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Facultat
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Circular Economy and Degrowth for food waste prevention and reduction

Bachelor Degree in Economics in English
Final Bachelor thesis

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Department of Economics and Economic History

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Abstract

Food production is the largest driver of ecological impact and transgression of planetary boundaries. Food waste and food waste management contribute significantly to GHG emissions, and more in general to environmental and social degradation. The concepts and the strategies deriving from the circular economy have been widely implemented to tackle this challenge. However, circularity itself does not imply sustainability. In particular, the degrowth movement argues that, in the context of entropy and taking into account evidence on inexistent decoupling, the potential of circular economy sustainability is limited by the pursuit of economic growth and capitalistic behaviours. The intention of this thesis is to study circular economy and degrowth approaches to food waste. Using the Food Recovery Hierarchy, I would like to investigate to what extent is circularity applied. Moreover, a further objective of this research is to explore the possibility and the outcomes of complementing circular economy with degrowth approaches to better manage food waste prevention and reduction.

Key words:

food waste, circular economy, degrowth, food recovery hierarchy, food waste reduction, food waste prevention, circularity, sustainability, economic growth.

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List of abbreviations

CE: Circular Economy

FWL: food waste and food loss

ES: Ecosystem services

EMF: Ellen MacArthur Foundation

CSA: community-supported agriculture

LCA: life-cycle assessment

Chapter 1. Introduction

1.1 Justification

The global food sector is facing significant challenges, as the world's population grows and incomes rise, increasing the demand for food production. However, this expansion is not sustainable, as food production is the single largest driver of ecological impact and transgression of planetary boundaries (Loken et al., 2020). According an analysis carried out by Springmann et al. (2018), if no technical changes or mitigation measures are taken, environmental pressures from the food system could increase by 50-92% by 2050.

One major contributor to this problem is food waste, which accounts globally for 40% of all food produced that is 2.5 billion tonnes of waste (Da Gama et al., 2021). Along the supply chain, 20-25% of food is lost after harvest on farm, transport, storage, wholesale and processing and 17% of food is wasted at the household, food service and retail levels (Da Gama et al., 2021). Food that ends up in the landfill is responsible for 8-10% of world GHG emissions, in fact if it was a country it would be the 3rd largest greenhouse gas emitter behind China and USA (*Food Wastage Footprint*, 2013). Moreover, the biggest contradiction of the food sector is that "We already grow Enough Food for 10 Billion People … and Still Can't End Hunger", as stated by the title of Holt-Giménez et al. (2012) paper, it is clear that hunger is produced by poverty and inequality, not scarcity. Reducing and improving food waste management can help saving food for human consumption, bringing savings for primary producers, companies and consumers and lowers the environmental ad climate impact of food production and consumption.

The food loss and food waste (FLW) challenge is addressed by the UN Sustainable Development Goal 12.3 (SDG 12.3) which sets the target for 2030 to "*halve per capita food waste at the retail and consumer level, and reduce food losses along the food production and supply chains*" (UN, 2015). The UN website includes information on circular economy (CE) as part of the knowledge resources and tools for SDG 12 (Belmonte-Ureña et al., 2021). The CE provides an alternative to the current linear *take-make-waste* material and energy flow model of the economy by maintaining the value of products, materials and resources for as long as possible and minimizing generation of waste

(European Commission, 2015). CE actions aim at increasing resource efficiency and decreasing environmental impacts by enhancing reducing, reusing, recycling, and recovering materials in production/distribution and consumption processes (European Commission. Directorate General for Research and Innovation., 2020; Kovacic et al., 2020).

CE is a concept that has gained popularity in recent years as a potential solution to the environmental crisis, while promoting economic growth and social progress (Korhonen et al., 2018). However, it is not clear whether this model can overcome the environmental and social crisis we face (O'Neill et al., 2018), as it has conceptual and practical limitations (Korhonen et al., 2018) . In particular CE faces: limits to circularity due to physical constraints and limits to sustainability due to inexistent decoupling of economic growth from environmental pressure (Giampietro, 2019; Hickel & Kallis, 2020; Schröder et al., 2019; Zink & Geyer, 2017).

Physical constraints to the CE include the limited availability of materials suitable for recycling and the existence of entropy. In the case of food waste, edible food can be reused for human consumption and inedible can be recycled for compost, therefore there is a potential for 100% circularity. This is the case of South Korea which, with rigid policies such as banning dumping in a landfill and compulsory food waste recycling, has managed to recycle about 95% of food waste in 2021 by using it for animal feed and turning it into biogas or fertilizers (Kim, 2019, 2022). Nevertheless, Seoul's food waste processing centres reports large amounts of fertilizer that remain unused, which is an indicator that food waste is too large, even if it is 100% circular (Kim, 2019).

Furthermore, CE is subject to the thermodynamics law of entropy, which means that every circular process or project will require energy and generate waste, leading to increasing entropy and decreasing exergy (Giampietro, 2019; Kallis et al., 2020).

The transition to a CE economy carries the explicit promise of decoupling. The Ellen MacArthur Foundation has often promoted the definition of CE as this "*new economic model seeks to ultimately decouple global economic development from finite resource consumption*" (Ellen MacArthur Foundation, 2015). Kallis and Hickel (2020) show that, even though global historical

trends show relative decoupling, there is no evidence of absolute decoupling, the 21st century experienced decoupling trends showing worse efficiency. Moreover, Kallis et al. (2020), argue that decoupling is also unlikely to happen in the future. Part of the reason why decoupling is not happening is related to the Jevons paradox, also known as the rebound effect, which occurs when improvements in material efficiency are offset by increase in consumption (Schröder et al., 2019; Zink & Geyer, 2017). As showed by Zhang, Dhir, and Kaur (2022), in the rebound effect related to CE is likely to happen also in food sector

Given the arguments exposed above, the implementation of CE has to go in hand with limits to resource extraction and energy use. Moreover, when implementing CE the volume and the pace at which the economy is growing is highly relevant (Arnsperger & Bourg, 2016). For this reason, embracing degrowth principles and concepts can be significantly useful for improving the environmental impact of CE practices (Arnsperger & Bourg, 2016; Hoehn et al., 2021; Kallis et al., 2020). In fact, the degrowth movement advocates that economic growth is highly detrimental for the environment and for social well-being and it strives to lessen the environmental impact by decreasing production and resource consumption of countries with high ecological footprints (Kallis et al., 2020). Arnsperger and Bourg (2016) argue that an "authentically circular economy" is one that consumes and produces less, moving closer to degrowth and consequently archiving true circularity.

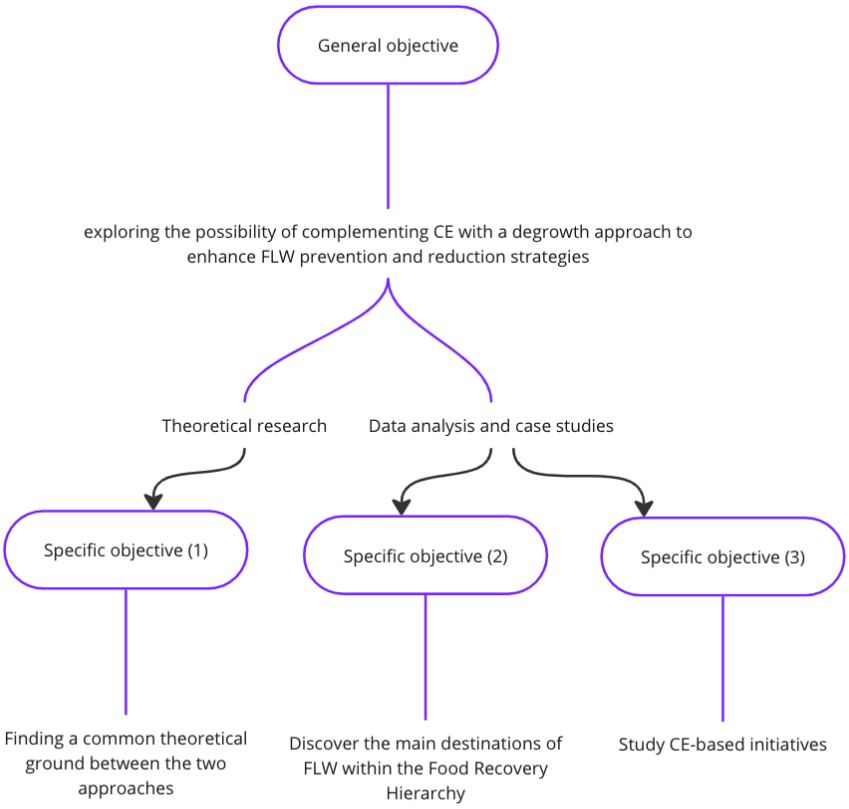
In this thesis I would like to explore more the possibility of complementing CE with a degrowth approach and show why this particularly important for food waste management.

1.2 General and specific objectives

The general objective of this thesis is to explore the possibility of complementing CE with a degrowth approach to enhance FLW prevention and reduction strategies. Specifically, I am interested in finding a common theoretical ground between the two approaches. For this, I will first offer a literature overview on CE a Degrowth common theoretical background: Ecological Economics (2.1).

Then, I am going to deepen on CE (2.2) and Degrowth (2.3) definitions, principles and applications to food loss and waste prevention separately. In section 2.4, I am going to review the existent literature on CE and Degrowth together. In the second part of the work, my objective is to discover the main destinations of FLW in the food supply chain at a national level for Spain mainly and study CE-based initiatives. For this, I am going to search and analyse the available data on FLW destinations (4.1.1 & 4.1.2). Finally, I will analyse Catalonia-based organizations that use circular solutions as well as, in some cases, degrowth principles to fight FLW (4.2). The methodology will be presented in Chapter 3.

Figure 1: General and specific objectives diagram



Chapter 2. Theoretical Framework

2.1 The Ecological Economics framework: The Paradigm shift

For this section, I am going to refer mainly to the text book “Ecological Economics: Principles and Applications” by H. Daly and J. Farley (2004), which constitutes a complete body of work on this trans-discipline that incorporates economics thought with insights from other social sciences as well as biology and physics.

Ecological economics challenges the neoclassical vision of the economy as an isolated system and instead recognizes its embeddedness in society and nature. The neoclassical vision of the economics machine, also adopted by environmental economics, has often been represented with the circular flow diagram. While the circular flow diagram is a useful tool for analysing the flow of exchange value, it contributes to a misleading vision of the economy as a whole by ignoring its relationship with the environment (Daly & Farley, 2004; Raworth, 2017). The limitations of this diagram are not due to its oversimplification but instead to the fact that it affects our pre-analytical vision of the economy. As systems thinker John Sterman points out, "*The most important assumptions of a model are not in the equations, but what’s not in them; not in the documentation, but unstated; not in the variables on the computer screen, but in the blank spaces around them*" (Sterman 2002, in Raworth 2017 p.58) In the case of the circular flow model, the linear throughput of matter-energy, or the metabolic throughput, is absent, making it difficult to see how the economy relies on the environment to sustain itself.

Ecological economics offers a holistic perspective that acknowledges the economy as a part of the wider ecosystem. Therefore, unlike environmental economics, which studies the

relationship between the economy and the environment as if they were separate entities, ecological economics views the economy as a subsystem of nature, which it's limited and scarce. Economic activities lean, either directly or indirectly, on resource extraction, use and waste production, producing contingent externalities that have continuously depleted the environment. Standard economics have tried to tackle this challenge by arguing that ecosystem services (ES) could be efficiently allocated by markets and that monetary values could be assigned to them. However, none of them satisfy the characteristics required to be efficiently allocated or provided by the market as they are rival and/or non-excludable and producing their equivalent substitutes is often not feasible. Even if we were able to allocate them separately, it wouldn't imply that all resource together are efficiently allocated. Most ES are nonmarket goods which are difficult to value because of our lack of knowledge on their functions and our lack of familiarity with valuing nonmarket goods (Daly & Farley, 2004). Moreover, commodification applied to ES can be quite controversial, monetary values may not be appropriate or meaningful (Daly & Farley, 2004) and questions of ethics and politics should be taken into account (D'Alisa, 2014).

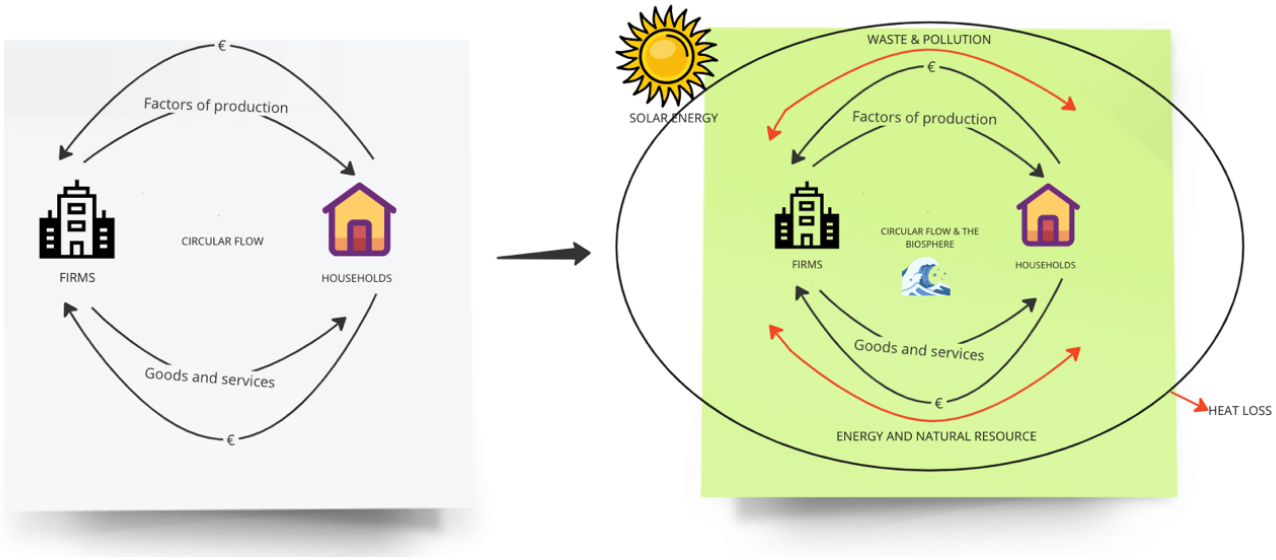
The economy is a open systems, that exchanges materials and energy with the environment (a closed system, where only energy flows in and out). The linear throughput of the economy, from raw material inputs to waste outputs, is in physical units and as such is subject to the laws of physics. The first law of thermodynamics tells us that energy it's preserved and cannot be created or destroyed, therefore we cannot make something from nothing and what was first used as input will eventually transform into waste. The second law of thermodynamics refers to the increasing level of entropy (disorder) of an isolated system, such as the universe. Therefore even if energy is conserved, its quality will deteriorate. In an open or closed system, external high quality energy can come in, reducing entropy, at the expense of increasing entropy somewhere else. Furthermore, materials can't be 100%

recycled and energy can’t be recycled at all. The economy transforms low-entropy materials into high-wastes.

As the economy grows, natural resources decrease or deteriorate, this is what we refer to as the opportunity cost of economic growth. Economic expansion is subject to the law of increasing marginal cost and the law of diminishing marginal returns. Therefore, the optimal point up to which an economy can grow is where marginal cost equal marginal benefits. In an "empty-world economy," where the economic subsystem is small compared to the broader ecosystem, the environment may seem abundant, and the marginal benefits are higher than the marginal cost. However, as the macroeconomy expands, it requires more resources, materials, and space. Eventually, this leads to a "full-world economy", where the marginal cost of growth may outweigh its marginal benefits, resulting in "uneconomic growth".

Ultimately, Ecological Economics reclaims the original meaning of economics, in Greek *oikonomia*, which is the art of wisely managing the “household”. Aristotle famously made a distinction between *oikonomia and chrematistike,* the latter meaning the art of making money. Ecological economics aims at staying within nature limits while considering simultaneously matters of efficiency, human and environmental well-being (Daly & Farley, 2004; Gerber & Scheidel, 2018).

Figure 2: The Paradigm shift, from the circular flow diagram to economics embedded in nature



2.2 Circular Economy

2.2.1 Definition, principles and strategies

Over the last decade, the concept of the circular economy has gained widespread attention among policymakers, business organizations, and governments worldwide, leading to a constant evolution of its meaning through its application. The existing literature has highlighted the ambiguity and lack of a widely accepted definition of the CE Prendeville, Cherim, and Bocken 2018).

Kirchher et al. (2017) after analysing 114 different definitions, define the CE as an economic system that replaces the current linear material and energy flow model of the economy with a circular one by enhancing reducing, reusing, recycling, and recovering materials in production/distribution and consumption processes. It operates at micro, meso, and macro levels and aims to accomplish sustainable development, creating environmental

quality, economic prosperity, and social equity for current and future generations. The CE is enabled by novel business models and responsible consumers.

The Circle Economy (Circle Economy, 2022) has outlined four main principles of a Circular Economy (CE): using less (*narrow*), using materials for longer periods of time (*slow*), substituting hazardous materials and processes with regenerative ones (*regenerate*), and recycling and reusing materials (*cycle*). Following these principles CE aims to reduce material inputs, extend the lifespan of resources, avoid hazardous materials and processes, and promote reusing and recycling of materials.

The Ellen MacArthur foundation (EMF), one of the most influential institutions of circular economy research and divulgation, has introduced the butterfly diagram to illustrate the flow of materials in the circular economy (Ellen MacArthur Foundation, 2013). This diagram (Figure 3) distinguishes between two main cycles: the technical cycle, for non-biodegradable materials such as metals, and the biological cycle, that includes biodegradable products such as food. CE strategies depend on which cycle the material belongs to. Strategies for the technical cycle include maintaining and reusing products, repairing, remanufacturing and recycling. Materials from the biological cycles can be cascaded for additional application in different values streams and when they can't be used further they can be composted, anaerobically digested to extract valuable components or produce energy sources. Along with these strategies, a CE should also contribute to entail regenerative production practices, that build natural capital instead of degrading it.

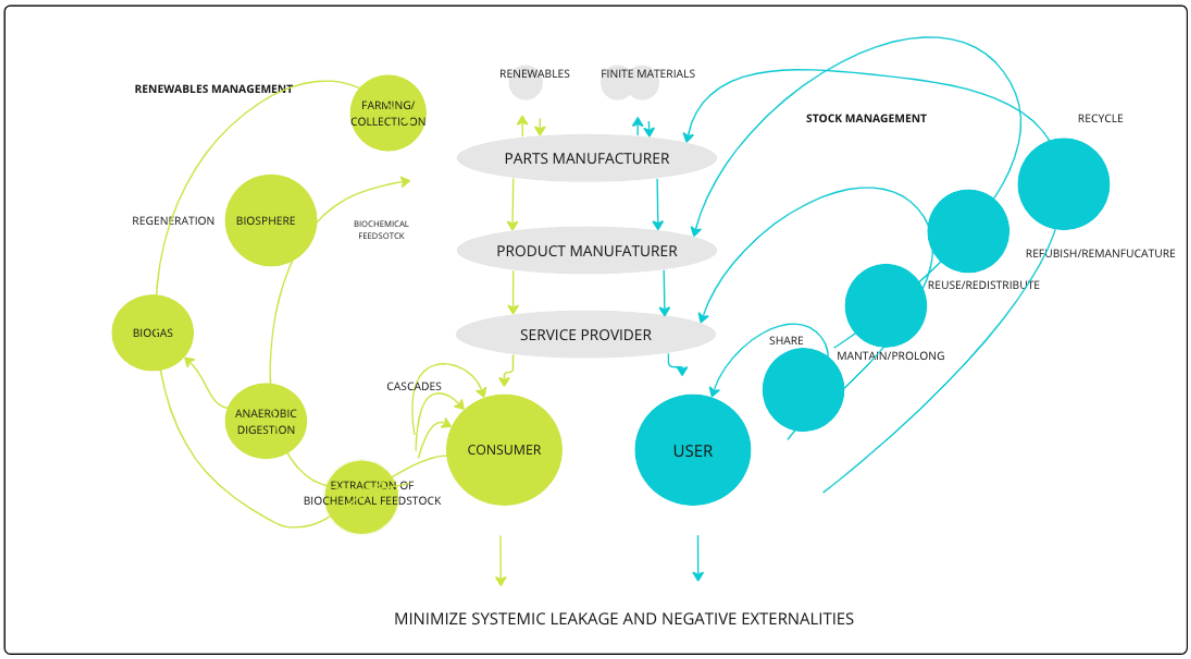


Figure 3: The Butterfly Diagram adapted from EMF

2.2.2 Actions for food loss and food waste prevention

Before addressing strategies for FLW prevention, it is crucial to define what constitutes FLW. Definitions vary significantly in the literature and require harmonization for efficient quantification (Teigiserova et al., 2020; Vittuari et al., 2016). According to the project Fusions, funded by the EC, food waste includes any food that has entered the food supply chain and has been removed or discarded at any stage before final consumption, whether edible or inedible. Immature products and food intended for feeding or industrial use are excluded from this definition (Stenmarck et al., 2016). FAO's definition differentiates between food loss and food waste, with the former referring to a decrease in edible food at production, post-harvest, and processing stages, while the latter involves edible food discarded at the retail and consumer levels (Vittuari et al., 2016). Fusions does not differentiate between food loss ad food waste, and the FAO does not include inedible food.

Teigiserova et al. (2020) propose a more comprehensive set of definitions that include: surplus food, as edible food, food waste, as naturally inedible and inedible due to exogenous or endogenous factors, and food loss, as food not accounted for.

Circular strategies for FLW, such as the ones illustrated by the butterfly diagram, can be found in the Food Recovery Hierarchy (excluding disposal), followed by the Environmental Protection Agency (EPA) and the European Commission (EC). From the most sustainable at the top of the pyramid to the least at the bottom tip, the Food Recovery Hierarchy includes:

- Prevention: avoid surplus generation and food waste thorough the supply chain
- Reuse: reuse surplus for human consumption (ex. redistribution networks, food banks)
- Reuse: use food that is no longer intended for human consumption for animal feed
- Reuse by products and Recycle food waste: revalorise by product and food waste
- Recycle to recover nutrients: Anaerobic digestion (more preferable) & Compost (less preferable)
- Recovery of energy: Incineration of waste to recovery energy
- Disposal: incineration without energy recovery, disposals into landfill or for sewage disposal

Accordig to Teigiserova et al. (2020), prevention and reuse for human strategies are suitable for surplus food, food loss is treated with the least preferable option (disposal) and the rest of strategies is apt for food waste.

Figure 4: Food Recovery Hierarchy

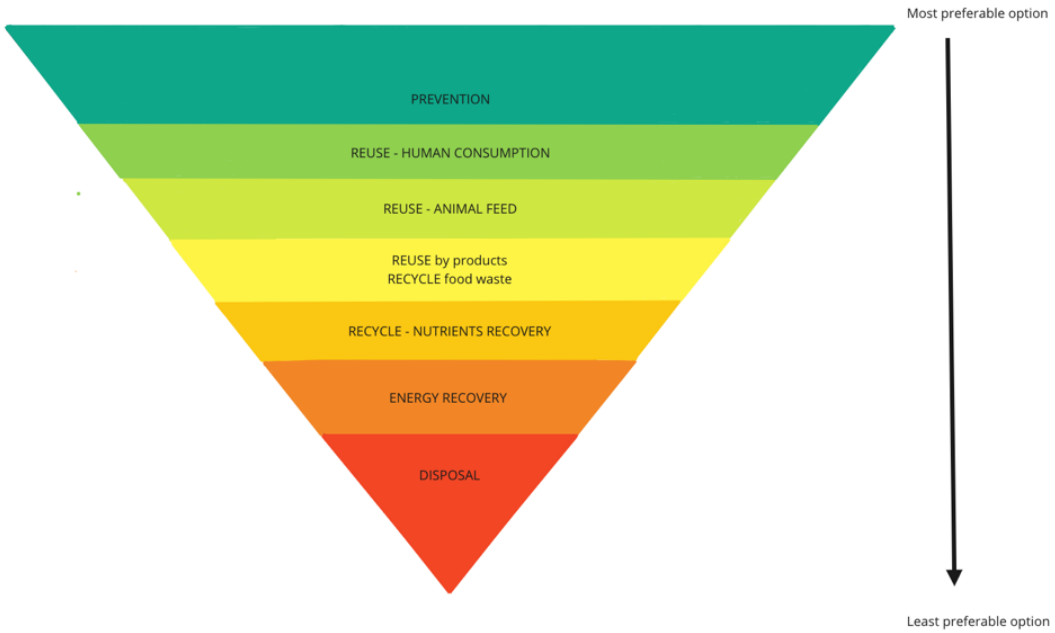


Table 1 Definitional Framework

	Definitional Framework	Definitional Framework	Excludes
Food and Agriculture Organization (FAO) (Vittuari et al. 2016)	*FW: "decrease in the quantity or quality of food resulting from decisions and actions by **retailers**, food service **providers** and **consumers**"* *FL: "decrease in the quantity or quality of food resulting from decisions and actions by food **suppliers** in the chain, excluding retailers, food service providers and consumers."*	Edible	Inedible
Fusions (Stenmarck et al. 2016)	FW: "Fractions of "food and inedible parts of food removed from the food supply chain" to be recovered or disposed (including - composted, crops ploughed in/not harvested, anaerobic digestion, bioenergy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea)."	Edible and Inedible	• Not mature; • Not intended for human consumption (feed or industrial use);
Teigiserova et al. (2020)	Surplus food: "edible food " FW: " naturally inedible (pits), industrial residue, inedible due to natural causes (pests), inedible due to ineffective management" FL: "not accounted for"	• Edible; • Inedible; • Not mature • Not intended for human consumption	

2.3 Degrowth

2.3.1 Definition, principles and strategies for FLW

The Degrowth movement is a critique to growth and capitalism which have produced a widespread process of commodification, social inequalities and ecological crisis also perpetuated by the exhaustive measure of GDP as a proxy for a nation's *flourishment* /development (D'Alisa, 2014). As an alternative it proposes the creation of a society that strives to satisfy its needs and achieve well-being, environmental and social justice all while deepening democracy and autonomy(D'Alisa, 2014; Kallis et al., 2020). This implies a new imaginary and a shift away from the dominant cultural and scientific narratives that portray human's true nature similar to the one of the *homo economicus*, who makes decisions based on utility maximization for individual gain (D'Alisa, 2014).

Degrowth principles and strategies aim for a structural change, for the purpose of this thesis I am going to illustrate the ones that are more relevant for the challenge of FLW. For this I refer mainly to the text Food for Degrowth by Nelson and Edwards (2020) which brings together a collection of experiences and theoretical studies on degrowth applied to the food sector. The book identifies useful concepts to analyse FLW from a degrowth perspective, the most relevant are: commodification, frugal abundance, autonomy, conviviality, commoning, conviviality and open relocalisation. These concepts will be used as a reference for the analysis of the case studies in section 4.2.

Commodification refers to the conversion of social and socio-ecological products, services, and relationships into goods that can be exchanged for money (D'Alisa, 2014). In the context of the food sector, Degrowth criticises the current system for food provision as it is driven by the ideological imperative to produce profit and growth. Capitalism appreciates

food not for its use value but, instead, for its exchange value, according to the Marxist definition of these concepts. This approach incentivizes the implementation of economies of scale with higher volumes of production, which in turn decreases the economic cost of food waste.

Frugal abundance is a principle that advocates for a frugal use of Earth's resources while living in personal, emotional, and philosophical abundance. From this perspective, overproduction and overconsumption of food can be avoided, which may result in a decrease in FWL as well.

Autonomy is a central principle of degrowth, which emphasizes the importance of direct governance, co-governance, and personal and collective agency. In this sense it means autonomy from the market, to liberate personal responses and personal production which are being replaced by the radical monopoly exercised by market-based industrial activities (D'Alisa, 2014). In the food sector, enhancing autonomy would mean encouraging agro-ecologists, neo-ruralism and alternative forms of sustainable self-provisioning.

Commoning refers to the practice of sharing resources and knowledge among members of a community. Commoning challenges the individualistic and competitive ethos of capitalism and promotes cooperation, mutualism, and solidarity. By sharing resources and knowledge, communities can achieve social and environmental efficiencies and reduce their dependence on global markets and corporations.

Conviviality is a principle that complements autonomy and commoning, and it refers to a cooperative, sociable, and sharing approach to life. Degrowth envisions a society in which conviviality is valued over individualism and materialism, and in which people prioritize human relationships and community wellbeing.

Open relocalisation is a principle that emphasizes the importance of producing and sharing goods and services locally to achieve social and environmental efficiencies because it

recognizes that globalization and economic centralization have led to the concentration of wealth and power in the hands of a few and have exacerbated social and environmental injustices.

Before even analysing degrowth strategies for food waste it is important to stress how a certain ideology can shape the definition of food waste, which will then have a direct impact on the magnitude and the characteristics of the problem. In the book (Chapter 14), Constanza Hepp considers this aspect and compares the definition from the Food and Agriculture Organization (FAO) and from the Swedish not-for-profit initiative to reduce waste Rude Food. By analysing FAO's definition, Hepp concludes that part of what they consider as food waste is food that according to the capitalist market logic has lost its exchange value (for example a mouldy orange). On the other hand, activists from Rude Food, embodying a degrowth spirit, focus on food's use value and propose solutions to revalue it. Different definitions spark different strategies. For instance, the FAO proposes greater efficiencies which can turn to be counterproductive due to the rebound effect.

Degrowth strategies act at the prevention level by changing:

- production practices: applying self-provisioning, permaculture and agro-ecology, community gardens and the keeping of livestock, promoting shared production and non-profit practices
- distribution practices: enhancing proximity food provisioning networks comprised of consumers' food cooperatives and small organic food producers using distinct forms of cooperation and reciprocity (CSA) in their socioeconomic exchanges
- consumer behaviour: adopting ethical diets by practicing political consumption

Practices such as self-provisioning, permaculture, agro-ecology, and community gardens can help to reduce food waste in several ways. Firstly, these practices often involve growing

and producing food on a smaller scale, which can lead to more efficient and sustainable use of resources. Efficiency improvements are not to be found in terms of reduction of working hours or creation of economies of scale, which obviously don't occur. Self-provisioning can entail a more efficient use of resources because it implies that you only produce what you will consume. In larger scale production systems asymmetric information between consumers and producers, and the economies of scale produce overproduction and a significant amount of the effort devoted to production is actually spent in producing what will then become waste. Moreover, more effort and resources will be needed to recover/dispose waste.

Secondly, degrowth practices tend to prioritize local and seasonal produce, which means that food is harvested and consumed when it is at its freshest and most nutritious. This can help to reduce food waste by reducing the amount of food that goes bad or spoils before it can be consumed. Thirdly, the promotion of shared production and non-profit practices can help to ensure that any excess food produced is distributed to those in need, rather than going to waste.

Enhancing proximity food provisioning networks, such as food cooperatives and CSA, can also help to reduce food waste by creating a more direct and efficient supply chain. By shortening the distance between food producers and consumers, there is less likelihood of food spoiling or being damaged during transportation.

Finally, adopting ethical diets and practicing political consumption can help to reduce food waste by encouraging consumers to make more informed and responsible choices about what they eat. This can include choosing to eat less meat, which can help to reduce the environmental impact of food production and decrease the amount of food that is wasted in the meat industry. It can also involve choosing to buy food with less packaging or choosing to purchase food from producers that prioritize sustainable and ethical practices.

2.4 Circular Economy and Degrowth

I have outlined the main principles and strategies adopted by CE and Degrowth approaches to address sustainability, particularly food waste reduction. The main differences between these two approaches rely on their respective position on growth and capitalism and on the importance of technology-based solutions.

The European Commission has stated that the transition to a circular economy will reduce pressure on natural resources and will create sustainable growth and jobs" (European Commission, 2020). Therefore, it envisions CE as a way to achieve what is known as "green growth", which is continued economic expansion within ecological boundaries. Hickel and Kallis (2020) have presented empirical data that doesn't support green growth theory. Even though, CE does not entail a critique to growth and capitalistic behaviour in the economy, the pursuit of infinite economic expansion it's not a prerequisite for its application.

Technology-based solutions are thought to be central and complementary for CE implementation (European Commission, 2020): on one hand they can accelerate circularity, for instance lowering the cost of circular procedures such as recycling, and on the other they can enable the dematerialisation of the economy and decrease the dependency on primary materials. The degrowth movement advocates that as long as population and income continue to grow, technological solutions are not enough to solve current environmental challenges (D'Alisa, 2014). Moreover, in some cases efficiency gains produced by technological innovations can lead to the Jevons' paradox, and therefore to more resource use (D'Alisa, 2014). Degrowth criticises the technological approach when it is used within the growth paradigm.

Nevertheless, recognizes that technology can be a powerful tool for social and environmental change, as long as they they support goals of fair, ethical, convivial, appropriate and political consumption and preserves peoples' needs and autonomy (Nelson & Edwards, 2020).

While some literature acknowledges these critical differences, it also proposes the possibility of a collaboration between the two visions, with CE abandoning the pursuit of economic growth. In particular, Arnsperger and Bourg (2016) define an "authentically circular economy" as one that consumes and produces less, moving closer to degrowth and consequently archiving true circularity. Additionally, Schröder (2019) calls for acknowledging both differences and similarities. As I have illustrated in the previous sections, CE and degrowth share an important part of their theoretical background in ecological economics and environmental goals. As explained by the author: "*degrowth can and should contribute to circular economy principles, as circular economic principles can contribute to an anchoring of degrowth commitments in an inescapably resource-dependent world*". It is worth mentioning the paper by Hoehn et al. (2021) which also proposes a degrowth approach to circular economy strategies in the context of food production and food waste reduction. They carry out a life-cycle assessment (LCA) of the Spanish food supply chain to determine the level of GHG emissions reduction needed in order to achieve compliance levels with the Paris Agreement targets. The results highlight the reduction of meat and fish and seafood consumption as the most useful path.

2.5 Research questions

Research in this area still remains quite unexplored partly because a considerable part of the literature considers that the two approaches might be inherently incompatible because of their different position on economic growth.

With this thesis I would like to contribute to the discussion by looking for an answer to the following research questions. Using the Food Waste Hierarchy framework, I will evaluate the current level of sustainability and circularity of food waste reduction strategies. Research questions in this area are:

1) To what extent are circular practices applied for FLW management? How far is the current model of FLW prevention and reduction from the shape of the Food Waste Hierarchy pyramid?
2) Are prevention measures observable in the current system of FLW management?

The study will continue taking into account case studies from Catalonia-based organizations that fight FLW, applying circular strategies. Research questions in this area are:

1) How do these local initiatives interpret circular strategies?
2) Is there any organization acting at a prevention level, through source reduction, applying degrowth-inspired principles?

Chapter 3. Methodology

In relation to the specific objective 2 (mentioned in Section 1.2), the main objective was to find reliable data on FLW destinations for Spain and Europe at the aggregate level. The data has been researched on: UN Statistics Division, OECD, World Bank (Data Bank), Eurostat, Istituto Nacional de Estadística (INE)

Once the data was collected, the definitions of the destinations specified in the data needed to be taken into account in order to construct the Real Food Recovery Pyramid. The latter is a recreation of the Food Recovery Hierarchy using real data. In order to assess the level of sustainability of the country taken into account I have compared the shape of the Real Food Recovery Pyramid with the Food Recovery Hierarchy. The closer to the shape of the latter the more sustainable. Moreover, the level of circularity has been evaluated according to the relative weight of reduce, reuse and recycle strategies as opposed to disposal strategies.

Regarding the specific objective 3, which entailed an analysis of Catalonia-based organizations that applied CE, the initiatives have been selected using the following sources:

- The webpage of the *Generalitat de Catalunya* dedicated to CE initiatives;
- The webpage of the *Ajuntament de Barcelona* dedicated to sustainable food;
- Pam a Pam: an interactive free online map of social and economic organizations that aim at enhancing mainly social inclusion and sustainability though local and autonomous initiatives;

The organizations had to satisfy the following requirements:

- Main goal: FLW prevention/reduction
- Acting in Catalonia

In order to qualitatively assess the organizations I have taken into account their annual reports from 2021 or alternatively their websites. From here, I have collected information on their circular strategies. In some cases these were very much linked with social strategies which were explicitly mentioned in the reports/websites. To have a complete picture of the organizations' strategy I have reported both CE and social actions. Moreover, using the degrowth principles studied in section 2.3, I have provided a further analysis.

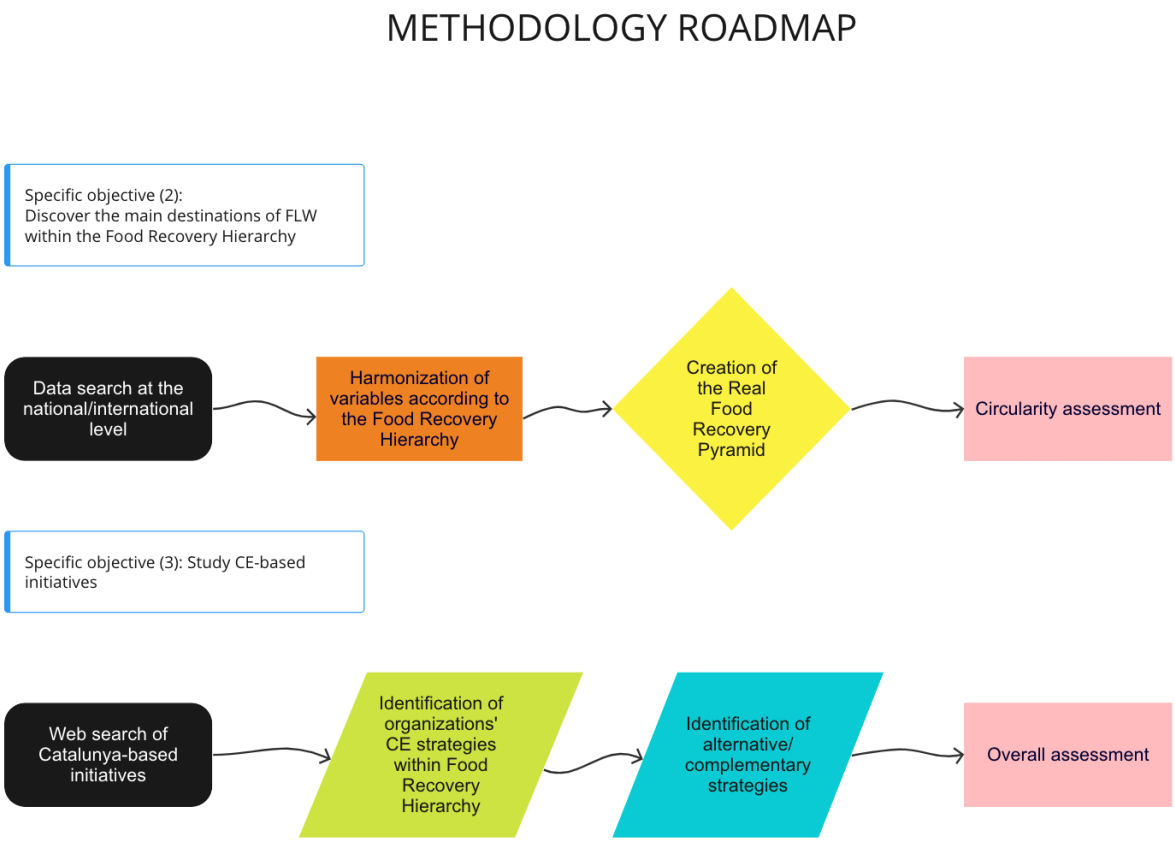


Figure 5: Methodology Roadmap

Chapter 4. Application and results

4.1 Data on food recovery

4.1.0 Missing data

The first finding of this research is that the World Bank, the UN and OECD have data on waste destinations but don't differentiate between food waste and other types of wastes (OECD, 2023; UN Statistics Division, 2019; World Bank, 2019). Eurostat and INE use as a proxy for food waste a number of different indicators which include also materials that are not strictly food waste (Eurostat, 2023b; INE, 2019).

According to a recent UNEP report (2021) only 25% of the global population lives in a country with high-quality data compatible with SDG 12.3 within the food service sector, and this percentage is lower for household waste (9%) ad for the retail sector (8%).

Given this constraint, I have based my analysis on data from Refed, a US online data centre, and a Spanish report on food waste at the agro-food industries' and distribution's level.

4.1.1 Refed data for US food system

ReFED is a national non-profit online data centre that combines over 50 public and proprietary datasets on the US food system. It allows to access and download freely through its website food surplus data from 2010 to 2019 by sector and at national and states level. In their website they clarify what they refer to as food surplus, this is "*all food that goes unsold*

or unused by a business or that goes uneaten at home – including food and inedible parts that are donated, fed to animals, repurposed to produce other products, and all of the destinations represented in food waste" (*Food Waste Problem | ReFED*, n.d.). This definition is quite close to Fusions'. The data available on ReFED website (*ReFED - Food Waste Monitor*, n.d.) provides detailed information on yearly food surplus by sector, destination, food type at the national and states' level. Destinations include from more sustainable to less: donation, animal feed, industrial uses, anaerobic digestion, compost, incineration, land application, landfill, not harvested, dumping, sewer. The less sustainable practices (from incineration to sewer) have been summed up into a single variable under the name "last resort disposal" to match EPA's Food Recovery Hierarchy.

Table 2: Refed Definitional Framework: Surplus food

	Definitional framework	Scope in the Food Supply Chain (FSC)	Includes	Excludes
Refed	*"all food that goes unsold or unused by a business or that goes uneaten at home – including food and inedible parts that are donated, fed to animals, repurposed to produce other products, and all of the destinations represented in food waste"*	Whole supply chain	Edible and Inedible	• Not mature • Not intended for human consumption

As showed by Figure 6 (below), US food surplus destinations from 2016 to 2021 haven't experienced any major change in their composition. The colours that have been used for Figure 6 and Figure 7 correspond to the colours of the Food Waste Hierarchy, except for composting which has been painted in lilac in order to differentiate it from anaerobic digestion, although they belong to the same category in the pyramid (recycle-nutrients recovery)

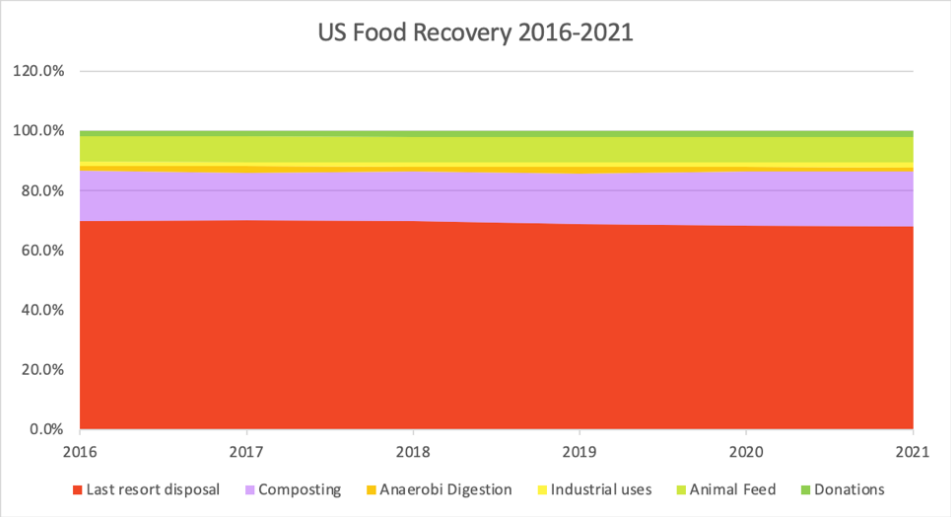


Figure 6 US Food Recovery 2016-2021

From 2016 to 2021 the available data shows an Food Recovery Pyramid very similar to the one depicted in Figure 7 for 2021. In 2021, the most popular strategy is by far the last resort disposal (68.1%), followed by compost (18.02%) and animal feed (8.6%).

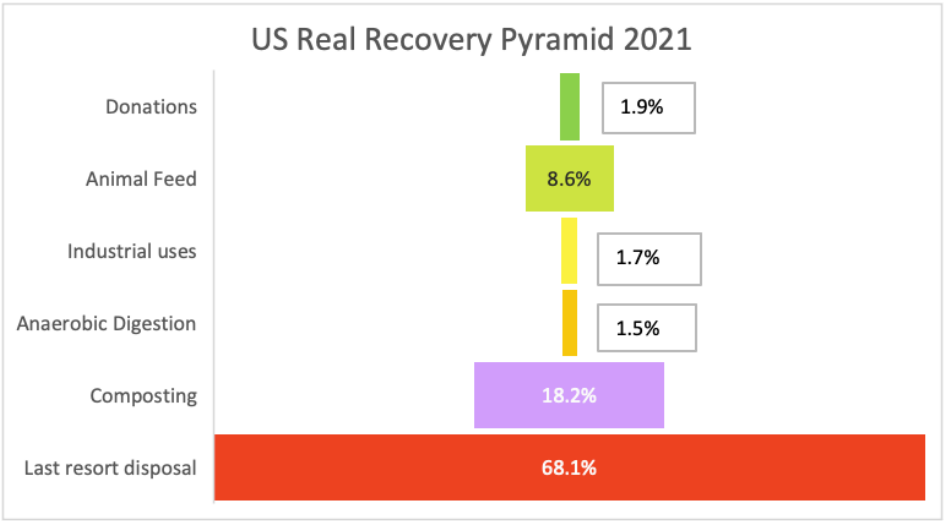


Figure 7 US Real Recovery Pyramid 2021

Moreover, from 2016 to 2021, surplus food as a share of food production has gone from 38.4% to 37.8% (Table 3), experiencing only a slight improvement. The limited timeframe does not allow us to conclude that the trend is actually decreasing. According to Refed in 2021 the 38% Food Surplus accounts for a $444 billion loss, equivalent of 149 billion meals.

Table 3: Refed Surplus Food as a share of total food production. Surplus food, Food consumed and food production are expressed in millions of tons.

Year	Surplus Food	Food Consumed*	Food production	%SurplusFood
2016	86.8	139	225.8	38.4%
2017	86.6	136	222.6	38.9%
2018	90.1	144	234.1	38.5%
2019	91.4	146	237.4	38.5%
2020	90.2	149	239.2	37.7%
2021	91	150	241	37.8%

Summarising, Refed data on US food surplus management is showing that:

- the ratio food surplus/food produced has not decreased significantly in the timeframe observed;
- the amount of food donated is persistently low relative to other less sustainable destinations;
- Last resort disposal (which include incineration, land application, landfill, not harvested, dumping, sewer) is by far the most used strategy;

The result is that the Real Recovery Pyramid is inverted relative to the Food Recovery Hierarchy, meaning that current US food recovery strategies are far from the sustainability target. There is plenty of room for improvement. In fact, even if we assumed that in 2021 the 1.9% that has been reused for human consumption corresponded to the total amount of edible food, the 68% treated with last resort disposal, could still me treated in more sustainable ways, applying CE.

Moreover, prevention which is at the top of the Food Recovery Hierarchy cannot be observed.

4.1.2 Spanish Data in the Industry and Distribution

The Spanish Ministry of Agriculture, Fishing and Nutrition published a report in 2020 (Ministerio de Agricultura, Pesca y Alimentación, 2020) on food waste in the industries and distribution companies in Spain. The report presents the solutions of a detailed questionnaire on food waste management and knowledge carried out by a sample of:

- 76 **industries** of which 46.05% are among the top100 national industries (for sales volume)
- 14 **companies** representing more than 80% of the total market share of food distribution in Spain

In this case the relevant definition of food waste in the report is: set of **edible** food products that were meant to be consumed by human, discarded from the agri-food chain due to economic or aesthetic reasons, or due to their proximity to the expiration date.

Table 4: Definitional Framework of the Spanish Ministry of Agriculture, Fishing and Nutrition report

	Definitional framework	Scope in the Food Supply Chain (FSC)	Includes	Excludes
Spanish Ministry of Agriculture, Fishing and Nutrition Report	*"set of food products discarded from the agri-food chain due to economic or aesthetic reasons, or due to nearing their expiration date, but which are still perfectly edible and suitable for human consumption. In the absence of possible alternative uses, they end up being eliminated as waste, resulting in negative externalities from an environmental perspective, economic costs, and loss of profits for companies."*	Whole supply chain	Edible	• Not mature • Not intended for human consumption • Inedible

Industries

At the industries' level the questionnaire differentiates between surplus and waste management. There is no data on the level of surplus with respect to total waste, therefore I have constructed two different pyramids for each (Figures 8 & 9).

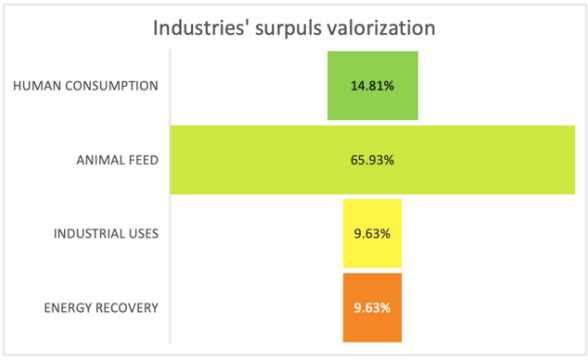


Figure 8: Spanish industries' surplus valorization

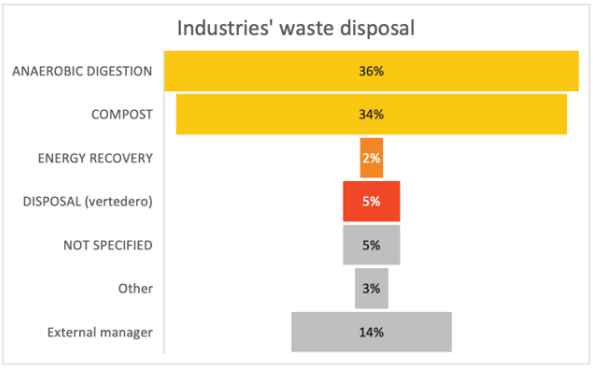


Figure 9: Spanish industries' waste disposal

Industries' food surplus is mostly directed to animal feed (65.93%) The report specifies that food donated to humans represents a much lower percentage with respect to animal feed because there is a very high proportion of food that is no longer suitable for human consumption that can be used for animals. Nevertheless, surplus is revalued at a high sustainability level according to the hierarchy. Food waste disposal presents a remarkable

level of circularity since anaerobic digestion and compost strategies are preferred to disposal and other practices.

Distribution companies

The pyramid for distribution companies (Figure 10) shows that 12% is directed to human consumption while the 43.3% of waste at the bottom is treated as urban solid waste and as such is managed at the lowest sustainability level of the pyramid with energy recovery or disposal.

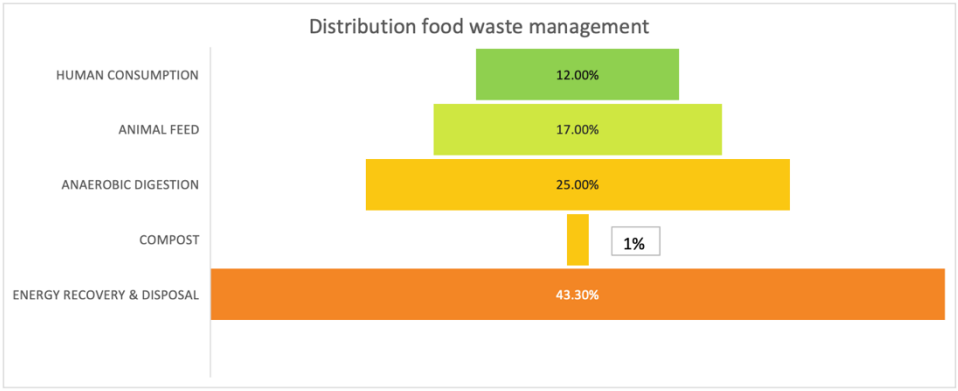


Figure 10: Spanish distribution companies waste management

Overall results

Distribution companies are still far from the shape of the Food Recovery Hierarchy since the Real Food Recovery is inverted and 43% of food waste is managed at the bottom of the pyramid. Nevertheless, in terms of circularity, 54% of food waste is managed at the top three layers.

It is harder to asses circularity and sustainability for food industries since we don't know the relative weight of food surplus and waste on total waste production and we can't

build a pyramid with surplus and waste together. Three hypothetical scenarios would be (Figure 11):

- %food suplus > %food waste: highly sustainable, high circularity

- %food suplus = %food waste: medium sustainable, medium circularity

- %food suplus < %food waste: low sustainable, low circularity

Figure 11: Spanish industries: 3 possible scenarios

It is important to note that industries and distribution companies don't report any prevention strategies which, according to the Food Recovery Hierarchy, should be the main action to fight food waste. This resonates with the data from the US. On the other hand it is harder, given the limited availability of Spanish data, to asses weather if the Spanish food sector is as unsustainable and linear as the US'. In fact, the data exposed by the report is unable to give a complete picture of the food waste management in Spain. According to

Eurostat (Eurostat, 2023a), in Spain industries and distribution companies produce roughly 41% of food waste, households alone produce 33.3%, the primary production sector 20% and the restaurants and food service sector 4,4% (Eurostat, 2023a).

4.2 Analysis of CE Case studies for food prevention

I will now use Fusions' definition of food waste, which includes edible and inedible food at any step of the food supply chain .

The selected organizations/initiatives that apply circularity for food waste prevention in the area of Barcelona and surroundings are the following:

- Espigoladors
- BCN Comparteix el Menjar de Nutrició sense Fronteres
- Too Good To Go
- Foodback (Mercabarna)
- Punt Verd (Mercabarna)
- Es-Imperfect (Espigoladors)
- Cercle Compostaire (Tarpuna)
- Revolta Eixample (Tarpuna)

4.2.1 Fundación Espigoladors

The Fundación Espigoladors is a non-profit foundation that includes Espigoladors and es im-perfect. The details about these two organizations are taken from their annual reports available on their websites (Fundació Espigoladors, 2021a, 2021b).

Espigoladors

Espigoladors was created in 2015 with the objective of reducing food waste in the agricultural sector by collecting unharvested crops with the traditional practice of "espigolades" or gleaning in English. This activity has been carried out by the organization in the surrounding areas of Barcelona such as Parc Agrari del Baix Llobregat, Camp de Tarragona, Terres de l'Ebre and Espai Agrari de la Baixa Tordera. Through the help of volunteers, Espigoladors collects surplus produce from farmers and donates it to social entities. Additionally, the organization collects data on food waste in the primary sector and has participated to the analysis of the food waste challenge with research projects also supported by the Catalan Department of Climate Action, Nutrition and Rural Agenda.

Espigoladors employs a circular economy approach, as stated on their website, by prolonging the lifespan of agricultural products and reducing waste generation while maximizing their usage. They also employ a social strategy to provide fresh and nutritious food to vulnerable groups. Furthermore, they advocate for the practice of gleaning as a means of raising awareness about the food waste problem and the unsustainability of the agri-food system, which is responsible for systematic food loss.

Es im-perfect

Es im-perfect was founded by the Fundación Espigoladors

in 2018 with the aim of revalorising local fruits and vegetables
rejected from the commercial circuit due to physical imperfections, price drops, or production surpluses by using them to produce plant-based pâtés.

Es im-perfect has a triple impact strategy aimed at improving: sustainability in the agro-food sector, social inequalities and access to healthy diets. Firstly, it addresses food waste with a circular economy approach by repurposing rejected food and giving it new value through a sustainable circular economy model. Secondly, it creates work opportunities for people at risk of social exclusion. Finally, it advocates for the universal right of a healthy and sustainable diet.

Es-imperfect and Espigoladors are not just committed to providing circular solution for food waste prevention and reduction. Their work aims at raising awareness, especially for people living in the cities, and at criticizing and giving visibility to the cracks of the current capitalistic model of production that seeks the maximum production at the minimum cost allowing for contingent food losses and waste. The Fundación Espigoladors advocates for a structural change towards more sustainable and local models, which will guarantee access to healthy food for everybody.

Through their work they offer an alternative food production system based on valorising resource for the their use-value instead of just the exchange value. Moreover, their work is carried out by applying other principles shared with the degrowth imaginary such as communing and conviviality. In fact, part of the objective of these projects aim to involve different stakeholders such as volunteers from the city and people at risk of social exclusion, into direct actions and allow them to learn together by sharing the gleaning experience and knowledge.

4.2.2 BCN Comparteix el Menjar – Nutrició sense Fronteres

BCN Comparteix el Menjar (Nutrició Sense Fronteres, n.d.)is a food-sharing project created in 2012 by the NGO Nutrició Sense Fronteres. The aim of this project is to rescue surplus food from hotels, restaurants, caterings and supermarkets in the metropolitan area of Barcelona and to donate it to social entities. Therefore, BCN Comparteix el Menjar applies circularity by reusing food loss acting at the highest sustainability level in the hierarchy after prevention.

Furthermore, the BCN Comparteix el Menjar is committed to promote the access to a healthy diet for the most vulnerable groups of the city.

Additionally, the organization organizes a number of activities such as intercultural workshops, food-related debates and solider meals that aim at creating a direct network between volunteers and receiving people that enhance knowledge sharing and convivial life. Therefore, it shares principles with the degrowth movement such as open relocalisation and conviviality.

4.2.3 Too Good to Go

Established in Denmark in 2016, Too Good to Go is a start-up of a digital platform that strives to combat food waste. It does so by providing a platform for stores and restaurants to sell their unsold products at a lower price, which would otherwise be wasted if left unsold at the end of the day. This app has become increasingly popular, in 2021 it was awarded as the 10th most downloaded app and it was able to rescue over 52 million meals

(which would be enough to feed the entire population of South Korea) (Too Good to Go, 2021).

In terms of circularity, the platform acts at the highest level of the hierarchy after prevention. Moreover, it allows any consumer that can download the app and afford the food available to participate to food waste reduction.

Unlike the initiatives that have been described so far, Too Good to go doesn't promote social inclusion nor accessible healthy food. Moreover, it doesn't apply any degrowth-inspired principle.

4.2.4 Mercabarna: FoodBack and Punt Verd

Mercabarna is a public limited company that is the biggest wholesale market of fresh food in Europe for sales volume and is located in Zona Franca (Barcelona). Mercabarna redirects food waste to FoodBack and to Punt Verd, both located in the same area. The former was built in February 2022 as a warehouses that collects edible surplus food that is then selected by Formació i Treball and donated to Banc d'Aliments de Barcelona. Punt Verd manages inedible food and process it.

Foodback applies a circular economy approach by donating the food surpluses. Furthermore, by collaborating with Formació i Treball it enhances job opportunity for vulnerable groups of society. Punt Verd, on the other hand, it applies CE but at a lower sustainability level according to the Food Waste Hierarchy, because it focuses on recycling.

Finally, Mercabarna is committed to several initiatives featuring schools aiming at raising awareness of the problem of food waste and on the importance of a healthy and sustainable diet. Moerover, it created a department in the Polytechnic University of Catalonia *(Cátedra*

UPC-Mercabarna) which goal is to study and analyse the FLW phenomenon to provide new solutions to the challenge.

4.2.5 Tapurna: Cercle Compostaire and Revolta Eixample

Revolta is a compost machine designed and proposed by the Tarpuna cooperative located in Barcelona (Tarpuna, n.d.). The aim of this machine is to be collaboratively used to compost urban organic waste so that it can be used for organic agriculture. Revolta is thought to be used in a decentralized way by schools, restaurants and households to enchance a more local and participative waste management. Revolta is now being implemented in the projects Cercle Compostaire and Revolta Eixample .

Cercle Compostaire is an initiative that uses Revolta to recover organic waste from the School Nabí in Vallvidrera (Barcelona) and donate it to the Can Pujades' and Tarpuna's vegetable gardens. The machine was rented thanks to a crowdfunding.

Revolta Eixample refers to the community project of the Association of Jardins d'Emma in the Eixample district of Barcelona that uses the machine to revalorise the organic waste of the households participating and use it for the urban gardens nearby and the domestic plants.

These two initiatives apply circular economy by revalorising organic waste through compost. In addition to this, Cercle Compostaire and Revolta Eixample are also applying degrowth-inspired principles such as: commoning and convivial technology. The latter is applied though the use of Revolta. Moreover, the Cercle Compostaire applies commoning by enhancing proximity food provisioning networks by donating the compost to Can Pujades.

Revolta Eixample is related to the commoning principle because it entails resource sharing among households.

4.3 Results

According to study carried out, I illustrate in the the map below (Figure 12) where, in the food supply chain, each organization recovers food waste from and which circular strategy they apply according to the Food Recovery Hierarchy.

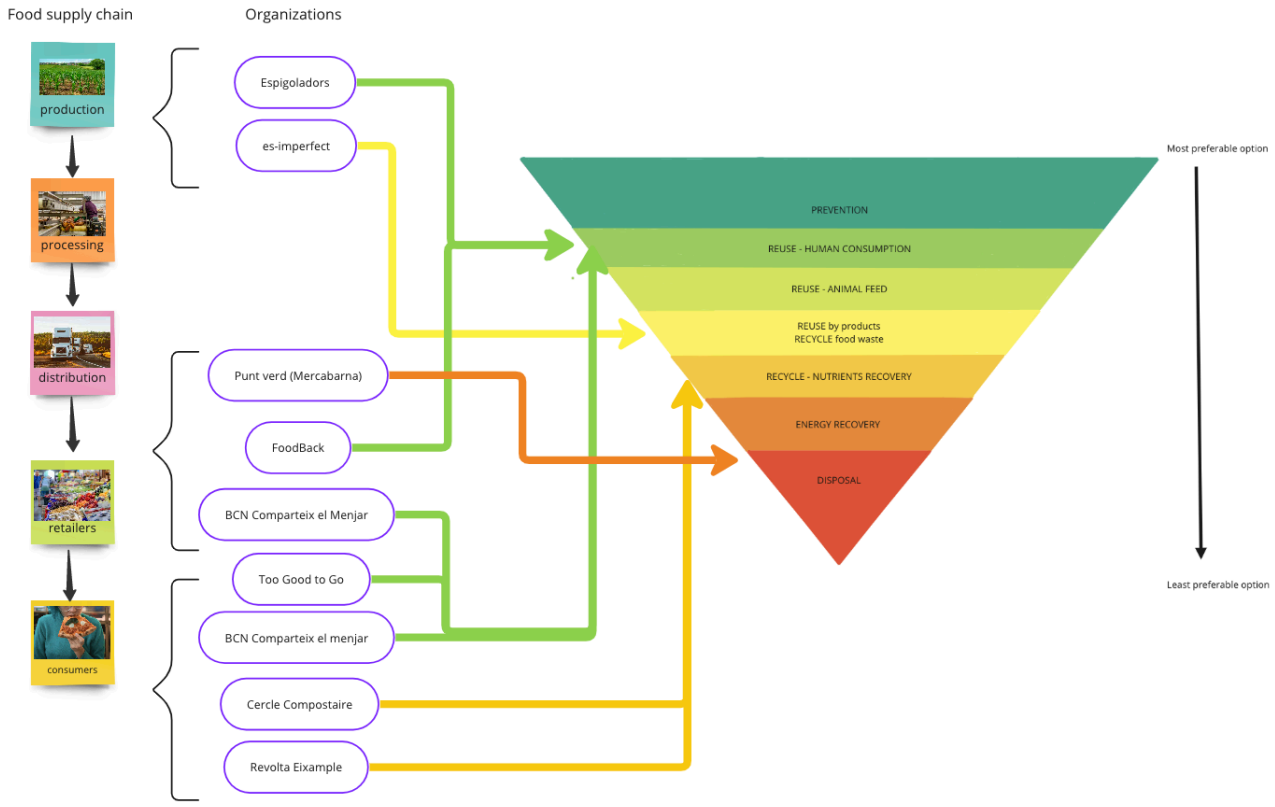


Figure 12: Organizations from the Food Supply Chain to the Food Recovery Hierarchy

Moreover, most of the organizations, implement circular strategies that link to a social strategy either by enhancing social inclusion, promoting a healthy diet, raising awareness on food waste and the environmental crisis (Table 5).

Table 5 Organizations' social and degrowth-inspired strategies

	Social transformation or inclusion	Promote healthy diet	Raise awareness on food waste and envrionmental crisis	Cultural change- Application of Degrowth principles/actions
Espigoladors	work opportunities for people at risk of social exclusion	Donation of fresh fruits and vegetables to social entities	Collaboration for research projects Campaigns	P: Commoning, Advocate for a structural change A: Recover fw according too ouse-value
es-imperfect	work opportunities for people at risk of social exclusion	Social campaigns and healthy products	Collaboration for research projects (Fundació Espigoladors) Campaigns	P: Commoning, Advocate for a structural change A: Recover fw according too ouse-value
BCN Comparteix el Menjar	access to healthy diet for people at risk of social exclusion	✔	food-related debates workshops	P: Open reloocalisation, Conviviality A: Comunity projects
FoodBack	work opportunities for people at risk of social exclusion	Yes: Actions by Mercabarna	Yes: Actions by Mercabarna	✖
Cercle Compostaire		Donate compost to ecological gardens	✖	P: Commoning, appropriate and convivial technology A: Proximity network
Revolta Eixample	Strengthen neighbours relations	✔	✖	P: Commoning, appropriate and convivial technology A: Comunity projects of decentralized waste management
Too Good to go	✖	✖	Campaigns	✖
Punt Verd				

Box colour legend:
● : it satisfies the what's indicated in the column title
● : given the organization specific characteristics, it cannot be analysed according to what's indicated in the column title

The first finding of this very simple analysis is that most of the organizations (6 out 8, the first 6 of Table 5) combine their fight for food waste with actions that promote social transformation and inclusion and/or the adoption of an healthy diet. Therefore, applying CE in this context has the potential to positively impact not only the environment but also social progress.

Among these six, four of them, Espigoladors, es-imperfect, BCN Comparteix el Menjar and Foodback (Mercbarna), promote all three of them donating fresh or healthy food to social entities. However, as opposed to Foodback, Espigoladors, es-imperfect and BCN Comparteix in addition to CE strategies, they also apply degrowth-inspired principles and actions (Table 5). By doing so, their overall positive impact might be amplified because they act at a prevention level by promoting a cultural change towards a societal model that relies on community, sharing, direct participation to problem solving and revaluing nature outside market-based logics.

From the quantitative analysis of Refed and Spanish distribution companies and industries the common result is that food prevention is essentially absent either because prevention actions are not being carried out (Spanish case) or because they are not sufficient (US case). According to the Food Recovery Hierarchy, prevention is the first and most relevant policy that should be followed in order to effectively manage food waste in a sustainable way. In this context, initiatives such as the ones carried out by the Fundación Espigoladors and BCN Comparteix el Menjar are targeting both food waste prevention by offering an alternative to the dominant narratives and strategies applied to food waste, and unequal food distribution though donation.

Chapter 5. Discussion

This thesis finds that the level of circularity in the food waste management is fairly low especially in the US, although there is also some evidence for the Spanish distribution companies. Despite the existence of the Food Waste Hierarchy, endorsed by the EPA and the EC, a significant portion of food waste continues to be disposed of as a last resort. Additionally, food prevention is essentially absent either because prevention actions are not being carried out (Spanish case) or because they are not sufficient (US case).

The case studies inform on how CE strategies can be complemented with actions enhancing social inclusion and access to healthy diets. Moreover, some of the organizations studied, by embracing degrowth-inspired principles have the potential to act at a prevention level by driving a cultural transition towards a society that values sharing, well-being and nature above economic growth.

Based on these findings, I argue that circular solutions are necessary and have positive impacts both environmentally and socially. More importantly, to fight food waste, reduction at the source (prevention) is a key action that needs to be implemented also adopting a degrowth approach, which would include following the principles described, but also, more radically, shrinking food production in the countries with overproduction. Of course, prevention measures should go in hand with redistribution.

There are important limitations of the study related to data availability and information reliability. The examination of Spanish food waste management is limited to the distribution and industries' production sectors which represent less than 50% of the food waste generated along the supply chain. Furthermore, the analysis of industries is incomplete due to a lack of data on their food waste structures. The case studies heavily rely on self-disclosed information from the organizations themselves, introducing uncertainty regarding

the extent to which these organizations genuinely implement environmental and social strategies as claimed.

Chapter 6. Conclusion

This study has contributed to research on food waste reduction and prevention by analysing current CE-based practices and by including into the discussion degrowth concepts and approaches. A data-based circularity assessment of food waste management using the Food Recovery Hierarchy has been proposed. The findings indicate that the current food waste destinations in the US and Spanish industries are characterized by environmental unsustainability and a lack of circularity. Consequently, it is evident that the achievement of a CE for food waste is still far from being realized. Additionally, there is no evidence of significant prevention measures. A degrowth approach, such as the one applied in the Catalonia-based case studies, could complement CE strategies by acting at a prevention level.

In order to further tackle food waste it is necessary to have a common definitional framework and data availability for food waste (and loss) across and within countries. Moreover, to monitor our progress towards SDG 12.3 we also need to have data available specifically on food waste destinations.

Further research on this topic could include a quantitative study on what would be a realistic shape of the Food Recovery Hierarchy, taking into account data on the level of edible and inedible food waste.

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