D6.13

Role of food waste valorisation potential

Assessment of the role of waste valorisation in meeting potential targets for waste reduction

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

Authors

Peter Metcalfe, Quadram Institute, Biosciences.

Manuscript completed in [March 2019]

Document title	Valorisation and EU food waste targets
Work Package	WP6
Document Type	Deliverable D6.13
Date	30.06.2019
Document Status	Final

Acknowledgments & Disclaimer

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

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1 Executive Summary

This report provides an overview of how the valorisation tasks within the REFRESH project support the EU food waste targets. By valorisation we mean redirecting former food waste[1] to either food products, feed products, or converting it to or extracting food or feed ingredients, taking into consideration a) adequate supply of such streams (their robustness of supply, quality and composition) and b) adequate market relevancy of the intervention (technologically feasible, economically viable, legislatively compliant and environmentally sustainable / beneficial).

The key conclusions found are:

1. Turning food waste into usable products (valorisation) can help towards achieving the EU food waste targets, but this only applies to food waste that was intended for human consumption.

2. Moates et al. (2016) defined the top 20 wastes suitable for valorisation. Of these, most are not suitable for human consumption. In fact, when comparing them with definitions set out in the rWRD, most are not defined as a formal food waste. Valorisation of these 20 waste streams would therefore not count towards EU food waste targets.

3. Data characterising specific individual food waste streams were unavailable at subsector level.

4. Extraction has high potential in terms of value generation. The market volumes for the high-value food ingredients are growing but are still limiting the potential.

5. In order to achieve large volumes, the animal feed option is essential.

In conclusion, only valorisation of processing food waste, mixed retail and catering food waste that is currently composted, anaerobically digested or sent to landfill and incinerators could largely contribute towards the waste reduction targets.

[1] We employ definitions by FUSIONS as well by EC:

- Food waste is any 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, bio-energy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea) (Östergren, 2014).
- "Food waste" means all food as defined in Article 2 of Regulation (EC) No 178/2002 of the European Parliament and of the Council (*2) that has become waste. (EC, 2018a)

Both definitions are similar in their intentions.

Estimates of these (rWFD defined) food wastes, produced from different parts of the food chain in the EU, has been extrapolated from a few studies available on food waste (Table 1).

Table 1 Estimates of the magnitude of food waste across EU-28 that could potentially contribute to food waste reduction through conversion to animal feed

Stage	Maximum food waste, edible fraction (Million tonnes)	Source
Processing	~8 Mton	Crude scaling of UK data to EU-28 (see text for caveats).
Food service/ catering	~5.5 Mton	Stenmarck et al 2016, Kemna et al 2017.
Retail	2.5 to 3 Mton	ICF 2018.

- These are indications for the theoretical maximum amount of food waste from catering, retail and processing which total around 16 M tonnes of food waste. On a per capita basis this is roughly around 30 kg, split more or less equally between processing and consumer and retail stages.
- There are major limitations to producing research findings from single Member States to the whole of the EU-28, however.
- Further detailed surveys or monitoring of food waste would be necessary to make useful estimates of the maximum quantities of food waste across the EU-28.

The actual potential for conversion to animal feed will be subject to economic considerations. These will be constrained by location of the food waste given that transport related collection and distribution of liquid feed was identified as a major cost (DeMenna et al 2018).

This indicates that the valorisation potential of a food waste will be reliant on the location of the waste. This is dealt with more specifically in economic scenarios modelled in REFRESH deliverable 6.11.

Therefore, further investigation into the location of food waste and the proximity of key regions of animal husbandry is required to make better estimates of food waste reduction potential. Without such data it is challenging to be able to extrapolate across all EU Member states to assess a realistic contribution to EU level targets of this approach.

2 Background

The headline aim of WP6 is to 'increase the exploitation of *food waste'* and the title of this deliverable refers to a target for waste reduction. The task description of 6.5.2: REFRESH Description of Actions 2015 refers to '*30% by 2025'* which places the scope of this deliverable title firmly within the context of the *EU food* waste policy targets, which can be found in the revised Waste Framework Directive (rWFD), (Box 1).

Box 1: EU Food waste targets

The revised Waste Framework Directive (rWFD) adopted on 30 May 2018 calls on the EU countries to reduce food waste and food losses at each stage of the food supply chain:

> *Member States should take measures to promote prevention and reduction of food waste in line with the 2030 Agenda for Sustainable Development, adopted by the United Nations (UN) General Assembly on 25 September 2015, and in particular its target of halving per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses, by 2030.*
>
> *Those measures should aim to prevent and reduce food waste in primary production, in processing and manufacturing, in retail and other distribution of food, in restaurants and food services as well as in households. In order to contribute and ensure to be on track towards the attainment of the UN Sustainable Development Goal, Member States should aim to achieve an indicative Union-wide food waste reduction target of 30 % by 2025 and 50 % by 2030.*
>
> –09 Point 31 and Article 9 (g) of Directive 2018/851 amending 2008/98/EC.

However, in the REFRESH project, and the scope of valorisation related tasks, food waste definitions may have been taken from the FUSIONS project definitional frameworks (Östergren et al 2014) which differ somewhat to those in the rWFD (see Box 2). In this respect waste reduction targets could be interpreted in several ways - namely:

A) Keeping within the definition of what constitutes food waste under EU policy. This definition is taken to be that of the revised EU Waste Framework Directive which explicitly links the rWFD with meeting the United Nations Sustainable Development Goal on halving per capita food waste at the retail and consumer levels (FAO 2018). However, a quantitative target is not clearly linked to the second aspect – *food waste along production and the supply chain*. Food waste is implicitly restricted only to waste from that inseparable at the point intended for human ingestion (Box 2).

Box 2: What is defined as 'food waste'?

Definitions of 'food waste' from rWFD, EU, FAO and the FUSIONS project have been investigated and can be found below.

1. The Revised Waste Framework Directive's (rWFD) definition of food waste is: 'Waste' is that which is discarded under the WFD article 3 definition. Under Article 2(2e) of the rWFD, former foodstuffs used as animal feed are now formally excluded from being classed as waste.

   The definition of what constitutes food impacts the definition of food waste. The rWFD amendments inserts point 4a to Article 3 of Directive 2008/98/EC which now specifically defines *food* in *food* waste from the General Food Law definition of food:

   Any substance or product, whether processed, partially processed or unprocessed, intended to be, or reasonably expected to be ***ingested by*** *humans (*Article 2: EC 178/2002)

   The article 2 definition of food also explicitly excludes from this any material that is: (a) feed; (c) pre-harvest plants or; (h) residues or contaminants. Feed is defined by the regulation as:

   *Any substance or product, including additives, whether processed, partially processed or unprocessed, intended to be used for oral feeding to animals (*Article 2(4): EC 178/2002)

   The term 'residues', however, is not defined further so leaves scope for interpretation.

2. The EU's action plan for the circular economy's delegated Act on food waste measurement is under consultation at the time of writing this report. This also defines 'food' laid down in Regulation (EC) No 178/2002, but proposes to include in food waste both *parts of food intended to be ingested and parts of food not intended to be ingested* ***but only where those were not separated from the edible parts when the food was produced****, such as bones attached to meat destined for human consumption.*

   Food waste, as defined above, includes fractions not intended to be ingested which arise at the retail/consumption stage only, but excludes those which are separated earlier in the food supply chain, or indeed any food that is (re)directed to animal feed:

   Food waste does not include losses at stages of the food supply chain where certain products have not yet become food *as defined in Article 2 of Regulation (EC) No 178/2002. In addition, it does not include by-products from the production of food that fulfil the criteria set out in Article 5(1) of Directive 2008/98/EC, since such by-products are used.*

3. The FAO's website definition of food waste differs from the EU rWFD's by also including as food waste:

   Alternative (non-food) use of food that is safe and nutritious for human consumption along the entire food supply chain, from primary production to end household consumer level, in addition to discarding for disposal.

Box 2 Continued: What is defined as 'food waste'?

This would include any food redirected for animal feed. It is not clear whether the definition of 'food that is safe and nutritious' – refers to that which is potentially edible, safe and nutritious, or whether food means only that which was intended for consumption in the population of concern. Which, for the latter, may be a culturally determined behaviour and somewhat subjective. An earlier FAO (2014) definition of food waste as food **appropriate** for human consumption being discarded or left to spoil at consumer level – regardless of the cause. Unhelpfully the critical term 'appropriate' is not qualified with any further definition.

4. The EU Commission's FUSIONS project definition is wider: *'Food waste is any food, and inedible parts of food, removed from the (post-harvest) food supply chain to be recovered or disposed'* (Bii in Figure 1 below). This contrasts with current proposed EU policy definitions, by *including* inedible parts of food separated at the post-harvest and processing stages (A4 & A5 in Figure 1).

   The term *inedible part of food* is not further defined for the FUSIONS food waste definition, so is left to further interpretation.

   The FUSIONS food waste definition also contrasts with the FAO website definition by excluding food which is sent for non-food uses of animal feed, bio-material processing or other industrial uses (the 'B-i' category in Figure 1) as food waste. Instead these are termed 'valorisation and conversion'. Food is defined by FUSIONS in the same way as EU food law.

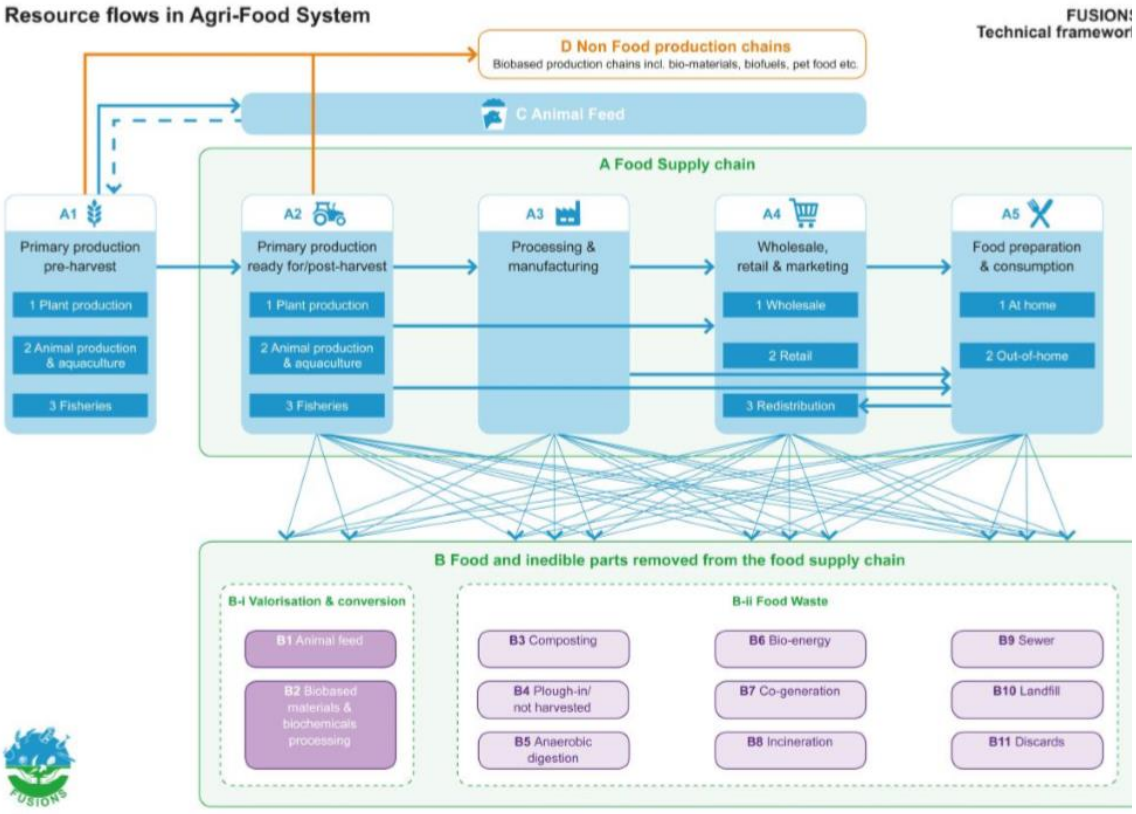

Figure 1 The FUSIONS technical framework defining the Food supply chain and Food waste (Östergren et al 2014).

B) Taking a broader EU FUSIONS food waste definition to include both food and inedible parts of food from the whole post-harvest food chain treated as waste (A2 to A5 and B3 to B11, respectively, Figure 1). As the FUSION project does not define 'inedible parts of food', it is assumed that this refers to parts of food *not intended for human ingestion* (taken from the EU definition of food). Unlike the proposed EU food waste definition (Box 2), the EU FUSIONS definition adds post-harvest and processing stages in addition to retail/consumer stage, as sources of (edible and inedible) food waste. However, like the EU's definition, food currently redirected to animal feed is excluded from the definition of 'food waste'. Unlike the EU, food (or indeed the inedible parts of food) *from any stage* of the post-harvest food chain converted to chemicals or materials *are* not considered food waste.

C) Aligning the scope to the FAO website definition of food waste. This defines food waste as both food that is discarded to disposal routes, *but also* any diversion of food to non-food use (including animal feed, bio-based materials). However, there may be some room for interpretation in how cultural contexts define food and therefore food waste (some may disregard certain types of edible and nutritious food chain by-products (used as animal feed or pet food) as food).

Both **B)** FUSIONS & arguably a broader interpretation of **C)** the FAO's website food waste definition, may include food chain materials that were not intended for use as food. FUSIONS includes non-edible parts of food entering disposal or waste recovery processes as food waste whereas, giving a global perspective, FAO may be interpreted to include potentially edible, safe and nutritious materials as food waste where culturally these may not commonly be intended for human consumption (used for pet food or animal feed instead) at the point of production.

This allows greater scope for counting materials that potentially contribute to waste reduction in general but are not necessarily compliant with the policy related food waste reductions and associated targets.

Table 2 Review of different 'food waste' definitions

	Definition of	**Included in the definition**	**Not included in the definition**
rWFD	Food in food waste	Any substance/product that could be ingested by humans	Feed, pre-harvest plants, residues, contaminants
EU	Food waste	Food ingestible by humans + food not ingested by humans (e.g. inedible parts that were not separated when the food was produced)	Parts that were separated from the edible parts when the food was produced

FAO	Food waste	Safe and nutritious food for human consumption that has not been used for consumption (including disposal)	
FUSIONS	Food waste	Food + inedible parts of food (post-harvest) that can be recovered or disposed	

3 REFRESH Work Package 6 Objectives and EU food waste targets

3.1 WP6 valorising *non-wastes* as well as *non-foods* from the food chain

The WP6 title valorisation of waste streams *and co-products* infers a wider scope for this work package, beyond just food waste, under the rWFD definition, and extending to the exploitation of both inedible parts of food including non-food materials that are not intrinsically part of food (e.g. packaging). This exceeds the FUSIONS definition of food waste that considered only disposal of inedible parts of food and food itself to be food waste, (see Box 2). Including food processing co-products also goes beyond waste definitions in its scope.

As outlined in the previous section, current non-food and non-waste status materials do not fall within the scope that can address EU *food waste* targets.

Whilst the WP 6 objective (WP6_Obj1) broadens the remit to inedible parts of food in the selection of a list of top 20 wastes suitable for valorisation, it also restricts the scope specifically to only wastes '*which are unavoidable'* from the wider food supply chain which has focussed attention away from policy related food waste. Food that becomes waste could have been eaten at some point*, so is inherently an avoidable waste.*

The reasoning for the focus on unavoidable waste, as Pleissner 2018 highlights, is that any industrial scale (valorisation) processes solely relying on wasted food as feedstock is somewhat of a paradox to sustainable development goals as it is based on an unsustainable behaviour.

3.1.1 Identification of top 20 wastes

The top 20 list of wastes suitable for valorisation (Moates et al 2016) consists of an unqualified mix of by-products, co-products and wastes from food processing industries. Summarising the top 20 wastes identified in D6.9, Table 3 shows that whilst some qualify under FUSIONS food waste definitions few may be associated with formal food waste definitions set out in the rWFD (b) and therefore, contribute to a per capita target for halving food waste by 2030. Whilst there is uncertainty in how many of these materials with potential edible/nutritional status could be interpreted as food waste under a broader interpretation of the FAO website definition.

Table 3 Summary of REFRESH D6.9 'Top 20 waste streams' and relevance to EU and other food waste definitions

Key

Yes	Yes - Considered as a food waste under (a or b or c) definitions.
	Partly or uncertain status - for example where a fraction could 'reasonably' be considered for human consumption in certain contexts, and examples of viable food use exist[2] - even if not consistently utilised as such but is used for non-food purposes for cultural reasons.
~~F~~	Not considered food (not intended for human ingestion) so not considered food waste.
~~W~~	Not classed as waste so not considered a food waste.

REFRESH D6.9 '*Waste streams*'	Management approach	Defined as food waste?		
		a) EU FUSIONS	b) EU rWFD	c) FAO website
Apple, tomato and orange pomace (*Peel, seeds, membrane residue after juice extraction*)	Conversion to food ingredients	~~W~~	~~W~~	B
	Nutraceuticals (flavonoids, carotenoids)	~~F~~, ~~W~~	~~F~~, ~~W~~	
	Animal feed	~~F~~, ~~W~~	~~F~~, ~~W~~	
	Anaerobic digestion or composting		~~F~~, ~~W~~	
Juice, fibre and protein from potato starch processing. *(excl. non-food industrial potato starch processing*)	Animal feed	~~F~~, ~~W~~	~~F~~, ~~W~~	
Ware potato processing - peels (steam or mechanical) and recovered starch.	Animal feed	~~F~~, ~~W~~	~~F~~, ~~W~~	
	Non-food chain use (plastics etc)	~~W~~	~~W~~	

[2] Nutritious value with suitable further processing so legal safety standards can be met, key examples being various edible eviscera such as offal and tripe (stomach) which is eaten in some EU countries such as Portugal, brewers spent grains ground as flour for use in some bread recipes in Germany etc.

REFRESH D6.9 '*Waste streams*'	Management approach	Defined as food waste?		
		a) EU FUSIONS	b) EU rWFD	c) FAO website
Wheatfeed & middlings *(excludes non-food industrial wheat starch processing)*	Animal feed	~~W~~	~~F~~, ~~W~~	
	Composting or incineration disposal		~~F~~, ~~W~~	
Whey and whey permeate	Conversion into foodstuffs	~~W~~	~~F~~, ~~W~~	~~W~~
	Animal feed	~~W~~	~~F~~, ~~W~~	
	Production of fuels and chemicals	~~W~~	~~F~~, ~~W~~	
	Anaerobic digestion/landspread		~~F~~	
Livestock blood permitted for food use at slaughterhouse	Conversion into foodstuffs	~~F~~	~~W~~	~~W~~
	Production of pharmaceuticals	~~F~~, ~~W~~	~~F~~, ~~W~~	
	Production of animal feed (blood meal, raw, albumin)	~~F~~, ~~W~~	~~F~~, ~~W~~	
	Production of fertiliser	~~F~~, ~~W~~	~~F~~, ~~W~~	
	Anaerobic digestion / industrial liquid waste treatment facilities			
Livestock blood permitted for food use at slaughterhouse. White and red offal incl guts & giblets. Additional residual proteinaceous matter and carcass fat from slaughterhouses, Bones/fat meal/hair/feathers/ hooves & feet/eggshells.	Production of foodstuffs (lard/tallow, tripe, sausages, casing etc)	~~W~~	~~W~~	~~W~~
	Production of animal feed (rendering)	~~F~~, ~~W~~	~~F~~, ~~W~~	
	Production of pet food	same as feed?	~~F~~, ~~W~~	
	Production of pharmaceuticals (collagen, gelatine, fats, insulin, heparin, pepsin, steroids)	~~F~~, ~~W~~	~~F~~, ~~W~~	

REFRESH D6.9 '*Waste streams*'	Management approach	Defined as food waste?		
		a) EU FUSIONS	b) EU rWFD	c) FAO website
	Production of chemicals/ raw materials (glues, soaps, plastics, fertilisers),	~~F~~, ~~W~~	~~F~~, ~~W~~	
	Anaerobic digestion/ waste treatment		~~F~~	
Crude & extracted press cake or spent meal	Animal feed	~~F~~, ~~W~~	~~F~~,~~W~~	Food Protein ?
Sugar beet pulp	Animal feed	~~F~~.~~W~~	~~F~~,~~W~~	~~F~~
Olive stones/mill waste	Industrial uses (kernel oil, activated carbon)	~~F~~, ~~W~~	~~F~~, ~~W~~	~~F~~
	Production of energy	~~F~~	~~F~~	~~F~~
Malting by-products (barley screenings, malt powder, malt culms, malt residual pellets)	Animal feed	~~F~~, ~~W~~	~~F~~, ~~W~~	
Brewing (spent grains, hops and yeast, surplus product / ullage) and distilling (dark grains, draff and pot ale/syrup)	Animal feed	~~F~~, ~~W~~	~~F~~, ~~W~~	
	Soil conditioner, composting, anaerobic digestion;		~~F~~	
Grape pomace/marc (skin and seeds)	Food ingredients or additives (oil, flour, colouring)	~~W~~	~~W~~	~~F~~
	Pharmaceutical, nutraceuticals or cosmetics (antioxidants & pigments, grapeseed oil)	~~F~~, ~~W~~	~~F~~, ~~W~~	
	Production of chemicals/fuels (ethanol)	~~F~~, ~~W~~	~~F~~, ~~W~~	
	Anaerobic digestion/ waste treatment		~~W~~	

Uncertainties in selection criteria

The list of unavoidable waste streams and co-products suitable for valorisation were identified by Sweet et al (2016) in REFRESH Deliverable 6.1 based on various criteria[3]. This has determined the scope for the online database FoodWasteEXplorer (REFRESH task 6.2) and, through subsequent refinement by REFRESH experts, a finalised list of 'top 20 wastes' suitable for valorisation (Moates et al 2016). The 'top 20 wastes' laid the basis for further tasks (REFRESH task 6.4) on lifecycle costing and greenhouse gas spreadsheet valorisation models.

High volumes and waste status

Various sources found during the activities of task 6.4 (developing TRL9 valorisation spreadsheet models) indicate that the waste status implied by a list of top 20 wastes may not accurately reflect policy definitions relating to current industry practices across the EU. Whether this had been considered by Sweet et al (2016) and Moates et al (2016) when determining that these top 20 wastes are present (available) in high volumes across the EU (Table 4) is unclear.

For many of the specific material streams identified as top 20 wastes for valorisation, data on the fraction that is waste (i.e. discarded and subject to disposal operations), and that which is conferred non-waste status (i.e. by-products or saleable co-products) for further use, are not readily available. This data does not appear collated at national or supranational levels and would rely on primary data from a representative survey of commercial food and drink business operators across the EU. This could be achieved by expanding approaches similar to that applied by Kerby & Vriesekoop 2017 for spent brewers' grains in small UK breweries, or surveying UK food processing subsectors by Parfitt et al 2016. However, with sampling reflective of the whole EU and for all of the processing sectors relevant to selected potential wastes, this would be ambitious and such extensive survey activities had not been planned as part of REFRESH.

Existing valorisation routes

Where valorisation routes were already considered to exist, high scoring of valorisation potential had been awarded by Sweet et al (2016). It can be seen in Table 4 (criterion 3, highlighted yellow) that high scoring is also concurrent with *wastes* present in high volumes. In this scoring it is unclear whether there could be saturation of current market demand from these existing waste valorisation routes and whether significant barriers exist in preventing further uptake, or if there is significant future potential for market growth.

Either way, for this deliverable report, determining how much waste is currently present would be an important first step in determining the

[3]Criteria were scored on whether i) materials were considered unavoidable post farm-gate and context of ii) whether existing valorisation routes existed other than AD and iii) potential for reduction through improved supply chain management and whether significant reductions could be effected by changes in iv) business or v) consumer behaviour. (Sweet et al 2016)

maximum potential that is available for further waste valorisation. This would require knowledge of current industry disposal rates, or indirectly estimating these using a mass balance of production and estimates of current quantities valorised. Either way to the authors knowledge such approaches, applicable to an assessment at EU scale, have not been published for most of the top 20 wastes with the exception of whey (Kemna et al 2017).

Scoring criteria used for prioritising 'waste streams' suitable for valorisation (Sweet et al 2016)	Whey concentrate	Whey permeate	Blood	Offal	Crude press cake	Spent grains	scoring
1) Is the waste stream present in high volumes?	3	3	3	1	3	3	Yes = 3 No= 0 Possibly = 1
2) Is the waste stream unavoidable and post farm-gate	3	3	3	3	3	3	Yes = 3 No= 0 Possibly = 1
3) Is there an existing valorisation route other than AD?	3	3	3	3	3	3	***Yes = 3*** ***No= 0*** ***Possibly = 1***
4) Can the waste stream be reduced significantly by improved chain management?	3	3	3	3	3	3	Yes = 0 No= 3 Possibly = 1
5) Can the waste stream be reduced significantly by changes in business behaviour?	3	3	3	3	3	3	Yes = 0 No= 3 Possibly = 1
6) Can the waste stream be reduced significantly by changes in consumer behaviour?	3	3	3	3	3	3	Yes = 0 No= 3 Possibly = 1
Aggregate score (Columns I-L)	18	18	18	16	18	18	

Table 4 selected examples of scoring used with regard to determining 'waste streams' suitable for valorisation (Sweet et al 2016).

Non-waste status

In at least several cases from the top 20 wastes identified by Moates et al 2016, evidence points towards there being a significant volume of the total (though not easily quantified across EU Member States) that may not actually be discarded as waste for recovery or disposal and are conferred non-waste status due to their established further use, most commonly as animal feeds.

Key examples are given below with regard to whey, oilseed and brewers spent grains.

Whey

Whey (of 44 million tonnes of liquid whey estimated from cheese production in the EU in 2011– only 1-2 million tonnes were estimated to have been disposed as an effluent waste stream, with 20 million tonnes processed for whey powder, 11 million tonnes for lactose recovery and further 11 million tonnes used for liquid animal feed (Kemna et al 2017).

EU sources indicates around 50 million tonnes of raw liquid whey was manufactured into whey products across the EU in 2015 (Eurostat 2016)[4]. The EU figure broadly aligns with a reporting of generic whey powder production, of 2 million tonnes solids per year[5]. In 2016 the total potential cheese whey solids availability had been estimated to be 4 million tonnes per year, (EWPA 2017) equating to 65 million tonnes of raw cheese whey, assuming 6% typical average solids. Whether the discrepancy of ~15 million tonnes, indicate raw whey is not captured for processing, does not preclude a substantial fraction (11 million) of this still being used as a liquid animal feed, as indicated by Kemna et al (2017).

It is considered likely that disposal of whey as a waste may be distributed across a multitude of smaller cheesemakers in the EU; or where the fraction is a processing residue is high in minerals (e.g. de-proteinised and de-lactose whey or mother liquor),[6] and is not able to access feed markets that may tolerate this, where the cost of dewatering or where transport for utilisation by farms or larger centralised processors may not be economic[7]. Since the raw whey in these circumstances was not intended to be food, it would be difficult to justify as a food waste under rWFD definitions.

Oilseed press cake

Another top 20 waste considered for valorisation is oilseed press cake. In the EU food oil, press cake is produced mainly by solvent extraction processing of three oil crop seeds: sunflower, rapeseed and (mainly imported) soy. The EU is the world's largest producer of rapeseed oil. The resulting press cake is used exclusively as feed for the livestock sector (USFAS 2017) in a process that typically requires desolventising and toasting. This contributes a revenue stream for oil processers; diversion from feed to alternative uses would not justifiably impact food waste policy targets.

Brewers spent grains

Surveys of 90 UK small and micro sized ('craft') breweries (in both urban and rural settings) shows that animal feed is still the dominant end use, from large-scale up to the smallest sources of production (Kerby & Vriesekoop 2017). Although there may be seasonal changes in demand for spent grain when pasture becomes available for cattle, storage in clamps is possible for

[4] Eurostat for EU Milk and milk products statistics accessed July 2018.
[5] Production figures published on the EWPA website, accessed Nov 2017.
[6] Tetra Pak 2019, also e.g. Fonterra, New Zealand market this as 'Proliq', but others indicate potential as a feed supplement. Friend et al 2004.
[7] Personal Communication, Lee Hartley, Head of R&D, Performance and Dairy Ingredients, Volac International Ltd.

up to 12 months and feed merchants may supply farms year-round. Of course this may not be the case across the whole EU (key beer producers being Germany, Poland, Spain, Netherlands and Belgium all producing >2 Million m^3 p.a.), but studies similar to (Kerby & Vriesekoop 2017) indicating the fate of brewers spent grain has not been found for other EU-27 member states. However, in view of lack of published evidence valorisation as feed is broadly accepted as the norm by other researchers (e.g. Mussato, 2014)

Offal

In UK abattoirs various organs, eviscera and offal has been considered to be an essential source of revenue accounting for so called '*the fifth quarter'* of income received from butchering animals and contributing to the profit margin of processors (EBLEX 2014). If not exported to foreign markets, pet food processors provide the largest domestic market for processed edible offals and animal by-products in the EU (Dobbelaere 2017).

In these respects, new forms of valorisation applied to existing markets for co-products and animal by-products with non-waste status would not fall within EU rWFD formal definition of food or waste and therefore be unable to contribute to food waste prevention targets.

3.1.2 Summary

Key uncertainties in the Top 20 *waste* streams for valorisation

Though there is limited quantifiable evidence, further investigation provides indications that, in at least several cases identified as top 20 wastes, it may be inaccurate to refer to these present as *waste in high volumes*. The term waste implies currently these are surplus to further use and disposed of. Evidence for some of these cases such as oilseeds indicates the opposite; these may be consistently and sometimes almost wholly utilised as industry co-products already. This has implications for what can be counted as the potential for valorisation contribution to waste reduction.

In identifying wastes streams suitable for valorisation (D6.9) the assessment criterion indicating greater suitability where valorisation routes already exist has not been elaborated on (e.g. how well established are these routes?) but appears to be used to indicate that there is capacity for further valorisation.

Whilst the identification of existing valorisation routes may indicate further potential, it may also indicate uses are already established within mature co-product markets.

There is uncertainty in understanding how much of the *high volumes of wastes present* are currently utilised by these routes, and how much potential is available for further valorisation capacity.

These factors will impact the true additional waste volume that is *available* for valorisation that could potentially contribute to understanding the significance for waste reductions.

For an unknown proportion of these materials, market demand may not be apparent and their disposal as waste will occur. Even if there is a market, accessing this may be limited by transport costs or pre-processing costs (water removal etc). The economic feasibility is therefore context specific, relating to processors' scale, their financial circumstances and geographical constraints. As such this is difficult to model across the whole of the EU, with only a few theoretical examples of this approach found in recent literature with associated high uncertainty (e.g. Cristobel et al 2018) and it is unclear what consideration is given to availability and competition with current material utilisation (e.g. current usage by existing large citrus feed mills[8] etc).

Unfortunately, though other organisations (e.g. WRAP, UK) have some sector maps and research, data required for indicating the proportions of the top 20 that are not exploited and disposed as waste, are, to the authors knowledge, not collated centrally by any organisation or by Member States across EU-27. More granular data relating to the fate of food processing streams is most likely only held at individual company level and is therefore not readily accessible. Such gaps in data have been highlighted elsewhere in food waste research literature, with calls for further primary data collection and more transparency from the commercial sector through volunteering of data (Xiu et al 2017).

Relevance to EU food waste policy

The contribution of the top 20 wastes is challenging for the policy related rWFD definitions. Most of the top 20 *wastes suitable for valorisation* outlined by Moates et al (2016) are not intended, or reasonably expected to be, for human consumption in the first place. As such, these may be excluded from the scope of EU policy definitions of food waste and associated reduction targets.

3.2 WP6 valorisation examples

Even though the examples used within WP6 will not strictly help towards achieving the EU target on food waste reduction, a number of valorisation examples have been developed which show they can still have significant impact.

3.2.1 Chicory fibres

As part of the Impact Assessment Texture Processing deliverable, chicory and carrot fibres were taken from an inulin factory and vegetable juice production facility respectively. Both side streams represent a source of pectic-polysaccharide-rich fibre and were subjected to thermophysical processing to assess their properties for incorporation into foods. The incorporation of added fibre is of interest to food manufacturers to enable high fibre claims to

[8] E.g. Zuvamesa https://www.zuvamesa.com/ website accessed April 2019

be made about products. The results demonstrated a technologically feasible route for the utilization of defined, traceable residues from the food manufacturing industries to impart functional characteristics when reformulating existing product recipes.

The REFRESH report 'Scale up models and processes, D6.5' investigated the techno-economic analysis (reviewing all unit operations within a suitable industrial processing chain and estimating its feasibility and profitability) of chicory waste. The case study, producing a food fibre from chicory extraction residues, showed that scale size is critical for producing the fibre at a competitive price compared to dietary fibres already in the market.

Currently the stream of chicory fibres is used as animal feed. Upgrading it to a food ingredient does not contribute to food waste reduction because the use of food waste for feed is not considered food loss.

3.2.2 Tomato side streams

The techno-economic analysis developed within D6.5 was applied to several processing/valorization chains that convert food wastes/side streams to high-value products (within the REFRESH report 'Food waste high value exploitation hypothesis testing, D6.12'). One case investigated was tomato side streams. The work demonstrated the importance of specific conditions on economic feasibility of high value valorization options.

Both wasted tomato in fresh supply chains and the pomace side streams from processing are largely treated as waste. Upgrading it to a food ingredient (oil extraction from seeds, carotenoids extraction from peels and selling the residues as feed, as presented in D6.12) will reduce the food loss. As shown in D6.12 the current world market for carotenoids represents about 10x the production potential of a tomato processing factory analysed within the report (this was estimated by using the volume of a plant (the Conesa factory that processes 340 kton of tomatoes per year) and comparing it with the total volume processed in EU). Thus, the current potential from a market perspective is still limited; with an annual growth of 10%, tomato waste would need to be processed in at least five such plants.

Calculations that confirm the high value valorisation of tomato processing side streams can be seen below:

- Europe produces about 3.8 Mton/year wastes (side streams) from tomato processing (figure 14 in REFRESH report 'Integration of LCC and LCA results to higher system levels: The German meat and EU tomato cases, D5.6'); these largely go to composting and anaerobic digestion (Table 9 in D5.6).
- The volume of side streams produced by the factory analysed in D6.12 has 260*340/6.5 = 13.6 kton side stream per year.
- The factory is able to handle three times its capacity (as shown in D6.12): 3 x 13.6 = 40.8 kton/year. This is about 1% of the total volume of tomato processing side stream in Europe.

As a result, high-value application is a good opportunity for adding value for large-scale food waste streams, but the total market in Europe is limiting.

D6.12 also shows that, even though there may be a very promising business case, high valorization opportunities for another food manufacturing side streams may be obstructed for other reasons related to product attributes. Extraction has high potential in terms of value generation. The market volumes for the high-value food ingredients are growing but are still not enough to reach full potential.

3.2.3 Recovery of food waste from food chains for animal feed

Around 5 million tonnes of former foodstuffs are currently distributed for animal feed per year in the entire EU (EFFPA 2019). This has potential for a significantly high return in value.

In comparison, the European wholesale, retail and food service generates about 15 Mton/year food waste (see REFRESH report 'Identification of food waste conversion barriers, D6.11'), which is about 40% of the total food waste generated in the production and supply chain. If the EU wants to increase the food waste valorisation percentage, significant improvements are necessary for the food wastes from wholesale, retail and food service.

Valorisation of these waste streams is technically most feasible as animal feed. Analysis of high valorisation opportunities has shown that this has a limit market potential (see above); furthermore, as shown in D6.12 the relatively small (and spatially scattered) processing technologies suffer from poor economies of scale. Thus, the largest outlet will be animal feed.

Current legislation is most limiting for valorisation via animal feed: (1) feed ban directly forbids application of most animal-protein containing streams to animal feed; and (2) strict rules relating to that ban make it impractical to keep streams free of such proteins separated from other wastes.

Refresh task 6.3.3 has produced guidelines on the possible treatment of mixed food wastes from catering, retail and food manufacturing for safe use as animal feed. These include food materials that otherwise would have contributed to products intended for human consumption, and so fall within the rWFD definition of food waste. The guidelines focus on surplus food that may contain meat or fish; details can be found in Box 3.

Box 3: Focus of REFRESH Technical guidelines on animal feed

The REFRESH D6.7 report focused on surplus foods that may contain meat or fish which is:

- Heat-treated and acidified in licenced, tightly controlled treatment factility that are located **off-farm**
- Sourced **only** from domestic catering sources, retail and manufacturing
- Destined **only** for non-ruminant, omnivorous livestock

The following are *excluded* from the guidelines:

- Ruminant feed
- Surplus food from households
- Surplus food from international catering, or international transport
- Surplus food treated **on-farm** or in other unlicensed premises
- Former foodstuffs which are legal defined in Regulation 2017/1017 (European Commission 2017a) to exclude surplus from catering sources. Combined with Regulation 1069/2009 this means that former foodstuffs do not contain animal by-products that are currently prohibited and this is how the European Former Foodstuffs Processors Association uses the term. Former foodstuffs already processed into animal feed are NOT the focus of these guideline.
- While there is some discussion of accidental or illegal feeding of untreated surplus food, the prevention of illegal and accidental feeding of untreated food waste falls outside the scope of these guidelines

Providing a first crude estimate of the potential magnitude of food waste practically available for this valorisation approach is challenging due to limitations on data available from processing, catering and retail sectors. De Menna et al (2018) attempted to quantify the consequences to lifecycle costs and greenhouse gas emissions of changing current animal feed for equivalents made from converting food waste into animal feed using a simplified attributional approach at the national level for France and the UK.

The authors present national food waste values (Table 5) for manufacturing and retail use estimates. However, Parfitt et al's data, on which De Menna et al (2016) base their assessment of retail and manufacturing food waste, differs for total waste from these sectors, (1 700 000 vs 1 484 000) of which 680 000 tonnes are reported to be diverted already, leaving approximately 1 million tonnes of food waste consisting of an unknown fraction of avoidable

(edible) and inedible food wastes, due to the FUSIONS food waste definition that the authors applied.

Moreover, in estimating the practical potential for an additional 130,000 tonnes of food waste that could be diverted for animal feed by 2025, Parfitt et al excluded food wastes (considered at risk of) containing animal proteins which are presently legally banned from feed. However, De Menna et al have assessed the potential if it were allowed; their assessment scope includes banned food materials under a scenario where effective processing of food waste into pig feed removed disease risk and became legal as a pig feed. Unfortunately, it is unclear how De Menna et al's food waste figures have been derived and therefore what fraction relates to a rWFD food waste definition relevant to reduction targets.

Table 5 A summary of food surplus (tonnes) available for valorisation in UK reported by De Menna et al 2018 and Parfitt et al 2016

Sector	Food surplus quantity that could potentially be used as animal feed (DeMenna et al 2018)	Food and drink surplus and waste (tonnes) in grocery retail and manufacturing, UK estimates, (Parfitt et al 2016)
Retail	**199 000**	**210 000**
Manufacturing	**1 484 000**	**1 700 000*** of which only 867 000 was reported as theoretically edible (originally intended as food) and only this is deemed as food waste

*Includes estimates of waste from 3rd party logistics.

Manufacturing sector food waste data

To the authors knowledge the study by Parfitt et al (2016) is the only published study scaling food waste from different subsectors of the food processing industries to a national level based on primary field work data and data from food business operators[9]. A synthesis of these data by Parfitt et al has been made to assess the quantity of food waste that theoretically may be avoidable (that is it could have been edible, with or without further processing) through prevention, redistribution for food and animal feed and that which is practically avoidable has then been scaled to a national level by business size data and provisional production data (PRODCOM 2014,

[9] 34 site audits in the UK supplemented by primary data from several companies alongside waste data extracted from site environmental permit applications (Parfitt et al 2016).

Eurostat) to extrapolate the proportion and value of food waste from each subsector.

An indication of UK food waste that has not been valorised but could be potentially available for valorisation from each food manufacturing subsector is shown in

Table 6. These are food waste as defined within the rWFD, i.e. actual food intended for consumption, and, unlike the wider FUSIONS definition, excludes inedible parts of food. The last column indicates the %, by mass, of food waste with respect to total production of each subsector, (after removing reductions for waste prevention and redistribution that Parfitt et al identifies). This is considered to represent the maximum theoretical % of food production available as food waste for valorisation.

Crudely applying these UK sub-sector % food waste to the same subsector production for the whole EU-28 using the same categorisation of 2014 PRODCOM data is shown in

Table 7. This gives a very crudely extrapolated total at the EU-28 level of around 8 million tonnes of food waste for the sub-sectors. This is approximately half the total food waste indicated by FUSIONS for processing industries based on extrapolating data from four Member States but is still within the FUSIONS reported confidence intervals (Stenmarck et al 2016; 16.9 ± 12.7 Million tonnes).

Limitations

Of course, crudely extrapolating estimated UK sub-sector food waste rates across the whole EU-27 (

Table 7), has major flaws. As can be seen in the appendix, the most notable is that the mix of food product types differ substantially between UK and the EU-27 as a whole, for obvious reasons of climatic and cultural influences between the UK and the rest of the continent.

Secondly, some of the product totals for categories in the UK data sets have been censored for commercial reasons (small number of companies providing data), but at the EU-27 level there are aggregated totals reported. Using this crude extrapolation with PRODCOM data could result in potentially greater absolute food waste fractions at the EU-27 level. Therefore, applying the

same rate of food waste from UK food processing subsectors to those of the EU-27 is problematic.

Finally, the subsectors may not represent a full coverage of food processing industry, and in assigning PRODCOM product descriptions to these categories there were notable categorical omissions for certain food products, for example such as those processed from vegetable oils and fats.

Rather this can be seen as a very crude first indication of the possible scale of potential valorisation of food waste to animal feed for further refinement, until granular food waste data is more readily available from implementation of the EU food waste monitoring platforms.

These proposals and standards are currently under development in sub-groups from the EU platform on food waste[10], especially where monitoring food lost in effluent is concerned (e.g. Zambrzycki 2018). At the global level the FAO's methodology for indicators 12.3.1 and 12.3.2 for food waste, have also only recently been proposed (FAO 2018).

Table 6 Food and drink food waste in UK food processing subsectors (estimated by Parfitt et al 2016†)

Food Processing Subsector	UK production Million tonnes	Food waste '000 tonnes †*	Prevention potential '000 tonnes †	Redistri-bution potential '000 tonnes †	Net food waste for animal feed '000 tonnes	UK food waste %
Alcoholic drinks	7,7	60	8		52,0	0,7%
Ambient products	1,3	130	30	5,4	94,6	7,0%
Bakery, cake & cereals	5,6	90	10	5,0	75,0	1,3%
Confectionary	0,8	30	4	3,0	22,5	2,8%
Dairy products	11,2	200	40	6,0	154,0	1,4%
Fruit & vegetables	0,9	100	17	30,0	53,0	6,0%
Meat, poultry & fish	5,5	160	20		140,0	2,5%
Milling	6,4	10	0,5		9,5	0,1%
Pre-prepared meals	1,5	60	15	5,0	40,0	2,6%
Soft drinks, fruit juices	11,0	25	5	2,2	17,8	0,2%
Sugar	Suppressed	2	0,1	-	1,9	n/a
	Totals	**867,0**	**150,1**	**56,6**	**660,3**	

* Food waste here is that intended for human ingestion that is discarded/disposed and is the *theoretically avoidable* fraction estimated in Parfitt et al 2016 *which was edible (i.e. a food waste)* within each subsector which has not been valorised and becomes waste. It does not include the inedible fraction (unlike the FUSIONS definition which does).

[10] Mandate for a subgroup on measurements of food waste was set out in March 2017. The sub-group will support the Platform's work in this area until end of 2019.
https://ec.europa.eu/food/sites/food/files/safety/docs/fw_eu-actions_subgroup-mandate_fw-measure.pdf

Table 7 Crude scaling of UK estimated food waste in food processing subsectors to EU-28 using high level waste to production ratio of manufacturing subsectors (see text for caveats)

Processing Subsector	EU28 food production (Million tonnes)	Food waste assuming estimated UK % (Million tonnes)
Alcoholic drinks	64,8	0,4
Ambient products	29,6	2,0
Bakery, cake and cereals	36,7	0,5
Confectionary	10,4	0,3
Dairy products	85,5	1,2
Fresh fruit and vegetable	11,5	0,7
Meat, poultry and fish	84,5	2,1
Milling	71,6	0,1
Pre-prepared meals	16,3	0,4
Soft drinks and fruit juices	143,1	0,2
Sugar	39,5	n/a
Totals	**593,6**	**~8 Million tonnes**

3.2.4 Conversion of retail and catering food waste to animal feed

Luyckx et al 2019 indicate a gross potential of 14 million tonnes of food waste, would be suitable for valorising to pig feed across the EU-28. The figure was derived by approximately halving[11] the total food waste across the EU-28 taken from FUSIONS estimates (Stenmarck et al 2016) for processing, catering and retail sectors after removing circa 5 million tonnes of former foodstuffs estimated to already be distributed for animal feed (EFFPA 2019).

Using food waste estimates made by FUSIONS includes inedible parts of food, some of which will be unsuitable for conversion into animal feed. However, since an assumption is made that half of the food waste will not be utilised

[11] This was based on observation that half of available food waste collected was suitable for conversion to pig feed for systems implemented in Japan (Luyckx et al 2019). EU-28 total for food waste has been taken from FUSIONS (Stenmark et al 2016) as the sum of Processing 16.9 ± 12.7; Wholesale and retail, 4.6 ± 1.2 and; Food service 10.5 ± 1.5 (million tonnes) for the year 2012. Primary processing and household food waste was not considered in the animal feed estimate.

for pig feed, as observed in the Japanese case, the 50% margin should allow for screening out of inedible parts of food waste unsuitable for feed.

It may not, however, be valid to assume that the figure for former food stuffs can be removed from the FUSIONS processing total, unless the extent to which FUSIONS data excluded existing animal feed is made clear[12],

Retail food waste

Parfitt et al 2016 also extend their research into retail food waste in the UK estimating 210,000 tonnes of retail food waste, (Table 5) but with indications that 30,000 tonnes could be prevented through improved operational controls and further 50,000 tonnes of this food waste could be reduced by re-distribution for consumption leaving potentially 130,000 retail food waste available for valorisation. However, only an additional 13,000 was identified as suitable for animal feed which, again, may be limited, by food containing ingredients currently banned from animal feed. This would not apply to the treatment of food waste in the pigfeed scenario outlined in REFRESH (Luycxk et al 2019 and De Menna et al 2018).

Estimates of food waste across the EU-28 associated with retail expiry date behaviours are indicated to be 2.5 M tonnes per year, representing 55% of total retail food waste (ICF 2018). This indicates total maximum potential retail food waste extrapolated to the EU-28 is approximately 4.5 M tonnes per year. Assuming similar proportions may be reduced through prevention and redistribution to that indicated by Parfitt et al for the UK, this would indicate an approximated 2.5 to 3 M tonnes retail food waste per year. How much of this could be available for diversion from current disposal operations of course is unclear and would depend on analysis of specific circumstances and commercial considerations of each case (logistics costs and effective safe de-packing etc).

Catering food waste

Primary sources for EU Member States indicate per capita ranges for food services food waste between 14-15 kg (UK, Finland) to 40 kg (Netherlands and Belgium) per year (Kemna et al 2017). Scaling the per capita FUSIONS estimate of 21.4 kg (Stenmarck et al 2016) to EU-28 population[13] amounts to ~11 M tonnes, but this includes inedible fractions.

Food waste defined by rWFD applies to the food fraction of catering waste (that which was formerly intended for consumption). However catering waste

[12] Even though the FUSIONS definitional framework for food waste would exclude animal feed Stenmarck et al 2016 report only 4 out of 19 responding Member States were able to provide data of sufficient quality, requiring additional requests due to variability of data to confirm the fractions of processing waste used for animal feed, no further details are provided on this fraction, however. Also due to a lack of data, FUSIONS authors assume 50% of the reported processing food waste quantity was edible.

[13] On 1 January 2018, the population of the EU was estimated at 513 million inhabitants (EuroStat) accessed Feb 2019.

disposal will be a mixture of food and preparation waste and parts of food such as pits, peelings, bones and remnants of packaging etc. Differentiating between these fractions is difficult where data on disposal of food may be combined with non-food organic processing wastes. In earlier studies in the UK the food services *food waste* fraction was found to be approximately 15 kg per capita[14], with 75% reported as avoidable (WRAP 2013). So, scaling crudely per capita, as an assumption for EU-28 population, indicates roughly 7.5 Million tonnes, of which roughly 5.5 million tonnes are avoidable (assumed potentially edible) food wastes.

Domestic food waste

By far the largest arising of food waste occurs from households, however domestic food waste has been excluded from the scope of valorisation to animal feed in REFRESH. This is due to the greater uncertainty regarding additional process controls required to mitigate risks and meet acceptable feed safety and quality standards. For further details on the rationale for excluding domestic food waste see Luyckx et al (2019).

Challenges and uncertainties

Assuming processes converting food wastes to pig feed outlined by Luycxk et al (2019) become approved, the fraction of the potential volume outlined above could be realised is dependent on commercial viability.

Assuming food waste is all available for animal feed at the point of removal from retail and catering sites, there would be some limitations placed on the amount that could be economically valorised to a liquid feed. Key ones look to be

- Transportation costs
- Feed processing plant economy of scale

These are context specific, depending on food waste sites' geographical density/size and geographic proximity to the pig feed processing plants. Also, viability partly relates to forecasts of future market price of equivalent competitor animal feeds, and by association, a commercial willingness to invest.

A further challenge to any valorisation is the variable and heterogeneous nature of mixed wastes arising from the diverse processing, retail, catering, hospitality and food service sectors, which could make standardising feed composition more selective, perhaps reducing the theoretical (maximum potential) quantities available for commercial utilisation to those that have more predictable compositions.

This makes it difficult to extrapolate with reasonable certainty how much of the potential sources of food waste outlined in previous sections would be

[14] 2011 data was used to indicate food services food waste of 920 000 tonnes divided by 63,182,000 as the total population of the United Kingdom of According to the 2011 census.

economically feasible to valorise as pigfeed with any useful level of precision across the whole of the EU-28. With better characterised single streams of non-food wastes as outlined in 3.1 this should be more tractable where less heterogeneous composition is assumed. Though even in such cases there is *high uncertainty* reported for assumptions used for cost data on transport, capital costs of laboratory scaled of extraction processes, yields and revenues and negligible waste costs etc (e.g. Cristobal et al 2018).

Instead, elaborations of economic cases are addressed, theoretically, for processing scenarios in single site level scenarios in REFRESH deliverables (D6.11 and D6.12) for animal feed from food waste and also high and moderate value cases for tomato pomace.

4 Conclusions

The rWFD definition of food waste (to which EU policy targets relate) excludes fractions that are not intended for human ingestion[15]. However, the FUSIONS definition has been used when compiling the REFRESH report on the top 20 wastes and this includes fractions that are not considered food waste within the EU policy targets.

Here, only the food fraction, *intended for human consumption*, is considered. This has been taken from research on each UK food processing subsectors and very crudely extrapolated to the same subsector groupings using PRODCOM data across the whole of the EU-28 following the approach by FUSIONS (Stenmarck et al 2016). This approximates to 8 M tonnes.

Applying valorisation approaches across the whole of the EU (similar to Cristobel et al 2018) to specific individual types of food wastes, (compliant with rWFD definitions) as identified from subsectors by Parfitt et al 2016, would be compatible with EU reduction targets. However, Parfitt et al 2016 do not quantify specific, segregable streams that would allow further investigation for valorisation, but provides only cumulative (mixed) subsector food waste totals.

Instead, these totals can only be given as crude indications of maximum theoretical additional quantities that can be conceived for contributing to EU food waste reductions, with valorising mixed food waste for animal feed.

Table 8 Estimates of the magnitude of food waste across EU-28 that could potentially contribute to food waste reduction through conversion to animal feed

Stage	Indicative Maximum food waste arising (Million tonnes)	Notes/date sources
Processing	~8	Crude scaling of UK sub-sector data (Parfitt et al 2016) to EU-28 (see text for caveats).
Food service/ catering	~5.5 - 7.5	Stenmarck et al 2016, Kemna et al 2017, WRAP 2013.
Retail	2.5 to 3	ICF 2018.
Total	~ 16	-

[15] Inedible parts of food such as pits, peelings, pomace, bones but also potentially edible fractions not typically eaten can be excluded from the definitions of food and considered residues under General food law article 2 definitions of **Regulation (EC) No 178/2002**

Limitations

This extrapolation is clearly not robust, and has major flaws and limitations, so can only be seen as very crude, but this is the only approach available due to a lack of primary data from subsectors of the food industry across EU-28.

Only indications for the theoretical maximum food wastes from catering, retail and processing have been used to estimate food waste in the EU-28. This approximates to 16 Million tonnes of food waste in total (Table 8). On a per capita basis this is roughly around 30 kg, split more or less equally between processing and consumer and retail stages. There are major limitations to the assumptions made when using research findings from a single Member State to the whole of the EU-28.

The extent to which this total figure can be valorised to contribute to policy on reducing food waste through the supply chain will depend on the economic factor, as well, of course, as the lifting of current feed ban on animal proteins in feed (See Luyckx et al 2019).

Quantifying a realistic potential based on economic criteria is less straight forward. For example, where transport cost may be a significant constraint for producing liquid feed from food waste, understanding the true potential would rely on further research integrating the site based cost models developed in REFRESH, (D6.11) with a broad geographical assessment of the distribution of food waste sources and processing plants that are within appropriate distances from viable feed markets (suitable farming regions) across the EU-28.

Potential

Even though the cases that were worked on within WP6 were not relevant for achieving the EU target on food waste reduction, a number of valorisation examples that were produced are still relevant and will have significant impact.

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6 Appendix

Crude scaling approach using food waste rates available for valorisation based on scaling Parfitt et al's UK findings across the EU-28 using PRODCOM data (see main text for caveats and acknowledged flaws of this approach)

The replicated grouping of categories of PRODCOM 2014 shows a reasonably broad[16] association with the volumes reported by Parfitt et al 2016 with only fruit and vegetable data, soft drinks and dairy to a lesser extent, as exceptions (Table 9). Parfitt et al used another data source representing UK primary production (not PRODCOM). Interestingly, fruit and vegetable primary production is more than 10 times greater than the mass of sold products reported in PRODCOM so there would be a need to reconcile this difference from further investigation if primary production data sources was essential for the approach used here.

However, *by value* the 2014 PRODCOM total UK fruit and vegetable production reported by Parfitt et al of (£1.3 Billion) matches the value for the replicated groupings here for fruit and vegetable products, (assuming 0.82-0.84 Euros to Sterling). So, in respect of crudely extrapolating processing food waste as a proportion of total production quantities PRODCOM production volume data is used as the denominator for fruit and vegetables wastes (rather than primary production). This is also the same for discrepancy in quantities reported by Parfitt et al for the soft drinks subsector. Cross checking with the same product groupings but for (monetary) sales value of production indicates £5.4 Billion which is the same value quoted by Parfitt et al 2016. This corroborates 11.2 million production volume found here, and the 15 million is presumed to be erroneous perhaps corrected in later amendments to the provisional PRODCOM data reported by Parfitt et al.

For dairy the 2014 PRODCOM data obtained gave a higher total for both the sales production quantity and value reported by Parfitt et al. Looking at the data there appears to be no way of rationalising this difference other than some of the PRODCOM dairy products listed were excluded from Parfitt et al's groupings, or the data has been revised by Eurostat since.

Table 9 EU-28 and UK PRODCOM 2014 annual food sales volume (million tonnes) grouped by Parfitt et al 2016 processing subsector groups

Subsector	EU28	UK	Parfitt et al 2016	% Deviation of UK grouping here to Parfitt et al's
Alcoholic drinks	64,8	7.7	8	-4%
Ambient products	29,6	1.3	1.6	-16%

[16] Differences occur due to the granularity products (see appendix) and respective choices for grouping, meaning that an exact set of products to that grouped by Parfitt et al is difficult to match through trial and error, in addition data can sometimes be changed retrospectively by Eurostat, where amendments may have been made since initial publication online.

Bakery, cake and cereals	36,7	5,6	5.6	0%
Confectionary	10,4	0.8	0.7	16%
Dairy products	85,5	11,2	10.2	10%
Fresh fruit and vegetable processing	11,5	0.9	*9**	*-90%*
Meat, poultry and fish	84,5	5,5	5.3	5%
Milling	71,6	6,4	6.1	5%
Pre-prepared meals	16,3	1,5	1.3	16%
Soft drinks and fruit juices	143,1	11,1	15**	-26%
Sugar	39,5	-		

*Parfitt et al 2016 used UK primary production data for fruit and vegetables not PRODCOM data which is production in sold volume. ** The 15 million tonnes appears to erroneous -see main text.

PRODCOM 2014 food production sales (tonnes) in subsector groupings

Food products categorised into Parfitt et al's (2016) sub-sector groupings	Sales production tonnes	
	EU-28	UK
Alcoholic drinks	**64,756,539**	**7,676,329**
Beer made from malt (excluding non-alcoholic beer, beer containing <= 0,5 % by volume of alcohol, alcohol duty)	37,500,000	4,890,029
Brewing or distilling dregs and waste (excluding alcohol duty)	9,626,639	1,075,137
Champagne (important: excluding alcohol duty)	230,950	-
Fermented beverages and mixtures thereof (including with non-alcoholic beverages, cider, perry and mead; excluding malt beer, wine of grapes flavoured with plants or aromatic substances)	2,478,032	968,689
Gin and geneva (important: excluding alcohol duty)	80,162	53,799
Port, Madeira, Sherry and other > 15 % alcohol	214,293	-
Pure alcohols (important: excluding alcohol duty)	60,000	-
Quality wine and grape must with fermentation prevented or arrested by the addition of alcohol, with a protected designation of origin (PDO) produced of an alcoholic strength of <= 15 % (excluding white wine and sparkling wine)	3,084,000	40
Rum and other spirits obtained by distilling fermented sugar-cane products (important: excluding alcohol duty)	90,000	-
Sparkling wine from fresh grapes (excluding champagne; alcohol duty)	800,000	300
Spirits distilled from fruit (excluding liqueurs, gin, geneva; grape wine or grape marc (important: excluding alcohol duty))	19,038	-
Spirits obtained from distilled grape wine or grape marc (important: excluding alcohol duty)	173,514	-
Spirits, liqueurs and other spirituous beverages (excluding spirits distilled from grape wine, grape marc or fruit/whisky, rum, tafia, gin and geneva, Vodka of an alcoholic strength by volume of <= 45.4%, spirits distilled from fruit) (important: excluding alcohol duty)	395,786	1,899
Vermouth and other wine of fresh grapes flavoured with plants or aromatic substances (excluding alcohol duty)	420,000	-
Vodka of an alcoholic strength by volume of <= 45,4 % (important: excluding alcohol duty)	295,680	19,821
Whisky (important: excluding alcohol duty)	720,000	650,860
White wine with a protected designation of origin (PDO)	1,624,000	-
Wine and grape must with fermentation prevented or arrested by the addition of alcohol, of an alcoholic strength <= 15 % (excluding sparkling wine and wine (PDO))	5,766,446	15,754

Food products categorised into Parfitt et al's (2016) sub-sector groupings	Sales production tonnes	
	EU-28	UK
Wine and grape must with fermentation prevented or arrested by the addition of alcohol, put up with pressure of CO2 in solution >= 1 bar < 3, at 20 °C (excluding sparkling wine)	1,177,998	-
Ambient products	**29,637,828**	**1,346,537**
Beans, preserved otherwise than by vinegar or acetic acid, except prepared vegetable dishes	1,138,506	-
Citrus fruit jams, marmalades, jellies, purees or pastes, being cooked preparations (excluding homogenised preparations)	115,616	47,380
Concentrated tomato puree and paste	1,067,170	-
Couscous	178,153	5,959
Drained, glace or crystallised fruit, nuts, fruit-peel and other parts of plants	75,728	-
Dried fruit (excluding bananas, dates, figs, pineapples, avocados, guavas, mangoes, mangosteens, citrus fruit and grapes); mixtures of nuts or dried fruits	128,213	22,934
Dried grapes	55,762	-
Dried mushrooms and truffles, whole, cut, sliced, broken or in powder, but not further prepared	5,226	-
Dried onions, whole, cut, sliced, broken or in powder, but not further prepared	60,000	-
Dried potatoes in the form of flour, meal, flakes, granules and pellets	431,493	-
Dried potatoes whether or not cut or sliced but not further prepared	3,009	-
Dried vegetables (excluding potatoes, onions, mushrooms and truffles) and mixtures of vegetables, whole, cut, sliced, broken or in powder, but not further prepared	104,481	218
Food preparations for infants, p.r.s. (excluding homogenised composite food preparations)	887,262	2,607
Homogenised composite food preparations for infant food or dietetic purposes p.r.s. in containers <= 250 g	519,674	-
Homogenised preparations of jams, fruit jellies, marmalades, fruit or nut puree and fruit or nut pastes	111,659	-
Homogenised vegetables (excluding frozen, preserved by vinegar or acetic acid)	36,378	-
Jams, marmalades, fruit jellies, fruit or nut purees and pastes, being cooked preparations (excluding of citrus fruit, homogenised preparations)	1,707,708	114,360
Malt extract	93,464	-
Mustard flour and meal	2,224	-
Peas, preserved otherwise than by vinegar or acetic acid, except prepared vegetable dishes	379,073	-
Potatoes prepared or preserved in the form of flour, meal or flakes (excluding frozen, crisps, by vinegar or acetic acid)	87,994	-
Potatoes prepared or preserved, including crisps (excluding frozen, dried, by vinegar or acetic acid, in the form of flour, meal or flakes)	1,804,186	171,900
Preparations containing cocoa for making beverages	156,921	26,286
Prepared mustard	328,312	2,089
Prepared or preserved groundnuts (including peanut butter; excluding by vinegar or acetic acid, frozen, purees and pastes)	299,481	47,213
Prepared or preserved mushrooms and truffles (excluding prepared vegetable dishes and mushrooms and truffles dried, frozen or preserved by vinegar or acetic acid)	299,837	1,921

Food products categorised into Parfitt et al's (2016) sub-sector groupings	Sales production tonnes	
	EU-28	UK
Prepared or preserved nuts (other than groundnuts); and other seeds and mixtures (excluding by vinegar or acetic acid, frozen, purees and pastes, preserved by sugar)	657,744	18,873
Prepared or preserved olives (excluding prepared vegetable dishes and olives dried, frozen or preserved by vinegar or acetic acid)	912,877	9,736
Prepared or preserved sweetcorn (excluding prepared vegetable dishes and sweetcorn dried, frozen or preserved by vinegar or acetic acid)	497,243	335
Preserved asparagus (excluding prepared vegetable dishes and asparagus dried, frozen or preserved by vinegar or acetic acid)	12,363	1
Preserved sauerkraut (excluding prepared vegetable dishes and sauerkraut dried, frozen or preserved by vinegar or acetic acid)	148,623	-
Preserved tomatoes, whole or in pieces (excluding prepared vegetable dishes and tomatoes preserved by vinegar or acetic acid)	1,275,168	-
Sauces and preparations therefor, mixed condiments and mixed seasonings (excluding soya sauce, tomato ketchup, other tomato sauces, mustard flour or meal and prepared mustard)	2,938,405	596,088
Soya sauce	50,137	-
Tomato ketchup and other tomato sauces	1,300,000	125,369
Unconcentrated tomato puree and paste	1,164,855	-
Vegetables (excluding potatoes), fruit, nuts and other edible parts of plants, prepared or preserved by vinegar or acetic acid	1,332,257	65,902
Vinegar and substitutes for vinegar (excluding made from wine)	587,095	84,621
Wine vinegar	280,202	2,747
#N/A	8,403,329	-
Bakery, cake and cereals	**36,676,884**	**5,578,404**
Bakers' wares, no added sweetening (including crepes, pancakes, quiche, pizza; excluding sandwiches, crispbread, waffles, wafers, rusks, toasted, savoury or salted extruded/expanded products)	1,908,979	386,671
Biscuits (excluding those completely or partially coated or covered with chocolate or other preparations containing cocoa, sweet biscuits, waffles and wafers)	520,530	-
Cake and pastry products; other bakers' wares with added sweetening matter	6,753,780	1,095,158
Communion wafers, empty cachets of a kind suitable for pharmaceutical use, sealing wafers, rice paper and similar products	10,363	-
Crispbread	153,444	-
Fresh bread containing by weight in the dry matter state <= 5 % of sugars and <= 5 % of fat (excluding with added honey; eggs; cheese or fruit)	19,600,000	2,952,554
Gingerbread and the like	212,000	2,800
Matzos	14,547	807
Mixes and doughs for the preparation of bread, cakes, pastry, crispbread, biscuits, waffles, wafers, rusks, toasted bread and similar toasted products and other bakers' wares	1,800,000	214,673
Muesli type preparations based on unroasted cereal flakes	300,000	108,789
Rusks, toasted bread and similar toasted products	908,395	190,236
Savoury or salted extruded or expanded products	680,569	128,348

Food products categorised into Parfitt et al's (2016) sub-sector groupings	Sales production tonnes	
	EU-28	UK
Sweet biscuits (including sandwich biscuits; excluding those completely or partially coated or covered with chocolate or other preparations containing cocoa)	1,953,794	271,076
Sweet biscuits; waffles and wafers completely or partially coated or covered with chocolate or other preparations containing cocoa	1,476,000	222,434
Waffles and wafers (including salted) (excluding those completely or partially coated or covered with chocolate or other preparations containing cocoa)	283,369	4,857
Waffles and wafers with a water content > 10 % by weight of the finished product (excluding ice cream cornets, sandwiched waffles, other similar products)	101,114	-
Confectionary	**10,382,600**	**809,227**
Boiled sweets	237,363	25,756
Caramel	200,199	14,873
Chewing gum	102,145	-
Chocolate and other food preparations containing cocoa, in blocks, slabs or bars > 2 kg or in liquid, paste, powder, granular or other bulk form, in containers or immediate packings of a content > 2 kg, containing >= 18 % by weight of cocoa butter	1,136,333	114,935
Chocolate blocks, slabs or bars (excluding filled, with added cereal; fruit or nuts, chocolate biscuits)	507,963	21,706
Chocolate blocks, slabs or bars with added cereal, fruit or nuts (excluding filled, chocolate biscuits)	410,687	5,401
Chocolate confectionery (excluding filled, in blocks, slabs or bars, chocolate biscuits, chocolates)	271,262	28,556
Chocolate flavour coating containing 18 % or more by weight of cocoa butter and in packings weighing > 2 kg	158,946	15,616
Chocolate milk crumb containing 18 % or more by weight of cocoa butter and in packings weighing > 2 kg	16,000	-
Chocolate spreads	561,119	-
Chocolates (excluding those containing alcohol, in blocks, slabs or bars)	543,200	123,468
Chocolates (including pralines) containing alcohol (excluding in blocks, slabs or bars)	79,735	175
Cocoa butter, fat and oil	375,227	-
Cocoa paste (excluding containing added sugar or other sweetening matter)	376,803	-
Cocoa powder, containing added sugar or other sweetening matter	157,907	212
Cocoa powder, not containing added sugar or other sweetening matter	465,917	-
Compressed tablets of sugar confectionery (including cachous)	63,800	15,760
Filled chocolate blocks, slabs or bars consisting of a centre (including of cream, liqueur or fruit paste; excluding chocolate biscuits)	960,000	55,296
Filled chocolate confectionery (excluding in blocks, slabs or bars, chocolate biscuits, chocolates)	354,978	17,081
Food preparations containing <18 % of cocoa butter and in packings weighing > 2 kg (excluding chocolate flavour coating, chocolate milk crumb)	129,440	-
Food products with cocoa (excluding cocoa paste, butter, powder, blocks, slabs, bars, liquid, paste, powder, granular, other bulk form in packings > 2 kg, to make beverages, chocolate spreads)	126,717	-
Gums, fruit jellies and fruit pastes in the form of sugar confectionery (excluding chewing gum)	860,714	73,782

Food products categorised into Parfitt et al's (2016) sub-sector groupings	Sales production tonnes	
	EU-28	UK
Liquorice cakes, blocks, sticks and pastilles containing > 10 % by weight of sucrose, but not containing any other substances	70,000	614
Protein concentrates and flavoured or coloured sugar syrups	815,259	132,127
Sugar confectionery and substitutes therefor made from sugar substitution products, containing cocoa (including chocolate nougat) (excluding white chocolate)	191,032	4,703
Sugar confectionery pastes in immediate packings of a net content >= 1 kg (including marzipan, fondant, nougat and almond pastes)	283,207	71,523
Sugar confectionery, n.e.c.	364,400	38,467
Sugar-coated (panned) goods (including sugar almonds)	162,442	12,013
Throat pastilles and cough drops consisting essentially of sugars and flavouring agents (excluding pastilles or drops with flavouring agents containing medicinal properties)	42,551	10,765
Toffees, caramels and similar sweets	223,572	26,400
White chocolate	133,681	-
Dairy products	**85,490,045**	**11,201,696**
Butter of a fat content by weight <= 85 %	2,000,000	121,955
Butter of a fat content by weight > 85 % and other fats and oils derived from milk (excluding dairy spreads of a fat content by weight < 80 %)	800,000	30,351
Buttermilk	894,927	60,626
Buttermilk powder	76,310	-
Casein and caseinates	95,183	-
Condensed or evaporated milk, sweetened	298,212	-
Condensed or evaporated milk, unsweetened	1,630,865	-
Curdled milk, cream, yogurt and other fermented products	3,141,171	130,648
Dairy spreads of a fat content by weight < 80 %	137,894	-
Flavoured liquid yoghurt or acidified milk (curdled milk; cream; yoghurt and other fermented products flavoured or containing added fruit; nuts or cocoa)	5,600,000	233,360
Grated, powdered, blue-veined and other non-processed cheese (excluding fresh cheese, whey cheese and curd)	6,000,000	347,236
Ice cream and other edible ice (including sherbet, lollipops) (excluding mixes and bases for ice cream)	2,988,507	304,972
Lactose and lactose syrup (including chemically pure lactose)	545,168	-
Milk and cream of a fat content by weight of <= 1 %, not concentrated nor containing added sugar or other sweetening matter, in immediate packings of a net content <= 2 l	3,070,833	322,927
Milk and cream of a fat content by weight of <= 1 %, not concentrated nor containing added sugar or other sweetening matter, in immediate packings of a net content > 2 l	3,849,727	831,592
Milk and cream of a fat content by weight of > 1 % but <= 6 %, not concentrated nor containing added sugar or other sweetening matter, in immediate packings of a net content <= 2 l	22,680,000	2,907,941
Milk and cream of a fat content by weight of > 1 % but <= 6 %, not concentrated nor containing added sugar or other sweetening matter, in immediate packings of a net content > 2 l	9,120,770	4,870,953

Food products categorised into Parfitt et al's (2016) sub-sector groupings	Sales production tonnes	
	EU-28	UK
Milk and cream of a fat content by weight of > 21 %, not concentrated nor containing added sugar or other sweetening matter, in immediate packings of <= 2 l	1,252,803	84,526
Milk and cream of a fat content by weight of > 21 %, not concentrated nor containing added sugar or other sweetening matter, in immediate packings of > 2 l	1,535,079	248,923
Milk and cream of a fat content by weight of > 6 % but <= 21 %, not concentrated nor containing added sugar or other sweetening matter, in immediate packings of <= 2 l	629,439	28,311
Milk and cream of a fat content by weight of > 6 % but <= 21 %, not concentrated nor containing added sugar or other sweetening matter, in immediate packings of > 2 l	160,000	30,961
Processed cheese (excluding grated or powdered)	692,336	5,079
Products consisting of natural milk constituents, n.e.c.	1,742,777	81,500
Skimmed milk powder (milk and cream in solid forms, of a fat content by weight of <= 1,5 %), in immediate packings of <= 2,5 kg	193,088	-
Skimmed milk powder (milk and cream in solid forms, of a fat content by weight of <= 1,5 %), in immediate packings of > 2,5 kg	1,367,653	72,406
Unripened or uncured cheese (fresh cheese) (including whey cheese and curd)	3,504,750	204,264
Whey and modified whey in liquid or paste forms; whether or not concentrated or containing added sweetening matter	8,708,035	96,157
Whey and modified whey in powder, granules or other solid forms, whether or not concentrated or containing added sweetening matter	1,873,553	131,889
Whole milk powder or full cream powder (milk and cream in solid forms, of a fat content by weight of > 1,5 %), in immediate packings of <= 2,5 kg	258,353	-
Whole milk powder or full cream powder (milk and cream in solid forms, of a fat content by weight of > 1,5 %), in immediate packings of > 2,5 kg	642,612	55,118
Fresh fruit and vegetable processing	**11,515,669**	**877,054**
Frozen potatoes, prepared or preserved (including potatoes cooked or partly cooked in oil and then frozen; excluding by vinegar or acetic acid)	4,600,000	509,000
Frozen potatoes, uncooked or cooked by steaming or boiling in water	403,198	-
Frozen vegetables and mixtures of vegetables, uncooked or cooked by steaming or boiling in water (excluding potatoes)	4,480,059	186,140
Fruit, prepared or preserved, n.e.c. (excluding Müsli)	2,032,413	181,915
Meat, poultry and fish	**84,520,218**	**5,539,632**
Beef and veal salted, in brine, dried or smoked	127,987	444
Bellies and cuts thereof of swine, salted, in brine, dried or smoked	506,000	14,347
Caviar (sturgeon roe)	64	-
Caviar substitutes	15,153	-
Cooking and other preparation services for the production of meat products		-
Dried fish, whether or not salted; fish, salted but not dried; fish in brine (excluding fillets, smoked, heads, tails and maws)	102,710	-
Edible offal of bovine animals, swine, sheep, goats, horses and other equines, fresh or chilled	2,143,717	122,608
Edible offal of bovine animals, swine, sheep, goats, horses and other equines, frozen	800,000	32,033

Food products categorised into Parfitt et al's (2016) sub-sector groupings	Sales production tonnes	
	EU-28	UK
Extracts and juices of meat, fish, crustaceans, molluscs or other aquatic invertebrates	35,935	-
Fish fillets in batter or breadcrumbs including fish fingers (excluding prepared meals and dishes)	407,246	108,919
Fish fillets, dried, salted or in brine, but not smoked	46,624	2,538
Fish heads, tails and maws, other edible fish offal: dried, salted or in brine, smoked	15,000	5,966
Fish, crustaceans, molluscs and other aquatic invertebrates, otherwise prepared or preserved, including prepared meals and dishes	2,231,733	-
Flours, meals and pellets of fish, fit for human consumption; fish livers and roes, dried, smoked, salted or in brine	5,000	-
Fresh or chilled carcases and half-carcases, of pig meat (including fresh meat packed with salt as a temporary preservative)	7,360,000	80,692
Fresh or chilled carcases, half-carcases and cuts, of lamb or sheep	505,600	213,235
Fresh or chilled carcases, half-carcases and quarters with bone in, of beef and veal	3,774,791	170,003
Fresh or chilled cuts of chicken	4,949,429	601,327
Fresh or chilled cuts of geese, ducks and guinea fowls	118,997	-
Fresh or chilled cuts of turkey	1,374,758	47,971
Fresh or chilled cuts, of beef and veal	3,196,583	563,437
Fresh or chilled fatty livers of geese and ducks	11,700	-
Fresh or chilled fish fillets and other fish meat without bones	323,881	59,591
Fresh or chilled fish livers and roes	1,138	-
Fresh or chilled hams, shoulders and cuts thereof with bone in, of pig meat (including fresh meat packed with salt as a temporary preservative)	4,150,000	193,271
Fresh or chilled or frozen cuts of geese, ducks and guinea fowls	204,155	-
Fresh or chilled or frozen poultry offal (excluding fresh or chilled fatty livers of geese and ducks)	1,533,890	240,774
Fresh or chilled or frozen whole geese, ducks and guinea fowls	194,663	-
Fresh or chilled pig meat (including fresh meat packed with salt as a temporary preservative; excluding carcases and half-carcases, hams, shoulders and cuts thereof with bone in)	8,367,113	249,231
Fresh or chilled poultry offal (excluding fatty livers of geese and ducks)	1,029,081	225,278
Fresh or chilled whole chickens	4,050,000	559,314
Fresh or chilled whole geese, ducks and guinea fowls	84,881	-
Fresh or chilled whole turkeys	345,664	6,489
Fresh, chilled or frozen edible meat and offal (including meat and offal of rabbits, hares and game; excluding frog legs, and meat and offal of poultry, bovine and equine animals, swine, sheep and goat)	225,000	2,632
Frozen carcases and half-carcases, of pig meat	86,251	-
Frozen carcases, half-carcases and cuts, of lamb or sheep	39,047	6,631
Frozen carcases, half-carcases, quarters and cuts, of beef and veal	604,170	24,035

Food products categorised into Parfitt et al's (2016) sub-sector groupings	Sales production tonnes	
	EU-28	UK
Frozen crustaceans, frozen flours, meals and pellets of crustaceans, fit for human consumption	91,000	19,254
Frozen cuts of chicken	1,358,842	163,572
Frozen cuts of ducks, geese and guinea fowls	85,158	-
Frozen cuts of turkey	173,879	14,379
Frozen fish fillets	219,874	22,048
Frozen fish livers and roes	10,000	-
Frozen fish meat without bones (excluding fillets)	45,368	58
Frozen hams, shoulders and cuts with bone in, of pig meat	409,210	-
Frozen pig meat (excluding carcases and half-carcases, hams, shoulders and cuts thereof with bone in)	1,916,286	83,149
Frozen poultry livers	41,806	1,875
Frozen poultry offal (excluding liver)	463,004	13,621
Frozen whole chickens	640,000	1,802
Frozen whole fresh water fish	6,239	-
Frozen whole geese, ducks and guinea fowls	109,782	-
Frozen whole salt water fish	683,078	142,015
Frozen whole turkeys	20,000	8,189
Hams, shoulders and cuts thereof with bone in, of swine, salted, in brine, dried or smoked	1,729,204	62,850
Homogenised preparations of meat, meat offal or blood (excluding sausages and similar products of meat; food preparations based on these products)	20,015	-
Liver sausages and similar products and food preparations based thereon (excluding prepared meals and dishes)	172,160	115
Meat of goats, fresh or chilled	9,500	-
Meat of horses and other equines, fresh or chilled	35,792	-
Meat salted, in brine, dried or smoked; edible flours and meals of meat or meat offal (excluding pig meat, beef and veal salted, in brine, dried or smoked)	400,000	1,381
Molluscs (scallops, mussels, cuttle fish, squid and octopus), frozen, dried, smoked, salted or in brine	170,088	6,815
Other aquatic invertebrates (striped venus, jellyfish, etc.), frozen, dried, smoked, salted or in brine; flours, meals and pellets of aquatic invertebrates other than crustaceans, fit for human consumption, frozen, dried, smoked, salted or in brine	8,551	-
Other fish, prepared or preserved, whole or in pieces (excluding minced products and prepared meals and dishes)	120,272	-
Other prepared or preserved meat or offal, including blood (excluding sausages and similar products, homogenised preparations, preparations of liver and prepared meals and dishes)	350,093	16,449
Other prepared or preserved meat, offal and mixtures of swine, including mixtures (excluding sausages and similar products, homogenised preparations, preparations of liver and prepared meals and dishes)	1,089,000	97,723
Other prepared or preserved poultry meat (excluding sausages, preparations of liver and prepared meals and dishes)	1,515,000	287,209

Food products categorised into Parfitt et al's (2016) sub-sector groupings	Sales production tonnes	
	EU-28	UK
Pig meat salted, in brine, dried or smoked (including bacon, 3/4 sides/middles, fore-ends, loins and cuts thereof; excluding hams, shoulders and cuts thereof with bone in, bellies and cuts thereof)	975,000	225,648
Prepared or preserved anchovies, whole or in pieces (excluding minced products and prepared meals and dishes)	18,614	-
Prepared or preserved crustaceans, molluscs and other aquatic invertebrates (excluding chilled, frozen, dried, salted or in brine, crustaceans, in shell, cooked by steaming or boiling) (excluding prepared meals and dishes)	245,881	26,857
Prepared or preserved fish (excluding whole or in pieces and prepared meals and dishes)	309,898	35,339
Prepared or preserved goose or duck liver (excluding sausages and prepared meals and dishes)	34,652	206
Prepared or preserved herrings, whole or in pieces (excluding minced products and prepared meals and dishes)	251,057	-
Prepared or preserved liver of other animals (excluding sausages and prepared meals and dishes)	107,961	881
Prepared or preserved mackerel, whole or in pieces (excluding minced products and prepared meals and dishes)	64,546	-
Prepared or preserved meat of swine: hams and cuts thereof (excluding prepared meals and dishes)	1,299,851	140,591
Prepared or preserved meat of swine: shoulders and cuts thereof, of swine (excluding prepared meals and dishes)	154,547	-
Prepared or preserved meat or offal of bovine animals (excluding sausages and similar products, homogenised preparations, preparations of liver and prepared meals and dishes)	692,402	213,702
Prepared or preserved meat or offal of turkeys (excluding sausages, preparations of liver and prepared meals and dishes)	436,353	33,096
Prepared or preserved meat, offal and mixtures of domestic swine, including mixtures, containing < 40 % meat or offal of any kind and fats of any kind (excluding sausages and similar products, homogenised preparations, preparations of liver and prepared meals and dishes)	271,271	28,955
Prepared or preserved salmon, whole or in pieces (excluding minced products and prepared meals and dishes)	30,873	7,732
Prepared or preserved sardines, sardinella, brisling and sprats, whole or in pieces (excluding minced products and prepared meals and dishes)	122,568	-
Prepared or preserved tuna, skipjack and Atlantic bonito, whole or in pieces (excluding minced products and prepared meals and dishes)	401,843	-
Sausages and similar products of meat, offal or blood and food preparations based thereon (excluding liver sausages and prepared meals and dishes)	5,134,470	310,014
Smoked fish (excluding herrings, Pacific, Atlantic and Danube salmon), including fillets, excluding head, tails and maws	86,171	17,533
Smoked herrings (including fillets, excluding heads, tails and maws)	13,502	2,729
Smoked Pacific, Atlantic and Danube salmon (including fillets, excluding heads, tails and maws)	168,882	23,078
#N/A	12,838,713	-
Milling	**71,612,897**	**6,426,611**
Bran, sharps and other residues from the sifting, milling or other working of cereals (excluding maize (corn), rice, wheat)	646,869	73,540
Bran, sharps and other residues from the sifting, milling or other working of maize (corn)	594,946	-
Bran, sharps and other residues from the sifting, milling or other working of rice	505,671	15,274
Bran, sharps and other residues from the sifting, milling or other working of wheat	9,268,000	882,401

Food products categorised into Parfitt et al's (2016) sub-sector groupings	Sales production tonnes	
	EU-28	UK
Broken rice (including enriched rice, parboiled rice)	483,280	-
Cereal flours (excluding wheat or meslin)	2,460,000	35,222
Cereals in grain form, precooked or otherwise prepared (excluding maize)	194,153	46,504
Crude maize (corn) oil and its fractions (excluding chemically modified)	168,320	-
Dextrins and other modified starches (including esterified or etherified, soluble starch, pregelatinised or swelling starch, dialdehyde starch, starch treated with formaldehyde or epichlorohydrin)	2,170,259	-
Flour and meal of dried peas, beans, lentils, sago, manioc, arrowroot, salep, jerusalem artichokes, sweet potatoes or similar roots or tubers; flour, meal, powder of edible fruit, nuts	79,930	9,206
Food preparations of flour, meal, starch, etc.	1,806,000	303,006
Germ of cereals, whole, rolled, flaked or ground (excluding rice)	360,000	68,457
Groats and meal of common wheat and spelt	110,634	-
Groats and meal of durum wheat	2,703,059	-
Groats and meal of oats, maize, rice, rye, barley and other cereals (excluding wheat)	1,015,008	108,321
Husked (brown) rice	164,141	-
Maize (corn) starch	1,488,506	147
Other prepared foods obtained by the swelling or roasting of cereals	1,591,367	491,298
Pellets of oats, maize, rice, rye, barley and other cereals (excluding wheat)	105,053	14,817
Pellets of wheat	241,185	574
Potato starch	1,160,719	25,284
Refined maize (corn) oil and its fractions (excluding chemically modified)	221,596	-
Residues of starch manufacture and similar residues	6,525,583	-
Rolled, flaked, hulled, pearled, sliced or kibbled cereal grains (excluding rice)	1,597,569	370,203
Semi-milled or wholly milled (bleached) rice (including camolino rice)	2,383,704	150,956
Starches (including rice, manioc, arrowroot and sago palm pith) (excluding wheat, maize (corn) and potato)	129,584	-
Tapioca and substitutes therefor prepared from starch, in the form of flakes, grains, pearls, siftings or similar forms	3,000	-
Wheat gluten (excluding wheat gluten prepared for use as a glue or as a glazing or dressing for the textile industry)	698,702	131,984
Wheat or meslin flour	31,640,000	3,699,417
Wheat starch	1,096,060	-
Pre-prepared meals	**16,330,653**	**1,509,627**
Cooked or uncooked pasta stuffed with meat, fish, cheese or other substances in any proportion	823,207	46,658
Dried, undried and frozen pasta and pasta products (including prepared dishes) (excluding uncooked pasta, stuffed pasta)	597,258	141,678
Other food preparations n.e.c.	4,400,000	350,906

Food products categorised into Parfitt et al's (2016) sub-sector groupings	Sales production tonnes	
	EU-28	UK
Other prepared dishes and meals (including frozen pizza)	2,022,000	80,428
Prepared meals and dishes based on fish, crustaceans and molluscs	258,934	53,405
Prepared meals and dishes based on meat, meat offal or blood	1,582,000	364,151
Prepared meals and dishes based on vegetables	610,865	158,624
Soups and broths and preparations therefor	1,316,681	305,824
Uncooked pasta (excluding containing eggs, stuffed or otherwise prepared)	3,135,848	-
Uncooked pasta, containing eggs (excluding stuffed or otherwise prepared)	1,583,860	7,954
Soft drinks and fruit juices	**143,126,624**	**11,050,307**
Apple juice	1,959,000	180,339
Frozen unconcentrated orange juice	90,000	-
Grape juice (including grape must)	1,131,867	-
Grapefruit juice	105,526	-
Mineral waters and aerated waters, unsweetened	56,000,000	1,584,707
Mixtures of fruit and vegetable juices	2,338,933	423,737
Non-alcoholic beer and beer containing <= 0.5% alcohol	638,172	-
Non-alcoholic beverages containing milk fat	1,150,709	-
Non-alcoholic beverages not containing milk fat (excluding sweetened or unsweetened mineral, aerated or flavoured waters)	12,000,000	-
Orange juice n.e.c.	122,177	-
Other fruit and vegetable juices n.e.c.	821,225	-
Pineapple juice	242,059	-
Tomato juice	167,724	13,264
Unconcentrated juice of any single citrus fruit (excluding orange and grapefruit)	201,181	-
Unconcentrated juice of any single fruit or vegetable, not fermented and not containing added spirit (excluding orange, grapefruit, pineapple, tomato, grape and apple juices)	1,013,534	-
Unconcentrated orange juice (excluding frozen)	2,799,641	335,300
Unsweetened and non-flavoured waters; ice and snow (excluding mineral and aerated waters)	7,662,648	216,776
Waters, with added sugar, other sweetening matter or flavoured, i.e. soft drinks (including mineral and aerated)	39,807,909	8,296,183
Non-alcoholic beverages, not containing milk, milk products and fats derived therefrom (excl. water, fruit or vegetable juices)	14,874,318	-
Sugar	**39,513,304**	**-**
Beet-pulp, bagasse and other sugar manufacturing waste (including defecation scum and filter press residues)	11,289,079	-
Cane molasses	130,541	-

Food products categorised into Parfitt et al's (2016) sub-sector groupings	Sales production tonnes	
	EU-28	UK
Chemically pure fructose in solid form; fructose and fructose syrup, containing in the dry state > 50 % of fructose; isoglucose excluding with added flavouring or colouring matter	1,294,317	-
Glucose and glucose syrup (excluding with added flavouring or colouring matter)	4,149,159	-
Maltodextrine and maltodextine syrup (excluding with added flavouring or colouring matter)	372,572	-
Molasses obtained from the extraction or refining of sugar (excluding cane molasses)	2,293,218	-
Other sugars (including invert sugar) n.e.c.	1,406,875	-
Raw cane and beet sugar in solid form, not containing added flavouring or colouring matter	1,618,866	-
Refined cane or beet sugar in a solid form (excluding white sugar)	167,296	-
Refined cane or beet sugar, containing added flavouring or colouring matter; maple sugar and maple syrup	60,532	-
Refined white cane or beet sugar in solid form	16,730,849	-
Grand Total	**593,563,263**	**52,015,424**