Circling the fruits and vegetables supply chain?

Potentials of circular economy approaches for zero food waste

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ABSTRACT

The Food and Agriculture Organization (FAO) estimates that about 30% of all food produced in the world is lost or wasted from farm to fork, which in absolute terms amounts to about 1.3 billion ton per year. To minimize this wastage across countries, the Sustainable Development Goals (SDGs) call for reducing global food waste by 50% at the retail and consumer level, and reducing food losses along production and supply chains, including post-harvest losses by 2030. Keeping this target in mind, it is necessary to rethink the way food is produced, processed and consumed and to develop sustainable strategies in the entire food system. Applying the concept of circular economy in food chains could be one promising instrument to achieve this goal. In this paper, we first review the global distribution of food wastage at different stages of food value chain, specifically for fruits and vegetables. Second, we review the concept of circular economy and its application to the food system aiming to identify existing initiatives that are implemented to circle the fruits and vegetables value chain. Among the identified business models, a case study analysis is applied to examine the potentials of using the circular economy concept to minimize food losses in more detail. Overall, the study points out that there are mostly isolated innovations related to reduce food losses at later stages of the value chain, containing future potentials to combine different approaches (in particular involving farmer's level) and to connect actors along the value chain.

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1. Introduction

The growing demand for food, increasing wealth, urbanization, changing preferences and diets, along with the competition for land, climate change and the need for natural resources protection have increased the focus on the issue of food waste over the past years (Runge & Lang, 2016). It has been estimated that about one-third of the global food produced (approximately 1.3 billion tons annually) gets lost or wasted while moving food from farm to the plate (Gustavsson et al., 2011). To minimize this wastage, the SDGs set up in 2015 call for cutting global food waste at the retail and consumer level, and reducing food losses along production and supply chains, including post-harvest losses by 50% by 2030 (UN, 2017).

FLW (FLW), through the inefficient and unsustainable handling of food, has both environmental and economic consequences. It has been estimated that land used for food production that is never consumed by humans accounts for about 28% of the world's agricultural land (FAO, 2013a), and around 38% of the energy used in agriculture production is either lost or wasted (FAO, 2015a). Additionally, FLW results in enormous wastage of water resources and represents a significant issue, particularly in the context of increasing water scarcity and the compounding impact of climate change (Runge & Lang, 2016). These aggregated impacts make FLW a significant contributor to climate change, accounting for about 8 % of total global GHG emissions (FAO, 2015b). Additionally, the economic consequence of FLW contributes to direct negative impact on the incomes of farmers and consumers. Around US$ 680 billion are wasted as a result of FLW in high-income countries, and US$ 310 billion low and middle-income countries (Gustavsson et al., 2011).

Having this in mind, it is necessary to rethink the way food is produced, processed and consumed and develop sustainable strategies in the entire food systems. Applying the concept of circular economy in food chains could contribute to more sustainable food systems. In food systems, the circular economy has a holistic character, enabling a systems-thinking approach (Halloran et al., 2014) to promote sustainability from production up to consumption (Mourad, 2016; Notarnicola et al., 2017). The circular economy aims to tackle the leading issue on food systems, which is related to FLW (Beausang et al., 2017). In addition, the approach is a tool to reduce and prevent food surplus, food waste generation; it also optimizes the use of resources with cycling loops, lesser environmental impact, and more efficient food patterns (Halloran et

al., 2014; Jurgilevich et al., 2016). Despite the increasing interest in the concept of circular economy, there are currently few studies on the concept (Jurgilevich et al., 2016) and its application on agriculture systems.

The circular economy for the food systems includes three stages in which strategies can be implemented, such as in the production stage, at the consumer level and very importantly, integration with the waste management sector (Jurgilevich et al., 2016). Circular economy is all about reducing the amount of waste generated, reuse the edible food, utilize its by and co-products, integrated closed-loop cycles with minimal needed inputs, and promoting more sustainable consumption patterns (Halloran et al., 2014; Jurgilevich et al., 2016; Toop et al., 2017). It is proposed in the literature, a food waste hierarchy in the food supply as "**Prevention – Reuse – Recycle – Recovery – Disposal"** (Papargyropoulou et al., 2014). In this framework, the food chain prevents at the initial stage the production surpluses or waste, the surpluses can be reused (redistributed) for human consumption, and the non-consumable waste can then be recycled for animal feed, composted, or recovered via bio-digestion. As a last option, only the unavoidable food waste should go for disposal.

This paper is structured in different sections. In Section 2, we first start discussing data sources, definitions, and the methodology used in the study. In section 3, we describe the overall pattern of FLW by disaggregating the analysis on food wastage based on region, commodity-wise and stages of wastage. Additionally, we give an overview of the importance of fruits and vegetable segment in developing and developed countries and examines the pattern of fruits and vegetable wastage. Moreover, the section closes with a discussion about the concept of circular economy and the application of it to agriculture systems and food supply chains. Section 4, presents the results of the review of innovative models adopting the circular economy concept to minimize food waste. In the last part, we analyze the results of two case studies from Germany, finalizing with an overall discussion and conclusion of the study.

1.1 Research Objectives

Given the fact that food losses are poorly ascertained to date and associated with a lack of data reliability (Runge & Lang, 2016), this paper intends to:

- Give an overview of the patterns of FLW globally, specifically focusing on fruits and vegetables.
- Review and compare circular economy strategies in the fruits and vegetables value chain in terms of design (e.g., stage of food system) and its circularity (assignment to "4Rs": reduce/prevent, reuse, recycle, recover).
- Analyse two cases based on guided interviews to explore the potentials of using circular economy to minimize FLW in more detail.

1.2 Research Questions

In regard to the objectives outlined, following research questions will be addressed:

1) What are the patterns of FLW in the fruits and vegetables value chain across the world?
2) Are there any existing initiatives that aims to minimize FLW in the fruits and vegetables value chain using the circular economy concept?
3) What are its potentials (chances, barriers and limitations) to minimize food losses?
4) Which lessons can be drawn from these models?

2. Methodology

This research follows a multi-step procedure. First, a literature review was conducted to collect data about the global fruits and vegetables production and food losses occurring in this system. It was found that the only comprehensive and comparable data source available on FLW is provided by the FAO (Gustavsson et al., 2011). The method used for calculating FLW by Gustavsson et al. (2011) is based on a simplified mass flow model by food group and region using estimates and assumptions from the literature and available macro-level data published in FAO's food balance sheets. There has been some skepticism regarding the assumptions made while quantifying FLW, especially for emerging and developing countries where food systems have rapidly transformed, while the literature used for the assumptions for these countries were old. Despite these limitations and due to lack of other sources of data, this study uses the data given by Gustavsson et al. (2011) to study the geospatial distribution of FLW and the stages in which food wastage occurs.

Further, the study reviews the circular economy concept and its applicability to the food system. For the literature review, the database of the University of Bonn, web of science and science direct were used. As these databases link several other literature databases and journal directories, it offers the opportunity to identify as many relevant hits as possible within a short time. With the aid of Boolean operators, the following search terms have been applied: “circular economy” AND “food waste” AND “food system”; or “circular economy” AND “agriculture production” AND “food waste”.

To identify innovative business model adopting the circular economy concept in the fruits and vegetables supply chain, we went through different data sources: scientific papers (searching for “circular” research projects), websites of leading grocery retailers and databases related to food wastage and activities against it (collecting ‘zero waste’ initiatives / business models in the sense of circular economy). Through this method, we identified 64 models adopted by different actors along the value chain, which were categorized as (1) initiatives in the retail segment, (2) technology-based innovations, (3) non-profit collaborations, (4) innovations in waste management, initiatives by (5) food producers, (6) manufacturers, (7) consumers, and (8) governance initiatives and others. The models were briefly described and analyzed regarding the targeted stage of the food chain and its circularity, assigning it to the circular economy strategies, i.e., reduce (prevent), reuse, recycle, recover activities/strategies.

Due to the fact that to date little is known about initiatives undertaken, which try to circle the fruits and vegetables supply chain. This paper follows an exploratory case study research design (see Hartley, 2004), allowing to draw up theoretical propositions about “a contemporary phenomenon within its real-life context” (Yin, 2003, pp.13-14). Within the identified initiatives, we selected two cases of similar circumstances (e.g., same location and stage of food system) which are comparatively analyzed to gain more information about the context and processes linked to develop a circular food system and to understand its potentials to minimize food losses.

Understanding case studies as a research strategy which represents a mixed (qualitative, quantitative, or both) method approach (Hartley, 2004), evidence was collected by using qualitative guided interviews. Taken into account three general analytic strategies of case

studies analysis (description, consideration of prior theoretical findings and rival perspectives) proposed by Yin (2009), thematic coding by Flick (1995) has been applied for evaluation.

3. Theoretical Background

3.1 Food losses and waste (FLW) along the value chain

A prerequisite to studying FLW along the value chain is to define the term 'food losses and waste'. Literature shows that there is no consensus in defining food losses or food waste so far (Runge & Lang, 2016). The difference in definitions of food losses and food waste can affect the methodologies used to measure and interpret loss (Schuster and Torero, 2016). In this paper, we have considered the definition provided by Gustavsson et al.,(2011) as they provide the only comprehensive global data on FLW. Gustavsson et al., (2011) define **"food losses"** as *"a decrease in mass (dry matter) or nutritional value (quality) of food that was originally intended for human consumption"*. Such losses occur mainly due to inefficiencies in the food supply chains, such as poor infrastructure and logistics, lack of technology, insufficient skills, knowledge, management capacity of supply chain actors, and lack of access to markets (Gustavsson et al., 2011). **Food waste** refers to *"food appropriate for human consumption being discarded, whether or not after it is kept beyond its expiry date or left to spoil"*. This fact occurs due to spoilage of food, or other reasons such as market oversupply, or individual consumer shopping/eating habits. Food wastage refers to any food lost by deterioration or waste. Thus, the term "wastage" encompasses both food losses and food waste (FAO, 2013b). Gustavsson et al., (2011) estimates that about 30% of all food produced in the world is lost or wasted from farm to fork, which in absolute terms is about 1.3 billion ton per year. The method used by them uses weights, such that a ton of grain is the same as a ton of fruit, which is the same as a ton of meat. However, Lipinski et al., (2013) highlight in their paper that food types vary widely in their water and caloric content per kilogram, therefore measuring by weight does not consistently reflect the energy in food products that could have been consumed by people. Lipinski et al., (2013) use the FAO Food Balance Sheets data to convert FAO's loss and waste estimates into calories. According to this measurement, around 24% of all food produced is lost or wasted. In some extent, it can be said that due to the significant amount of food being lost or wasted, the overall global food availability is seemly lower,

affecting negatively food security and the environment, considering the additional food produced to compensate the food not ultimately consumed by people (Lipinski et al., 2013). FLW occur at different places along the food value chain: in production, post-production producers, processing, distribution, and consumption. The occurrence of FLW along the value chain varies across the different geographical locations and among commodities (Parfitt et al., 2010; Schuster & Torero, 2016; Smil, 2004). **Figure 1** illustrates examples of food waste and losses throughout the food value chain.

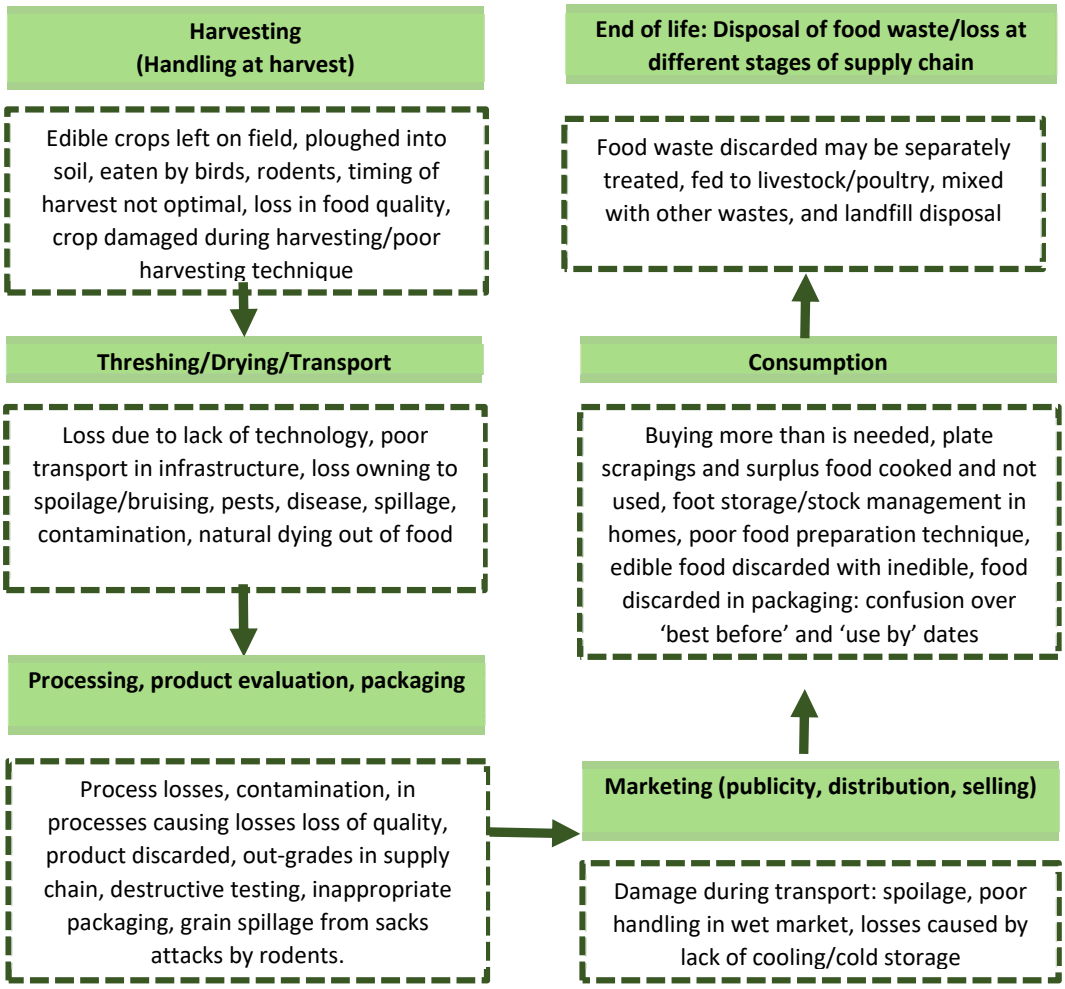

Figure 1: FLW along the food value chain

Source: Adapted from Parfitt et al. (2010) and Papargyropoulou et al. (2014)

3.1.1 Region-wise food losses and waste

Overall FLW along the supply chains are higher in developed countries than those in developing countries, with an average of 280-300 kg per capita per year food losses in Europe and North America, 120-170 kg per capita per year in Sub-Saharan Africa, and South and Southeast Asia. Per capita food wasted in the consumption stage in Europe and North America is about 95-115 kg/year, while the figure in sub-Saharan Africa and South/Southeast Asia is only 6-11 kg/year (Gustavsson et al., 2011). About 56% of the total FLW occurs in the developed world namely North America, Oceania, Europe and industrialized Asian nations of China, Japan, and South Korea, whereas, the developing world accounts for 44 % of the wastage (Lipinski et al. 2013). Considering the stages of the value chain, around 24% of global FLW occurs at production, another 24% during handling and storage and 35% at consumption (Lipinski et al., 2013). However, there is considerable variation in the stages of food losses and waste between developed and developing countries, and between rich and poor producers and consumers (Gustavsson et al., 2011; Hodges et al., 2011; Lundqvist et al., 2008; Papargyropoulou et al., 2014). **Figure 2** presents the region-wise data on FLW as measured in energy percentage of kilocalories (Kcal) lost and wasted.

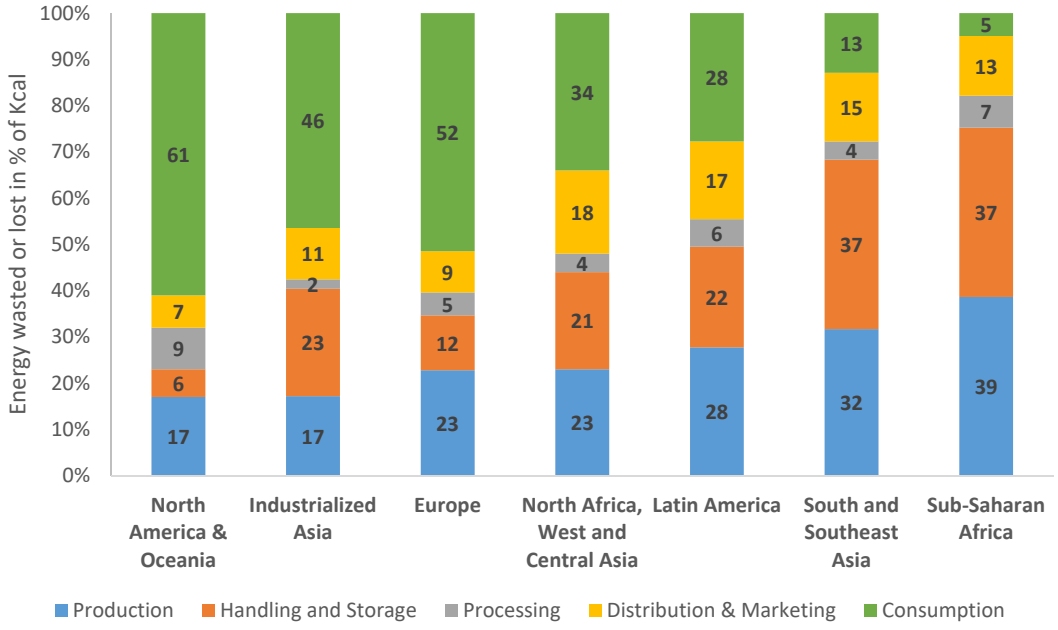

Figure 2: Region-wise FLW in Kcal percentage

Source: Adapted from Lipinski et al. 2013. Note: Numbers may not sum up to 100 due to rounding off

It can be observed that in highly industrialized countries, the major FLW occur during the distribution and marketing and at consumer stage, while in developing countries occur mostly during the production, handling and storage. The food losses occurring at the initial stage of the food value chain, in developing countries, is attributed to financial and structural limitations in harvest techniques, storage, and transport infrastructures (FAO, 2013b). Moreover, losses might be resulted due erratic climatic conditions, high humidity, high temperatures, with attacks from rodents, insects, mold and other agents (Lundqvist et al., 2008). In developed countries, harvesting, transport, and processing are comparatively efficient. However at the end of the food chain, there is substantial wastage in wholesaling, retailing and consumption, attributed to consumer behavior and lack of communication in the supply chain (FAO, 2013b; Lundqvist et al., 2008).

3.1.2 Commodity-wise food losses and waste

The identification of commodity lost or waste depends on the measuring method. **Figure 3** presents the results of both share of global loss and wasted measured in terms of Kcal (Lipinski et al., 2013) and share of global FLW measured in terms of weights (Gustavsson et al., 2011).

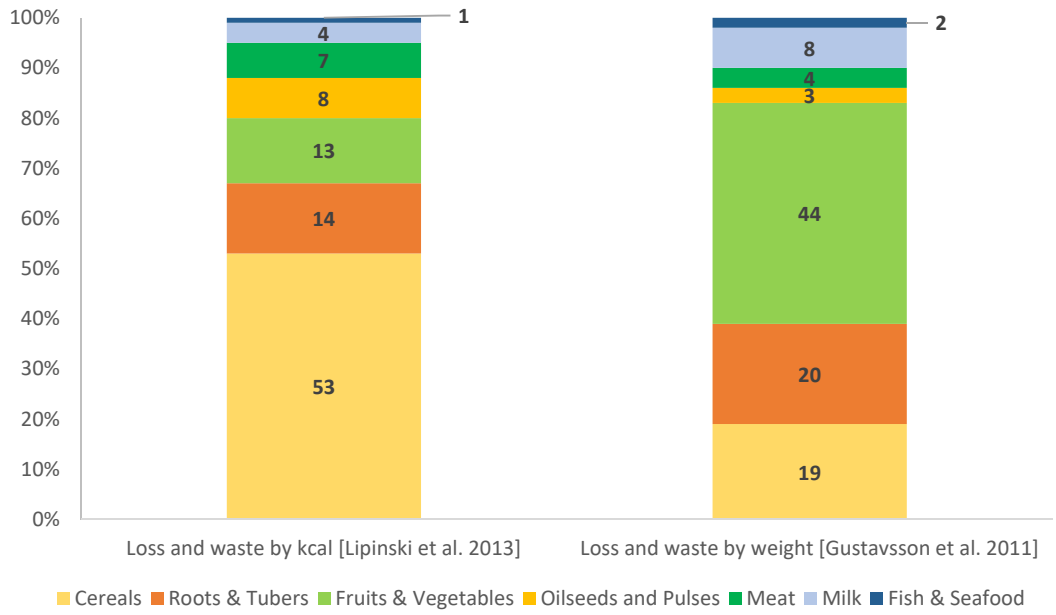

Figure 3: Share of global FLW by commodity

Source: Adapted from Lipinski et al. 2013

It can be seen that cereals contribute the most FLW relative to other food commodities on a caloric basis while fruits and vegetables are the largest source of loss and waste on a weight basis.

3.2 Implications of food losses and waste

3.2.1 Environmental consequences

Food production utilizes natural resource base that is increasingly coming under pressure as it supports multiple demands. Current estimates highlight that, 28% of the world's agricultural land area is occupied to produce food never consumed by humans (FAO, 2013a). Food systems consume about 30% of available global energy, and out of this portion, 38% is either lost or wasted (FAO, 2015a). Additionally, food systems utilize water resources especially in the form of irrigation during the production stage. FLW results in enormous wastage of water resources and represents a significant issue, particularly in the context of increasing water scarcity and the compounding impact of climate change (Runge & Lang, 2016). Moreover, producing food that will not be consumed leads to additional greenhouse gas (GHG) emissions that contribute to climate change. The life cycle of food from the production stage up to the ending consumption have an embedded carbon at each stage which has GHG impact (Lundqvist et al., 2008; Papargyropoulou et al., 2014).

Wasted food leads to overutilization of water and fossil fuels and to increasing greenhouse gas emissions, i.e., methane and carbon dioxide arising from degradation of food in landfills (Hall et al., 2009). As an example, in the US, the fraction of energy that is lost, because it is embedded in the food wasted, amounts to one-fourth of all the energy required to produce the food consumed in the country, with meat, poultry and fish being the food categories requiring the most significant energy for production (Cuéllar & Webber, 2010). These aggregated impacts make FLW a significant contributor to climate change, accounting for about 8 % of total global GHG emissions (FAO, 2015b).

3.2.2 Economic consequences

FLW contribute to direct negative impact on the income of farmers and consumers (Gustavsson et al., 2011; Lundqvist et al., 2008). Smallholder farmers living in the margins of

food insecurity in most developing countries are dependent on agriculture for livelihood. Inefficiency in farming techniques and poor infrastructure such as roads, storage, and power result in high post-harvest losses and thereby negatively affects incomes. Reduction of food losses could have an immediate and significant impact on their livelihoods (Papargyropoulou et al., 2014).

FLW result in an economic loss of around US$940 billion globally per year (Lundqvist et al., 2008). A few papers have quantified region-wise amount of loss in terms of money. For example, in the US, food waste at the retail and consumer levels alone accounted for a loss of US$165.6 billion, which accounts for almost 10 % of the average amount spent on food per consumer (Buzby & Hyman, 2012). The estimated food and drink wasted in UK homes that could have been eaten has a retail value of approximately £12 billion (Quested et al., 2011). In Sub Saharan Africa, the value of all food-grain lost post-harvest was estimated to be around USD$ 4 billion per year (World Bank, 2011). These estimates give an overview of the amount of money that is being lost due to FLW. Hanson & Mitchell (2017) estimates that for every US$1 invested by businesses in training staff to lose less food in production, US$14 or more can be saved.

3.2.3 Social consequences

Such high magnitude of FLW across the globe has several social implications. On ethical grounds, when around 815 million people in the world are affected by chronic food deprivation, food wastage to the tune of 30% (Development Initiatives, 2017; Gustavsson et al., 2011) of total food produced is a travesty.

Food insecurity is often not an issue of food availability but an issue of food access (Sen, 1981). In developing countries where an average household spends about 40 % of their total expenditure on food, reducing food wastage by improving the efficiency of the food supply chain has the potential to bring down the cost of food to the consumer and thus increase access (Papargyropoulou et al., 2014). Lipinski et al. (2013) estimate the total amount of calories lost due to FLW to be around 1.5 quadrillion kcal in a year. If we assume that the daily energy necessary for balanced nutrition diet of a person equals to about 2,700 kcal, then we can calculate that the loss of calories through FLW could potentially feed around 1.52 billion people.

FLW also have implications for human health. For example, Sub-Saharan Africa and South and Southeast Asia on an average lose around 120-170 kg per capita per year of food (Gustavsson et al., 2011). Many countries in this region are also amongst those with the highest prevalence of undernutrition among children under age 5. Around 78 million children under the age of 5 are underweight in South Asia, while the corresponding figure for the sub-Saharan is about 32 million (Development Initiatives, 2017). Additionally, per capita wasted food by consumers in Europe and North America is about 95-115 kg/year (Gustavsson et al., 2011). These regions also have a high incidence of obesity. For example, around 34% of the adult population in North America is reported as obese while the corresponding figure for Europe is about 22% (Development Initiatives, 2017).Hall et al., (2009b) argue that the increase of food waste in the US suggests that the US obesity has been the result of increased food availability and marketing with Americans unable to match their food intake with the increased supply of cheap, readily available food. Thus, addressing the oversupply of food energy may also help reduce obesity and decrease food waste.

3.3 Overview of the fruit and vegetable segment

3.3.1 Production of fruits and vegetables

In 2014, the world produced around 1,169 million tons of vegetables (including melons) and 689 million tons of fruit (FAOSTAT, 2017). Region-wise disaggregation of the data shows that Asia is the largest producer of fruits and vegetables, producing around 77.0% of global vegetable production and 53.7% of the fruit production (FAOSTAT, 2017) see **Figure 4**. **Figure 4** illustrates the share of production of fruit and vegetables around the world in 2014, according to the FAO statistics division.

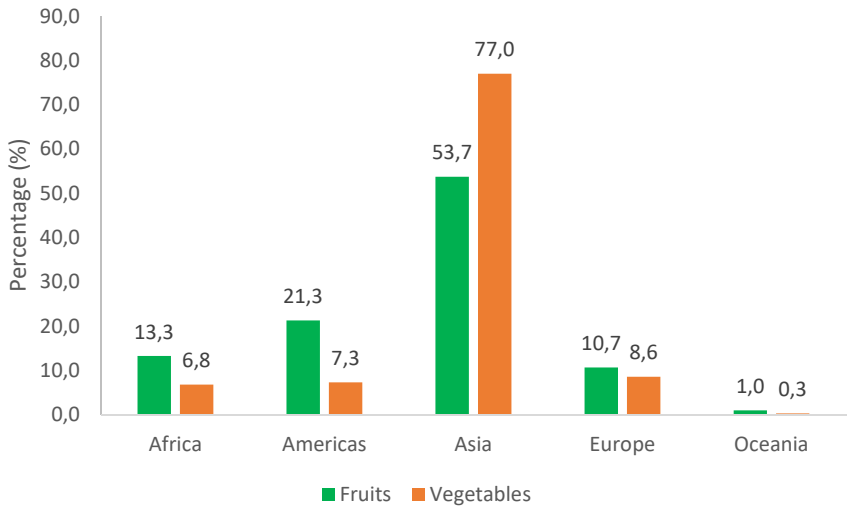

Figure 4: Share of regional production of fruits and vegetables (in %) in 2014

Source: (FAOSTAT, 2017). Note: The FAO excludes vegetables for animal feed, and includes green cereals, such as corn, green beans and peas freshly consumed. Although melons and watermelons are usually considered fruit crops, they are counted within the vegetable category, due to botanical characteristics (FAOSTAT, 2017)

The **Table 1** lists the most produced fruit and vegetables in the world. Tomatoes are the largest produced vegetables, accounting for an estimate of 170.8 million tons (14.6%) in 2014, followed by watermelons (9.5%), onions (7.6%), cucumbers (6.4%), and cabbages (6.1%). Within the fruits segment, bananas are leading, summing a total of 114.1 million tons produced (16.6%), followed by apples (12.3%), grapes (10.8%), oranges (10.5%), and mangoes (6.6%).

Table 1: Top 10 produced fruit and vegetables in the world in millions of tons (in 2014)

Vegetables including melons	Million tons	Shares (%)	Fruit excluding melons	Million tons	Shares (%)
Tomatoes	170.8	14.6	**Bananas**	114.1	16.6
Watermelons	111.0	9.5	**Apples**	84.6	12.3
Onions	88.5	7.6	**Grapes**	74.5	10.8
Cucumbers	75.0	6.4	**Oranges**	72.3	10.5
Cabbages	71.8	6.1	**Mangoes/guavas**	45.2	6.6
Eggplants	50.2	4.3	**Plantains**	30.7	4.4
Carrots/turnips	38.8	3.3	**Tangerines/mandarins**	30.4	4.4
Chilies/peppers	32.3	2.8	**Pears**	25.8	3.7
Melons	29.6	2.5	**Pineapples**	25.4	3.7
Pumpkins/squashes	25.2	2.2	**Peaches/nectarines**	22.8	3.3

Source: (FAOSTAT, 2017)

3.3.2 Trade of fruits and vegetables

The global value of trade (import and export) of fruits and vegetables has increased over the last five years (**Figure 5**). There is a great opportunity for the fruit and vegetable sector to help reduce poverty, contributing to higher incomes to small farmers in developing countries (FAO, 2013; Weinberger and Lumpkin, 2007). The fruit and vegetable production is a very profitable agricultural system in short space-time, due to the short-cycle and diverse crop mixture possibilities, despite required inputs (Bevilacqua, 2008). Additionally, consumers demand even more fruits and vegetables to fulfill the 400g recommendable dietary intake (WHO, 2017) for a healthy diet and reduce the risk of non-communicable-diseases (Pollard et al., 2002).

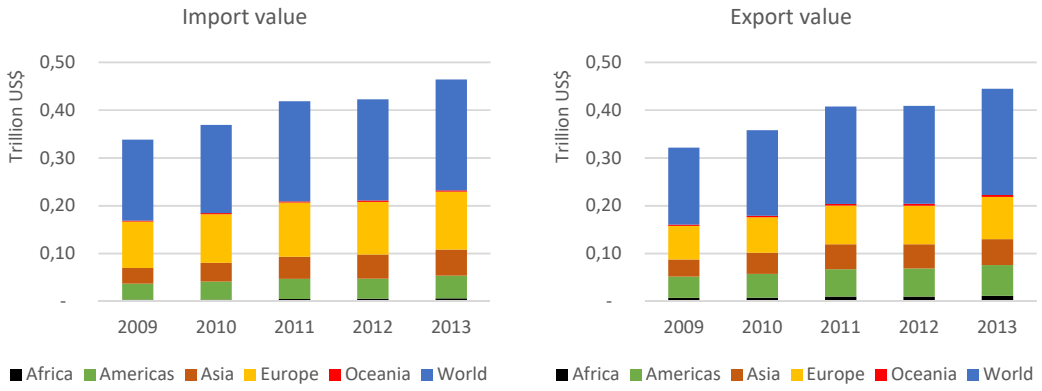

Figure 5: Global and regional import and export values of fruit and vegetables 2009-2013

Source: (FAOSTAT, 2017)

It is important to highlight the contribution of fruits and vegetables to the European retailer sector and the movement of imports within the EU (Peperkamp, 2015). Europe has a considerable share in the global trade of fruits and vegetables, being a significant importer and exporter at the same time. Europe contributes to around 39.5% of global export and around 52% of global import (**Figure 6**).

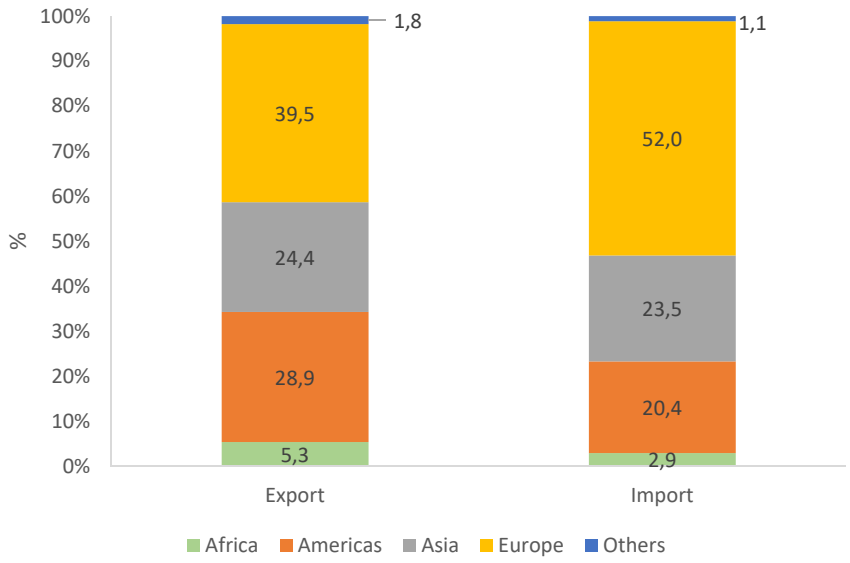

Figure 6: Region-wise share of export and import of fruit and vegetables (Percentage of export value and import value respectively)

Source: (FAOSTAT, 2017)

The main final destinations in the EU are Italy, Spain, France, and Germany. Fruit and vegetable movements in the EU are originated from the EU itself, around 80% of the fruits and 86% of the vegetables (Peperkamp, 2015). The European fruit and vegetable market owns a value of 51.8 billion euros alone (De Cicco, 2016). However, many fruit and vegetable imports are complemented by imports originated from developing countries, mainly Latin America, the Caribbean and Northern Africa (Peperkamp, 2015). Although the fruit and vegetable trade originated from the developing countries are increasing, there are many market regulations and restrictions imposed by the importers (FAO, 2003).

There are several factors, which contribute to consumer choice to fruits and vegetables, including the lifestyle, quality, socioeconomic context, and food values (Pollard et al., 2002). Fruits and vegetables are not only consumed fresh, but there is a massive market on processed food, including fruit and vegetable preserves, juices tomato processed sauces, frozen, ready to eat meals, and mini processed fruits and vegetables (De Cicco, 2016).

3.3.3 Food losses and waste of fruits and vegetables

In developing countries the demand for fruits and vegetables are increasing with urbanization and changing lifestyles. In tandem with these dynamic changes, producers are diversifying their product portfolio towards high-value commodities such as fruits and vegetables, while in developed countries a higher demand for processed food keeps an elevated demand for fruits and vegetables. Despite the importance that fruits and vegetables hold in both developing and developed countries, a large part of the production is either lost or wasted along the value chain. FAO estimates that 44% (1.6 Million tons) of fruits and vegetables produced globally are lost along the value chain (**Figure 7**).**Table 2** also presents other estimates of post-harvest losses in fruits and vegetables in few developing and developed countries. However, the method of calculating FLW across these studies are not standardized. Therefore, we use the data presented in Gustavsson et al., (2011) to understand the amount of fruits and vegetables wasted at different stages of the value chain in **Figure 7**.

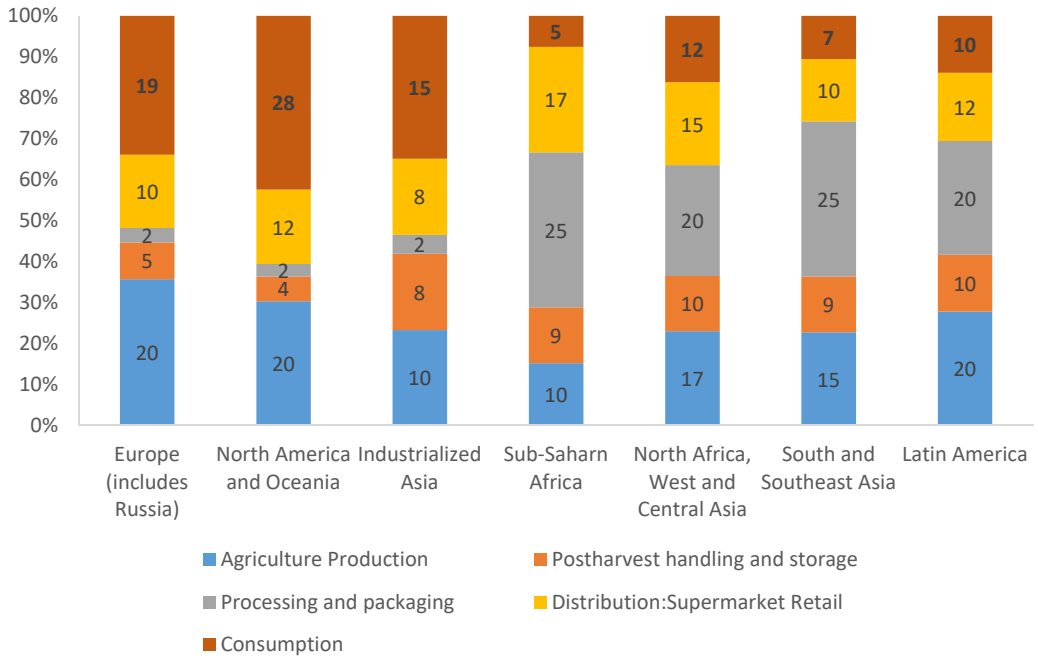

Figure 7: fruit and vegetable wastage along the value chain

Source: Adapted from Gustavsson et al. 2011

Table 2: Postharvest loss estimates for fruits and vegetables

Country	Commodities	Post-harvest losses (%)	Reference
India	Fruits and Vegetables	40	(APO and FAO, 2006)
Indonesia	Fruits and Vegetables	20-50	
Iran	Fruits and Vegetables	>35	
South Korea	Fruits and Vegetables	20-50	
Philippines	Fruits and Vegetables	27-42	
Sri Lanka	Fruits and Vegetables	16-41	
Thailand	Fruits and Vegetables	17-35	
Vietnam	Fruits and Vegetables	20-25	
China	Fruits and Vegetables	20-30	(Liu, 2013)
Fiji	Tomatoes	32.9	(Underhill and Kumar, 2015)
Ethiopia	Tomatoes	45.3	(Kasso and Bekele, 2016)
	Mango	43.5	
	Potatoes	37.1	
	Orange	35.5	
	Mandarin	34.2	
	Papaya	30.3	
	Onion	25.2	

Source: Compiled by authors

Globally, on average around 16% of fruits and vegetable wastage occurs at the production stage, 7.9% during postharvest handling and storage, 13.7% during processing and packaging and 25.7% during retail and consumption (derived from Gustavsson et al., 2011). **Figure 7** presents region-wise stages of food wastage along the fruits and vegetable value chain. It can be observed that in North America and Oceania, the highest wastage of fruits and vegetables occurs in the consumption stage (28%), followed by production (20%) and then retail segment (12%). In Europe, largest amount of fruits and vegetable loss occurs in the production stage (20%), followed by consumption (19%) and retail (10%). In developing regions such as sub-Saharan Africa, most fruits and vegetables are lost during the processing stage (25%), followed by retail (17%) and production (10%). Similarly, in South and Southeast Asia, Latin America and North Africa, West and Central Asia maximum amount of wastage of fruits and vegetables are lost during the processing stage. In contrast, the wastage during processing stage in developed regions is very low about 2%.

Several reasons have been documented for such high amounts of losses and wastes of fruits and vegetables. Marketing norms or standards of trade contributes substantially to losses and waste of fruits and vegetables (Gustavsson et al., 2011; HLPE, 2014). Other reasons for food losses on the production side include losses due to pests and diseases, overproduction and unfavorable market conditions, inadequate post-harvest infrastructure (Runge & Lang, 2016).

In developed countries, regulation of specific marketing standards aims to guarantee food safety and facilitated trading. On the other side, these regulations seem to exacerbate the problem of overproduction and food losses (Göbel et al., 2012). For farmers, there are up to now few opportunities (e.g., use or sell as fodder, energy resource, donations) to merchandise rejections profitably. In many cases, fruits and vegetables which do not fit to the marketing standards/quality norms are just left on the field or thrown away. Alternative distribution channels which allow to save vast amounts of fruits and vegetables and provide farmers cost-covering selling opportunities are missing. Despite the partial abolition of the EU-wide particular marketing standards for fruits and vegetables in 2009, it seems that shapeless or different-colored fruits and vegetables are still not offered in supermarkets (Welovefood, 2017). A study by order of the EU-commission revealed that the abolition failed to reduce the food losses (Frieling et al., 2013). One reason seems to be that the trade set up strict own quality standards, stimulating food losses on farmers level (Runge & Lang, 2016).

Developed countries have efficient and extensive system of cold chain that prolong the shelf-life of perishable commodities such as fruits and vegetables. Additionally, advanced management practices and technology has ensured efficient supply chains and inventory management. In developing countries, poor post-harvest infrastructure such as cold storage, poor road conditions, power outage, contributing to high post-harvest losses. Other important reasons for losses on the production side include losses due to pests and diseases, overproduction and lack of marketing infrastructure.

3.4 Circular economy in the context of food systems: the concept, strategies and limitations

3.4.1 About circular food systems

The term of circular economy is derived from industrial ecology and cradle-to-cradle approaches, to imitate nature and seek optimization of resources (Ellen MacArthur Foundation, 2013; Jurgilevich et al., 2016; Strazza et al., 2015). Circular economy embraces “design out waste”, diversity, systems thinking, cascading flows, closed-loop cycles, life cycle thinking, renewable energy use, and add value to waste (Ellen MacArthur Foundation, 2013;

Jurgilevich et al., 2016; Noya et al., 2017; Sala et al., 2017; Stoknes et al., 2016). The circular economy is a promising technology for sustainable development aims (Korhonen et al., 2018), offering the possibility to integrate sustainability into the business context (Ritzén and Sandström, 2017). In summary, the circular economy could be understood as the 4Rs activities/strategies "**reduce-reuse-recycle-recover**" in a system viewpoint (Kirchherr et al., 2017; Korhonen et al., 2018).

The current food systems are suffering pressure due to increasing food demand and faces socioeconomic, environmental challenges (Halloran et al., 2014; Notarnicola et al., 2017; Sala et al., 2017). Food waste is one of the leading challenging issue in the food systems (Beausang et al., 2017), and the overall inefficiency in the food supply chain is the primary driver of food waste and the wasteful use of natural resources (Jurgilevich et al., 2016). The primary production has its great contribution (Toop et al., 2017), along with upstream actors of the food chain (Jurgilevich et al., 2016).

In food systems, the circular economy is a holistic, systems-thinking approach (Halloran et al., 2014) to promote sustainable food systems from production up to consumption (Mourad, 2016; Notarnicola et al., 2017). The primary goal is to reduce and avoid food surplus, food waste, and food losses, optimize the utilization of resources, utilization of by- and co-products, nutrient cycling and avoid environmental impacts (Halloran et al., 2014; Jurgilevich et al., 2016). In this sense, the circular economy can help to ensure food security, support Earth's living-supporting systems (Kuisma and Kahiluoto, 2017), generate lesser environmental impact (Noya et al., 2017), produce renewable energy, minimize impacts of climate change (Strazza et al., 2015). According to Garrone et al. (2014), a proper management of food surplus is the key to reduce food losses, as the example of the fruit and vegetable sector, where food losses cause is due to overproduction and noncompliance with the market norms. Therefore, circular economy technology can be a way to improve inefficiency of food systems (Halloran et al., 2014), to reduce food waste, revalorize food waste, co- and by-products (Jurgilevich et al., 2016; Toop et al., 2017).

Papargyropoulou et al. (2014) propose a sustainable food waste hierarchy in the food supply as "**Prevention – Reuse – Recycle – Recovery – Disposal" (Figure 8)**. In this framework, there is prioritization, in which prevention of food waste and overproduction is the primary strategy.

If not succeeded, agricultural surpluses can be redistributed (reused) or recycled via composting, bio-digestion, animal feed, or energy recovery, but waste disposal should be avoided.

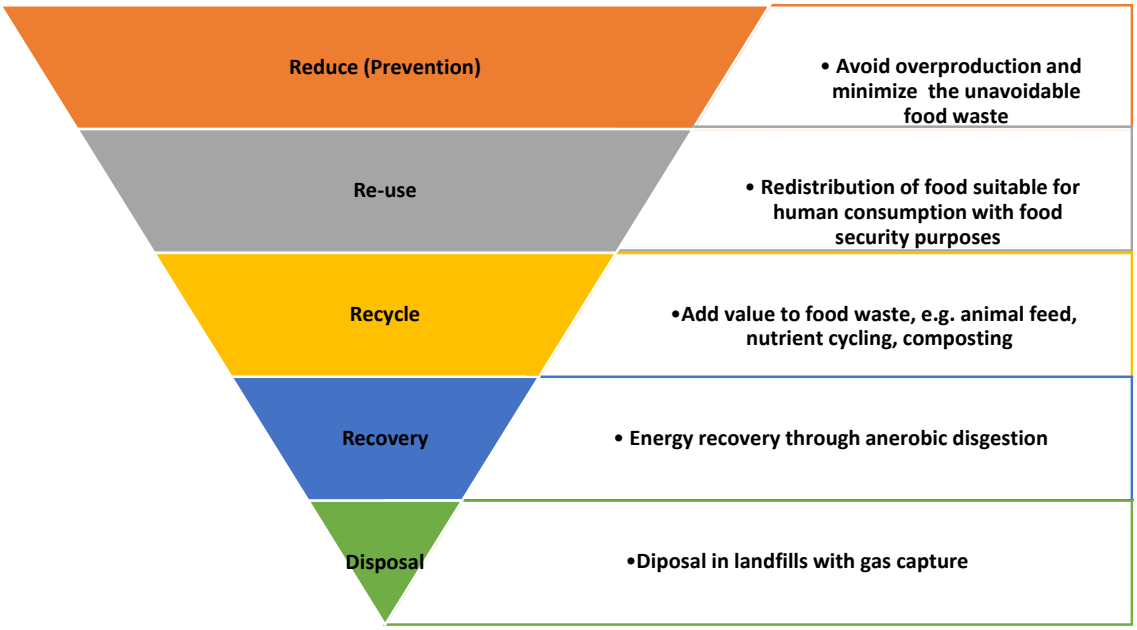

Figure 8: Food waste hierarchy prioritization of the 4Rs

Source: Figure adapted from Papargyropoulou et al. (2014) adding the "recycling" to the framework based on Jurgilevich et al., 2016; Kirchherr et al., 2017.

According to Jurgilevich et al. (2016), the circular food system can work synchronized at all levels of the entire supply chain considering three main stages: "food production, food consumption, food surplus and waste management" as illustrated in **Figure 9**. One crucial stage is the **management of food waste and avoidance of overproduction**, which adds value to food waste, the utilizes by-products, recycles nutrient recycling, reuses matter, and recovers energy. At the **farm level**, recycling of nutrients and reuse of matter creating value chain closed loop inputs. At the **end of the chain**, it is crucial strategies towards efficient and sustainable consumption, sustainability awareness and an efficient use of the input resources and avoid surpluses.

Figure 9: Circular food system

Source: Retrieved from Jurgilevich et al. (2016)

3.5 Circular food system initiatives, chances and limitations

3.5.1 Primary production strategies

It is clear the potential of the circular economy in the agricultural system through integrated closed-loop cycles, minimal needed inputs, considering the role of agriculture in the provision of environmental conservation (Dimitrov & Ivanova, 2017). The leading causes of waste on the farm are due aesthetics and marketing norms, and farm managing practices (Beausang et al., 2017; Willersinn et al., 2017). The current waste produced on the farm have destinations such as standard disposal, composting, food redistribution, animal feed, and biogas digestion (Beausang et al., 2017; Willersinn et al., 2015).

The circular economy could provide a proper and efficient use of the biotic (matter and nutrients) resources and reduce the food losses on the farm (Kuisma & Kahiluoto, 2017). Nutrient cycling is a good strategy to optimize the reuse or recovery of the necessary nutrients as returning inputs for production stage (Jurgilevich et al., 2016).

As described by Dimitrov & Ivanova (2017), the organic farming itself is already an excellent circular strategy, as a sustainable way of production and efficient resource use. Prevention of food waste should be the priority on the production level, along with recovery and recycling

tactics to the unavoidable waste, for example, animal feed, compost or energy generation (Beausang et al., 2017; Mourad, 2016). Besides being of interest to add value to waste, there is still a barrier to implement recycling strategies, such as bio-digestion, and to quantify appropriately the waste generated on farm level (Beausang et al., 2017).

3.5.2 Towards sustainable consumption and retailers alternatives

Sustainable consumption patterns, for instance, less animal-based, contributes to the reduced use of inputs (Jurgilevich et al., 2016). Kuisma & Kahiluoto (2017) identified that the most significant inefficiency regarding resource use, is the animal production, and although manure can still provide nutrients or energy generation through recycling, yet the plant-based production systems are more biotic efficient.

According to Cicatiello et al. (2017), there are two types of food waste, edible and inedible fractions, with a considerably high degree of recoverability (Garrone et al., 2014). Strategies involve the internal management to reduce waste generation and redistribute the still edible fraction of waste to human consumption without the loss of nutritional quality and with the minimum economic loss for the retailer (Cicatiello et al., 2017). Nevertheless, the recording of food waste is problematic in the retail sector, and the food redistribution implies ethical issues. There is still the need to valorize waste at this stage of the chain in economically viable terms (Cicatiello et al., 2017) for retailers to engage in the circular economy beyond simplistically reduce and re-use strategies, concerning mainly the inedible fraction.

3.5.3 Food waste management and nutrient cycling

The literature reported many different initiatives comprising food waste prevention, reuse or recovery, and recycling initiatives, such as “food-to-food” and “from-field-to-fork” initiatives using life cycle assessment (Notarnicola et al., 2017; Noya et al., 2017; Strazza et al., 2015). One aspect to keep in mind is that in circular economy “waste is food” (Ellen MacArthur Foundation, 2013). Overproduction can lead to food surpluses, which is a suitable for human consumption. Although food waste is inedible, it is still a material rich in nutrients to be recovered or recycled (Jurgilevich et al., 2016). Moreover, adding value to the food waste is one way to make it economically viable (Toop et al., 2017).

Many studies experimented initiatives of recovery and recycling. For instance, utilization of recycled nutrients as green manure in crop production (Kuisma & Kahiluoto, 2017), recovery of energy through the conversion of food waste to biogas (De Clercq et al., 2017), food waste prevention, reduction, and nutrient recycle (Halloran et al., 2014). Additionally, combined approaches such as by Garrone et al. (2014), who proposed a model for food waste reduction estimating the degree of recoverability of surpluses. Stoknes et al. (2016) created, as well, a new technology called "digeponics" to recycle food waste to energy and fertilizer in a cyclic looping production strategy.

Toop et al. (2017) evaluated the application of circular economy to the agri-food sector using anaerobic digestion "Agrocycle" through nutrient recovery from agricultural waste, plus generation of energy and heat, as illustrated in **Figure 10**. This innovative model integrates production, retailer, and processing stages, within a closed loop and cycling inputs activities, for example, generation of energy, biofuels, biofertilizers from food waste, recycling of resources such as water, make use of bio-industrial processes, including pharmaceuticals, polymers. This model was elucidated due to its relevance and the myriad of circular economy application to the food system.

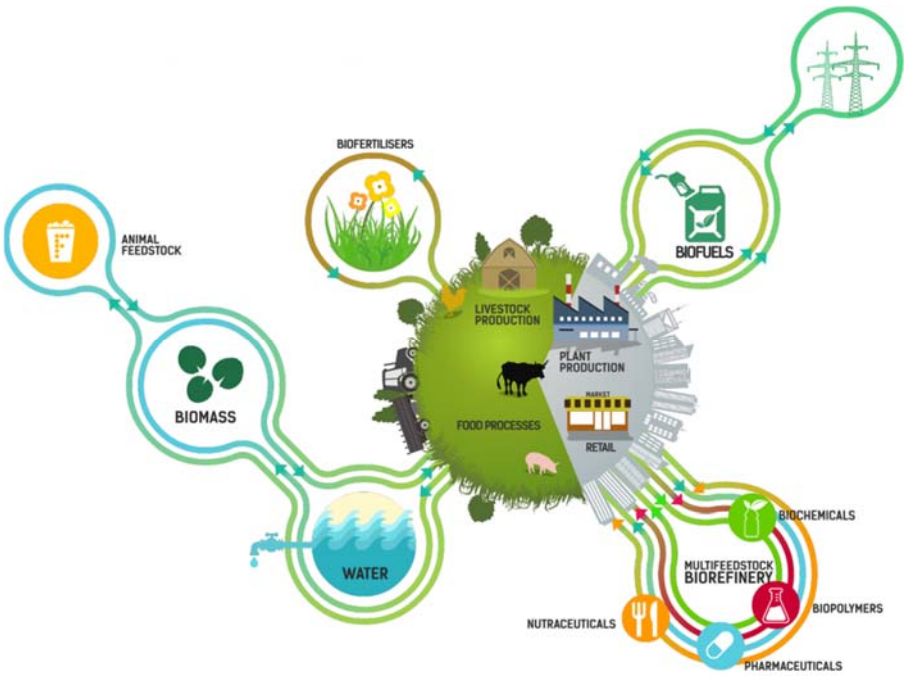

Figure 10: Food waste management example in circular food systems

Source:Retrieved from Agrocycle, 2017; Toop et al., 2017

3.5.4 Circling the entire food chain

Examples of circular economy strategy applied in the food supply chains, using the 4Rs strategies can be summarized in **Table 3**, based on literature review.

Table 3: Circular economy in food systems

Strategy	Examples	Stage of food chain
Reduce	Prevention of food waste and loss; avoid overproduction, promote efficient resource use; promote less restriction on cosmetic standards; connect to processing facilities; retailer in-store management; consumer awareness; sustainable consumption	Entire food chain, but most linked to the production and consumption
Reuse	Redistribution of surplus; food processing; redistribution of edible food waste to human consumption	Mostly at the ending point of the chain
Recycle	Nutrient cycling; biotic resource use; utilization of recycling material as animal and green manure; composting; digestion of organic waste; fertilizing; animal feed; biodigestion, water recycling; closed loops; use of by- and co-products; bioprocessing	Waste Management applicable to the entire food chain.
Recover	Biodigestion to generate energy, biogás, biofuels	Entire food chain, more production stage

Source: Table created by the authors based on reviewed literature

Most of the strategies can be applied almost to the entire food chain, cycling loops of inputs, nutrients, and matter. Important is to remember the prioritization previously cited for food waste reducing strategies, connect production and consumption, facilitate recycling initiatives, and make the beneficial use of renewable recovered energy.

However, as some authors stressed, the concept needs to overcome the dependency on the already established economic development model and make it possible to integrate disconnected ideas and perspectives (Korhonen et al., 2018; Ritzén and Sandström, 2017). As highlighted by many authors, there is a need to integrate all actors of the food supply chain for a proper circular economic development, in which prevention plays an essential role to integrate the stakeholders (Beausang et al., 2017; Jurgilevich et al., 2016; Mourad, 2016; Papargyropoulou et al., 2014).

4. Results and Discussion

4.1 Review of circular economy models in the fruits and vegetables value chain

Since the Sustainable Development Goals set a target of cutting FLW on a global level to half by 2030, few countries have adopted national FLW reduction goals. For example, in 2016, the US Department of Agriculture and Environmental Protection Agency announced the first-ever domestic goal to reduce FLW (EPA, 2017). Similarly, the EU in 2016 committed to food waste prevention as an integral part of the "Circular Economy Package" to achieve the SDG target (Gassin, 2017). Further, France was the first country to make it illegal for supermarkets to throw out unsold food. Italy followed this, thereby obligating supermarkets to donate unused food to charities, animal feed or composting companies (Esposito et al., 2016).

Globally there have been several other initiatives by multi-stakeholder collaborations and governments to reduce FLW such as:

(i) The Consumer Goods Forum (CGF): In 2014, CGF envisaged a vision to eliminate waste from their products and services, throughout their lifecycles, including supply chains, manufacturing operations, distribution, use and post-use recovery by adopting the concept of a circular economy. In 2015, members of the CGF committed to halve food waste within 400 retailer and manufacturers members by 2025. CGF also amins to support UN Goals to halve per capita global food waste at the consumer level, to reduce food losses along production and supply chains, including post-harvest losses, and maximise the value of the remaining waste (The Consumer Goods Forum, 2015).

(ii) Champions 12.3: In September 2015, a collation of executives from government, businesses, international organisations, research institutions, farmer groups and civil society dedicated to inspiring ambition, mobilizing action and accelerating progress towards achieving SDG 12.3 by 2030 formed (Champions 12.3, 2017).

(iii) FLW Protocol: In June 2016, the first global standard to quantify FLW was introduced through an international partnership. The objective of the protocol is to assist countries, companies and other organisations to estimate consistently how much food is lost and wasted and identify where the loss and waste occur (WRI, 2017).

All these resolutions and commitments have initiated innovative circular economy methods to minimize FLW by the private and public sectors, and community organizations in many countries, especially in the EU, UK, and USA. In this section, we review these innovative initiatives adopted under the 4Rs hierarchy, i.e., reduce (prevent), reuse, recycle, recover activities/strategies by different actors along the food value chain, i.e. producers, suppliers, distributors, retailers, consumers, food industry, waste management. The purpose of this section is to highlight existing strategies, categorized according to the observed patterns, and following the framework of circular economy. **Table 4** represents few examples of models based on desk review, categorized as already described in the methodology section.

Table 4: Circular economy Business Models to minimize FLW along food value chains

Business Model	Example of cases	Stage of food system	4Rs Hierarchy	Circular economy strategies	Location
1. Initiatives in the Retail Segment					
1. Large Format Retail	(i) Tesco Supermarket (TESCO, 2017)	Producer/Supplier	Reduce & Reuse	**Broadening specification:** launched a new range of imperfect fruit and vegetables; **Partnerships:** suppliers aim to adopt the SDG to halve food waste by 2030; **Managing oversupply**: sell extra-large boxes of fruits and vegetables from bumper crops at a lower price	UK
				Food sharing: donation of food surplus from suppliers to charity partners	
		Processing	Reduce and Reuse	**Food processing**: provide growers a stable demand for produce that falls outside specifications to suppliers of fresh and frozen foods	
		Retail	Reuse	**Food sharing**: donation of in-store food surplus	
		Consumer	Reduce & Reuse	**Sustainable consumption**: promote less wasteful promotions/offers to avoid overconsumption; **Product innovation**: packaging to increase shelf life and frozen foods	
		waste management	Recycle	**Animal feed**: conversion of food waste into livestock feed; **Biodiesel**: processing vegetable oils and animal fats into bio-diesel	
			Recover	**Energy recovery**: anaerobic digestion from food waste and incineration	
	(ii) Waitrose Supermarket (Waitrose, 2017)	Producer/Supplier	Reduce	**Broadening Specification**: new line of imperfect fruits and vegetables sold in larger value bags	UK
		Retail	Reuse	**Food Sharing**: donation of surplus food from outlets to charities	
		Consumer	Reduce	**Sustainable consumption**: Consumer Awareness Programs	
		waste management	Recover	**Recover energy**: food waste and other organic matter (including horticultural waste and spent coffee grounds) are sent to generate energy through anaerobic digestion	
	(iii) Edeka Südwest (BMEL, 2017a)	Retail	Reduce & Reuse	**Managing oversupply**: online shop that sells the in-store food surplus at reduced prices; **Broadening specification**: regional products in seasonal supplies; **Food sharing**: perishables are donated to local food banks.	Germany

Business Model	Example of cases	Stage of food system	4Rs Hierarchy	Circular economy strategies	Location
	(iv) PLUS-supermarket (Detailhandel Nederland, 2016)	Retail	Reuse	**Product innovation**: Prepare ready-to-eat meals using foods near at the expiration date, or aesthetically objectionable	Netherlands
	(v) Jumbo and Emté (Detailhandel Nederland, 2016)	Retail	Reuse & Recycle	**Product innovation**: Soup made from waste streams in the entire supply chain; **Composting**: add value to food waste through composting and or fermentation	Netherlands
2. Low-cost Supermarket	(i) Rema 1000 (Rodionova, 2017)	Retail	Reduce	**Managing oversupply**: Replaced all its quantity discounts with single item discounts to minimize food waste.	Denmark
	(ii) Penny (Penny, 2016)	Retail	Reuse	**Broadening specification**: new range of100% organic fruits and vegetables considered aesthetically objectionable	Germany, Austria
	(iii) Norma (BMEL, 2017b)	Retail	Reduce	**Innovation**: research cooperation to optimize forecast methods in ordering processes to reduce food losses	Germany
	(iv) Dirk (Detailhandel Nederland, 2016)	Retail	Reuse	**Product innovation**: repackaging fruit and vegetables, which had damaged packing. Repackaged food is labeled, indicating that the products have the same quality but are price-reduced	Netherlands
3. Organic Supermarket	(i) Tegut and Bio Company (Würz, 2014)	Retail	Reduce, Reuse & Recover	**Manage oversupply**: in-store management to reduce food losses, storage management, cutting of prices; **Product innovation**: food processing, food repacking; **Food sharing**: collaboration with food banks; **Energy recovery**: using organic waste for biogas production	Germany, Ecuador, Bolivia, Peru
4. Surplus Food Supermarket	(i) WeFood (Payton, 2016)	Retail	Reuse	**Managing oversupply**: sells goods that regular supermarkets can no longer sell due to overdue 'best before' dates, incorrect labels or damaged packaging.	Denmark
5. (Online-) Local Grocery Store	(i) The Good Food[1] (The Good Food, 2017)	Retail	Reduce & Reuse	**Broadening specification**: collaboration with producers to source fruits and vegetables usually rejected by retailer to be sold in a retail outlet, food boxes, or new products through online or local shops	Germany

[1] Other examples doing the same type of initiative, but not listed in the table: (ii) Hunkelstide, (iii) Be Bananas, (iv) Dörrwerk, (v) Im Angebot, (vi) Querfeld, (vii) Etepete, (viii) einzigArtig, (ix) Sirplus (BMEL, 2017v, 2017w, 2017x, 2017y, 2017z, 2017aa, 2017ab; ETEPETETE, 2017)

Business Model	Example of cases	Stage of food system	4Rs Hierarchy	Circular economy strategies	Location
6. Supermarket alliances	(i) all supermarkets in the Netherlands (Detailhandel Nederland, 2016)	Retail	Reuse	**Food sharing**: supermarkets in the Netherlands have relations with food banks ensuring the liability for food safety	Netherlands
2. Technology-based Innovations					
1. App Based Aggregators	(i) Food Cloud (FoodCloud, 2017)	Producer/Supplier/Distributors	Reuse	**Web Platform:** food hubs connecting food businesses such as farms, manufacturers, and distributors who have volumes of surplus food	Ireland
		Retail	Reuse	**Food sharing App:** food cloud to connect supermarkets with charities institutions working in food insecure communities	Ireland and the UK
	(ii) Spoiler Alert (Spoiler Alert, 2017)	Producer/Supplier/Distributors	Reduce, Reuse & Recover	**Web platform**: cloud-based reporting and analytics platform for real-time tracking of unsold inventory and organic waste across a portfolio of locations and destinations; **Online shopping**: an online marketplace that facilitates real-time food donations, discounted sales, and organic waste recovery opportunities	USA
		Retail			
	(iii) MealConnect (Feeding America, 2016)	Producer/Supplier/Distributors	Reuse	**Web platform**: to connect donors with surplus food to their local food banks and their partners	USA
		Retail			
		Consumer			
	(iv) Foodloop (FoodLoop, 2017)	Retail and Consumer	Reuse	**Food sharing App**: Through the app, retailers can offer products of short shelf life. Consumers can check in real time new offers available	Germany
	(v) Mundraub (BMEL, 2017c)	Consumer	Reduce & Reuse	**Food Mapping**: map the geographic positions of fruit plants/fruit trees which can be harvested by everyone	Germany and globally
2. Waste Reduction Appliance	(i) Blue Apple (Bluapple, 2017)	Consumer	Reduce	**Appliance**: Absorbs ethylene gas that is produced while fruits and vegetables ripen thereby increasing shelf life in the refrigerator	USA
3. Tracking Applications	(i) Green Egg Shopper (Esposito et al., 2016)	Consumer	Reduce	**App for sustainable consumption**: to manage shopping lists, reduce food waste, watch expenses, and avoid over buying. Reduces food	-

Business Model	Example of cases	Stage of food system	4Rs Hierarchy	Circular economy strategies	Location
				waste by keeping track of best by/expiration dates and providing alerts	
4. Monitoring of food losses	(i) Resource Manager Food (RmFood) (BMEL, 2017d)	Consumer	Reduce	**Monitoring too**l: quantify and analyze the reasons of food losses occurring in catering facilities and optimization of menu planning	Germany
3. Non-Profit Collaborations					
1. Donation Aggregators	(i) FareShare (FareShare, 2017); (ii) FoodShare (FareShare, 2017) ; (iii) foodsharing.de (foodsharing, 2017)	Food Industry, Consumer	Reuse	**Food sharing**: connect consumers, manufacturers, industries, and retailer: food donations for vulnerable populations, collection of retailer and food industry and further donation for vulnerable populations and food insecure communities.	UK, USA, Germany, Austria
	(iv) Das Geld hängt an den Bäumen(Hamburg) (BMEL, 2017e); (v) Public apple harvesting (Berlin) (BMEL, 2013a); (vi)"Marmelad für alle" (BMEL, 2017f)	Production, Consumer	Reuse	**Food processing**: Hiring disabled persons to harvest and process apples to juice which is sold for cost-covering; fruit jam processing by the German youth **Food sharing**: public apple harvesting for donation	Germany
4. Innovations in Waste Management					
1. Waste Management	(i) Bio-Bean (bio-bean, 2016)	waste management	Recover & Recycle	**Biofuels**: Extracts oils from coffee grounds for biofuels	UK
	(ii) Starbucks (Starbucks, 2016)	waste management	Recover & Recycle	**Animal feed**: Makes feed from used coffee grounds	Japan
	(iii) Turning Earth (Turning Earth, 2010)	waste management	Recover & Recycle	**Energy recovery**: Produces electricity and natural gas from food waste using anaerobic digestion	USA
	(iv) Quest Recycling Services (Quest, 2017)	waste management	Recover & Recycle	**Food recycling**: Provides food recycling services that help companies reduce waste-disposal costs	USA

Business Model	Example of cases	Stage of food system	4Rs Hierarchy	Circular economy strategies	Location
5. Initiatives by Food Producers					
1. Food Producer	(i) Back to the Roots (Back to the Roots, 2017)	Production	Recycle	**Nutrient cycling**: Grows mushroom out of coffee grounds	USA
	(ii) Brocker Möhren GmbH (BMEL, 2017g)	Production	Reduce	**Prevention of harvesting waste**: special harvest method guarantees to harvest all planted carrots crops with no waste	Germany
	(iii) Georg Thalhammer (BMEL, 2017h)	Production	Reduce & Reuse	**Food processing**: Processing of out of standard pumpkin to gourmet food products	Germany
	(iv)Remlinger Rüben (BMEL, 2017i)	Production	Recycle	**Nutrient cycling**: Procedure to mix food waste, soil and manure for fertilization; **Animal feed**: non-marketable goods for fodder production; **Food processing**: rejections used for processing and catering	Germany
		Retail	Reduce, Reuse & Recover	**Sustainable consumption**: cooperation with local retailer Tegut to sensitize consumers, education of employees, discounts for low shelf-life; **Food sharing**: food donations; and **Energy recovery**: selling for bioenergy	
	(v) Ökodorf Brodowin (BMEL, 2017j)	Production	Reuse	**Food processing**: processing rejections to instant meals which are sold directly at the farm	Germany
6. Initiatives by Food Manufacturers					
1. Food Manufacturer	(i) Kellogg (Kellogg's, 2017)	Production	Reduce	**Partnerships**: to identify ways of reducing food losses	Worldwide
		Processing	Reuse, Recycle & Recover	**Food sharing**: Edible food is donated to people in need; **Animal feed**: food waste is used for animal feed; **Nutrient cycling**: bio-recycling, composting, and incineration (**recover**)	
		Consumer	Reduce	**Sustainable consumption**: standardize food date labels that communicate if food is safe to consume to reduce unnecessary food waste.	
	(ii) Danone (Erickson, 2017)	Processing	Reuse & Recycle	**Food processing**: Leftover acid whey is converted to baby food	Worldwide

Business Model	Example of cases	Stage of food system	4Rs Hierarchy	Circular economy strategies	Location
	(iii) Pepsico (Pepsico, 2013)	Processing	Recycle & Recover	**Anaerobic digestion**: Waste from potatoes, corn and broken chips are processed in an anaerobic digester to produce biogas and organic digestive.	Turkey
	(iv) Coppenrath & Wiese (BMEL, 2017k)	Processing	Reuse	**Food processing**: processes too small apple pieces into applesauce and jam which were lost in former times	Germany
7. Initiatives by consumers					
Community farming	(i) Garten Coop Freiburg (BMEL, 2014a); (ii) Andernach (Germany) (BMEL, 2014b); (iii) Genf (Switzerland) (Les Jardins de Cocagne, 2017)	Production	Reduce	**Sustainable production**: Community supported agriculture for food self-sufficiency; urban farming	Germany, Switzerland
Awareness raising and education	(iv) ShoutOutLoud e.V. (BMEL, 2017l); (v) consumer advice center in Hessen and NRW (Germany) (BMEL, 2017m, 2014c)	Consumer	Reduce	**Consumer awareness program**: program against food waste through consumer awareness, consumer advice centers, and efforts from shops and restaurants against food losses, public exchange food boxes, communal cooking with saved food.	Germany
	(vi) Dinner Exchange (BMEL, 2014d); (v) Homeless veggie dinner (BMEL, 2013b); (vi) Instock Restaurant (Detailhandel Nederland, 2016)	Consumer	Reuse	**Dinner exchange**: Organizing dinner parties at which food losses are cooked (e.g., fruits and vegetables collected from supermarkets, producers, market trader). Participation fees are partly donated to organizations dealing with equal food distribution; homeless veggie dinners.	Germany, Netherlands and other EU-countries
8. Governance initiatives / Others					
Supporting research on food losses	(i) Research study 'LEDANA' (BMEL, 2017n)	Retail	Reduce	**Research on food losses**: NRW Ministry of consumer protection commissioned researchers of University of Witten/Herdecke to develop a guideline for the food industry containing practical implications against food losses	Germany
Awareness raising / consumer education	(ii) Zu gut für die Tonne (BMEL, 2017o); (iii) Baden-Württemberg (BMEL, 2017p); (iv) Rhineland-Palatinate (BMEL, 2017q)	Consumer	Reduce	**Consumer awareness**: Federal Ministry of Food and Agriculture organized action days about food waste; Workshops and public events by Ministry of consumer protection of Baden-Württemberg and Ministry of nutrition Rhineland-Palatinate	Germany

Business Model	Example of cases	Stage of food system	4Rs Hierarchy	Circular economy strategies	Location
Forming alliances	(v) "Wir retten Lebensmittel" (BMEL, 2017r); (vi) Hamburg isst dabei" (BMEL, 2017s); (vii) Brandenburg (BMEL, 2017t); (viii) Saarland (BMEL, 2017u)	All Stages	Reduce	**Partnerships**: Building up a federation of different actors of food industry (including researchers) to develop ideas against food waste, round tables in Bavaria, Brandenburg and Saarland (Ministries of consumer protection)	Germany

Source: Compiled by the authors using many sources

4.1.1 Initiatives in the retail segment

Table 4 displays few examples of large format retailers, low-cost supermarkets, online grocery stores and local retailers, these are practical examples of adoption of the circular economy approach to reducing food waste and loss. At one side, it is observed that the large format retailers have taken an holistic approach to reduce FLW comprising the whole value chain by adopting all aspects of a circular economy such as reducing, reusing, recycling and recovering food that would have otherwise been disposed to the garbage bin. On the other side smaller low cost supermarkets, online grocery stores and local retailers have strategised only the aspect of 'reuse' of the surplus food from their outlets. Nevertheless, there are other minor examples on recycling or recovering strategies, such as convertion of food waste into animal feed, biodigestion and energy recovery.

From these cases, few strategies can be drawn to reduce FLW along the food value chain. Broadening specifications and launching a new range of out of standards fruits and vegetables sold at lower prices by retailers was a very used strategy **to reduce or prevent** food waste at the upstream production stage. The availing of this produce will ensure a regular demand for fruits and vegetables that are otherwise aesthetically objectionable, thereby reducing the food losses at the farm level. Likewise, strengthening partnerships along the food supply chain can enhance the efforts to reduce the overall food waste produced. Connecting farmers to charity organizations so that any food surplus produced can be **reused through food sharing** by food insecure people. Additionally, as a circular economy strategy to reuse the producer's food surplus, the connection of farmers to food processors (e.g. frozen fruits and vegetables) ensures that there is a constant demand for fruits and vegetables that fall outside the large format retailer's specifications.

Moreover, managing the oversupply to reduce wastage of edible parts in retail outlets, replacement of all quantity discounts with single item discounts could be a strategy to reduce or prevent wastage. Surplus food from retail stores could be reused by collaboration with non-profit charity organisations for human consumption. Inedible food waste can be sent for **recycling** to

recover energy through anaerobic digestion, which would **reduce** disposal to landfills. Additionally, to minimize the food waste at the consumer level, few retailers have discouraged promotions such as "Buy one Get one free", replacing them by price cut promotions instead, as sustainable consumption strategy. Other initiatives include packaging innovations to increase shelf life, product innovations such as frozen foods and consumer awareness programs that highlight aesthetically objectionable fruits and vegetables are just as packed with energy and just as tasty as their fellow fruits and vegetables.

4.1.2 Technology-based innovations

In recent years, there have been few interesting technological innovations, such as web platforms, food sharing Apps to aggregate demand for surplus food from non-profit charity organisations, food banks and consumers to producers, manufacturers, distributors, and retailers. **Table 4** presents examples of start-ups working in collaboration with big format retailers such as Tesco, Aldi, Lidl, Waitrose amongst others that have too much food togehther with charities working in communities that have too little. Such a tripartite agreement between retailers, app-based platforms and non-profit organisations ensures that food that would have been otherwise wasted is shared/ reused by sections of society that is food insecure.

There has also been the development of innovative applications for online shopping aligned with sustainable consumption concepts that help consumers keep track of what they buy best by/expiration dates and offer recipe suggestions to reduce food wastage. Moreover, **Table 4**also displays an example of waste reducing appliance that absorb the ethylene gas produced while fruits and vegetables ripen thereby increasing shelf life in the refrigerator. Many other examples of technology based innovations have been listed in **Table 4**, such as food mapping apps, monitoring tools, all in all, help consumers to **reduce** food waste, cycle back surplus food, and **reuse** it instead of sending it to landfills.

4.1.3 Non-Profit collaborations

Table 4 highlights two examples of non-profit organisations that aggregate donations by collecting fresh in date and good to eat surplus from the food industry which would otherwise go to waste and distribute to homeless hostels, children's breakfast clubs, lunch clubs for older people, domestic violence refuges, and community cafés amongst others. They work in collaboration with manufacturers, retailers, and app-based surplus food aggregators to **reuse** excess of food through food sharing and food processing strategies.

4.1.4 Innovations in waste management

There are few interesting examples of waste management cases, to **recycle** inedible parts of food that otherwise would be disposed into landfills. Few companies collaborate with the food industry to provide recycling services that help them reduce waste-disposal costs and **recovers** electricity and natural gas from food waste using anaerobic digestion. There are also examples of innovative utilization of food at the end of their lifecycle such as extraction of oils from coffee grounds for biofuels or making animalfeed on used coffee grounds. Such innovations require research to utilize different parts of food that go to waste for an alternative purpose.

4.1.5 Initiatives by food producers

Examples from **Table 4** point out that at the farm level producers can collaborate with food processing companies by selling produce that is rejected by traders or retailers due to specification issues for food processing, or they could alternatively collaborate with non-profit organisations to **reuse** food that is edible for human consumption in food sharing and consumer awareness initiatives. There are also possibilities to apply recycling strategies at the production level by considering nutrient cycling through green fertilization, conversion of food waste into animal feed, and bioenergy recovery. Reducing food waste at farm level has also been achieved in one case in the **Table 4**, using technologies to prevent food waste generated in the harvest.

4.1.6 Initiatives by food manufactures

Strategies for food manufacturers could include partnerships to enhance efforts to reduce food waste, or engaging in sustainable consumption strategies through standardization of food date labels that communicate to consumers if food is safe to consume to reduce unnecessary food waste. Likewise, edible food could still be reused in food processing of leftover parts into by-products, such as the example of Danone, which uses leftover acid whey to process baby food, or Coppenrath & Wiese, which process apple surpluses into applesauce and jam. The inedible parts in these cases were recycled in composting, nutrient cycling, animal feed, or recovered, such as potatoes and corn waste from Pepsico to produce biogas through anaerobic digesters.

4.1.7 Initiatives by consumers

The focus encountered in the consumer initiatives is on food reducing and reusing strategies. Examples are promoting sustainable production methods such are self-sustaining farming and urban agriculture. Consumer awareness regarding food waste and the promotion of sustainable consumption choices were observed in the cases, such as communal cooking with saved food, dinner exchange using food waste, or food donations for homeless, and charity institutions.

4.1.8 Governance initiatives and others

Our cases on Governance initiatives are also targeting food waste reductions strategies. There are many strategies including research on food losses, consumer awareness program and building partnerships carried out by some German ministries, to develop guidelines for food waste and losses prevention, among consumers, industries and researchers.

4.1.9 Circular economy at the entire value chain

All circular economy strategies adopted by various business models in **Table 4** were summarized in **Table 5**. The interaction among activities and actors in the value chain, illustrated in **Figure 11**.

Table 5: Summary of circular economy strategies based on reviewed cases

Reduce	Reuse	Recycle	Recover
Broadening specifications	Food sharing	Animal feed	Energy recovery
Partnerships	Food processing	Biodiesel	Anaerobic digestion
Managing oversupply	Product innovation	Nutrient cycling	
Sustainable consumption	Food mapping	Processing into by-products	
Sustainable production	Online shopping	Green fertilizer	
Product innovation	Monitoring tools		
Technology-based apps and platforms	Communal cooking		
Appliance technologies	Food donations		
Consumer awareness programs			
Research			

Source: Compiled by authors

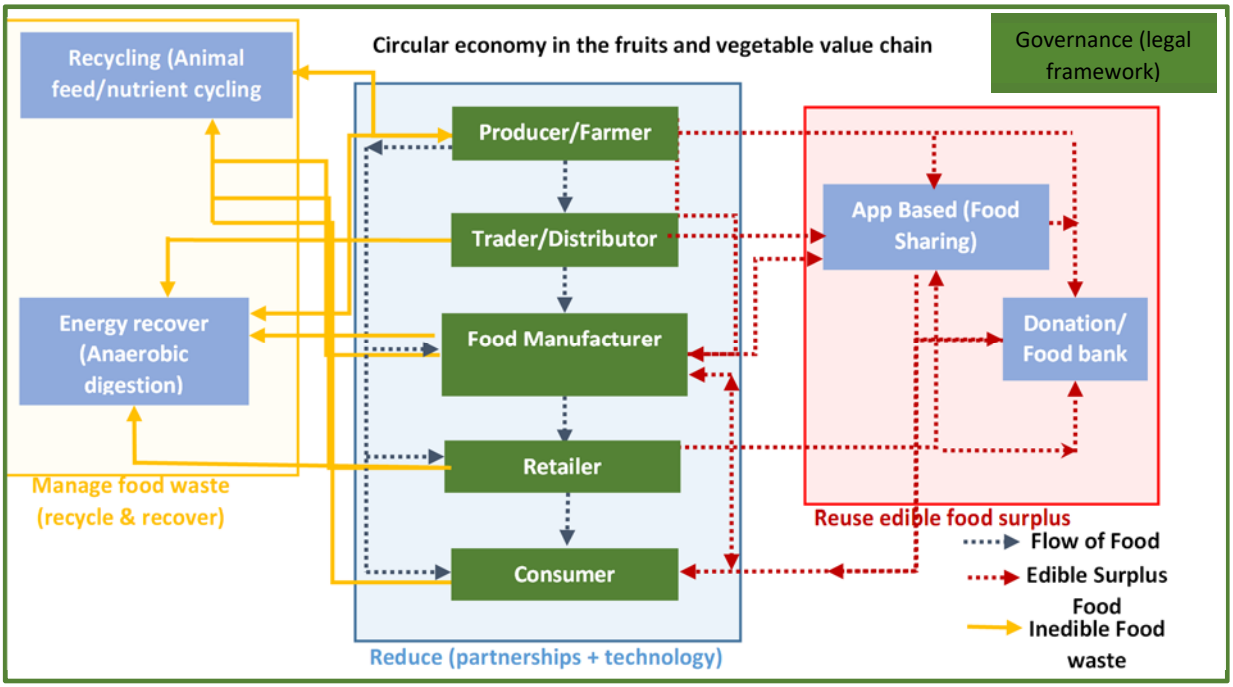

Figure 11: Circular economy strategy to reduce FLW along the value chain

Source: Figure created by authors based on the case study review

It is possible to see that most of 'reduce' activities can be implemented in all stages of the food value chain. Partnerships and technological development can foster better resource use, avoidance of food surplus generation, and better interactions and communication between actor

can help to improve the reuse of the edible fraction by processing, or food sharing, creating by-products. The consumer is also key to as part of sustainable consumption, and part of the reuse of the food, which would be otherwise disposed of. Nevertheless, considering circular economy frame, the inedible food waste can be recycled or recovered. Essential to highlight that a better relationship among actors of value chains, supported by the legal frame, is the ultimate way for a successful circular economy development.

4.2 Case Study Analysis

Among the identified initiatives, two cases at retailer's stage (one low-cost supermarket (sustainability representative) and one local grocery store (founder); both related to the circular strategy 'reuse') were selected for further analysis. Using thematic coding adapted from Flick (1995), three steps were applied to analyze the interview data: 1. case description, 2. thematic analysis and 3. case comparison. **Table 6** shows the results of this case study analysis. In Step 2, three main categories could be identified: *I. Problem definition: food losses & current treatment practice*, *II. Problem solving potentials of circular economy (C.E.) approaches* and *III. Stakeholder relations*. Latter was created as one own category since it has been seen as a crucial point implying chances as well as barriers/limitations of circling the food chain.

Table 6: Case Study Analysis Results

	Case 1	**Case 2**
1. Case-by-case analysis / case description	**'I think no supermarket likes to waste food.'** For nearly a year, the interviewee is working as a sustainability representative (responsible for fresh food sustainability) for one of the leading German food retailers. Previously, he worked in the research field. Since food losses always constitute financial losses, it is according to him a basic economic need to work resource saving and to avoid food waste. (Circular) efforts against food losses are part of his point of view of grocery retailers' occupational self-image. He puts emphasis on talking about food losses in a differentiated way.	**'I am afraid that there is a system in which food losses are used for realizing profit on every stage of the value chain.'** Working on the startup for three years, the interviewee has incorporated a non-profit-supermarket, which sells food losses in January 2017. Previously, she has already engaged in foodsharing.de. For her, food losses represent a pronounced social problem, but efforts undertaken so far are not getting to its roots. She feels to some degree incapable of opposing 'a system budgeting food losses' which according to her is leading to an inoperative circular food system.
2. Thematic analysis by categories		
I. Problem definition: food losses & current treatment practice		

(Perceived) extent of food losses	• Due to various prevention models, very little amount of fruits and vegetables losses at the company group (~1%)	• Based on her experiences in collecting food, 'really severe masses' of food are lost along the supply chain, e.g. o One vanload once a week (e.g. including >14 boxes of vegetables, 20 boxes of bananas) & additional carloads are collected from farmers and from one package station for organic food (high amount of food got from sorting machines) o Irregular occasions: In one supermarket, one big trolley of mushrooms was picked up which just has been in stock to create space for new deliveries; another container full of bananas and cucumber o In 2016 every second potato did not come on the market
Causes of food losses	• Main reason: food wastage at consumer level • Reasons at retailer stage differ: o EU marketing standards → major problem, intercept trade ('absolutely much food is not allowed to place on the market') o Quality standards of the trade → acceptance of internal food quality varies (e.g. different regulation of maximal amounts of pesticide residues) o Damages, spoilage → not useable food is picked out o 'Border cases': still edible food is cleared out for convenience (not being used for further processing) → Further processing of edible food is relative to the volition and ingenuity of each store manager and suitable qualifications • Definition problems have to be considered, e.g. farmer level: 'no clear boundaries for when a salad is a plant, residual plant or food'	• Distinguishes between food losses occurring at farmer stage (adverse weather conditions (e.g. inducing too fast growth), overproduction, aesthetical objectionable crop (left on field) and food wastage at other stages of the food chain • Processing stage: sorting losses due to millimeter-thin standards • Consumer behavior o Retailer: inadequate & inflexible purchasing management o Consumers: aesthetical claims, lack of information • Legal regulation setting up obstacles to redistribute / share or donate food (e.g. ban to offer exposed goods) → for retailers fear of becoming liable and getting a bad press • At every stage of trade: food losses / wastage are already budgeted which is coming along with making a profit
Business practices against food losses	• Sustainability department (supports purchasing 'green products') • Seasonal planning & high percentage of contract-farming to insure sale & purchase of goods for farmers and retailer (linked with strategic suppliers in case of arising lacks of goods) • Sale of organic and locally produced fruits and vegetables (latter to be expanded in future) • Processing of food losses and redistribution by other marketing channels (e.g. juices, fruit salads offered at fresh food counters) • Own marketing channels for organic food rejections due to aesthetical norms • 'Recycling and waste separation as much as possible'	• Regularly harvesting of food left on field and collection of goods in stock and at packaging stations as much as possible ('we save masses of food') • Partly processing fruits and vegetables to further products • Supermarket is based on voluntary working team and follows mainly the principle 'pay what you want / can' → addressing the masses, bringing together people sharing same opinion, enabling people with low income to get fresh organic food, sensitizing consumers for the extent of food losses and required efforts to oppose it • Raising consumer's awareness of doubting minimum shelf-life

	• Internal awareness raising (discussion and consideration of the subject in internal decision processes)	
II. Problem solving potentials of circular economy (C.E.) approaches		
Knowledge of C.E.	• So far no knowledge of C.E. concept	• So far no knowledge of C.E. concept, associates it with organic farming
Need for action and chances of C.E. strategies	• 'I think the problem is already considered in many regards and at every stage of the food chain.' • C.E. takes up a natural need of every entrepreneur: aiming to use a recycling system in which as many resources as possible are re-used → contains economic incentives to support C.E. approaches → live up a subject which is already in the public mind • Each actor of the food chain is responsible, but consumers as main reason have to be addressed in particular, e.g. by abandoning best-before date and educating consumer's sensors • Support already implemented initiatives like food banks, food sharing apps, information campaigns. Regarding the trade, common quality standards could facilitate farmer's work (e.g. pesticide management). Trading houses having problems with food processing should check cooperation potentials • By marketing ugly food: increased yield for farmers (harvest more food of low quality) / sale of goods, contribute to obtain consumer acceptance for differences in food appearance • General food wasting ban for supermarkets could regulate the wastage of still edible food • Adjustment or abolition of EU-marketing standards is required because it induces food losses on first stage in food chain	• Intern: As the startup is showing great success, expanding set of food suppliers (e.g. wholesaler) and increasing resources to be able to save more food are considered • Expanding (similar) food saving and food sharing activities as there are masses of food at different stages of the supply chain not being saved so far → Addressing farmers allows saving ('perfect') food at the early stage of food chain in particular due to the high amount of crops left on field. Deficient fruits & vegetables can be processed soon. • Change of policy required, e.g. facilitate food sharing/saving in terms of liability questions (has to go along with a change of image / public perspectives), change marketing norms • For famers: considering direct sales, looking for cooperation partners not demanding strict marketing standards, optimizing corporate planning, implementing organic farming, engaging proactively in food saving • For retailers: optimizing purchasing management (e.g. enabling redistribution between supermarkets, facilitating decisional power, making contract-farming more flexible) • Marketing of 'ugly food' in supermarkets / discounters could contribute to increase farmer's yield
Barriers & limitations of C.E. strategies	• Joint responsibility of all actors along the food chain → retailer's range of influence is limited • Changes in policies (e.g. marketing standards) are missing or slow acting • Internal diffusion of responsibility (e.g. store manager vs. head office) • Common definition of food losses is missing → trashing food or food waste? • Inedible food is wasted by default: Are there existing alternatives? • 'Zero waste' is unachievable in production processes as there are always (polluted) by-products • Permanent efforts and consistency are needed to counteract food losses successfully	• Approaches like food sharing or establishing supermarkets offering food losses are not tackling the roots of the problem as they are based on 'something deeply going wrong in our society' • Policies fail, e.g. awareness campaigns miss to reach the public • For farmers there is lack of alternative marketing channels and donation opportunities are limited (e.g. short harvest time); self-initiative is needed to minimize rejections due to aesthetical norms • As far as 'food losses are obviously budgeted, there is always a somebody in the value chain who squeezes profit from losses occurring at other stages' • Non-transparent food system: lack of information where, why and to which amount food losses happen • Food sharing / redistribution models are on the one side confronted with food losses topping their

		resources to save and market it and on the other side experience limitations in accessing goods • Split in consumer behavior: no acceptance of 'ugly food'
III. Stakeholder relations		
Identity & conflict of interests	• Intern: Head office - store managers: standards & support vs. subjective decision-making of assortment and treatment of goods • Retailer - government: collaboration vs. dependency (forming trade obstacles, inflexible regulation) • Retailer - farmers: interdependency vs. forming regulatory obstacles • Retailer - consumers: pulling together (share opinion) vs. reluctance (consumer behavior) → BUT…today's consumption patterns might be self-imposed by the trade ('Maybe we educated consumers to believe that minimum shelf-life means expiry date')	• Networking with farmers (share same opinions, mutual profits) • Stable like-minded customer base vs. ignorance? • Farmers are subject to multiple dependencies o Consumers: direct sale of 'ugly food' is partly not accepted o Wholesaler/retailer: strict regulations (in particular discounters) regarding aesthetics (implies policy's accountability) • Policy makers - consumers: shuffling off responsibility? • Media - retailer: exacerbating the problem by bad press?
3. Case comparison	According to the interviewee, food losses seem to pose a problem mainly at consumer's stage. 'Certain consumption patterns have developed in former times and we now have to regress.' From an economic view, he takes prevention of food losses for granted. Given to the fact, that there are already various possibilities to minimize food losses and a rising public awareness, he is optimistic about a more circular food system in the near future. In the sense of a common responsibility, 'every actor is able to impact food losses positively by taking just a few actions.' To circle the food chain, need for action is required in particular by policy makers, whereas the own corporate practice almost tapped the full potential.	According to the interviewee, food losses seem to be a problem of huge extent and even underestimated due to a lack of transparency in the food chain. Although consumers have to contribute in minimizing food losses, 'they are charged as so often so that the problem is pushed away.' In 'a system budgeting food losses and thus making profit from it', policy makers and trading actors are most accountable to circle the food chain. She is pessimistic about finding a solution in the near future. From her perspective, existing efforts to minimize food losses could be expanded at all stages of the value chain but strategies which really tackle the problem are completely missing so far.

As the thematic analysis reveals, the extent of food losses and opportunities to counteract it are perceived extremely contrary by the interviewees (e.g. 'very little amount' (Case 1) vs. 'really severe masses' (Case 2)). While according to case 2 food losses seem to be budgeted in the food system (and therefore realizing profit for the following stage of the value chain), there exists a basic economic need to work resource saving (and therefore inducing every entrepreneur to prevent food losses) according to case 1. Regarding the causes of food losses, both cases charge in particular policy makers to come up with inadequate and inflexible regulations, which intercept to trade more food (e.g. EU-marketing standards) and fail to raise consumer's awareness. Both interviews pointed out that a common consensus about defining food losses is missing which might pervert the true size of the problem and which leads to different views of accountability.

Regarding the retailer's stage, it remains for example unclear, if all possibilities to minimize food losses are exhausted (as being said in case 1). Considering the answers given by case 2, there could be potentials to e.g., optimize the purchasing management and to facilitate the distribution of decisional power. On the other side, the internal diffusion of responsibility might also contribute to the emergence of food losses (e.g. dependency on store manager's prevention ambitions). Interestingly, although both cases show circular initiatives (see **Table 6** at 'business practices against food losses'), the concept of circular economy by itself is not well known. To develop a more circular food system, both cases indicate to support already implemented models like alternative marketing channels for 'ugly food', food sharing (apps) and food donating. According to both interviewees, this requires changes of policy (e.g. in terms of liability questions) and intensification of cooperative partnerships. Latter need for action can also be underscored by several conflict of interests this case study revealed (see **Table 6** at 'Identity and conflict of interests'). Even though the consumer's responsibility is viewed contrary ('main reason' (case 1) vs. 'is charged as so often' (case 2)), the interviewees agree on the fact, that raising awareness of doubting minimum shelf-life (going along with discussion about the need of expiry date) is required. In general, both cases point out chances of circular economy approaches to minimize food losses, which are faced with various barriers/limitations like a lack of information, alternative marketing channels and food recovering possibilities (for farmers and retailers), interdependencies or limited resources (see **Table 6**).

5. Discussion and Final Remarks

The fruit and vegetable sector has grown globally regarding production and consumption, but around 44% of the production is either lost or wasted along the value chain. The emergence of food waste and losses in the fruits and vegetables supply chain varies differently among countries. While in high-income countries, the most significant amount of wastage occurs at the consumption and retail segment, in low-middle-income countries it is generally in the first stages of the food chain, i.e., production, packing, and processing, due to insufficient food technology to ensure quality and inadequate infrastructure. In this sense, it is possible to assume that

technological development plays an essential role in extending fruit and vegetable shelf life and reduce wastage. Still, the food waste in the production stage similarly occurs due to overproduction, harvest losses and lack of marketing infrastructure. Additionally, there has been a growing consumer intolerance towards cosmetic defects such as imperfections, color, and shape. Consumer's demand for 'perfect fruits and vegetables' results in retailers and distributors defining narrow specification norms, making it difficult for producers to meet the aesthetical norms.

Our study revealed that marketing standards are critical to fruit and vegetable waste and losses. Changing legal regulations would be the key determinant to minimize food losses in the sector. For instance, EU-marketing norms are still in place for a vast range of business in the fruit and vegetable supply chain, affecting not only EU exporting countries but also all fruit and vegetable suppliers from developing countries. Given to the fact that the fruit and vegetable production of the Global South will rise in future, the demand of tackling trading obstacles by a change of policies has to be underscored. As a matter of fact, "ugly food" has continuously been placed on the market, despite the consumer rejection, along with the additional oversupplied crops left on the field, because alternative marketing channels are missing, or there is not an option for circular economy strategies available.

In this paper, we review 64 business models in the EU, US, UK, and other high-income countries that adopted certain aspects of the circular economy strategy at different stages of the fruits and vegetable chain. Through this exercise we find few interesting examples of utilization of the circular economy concept whereby different actors along the fruits and vegetable value chain have collaborated and used technology to minimize wastage by adopting the 4R strategy. Since the global community has agreed on achieveing the target of SDG 122.3 by 2030, the circular economy concept is one promising instrument for reaching the targets and minimize food losses. Supermarkets are the main drivers of food marketing channels in developed countries, and therefore, they have the potential to lead the agenda of reducing of food wastage, by adopting a multi-pronged circular economy strategy comprising all stages from production to consumption.

Having identified various business models in this review, we noted some examples of large format retailers that have adopted circular strategies. Those strategies include collaboration with different stakeholders, such as technology-based aggregators, non-profit organizations, food processing industries, units to promote the reuse of food surpluses. For instance, the introduction of an in-house new range of 'ugly fruits and vegetable' and use of pricing strategy has created a new market for fruits and vegetables that would have otherwise been rejected due to aesthetical norms. Food-sharing apps could be used to intensify the redistribution of surplus food for donation activities. Technology-based innovations such as food surplus aggregators can play an essential role in connecting actors with surplus food to those who need food.

Moreover, linking producers to food processors or retailers to food processors also can minimize food wastage. Technology-based innovations such product development and innovation, processing food into by-products, development of apps, platforms able to aggregate food surpluses and better connect actors od the value chain. It is essential to highlight that "reduce" actions are the central piece in the 4Rs hierarchy working as a connector between the actors of the value chain. Circling flows of nutrient and matter were seen as activities taken to recycle the inedible fraction of food waste, as an input on the productive stage, or the transformed into by-products, or as energy recovered. Actors along the food chain should be incentivised to take actions on recycling and recovering strategies, in order to add value to food waste. However, aiming for zero waste is seen critical, as there will always arise (polluted) by-products in production processes.

All these examples highlight that there are existing strategies in the framework of the circular economy to reduce the loss of fruits and vegetables from farm to fork. However, there is a need for closer collaboration amongst actors. Although our interviewees partly doubt consumer's accountability and willingness to change consumption behavior, we suggest a joint responsibility of all actors along the food chain ('from farm to fork'). Stakeholder relations could be seen as a crucial point in the case study analysis, including identity and conflict of interests. Building cooperative partnerships and intensifying existing collaboration between actors of the food chain are underachieved regarding its potentials to minimize food losses. Although limitations remain

and zero waste seems to be unachievable in close future, some barriers could be broken down if all actors engage step in the right direction 'towards zero waste.' To do so, there is a pressing need for a common commitment by governments and businesses in the Global North and South to target the SDG related reduction of food losses and waste by 50% by 2030. Additionally, standards of defining and measuring food losses across countries and businesses need to be formulated so that the quantum of food wastage is measured comparably and managed.

In regard to the rising public sensitization and increasing food saving efforts, there is a need to change consumer behavior. Potentials to circle the food chain might also be inherent in supporting processing of food losses, in particular addressing emergencies like at the farmer's stage. Some business models (especially of big retailers) already reach to integrate the entire value chain. In future, including actors more from the outside of the food chain, e.g., researcher, could be considered. Furthermore, research is required to resolve definition problems, which are interlinked with accountability questions and that research efforts could examine existing policies on food wastage. Even if circular strategies identified in this paper are applied in high-income countries, 'lessons learned' (e.g., the importance of collaboration) could be transferred if taking into account local occurrences in the fruit and vegetable production.

Although we attempted to include several databases to find a preferably extensive literature stock, this study has some limitations, and might not provide a complete picture of all existing initiatives. As well, the small sampled case study probably comes up with selection bias, due to restrictions on resources in the context of this work. This fact could result in somewhat different interpretations depending on the individual researcher, and evaluation methods applied.

In total, our study showed various potentials of circling the food chain and that mostly all initiatives could be implemented through close collaboration amongst different actors along the value chain. Finally, it is important to consider that current food supply chains are the most dynamic and interacting systems, which indicates that making it more circular make major contribution to support a global sustainable food production.

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