Methodology for evaluating environmental sustainability

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Glossary

The definition of the terms in the glossary have been taken from the ISO standard for life cycle assessment (ISO, 2006a), and the PEF guide (EC, 2013) marked with asterisk (*), unless otherwise stated.

allocation	Partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems
attributional LCA*	Refers to process-based modelling intended to provide a static representation of average conditions, excluding market-mediated effects.
consequential LCA	Modelling principle that identifies and models all processes in the background system of a system in consequence of decisions made in the foreground system (EC, 2010).
co-product	Any of two or more products coming from the same unit process or product system
cradle to gate*	A partial product supply chain, from the extraction of raw materials (Cradle) up to the manufacturer's "gate". The distribution, storage, use stage and end-of-life stages of the supply chain are omitted.
cradle to grave*	A product's life cycle that includes raw material extraction, processing, distribution, storage, use and disposal or recycling stages. All relevant inputs and outputs are considered for all of the stages of the life cycle.
direct land use changes (LUC)*	The transformation from one land use type into another, which takes place in a unique land area and does not lead to a change in another system.
environmental impact*	Any change to the environment, whether adverse of beneficial, that wholly or partially results from an organisation's activities, products or services (EMAS regulation)
functional unit	Quantified performance of a product system for use as a reference unit (comment: in the PEF guide the term "unit of analysis" is used)
impact category	Class representing environmental issues of concern (e.g. climate impact) to which life cycle inventory analysis results may be assigned

indirect land use changes (iLUC)*
Occur when a demand for a certain land use leads to changes, outside the system boundaries, i.e. in other and use types. These indirect effects can be mainly assessed by means of economic modelling of the demand for land or by modelling the relocation of activities on a global scale. The main drawbacks of such models are their reliance on trends, which might not reflect future developments. They are commonly used as the basis for political decisions.

life cycle
Consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal

life cycle assessment (LCA)
Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle

life cycle impact assessment (LCIA)
Phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product

life cycle inventory analysis (LCI)
Phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle

mid-point/end-point impact assessment*
A differentiation can be made between "mid-point" and "end-point" impact assessment methods. Mid-point methods assess the impacts earlier in the cause-effect chain. For example, midpoint methods express global warming as CO_2-equivalents while endpoint methods express it - for example - as Disability Adjusted Life Years (years of loss of (quality of) life due to illness or death due to climate change).

process
Set of interrelated or interacting activities that transforms inputs into outputs

product
Any goods or service

product system
Collection of unit processes with elementary and product flows, performing one or more defined functions, and which models the life cycle of a product.

system boundary*
Definition of aspects included or excluded from the study. For example, for a "cradle-to-grave" environmental footprint (EF) analysis, the system boundary should include all activities from the extraction of raw materials through the processing, distribution, storage, use, and

disposal or recycling stages.

system boundary diagram*
Graphic representation of the system boundary defined

Waste hierarchy
Priority order of waste management strategies, placing prevention at the top, followed by preparing for re-use, recycling, recovery, and as the last option, disposal (Directive, 2008)

List of abbreviations

CFP Carbon Footprint

EMAS Eco-Management and Audit Scheme

FU Functional Unit

iLUC Indirect Land Use Change

LCA Life Cycle Assessment

LCC Life Cycle Cost assessment

LUC Direct Land Use Change

PCR Product Category Rules

PEF Product Environmental Footprint

SB System boundaries

WP Work Package

Executive summary

The aim of this report is to review measures and methodologies for evaluating the environmental sustainability dimension of food waste. The purpose is to provide input to REFRESH task 5.1.3 in which method recommendations will be given for evaluating the environmental impact, as well as life cycle costs, of different measures regarding food waste, namely prevention, valorization and waste management options. To structure the thinking on what the methodology challenges are, four REFRESH situations regarding food waste have been defined and described covering: Prevention at source, valorisation maintaining quality, valorisation as part of waste management and end of life treatment.

When exploring existing standards, guidelines and LCA case studies related to food waste, the focus was on answering the following questions:

- How much guidance is there already on evaluation of environmental impacts of food waste?
- What are the commonly used approaches for key methodological aspects?
- What are areas where there are methodological challenges / gaps / differences?
- Do different types of documents, e.g. standards / protocols, case studies align or not?

Results from the review where analysed, paying special attention on these main methodological aspects: functional unit, system boundaries, cut-off criteria, allocation, environmental impact categories, end-of-life, land use change, ecosystem services.

The literature review shows there are a number of documents for guidance when it comes to environmental assessment of products and services, and also guidance focused specifically on food systems. Some of those are very detailed and can be difficult to read for non-experts, others are giving a lot of space for the practitioner to scope an LCA. Within REFRESH we therefore recommend task 5.1.3 and deliverable 5.3 to focus on bridging the gap between existing standard and guidance documents and practitioners, who might be experts on the systems they are assessing but not in LCA. We will do this by:

- Addressing some of the most challenging aspects identified from the literature review
- Providing a lot of food waste specific examples
- Using REFRESH situations to elaborate on method choices
- Encourage the practitioner to ask the important questions and thus help better scoping LCAs
- Provide a set of questions that should be asked when scoping an LCA

The review highlights the main methodological challenges when assessing environmental impact of measures for food waste. Our recommendation is to focus deliverable 5.3 (Generic strategy for LCA and LCC) on these:

- Does the question being asked result in an attributional or consequential model?
- Describing a suitable functional unit (FU) and system boundary (SB) connected to the question(s) being asked; some examples of questions and corresponding FU and SB are given in section 4.1.
- Dealing with multi-functionality (allocation/system expansion)
- What environmental burden a flow from the food chain should have depending on the situation
- How should a replaced product be identified, and on what basis? In which market is the product replaced (local, European, global)? Data sources to use?
- Which are the most important environmental indicators to focus on? Climate impact is common, but standards require many aspects to be explored. What is relevant but also feasible?

1 Introduction

The aim of this report is to review measures and methodologies for evaluating the environmental sustainability dimension of food waste. The purpose is to provide input to REFRESH task 5.1.3 in which methodological recommendations will be given for evaluating the environmental impact, as well as life cycle costs, of different measures regarding food waste, namely prevention, valorization and waste management options. These methodological recommendations should work at different levels in the food chain (micro-level, e.g. business to macro level e.g. country or region). To structure the thinking on what the methodology challenges are, relevant REFRESH situations regarding flows from the food chain have been defined in this report.

In this task we consider measures for flows from the food chain, whether they are valorized or treated in other end of life routes, aligned to the FUSIONS' approach. We explore what methodological challenges there are when assessing the environmental impact of different measures for preventing, valorising or waste handling flows from the food supply chain (including packaging when relevant).

The report starts with a section of how the literature review has been conducted, followed by a description of the developed REFRESH situations. Then, the method issues from the review are analysed and interpreted, and finally the conclusions and outlook are summarized.

2 Literature review

This section describes how the method and rationale of how the literature review was conducted.

2.1 Aim and scope of literature review

From the outset it was important to have a clear defined scope for the literature review and to have an appropriate number of relevant documents to review. The aim of the review is to identify:

- How much guidance is there already on evaluation of environmental impacts of food waste?
- What are the commonly used approaches for key methodological aspects?
- What are areas where there are methodological challenges / gaps / differences?
- Do different types of documents, e.g. standards / protocols, case studies align or not?

It was not the intention to compile an overview of what publications exist in this space, but to select those that will give the most relevant insights for the aim of this review. Publications should address environmental life cycle relevant aspects and have a food waste focus. In addition, fundamental LCA method standards and protocols were included to ensure grounding in standards and because many of the reviewed documents referred to them. Other documents solely focusing on methodology issues without direct reference to food waste were not included at this stage. However, for Task 5.1.3 additional literature will be reviewed for specific methodological issues when needed. Packaging is only addressed in the context of food, no stand-alone packaging documents were included.

2.2 Method of review

The literature review has been split into four discreet sub-tasks:

- Identify relevant documents to review
- Devise structure on how to document information from reviewed documents
- Analyse and interpret information from reviewed documents
- Provide recommendations and outlook to subsequent tasks, in particular 5.1.3

2.2.1 Identification of relevant documents

First, relevant documents were identified by searching scientific publication databases, using internet search engines and using existing knowledge within the task team. Search words were in relation to 'food waste', 'valorisation' and 'waste prevention'. The identified documents fall into the following groups:

- General standards
- Sectorial guidelines
- Sub-sectorial guidelines
- Product specific guidelines
- Other methodological inputs (reports, scientific journal papers, etc.)

A list of the reviewed documents is given in

Annex B: Summary of reviewed documents, **Table 7**.

2.2.2 Structure for documentation

To structure the review and to facilitate the analysis and interpretation a template was devised summarizing key methodological aspects for each of the reviewed documents. Inspiration was taken from unpublished work by the European Food SCP Round Table Working Group 1: *Working paper: Product Category Specific Rules: needs, the role of the Protocol, and Round Table governance*. The aspects covered in the template were discussed and agreed upon during working meeting sessions by the task partners. As this review needed to be the foundation for a standard approach for evaluating the environmental dimension of food waste, those aspects are focused on where the biggest need for guidance and harmonization is needed. Emerging aspects, e.g. ecosystem services are also included. The following aspects were covered in the review for each of the reviewed documents:

- **General information** (objective, target audience, owner)
- **Applicability:** for what type of product, service or sector is this information relevant
- **Functional unit:** what functional unit has been applied, based on what rationale
- **System boundaries:** how they are set and with what explanation
- **Data quality requirements / handling data gaps:** what data guidelines are followed, what data sources are used, documentation of data sources, how data gaps are filled
- **Handling multi-functional processes (allocation/system expansion):** Is it documented how these are handled, what approaches are used, what rationale is given?
- **Handling of end-of-life:** Is end-of-life specifically addressed, what approaches are used, what rationale is given? also packaging is considered here
- **Environmental impact categories recommended or included:** depending if it is a standard/protocol or case study, which environmental impact categories are addressed in this document. This includes also water consumption and water scarcity.
- **Land use change:** Is it addressed in the document, how is it dealt with / what recommendations are given. This includes direct and indirect land use change
- **Ecosystem services:** Which are addressed, what method is recommended/used?
- **Exclusion / cut-off**: Linked to system boundary, how complete are systems covered, what cut-off rules are used?
- **Other:** any other relevant issue that should be highlighted

In some cases, additional documents were identified during the review (e.g. because they were referenced in a reviewed document) and were relevant to this project. These were either included in this literature review, if they fulfilled the scope of the review, or, otherwise, were kept in reference for a later task.

A full list of completed templates is included in

Annex B: Summary of reviewed documents.

2.2.3 Analysis and interpretation

The structure of the templates allowed for easy cross reading of specific aspects, e.g. how is end-of-life handled across the documents. Out of the long set of aspects covered the most relevant are analysed and interpreted in more detail. These are: system boundary, functional unit, cut-off criteria, allocation, environmental impact categories, handling end-of-life, ecosystem services and land use change. Again, the analysis did not just give an overview of how these aspects are covered in the reviewed documents, but particular emphasis was put on identifying patterns, clusters and common practices. Each aspect section ends with a 'take out' statement (see section 4 All other aspects are summarized in brief in section 4.8.

2.2.4 Conclusions and outlook

As the last step of the literature review the findings from the

Analysis and interpretation were combined and inter-dependencies highlighted. Additional comments were provided in regard to where methodology is already sufficient in agreement, where the biggest gaps in guidance are, and what are the methodology aspects which need to be addressed in Task 5.1.3. These are complemented with observations and insights gained from the literature review and from discussions during working meetings by the task members.

According to the project plan environmental and costing dimensions of the life cycle assessments are only combined in task 5.1.3, however, it was important for the task members to seek close alignment and an inter-disciplinary way of working from the start. This allows early identification of commonalities and differences and will give a good starting basis for later combining the environmental and costing perspective. Some initial observations from this early interaction are included in this section.

3 REFRESH Situations

To structure the thinking on what the methodological challenges are when evaluating different measures regarding flows from the food chain, relevant REFRESH situations have been defined, described in this section.

3.1 Purpose and link to other activities

To structure the thinking of REFRESH WP 5.1.1 and WP 5.1.2 in view of task 5.1.3: 'standard system approach for evaluating the environmental dimension and life cycle cost of food waste', four REFRESH *situations* are defined which form the skeleton around which the later task of 5.1.3 will be built. The situations try to group different types of circumstances – situations – under which food and food waste will leave the food supply chain and be treated through different routes (destinations). The hypothesis is that similar situations will require similar methodological choices and thus should give a good structure around which to develop a methodology framework. At this stage this merely is a stepping stone to guide the authors thinking and as such will be developed further during task 5.1.3.

These situations are meant to guide in both environmental and cost assessments; hence, the description of the situations are present in both reports: D5.1 and D5.2 which covers methods for cost assessment.

There are many food commodities that are used in the food supply chain, but which might also be used in other types of goods, e.g. vegetables oils might be used in personal care products. There are also many supply chains producing several outputs which feed into different supply chains, e.g. bio-diesel production also produces glycerol, a common ingredient in many food products. It is not helpful if all possible sources and supply chains which feed into the food supply chain are mapped out. REFRESH, therefore, like FUSIONS focuses on flows from the food supply chain and thus the focus for the situations is there.

3.2 Description of REFRESH situations

The following four situations are defined: prevention at source, valorisation maintaining quality, valorisation as part of waste management and end of life treatment.

Important features of these REFRESH situations are:

- They can take place at any point/process in the life cycle.
- They can take place within the remit of any stakeholder.

- More than one situation can occur at the same life cycle stage, e.g. part of an output is valorised at source, part becomes input to a waste management system and is then in turn valorised.
- More than one situation can occur at different life cycle stages within a life cycle under investigation.
- All final destinations can be accommodated (hypothesis).
- While the presented order of situations has some alignment to the waste hierarchy, all examples given within a situation will not have similar environmental impact.

The situations are described in detail below. How destinations of food waste used in FUSIONS (2015) and Food Loss & Waste Protocol (FLW, 2015) align to the four REFRESH situations are provided in **Table 6** in Appendix A.

3.2.1 Prevention at source

Waste prevention (see

Table **1**) which is the highest priority of the waste hierarchy, is defined as the prevention of waste at source through avoidance, reduction and reuse, but excluding off site recycling. The Waste Framework Directive especially in Article 3, clause 12-13, states that prevention means taking measures before a substance, material or product has become waste, which reduce: (a) the quantity of waste, including through the re-use of products or the extension of the life span of products; (b) the adverse impact of the generated waste on the environment and human health; (c) the content of harmful substances in materials and products (Zorpas and Lasaridi, 2013). Despite the order of priority in the waste hierarchy, only a few studies measure waste prevention in the context of waste management (Laurent et al., 2014).

As an initial thought model, the authors propose that prevention at source can only take place if there has been waste of resources, either by generation of food waste or production of other outputs which were utilized but not as such a desired output (i.e. produced on purpose), otherwise it cannot be prevented. If there was never wastage of resources in the first place, there cannot be prevention. Put differently, not doing the prevention measure would lead to wasted or inefficient use of resources.

Depending on where in the life cycle the prevention takes place, more or fewer processes will be affected. If through a new technology more can be harvested, then this will only affect the agricultural stage; if food waste is prevented at the consumer level, then the prevention will show benefits for the whole life cycle up to that stage. While prevention is generally seen as reducing environmental impacts, there might also be trade-offs, e.g. if less is needed there might be poorer scale of economy in some instances, or actions for prevention might result in environmental burden (e.g. energy for better preservation), which need considerations.

It is worth keeping any rebound effects, as highlighted by Laurent and colleagues (2014), in mind when discussing system boundaries later in the project.

Table 1: REFRESH situation: Prevention at source

Prevention at source: the flow is avoided	
Technology routes	**Examples**
- Redesign and optimisation of processes - New technology - Re-work of material - Behavioural change	- Re-works on manufacturing, which was previously discarded as waste, e.g. content of wrongly packaged product is repacked - More efficient change over from one product or flavour to another - Consumers to use up their purchased food in time so they do not have to throw away spoilt food - Retailers marking down the price to sell items close to use-by-date (reduces wastage at retailer, but not necessarily at consumer end)

3.2.2 Co-product valorisation

Co-product valorisation, see Table 2, can be at any point in the life cycle, including the consumer stage which itself does not produce a marketable output linked to the existing product chain but still can produce material outputs, e.g. peelings which can be valorised. For this situation it is important that outputs of the valorisation need to replace another marketable product. Some of the environmental burden from the upstream supply chain will be attributed to the outputs going into this situation.

The advantage of co-product valorisation over valorisation as part of waste management is that it utilizes, in general, outputs for which the origin is known, which are uncontaminated, high quality material flow, which therefore may allow usage within the food supply chain.

Table 2: REFRESH situation: Co-product valorisation

Co-product valorisation: The flow is valorised into a product that replaces another marketable product. The generator of the flow sees a value with the flow.	
Technology routes	Examples
- Animal feed production - Biobased material and biochemical processing - Bio-energy production - Fermentation	- Use of bagasse for energy production - Use of by-product plant material for bioplastics, such as PLA - Use of fish industry residues as input for feed production - On-site treatment of manufacturing food waste in AD (it is of value for the generator) - On-site recycling (for a different use than its original) e.g. used coffee grounds as fertiliser for office plants assuming it replaces fertilizer - On-site composting - Home composting (if compost replaces shop bought compost or substances used for soil improvement).

3.2.3 Valorisation as part of waste management

Valorisation as part of waste management (

Table 3) can be at any point in the life cycle. The material flow may be mixed with other materials for further treatment with the aim to utilize the material before final disposal. This stage can include a change of owner of the material flow and may be accompanied by a loss of traceability or an increase in contaminations. It starts, e.g. by being collected within a municipal waste management system. The output from this valorisation still replaces a marketable product.

Table 3: REFRESH situation: Valorisation as part of waste management

Valorisation as part of waste management: the flow is mixed with other materials and treated in waste treatment process that gives a product that replaces another marketable product. The generator of the flow wants to discard the flow (sees no value).	
Technology routes	Examples
- Composting by waste management companies - plough in if for the purpose of soil enhancement - Not harvested if for the purpose of soil enhancement - Anaerobic digestion - Co-generation/Incineration if with energy recovery	- Bio gas production in an anaerobic digestion - Incineration linked to district heating system

3.2.4 End of life treatment

The purpose of this situation is to handle material, reduce its quantity and stability for final disposal. The technologies are not designed to maximize any valuable outputs. For instance, a landfill is not designed to optimize methane production, quite the contrary. Examples are given in **Table 4**.

Table 4: REFRESH situation: End of life treatment

End of life treatment: the treatment does NOT result in any product that replaces another marketable product	
Technology routes	Examples
- Plough in - Not harvested with no change in	- Incineration without energy recovery

fertilizer use

- Incineration without energy recovery
- Wastewater treatment
- Landfill with and without gas recovery
- Discards to land or sea

- Composting as treatment to stabilise material
- A consumer pouring spoilt milk down the drain and no biogas production from waste water treatment plant
- Left over product in a production line washed out during line change over

4 Analysis and interpretation

Here, information from the review is analysed regarding the main methodological aspects: functional unit, system boundaries, cut-off criteria, allocation, environmental impact categories, end-of-life, land use change, ecosystem services. At the end of this section, other general issues are also discussed briefly.

4.1 Functional unit and system boundaries

In both standards addressing a range of impacts, as well as single impact standards, e.g. Water footprint and carbon footprint, we see that they all follow the ISO standard for LCA (ISO, 2006a; ISO 2006b) in requiring that the functional unit (FU) and system boundaries (SB) of your study should be in line with the goal and scope. In other words, the purpose of the study very much determines how you define the functional unit and system boundaries. All standards stress that if you are comparing two or more products or processes, the functional unit should be the same. Regarding the system boundaries, the standards highlight that all process steps that contribute significantly to the environmental impact should be included. Some standards are very specific; in particular the standards focused on products such as the product environmental footprint (EC, 2013) standard and product category rules (e.g. PCR 2010:01; PCR 2011:20). To give an example of the level of detail, in the PCR for pasta it is stated that the following stages should be included:

- **Upstream:** Production in agriculture (production of seeds, fertilizers, energy, detergents, packaging, milling of flour)
- **Core:** Manufacturing of pasta, production of energy, transport of raw materials, waste treatment processes
- **Downstream:** Transport of pasta to retailer, cooking of pasta, handling of packaging after use

When looking at the reviewed case studies of environmental assessment that explore food waste in one way or other, two groups are identified based on two different aims, see groups A and B in table 5.

Table 5: Different purposes of case studies explored, and corresponding system boundary and functional unit.

	Group A	Group B
Aim	- Compare different valorisation or waste management options for food waste	- Explore the environmental impact of food waste generation (i.e. additional impact due to producing too much food which downstream becomes waste)
System boundary	- From point of waste generation to production of new product or waste management (downstream) - All case studies in group A use this system boundary	- From cradle to waste, i.e. including all upstream processes of producing the food that is then wasted downstream. - All case studies in group B use this system boundary
Functional unit	- Mass based - Mass of waste treated OR mass of valorised product	- Mass based - Mass of food consumed OR mass of waste generated

Within each of these two groups the system boundaries have been set consistently. Case studies in which the aim is to compare valorisation/waste treatment options have used a boundary starting at the waste generation and ends with the valorisation or waste treatment step. Whereas the case studies in group B have all used a cradle to waste system boundary, which includes all production steps of producing the food upstream. However, when it comes to the functional unit, there are differences within each group. In group A the functional unit is either the amount of waste treated or the amount of valorised product. In group B the FU is either the amount of food consumed or the amount of food waste generated. All studies have used a mass based functional unit, i.e. no inclusion of any quality aspects. There is no consistency in how the FU is defined in these studies, which is not a problem as long as it is not necessary to make comparisons across studies with different functional units.

In REFRESH, the aim is most in line with group A, to explore environmental impact of different ways of handling streams from the food chain, so it might seem logical that we use a similar system boundary: from point of waste generation to valorization or treatment. However, none of the explored case studies have looked at upstream effects of preventive measures, and we also need to cover this in the method, which means also taking the production of food into account in the system boundary as avoided impact. None of the reviewed references give guidance on how to compare across these two groups, e.g. prevention measures with valorisation options. However, some standards and guidance documents have sections focusing in general on relevant aspects when comparing studies, e.g. the ILCD (EC, 2010).

Key message: There is consensus in the standards in that it is the purpose of the study that determines how you set the FU and SB. In application in case studies there is more consensus in setting of the system boundary but not regarding the FU, and guidance on how you define FU and SB in comparison of prevention, valorisation and waste handling is lacking; this needs more attention. Some examples of questions regarding handling of flows from the food chain are given in Figure 1 to Figure 4 below, with corresponding examples of functional units and system boundaries for illustration (not an exhaustive list). The upgrade and treatment processing often leads to additional outputs (e.g. upgraded products or energy), that need to be handled by allocation or system expansion; this is not shown in these figures but discussed in section 4.3 below.

Figure 1: Example of SB and FU for the questions: What is the impact of food waste at all stages in the chain? What is the environmental impact if I prevent, upgrade or treat the waste (includes avoided impacts)?

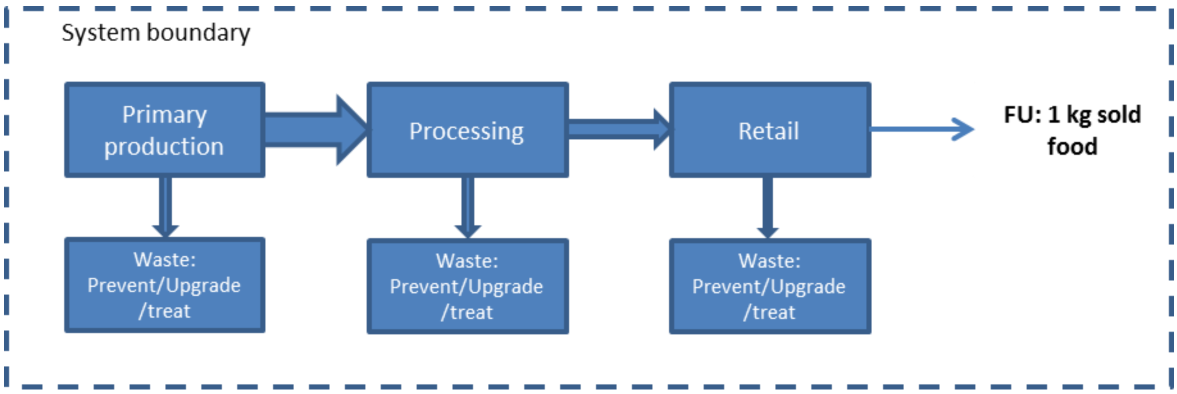


Figure 2: Example of SB and FU for the questions: What is the impact of food waste from one stage in the chain? What is the environmental impact if I prevent, upgrade or treat the waste from this stage in the chain?

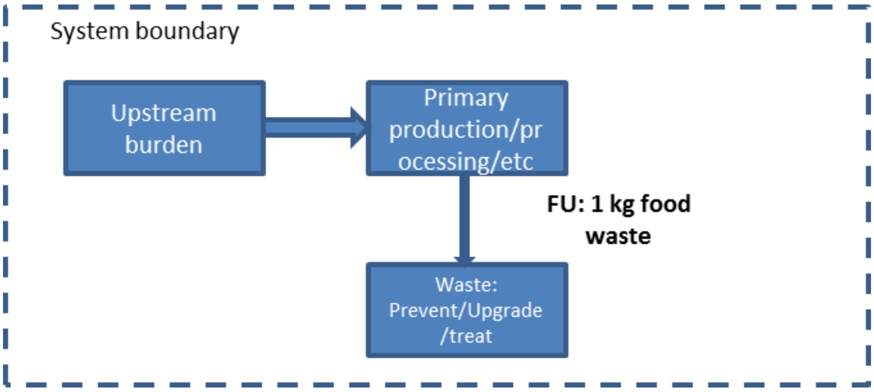


Figure 3: Example of SB and FU for the questions: What is the environmental impact if I upgrade or treat the waste FU: 1 kg of waste.

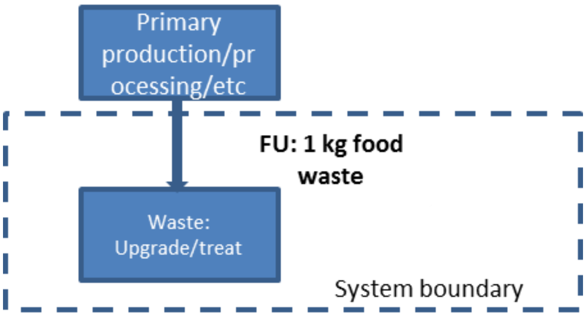
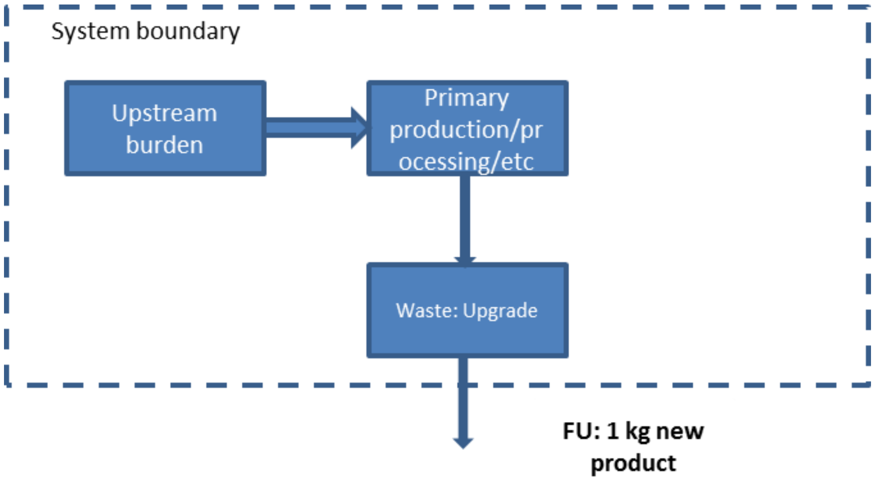


Figure 4: Example of SB and FU for the question: What is the environmental impact of the upgraded product? Assumes that some burden from the upstream processing is allocated to the waste stream. FU: 1 kg of upgraded product.



4.2 Cut-off criteria

Within the selected system boundaries of the study, it is often necessary to exclude some flows to limit the data collection effort, and/or to exclude those parts that contribute insignificantly to the environmental impact. The criteria for excluding parts within the system are called cut-off criteria. The ISO (2006a) and ILCD (EC, 2010) standards stress that the criteria used to exclude flows are to be clearly explained and that the effect on the results should be described. Other standards are even more specific, stating the parts that should be excluded. For example, AFNOR (2012), PAS2050 (BSI, 2011) and the PCRs for pasta and vegetables (PCR 2010:01; PCR 2011:20) all exclude transport of employees from home to workplace. PAS2050 for horticultural products (BSI, 2012) exclude production of tractors, machines and buildings, as do the PCRs for vegetables and pasta. Another way of specifying the criteria for cut-off is to set a limit to excluded flows, as a percentage (either based on mass, energy or environmental significance); e.g. the ISO Water footprint standard (ISO, 2014) specify that processes that are estimated to cumulatively contribute less than 1% of the water footprint may be omitted, and the IDF standard (2010) and the Beverage industry standard (2010) state that 95% of emissions should be covered. The difficulty of setting a limit based on environmental significance is to determine how much the omitted flows contribute to the overall impact without first having done an LCA that covers *all* flows. A procedure, suggested by the Food Round table (2013) is to use a stepwise procedure for this: first to do a screening, followed by a more detailed analysis.

Regarding case studies of environmental assessment of food waste, the reviewed examples rarely explain what criteria has been used to motivate the excluded parts; in the best cases, *what* has been excluded is stated but not the underlying basis.

Key message: The purpose of the study determines the level of detail needed in the study, and thus what might be excluded or not. However, to be in line with the standards, it is important to clearly explain what has been excluded, on what basis, and also to discuss impact on the results. In general, from the product standards we have reviewed, typical aspects that are excluded are employees transport to and from the workplace, transport of consumer to and from retailer, and production of capital equipment (tractors, machinery).

4.3 Handling multi-functional processes

In many processes or production systems more than one product is produced, in such cases it is necessary to divide the environmental impacts from the process or production system between the products. Two ways of handling this is by system expansion and allocation, which is discussed in this section. All standards agree on the same hierarchical structure for dealing with multifunctional processes, and follow the ISO 14040 (2006a) recommendations which are in order of preference:

1. allocation shall be avoided by sub-dividing the system, or expanding the function of the system;
2. allocation based on underlying physical relationship; and
3. another relationship shall be used for allocation.

The ILCD Handbook (EC, 2010) also provides detailed guidance on provisions on solving multi-functionality by allocation. The PAS 2050 (2011) and AFNOR BP X30-323-15 (2012) develop some additional examples and methodology.

Most of sectorial and specific guidelines also follow the ISO 14044 recommendations, such as the FOOD SCP RT ENVIFOOD Protocol (2013), PAS 2050 (2012) and IDF (2010).

Most of specific guidelines and other sources follow the ISO 14044 recommendations and propose a hierarchy of allocations rules. For instance, recommendations of the PCR 2011:20 (Vegetables) and PCR 2010:01 (Uncooked pasta) are in order of preference:

1. Partitioning, which should:
    - divide the unit process into one or two sub-processes (PCR Vegetables); and
    - reflect the underlying physical relationships between them; i.e. they should reflect the manner in which the input and output are modified by quantitative changes in the products delivered by the system (PCR pasta).
2. If it is not possible to implement the first option, the mass allocation is then allowed, according to both PCR Vegetables and Uncooked pasta.

3 Besides, in the PCR for vegetables, it is specified that system expansion is not allowed.

In the case studies explored both allocation and system expansion is used:

- system expansion, in Lorentzon et al. (2010), Erikson et al. (2015), Sonesson (2009), Dornburg et al. (2005);
- mass allocation in Vandermeersch et al. (2014), Münster et al.(2015), Lundie & Peters (2015).

There are two fundamentally different approaches in LCA: an attributional approach or a consequential one. Attributional LCA (ALCA), also called a book-keeping LCA, describes the environmental impact within a chosen system attributed to the delivery of a specified amount of the functional unit. For example, an application of ALCA is when you want to report the environmental impact of your current practice of waste handling in the annual report of your company. Consequential LCA (CLCA), on the other hand, describes how the environmental impact within a system changes in response to a change in output of the functional unit. For example, an application of CLCA is when you want to investigate the environmental consequences of alternative options for handling the company's waste streams. It is the question to be answered that should determine which approach to use, i.e. are you exploring a status-quo situation (ALCA) or consequences of a change (CLCA). However, it is not always explicitly reported in LCA studies which approach has been chosen. There is a strong connection between the type of LCA and the choice of how to handle co-products, i.e. allocation or system expansion. Consequently, there is also little information on the rational of how substitution products are chosen: a similar product (ALCA) or a marginal product (CLCA). In the REFRESH situations (see section 3 both CLCA and ALCA can be relevant to use, but it is important to distinguish if you are looking at a change or a steady state scenario when phrasing the question.

Key message: The ISO standard for LCA (2006a) states that allocation should be avoided by subdividing the system, and if that is not possible system expansion should be used. Allocation is the last option. Most other standards advocate the same hierarchy, with the exception of some PCRs which do not allow system expansion (e.g. the PCR for vegetables). The main difficulty of using system expansion is to identify and give rationale for the substituted products and data to be used.

4.4 Environmental impacts categories

In most reviewed sources, environmental impact categories are selected regarding the purpose of the environmental assessment and the availability of data. Climate change is by far the most commonly analysed environmental impact category. Indeed, this indicator is mentioned in every literature review source except in water footprint assessments.

Most standards follow ISO 14044 (the exception being the single issue standards such as carbon footprint standard) and recommend to have a multi-impact approach in order to have a complete overview of environmental impacts. For instance, the European Commission recommends common methods to measure and communicate on life cycle environmental performance of products and organisations within the Product Environmental Footprint/Organisation Environmental Footprint (PEF/OEF) methodology (EC, 2013). This methodology requires inclusion of the following indicators:

1. Climate Change/Global warming potential (GWP),
2. Ozone Depletion,
3. Ecotoxicity for aquatic fresh water,
4. Human Toxicity - cancer effects,
5. Human Toxicity – non-cancer effects,
6. Particulate Matter/Respiratory Inorganics,
7. Ionising Radiation – human health effects,
8. Photochemical Ozone Formation,
9. Acidification,
10. Eutrophication – terrestrial,
11. Eutrophication – aquatic,
12. Resource Depletion – water,
13. Resource Depletion – mineral, fossil
14. Land Transformation.

It is also stressed that all of the specified default impact categories above and associated specified PEF (EC, 2013) impact assessment models shall be applied. Any exclusion shall be explicitly documented, justified, reported in the PEF report and supported by appropriate documents.

The ILCD Handbook (EC, 2010) outlines that the selected LCIA methods in their entirety should by default cover all listed impact categories in the standard (similar to the impacts above) and provides characterisation factors on mid-point level. The AFNOR BP X30-323-15 (2012) also indicates that provided mid-point LCIA methods shall be used. For food and pet food products, AFNOR (2013) requires climate change (indicator emissions of Greenhouse Gases-GHG); impact on water, in its qualitative and quantitative aspects and impact on biodiversity.

Most sectorial and sub-sectorial guidelines, product specific guidelines, and other food waste related LCA studies only focus on GHG emissions. Few of them recommend having a multi-impact approach, such as the Food Round Table protocol (2013) and the FAO report (FAO, 2013).

The literature review described in the EU FUSIONS report (FUSIONS, 2015) found that in LCA literature, on nine selected indicator food products up to thirteen environmental impact categories were assessed: global warming potential (GWP); eutrophication potential (EP); acidification potential (AP); photochemical ozone creation potential (POCP); ozone depletion potential (ODP); human toxicity potential (HTP); ecotoxicity potential (ETP); abiotic resource depletion (ARD); biotic resource depletion (BRD); reported energy (RE); land use (LU); biodiversity (BD); water use (WU). For these indicator products a review of which LCA data was available was performed. There was sufficient data reported to cover at least part of the food supply chain for four of the environmental impact categories (GWP, EP, AP & RE) for all nine of the selected indicator products. Global warming potential is undoubtedly the most widely reported impact category which is most likely due to the widespread public awareness and media interest in climate change. There is also reasonable LCA data on the following two attributes: POCP & LU for all nine indicator products. Biotic resource depletion (BRD) and biodiversity (BD) were found to receive little to no attention in the LCA literature of the selected indicator products. It should also be noted that most LCA studies use the farm gate as the system boundary with increasingly less information reported as the product moves along the food supply chain.

Key message: Standards recommend covering all significant environmental impacts; in practice climate change is the impact which is most reported.

4.5 End of life

In case studies: End of life is in general addressed as a discreet life cycle stage, however, particularly in the reviewed case studies, the focus lies on the end of life aspects of the assessed FU, waste arising across the life cycle is not equally reported on. Interestingly, studies, where the main objective is to examine the impact of different waste treatment and disposal routes are in general only briefly addressing how waste generated along the assessed system is dealt with. In the case studies reviewed, the predominant approach is system expansion, i.e. giving credits for avoided burden due to replacing other products. Very little detail is provided regarding the rationale of how replaced products are chosen and what the criteria are to qualify them as such and if it actually reflects the market situation. This links into the discussion on functional units above, where mass is the dominant characteristic of outputs with no or only little consideration of quality.

Standards and guidelines: The standards and guidelines approach end of life aspects in general with a broader view for any occasion when waste arises but often inspired by packaging terminology and situations.

Some documents, e.g. ILCD handbook (EC, 2010), emphasise that recycling is methodologically a case of multi-functionality. This fully applies not only to end-of-life products but to all types of waste, as long as any valuable products are recycled from the waste (ILCD chapter, appendix 14 (EC, 2010)). The main challenge is to address the dual purpose of materials and products, on the one hand their primary purpose for which it was made for, and on the other hand the provision of secondary resource. This is turn leads to the problem of how to allocate waste related emissions (e.g. if a material is used in two consecutive life cycles, how should the environmental impact from the primary production of the material, the recycling process, and final waste management be split between the first and second use of the material). Here, it is worth noting that, as stated by ISO 14044 (2006b), that allocation can be avoided by subdivisions and system expansion. In this way the actual situation on the market can be considered.

The PAS2050 (BSI, 2011) is quite specific and prescriptive by design and makes exceptions to the generally prescribed approach, depending on the situation. It states that where waste results in GHG emissions (e.g. organic matter disposed of in a landfill), those emissions (CO_2 and non-CO_2) shall be allocated to the product system that gave rise to the waste. This allocation also applies to methane combusted without the generation of useful energy (i.e. flaring). An exception to this is energy recovery from waste combustion. Where waste or fuel derived from combustion of waste to generate useful electricity and/or heat, GHG emissions shall be allocated to the generation of the energy. GHG removals shall also be allocated to the energy generation system. This means that the user of this energy will have to carry the impact from combustion and does not come burden free.

Several standards and guidance documents provide End of life Formulas: Fundamentally, there are two approaches. The 100/0 method (= cut off or recycled content method) and the 0/100 method (closed loop approximation method). Different standards and guidelines give either:

- freedom to the assessor to decide the best approach as long as it is in line with ISO 14040 (2006a) and ISO 14044 (2006b), e.g. ISO/TS 14067 for the Carbon Footprint of Products (ISO, 2013),
- link it to change or absence of change of material properties (e.g. the PAS 2050) or
- suggest a hybrid formula, mixing the 100/0 and 0/100 approach. The PEF (EC, 2013) proposes a 50/50 approach, the Beverage Industry sector guidance for Greenhouse Gas Emissions Reporting (2010) proposes a hybrid approach (focus is on packaging): for the virgin material input fraction the percentage of the content that will be recycled is credited (0/100 approach), for the recycled input fraction the emissions due to recycling is accounted for (100/0 approach).

The ILCD (EC, 2010) discusses end of life to the greatest detail of all reviewed documents in Appendix 14 of the Detailed guidance chapter, addressing a wide range of connected methodological topics.

Key message: While how waste related emissions should be accounted for is a constant point of discussion in guidance and standard development, in the reviewed studies it was often avoided by using system expansion. However, no or little information is given on the assumptions on how credits are given or how substitute products are identified.

4.6 Ecosystem services

Ecosystem services (ESS) is specifically addressed here as it is a topic that is currently getting a lot of attention. On the whole, ESS and biodiversity have not yet been specifically addressed in standards and case studies, in fact, many reviewed documents do not mention it at all. However, it needs to be kept in mind that most impacts have some link to ecosystem services. A number of documents mention the term ESS or biodiversity but also state that the lack of agreed methods make it difficult to include in standards. The PEF (EC, 2013), refers to biodiversity as a possible additional information. The ILCD handbook (EC, 2010) in its review of impact assessment methods lists a number of methods that directly or indirectly address biodiversity. In its recommendations the handbook states that for endpoint methods, also the presence of a dose-response model for biodiversity/bioproductivity is considered relevant.

Key message: ESS is not yet sufficiently matured and recognized to be addressed explicitly but it is implicitly touched upon by a number of impact categories.

4.7 Land use change

Direct Land Use Change (LUC) is mentioned in most standards and guidelines. Focus is usually on greenhouse gases. Some also refer to other linked impacts and emissions. Either by stating very generally that a recognised method should be used, or more explicitly, referring to specific methods, in particular to the PAS 2050 (BSI, 2010) and IPCC Guidelines for National Greenhouse Gas Inventories – the latter also as backup for the PAS 2050 if the relevant country or land use change is not included.

Some documents are more explicit as to what exactly needs to be considered than others, e.g. the ILCD (EC, 2010) recommendations or the ISO/TS for the carbon footprint of products (ISO, 2013) mention soil carbon changes. The ILCD Handbook further states that emissions of nutrients shall be modelled explicitly as part of the land management process.

The PAS 2050-1:2012 (BSI, 2012) is very explicit and detailed on land use change. It distinguishes between land use change when the previous land use is known, and when it is not known. In the former case LUC emissions consist of both, GHG emissions as well as removals from vegetation and soil carbon stock changes (using the IPCC Guidelines for National GHG inventories). In accordance with the PAS 2050, the carbon stock change shall be linearly amortised during a period of 20 years. If the previous land use is not known, a worst case value should be used (detailed instructions on how to calculate this are given). The PAS 2050-1:2012 on the greenhouse gas emissions from horticultural products further provides an Excel tool to help with calculating LUC GHG emissions.

Indirect land use change is usually addressed in documents mentioning direct land use change. Some documents mention that it should be considered once recognized methods are available. It is emphasized by some that indirect land use should be presented separately and not be rolled up in the overall GHG calculations (e.g. by the PEF). The ILCD handbook sees indirect land use change as an issue of consequential modelling.

In some case studies a simplified proxy of land occupation is used, however, no connected impacts are made.

Key message: Direct LUC needs to be considered. PAS and IPCC are key methods in this context, and some commercial databases already include direct land use change emissions for agricultural products.). Indirect LUC is important if consequential modelling is applied.

4.8 General observations

Data quality is another important aspect in environmental assessment studies. The case studies explored show that the difference in emissions can vary significantly depending on which data are used; so this needs attention in the coming tasks in WP5, focusing e.g. on LCI data for different end-of-life routes.

It is important to be aware that certain measures around waste will be restricted due to legal and local circumstances; e.g. if food waste can be landfilled or facilities are available locally. For decision makers it is important to distinguish between real options and theoretical comparisons.

When it comes to carbon, there is a distinction between fossil and biogenic carbon, and there are methodological differences in how to account for biogenic carbon in LCA when assessing climate impact, i.e. when to take biogenic carbon into account and when not. In the life cycle of bio-based products, there is an uptake of carbon dioxide (CO_2) from the atmosphere during biomass production, and the product can thus contribute to reduce the CO_2 level in the atmosphere if the lifespan of the product is significant. Furthermore, land use and land use change can lead to emissions of CO_2 which have not been circulating for a significant time (e.g. release of soil carbon, cutting down and burning of rainforest). Some standards give recommendations on what carbon to account for when assessing climate impact, e.g. PAS2050 (BSI, 2011).

Regarding how to communicate an LCA result; when showing the environmental impact of the different life cycle stages, the burden associated with the additional food production caused by wastage (i.e. production of ‘extra’ food that is later wasted) can be assigned in two different ways. In FUSIONS (2015) the waste related impact was placed at the life cycle stage where the waste arises (e.g. the consumer stage is shown to be an environmental hotspot since a lot of waste arises there, and the main part of this impact comes from producing the food that is wasted). Depending on the purpose of the study, the most appropriate display of the burden can be applied.

5 Conclusions and outlook

The literature review shows there are a number of documents for guidance when it comes to environmental assessment of products and services, and also guidance focused specifically on food systems. Some of those are very detailed and can be difficult to read for non-experts, others are giving a lot of space for the practitioner to scope an LCA.

Standards and guideline (unless they are PCRs or are aimed at reporting) are usually made for wide application, both, across many products and services. They are also not step by step guidelines on how to do an LCA. Thus the practitioner needs to have in-depth knowledge of LCA in order to carry one out. At the same time, as LCA is no longer a tool used by few but is a widely used approach to evaluate the impacts of systems it cannot be expected from every practitioner to have this high level of LCA knowledge and skills. Within REFRESH we will, therefore, focus on bridging the gap between existing standard and guidance documents and practitioners, who might be experts on the systems they are assessing but not in LCA. We will do this by:

- Addressing some of the most challenging aspects identified from the literature review
- Providing a lot of food waste specific examples
- Using REFRESH situations (see section 3 to elaborate on method choices
- Encourage the practitioner to ask the important questions and thus help better scoping LCAs
- Provide a set of questions that should be asked when scoping an LCA

The expected benefit will be that:

- The quality of LCAs and thus the relevance of their results will improve
- Potentially less time is needed when scoping the study
- Giving reassurance to practitioners on method choices and practitioners will feel more confident about their studies

The review highlights main methodological challenges when assessing environmental impact of measures for food waste. Our recommendation is to focus deliverable 5.3 (Generic strategy for LCA and LCC) on these:

- Does the question being asked result in an attributional or consequential model?

- Describing a suitable functional unit and system boundary connected to the question(s) being asked; some examples of questions and corresponding FU and SB are given in section 4.1.
- Dealing with multi-functionality (allocation/system expansion)
- What environmental burden a flow from the food chain should have depending on the situation
- How should a replaced product be identified, and on what basis? In which market is the product replaced (local, European, global)? Data sources to use?
- Which are the most important environmental indicators to focus on? Climate impact is common, but standards require many aspects to be explored. What is relevant but also feasible?

Besides these, deliverable 5.3 will also address the challenge of combining LCA with the LCC approach, which will require some attention on which areas align and which do not. To give an example, one aspect that has been discussed at this stage is cut-off rules. The processes that do not contribute significantly to the environmental impact of a product are typically R&D activities at the firm, and production of capital goods, which are therefore often omitted from the LCA. In LCC however, these activities can contribute a lot to the cost, and can therefore be included in the LCC. Therefore, different cut-off criteria can be applied resulting in different processes to be covered in the assessment. Other methodological issues, similar to this one, which arises when you combine LCA and LCC will need to be discussed and the recommended approach described.

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7 Annex A: Alignment of REFRESH situations with other frameworks

Table 6 shows how FUSIONS and FLW standard destinations align to the REFRESH situations. Most notably prevention was not within the scope of either of these documents.

Table 6: Destinations of FUSIONS (2015) and Food Waste and Loss Standard (2015) aligned to the four REFRESH situations.

Situations	Prevention at source	Co-product valorisation	Valorisation as part of waste management	End of life treatment
Destinations in FUSIONS		Animal feed (B1), biobased material and biochemical processing (B2), Bioenergy (B6)	Composting (B3), plough in/not harvested (B4) (if for the purpose of soil enhancement), anaerobic digestion (B5), Co-generation (B7)	Plough in / not harvested (B4) *(if not for the purpose of soil enhancement)*, Incineration (B8), Sewer (B9), Landfill (B10), Discards (B11)
Destinations in FLW standard		Animal feed, bio-based materials and biochemical processing, fermentation	Codigestion / anaerobic digestion, composting / aerobic digestion, incineration *(if with energy recovery)*, land application, Plough in / not harvested *(if for the purpose of soil enhancement)*	Incineration *(if without energy recovery)*, landfill, Plough in / not harvested *(if not for the purpose of soil enhancement)*, open burn, refuse / discarded or dumped to land or sea, sewer

8 Annex B: Summary of reviewed documents

Table 7: List of literature sources covered in the review.

Category of document	Name	Country	Type of standard/Initiative/Comment
1 General standards	1.1 ISO 14040/14044 Life cycle assessment – Principles and framework – Requirements and guidelines	Worldwide	Reference LCA standards
	1.2 European Commission's Product Environmental Footprint guide: 2013	European Union	European reference Environmental Footprint methodology for products
	1.3 The International Reference Life Cycle Data System (ILCD) Handbook	European Union	General-level guidelines on LCA
	1.4 PAS 2050:2011 - Assessing the life cycle greenhouse gas emissions of goods and services	UK	Carbon footprint standard
	1.5 ISO/TS 14067:2013 Carbon footprint of products	Worldwide	Carbon footprint standard
	1.6 Water Footprint Network methodology (WFN): 2011	Worldwide	Water footprint standard
	1.7 ISO 14046:2014 Water footprint – Requirements and guidelines	Worldwide	Water footprint standard
2 Sectorial guidelines	2.1 BP X30-323-15. « General principles for an environmental communication on mass market products — Part 15: Methodology for the	France	Granelle de l'environment

	environmental impacts assessment food products”		
	2.2 Envifood protocol – Environmental assessment of food and drink protocol version 1.0:2013	European Union	European Food sustainable consumption and production round table
2 Sub-sectorial guidelines	3.1 Beverage Industry Sector Guidance for Greenhouse Gas Emissions Reporting. Version 2. 2010	Worldwide	Beverage Industry Environmental Roundtable
	3.2 PAS 2050-1:2012 Assessment of life cycle greenhouse gas emissions from horticultural products	UK	BSI
	3.3 IDF, 2010. A Common Carbon Footprint Approach for Dairy: The IDF Guide to Standard Lifecycle Assessment Methodology for the Dairy Sector	Worldwide	IDF - The International Dairy Federation
4 Product-specific guidelines	4.1 Vegetables (being updated 2015) – open for consultation	Sweden	International EPD system
	4.2 Uncooked pasta, not stuffed or otherwise prepared (2010:01)	Global (Sweden)	International EPD system
5 Other methodological inputs	5.1 FAO report: Food Wastage Footprint Impacts on natural resources		
	5.2 SIK report 806 (in Swedish), Att kombinera processintegration och miljösystemanalys för totalt minskad energiförbrukning (PIMSA)	Sweden	
	5.3 FUSIONS del 1.6		

	5.4 Lopes 2015 Valorisation of fish by products		
	5.5 Vandermeersch 2015 Env sust assessment of food waste valorisation options		
	5.6 Eriksson Carbon 2015 FP in food waste hierarchy options	Sweden	
	5.7 Scholz 2015 C FP of supermarket food waste	Sweden	
	5.8 Münster (2015) Economic and environmental optimisation of waste treatment		
	5.9 Lundie 2005 LCA of food waste management options		
	5.10 Sonesson Application of LCA in reducing waste and dev. coproducts in food processing		
	5.11 Dornburg, V. & Faaij, A.P.C. 2005. Cost and CO2-Emission Reduction of Biomass Cascading: Methodological Aspects and Case Study of SRF Poplar. Climatic Change (2005) 71: 373–408.		

1.1	ISO 14040 / 14044 Life cycle assessment – Principles and framework – Requirements and guidelines
General information (Objective, target audience, owner)	General base-line guidance on LCA, targets all kind of organizations, owned by ISO
Applicability	Any good and service
Functional unit	Functional unit shall be consistent with goal & scope - the same functional unit shall be selected for comparisons (ISO 14044 sect. 4.2.3.2)
System boundary	system boundaries shall be consistent with goal & scope of the study - criteria used in establishing system boundaries shall be explained (ISO 14044, sect 4.2.3.3)
Data quality requirements/handling data gaps	data quality requirements should be addressed (quantiatative and qualitative), in particular in studies that intended for public communication (ISO 14044 sect 4.2.3.6.3) sources shall be referenced (ISO 14044 sect 4.3.2.1)
Handling multi-functional processes (allocation)	a hierarchical structure for allocation is given. In order of preference: 1) allocation shall be avoided by sub-dividing the system, or expanding the function of the system 2) allocation based on underlying physical relationship 3) another relationship shall be used for allocation
Handling end-of-life	End of life is one of product life cycle stage
Environmental impact categories recommended or included	multi-impact approach required to gain image of environmental impacts
Land use change	-The biodiversity and land use change are ones of impact categories

Ecosystem services	-
Exclusions/cut-offs	Cut-off criteria shall be clearly explained, possible cut-off criteria are mass, energy, environmental significance (ISO 14044, sect. 4.2.3.3.3)
Other	

1.2	**European Union, Commission recommendation: Use of common methods to measure and communicate the life cycle environmental performance of products and organisations**
General information (Objective, target audience, owner)	The European Commission recommended rules for calculating and communicating the life cycle environmental performance of products (PEF) and organisations (OEF), developed by the EC Joint research centre (JRC), published 4.5.2013 in the Official Journal of the European Union (L 124). The methodology is currently tested in pilot studies. Annex II described the rules for PEF.
Applicability	Any good and service
Functional unit	Called unit of analysis. Shall be defined according to: The function: “what” The extent of the function or service: “how much” The expected level of quality: “how well” The duration/life time of the product: “how long”
System boundary	System boundaries shall be defined following general supply-chain logic, including all stages from raw material extraction through processing, production, distribution, storage, use stage and end-of-life treatment of the product. The system should be divided into foreground processes (i.e. core processes in the product life cycle for which direct access to information is available and background processes (i.e. those processes in the product life cycle for which no direct access to information is possible. A system boundary diagram should be included in the scope definition.
Data quality requirements/handling data gaps	Comprehensive data quality criteria are described regarding technological, geographical and time representativeness, and also completeness, methodological appropriateness and consistency, and parameter uncertainty. The data quality evaluation includes a process for semi-quantitative assessment of data quality (this is required for at least 70% of contributions to each EF impact category) with a score of at least 3.0 (scale 1-5). Review and compliance with ILCD nomenclature and documentation is also required. Specific data shall be collected for all foreground processes. However ok to use generic data if more representative. Any data gaps shall be filled with best available generic data or extrapolated data, shall not account for more than 10% of the overall contribution to each impact category.

Handling multi-functional processes (allocation)	A hierarchical structure for allocation is given. In order of preference: 1) allocation shall be avoided by sub-dividing the system, or expanding the function of the system and showing results for the expanded system as a whole rather than on individual co-product level. 2) allocation based on underlying physical relationship with direct substitution if a substitution effect can be demonstrated and the substituted product can be modelled. If not, allocation based on underlying physical relationship. 3) another relationship shall be used for allocation, with indirect substitution if such an effect can be identified and the substituted product modelled, if not use allocation based on other relationship, e.g. economic.
Handling end-of-life	As it is often not known exactly what will happen at the end-of-life of a product, end-of-life scenarios shall be defined. These shall be based on current (year of analysis) practice, technology and data. Specific guidance is given to estimate the overall emissions associated to a certain process involving recycling and/or energy recovery. These moreover also relate to waste flows generated within the system boundaries (Annex V Dealing with Multi-functionality in End-of-Life situations). The recommended formula splits the burden and benefit due to recycling equally between the producer using recycled material and the producer producing a recycled product (50/50).
Environmental impact categories recommended or included	1. Climate Change, 2. Ozone Depletion, 3. Ecotoxicity for aquatic fresh water, 4. Human Toxicity - cancer effects, 5. Human Toxicity – non-cancer effects, 6. Particulate Matter/Respiratory Inorganics, 7. Ionising Radiation – human health effects, 8. Photochemical Ozone Formation, 9. Acidification, 10. Eutrophication – terrestrial, 11. Eutrophication – aquatic, 12. Resource Depletion – water, 13. Resource Depletion – mineral, fossil and 14. Land Transformation. All of the specified default impact categories above and associated specified EF impact assessment models shall be applied. Any exclusion shall be explicitly documented, justified, reported in the PEF report and supported by appropriate documents. This can also be determined in a developed PEFCR. Additional environmental information may include (non-exhaustive list): Bill-of-materials data; Disassemblability, recyclability, recoverability, reusability information, resource efficiency; Information on the use of hazardous substances; Information on the use of hazardous substances; Information on the disposal of hazardous/non-hazardous waste; Information on energy consumption; Information on local/site-specific impacts, e.g. local impacts on acidification, eutrophication and biodiversity.
Land use change	Greenhouse gas emissions that occur as a result of direct land use change shall be allocated to products for (i) 20 years after the land use change occurs or (ii) a single harvest period from the extraction of the evaluated product (even if longer than 20 years) and the longest period shall be chosen (elaborated in Annex VI). Greenhouse gas emissions that occur as a result of indirect land use change shall not be considered unless PEFCRs explicitly require to do so. In that case, indirect land use change shall be

	reported separately as Additional Environmental Information, but it shall not be included in the calculation of the greenhouse gas impact category.
Ecosystem services	Biodiversity may be considered, see additional environmental information above.
Exclusions/cut-offs	All limitations and assumptions shall be transparently reported. See also data quality above.
Other	

1.3	ILCD Handbook
General information (Objective, target audience, owner)	The overall objective of the ILCD Handbook is to provide a common basis for consistent and quality-assured life cycle data and detailed Life Cycle Assessments. The ILCD Handbook is a series of technical documents that, in line with the international standards on LCA (ISO 14040/44), provide comprehensive and detailed method provisions for Life Cycle Inventory (LCI) and Life Cycle Assessment (LCA) studies as covered by the ISO 14040 and 14044:2006 standards. The main target audience of the ILCD Handbook are LCA practitioners, data providers, and reviewers. European Commission - Joint Research Centre - Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook - General guide for Life Cycle Assessment - Detailed guidance. First edition March 2010. EUR 24708 EN. Luxembourg. Publications Office of the European Union; 2010.
Applicability	All good and service.
Functional unit	Section 6.4 of the detailed guidance includes provisions on function, functional unit and reference flow.

System boundary	Section 6.6 of the detailed guidance includes provisions on system boundary identification and cut-off criteria
Data quality requirements/handling data gaps	Provisions are provided on the representativeness of LCI data. In particular provisions on technology, geographical and time-related representativeness are provided in sections 6.8.2, 6.8.3, 6.8.4 of the detailed guidance.
Handling multi-functional processes (allocation)	Further detail on data quality is given in Annex A "Data quality concept and approach" of the detailed guidance. Section 6.2.1 of the detailed guidance includes provisions on consistency of methods, assumptions and data.
Handling end-of-life	Annex 14 of the detailed guidance provide guidance on reuse, recycling and energy recovery.
Environmental impact categories recommended or included	The selected LCIA methods in their entirety should by default cover all of the following impact categories and provide characterisation factors on midpoint level. Impact categories ("midpoint level"): Climate change, (Stratospheric) Ozone depletion, Human toxicity, Respiratory inorganics, Ionising radiation, (Ground-level) Photochemical ozone formation, Acidification (land and water), Eutrophication (land and water), Ecotoxicity (freshwater, marine, terrestrial), Land use, Resource depletion (of minerals, fossil and renewable energy resources, water, ...). [ISO!] Sections 6.7.3, 6.7.4 and 6.7.5 are dedicated to environmental impact factors. On water use: Section 7.4.3.6.5 Water use Water use: It is recommended to differentiate at least: - on the input side: surface freshwater, renewable groundwater, fossil / deep ground water, sea water - on the output side: Emission/discharge of water in liquid form emission in form of steam - other water quality changes, especially by chemical substances shall be inventoried as separate elementary flows. Water use – Recommended Impact Assessment methodology and classification at midpoint Model for water consumption as in the Swiss Ecoscarcity (Frischknecht et al, 2008) See the draft guidance on recommended impact assessment methodologies for more info.
Land use change	Land use change – Inventory [Detailed Guidance Provisions: 7.4.3.6 Resource elementary flows] Emissions from land use and transformation: If land use and/or land transformation are modelled, carbon dioxide and other emissions and related effects should be modelled as follows: - Soil organic carbon changes from land use and transformation: For CO2 release from or binding in soil organic carbon

	(SOC) caused by land use and land transformation, the use of the most recent IPCC CO2 emission factors shall be used, unless more accurate, specific data is available. Detailed provisions and table with the IPCC factors: see chapter 7.4.4.1 and annex 13. (7.4.3.6.3) - Land use and transformation related CO2 emissions from biomass and litter: For virgin forests and for soil, peat, etc. of all land uses shall be inventoried as "Carbon dioxide (fossil)". Emissions from biomass and litter of secondary forests shall be inventoried as "Carbon dioxide (biogenic)". This applies unless the selected LCIA method requires otherwise. (7.4.3.6.4) - Nutrient losses: Emissions of nutrients shall be modelled explicitly as part of the land management process. Detailed provisions see chapter 7.4.4.1. - Other emissions: Other emissions in result of land transformation (e.g. emissions from biomass burning, soil erosion etc.) should be measured or modelled for the given case or using authoritative sources. Detailed provisions see chapter 7.4.4.1. (7.4.3.6.3) No specific provisions on Indirect Land Use Change (ILUC) are provided by the ILCD Handbook. Land use – Recommended Impact Assessment methodology and classification at midpoint Model based on Soil Organic Matter (SOM) (Milà i Canals et al,,2007). See the draft guidance on recommended impact assessment methodologies for more info.
Ecosystem services	It is recommended that selected LCIA methods provide modelled category endpoint factors that are coherent with the midpoint level and that cover all relevant damages to the three following areas of protection (6.7.2): Category endpoints ("endpoint level"): Damage to human health, Damage to ecosystem, Depletion of natural resources. These relate to the three areas of protection "Human health", "Natural environment", and "Natural resources", respectively. [ISO+].
Exclusions/cut-offs	Section 6.6 of the detailed guidance includes provisions on system boundary identification and cut-off criteria.
Other	The document has been developed to provide comprehensive and generally applicable for the three main goal situations encountered in LCA studies: - Situation A ("Micro-level decision support"): Decision support on micro-level, typically for product-related questions. “Micro-level decisions” are assumed to have only limited and no structural consequences outside the decision-context, i.e. do not change available production capacity. The effects are too small to overcome the threshold to be able to cause so called large-scale consequences in the background system or other parts of the technosphere - Situation B ("Meso/macro-level decision support"): Decision support at a strategic level (e.g. raw materials strategies, technology scenarios, policy options, etc). “Meso/macro-level decisions” are assumed to have also structural consequences outside the decision-context, i.e. they do change available production capacity. The analysed decision alone results in large-scale consequences in the background system or other parts of the technosphere - Situation C ("Accounting"): Purely descriptive documentation of the system under analysis (e.g. a product, sector or

country), without being interested in any potential consequences on other parts of the economy. Situation C has two sub-types: Situation C1 that includes existing benefits outside the analysed system (e.g. credits existing recycling benefits) and Situation C2 that does not do so.

1.4	PAS 2050:2011
General information (Objective, target audience, owner)	Specification for the assessment of the life cycle greenhouse gas emissions of goods and services, owned by the BSI (UK)
Applicability	Any goods and service
Functional unit	Assessment of the GHG emissions arising from the life cycle of products shall be carried out in a manner that allows the mass of CO_2e to be determined per functional unit for the product. The functional unit shall be recorded to two significant figures. Where a product is commonly available on a variable unit size basis, the calculation of GHG emissions shall be proportional to the unit size (e.g. per kilogram or per litre of goods sold, or per month or year of a service provided).
System boundary	The system boundary shall be clearly defined for each product under assessment and shall include all of its material life cycle processes.
Data quality requirements/handling data gaps	Primary activity data shall be collected from those processes owned, operated or controlled by the organization implementing this PAS. The primary activity data requirement shall not apply to downstream emission sources.
Handling multi-functional processes (allocation)	The preferred approach to allocation of emissions and removals to co-products shall be, in order of preference: a) dividing the unit processes to be allocated into two or more subprocesses and collecting the input and output data related to these subprocesses; or b) expanding the product system to include additional

	functions related to the co-products where: 1) a product that is displaced by one or more of the co-products of the process being considered can be identified; and 2) the avoided GHG emissions associated with the displaced product represent the average emissions arising from the provision of the avoided product. Where neither of these approaches is practicable and where supplementary requirements in accordance with the principles set out in 4.3 have been developed to deal with allocation (e.g. on the basis of physical allocation or mass) in connection with the product being assessed, they should be used. When used, the method should be uniformly applied. Where the approaches in a) and b) are not practicable and applicable supplementary requirements are not available, the GHG emissions and removals arising from the process shall be allocated between the co-products in proportion to their economic value.
Handling end-of-life	Where waste results in GHG emissions (e.g. organic matter disposed of in a landfill), those emissions (CO2 and non-CO2) shall be allocated to the product system that gave rise to the waste. This allocation also applies to methane combusted without the generation of useful energy (i.e. flaring). Where waste or fuel derived from waste is combusted to generate useful electricity and/or heat, GHG emissions shall be allocated to the generation of the energy. GHG removals shall also be allocated to the energy generation system. Also recommendation on how to derive emissions from reuse and recycling of material.
Environmental impact categories recommended or included	Climate change.
Land use change	The GHG emissions and removals arising from direct land use change shall be assessed. Guidelines are provided on how to derive the emissions.
Ecosystem services	-
Exclusions/cut-offs	The system boundary of the product life cycle shall exclude the GHG emissions associated with: a) human energy inputs to processes and/or preprocessing (e.g. if fruit is picked by hand rather than

	by machinery); b) transport of consumers to and from the point of retail purchase; c) transport of employees to and from their normal place of work; d) animals providing transport services.
Other	

1.5	TS 14067:2013 Carbon footprint of products – Requirements and guidelines for quantification and communication
General information (Objective, target audience, owner)	Guidance on carbon footprint calculations and communication, targets all kind of organizations, owned by ISO
Applicability	Any good and service
Functional unit	The FU shall be consistent with the goal and scope. The FU shall be clearly defined and measurable. When the use of the PCR is decided, the requirements in the PCR shall be followed. Having chosen the FU, the reference flow shall be defined.
System boundary	The setting of the system boundary can be different depending on the intended use of the CFP study. If intended to be publicly available, the quantification shall comprise of all stages in the life cycle. If not, as a minimum, a partial CFP shall represent the cradle-to-gate GHG emissions. When the use of the CF-PCR is decided, the requirements in the PCR shall be followed.
Data quality requirements/handling data gaps	Site-specific data shall be collected for individual processes under the control of the organisation undertaking the CFP study. Also where practicable for those unit processes that contribute significantly to the CFP but are not under the control of the organisation. Secondary data shall be justified and documented with reference in the CFP report.
Handling multi-functional processes (allocation)	a hierarchical structure for allocation is given. In order of preference: 1) allocation shall be avoided by sub-dividing the system, or expanding the function of the system 2) allocation based on underlying physical relationship

	3) another relationship shall be used for allocation
Handling end-of-life	All GHG emissions and removals arising from the end-of-life stage of a product shall be included in a CFP study, if this stage is included in the scope. Specific guidance if given for handling recycling of materials (Annex C).
Environmental impact categories recommended or included	100 year GWP (Annex A gives characterization factors)
Land use change	When significant, the GHG emissions and removals occurring as a result of direct land use change shall be assessed according to recognised methods such as IPCC Guidelines for National Greenhouse Gas Inventories. Shall be documented separately. Indirect land use change shall be considered, once and internationally agreed procedure exists. Also GHGs from soil carbon change should be considered.
Ecosystem services	-
Exclusions/cut-offs	Consistent cut-off criteria that allow the omission of certain processes of minor importance shall be defined within the goal and scope. The effect of the selected cut-off criteria on the outcome of the study shall be assessed and described.
Other	

1.6	Hoekstra et al (2011), Water footprint assessment manual, Earthscan
General information (Objective, target audience, owner)	Developed by the water footprint network (WFN).
Applicability	Wide range of applications: e.g. process step, a product, a consumer, a group of consumers (in a nation, municipality, province or other administrative unit, catchment area or river basin), a geographically delineated area (nation, municipality, province or other administrative unit, catchment area or river basin), a business, a business sector or humanity as a whole.
Functional unit	Depends on scope of study, e.g. product, business, consumer, area etc. Defined by user. For agricultural products, often expressed on a weight basis (per kg of crop or other output)

System boundary	One has to be clear and explicit about the 'inventory boundaries' when setting up a water footprint account. The inventory boundaries refer to 'what to include' and 'what to exclude' from the accounts and should be chosen as a function of the purpose of the account.
Data quality requirements/handling data gaps	The manual includes some comments that the scope of a WF assessment determines how detailed data needs to be. Some examples are given but no fixed rules.
Handling multi-functional processes (allocation)	Economic allocation.
Handling end-of-life	As defined in goal and scope.
Environmental impact categories recommended or included	Water footprint is a volumetric measure of water consumption (Blue+Green WF) and pollution (Grey WF). It is NOT a measure of the severity of the local environmental impact of water consumption and pollution.
Land use change	-
Ecosystem services	-
Exclusions/cut-offs	There are not fixed rules but some general rules of thumb are given to give the assessor some guidance. E.g. As a rule of thumb, one can expect that when a product includes ingredients that originate from agriculture, those ingredients often give a major contribution to the overall water footprint of the product. This is the case because an estimated 86% of the water footprint of humanity is within the agricultural sector. Industrial ingredients are likely to contribute particularly when they can be associated with water pollution (so they will contribute to the grey water footprint). A general rule is: include the water footprint of all processes within a production system (production tree) that 'significantly' contribute to the overall water footprint. The question remains what 'significant' is; one can say for instance 'larger than 1%' (or 'larger than 10%' when interested in the largest components only).
Other	

1.7	ISO 14046 Environmental management - water footprint – principles, requirements and guidelines
General information (Objective, target audience, owner)	Intended objective is to react to the increasing demand for assessing and reporting water footprints and the need to ensure consistency.
Applicability	processes, product system, services, organisations
Functional unit	FU needs to be clearly defined and documented. No fixed FU. If PCR are developed then FU might be prescribed.
System boundary	It needs to be clearly stated if the WF is to be determined for a specific process, a product system/service or an organisation. If product system is assessed then ISO 14044 applies (se 1.1). Criteria used in building the system boundary shall be explained and described. Unit processes that are included or excluded shall be clearly identified and justified. Local availability of the resource [water] shall be considered. Unit processes which are located in regions with different water scarcity shall be kept separate and differences stated.
Data quality requirements/handling data gaps	Preferably, primary data shall be collected. Secondary data shall only be used where collection of primary data is not possible or practicable and may include literature data, calculated data, estimates or other representative data. For each elementary flow, in general, four categories of data should be included: quantity of water used, type of water used, form of water use and geographic location of water withdrawal and return. The standard gives suggestions which type of data should be collected. The treatment of missing data shall be documented. Where assumptions are made, these shall be clearly indicated as such and the basis for the assumptions shall be described. The importance of the missing data should be assessed.
Handling multi-functional processes (allocation)	The same as ISO 14044: a hierarchical structure for allocation is given. In order of preference: 1) allocation shall be avoided by sub-dividing the system, or expanding the function of the system 2) physical allocation shall be used 3) another relationship shall be used for allocation
Handling end-of-life	As defined in goal and scope, nothing mentioned on EoL in particular.

Environmental impact categories recommended or included	Water footprint inventory result (m3 water) OR water footprint profile (i.e. characterised results, e.g. kg PO4eq, m3 H20eq etc)
Land use change	-
Ecosystem services	-
Exclusions/cut-offs	Consistent cut off criteria shall be defined which allow the omission of processes that are estimated to cumulatively contribute less than 1% of the total water footprint of the system under analysis.
Other	

2.1	AFNOR BP X30-323- 15 (2012), General principles for an environmental communication on mass market products - Part 15 methodology for the environmental impacts assessment of food products
General information (Objective, target audience, owner)	Objective: to provide information at the consumer, allow comparison of products belonging to the same category and, when relevant, between product categories. Audience: food industry.
Applicability	Food and animal feed products.
Functional unit	Defined at the Product Category Rules. For food and feed products it includes their packaging. The functional unit may be either the 100g/100ml, or the portion, considering these quantities "as consumed".
System boundary	From raw material acquisition through to end-of-life and disposal. Seven steps compose the product life cycle: producing raw materials, packaging, manufacturing (preparation or processing), transport, distribution, use and end of life (those could be excluded – it depends on the sub category of product).
Data quality requirements/handling data gaps	ADEME set up a Governance Advisory Committee for the public database. This committee assesses data quality and critical review.

	No minimum data quality requirements are specified. Specific requirement provided at PCR-level. Primary data is preferred. Secondary data not derived from recommended sources must be reviewed by committee.
Handling multi-functional processes (allocation)	Adopt ISO 14044. Attributional approach. - Allocation rules for recycling and energy recovery are proposed per materia. - Allocation for recycling: provides very detailed guidance and equations for closed-loop recycling and open-loop recycling, with or without energy recovery.
Handling end-of-life	Information is also provided for end-of-life of food waste and packaging.
Environmental impact categories recommended or included	LCIA methods recommended by the JRC are followed. Impacts categories are fixed by product categories. Default set of provided mid-point LCIA methods shall be used. For food and pet feed products, impacts categories are: - Impact on climate change (indicator emissions of Greenhouse gases) - Impact on water, in its qualitative (aquatic eutrophication and ecotoxicity) and quantitative aspects (water consumption and in the medium to long run, water stress) - Impact on biodiversity Impact on water, in its qualitative (aquatic eutrophication and ecotoxicity) and quantitative aspects (water consumption and in the medium to long run, water stress) are taken into account.
Land use change	Direct land use change: Reference to IPCC methodology; Indirect land use change: Will be considered once an internationally agreed method has been established
Ecosystem services	Not mentioned.
Exclusions/cut-offs	Exclusions: - Carbon offset - R&D - Transport of employees from home to workplace - Services associated with product or system (e.g. advertising, marketing, etc.) - Transport of consumer to and from the point of retail purchase Cutt-off: 5 % mass and energy and environmental impact

Other

2.2	**Food SCP RT (2013) ENVIFOOD Protocol, Environmental Assessment of Food and Drink Protocol, European Food Sustainable Consumption and Production Round Table (SCP RT), Working Group 1, Brussels, Belgium.**
General information (Objective, target audience, owner)	Output of the European Food Sustainable Consumption & Production Round Table Scope: The ENVIFOOD Protocol specifies requirements for assessing the environmental impacts associated with food and drink products along with their life cycle. The Protocol aims at ensuring that assessment results are scientifically reliable and consistent in supporting informed choice. The Protocol also highlights areas in which further guidance is required, e.g. by PCRs. When accompanied by PCRs, the Protocol provides guidance to support: - The development of consistent environmental assessments of intermediate products in the context of business to business, and of consumer products in the context of business to consumer communication - The identification of environmental improvement options Target audience are environmental managers and LCA experts but this Protocol also represents a stepping stone towards the development of user-friendly and affordable tools for the assessment and communication of environmental impacts. If accompanied with high quality data, those tools are able to drastically alleviate SMEs from the disproportionate burden of such assessment. These documents are indispensable for the application of this methodology: - The guiding principles of the Food SCP Round Table (2010) - ISO 14040:2006 – Environmental Management – Life cycle assessment – Principles and framework
Applicability	Food and drink products
Functional unit	As per ISO 14044:2006; special note that the specification of functional units covers the situation in which the function is provided as accurately as possible (e.g. packed, unpacked, on shelve, on plate, at farm gate). For B2B communication-related application in supply chain for consumer goods (final use might not always be known): If a payment is common in B2B relationships (e.g. for the payment of intermediate products, fat content of milk may be used), this functional unit may also be used for the calculation of life cycle impacts. For B2C communication-related applications: the unit of analysis is the functional unit that should be in line with the requirements of the EU Regulation 1169/2011 on the provision of food information to consumers for nutrition declaration, as relevant. Hence the functional unit should be expressed per weight or volume (i.e. 100 g or ml). In addition, it may be expressed otherwise (i.e. per portion, per consumption unit or per unit sold) as stated by the relevant PCRs.

System boundary	System boundaries for B2B for communication-related application: all relevant life cycle stages should be included from cradle-to-gate System boundaries for B2C for communication-related application: All relevant life cycle stages should be considered in the system boundary (i.e. from cradle-to-grave). However, different system boundaries can be set up, depending on the use phase of the product group concerned. All assumptions shall be clearly reported. More details are given depending on type of product, i.e. (1) products with no specific instructions on amounts and how to use in final dish on pack (e.g. salt, flour); (2) products which are characterised by typical/dominant use, some variable components are possible (e.g. coffee beans, tea, ice cream in a tub); and (3) products with clear, unambiguous instructions on use (e.g. ready meals, ice cream on a stick, instant soup) More details on specific life cycle stages: Use phase Waste management (see 'Handling end-of-life)
Data quality requirements/handling data gaps	As per ISO 14044:2006 Primary data are required for processes operated or managed by (i.e. under managerial or financial control) the reporting organisation. Exceptions are possible whenever high quality secondary data are available and may best represent reality (e.g. emissions from livestock, their manure and soil). A product that may derive from different production plants shall be represented by weighted averages. Whenever primary data are not available, then secondary data of the highest practical quality should be used. Whenever there is a lack of datasets, their significance should be evaluated first, before pursuing the use of extrapolated data. In this context, a dataset is significant if it is above the cut-off threshold. If the estimated data have the potential to change the conclusion of the study (see the section on system boundaries), then they should be included. Data extrapolations may be used for this purpose. Preference shall be given to primary and secondary data which are compliant with the ILCD Data Network entry level requirements (EC, 2012). Secondary data should be country-specific. To assess data quality, the PEF data quality indicator (EC, 2013a) should be used. Data and calculations need to be transparent, enabling external peer reviews.
Handling multi-functional processes (allocation)	As per ISO 14044:2006 Three types of substitution are distinguished: Specific substitution Substitution of the country-mix of the specific superseded products Substitution of a wider function or the market that is superseded
Handling end-of-life	Waste streams to be modelled: Pre-consumer: All waste occurring during the production of a food and drink product up to the point of sale are part of the

	industry inventory Post-consumer: for waste generation from use phase primary input data should be preferred. Methodology for consumer studies, as well as default data to be used in the absence of primary data, should be subject to more specific product guidance such as PCRs or sector guidance. Some potential food and drink waste is diverted from the waste disposal stream by the consumer. Waste treatment may also occur at the household level, for example in the case of home composting. For existing products, waste treatment statistics and recycling statistics may be used if it can be justified through third party verified information. For packaging, for example, compliance with CEN Packaging Standards can be assessed. In all other cases conservative estimates should be used. For existing products, specific end-of-life data at the given geography shall be used. Waste treatment statistics and recycling statistics may be used as proxy if such specific data are not available. The decision shall be documented and justified. For broader analyses it may be advisable also to consider technological changes and developments in waste treatment. Appendix D gives a checklist of options for waste treatment. It is suggested to keep both in the inventory, calculate Life Cycle Impact Assessment (LCIA) results separately, use the first 100 years and discuss results including the long-term emissions. In line with the Food SCP Round Table’s principles 1, 2 and 3, differentiation of the ILCD inventory needs justification.
Environmental impact categories recommended or included	A table lists recommended methods representing the latest scientific consensus. In addition, inventory data can provide relevant information about a product’s environmental performance, e.g. the use of energy divided by energy source. Water use is part of the resource depletion category and should be assessed. Given its importance for the food and drink sector, the water use indicator shall be reported separately from other resources. The ENVIFOOD Protocol does not give any guidance and recommendations on grouping, weighting and normalisation.
Land use change	Chapter 6.5.3 is dedicated to land use change. LUC can be calculated on macro-level, when micro-level data are not available or micro-level, when the origin of the functional unit is known. For the inventory of the macro-level approach, PAS 2050-1:2012 for horticulture shall be adopted.
Ecosystem services	Ecosystem mentioned in context of water and biodiversity (which is not listed as a recommended impact because underpinning methods for assessing some of the midpoints are still under development). Annex F gives an overview of how biodiversity links to land use, blue water footprint, climate change, acidification, eutrophication and ecotoxicity.
Exclusions/cut-offs	Identification of significant potential impacts: Exclusion of impacts is only allowed if robust, substantiated and transparent argumentation is provided. A stepwise approach (screening phase and then detailed analysis) is recommended. Criteria to identify relevance of impact categories:

Relevance of impact for food and beverage: Justified with evidence
Scientific robustness and applicability of methods and models
Correlation between impact categories (win/win situations)

Other

3.1	**Beverage Industry Sector Guidance for Greenhouse Gas Emissions Reporting (2010) Beverage Industry Environmental Roundtable, Version 2010, January 2010**
General information (Objective, target audience, owner)	There are two primary protocols in the field of GHG emissions reporting, the GHG Protocol (for enterprise-level reporting) and PAS 2050 (for product carbon footprinting). This guidance is intended to be used to estimate emissions of the six primary GHGs (CO2, CH4, N2O, SF6, HFCs and PFCs) either individually or collectively in terms of carbon dioxide equivalent. The PAS requires inclusion of those addressed in the Montreal Protocol. Whether a company should include certain GHGs in a given report will be determined by the requirements of each reporting program.
Applicability	Beverage industry (enterprise reporting and product-level reporting
Functional unit	Not prescribed but examples of 1 litre or serving are given
System boundary	Discusses details of organisational boundaries for scope 1, 2 and 3. GHG emissions associated with generation of by-products should be accounted for up to the point where the by-products can be beneficially reused. Energy demand for wastewater treatment needs to be evaluated.
Data quality requirements/handling data gaps	Provisions default CO2 emissions factors depending on fuel (but only available for members of BIER).
Handling multi-functional processes (allocation)	For most parts no fixed rules, e.g. transport should be allocated to cargo based on weight, volume or economic value.
Handling end-of-life	Mentions that waste GHGs associated with waste disposal should be included in scope 3. Waste treatment needs to be considered up to the ultimate disposal. Account for 'waste product' that become co-products up to the point of differentiation, and then allocate by economic value. In case of materials which are recycled for reuse in another product's life cycle (e.g. PET), use an allocation method based on market recycling rates. Dependent on market conditions, this approach affords the environmental benefits of recycling either to the recyclers or to the beverage producer. Details in the appendix of the guidance. Recommended approach to recycling: For fraction of material that is from virgin raw

	material, consider collection rate, for fraction that is recycled material use composition based approach.
Environmental impact categories recommended or included	GHG only
Land use change	Not mentioned
Ecosystem services	Not mentioned
Exclusions/cut-offs	As per PAS 2050 Flows contributing less than 1 % to total emissions can be excluded as long as 95 % of emissions are covered.
Other	Account for all emission up to bottling as they occur in the year in which the product's carbon footprint reporting occurs (relevant e.g. for Whiskeys with long maturity times). Losses during maturing (angel's share) through evaporation should be estimated using an average annual loss. Fully report and disclose purchase and sale of any carbon offsets / renewable energy certificates separately from emission calculations

3.2	**PAS 2050-1:2012 Assessment of life cycle greenhouse gas emissions from horticultural products. Supplementary requirements for the cradle to gate stages of GHG assessments of horticultural products undertaken in accordance with PAS 2050**
General information (Objective, target audience, owner)	Public available specification by the British Standards Institution (BSI) Supplementary to PAS 2050 Purpose: To provide - A horticultural focus for aspects of the PAS 2050 assessment where options are permitted - Rules or assessment requirements that are directly relevant to the main sources of emissions from horticulture - Clarity on how to apply specific elements of the PAS 2050 assessment within the horticultural sector
Applicability	Horticultural products
Functional unit	FU can only be determined within the scope of such an assessment, in relation to the use and intended purpose of the horticultural product being assessed.
System boundary	Cradle to gate The horticultural product as a 'crop' is assessed including packaging and labelling employed during propagation and growth and to effect a successful transfer of the crop or plant to the intended purchaser, in addition to the actual crop or plant. The processes to be assessed therefore include all activities related to the propagation, growing, harvesting and marketing of plants including activity to create favourable conditions for growing. Explicitly following activities shall be included: - Seed or young plant production - Storage of young plant material - Crop growing - Storage of crops - Transport - Waste management The assessment shall include all GHG emissions and removals of waste (including all upstream emissions) arising during productions up to the point at which the product leaves the grower.

	GHG emissions likely to arise after the cradle-to-gate stages of production are to be assessed in accordance with the requirements of PAS 2050:2011. However, in the case of peat that is passed on to the consumer, the horticultural specification sets out specific requirements on how to calculate GHG emissions. A detailed list of 16 points states what shall be included: Plant input material; plant protection chemicals and minerals; biological pest control; materials used for pest management (no chemicals); synthetic and mineral fertilisers; organic fertilisers; supplementary CO2; energy carriers; materials used as substrate; material used for containing substrate; materials used for soil covering; materials used for guiding growth of plants and tree;, packaging materials (labels included); transport; consumable used for maintenance of capital goods. Items listed may however be excluded under the materiality rules (PAS 2050 Clause 6.3) provided the nature and extent of any such exclusion is unambiguously recorded
Data quality requirements/handling data gaps	As per PAS 2050:2011. Additional guidance is given regarding: - the period of data sampling and variability in emissions in cultivation of horticultural products - Data sampling – representative samples
Handling multi-functional processes (allocation)	Detailed description of - allocation of co-products - allocation of soil emissions of organic fertilisers and soil improvers in crop rotation allocation of emissions from fossil carbon containing fertilisers or soil improvers including relevant formulas and examples
Handling end-of-life	Waste management should be included of any waste arising within the system boundary. No specifics given here therefore as in PAS 2050:2011
Environmental impact categories recommended or included	Global warming potential only but emphasised that not the only indicator for environmental impacts of horticultural products. Additionally, information is provided as to the treatment of fossil and biogenic carbon in horticultural products that are likely to be transferred to users downstream. Included sources of GHG emissions: - Emissions and removals of biogenic carbon (e.g. where the biogenic carbon does not become part of the product) - CO2 emissions arising from burning fossil carbon sources, e.g. fossil fuels, peat, limestone - CH4 emissions arising from manure used, e.g. as fertiliser - N2O emissions from soils and agricultural processes CO2 captured in product intended for human consumption can be excluded For carbon containing materials added during cradle-to-grave stages which are likely to give rise to emissions during use and end of life of the product within 100 years, the potential emissions from those sources shall be assessed as if released at the beginning of the assessment period.

Land use change	A hierarchy is given which should be applied when determining the GHG emissions and removals arising from land use change occurring not more than 20 years or a single harvesting period prior to the assessment (whichever is longer). Details are given of how LUC should be calculated as well as an excel tool.
Ecosystem services	Out of scope
Exclusions/cut-offs	PAS 205-1 does not specify requirements for communication of assessment outcomes but does include specific requirements relating to how information on GHG emissions arising during the cradle-to-gate stages is to be conveyed to downstream business partners. Four inputs to be excluded are listed: Production and maintenance of goods used for climate control; production and maintenance of tractors, machines and other energy using equipment on the farm; production and maintenance of irrigation equipment; production and maintenance of buildings, roads and pavements and other floor covering on the farm.
Other	While capital goods are excluded, in the appendix there is an informative section on the contribution of materials and products used for greenhouses (glass or plastic) in the cradle-to-gate assessment.

3.3	**IDF (2010) A common footprint approach for dairy. The IDF guide to standard lifecycle assessment methodology for the dairy sector. Bulletin of the International Dairy Federation 445/2010**
General information (Objective, target audience, owner)	Attributional approach to calculating the carbon footprint of both dairy farming and manufacturing, Builds work by: ISO 14040, 14044 and 14067; BSI, DEFRA, Carbon Trust, WBCSD, WRI, IPCC, FAO. IDF common carbon footprint methodology is more relevant and specific to the dairy sector with ISO, PAS and WBCSD/WRI protocols feeding into it.
Applicability	Dairy sector
Functional unit	If study is conducted on-farm: 1 kg of fat and protein corrected milk (FPCM) at farm gate in the country in which the analysis is taking place.
System boundary	FARMING: Feed production and its inputs to farm gate include, but are not limited to: - Production of milk on-farm - Production and supply of supplementary feed - Production of synthetic fertiliser and its delivery - Production and delivery of any other crop and pasture inputs, e.g. pesticides - Any activities which take place on the farms e.g. feed production for the dairy cow replacements and any cows grazed away over the winter - Releases resulting from processes, including chemical and ingredients production on farm - Refrigerant manufacturing and losses and other emissions sources on-farm - Usage of energy that has greenhouse gas emissions associated with it - Consumption of energy carries that were themselves created using processes that have GHG emissions associated with them (e.g. electricity) - Waste that produces greenhouse gas emissions PROCESSING: System boundaries encompasses but is not limited to: - Transport of raw milk to the processing sites - Production, delivery and consumption of operating materials, e.g. chemicals, packaging materials and ingredients

- Freshwater usage on site and wastewater treatment.
- Releases resulting from processes, including chemical and ingredient production, refrigerant manufacture and losses and other remissions sources
- Usage of energy that has greenhouse gas emissions associated with it
- Consumption of energy carriers and their production
- Waste that produces greenhouse gases

Data quality requirements/handling data gaps

It should be stated if primary (preferred) or secondary data is used, references given and the site where data are collected from stated. Time-related, geographical and technological coverage should be stated, as well as how representative these are for the study.

There are various methods and sources for determining emissions of sources or activities, which are tiered according to their accuracy. The example stated by IPCC is given where: Tier 1 are literature data, and tier 2 level calculation requires detailed country-specific data on gross energy intake and methane conversion factors for specific livestock categories. Tier 3 requires even more accurate and scientifically accepted data from direct experimental measurements concerning, for example, diet composition in detail, concentration of products arising from ruminant fermentation, seasonal variation in animal population or feed quality and availability and possible mitigation strategies.

Tier 2 set as minimum requirement in this standards.

Handling multi-functional processes (allocation)

Based on ISO 14044

Specific recommendations are as follows:

Preferred approach	Allocation situations	Choice	Result
ISO hierarchy	Feed (pre farm)	Economic	Depends on kind of feed
	Milk/meat & calves (farm)	Physical causality	Based on energy feed inputs to the system and associated milk and meat production.
	Manure export (farm)	System expansion	Replaces N, P & K in chemical fertiliser
	Processing (dairy site)	Mix	Based on milk solids for raw milk, specific values for USE OF energy, water etc
	CHP (farm, dairy site)	System expansion	Replaces electricity from national grid or heat

More details are described.

Handling end-of-life

Listed as part of system boundaries but not specifically addressed.

Environmental impact categories recommended or included	Greenhouse gases only but acknowledges that there are other important issues, such as water and ecosystem quality. Emissions included: - Fossil CO2, - biogenic CO2 from direct land sue change - biogenic carbon storage in packaging material - Fossil methane emissions (leakage from e.g. natural gas) - Biogenic methane emissions (enteric fermentation and manure management, storage and spreading / on field) - Nitrous oxide emissions (from production of N-fertiliser, direct N2O emissions from field and manure management / storage, indirect N2O emission from filed (NO3 => N2O and NH3 => N2O) and manure management / storage (NH3 => N2O)) The guidelines state not to take i.e. changes in soil organic matter (carbon) in to account because of lack of scientific data at the world level. This should not prevent taking anybody from calculating it but it needs to be reported separately.
Land use change	As in PAS 2050 Section 5.5 and Annex 5
Ecosystem services	Ecosystem quality is mentioned as another important issue but not address in this guidelines.
Exclusions/cut-offs	95 % of likely emission from feed production to farm-gate to meet PAS2050 requirement. Flows of less than 1 % can be excluded as long as 95 % of emissions are covered.
Other	Attributional approach to calculating the carbon footprint of both dairy farming and manufacturing, Builds work by: ISO 14040, 14044 and 14067; BSI, DEFRA, Carbon Trust, WBCSD, WRI, IPCC, FAO. IDF common carbon footprint methodology is more relevant and specific to the dairy sector with ISO, PAS and WBCSD/WRI protocols feeding into it.

4.1	**PCR 2011:20 Vegetables (Environdec.org), being updated**
General information (Objective, target audience, owner)	Product category rules according to ISO14025, being updated, to be published 2016-01-15, sets rules to follow for environmental product declarations. This table refers to the draft open for consultation, which is currently being reviewed. Hence the final version might differ.
Applicability	Vegetables (products of agriculture, horticulture and market gardening).
Functional unit	The declared unit (DU) is 1 kg of packaged vegetable (weight of packaging is not included in this 1 kg).
System boundary	Upstream processes: Production of materials used in agriculture and primary and secondary packaging Core processes: Transport to core process, cultivation, transport of vegetables to processing plant, preparation of final product, waste treatment of manufacturing waste. Downstream processes: Transport to retailer, use of product, handling of packaging after use and waste treatment of any wasted part of product These three stages are to be reported separately in the EPD.
Data quality requirements/handling data gaps	Site specific data shall be used for all core processes. For upstream and down-stream processes generic data may be used but must follow rules of precision, completeness and representativeness.
Handling multi-functional processes (allocation)	If allocation cannot be avoided by dividing the unit process into two or more sub-processes and collecting the environmental data related to these sub-processes, mass allocation shall be adopted to allocate the environmental burden among the co-products suitable for human consumption. By-products not suitable for human consumption shall be considered as flows that leave the system and their amount shall be declared separately. System expansion NOT allowed.
Handling end-of-life	Final waste treatment of packaging is included in calculations. Any environmental benefit of recycling is to be illustrated in the EPD. The scenario should reflect the current waste treatment handling in the region where the vegetable is sold. No info on how to model EoL treatment of vegetable waste.

Environmental impact categories recommended or included	Compulsory: GWP, acid, ozone creation and eutrop., plus material, energy and water resource use, and waste generation
Land use change	Not considered.
Ecosystem services	Not considered.
Exclusions/cut-offs	The manufacturing of production equipment, buildings and other capital goods shall not be included. Business travel and staff commuting shall not be included.
Other	Product category rules according to ISO14025, being updated, to be published 2016-01-15, sets rules to follow for environmental product declarations. This table refers to the draft open for consultation, which is currently being reviewed. Hence the final version might differ.

4.2	**PCR 2010:01 Uncooked pasta (Environdec.org), version 2.01**
General information (Objective, target audience, owner)	Product category rules according to ISO14025, published 2015-01-27, sets rules to follow for environmental product declarations.
Applicability	Pasta products.
Functional unit	The declared unit (DU) is 1 kg of pasta
System boundary	Upstream processes: Production in agriculture (production of seeds, fertilizers, energy, detergents, packaging, milling of flour) Core processes: Manufacturing of pasta, production of energy, transport of raw materials, waste treatment processes. Downstream processes: Transport of pasta to retailer, cooking of pasta, handling of packaging after use. These three stages are to be reported separately in the EPD.
Data quality requirements/handling data gaps	Site specific data shall be used for all core processes. For upstream and down-stream processes generic data may be used but must follow rules of precision, completeness and representativeness.
Handling multi-functional processes (allocation)	Partitioning should reflect the underlying physical relationships between them; i.e. they should reflect the manner in which the inputs and outputs are modified by quantitative changes in the products delivered by the system. If allocation cannot be avoided in this manner, allocation by mass shall be used. Different cuts of pasta (i.e. long and short formats) shall be considered the same product. Products that are not compliant to the quality requirements and are destined to other chains (such as animal food) must be considered waste.
Handling end-of-life	Final waste treatment of packaging is included in calculations. Any environmental benefit of recycling is to be illustrated in the EPD. The scenario should reflect the current waste treatment handling in the region where the pasta is sold.
Environmental impact categories recommended or included	Compulsory: GWP, acid, ozone creation and eutroph., plus material and energy and water resource use, and waste generation Voluntary: ecological footprint, Water foorptint, land use, aquatic ecotox, marine eutroph.

Land use change	Yes, but voluntary, refers to IPCC recommendations on how to calculate (unclear which report)
Ecosystem services	No
Exclusions/cut-offs	The manufacturing of production equipment, buildings and other capital goods shall not be included. Business travel and staff commuting should not be included.
Other	

5.1	FAO, 2013, Food Wastage Footprint, Impacts on natural resources - Technical Repor
General information (Objective, target audience, owner)	The aim of the project is to provide a worldwide account of the environmental footprint of food wastage along the food supply chain, focusing on impacts on climate, water, land, and biodiversity. The model that was developed for this purpose seeks to answer one key question: “Where do the impacts come from?” This implies to pinpoint the major contributors to the footprint that is to say regions, commodities, or phases of the food chain considered as “environmental hotspots”.
Applicability	Food waste.
Functional unit	1 kg of food or 1 kg of food wastage.
System boundary	Carbon footprint: For all commodities, the system studied is based on a life cycle approach, covering the entire “food cycle” from “cradle to grave”. The system thus includes the following phases: agricultural production, postharvest handling and storage, processing, distribution, consumption and end-of-life.
Data quality requirements/handling data gaps	The IPCC has set an international convention to not report CO2 released due to the landfill decomposition or incineration of biogenic sources of carbon. - Only methane emissions (expressed as tonnes of CO2 eq.) are accounted for in landfill impact factor. - Only CO2 coming from fossil carbon is counted in GHG emissions of incineration. Food waste contains no fossil carbon and therefore no CO2 emissions are accounted for. Less significant emission of NO2 coming from combustion processes are however taken into account. Impact factors for each disposal route are calculated using IPCC guidelines (IPCC 2006). It must be underlined that IPCC’s approach does not make any distinction between food commodities. In other words, impact factors are calculated for 1 kg of food wastage, be it meat or fruits or any other commodity.
Handling multi-functional processes (allocation)	Not mentioned.

Handling end-of-life	A methodology/equation is proposed to take into consideration end-of-life's products. Different disposal route (i.e. dumps, landfills, compost, and incineration) have been presented in a table.
Environmental impact categories recommended or included	Environmental footprints have been calculated for environmental "quantifiable "components, which are climate, water and land (land occupation assessment). Biodiversity also has been assessed through a combined semi-quantitative/qualitative approach. A methodology is provided in order to calculate the water footprint. The primary objective of the water component is to calculate impact factors that will translate the food wastage volumes of the FWF database into cubic meters of water. A second objective is to give an overview of the level of water scarcity in the world regions where lost/wasted food was produced. This methodology is based on The Global standard on water footprint assessment developed by the Water Footprint Network (WFN) defines the water footprint of a product as the total volume of freshwater that is used directly or indirectly to produce the product. It is estimated by considering water consumption and pollution in all steps of the production chain (Hoekstra et al. 2011). **System boundary**: only on the agricultural production phase, since agricultural processes since they often are the major contributors to the overall water footprint of the product (Hoekstra et al. 2011). An underlying assumption made in the quantification of water footprint is that the production sub-region is similar to the consumption sub-region. For instance, water footprint of beef meat wasted in USA is calculated with the water impact factor of 1 kg of meat produced in the USA. This is based on a macro analysis of FBS. The FBS's macro analysis shows that for most commodities, imports are only limited share of total domestic food supply except for fruits (and fish & seafood). For that reason, fruits water footprint used in the model are world averages and not regionalised figures. Whenever data was missing for a given set of country * product, the footprint value was replaced by the world average footprint value. Water scarcity per region has been taken into account thanks to data of the GAEZ v3.0 portal.
Land use change	Not assessed in this study. However, a methodology is proposed to assess land occupation, which does not address the issue of land use change.
Ecosystem services	Biodiversity also has been assessed through a combined semi-quantitative/qualitative approach.
Exclusions/cut-offs	Due to unavailability of data, water footprint for fish and seafood was not taken into account. Besides, it can be pointed out that water footprint experts consider fish and seafood to be a "low or non-water consumptive" product category (Zimmer & Renault 2003).

Other

5.2	**Lorentzon et al. (2010): Att kombinera processintegration och miljösystemanalys för totalt minskad miljöpåverkan (PIMSA), SIK report 806, www.sik.se**
General information (Objective, target audience, owner)	Company handling waste from slaughterhouses, assessment of environmental impact of different processing of the waste flows, and different product mix out from plant
Applicability	Slaughterhouse waste streams
Functional unit	Annual production of product mix from plant (soup stock, fat, bone meal etc)
System boundary	The waste is considered ‘free’ and only the processing at the site is included, and the production of auxiliary materials, as well as avoided impacts from production of replaced products. Gate-to-gate.
Data quality requirements/handling data gaps	-
Handling multi-functional processes (allocation)	System expansion is used to make the annual output similar from the different scenarios, and thereby make them comparable.
Handling end-of-life	Incoming waste is ‘free’ (without rucksack)=raw material in the process, processing of the waste is included, burden is not allocated to the different products, the FU is the product mix altogether
Environmental impact categories recommended or included	CF and CED
Land use change	Not included
Ecosystem services	Not considered

Exclusions/cut-offs	-
Other	

5.3	**FUSIONS, Criteria for and baseline assessment of environmental and socio-economic impacts of food waste, Final Report, November, 2015.**
General information (Objective, target audience, owner)	Objective: to provide a common methodology for environmental assessment of food waste along the value chain in Europe. Thus, there is not an entire food waste life cycle assessment. The focus lies on the common methodology for a European environmental assessment of food waste and the identification and publication of existing data gaps. The results shall also serve as a shortlist of measures for decision makers to improve the validity of environmental impact estimations of food waste in the future.
Applicability	Food waste in Europe.
Functional unit	1 kg of food product utilized by the consumer.
System boundary	The current study is focusing on food waste prevention meaning that each ton of prevented food waste does not only reduce the environmental impact from waste management efforts but also includes the prevention of all other life cycle stages from cradle to grave. System boundary: all emissions starting from primary production and ending with the recovery and disposal of food waste are covered, excluding the animal feed production and the valorization and conversion of food and inedible parts removed from the food supply chain. The system boundaries are set in relation to the current available studies on environmental emissions and to the availability of quantitative data on food and inedible parts leaving the food supply chain.
Data quality requirements/handling data gaps	Two different methods are presented for the bottom up as well as the top down approach to address data gaps.
Handling multi-functional processes (allocation)	The allocation methodology (e.g. market value in the case of economic allocation) is dependent on the literature sources used. Emissions allocated to by-products coming from food production (e.g. leather, bonemeal, starch, fisheries by-catch) and to food residues which are fed to animals or are going another valorization step are therefore not included. This means that also credits which may be related to these products due to system expansion are also not covered in this assessment.
Handling end-of-life	**Bottom up approach:** The end-of-life stage covers all operations for the food waste disposal and recovery, which are composting, plough-in/not harvested, anaerobic digestion, bio-energy, co-generation, incineration, sewer, landfill and discards.

	Operations involved in the valorisation and conversion process (e.g. animal feed) in the food supply chain are not included in the end-of-life stage. **Top down approach:** At each stage is waste disposal, which has the same options as those shown for waste at end of life, which are landfill, energy recovery, composting/ Anaerobic digestion and landspreading.
Environmental impact categories recommended or included	The LCA literature found for the selected indicator products[1] was assessed for reported information on thirteen environmental impact categories as follows: global warming potential (GWP); eutrophication potential (EP); acidification potential (AP); photochemical ozone creation potential (POCP); ozone depletion potential (ODP); human toxicity potential (HTP); ecotoxicity potential (ETP); abiotic resource depletion (ARD); biotic resource depletion (BRD); reported energy (RE); land use (LU); biodiversity (BD); water use (WU). The data was collated and scored according to the following key to indicate its apparent quality and robustness. It can be seen that there is sufficient reported information covering at least part of the food supply chain for four of the environmental impact categories (GWP, EP, AP & RE) for all nine of the selected indicator products. Global warming potential is undoubtedly the most widely reported impact category probably reflecting the huge public and media interest in climate change. The initial calculations of the environmental impact of food waste in the EU will focus mainly on GWP with some attention to EP % AP. There is also reasonable information on the following two attributes: POCP & LU for all nine indicator products. Biotic resource depletion (BRD) and biodiversity (BD) were found to receive little or no attention in the LCA literature of the selected indicator products. It should also be noted that most LCA studies use the farm gate as the system boundary with increasingly less information reported as the product moves along the food supply chain.
Land use change	There is reasonable information on this environmental impact.
Ecosystem services	Not mentioned.

[1] Indicator products: Apples (non-organic); Tomatoes, loose(non-organic); Potatoes (non-organic); Bread (non-organic); Milk (conventional / non-organic); Pork (conventional / non-organic); Beef (conventional / non-organic); Chicken (conventional / non-organic) and White fish (wild caught).

Exclusions/cut-offs	Data on food and inedible parts removed from the food supply chain to valorisation and conversion (incl. animal feed) is lacking and is therefore beyond the system boundaries of this assessment. The high complexity of all waste flows cannot be covered during the FUSIONS project and simplifications have to be applied. Nevertheless for future studies on e.g. the valorisation of food waste, these flows have to be covered in more detail. Emissions allocated to by-products coming from food production (e.g. leather, bonemeal, starch, fisheries by-catch) and to food residues which are fed to animals or are going another valorization step are therefore not included. This means that also credits which may be related to these products due to system expansion are also not covered in this assessment.
Other	Objective: to provide a common methodology for environmental assessment of food waste along the value chain in Europe. Thus, there is not an entire food waste life cycle assessment. The focus lies on the common methodology for a European environmental assessment of food waste and the identification and publication of existing data gaps. The results shall also serve as a shortlist of measures for decision makers to improve the validity of environmental impact estimations of food waste in the future.

5.4	**Lopes, C., Antelo, L. T., Franco-Uría, A., Alonso, A. A., & Pérez-Martín, R. (2015). Valorisation of fish by-products against waste management treatments – Comparison of environmental impacts. Waste Management, 46, 103-112. doi: http://dx.doi.org/10.1016/j.wasman.2015.08.017**
General information (Objective, target audience, owner)	Stimulated by changes in Common fisheries policy which aims at eliminating discards and an obligation to land catches of regulated species – thus leading to an expected increase in fish-by-products. Comparison of valorisation (as fish meal and oil), composting, incineration and landfilling of fish by-products. Audience: as decision support for decision makers to understand also environmental implications of different scenarios Method: Ecological footprint and LCA (streamlined)
Applicability	Fish by-products with some wider applicable insights
Functional unit	Not explicitly described 9120 t, the amount of fish by-products generated by the activity of fishing industries established in a fishing port, i.e. the port of Vigo (NW Spain). Consists mainly of low fat entire specimens of small/medium fish (mackerel, whiting, great silver smelt or boarfish) and smaller percentage of subproducts (viscera, skin, bone, etc.) resulting from different types of fish processing, like filleting or evisceration
System boundary	Transport from harbour to treatment site and emission from treatment. Input into system is waste (burden free)
Data quality requirements/handling data gaps	Some primary data, some data estimates
Handling multi-functional processes (allocation)	Allocation not mentioned

Handling end-of-life	System expansion for outputs of treatment
Environmental impact categories recommended or included	In LCA focus on global warming and acidification potential
Land use change	No impact from LUC but land occupation of facilities (but not allocated to FU), only total area of e.g. landfill considered in Ecological footprint
Ecosystem services	Impacts from aquaculture in open sea Impacts of aquaculture production onto marine life, e.g. drugs could be biotransferred
Exclusions/cut-offs	Pollutants in feedstock: Bioaccumulation of pollutants (contained in fish by-products) if valorised as animal feed is a highlighted risk. Similar risks exist if fish oil is used by humans as source of omega 3. Bio-accumulation can also take place if composted and thus reach the human food chain.
Other	Different evaluation methods show different results.

5.5	Vandermeersch, T., Alvarenga, R. A. F., Ragaert, P., & Dewulf, J. (2014). Environmental sustainability assessment of food waste valorization options. Resources Conservation and Recycling, 87, 57-64. doi: 10.1016/j.resconrec.2014.03.008
General information (Objective, target audience, owner)	The objective is to evaluate which food waste valorisation option could bring more environmental gains, considering the reality of a company from a retail sector in Belgium. The assessment is done on three levels: With a resource efficiency perspective at gate-to-gate through exergy analysis With a resource efficiency perspective at cradle-to-gate through exergetic life cycle assessment Scenario 1: all food waste enters anaerobic digestion Scenario 2: bread is going to a feed production plant and the rest to anaerobic digestion
Applicability	Retail sector on Belgium with some wider applicable insights
Functional unit	1000 t of food waste of which 100 t of bread waste
System boundary	Transport from retail to return centre, return centre sorting, transport to anaerobic digestion or feed production
Data quality requirements/handling data gaps	Primary data from return centre, anaerobic digestion and feed production, incl. transport in between, background data Ecoinvent 2.2
Handling multi-functional processes (allocation)	In return centre mass allocation of electricity inputs
Handling end-of-life	System expansion

Environmental impact categories recommended or included	18 Recipe midpoints, three end points and a single score, Hierarchist version, World normalisation factors. No recommendations on impact categories
Land use change	As covered in Ecoinvent data
Ecosystem services	Not mentioned
Exclusions/cut-offs	Not mentioned
Other	

5.6	**Eriksson, M., Strid, I., & Hansson, P.-A. (2015). Carbon footprint of food waste management options in the waste hierarchy – a Swedish case study. Journal of Cleaner Production, 93, 115-125. doi: http://dx.doi.org/10.1016/j.jclepro.2015.01.026**
General information (Objective, target audience, owner)	Carbon footprint of 5 waste streams (bananas, grilled chicken, lettuce, stewing beef and wheat bread) in 6 end of life scenarios (landfill, incineration, composting, anaerobic digestion, animal feed and donations) The objective is to compare the outcome, with regard to greenhouse gas emissions, of different food waste management scenarios available to supermarkets in Uppsala. The overall aim was to provide more detailed knowledge about the quantity of emissions avoided with applying a more prioritised step in the waste hierarchy for the management of food waste.
Applicability	Specific to retail in Uppsala with some wider applicable insights
Functional unit	Removal of 1 kg of food waste (including packaging) from the supermarket
System boundary	From transport from supermarket to treatment site and treatment including system expansion
Data quality requirements/handling data gaps	Specific data for waste management scenarios from Uppsala was used
Handling multi-functional processes (allocation)	Allocation not mentioned, if then as part of figures taken from literature
Handling end-of-life	System expansion for outputs of treatment
Environmental impact categories recommended or included	Only GHG were considered

Land use change	Na (literature number for primary production of the substitute products were used, no details as to if and how LUC is considered there)
Ecosystem services	Not mentioned
Exclusions/cut-offs	Not mentioned
Other	Chose products to represent food waste (mass, greenhouse gas emissions, energy and water contents and range of environmental burden across the life cycle). Findings: Waste valorisation measures should focus on food products with the potential to replace production of goods and services, rather than on food products that are wasted in large quantities or have a high carbon footprint

5.7	**Scholz, K., Eriksson, M., & Strid, I. (2015). Carbon footprint of supermarket food waste. Resources Conservation and Recycling, 94, 56-65. doi: 10.1016/j.resconrec.2014.11.016**
General information (Objective, target audience, owner)	The aim of this study is to analyse wasted retail food in terms of GHG emissions, in order to obtain knowledge about the climate impact pattern of food waste in supermarkets. Specific objectives were to identify hotspots by determining the impacts and to quantify and illustrate the discrepancies between mass and carbon footprint profiles of waste. Not an LCA but cradle to gate carbon footprint assessment of food waste, a form of contribution analysis
Applicability	Any goods
Functional unit	Assessed wasted carbon footprint of food waste from six stores of the Swedish Retailer Willys in the Uppsala Stockholm area over a three year period. It included (1) waste deemed not sellable, e.g. due to a passed best-before-date, damage or colour change of product and (2) pre-store waste, i.e. waste rejected at delivery.
System boundary	Cradle to gate All emissions associated with primary production, we well as emissions caused by processing and transportation up to the retailer, were considered. Emissions from land use change were not included. Emission associated with store operation and packaging were not included, since data availability was not sufficient and their impact was considered to be relatively low.
Data quality requirements/handling data gaps	Literature and as described in Scholz 2013 Crossreading from similar products where data gaps exist
Handling multi-functional processes (allocation)	As given in literature Mention that GHG emission are usually allocated to the animal carcass at the slaughterhouse, which means no emissions are associated with blood or organs (inputs to make black pudding and pâté)
Handling end-of-life	Not within scope
Environmental impact categories recommended or included	Carbon footprint only
Land use change	LUC is not included

Ecosystem services	Not mentioned
Exclusions/cut-offs	Bread which is managed separately LUC was excluded, as were emissions associated with store operations and packaging
Other	

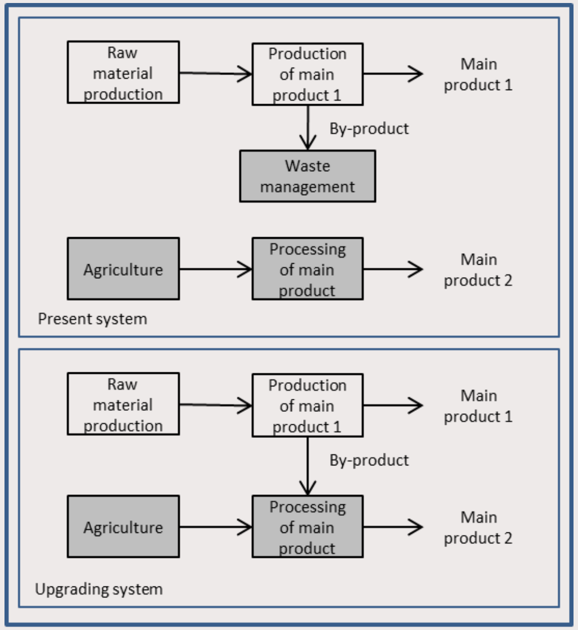
5.8	**Münster, M., Ravn, H., Hedegaard, K., Juul, N., Ljunggren Söderman, M., (2015), Economic and environmental optimization of waste treatment, Waste Management 38, 486-495.**
General information (Objective, target audience, owner)	Presentation of the new systems engineering optimization model, OptiWaste, which incorporates a life cycle assessment (LCA) methodology and captures important characteristics of waste management systems. As part of the optimization, the model identifies the most attractive waste management options. The model renders it possible to apply different optimization objectives such as minimizing costs or greenhouse emissions or to prioritize several objectives in different weights. Target audience: waste companies and national authorities Objectives in the case study: An illustrative case is analysed, covering alternative treatments of one tonne of residual household waste such as incineration of the full amount or sorting out organic waste for biogas production for either combined heat and power generation or as fuel in vehicles.
Applicability	Waste (not only food waste).
Functional unit	Alternative waste treatment of 1 tonne residual household waste. The residual household waste is a weighted average of Danish household waste mainly consisting of organic waste (50%), paper and cardboard (20%) and plastic (10%).
System boundary	Waste management LCA typically focus on comparing two management alternatives during all phases from waste generation to final disposal. Energy systems analysis (**ESA)** focuses on one step of the life cycle (energy recovery), with a simulation of all interacting energy technologies (e.g.: process of conversion of fuel (such as waste) to electricity and heat).
Data quality requirements/handling data gaps	Handling data gaps between LCA and ESA methodology: Many qualities of flows that have to be handled in LCA and not in ESA. Different needs of modelling time in waste and energy systems. Details on geographical conditions are important in both methodology
Handling multi-functional processes (allocation)	Mass allocation
Handling end-of-life	Comparison of environmental impacts regarding the end-of-life of residual household waste depending on the three waste management systems: incineration only, incineration and production of biogas for heat and power plant,

	incineration and production of biogas for vehicles.
Environmental impact categories recommended or included	Environmental impact categories: total greenhouse gas emissions (CO2, CH4 and N2O). Economic categories included: total operation costs.
Land use change	Not mentioned.
Ecosystem services	Not mentioned.
Exclusions/cut-offs	Regarding the LCC analysis: Externalities, such as environmental damage costs, have not been internalized in the costs.
Other	

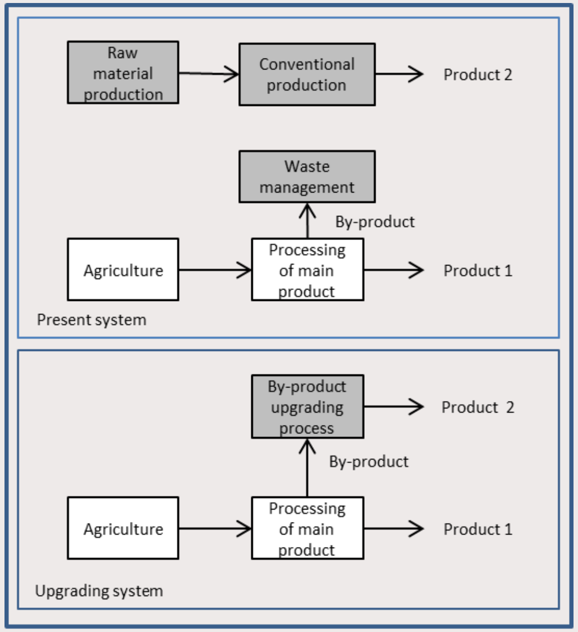
5.9	**Lundie, S., Peters, G. M, (2005).** **Life cycle assessment of food waste management options, Journal of Cleaner Production, 13, 275–286.**
General information (Objective, target audience, owner)	Environmental assessment of alternative means of managing food waste: comparison of service provided by household in-sink food waste processor (WFP) unit and alternatives to it: home composting, landfilling food waste with municipal (called “codisposal” in the study) and centralised composting of green (food and garden) waste. Audience: Waverley Council (a local government in Sydney) Method : LCA methodology
Applicability	Household food-waste in Sydney
Functional unit	Management of the food waste produced by a Sydney household in one year**.** In the Waverley Council area, this amounts to 182 kg (wet) per annum based on an average of 2.1 persons per household in this area.
System boundary	From the household food waste production to the farm/garden/horticultural application or flaring of landfill gas. Input into system is household waste.
Data quality requirements/handling data gaps	Some primary data are used, some data estimates.
Handling multi-functional processes (allocation)	Mass allocation.
Handling end-of-life	Not mentioned.
Environmental impact categories recommended or included	Eight environmental indicators and impact categories : - water usage - energy usage: non-renewable and renewable energy consumptions - climate change - human toxicity potential (HTP) - aquatic eco-toxicity potential (AETP)

	- terrestrial eco-toxicity potential (TETP) - eutrophication potential - acidification potential Water usage is an environmental indicator of particular interest in Australia, since it is one of the driest continents on earth. Thus, the indicator “water usage” has been taken into account for this study.
Land use change	Not mentioned.
Ecosystem services	Not mentioned.
Exclusions/cut-offs	Detailed modelling of the **beneficial use of by-products**, such as compost and biosolids, is not part of the study due to the chemical complexity of these materials.
Other	

5.10	**Sonesson (2009), Chapter 4 Application of LCA in reducing waste and developing coproducts in food processing in Handbook of waste management and co-product recovery in food processing, volume 2, Woodhead publishing ISBN 978-1-84569-391-6**
General information (Objective, target audience, owner)	Method for environmental assessment of upgrading food waste
Applicability	Food waste
Functional unit	Case one: Products coming out from a system, product 1, product 2 etc… (category 1 below) Case two: removal of 1000 kg of waste from cabbage system. (category 2 below)
System boundary	Gives three scenarios of waste handling : category 1) Waste is used as ingredients in other product, category 2) Waste is used to produce product already on the market, category 3) Waste is used to produce new product not on the market. In all three, no allocation between waste and main product is necessary, since both are within system boundary. In these comparative LCAs, only those parts of the system that are affected by the upgrading process are included, i.e. parts that are unchanged are not included.



Category 1: Grey parts included in system boundary

	 Category 2&3: Grey parts included in system boundary
Data quality requirements/handling data gaps	This method requires a lot of data on alternative production of products (to make compared scenarios equivalent), and assumptions have been made on these since data is often lacking.
Handling multi-functional processes (allocation)	System expansion.
Handling end-of-life	The handling of the waste stream is the main process in the system in this study.
Environmental impact categories recommended or included	GWP, Acid plus other, but mainly GWP
Land use change	Not considered.

Ecosystem services	Not considered.
Exclusions/cut-offs	Not specifically addressed.
Other	

5.11	**Dornburg V. & Faaij A., Cost and CO2 emission reduction of biomass cascading: methodological aspects and case study of SRF polar, Climatic Change (2005) 7:373-408**
General information (Objective, target audience, owner)	Biomass-cascading study of polar wood
Applicability	Biobased valorization chains
Functional unit	One ha and one year of poplar production (and the functions provided by this)
System boundary	Production of wood and all following process steps, the same for the reference system (the reference system includes the products that are replaced by the products from the poplar system)
Data quality requirements/handling data gaps	-
Handling multi-functional processes (allocation)	System expansion. All products are compared to a reference system that produces some kind of replaced product. To derive savings from each ha and year of poplar production.
Handling end-of-life	See above
Environmental impact categories recommended or included	Carbon footprint only
Land use change	Not considered.
Ecosystem services	Not considered.
Exclusions/cut-offs	Not specifically addressed.

Other	Cost calculation included

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