EIP-AGRI Focus Group Reducing food loss on the farm: a holistic approach

STARTING PAPER FOR THE FOCUS GROUP

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1 Introduction

Agriculture is a critical sector of the EU economy, providing the food, feed, and biofuels that help sustain society. The EU primary agricultural sector is worth €200 billion per annum in gross value added and employs roughly 22 million people. Agriculture is also at the centre of the challenges associated with population growth, food security, climate change and resource scarcity. In the next decades, the agri-food system will face an unprecedented "confluence of pressures", including a significant increase in global population, intensifying competition for scarce resources and the existential threat of climate change (FAO, 2014).

The agri-food system is also wasteful. Inefficiencies in the agri-food chain mean reduced productivity, wasted energy and natural resources that are invested in the production of products that ultimately become waste. The UN Food and Agricultural Organisation estimates that inefficiencies in the global food economy cost US$1-2 trillion per year. Ultimately, when analysing the entire agri-food chain, up to one-third of the food produced for human consumption every year is wasted (Gustavsson et al 2011). For Europe, around 88 million tonnes of edible food are wasted each year, with an estimated cost of €143 billion (Fusions, 2016). This waste equates to a financial loss as well as loss of the resources that were invested in its production, with consequent negative environmental impacts.

When considering wastage in the supply chain, most attention and data gathering have focussed on downstream food losses such as those at the retail and final consumption stage. Primary production has been neglected traditionally as it has been considered the most difficult to analyse and quantify, with insufficient data being available (Redlingshöfer, 2017) and with farmers not identifying waste as a priority issue (Beausang et al, 2017).

1.1 Primary Production Losses

When accounting for losses or waste on the farm, there is no agreed definition of what to include. Hartikainen et al (2018) focus only on the edible part of food that was intended for human consumption, while others include both edible and inedible components when they determine waste figures. Analysis by Beausang et al. (2017) highlighted that for many actors involved in primary production, the term 'food waste' is not used, because the material is often not 'wasted' but used as some other valuable input, even if this means that it is ploughed back into the field. Food that doesn't leave the farm is called unmarketable, surplus food, over-production, or simply 'ugly' or 'wonky'.

Box 1: Virtual food losses
Another dimension of 'food loss' on the farm that is not normally considered is the 'opportunity foregone' arising from inefficient on-farm operations. For example, a farmer who fails to operate to best practice (e.g. inadequate fertiliser application, inappropriate crop variety use, etc.) produces lower yield and quality that the farm's potential. This is a 'virtual loss' of food but, while ignored in general assessments of losses, nevertheless it is a real loss to the system.

Regardless of the definition, evidence from research that has been undertaken for primary production losses reveals that there is a significant amount of material generated on farms that were meant to be eaten by humans and did not make it to the next step, as well as valuable inedible materials that are generated as a result of food production. Initial FAO estimates from 2011 (Gustavsson et al 2011) reported that primary production losses in Europe ranged from 2% for cereals to 20% for roots, tubers, fruits and vegetables. More recent estimates for individual countries/regions reveal similar values. Beretta et al (2013) reported a similar result for fresh vegetable production in Switzerland, with an average of 28.5% of vegetables lost at the primary production stage. Redlingshöfer (2017) and Beausang et al (2017) respectively provide estimates for

France and Scotland, while a major study conducted by WRAP in the UK estimated that the waste for strawberries ranged from 3% - 17%, while for lettuces it was 7% - 47%; with some producers having almost half their crops become waste (WRAP, 2017).

1.2 Causes of primary production food loss

Food is lost through inefficiencies in the way we produce, process, store and transport it, which may spoil the food or cause a loss in its nutritional value – in addition to market failure and contractual obligations. Unlike downstream losses, primary production losses can often be caused by external factors, such as weather conditions, diseases, market conditions, supplier contracts, etc, whereas in other parts of the food supply chain food waste is more dependent on internal factors, such as bad planning and variations in technology efficiencies.

Wastes generated during primary production can be broadly summarised as 'practice based' and 'market based'. 'Practice based' refers to direct waste generated during the operations of growing and harvesting the crops. 'Market based', on the other hand, is waste that is generated as a result of external market events that influence production on the farm. Figure 1 presents a summary of some of the main causes of wastes generated on the farm.

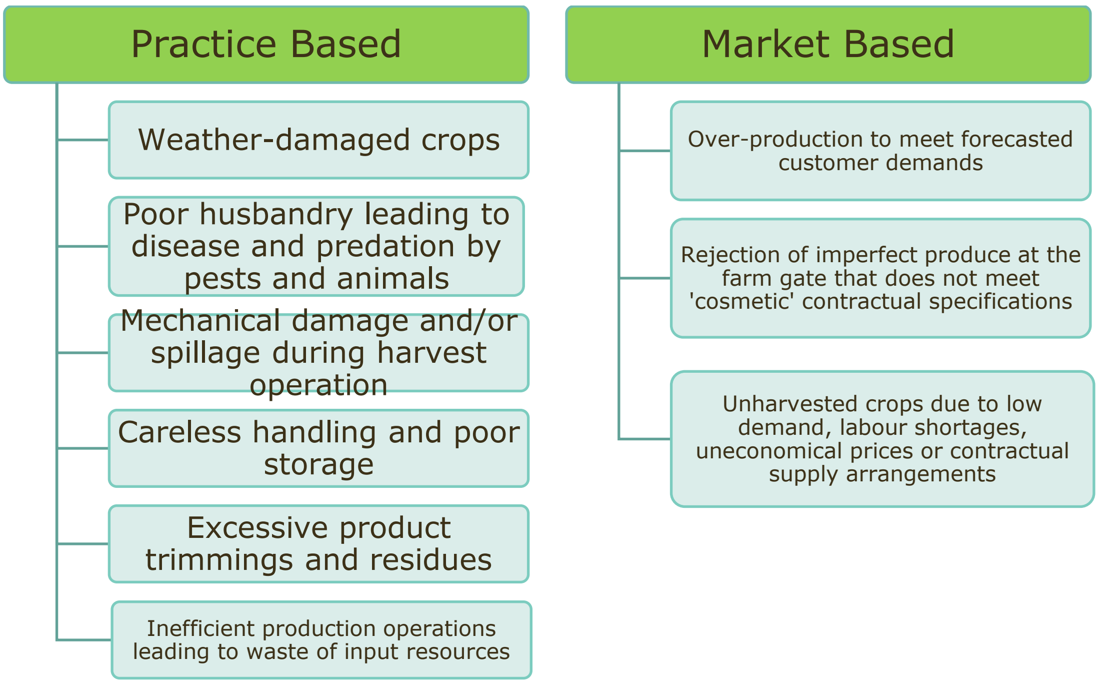

Figure 1. Examples of some 'practice based' and 'market based' primary causes of food loss on farms

'Practice based' wastes are more tangible and have traditionally been better understood and managed. Only recently are the problems of 'market based' losses becoming better appreciated. New research by WRAP (2017) highlights that significant amounts of over-production occur by producers as a form of risk management for meeting retailers' demands. According to WRAP, fear of losing business is the major concern. Since retail forecasting and crop production are not exactly aligned, the expectation of high in-stock levels of fresh produce is chiefly met by growers producing more than anticipated demand (Lillywhite, 2016). While over-production can provide buffering capacity to ensure a consistent flow of quality products through the supply chain, the downside can be high levels of in-field waste of saleable product when supply and demand

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do not balance (Lillywhite, 2016). The key problem being that it is more 'economically advantageous' to waste food rather than under-deliver to a customer (Lillywhite, 2016). WRAP estimates that nearly 20% of the UK lettuce crop is not harvested due to these 'market based' losses.

Figure 2, from Beausang et al (2017), presents an overview of the main pathways leading to waste arising during primary production.

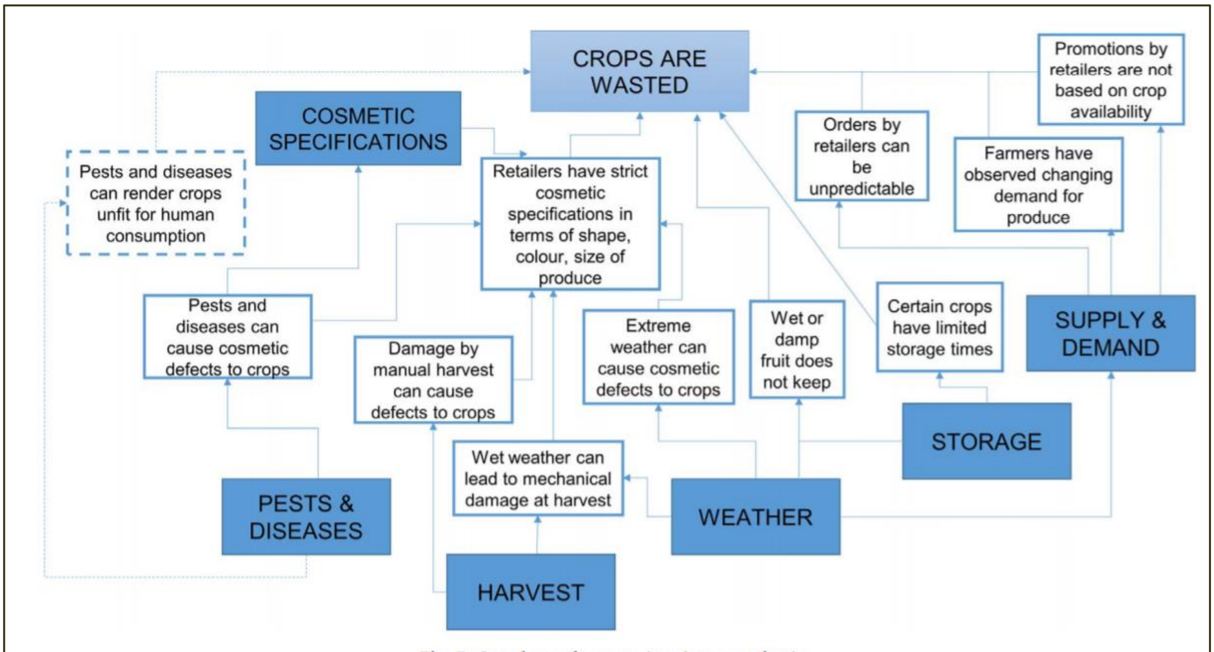

Fig. 5. Causal map for waste in primary production.

Figure 2. 'Causal map' of the sources of primary production waste (Beausang et al, 2017)

2 Constraints

2.1 On-farm and off-farm constraints

Primary producers operate with many constraints. To be successful, producers generally aim to maximise the crop yield per unit area, reduce the risks of crop failure, minimise operating costs, and sell crops for the highest price possible. This requires, among other things, effectively managing input resources like fertiliser, water, and seed (quantity and quality) and minimising the impact of unpredictable variables (such as the weather and pests) in addition to managing customer supply requests (Accenture, 2017). Market requirements which dictate product specifications (e.g. product size range; or the so called 'cosmetic specifications' – i.e. visual characteristics of the food product), and contractual arrangements with the purchaser (processor, retailer, wholesaler, consumer) also dictate a major part of their production strategy.

Small operators in the food supply chain, including farmers, are vulnerable to unfair trading practices employed by larger partners in the chain. These smaller farmers generally lack bargaining power and alternatives to get their products to consumers, which can lead to their produce being wasted. New legislation

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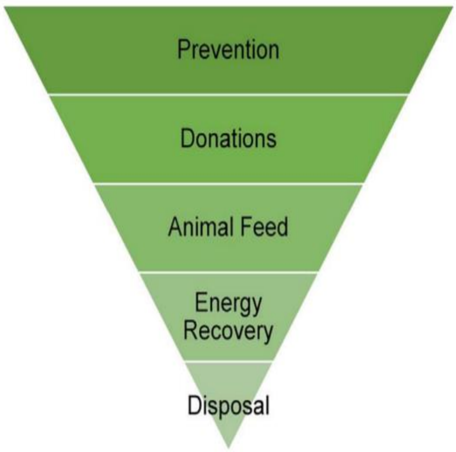
which has been proposed by the European Commission will ban unfair trading practices, including late payments for perishable food products, last minute order cancellations, unilateral or retroactive changes to contracts and forcing the supplier to pay for wasted products (European Commission, 2018). The Commission's proposal, which will take the form of a directive, applies to anyone involved in the food supply chain – be it a retailer, a food processor, a wholesaler, a cooperative or producers' organisation, or a single producer engaging in any of the unfair trade practices identified.

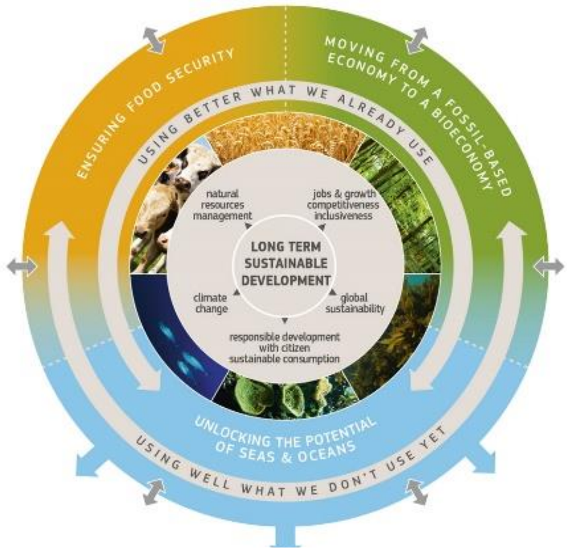
Box 2: 'Market specifications'

Many of the causes of food waste as identified by farmers are due to factors further along the food supply chain. For example, 'market specification' is a persistent issue for farmers that leads to edible produce being graded out on the farm. Supermarkets order fresh produce that must fit exacting size, shape and colour specifications, regardless of the nutrition, taste and value of the food. Farmers have also indicated that a concentration of power among large retailers has resulted in fewer outlets for lower grade and surplus produce (Feedback, 2018). The same mechanism applies to crops that are sold directly as food (vegetables and fruits) and also to crops that are processed (cereals into flour, grape seed, sugar beet, etc.). The market specifications here relate to meeting the standards for the industrial processing rather than visual aspects of the produce. Given the costs of adapting an industrial food processing chain, it may prove even more difficult to have these standards evolving than consumers accepting "ugly" vegetables.

When it comes to waste generation on the farm, the farmer has control over only some of the factors influencing waste generation. Consequently, as the farmer does not have direct control over all factors of production (e.g. weather, markets, etc.), the overall objective is to minimise risk, maximise the financial return to producers as well as utilisers of waste streams through a 'win-win strategy'.



Waste Hierarchy: Enshrines the role of preventing and reducing the amount of waste generation as the top priority, Beausang et al (2017)



Bioeconomy Strategy: Developing the high value opportunities that are available from using waste as a feedstock,
European Commission (2012)

Figure 3. Waste Hierarchy and Circular/Bioeconomy strategies. There is a real risk that generating a market for 'valorised' waste reduces the incentive to minimise

In defining food losses, 'food loss and waste' applies to both 'food' that is intended for human consumption and to its associated inedible parts which leave the human food supply chain (Champions 12.3, 2017). The two key policy narratives that are shaping how food waste is viewed and how to manage it sustainably are the

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waste hierarchy, established as part of the EU Waste Framework Directive (European Commission, 2008), and the EU's Circular and Bioeconomy strategies (European Commission, 2012; 2015) (Figure 3).

The waste hierarchy was designed to prioritise pathways for waste, being developed to look at waste management as a service. It offers little insight to evaluating the value of waste as a potential resource. The circular/bioeconomy concept, on the other hand, promotes the effective reuse and valorisation of food wastes to ensure resource recovery and security. The EU's bioeconomy and circular initiatives (European Commission 2012; 2015) are driving the utilisation of wastes and their conversion into new products and bio-energy in an effort to add further value to the economy and improve the environmental performance of EU industries, by using less virgin materials. With this there is a danger of generating a market for recycled products, thus reducing the incentives to minimise waste in the first instance. Consumer dynamics are a major driver of 'circular economy' practices, not all beneficial.

Box 3 : Policy

Policy is a very powerful tool with the ability to instigate immediate change in practice across society. However, given its power, policy must be carefully designed and thought through in order to avoid unintended negative consequences. The policy landscapes of the European Commission in addition to the UN Sustainable Development Goals are driving the management and ultimate reduction of food waste at all stages in the supply chain.

2.2 Life Cycle Assessment (LCA)

The full environmental impact of different farming systems can be very difficult to assess. Specific changes that may appear positive can have unintended negative consequences. Policy is such an important 'driver' of farming operations, its use must be carefully designed with a holistic approach vital.

It is essential that a holistic systems-based approach is taken for the full life cycle. However, as eco-systems are global, it is not possible to undertake a truly holistic assessment. LCA tools have been used extensively for assessing waste management and are being used now to evaluate the implications of waste valorisation within a 'circular economy'. Life cycle assessments are limited to the boundaries chosen for their evaluation.
Sustainability assessment needs to be further investigated through Life Cycle Assessment (LCA) when comparing bio-based products and fossil-based alternatives. The transition towards more sustainable production and consumption patterns needs a holistic approach and life cycle thinking is progressively seen as a key concept for supporting this objective (Sala et al, 2015). Notarnicola et al (2017) reviewed the challenges of using life cycle assessment in supporting sustainable agri-food systems and found that despite the increasing number of LCA food studies, several challenges still need to be addressed in order to ensure that LCA is delivering robust results. LCA studies of crop production systems have been carried out (Nemecek et al, 2001; Caffrey and Veal, 2013). Nemecek et al (2001) highlighted that life cycle assessments (LCAs) of different farming systems are typically carried out for a single crop, whilst farmers optimise their production for a whole crop rotation. When a single crop is analysed, some emissions, such as nitrate leaching, occur mainly during the fallow periods between crops and are not included in the analyses. Nemecek et al (2001) also found that fertilisers and pesticides had only a limited influence on the results of LCA, when compared to organic manure.
Given the regional specificity of the crop rotation and the high level of nutrients available from the soil, care must be taken when applying LCA results to other agricultural systems (Nemecek et al, 2001). This is because there are various factors that increase the complexity of determining impacts associated with agricultural production systems including multiple products from a single system, regional and crop specific management techniques, temporal variations, spatial variations (Caffrey and Veal, 2013).

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3 Addressing the problem: a holistic approach

3.1 Identifying food loss streams

To determine how to effectively manage primary production food losses, a holistic approach is necessary. This starts with categorising wastes that are generated to help identify the most sustainable option for their management. As highlighted previously, the definition of agri-food waste is subjective and very much stakeholder dependent. The EC's Waste Framework Directive provides a definition of waste as "items that people no longer have any use for, which they either intend to get rid of or have already discarded".
However, in the agri-food chain, and particularly at the primary production stage, many material flows may be considered valuable resources. A prime example is that of crop and other vegetable residues which can either be viewed as a material to be exported from the farm as a feedstock for valorisation or as a vital resource to be kept within the agricultural system to provide necessary 'ecosystem services'. To overcome this ambiguity, it has become important to categorise the tonnes of biogenic agri-food wastes that are generated each year into 'avoidable' and 'unavoidable' wastes, summarised in Table 1.

Table 1. Definitions of 'avoidable' and 'unavoidable' wastes

'Avoidable' Wastes	'Unavoidable' Wastes
'Avoidable' agri-food wastes are consumable material streams that have been generated by poorly managed systems and would not exist if the system was managed properly (i.e. waste generated from inefficient production systems). These can be both 'practice based' and 'market based' wastes (cf. fig 1) such as crop wastage due to over planting and products that do not meet strict specifications.	'Unavoidable' agri-food wastes are materials arising from efficiently operated food production systems that are not edible, typically described as by-products, co-products, or residues. These are typically 'practice based' e.g. crop residues, leaves, peels. Unavoidable agri-food wastes cannot be prevented and are typically homogeneous streams. These are not losses but unavoidable by-products of production.

Beretta et al (2013) highlighted that nearly 80% of fresh vegetable losses at primary production can be considered avoidable. WRAP (2017) further emphasise that there is very little completely unavoidable crop waste in primary production. While WRAP acknowledges that avoidable on-farm wastes are *theoretically* avoidable, the degree to which they are *practically* avoidable is unclear.

Box 4: Lettuce production losses

Indicative data collected by WRAP for the 2015 UK lettuce crop showed that 19% of the lettuce crop was not harvested by growers. Once harvested, UK growers estimated that nearly a quarter (24%) of the lettuce head weight was left in the field as a result of trimming. On average, 1% of the harvested crop was rejected by the customers.
It was found that lettuce that was unharvested, its trimmings and some unpackaged rejected product were almost always returned to the land. Trimming waste was viewed as being practically unavoidable (but theoretically avoidable), because the older damaged outside leaves would not be considered edible. All growers interviewed incorporated some form of over-production into their planning – and this was also considered an '*unavoidable*' part of doing business**.** It was viewed to be much more costly to growers to have too little crop than to have too much, both in an immediate sales sense as well as in a long-term supplier relationship sense. Over-production was generally between 10-15%.

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3.2 Sustainable pathways for managing food losses

'Avoidable' losses on the farm ultimately represent mismanagement and inefficient operations, and the waste hierarchy should govern their management i.e. these material streams should be prevented and reduced as much as is economically and technically possible. 'Unavoidable' wastes, on the other hand, can be viewed as a resource, as they cannot be prevented and thus their effective utilisation should be prioritised.

Many agricultural waste material streams are ideal raw materials for biological processes to create new products (or existing products by new processes), providing a major opportunity for EU agriculture and industry. The characteristics of 'unavoidable wastes' [i.e. 'Agricultural Wastes, Co-products and By-products' (AWCB)] mean they can act as a source of renewable carbon, feedstock for making valuable chemicals, fertilisers and fuels, replacing many common chemicals that rely on virgin fossil material. However, many wastes generated through crop and animal production are often retained in the soil, in an effort to promote physical, chemical, and biological attributes of soil health. Many on-farm food wastes are simply ploughed back into the fields, used as feedstock for composters/anaerobic digesters, and animal feed.

Box 5: Soil Health
The removal of waste products from the farm for off-farm 'valorisation' (where traditionally they may have provided soil organic matter and nutrients through incorporation into the soil) may have negative impacts on soil health and the longer-term sustainability of farming systems; and this has to be accounted for in a holistic assessment of the off-farm use of such material. There is a lack of verified data on the sustainable removal rates for waste products arising from cereal (straw), fruit or vegetable crops. Work by Dr Simon Jeffery and his team at Harper Adams University (UK) is using nematode populations as soil health indicators (sjeffery@harper-adams.ac.uk).

As highlighted by Scarlat (2010), while there are significant amounts of residues produced on farms, a large fraction of these residues are currently used for on-farm applications. For vegetable production, residues are common sources of organic matter for decomposition which are typically incorporated into the soils after harvesting. Vegetable crop residues constitute an important link in the soil nutrient and organic carbon cycle, aiding in the maintenance of soil quality and fertility (Agneessens et al, 2014). Vegetable crop residues also result in large amounts of biomass with a high N content left behind on the field. Given the particular contribution of vegetable crop residues to N cycling and the potentially very large N losses, it is of vital importance to manage these residues in such a manner that N can be conserved maximally for the next crop. No specific data currently exist that estimate sustainable removal rates for fruit or vegetable crops. What is clear from the literature though is that maintaining or returning nutrients to the soil is vital for continued productivity and soil health. Valorisation technologies can aid in this endeavour by stabilising residues, preventing N losses, and returning nutrients to soils at more appropriate times.

Box 5: 'Fossil Food' - waste prevention is a priority
The AgroCycle framework, developed as part of the H2020 AgroCycle Project (www.agrocycle.eu), is being designed to help identify the pathways most suitable for agri-food waste streams. This framework highlights the trade-offs between availability of agricultural wastes and their suitability for valorisation. For example, valorisation technologies that rely on 'avoidable waste', such as over produced fruits/vegetables, as a feedstock, effectively create a demand for this waste and in turn transform it into a valuable commodity. This conflicts with potential efforts to prevent this waste in the first instance. The existing evidence suggests that the majority of waste generated on farm is theoretically avoidable. The upstream investment in fossil inputs (e.g. fuel, phosphorus, soil) and natural capital impacts (e.g. land use, soil degradation) means that our food can be regarded as a quasi 'fossil food' (Holden et al, 2018). This makes reduction and prevention of this waste, where feasible, a priority to create a sustainable, secure agri-food supply system.

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4 Food loss Research

4.1 Research and innovation priority areas

Research on food loss during primary production is today generating considerable interest. The initial pioneering global assessment by Gustavsson et al (2011) provided the first major look at the extent and causes of food loss. Since then, much work has been done on developing an understanding of what constitutes primary production losses, why they occur, and how best to manage them. A number of key research topics have emerged, topics that we feel should remain a priority for EIP-AGRI.

1) **Defining food losses:** The FUSIONS project provided the first attempt to provide a definitional framework for food waste (Östergren et al, 2014). The Food Loss and Waste (FLW) Protocol, which includes representatives from the FAO, FUSIONS, WRAP, and the World Resources Institute (WRI) launched the Food Loss and Waste Accounting and Reporting Standard (the FLW Standard) in 2016 to help stakeholders quantify and report food waste. However, inconsistencies in published literature regarding the boundaries, timeframes and definitions of food waste are still prevalent. New concepts such as the term 'side flow' (SF) have been developed to better describe food waste in primary production (Hartikainen et al, 2018). Much effort is also being placed on better understanding how primary producers view food waste (Beausang et al, 2017). A clear, consistent approach to defining losses on the farm therefore still remains a research priority.

2) **Quantifying food losses**. Stenmarck et al (2016) outlined that analysing and quantifying primary production losses remains the most difficult of all stages in the agri-food chain. Significant amounts of work are ongoing at country level to quantify the amounts of losses that occur at primary production. Loss estimates for Switzerland (28% for fresh vegetable, Beretta et al, 2012), France (12% for many fruits and vegetables, Redlingshöfer et al, 2017), Nordic countries (10-26% for open field vegetables and fruit, Hartikainen et al, 2018), and Scotland (5-30% for common fruits and vegetables, Beausang et al, 2017) have been published to date. Continuing these quantification steps for other countries and for all specific agricultural products is still a necessity.

3) **Why food losses occur.** In-depth research on the causes of food losses is not common but insightful efforts by Beausang et al (2017) and WRAP (2017) among others have helped better explain the role of external factors in causing losses on the farm. Detailed analyses on particular crops (such as lettuce and strawberries in WRAP, 2017) reveal that each individual crop has specific factors that generate losses. Exploring these factors for all crops should be a priority.

4) **Waste prevention:** CB Insights (2017) document the level of innovation in the agri-tech space. A small selection of technologies and strategies are highlighted in Section 5. The key now is for producers to better understand how this technology can help them make better informed decisions to ultimately reduce food loss. For example, 'Digital Agriculture' offers exceptional opportunity to control, monitor and optimise on-farm operations.

5) **The role of residues.** The removal of crop waste material from the farm (e.g. for use in an off-farm valorisation process) may have negative impacts on the sustainability of the farming systems (e.g. soil degradation, economic impacts, greenhouse gases impacts, etc.). The by-products of food production and their role within the farm ecosystem have been explored by Scarlat (2010) for European crop residues. A better understanding of sustainable removal rates is necessary for all crops to determine if this waste is available for valorisation or whether it should remain in the fields.

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4.2 Funded research projects

Several large-scale research projects are currently ongoing across Europe that deal with some of these research priorities. Examples are listed below, and there are numerous others funded at European, Regional and National scales across Europe.

Table 2. Examples of ongoing research projects in Europe

Research Project	Funding source	Focus
AgroCycle (www.agrocycle.eu)	EC Horizon 2020	Applying the 'circular economy' across the agri-food chain
NoAW (www.noaw2020.eu)	EC Horizon 2020	Applying the 'circular economy' across the agri-food chain
H2020 AgriMax (www.agrimax-project.eu)	EC Horizon 2020	Developing two pilot processing plants for extracting high-value compounds from agricultural and food processing waste
CONSUS (www.consus.ie)	Science Foundation Ireland (SFI)	'Digital Agriculture'
SYSTEMIC (www.systemicproject.eu)	EC Horizon 2020	Recovery of mineral nutrients (N, P, K) and the production of various (nutrient-depleted) organic soil improvers and fertilisers
Food Heroes	Interreg North West	Reducing losses in the 'neglected' first parts of the food chain

5 Strategies and solutions

Any sector which wastes up to 30% of its products along the supply chain is not only inefficient and polluting, but it also means that it is ripe for disruption and innovation. The level of wastage in the agri-food chain has prompted the development of a range of new technologies which seek to make the agri-food chain more efficient and less wasteful, particularly when it comes to primary production. Significant value creation opportunities exist in capturing lost value on the farm, in the form of reducing 'avoidable' waste. For 'unavoidable' wastes, maximising value creation by utilising these resources for high value applications in the bioeconomy should be the priority.

5.1 Preventing food waste – technology solutions

Terms such as 'precision agriculture', 'smart farming', 'digital agriculture' are now widely used to broadly describe the emergence of technology and data analytics to help manage the complexities of agricultural operations. Several promising technology options exist that are currently being used to address food loss.

Precision agricultural systems that observe, measure, and analyse the needs of individual fields and crops to ensure optimum production and prevention of damage. Companies such as: BlueRiver and Contour precision farming systems are developing smart farm equipment to manage crops at plant level

Remote sensing: advanced disease detection and prevention and pest control. Examples include thermal imaging and biosensors. **Sensilize** is a remote sensing technology to detect and locate stressed crops early on. Another tool, **Arable** is a weather and crop monitor used to manage weather risk and crop health, delivering real-time insights from the field.

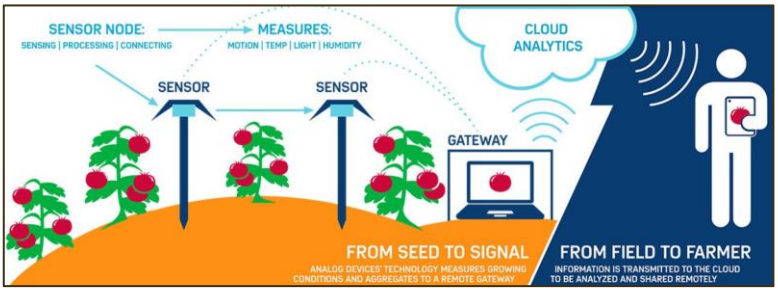
Software systems: to feed in data for better farm management. Apps such as Climate FieldView collect, store, and visualise critical field data. Geo-intelligence satellite data driven system from AgSpace

Farm-to-Fork digital marketplace: are emerging for surplus food management: redistributing food surplus to feed people in need. E-commerce platforms to facilitate purchase direct from farmers. Aps such SpoilerAlert, Food Cloud, and toogoodtogo as well as the newly launched AgroCycle 'market place' helping to better connect food surplus with customers
www.agrocycle.eu

Ecommerce: Employing new technology to deliver non-spec 'wonky' or 'ugly' produce, purchasing directly from farmers and making available to customers through direct delivery. Companies such as Imperfectproduce and wonky veg boxes are pioneering these new markets.

Monitoring: Improve grower-retailer collaboration by better tracking and developing better quality metrics to ensure that fresh produce is accurately categorised and not rejected. Zest labs has developed freshness management solution that measure time, temperature, location and ensures other data are autonomously monitored for each pallet of produce from harvest, to pack-house, to retail

Box 6: The Internet of Tomatoes



Analog Devices Plc is building a complete sensor-to-cloud solution that will empower farmers to make better decisions throughout the growing cycle, i.e. their 'Internet of Tomatoes' project. The platform-based sensing, processing and communications solution can measure environmental data – humidity, temperature and ambient sunlight – with a high level of accuracy and help create models to predict growth, pest infestations, and water needs. These factors are all crucial for preventing disease and pests and hence avoiding significant crop losses in practice.

Placed among the tomato plants at various locations throughout the crop, this solution will monitor the growing environment and keep tomato farmers apprised of real-time conditions and trends (taking sensory information from the field, relaying that content to a cloud application, and providing rich information back to farmers on handheld devices). See Analog's IOT page for more details.

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5.2 Strategies for reduce food loss

As outlined earlier, the primary food losses reduction strategies can be broken down into 'practice based' and 'market based'. Table 3 presents an overview of some key strategies for the reduction of crop wastage in primary production, adapted and updated from WRAP (2017).

Table 3. Summary of strategies for reducing food loss in primary production (after WRAP, 2017)

Strategy	Theory of Change
Develop new crop varieties	Development of new varieties that are less susceptible to disease, can reduce crop losses
Better agronomy practices and improved chemicals	Limiting the damage of pests/diseases is central to reducing crop wastage
More precision agriculture techniques	'Data harvesting' and the embedding of effective sensor technology can help farmers better manage crops
Improved storage and preservation methods	Ensuring adequate and appropriate storage facilities (e.g. ventilated, cold, etc.) can drastically cut food losses, helping farmers avoid losses due to spoilage and pests
Demand forecasting and sharing information	Retailers can be more forthcoming in sharing forecast data for specific food items to help farmers with their production planning and prevent over-production
Further collaboration efforts within the supply chain	WRAP (2017) highlight that UK supermarket Asda's sourcing arm IPL is helping its growers use a new yield forecasting tool. Growers now use smart phones to upload photos of their crop throughout the season, and intelligent software uses these images to assess the crop's potential in relation to data from local weather stations, and historical data. Growers, IPL and Asda receive a yield report to make accurate decisions earlier in the season that reduce the risk of both gluts and shortages, at farm and retail level. These collaborative efforts provide an effective template for others to follow
Increase diversity of crop base	Given the inevitable variability in crop quality, having a diversity of customers with different needs may reduce risk to the farmer and enhance overall productivity - harnessing new technology and using market places such as **laruchequiditoui.fr**
Redistribute surplus crop for animal/human feed	Identifying suitable distribution chains for surplus crop is essential to determine the effectiveness of this strategy. Redistribution specialist like ***Food cloud*** and apps such as **SpoilerAlert. Gleaning Network** is actively working with farmers across Europe to salvage surplus crops for redistribution.
Work with retailers to have more flexible quality specifications	Explore market niches by marketing 'ugly' (i.e. misshapen and non-spec) vegetables directly to customers e.g. through new app delivery services like **Imperfect Produce, wonky veg** boxes, and the **Fruta Feia** cooperative

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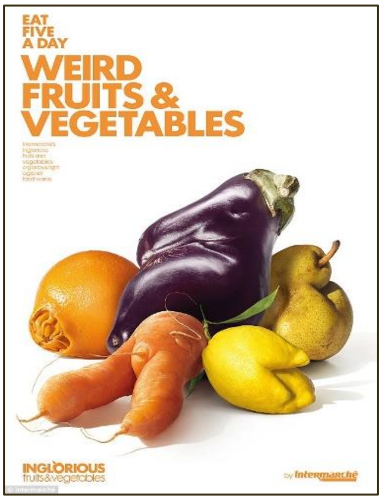
Box 7: Wonky/Ugly Produce

France's third largest retailer, Intermarche launched a viral "inglorious fruits and vegetables" campaign to get consumers to see the beauty of ugly produce in order to combat food waste. UK supermarket Asda sells a wonky vegetable box at a price that is 30% cheaper than standard lines and Waitrose stocked apples prominently branded as "weather blemished" - the result of extensive visual damage from hail stones at its South African farm suppliers.

These iniatives can be deemed win-win-win: consumers get the same quality products for cheaper, the growers get money for products that are usually wasted, and the retailers increase their business by selling a brand new line of products



5.3 Creating value from unavoidable wastes

Many agri-food wastes are ideal raw materials for biological processes to create new products, providing major opportunities for EU agriculture to become a crucial supplier of feedstock for the emerging bioeconomy. The characteristics of agri-food wastes mean they can act as a source of renewable carbon for making valuable chemicals and fuels, replacing many common chemicals that rely on virgin fossil material. A wide range of technologies already exists to transform primary production food losses and primary processing waste into valuable products (Lin et al, 2012). These residues are a by-product of food production in the form of crop residues (e.g. straw), leaves, peels, and trimming wastes which are not suitable for human consumption. Maximising the value from farm-generated 'unavoidable wastes' remains the priority, with the biorefining value pyramid (figure 4) showing the potential valorisation pathways.

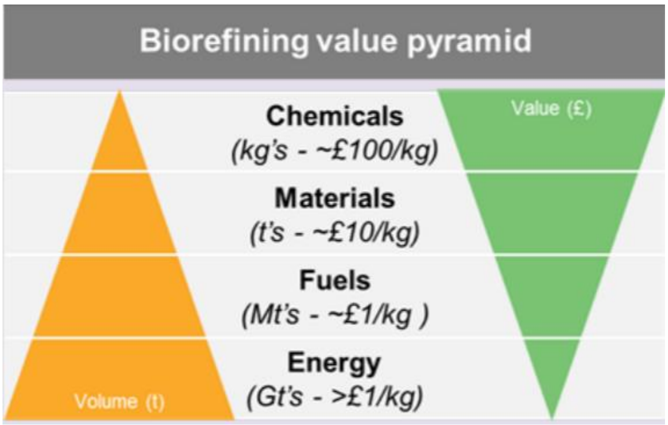


Figure 4. Biorefining value pyramid (DBS, 2015)

The utilisation of these residues is not always economically feasible or environmentally sustainable. As outlined in Section 4, much research is currently ongoing on food residue valorisation. However, the production of energy and biomaterials from food waste is at an early stage of development. Imbert (2017) highlights that there is still a strong need to reduce uncertainty and encourage transparency, by providing precise information on the availability of food waste and by ensuring a lower environmental impact of bioenergy and biomaterials.

6 Summary – key issues

Reducing food loss on the farm first requires an understanding of why losses occur, followed by identifying and evaluating practices and technologies that can limit food loss. This paper sets out a broad vision of why losses are occurring on the farm, distinguishing between 'practice based' and 'market based'. A broad overview of technologies and strategies is presented, outlining the opportunities that currently exist. Figure 5 (from AgroCycle) presents an overview of the interdependencies along the complete agri-food chain (from farm to consumer and beyond into the bioeconomy). Primary production (on-farm) is central to the integrity of the whole system.

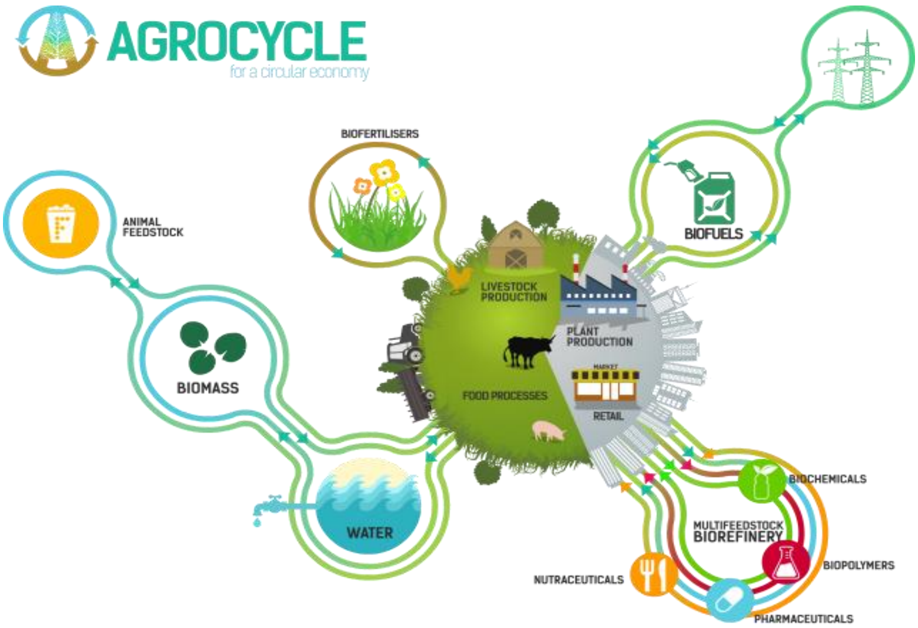


Figure 5. Overview of the interdependencies along the complete agri-food chain (www.AgroCycle.eu)

In summary, **the overall emphasis must be on enhancing operational efficiency on the farm, thereby reducing on-farm food losses**. However, post-farm gate operations impact directly on the farming operations, hence **a holistic approach is required to ensure food loss minimisation** – farms cannot operate in isolation from market forces. Policy is a key driver of system operations but ill-conceived policy can unleash untold harm. The feedstock for a bioeconomy must be sustainable, hence a bioeconomy can only be built upon the availability of sustainable supplies of 'unavoidable' wastes as feedstock. Thorough LCA is required for all systems, and the challenge is to identify the appropriate boundaries for the LCA. Food production is for a global market, hence potential impacts of farming are global. Soil is the fundamental resource on which the world's agriculture is based, hence systems must protect the soil – sustainable levels of product removal from the farm need to be assessed.

The following (Table 4) is a list of questions and issues that need to be considered regarding the minimisation of on-farm food waste

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Table 4. Key starting questions for EIP-AGRI Focus Group regarding the minimisation of on-farm food losses

Suggestion of key issues to be considered by the EIP-AGRI Focus Group : Food Loss on the Farm
1. **Definition and quantification of on-farm food losses –** what constitute food losses on the farm? 'avoidable' and 'unavoidable' wastes; and define the boundaries; 2. **The necessity for using a holistic approach** – local, regional, EU, global: how are all these levels addressed? Is the global food trade the key defining parameter? 3. **Soil health:** how can soil health be assured when 'exporting' wastes from the farm? 4. **Prioritising the use of land for food production.** How does this link in with the bioeconomy? 5. **Risk management:** how to address over-production to meet market needs? 6. **Efficiency**: is 'producing more from less' the proper approach? And what are the consequences for the full agri-food chain? 7. **Potential for waste reduction on the farm**: how much of the food loss that is currently reported/analysed can be considered avoidable in practice? 8. How do **post-farm gate** issues impact on pre-farm gate food losses? And how can these be addressed? What are the relative impacts of 'practice based' and 'market based' losses on the farms? 9. **Policy v. good science.** How can the unintended negative impacts of policy be avoided? Is policy necessary or can we rely on the 'free market'? 10. **Holden's 'Fossil Food' concept:** what does this mean? 11. How can **'Digital agriculture'** contribute to minimising on-farm food waste? What other technologies and systems can contribute? 12. Where does the **consumer** fit in all this? Is **consumer education** an important element in reducing on-farm food waste? 13. **The farmer**: how can the farming community optimise production systems to minimise on-farm waste? 14. How can **EIP-AGRI contribute to reducing food losses on the farm?**

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7 References

AgroCycle (www.agrocycle.eu) Accessed 28-05-2018

AgriMax (www.agrimax-project.eu) Accessed 28-05-2018

Accenture, 2017: Digital Agriculture: Improving Profitability, Accenture, 2017

Agneessens, L., De Waele, J., De Neve, S. (2014) Review of Alternative Management Options of Vegetable Crop Residues to Reduce Nitrate Leaching in Intensive Vegetable Rotations. Agronomy, Vol 4 pp. 529-555

Beretta, C., Stoessel, F., Baier, U., Hellweg, S. (2013) Quantifying food losses and the potential for reduction in Switzerland Waste Manage., Vol 33, pp. 764-773

C. Beausang, C. Hall, L. (2017) TomaFood waste and losses in primary production: qualitative insights from horticulture Resour Consev. Recy., Vol 126, pp. 177-185

Caffrey, K, R., Veal, M.W., 2013. Conducting an Agricultural Life Cycle Assessment: Challenges and Perspectives. The Scientific World Journal.

CB Insights:https://www.cbinsights.com/research/agriculture-tech-market-map-company-list/ Accessed 21-05-2018

Champions 12.3, 2017 "Guidance on interpreting sustainable development goal target 12.3"
https://champs123blog.files.wordpress.com/2017/10/champions-12-3-guidance-on-interpreting-sdg-target-12-3.pdf Accessed 28-05-2018

DBS, 2015 Department for Business, Innovation and Skills 'Building a high value bioeconomy: opportunities from waste' 2015.

Europarl, 2017 Cutting Food Waste – Press Release, 16-05-2017. Accessed 31-05-2018 http://www.europarl.europa.eu/news/en/press-room/20170509IPR73930/cutting-food-waste

European Commission, 2008 European Parliament and the Council of the European Union 'Directive 2008/98/EC of 19 November 2008 on waste and repealing certain directives' Official Journal of the European Union 2008: L 312, pages 3-30. Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:312:0003:0030:en:PDF

European_Commission, 2012, Innovating for Sustainable Growth: A Bioeconomy for Europe, Brussels, 13.2.2012. COM(2012) 60.

European_Commission, 2015, Communication from the commission to the european parliament, the council, the european economic and social committee and the committee of the regions. Closing the loop - An EU action plan for the Circular Economy. COM(2015) 614 final. Brussels, 2.12.2015

European Commission, 2018 https://ec.europa.eu/commission/news/tackling-unfair-trading-practices-food-supply-chain-2018-apr-12-0_en Accessed 30-05-2018

FAO, 2014 Building a common vision for sustainable food and agriculture. Principles and Approaches. Food And Agricultural Organisation of the United Nations, Rome, 2014

Feedback, 2018. Farmers talk food waste – supermarkets role in crop waste on UK farms.
https://feedbackglobal.org/wp/wp-content/uploads/2018/02/Farm_waste_report_.pdf

FLW Standard, http://flwprotocol.org/flw-standard/ Accessed 28-05-2018

Fusions 2016 Stenmarck, A., Jensen, C., Quested, T., Moates, G. (2016) Estimates of European food waste levels. EU FP7 Fusions.

Gustavsson, J., Cederberg, C., Sonesson, U., Emanuelsson, A., 2013. The methodology of the FAO study: "Global Food Losses and Food Waste-extent, causes and prevention" – FAO, 2011. SIK, Göteborg

Hartikainen, H., Mogensen, L., Svanes, E., Franke, U. (2018) Food waste quantification in primary production – The Nordic countries as a case study. Waste Management, Vol 71, pp 502-511

Holden, N.M.H, White, E.P., Lange, M.C., Oldfield, T.L. (2018) Review of the sustainability of food systems and transition using the Internet of Food. Under review

Imbert, I. (2017) Food waste valorization options: opportunities from the bioeconomy. Open Agriculture, Vol 2 pp. 195-204

Lillywhite, R.D., McCosker, C., Sheane, R. (2016) The embedded resource and environmental burden of deliberately wasted lettuce. 10th International Conference on Life Cycle Assessment of Food 2016

Lin et al. 2012. Food waste as a valuable resource for the production of chemicals, materials and fuels. Current situation and global perspective. Energy & Environmental Science 6: 426-464.

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Nemecek, T., Frick, C., Dubois, D., Gaillard, G., 2001.Comparing farming systems at crop rotation level by LCA. In: Geerken, T., Mattson, B., Olsson, P. & Johansson, E., (eds.), Proceedings of the International Conference on LCA in Foods, Gothenburg. SIK, VITO, Gothenburg, 65-69

NoAW (**www.noaw2020.eu**) Accessed 28-05-2018

Notarnicola B., Sala S., Anton A., McLaren S.J., Saouter E., Sonesson U. (2017). The role of life cycle assessment in supporting sustainable agri-food systems: A review of the challenges. Journal of Cleaner Production, 140(2), 399-409.

Östergren, K., Gustavsson, J., Bos-Brouwers, H., Timmermans, T., Hansen, O.J., Møller, H., Anderson, O'Connor, C., Soethoudt, H., Quested, T., Easteal, S., Politano, A., Bellettato, C., Canali, M., Falasconi, L., Gaiani, S., Vittuari, M., Schneider, F., Moates G., Waldron, K., Redlingshöfer, B., 2014. FUSIONS project Definitional Framework for Food Waste, Full Report, 3 July 2014. <http://www.eu-FUSIONS-project.org/index.php/publications>

Redlingshöfer B, Coudurier, B., Georget, M. (2017) Quantifying food loss during primary production and processing in France, Journal of Cleaner Production, Vol 164 pp. 703-714

Sala, S., Ciuffo, B., Nijkamp, P. (2015). A systemic framework for sustainability assessment, Ecol. Econ., Vol 119, pp. 314-325.

Scarlat, N., Martinov, M., Dallernand, J.F. (2010) Assessment of the availability of agricultural crop residues in the European Union: Potential and limitations for bioenergy use. Waste Management, 20, pp. 1889-1897

Stenmarck, Å., Jensen, C., Quested, T., Moates, G. (2016). Estimates of European Food Waste Levels. Stockholm, Sweden. **www.eu-fusions.org/phocadownload/Publications/Estimates%20of%20European%20food%20waste%20levels.pdf**

UN, 2015 Transforming our world: the 2030 Agenda for Sustainable Development. Resolution adopted by the General Assembly on 25 September 2015. United Nations, 2015

WRAP (2017) Food waste in primary production – a preliminary study on strawberries and lettuce. Prepared by 3Keel LLP and University of Warwick. **http://www.wrap.org.uk/sites/files/wrap/Food_waste_in_primary_production_report.pdf**