Food procurement and short food value chains

AN ANALYSIS OF CASE STUDIES
IN PUBLIC AND PRIVATE REALMS

Edited by
Davide Fassi

DESIGN FOR
SYSTEMIC CHANGE

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9. Cultivating sustainability: transforming food waste into circular economy solutions

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ABSTRACT

Food waste is a significant global problem with extensive social, economic, and environmental impacts. According to the United Nations Environment Programme, food waste includes both edible and inedible parts removed from the human food supply chain. Despite substantial global food production, billion people face hunger, while food waste incurs considerable environmental, economic, and societal costs. Reducing food loss and waste is crucial for sustainability. Circular economy principles offer a promising approach to address this issue, as highlighted by the EU's circular economy action plan, which aims to double circular material use and halve residual waste. The European Commission prioritizes prevention in its hierarchy of food surplus strategies, followed by recycling, recovery, and disposal. Adhering to this hierarchy helps stakeholders minimize waste and enhance resource efficiency. Implementing a circular economy framework and prevention strategies can significantly reduce food surplus while promoting sustainability. However, achieving these goals requires collabora-

tive action, innovative solutions, and systemic changes in consumption and production patterns. This chapter reviews scientific literature to examine the impacts of logistics in the agri-food supply chain and identifies best practices and strategies for sustainable development. Addressing food waste is not only a moral and environmental necessity but also an opportunity to develop circular economy solutions that mitigate negative impacts and foster a sustainable future.
Keywords: Agri-food supply chain, circular economy, sustainability, prevention, reuse, recycling, strategies, food waste.

9.1 Introduction

Food waste is a global issue with significant socio-economic and environmental impacts. The scale of food wastage has reached unprecedented levels, with 14% of the world's food lost after it is harvested and before it reaches the shops (FAO, 2019). Despite the substantial global food production capacity, over than 3,1 billion individuals face persistent challenges in accessing an adequate and healthy diet, and more than 690 million people experience chronic hunger (FAO, 2022). This situation not only represents missed opportunities to improve food security but also incurs an annual cost of 2,6 trillion USD for the environment, economy, and society (Gustavsson *et al*., 2011; FAO, 2020).

Reducing food loss and food waste (stands as a fundamental imperative in the pursuit of sustainability (Zarbà *et al*., 2021). Most of the global hunger occurs in low-income countries, while the largest share of food waste occurs in middle- and high-income countries. However, food insecurity and food waste can coexist within countries and regions (FAO, 2021). For instance, in developed regions such as Europe and North America, annual food waste accounts for 168 Mt, while a significant portion, up to 12% of the population, continues to confront challenges related to food insecurity (Caldeira *et al*., 2019a).

As the world grapples with the challenges of sustainability and resource management, the concept of a circular economy presents a promising solution to the problem of food waste. A circular economy is a regenerative system designed to minimize resource input, waste,

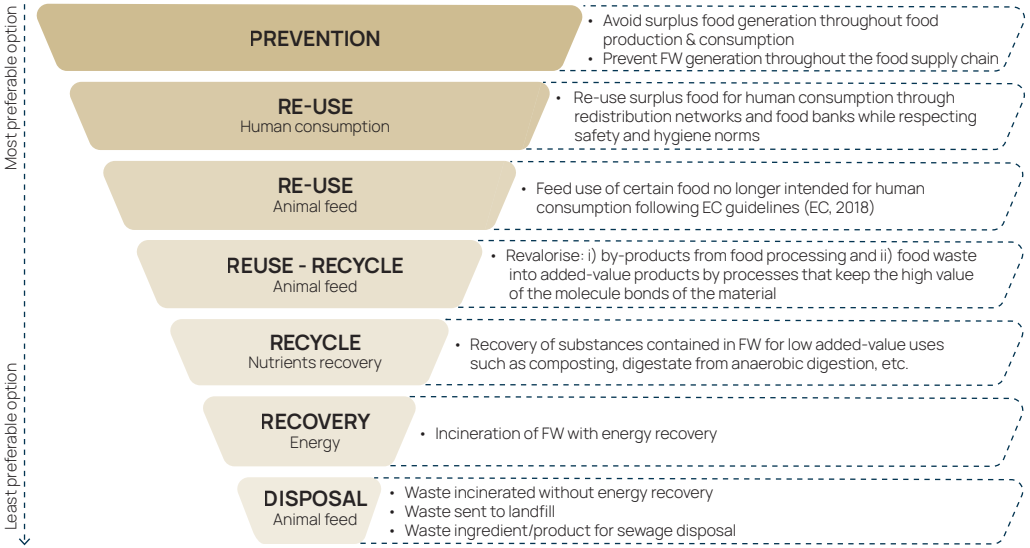

Figure 1. Hierarchy for prioritisation of food surplus, by-products, and food waste (FW) prevention strategies. European Commission, 2021.

emission, and energy leakage by slowing, closing, and narrowing material and energy loops.

The hierarchy pyramid (Figure 1) illustrates the preferred strategies for prioritizing food surplus, by-products, and food waste prevention (European Commission, 2021). At the top of the hierarchy is prevention, emphasizing actions aimed at minimizing or avoiding food waste generation through improved production, distribution, storage, and consumer behaviour. Next are recycling and recovery methods, including composting and anaerobic digestion, which help divert waste from landfills but are less preferable due to resource requirements. At the bottom is disposal, considered the least desirable option due to its environmental impact and failure to address the root causes of food waste.

By following this hierarchy, policymakers, businesses, and individuals can prioritize actions that have the greatest potential for reducing food waste and maximizing resource efficiency throughout the food supply chain. The European Commission and Eurostat have established a framework for monitoring progress toward achieving a circular economy using available statistical data. This framework primarily targets aspects of resource utilization and waste management within the circular economy. However, it currently does not encompass elements aimed at prolonging the value of products and materials,

such as designing for circularity, repair, and reuse. Implementing this framework will necessitate a significant overhaul of the production and consumption models. It will also require a fundamental shift in how to perceive resource utilization and disposal, along with the adoption of new consumer behaviours, such as opting for car sharing instead of individual vehicle purchases. Additionally, the EU has outlined several objectives in its circular economy action plan. Specifically, the plan aims to double the rate of circular material use and halve the EU's residual waste (European Environment Agency, 2023).

Recognising the urgency of this issue, several initiatives have emerged that aim to tackle food waste while promoting sustainable circular economy solutions. Developing appropriate initiatives to reduce food loss and waste formation is essential. Activating circular models for valorising food waste and managing irreducible waste sustainably requires a clear understanding of the existing amount of food waste. To achieve the goal of reducing food waste, a collaborative approach involving institutions, governments, private entities, and households is needed. Successful reduction efforts would yield numerous benefits, including economic savings, environmental protection, and social improvements by contributing to the fight against food insecurity. This chapter aims to review the scientific literature to examine the economic, environmental, and social impacts, highlighting best practices, strategies, and potential contributions to sustainable development.

9.2 Material and Methods

The literature review was performed based on a specific scientific literature-searching procedure. To carry out this study, the authors performed bibliographic research looking for articles that reflect the scope of the review. Once the research phase was completed, the authors carried out a selection based on some specific criteria correlated to the expertise area.

The thematic research area of the present chapter was identified in the distribution phase of the agri-food supply chain. The research was carried out by investigating the three hierarchy strategies (prevention or reduction, reuse, and recycling) identified by the

European Commission (European Commission, 2021) for food waste management considering the three pillars of sustainability, through the collection of articles by using the Google Scholar databases, searching the following combination of keywords:

1. for economic aspects:
    - distribution phase AND economic sustainability AND food waste reduction OR food waste prevention;
    - distribution phase AND economic sustainability AND food waste reuse;
    - distribution phase AND economic sustainability AND food waste recycling;
2. for environmental aspects:
    - distribution phase AND environmental sustainability AND food waste reduction OR food waste prevention;
    - distribution phase AND environmental sustainability AND food waste reuse;
    - distribution phase AND environmental sustainability AND food waste recycling;
3. for social aspects:
    - distribution phase AND social sustainability AND food waste reduction OR food waste prevention;
    - distribution phase AND social sustainability AND food waste reuse;
    - distribution phase AND social sustainability AND food waste recycling.

The literature review was conducted between April 2024 and June 2024. No limitations were placed on language, time, or publication status, and duplicate entries were not included in the final analysis.

9.2 Results and Discussion

Literature analysis

The literature has been arranged by the European Commission's waste policy, which focuses on prevention and reduction rather than disposal (prevention, reuse, and recycling), taking into account the three pillars of sustainability (economic, environmental, and social) (table 1).

Sustainability pillar	Economic	Environmental	Social
Prevention	Cristóbal *et al*., 2018 Huang *et al*., 2021 Annosi *et al*., 2021	Bottani *et al*., 2018 Leal Filho *et al*., 2023 Read and Muth, 2021 Diaz-Ruiz *et al*., 2019 Sagi and Gokarn, 2023 Chroni *et al*., 2021 Loiseau *et al*., 2020 Ottomano Palmisano *et al*., 2021	Lombardi and Costantino, 2021 Sgroi *et al*., 2024 Mazzucchelli *et al*., 2021 Fassi and Meroni, 2023 Benge, 2017
Reuse	Goossens *et al*., 2019 Bottani *et al*., 2019 Colombo de Moraes *et al*., 2020 Huang *et al*., 2021 Cristóbal *et al*., 2018	Bottani, et al., 2018 Aramyan *et al*., 2017 Adedeji, 2022 Ekren and Kumar, 2022 Wani *et al*., 2024	Hebrok and Boks, 2017 Secco *et al*., 2024 Mura *et al*., 2019
Recycle	Cristóbal *et al*., 2018 Sarker *et al*., 2022	Tuni and Rentizelas, 2022 Bottani *et al*., 2019 Bottani *et al*., 2019	Lombardi and Costantino, 2021

Table 1.
Scientific bibliography collected and grouped according to the three pillars of sustainability and considering the management of food waste at the distribution stage.

To achieve effective sustainability in all three stages of the hierarchical pyramid – prevention, reuse, and recycling – it is essential to consider the three pillars of environmental, economic, and social sustainability in an interactive and entwined synergy (Annosi *et al*., 2021; Huang *et al*., 2021; Lombardi & Costantino, 2021; Ottomano Palmisano *et al*., 2021). This integrated approach is supported by the scientific literature emphasizing the importance of the European Commission's hierarchical rules (Loiseau *et al*., 2020; Huang *et al*., 2021). However, some authors pointed out that the European Commission's framework highlights mostly the environmental focus. Although this pillar is represented as the fundamental basis. When considering other criteria, such as economics, other tools are needed to pursue the optimization of the circular process (Cristóbal *et al*., 2018). Indeed, to achieve the most environmentally sustainable results, when programming a prevention program, the scarcity of economic resources has to be considered. Also, the economic perspective helps maximize the social benefits and mitigate the social impacts associated with food waste (Moraes *et al*., 2020; Sgroi *et al*., 2024). Moreover, the potential insights that might result from the present research intend to try to

be as general as possible to apply to a variety of cases that could also exceed the European Union context. Other Countries, not part of the European Economic Space, face the food management issue (Sarker *et al*., 2022; Graham-Rowe *et al*., 2014).

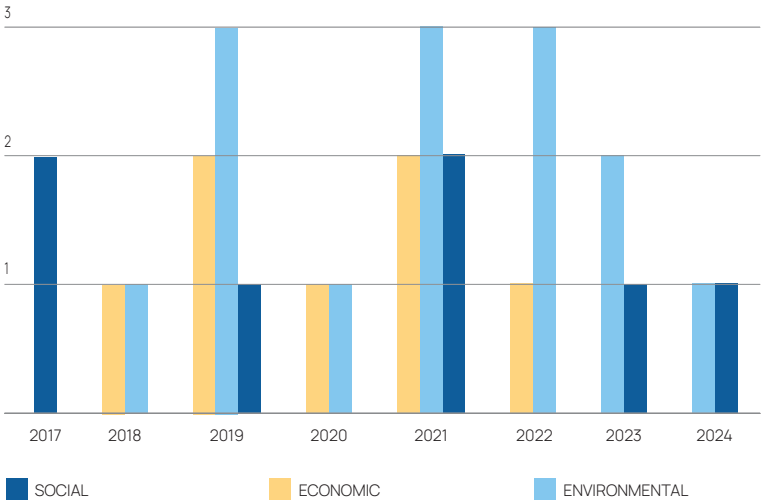

Figure 2. Trends in scientific research on the management of food waste at the distribution stage concerning the three pillars of sustainability.

Figure 2 presents the evolution of the scientific landscape on food waste management. In particular, it shows that the scientific interest focused on the distribution stage perspective started recently, for environmental and economic, from 2018, only the social sustainability publication increased from 2017. The interest in this topic is remarkable and it shows an increase in the number of publications, in the period from 2017 to 2024, 7, 14, and 7, for the economic, environmental, and social pillars respectively.

Economic consideration and best practices identifications

The European Council (2024) highlighted that almost 59 million tonnes of food waste is generated in the EU annually, corresponding to about 131 kg per person. More than half of food wasted occurs in households (53%), while considerably fewer shares come from processing (20%), production (11%), restaurants and services (9%), and retail and distribution (7%). In economic terms, about 132 billion euros is lost every year because of food waste.

According to the Circular Economy (CE) Action Plan (European Commission, 2015), food waste prevention is a crucial topic within

the European political debate, so food waste is included among the *priority areas* that should be considered to strengthen the circularity of the European economy.

Best practices for reusing food waste have been described by several scientific papers. Perishable food and/or close to expiring at the retail stage can be redistributed by charitable organizations (Goossens *et al*., 2019). The redistribution of unsold food still suitable for human consumption is certainly an ethically preferable option that involves the adoption of appropriate management systems that ensure food safety for the final recipients and the economic sustainability of the redistribution process. Specific channels dedicated to the *reverse* logistics of unsold food are still underdeveloped in Italy.

According to Bottani *et al*. (2019), the most challenging problems to be addressed to ensure the economic sustainability of redistribution are related to the efficient design of the routes of the vehicles collecting the food from retail outlets, and to the number and location of food distribution centres. To facilitate the adoption of efficient redistribution schemes, best practices such as collaboration with food donation NGOs are proposed to better define the location of stores and distribution centres and to know the quantities of food offered and demanded (Colombo de Moraes *et al*., 2020).

Best practice in food reuse is also related to the possibility to reprocess food, by retailers that transform the surplus fruit nearing the end of its shelf life into juices, fruit cakes, or pies (Huang *et al*., 2021). Food unsold by retailers can be resold by specialised discounts, as observed particularly in the U.K. and Denmark, or by retailers themselves through platform apps such as *Too Good To Go* (EU) and *Flashfood* (U.S. and Canada), which allow consumers to buy extra discounted food packaged by retailers at the end of the day. Another way of managing unsold food is to offer it free or at a reduced price to staff at the point of sale or to use it for meals in the staff canteen (Huang *et al*., 2021).

According to Cristóbal *et al*. (2018), food waste can be reused for feeding animals after it is heat-treated and dehydrated and either mixed with dry feed or directly fed. Recycling strategies can maximize the value of food wasted contributing to achieving a circular economy model. Currently, there is no extensive scientific literature

suggesting best practices for recycling food waste generated at the distribution phase.

However, Cristóbal *et al.* (2018) and Huang *et al.* (2021) pointed out the following best practices: i)transport food waste to a centralized plant where it is converted into compost; ii) perform anaerobic digestion, a process in which microorganisms can break down food waste in the absence of oxygen resulting in two end-products: biogas and digestate. Also, Sarker *et al.* (2022) and Huang *et al.* (2022) highlighted that the development of innovative technologies can convert food waste into high-value items, such as bioactive compounds (e.g. pectin, polyphenols, and carotenoids) bioplastics, and biofuels (e.g. biodiesel, biogas, and electricity).

Environmental consideration and best practices identifications

To implement sustainable food systems that ensure food and nutrition security, it is crucial to make all components of agri-food systems sustainable, efficient, and resilient (Ottomano Palmisano *et al*., 2021). This approach involves addressing both product supply and consumptive demand elements to achieve sustainable food consumption and production patterns. Reducing food losses and waste is a key strategy in this context, which can be addressed through various measures. Beretta *et al.* (2013) found that 48% of the total calories produced are lost across the whole food value chain, with half of these losses being avoidable given appropriate mitigation measures. This emphasizes the need for accurate data collection to monitor and target strategies to reduce food waste.

Tuni and Rentizelas (2022) applied an eco-intensity-based method to assess the environmental sustainability performance of a multi-tier food supply chain. They found that the method was able to support the improvement of the supply chain environmental performance and contribute to the wider green supply chain management field. This study demonstrates the potential of eco-intensity-based methods for assessing and improving environmental sustainability in agri-food supply chains (Tuni & Rentizelas, 2022).

According to Bottani *et al.* (2018), the best practices could search involve finding ways to reuse agri-food waste by upcycling it into valuable products and integrating circular bioeconomy prin-

ciples. At the same time, there's a need to encourage changes in behaviour and improvements in food labelling practices to support these initiatives. Additionally, when looking closely at the environmental impacts of different situations, such as the duration of storage for perishable food waste, the urgency becomes apparent. For example, limiting storage to 5 days can increase environmental impact by 25% (average across different impact categories), a significant finding that needs attention (Bottani *et al*., 2018). Exploring alternative paths, such as using perishable food waste as animal feed, is also important. It's something to be explored in future research, especially when considering longer storage times or different uses. Furthermore, the European Commission's push to reduce landfill sites in the EU adds another layer of importance (Bottani *et al*., 2019).

Loiseau *et al*. (2020) suggest that logistics play a significant role in environmental impact and there's room for improvement. They emphasize the need to evaluate how short and local supply chains can enhance their environmental performance compared to traditional ones. The results indicate that optimization of logistics in short-supply chains could lead to better performance than conventional ones. Consumers also impact environmental sustainability through their food purchasing habits, especially in urban areas. The findings can be applied to fresh products like fruits and vegetables, but further research is needed to understand supply chain organization for different food categories.

Further to optimize food redistribution and maximize its positive impact, proposing the Life Cycle Assessment (LCA) study for the redistribution centre would be beneficial. This study would involve assessing the environmental impact of recovered fruit and vegetable products throughout their life cycle, including production, transportation, storage, and distribution processes. By quantifying environmental impacts and identifying areas for improvement, such as reducing emissions or optimizing transportation routes, the redistribution centre can enhance its sustainability practices and contribute to greater environmental benefits.

Social consideration and best practices identifications

Food waste reuse could be done at different points of the food chain:

- directly from the wholesale markets (e.g. Recup);
- from markets and supermarkets food overflow (e.g. Food Hub Milan);
- from the private and public catering system, such as *Avanzi popolo 2.0* (Lombardi & Costantino, 2021);
- from physical or digital Neighbours networks of local markets, e.g. *To Good To Go* (Mazzucchelli *et al*., 2021; Sgroi *et al*., 2024), *SOSpesa Nolo* (Fassi & Meroni, 2023);
- sharing among community-based fridges from local businesses and households food overflow (Benge, 2017).

People may not necessarily establish the connection between food waste and environmental issues (Graham-Rowe *et al*., 2014).

Although it seems clear, from the theoretical point of view, what are the consequences of personal actions, this seems, in practice, to be not sufficient to change individual habits and customs (Hebrok & Boks, 2017). The significant proportion of domestic leftovers in Italy, 74% of the total food waste in the supply chain (Eurostat, 2021), highlights the lack of awareness among people in their homes regarding the impact of their actions. Further, the role of the individuals could affect the community they are in by bringing their concerns about the topic into their social circles, families, and jobs. It is crucial to enhance personal awareness towards these issues by starting an educational process in the young generations to enhance the sense of responsibility towards their relationship to food production, consumption, and its end of life, having the chance to establish a deep link between their dietary decisions, and the ecosystem they are a part of. Therefore, starting within the educational system (schools, universities) and intertwining with the related food system it is possible to implement these strategies:

- providing a didactic laboratory where students can physically engage with food waste;
- awareness related to the monitoring systems to measure the amount of food waste generated (e.g., Bergamo Food Policy, 2023; Secco *et al*., 2024);
- reducing portion sizes to minimize food waste;

- training catering staff to improve food presentation (Ferreira *et al*., 2014);
- training staff to prepare meals from scratch while paying attention to food waste and leftovers (EatingCity, 2014; Martinez, 2015);
- assessing the quality of meals by involving the users (e.g. Berkley_Dining);
- involving students in the meal preparation process (Romani *et al*., 2018; Willet *et al*., 2019);
- ensuring the redistribution of surplus food to those in need at short and medium distances (i.e. charity associations).

In this way, the weaknesses in the food system, that result in food waste within the supply chain, might be transformed into a chance to tackle inequalities, promote consciousness, and develop a sense of responsibility towards individuals and their everyday actions. Addressing food waste as a valuable resource creates a virtuous circular economy, may turn socio-economic dynamics, and promote a fairer and more empowered community, implementing economic growth and enhancing resilience (e.g. *SOSpesa Nolo*, *Avanzi Popolo 2.0*). Effective management of food overflow can assist vulnerable people while fostering a culture of social innovation that promotes awareness about food and its wastage (Mura *et al*., 2019).

Food no longer edible for human consumption is useful for composting, following a circular economy approach that prioritizes efficient material and waste management to promote community co-operation and openness (e.g. *Coltivando*). The process also facilitates the construction of new services that reduce environmental negative impact, taking care of green areas and engaging communities (Slater *et al*.,2010; Fassi *et al*., 2012), helping to create a consistent network among people.

9.4 Conclusion

The interest in food waste management, particularly at the distribution stage, and from the perspective of the three pillars of sustainability, has gained significant attention in the scientific literature.

Despite being relatively new, this trend has shown consistent growth, suggesting that it will continue to increase in the coming years. The emphasis on sustainability in scientific studies is reassuring, as this issue has widespread impacts on many fundamental aspects of daily life (Hebrok & Boks, 2017). Additionally, empowering collaborative actions among stakeholders can lead to more sustainable approaches in social, economic, and environmental aspects. The European Commission principles constitute a driver framework for the best promising approach, recognizing the importance of the role of the involved parties and the need for concerted and uniform rules and standards within the European Union.

In this perspective, the analysis performed in the chapter demonstrated the power of collaboration between stakeholders, including non-profit organizations, local businesses, government bodies, and communities. These initiatives employ innovative strategies such as food redistribution, awareness campaigns, technological solutions, and circular economy principles to minimize waste, redistribute surplus food to those in need, and foster sustainable practices. From intercepting surplus food at wholesale markets to launching food-sharing platforms and implementing life cycle assessments to quantify environmental impacts, each case study showcases unique approaches to addressing food-related challenges while promoting social inclusion and environmental stewardship. Collectively, these initiatives highlight the importance of holistic, community-driven approaches to tackling complex issues surrounding food waste and insecurity.

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