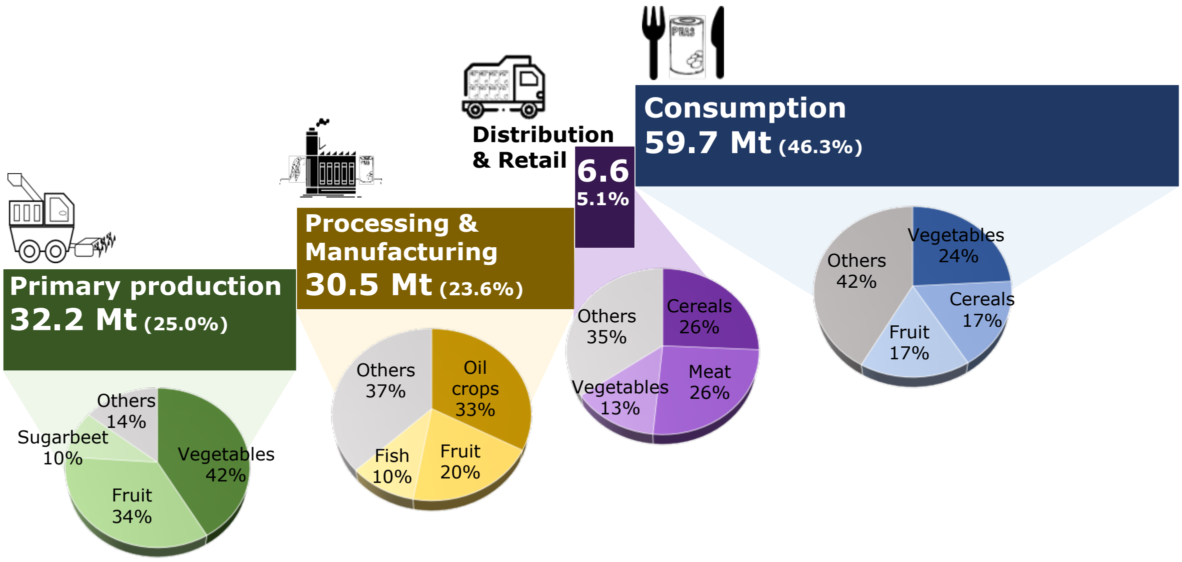


Figure 4. Amount of food waste (in fresh weight) generated during the different stages of the food supply chain (bars) and breakdown by main food groups (pie charts). Source: Caldeira et al. (2019a)[10].

[11] Food available includes food consumed, water content and by-products (e.g. for sugarbeet it includes water that is evaporated in the sugar processing process and molasses used for animal feed).

While fruit and vegetables only represent 21% of available food, they account for as much as 76% and 41% of the food waste generated during primary production[12] and consumption, respectively. The significant shares that these food groups have in the food waste generated at the consumption stage is related to their high inedible fraction at the point of purchase and their high perishability compared to other food groups.

Oil crops represent 33% of the total food waste generated by food processing and manufacturing, mainly due to the processing of olive oil (e.g. waste pomace)[13]. Fruit (20%) and fish (10%) also contribute significant quantities at this stage, since the processing of fruit and fish generates a significant amount of food waste that is not usually valorised. On the other hand, a large share of the inedible parts produced during the processing of different food groups is valorised in other industries, and it is therefore not counted as food waste. For example, bones, blood, inedible organs, and skin from the processing of meat are used as fertiliser, feedstuffs, binders, clothing, pharmaceuticals, etc., while milling residues from cereals processing, brewer's spent grain from beer production, oilcake from vegetable oil production and residues from the potato processing industry are often used as animal feed.

4. What options are available for the valorisation of food waste into high added-value products?

When food (or its parts) cannot be consumed by humans, other options, including reuse, recycling and recovery, should be considered in order to avoid waste disposal. Recycling includes options that yield low added-value products, such as bioenergy carriers (e.g. biogas and biomethane, bioethanol, biohydrogen, bio-oil, biochar), compost, etc., and options that can give rise to high economic added-value products.

Focussing on the latter, recent research and development has led to the extraction and recovery of value-added components for industrial applications (e.g. cosmetics and nutraceuticals, food preservation and packaging products, pharmaceuticals, etc.), as well as to the conversion of food waste into bio-based building blocks that can be used in a wide range of applications as bio-materials (e.g. bioceramics, biopolymers, etc.).

These efforts focus on food waste in the processing stage, which offers great homogeneity of waste streams (facilitating conversion technologies) and large and concentrated quantities of waste (reducing logistic and capital costs). This stage therefore provides a stable supply for the valorisation processes and prevents waste further downstream in the food chain. Many of the valorisation pathways that are being developed target waste from fruit processing (44% of the total number of different valorisation pathways), followed by cereals (11%) and fish-based food (11%). Large shares are also geared towards obtaining polyphenols (25%), polysaccharides (14%), enzymes (10%) and fatty acids (10%)[14].

Fruit processing waste is treated mainly to obtain substances used for food additives, pharmaceutical products and cosmetics, such as phenolic compounds, essential oils and other fatty acids, as well as lycopene and other bioactive compounds (see Figure 5). They can also be used to produce intermediate products, such as enzymes, which can be used for a wide range of applications. Waste from the processing of oilseed, sugar, starchy crops and vegetables can be turned into polyphenols (namely phenolic compounds and flavonoids). Other extensively researched valorisation pathways are the recuperation of protein hydrolysates and other bioactive peptides from the waste generated by meat and fish processing, and the production of organic acids from the processing of cereals, both for nutraceuticals and food additives.

[12] Fish discards from fishing (i.e. production stage) are not counted as food waste in the fish group due to lack of data. The reformed Common Fisheries Policy (CFP) and initiatives such as the Community-led local development (CLLD) scheme support the reduction of wasteful practices in European fisheries.

[13] As there are no official statistics from European olive mills on the amount of olive pomace being used for energy generation (bioelectricity, co-generation, process heat or heating) or compost, the amount of waste may be overestimated. A large quantity (circa 14.7 Mt) of oil cake from oilseed processing, used as animal feed, is excluded.

[14] The variety, number and shares of valorisation pathways are based on the literature review conducted by Caldeira et al. (2020).

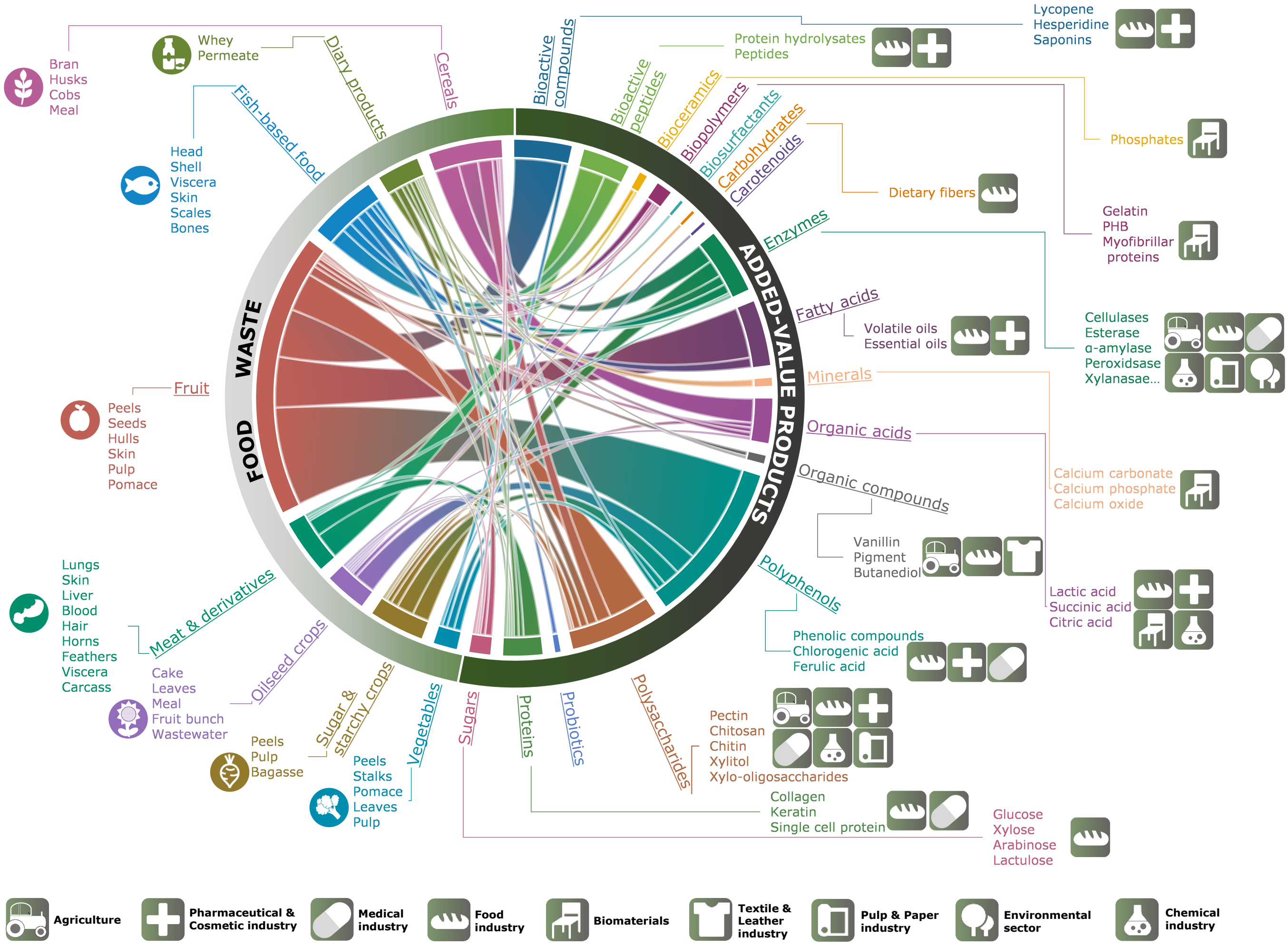


Figure 5. Potential pathways to valorise food waste into added-value bio-based products and the sector of application. The thickness of the connecting lines represents the number of different pathways tested, as documented in the scientific literature. Source: adapted from Caldeira et al. (2020).

The processes and technologies used in these valorisation pathways are very diverse and combine different techniques, from biochemical (e.g. enzymatic, chemical and acid hydrolysis, fermentation, extraction, etc.) to thermo-physical (e.g. supercritical fluid extraction with CO_2, ultrafiltration, ultrasound extraction, etc.) methods. However, most are currently at the laboratory scale and their feasibility at the industrial scale is yet to be proven. Their technological and economic potential depends on several factors, such as the availability and logistics of food waste streams, pre-treatment processes performed and the ability to scale the process up to an industrial scale.

In addition to the lack of information on the viability and performance at the industrial scale, other limitations and barriers identified for the valorisation of food waste in biorefineries include, inter alia, the availability of the feedstock and the logistics for its supply; costs of the process and market prices of the bio-based products obtained; and the need for standardisation of certain processes (e.g. extraction of bioactive proteins from fish waste) (Caldeira et al., 2020).

Innovative food waste valorisation options and their environmental, economic and social impacts should be assessed carefully over the entire life cycle of expected products using appropriate holistic and integrated methods (such as life cycle assessment) in order to demonstrate that they are no less sustainable or safe than conventional options (e.g. anaerobic digestion).

5. How should actions to tackle food waste be designed and implemented?

Tackling food waste is key to achieving sustainability. The Commission is committed to halving per capita food waste at retail and consumer levels by 2030 (Sustainable Development Goal 12, Target 12.3), and recently adopted EU strategies integrate food waste considerations[15]. The Commission plans to propose legally binding targets to reduce food waste across the EU using data expected from Member States as of 2022, as well as to integrate food loss and waste prevention into other EU policies (EC, 2020).

The waste hierarchy[16] - developed in the 1970s to prioritise waste management strategies - has evolved and been adapted to food waste (see Figure 6). This pyramid ranks the preferred strategies, focusing first on prevention actions, followed by reuse pathways of surplus food[17] fit for human consumption, reuse of food no longer intended for human consumption as animal feedstuff, recycling of material into high added-value products (without complete degradation), recycling of nutrients, recovery of energy and, as the least preferable option, the disposal of food waste.

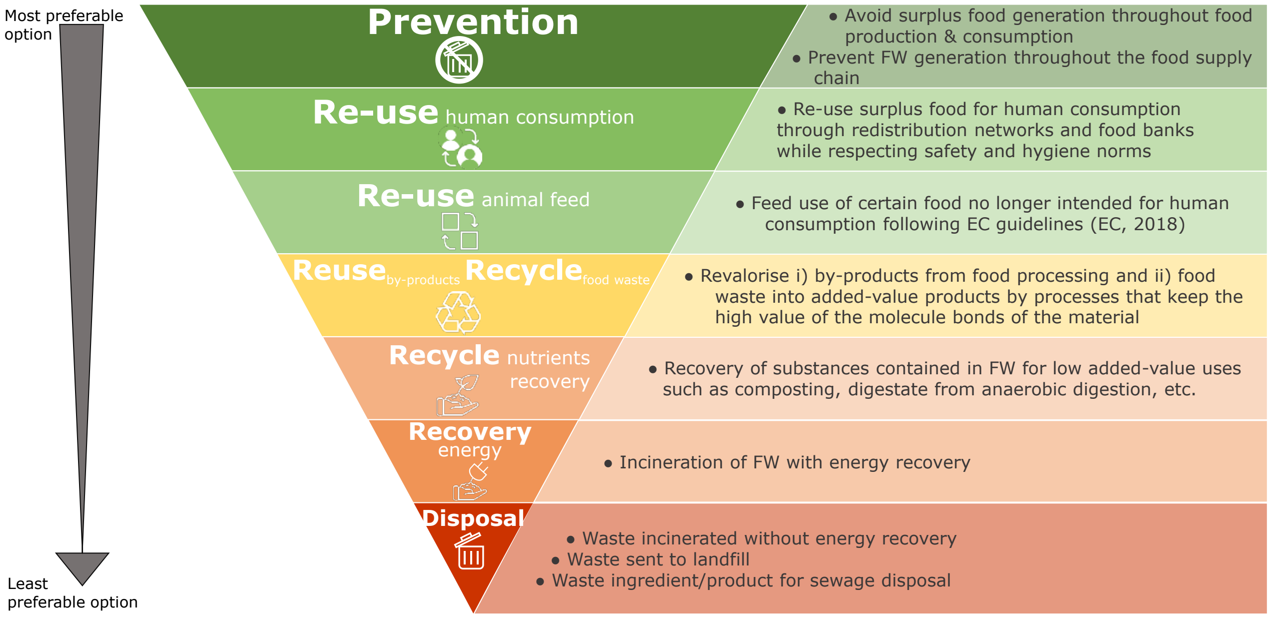


Figure 6. Hierarchy for prioritisation of food surplus, by-products and food waste (FW) prevention strategies[18]. Adapted from Teigiserova et al. (2020), Papargyropoulou et al. (2014) and UNEP (2014).

Preventing food waste will potentially result in the reduction of resources for the strategies downstream in the pyramid, thereby impacting their economic feasibility (e.g. there will be less demand for human resources to redistribute surplus food, or for investment in recycling and valorisation technologies).

The food waste hierarchy should guide the development of strategies that tackle food waste. Such strategies are underpinned by actions whose performance should be evaluated in terms of quality, effectiveness, efficiency, sustainability over time, transferability and scalability, and intersectoral cooperation (Caldeira et al., 2019b).

Key aspects in assessing the performance of food waste reduction actions are the identification of the problem, definition of the target and goals through SMART (Specific, Measurable, Achievable, Relevant, Time-Bound) objectives, and close monitoring and follow-up activities. To monitor, follow up and prioritise the prevention actions, Key Performance Indicators (KPIs) need to be established and measured to track the achievement of each action´s goals and help avoid significant trade-offs, e.g. between the environmental

[15] Bioeconomy Strategy (EC, 2018b), new Circular Economy Action Plan (EC, 2020b), Farm to Fork Strategy (EC, 2020). The Biodiversity Strategy for 2030 (EC, 2020c) also links food systems and food security with biodiversity.

[16] The waste hierarchy is a principal waste management framework by which to identify the actions most likely to deliver the best overall environmental outcome.

[17] Finished food products (including fresh meat, fruit and vegetables), partly formulated products or food ingredients that may arise at any stage of the food production and distribution chain for a variety of reasons.

[18] Some food waste treatment processes can be associated with more than one category. For example, anaerobic digestion produces fertiliser (digestate) and energy (biogas), and can be considered as both 'Recovery of nutrients' and 'Recovery of energy'.

benefits of an action and the cost of its implementation. KPIs are then analysed to identify opportunities for improvement and to design a follow-up plan to ensure long-term sustainability. This evaluation framework follows a three-step process (i.e. action planning, action implementation, and post-action monitoring) to design, implement and assess actions and strategies to tackle food waste (Figure 7).

However, since actions that address food waste may be highly diverse in nature and goals (e.g. awareness campaigns vs food waste valorisation strategies), the indicators in the evaluation framework should be tailored to the type of action. Accordingly, only actions whose performance is assessed by the same set of KPIs can be compared. Furthermore, the provision of appropriate data to compute the SMART objectives and KPIs of the evaluation framework should be ensured to develop and assess actions and strategies to tackle food waste (Caldeira et al., 2019b).

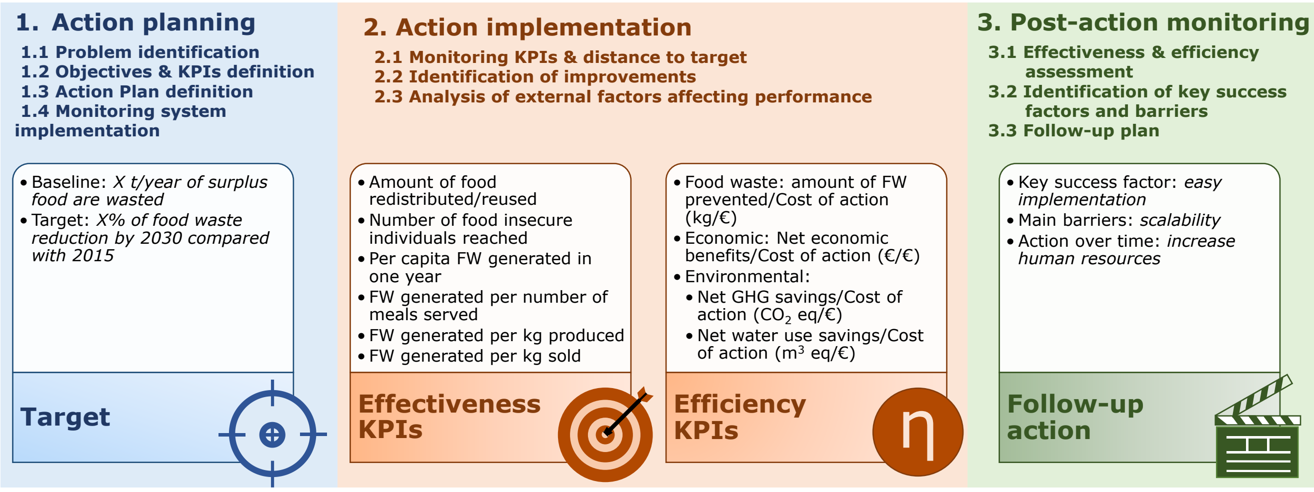


Figure 7. Process and steps for the development of food waste (FW) prevention actions. Adapted from Caldeira et al. (2019b).

In the design phase, actions for tackling food waste must consider barriers already identified, such as administrative burdens and extra effort for action monitoring, and the limitations to the use of certain food waste due to food safety legislation.

The JRC has developed a food waste prevention calculator[19] to help practitioners (e.g. local, regional or national administrations and other actors within the food supply chain) in the identification of potential trade-offs during the design phase of a food waste prevention action, and to provide data for several KPIs. Life cycle assessment (LCA) is a pivotal method for addressing multiple environmental impacts and trade-offs. Hence, the calculator is based on LCA in order to perform cost-benefit analyses and environmental savings' assessments[20] of different food waste prevention actions (De Laurentiis et al., 2020).

[19] The food waste prevention calculator is available at the EU Platform on Food Losses and Food Waste (https://ec.europa.eu/food/safety/food_waste/eu_actions/eu-platform_en), under "Key recommendations for actions of the EU Platform on Food Losses and Food Waste".

[20] The environmental impacts and benefits deriving from the implementation of a food waste prevention action are calculated using the Life Cycle Assessment method, which allows for the evaluation of 16 different categories of impact covering the entire food supply chain, from the agricultural stage up to waste treatment. The economic benefits and environmental savings are assessed considering both the burden and benefits of the actions, namely: i) the cost or environmental impacts of the avoided food production, ii) the cost or environmental impacts of avoided food waste management, and iii) the cost or environmental impacts of the implementation of the action.

Knowledge gaps

1. Existing data on food waste and reporting schemes are characterised by significant uncertainty due to, e.g., limited representativeness of the sample used for the collection of primary data.

2. Food flows vary significantly between different countries, e.g. due to different eating habits and waste collection systems. Robust and representative data on food waste are not available for all EU Member States.

3. The quantities of food waste presented in this brief are subject to methodological limitations. For example, due to a lack of official statistics, the amount of fresh products entering the distribution stage was estimated by means of mass balances. The coefficients used to determine food waste during the primary production stage were based on a study that covered Nordic countries. Furthermore, the amount of food waste in the processing and manufacturing stage depends on specific processing technologies and on the efficiency of production processes, which have not been taken into account in this quantification exercise.

4. Comprehensive and comparable analyses of the techno-economic feasibility and of the environmental impacts of potential valorisation pathways of food waste are needed. The types and amounts of food waste available at different geographical locations of producers, intermediaries and potential end-users of the high added-value products should also be assessed in detail.

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