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Against food waste: an LCA study of the network "Empori della Solidarietà" in the Veneto Region (Italy)

Supervisor
Elena Semenzin, PhD

Assistant Supervisor
Anna Carlesso, MSc
Elisa Giubilato, PhD
Lorena Franz, ARPAV
Stefania Tesser, ARPAV

Graduand
Tiziana Pastorello
Matriculation number
836622

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SOMMARIO

Lo spreco alimentare rappresenta un problema di ordine economico, sociale ed ambientale tale da comparire tra gli obiettivi del programma di azione dell'ONU *Agenda 2030 per lo Sviluppo Sostenibile.* Con la costante crescita della popolazione che ci si aspetta nei prossimi anni, sarà di fondamentale importanza ridurre lo spreco alimentare, per permettere a sempre più persone di avere accesso al cibo, all'acqua e alle risorse naturali.

Nel campo del recupero delle eccedenze alimentari operano diverse associazioni, tra cui gli "Empori della Solidarietà", ampiamente diffusi nella Regione Veneto. Gli empori solidali si occupano di recuperare le eccedenze alimentari dalla Grande Distribuzione Organizzata o dalle aziende produttrici per ridistribuirle agli indigenti. Accanto a questa attività, lo scopo di tali associazioni è anche quello di mettere in atto un programma di accompagnamento, che conduca le persone bisognose attraverso un percorso di reinserimento sociale, fornendo loro le basi per una corretta spesa alimentare e una corretta nutrizione.

Il presente lavoro di tesi si focalizza sulla valutazione degli impatti ambientali connessi all'attività degli "Empori della Solidarietà" presenti nella Regione Veneto e degli impatti ambientali evitati grazie alla loro attività di recupero. Dal momento che le eccedenze recuperate rappresentano un rifiuto evitato, verranno a mancare tutti gli impatti connessi direttamente allo smaltimento dei rifiuti in impianti di compostaggio, digestione anaerobica o incenerimento, come evidenziato anche da studi precedenti.

La metodologia impiegata è quella dell'Analisi del Ciclo di Vita (Life Cycle Assessment, LCA) (ISO 14040:2006; ISO 14044:2006) che, tramite il supporto del software Simapro, permette di eseguire la valutazione degli impatti dal momento della produzione degli scarti alla loro ridistribuzione (scenario 1) rispetto al loro smaltimento (scenario zero).

Una volta definiti i confini del sistema, è stato predisposto un questionario per la raccolta dei dati primari presso gli empori. Tale raccolta dati è stata condotta direttamente sul campo tramite interviste a persone di riferimento nella gestione degli empori. I dati raccolti riguardano i consumi di energia elettrica, combustibile per il riscaldamento, acqua, detersivi utilizzati per la pulizia degli empori; la quantità di eccedenze alimentari recuperate; i mezzi utilizzati e i chilometri percorsi per portare a termine l'attività di recupero. Dal momento che il personale di riferimento degli empori svolge attività volontaria, lo studio presenta numerose assunzioni, che verranno illustrate

ampiamente nel testo, e che si sono rese necessarie per rendere i dati adatti ad essere inseriti in Simapro.

Il metodo utilizzato è ReCiPe Midpoint Hierarchist, che individua 18 categorie d'impatto, tra cui il cambiamento climatico su una scala di dieci anni, l'uso del suolo e l'esaurimento delle risorse idriche.

I risultati ottenuti verranno condivisi con gli empori stessi, e con ARPAV, per dare risalto alla tematica dello spreco alimentare, supportando il recupero delle eccedenze anche attraverso dati scientifici.

SUMMARY

The waste of food is an economic, social and environmental problem included among the Sustainable Development Goals of *Agenda 2030*. With the steady population growth expected in the coming years, it will be crucial to reduce food waste to enable more and more people to have access to food, water and natural resources.

In the field of food waste, there are associations that recover and redistribute food surplus such as the "Empori della Solidarietà" of the Veneto Region. They are a network of associations that recover food surplus from organized large-scale distribution and from production holdings to redistribute it to deprived persons. In addition to this activity, the purpose of these associations is also to implement an accompanying program, which will lead people in need through a path of social reintegration, providing the basis for proper food spending and nutrition.

This thesis work focuses on assessing the environmental impacts of "Empori della Solidarietà" in the Veneto Region and the environmental impacts avoided by their recovery activities. Since the surplus recovered is a waste avoided, all impacts directly related to the disposal of waste in composting, anaerobic digestion or incineration plants will be lacking, as also highlighted by previous studies.

The applied methodology is Life Cycle Assessment (LCA) (ISO 14040:2006; ISO 14044:2006), that, through the use of Simapro software, allows to assess environmental impacts from the production of food waste to its redistribution (scenario 1) as compared to its disposal (scenario zero).

After defining system boundaries, the different impact categories were identified and a questionnaire for collecting primary data from emporiums was prepared. This data collection was carried out directly in the field through interviews with reference persons in the management of the emporiums. The data collected concern the consumption of electricity, consumption of heating fuel, water, detergents used to clean the emporiums; the quantity of food surpluses recovered; the means used and the kilometres travelled to complete the recovery activity. Since the reference staff of the emporiums carries out the activities on a voluntary basis, the study presents numerous assumptions, which will be extensively illustrated in the text, and which were necessary to make the data suitable for inclusion in Simapro.

The method used is the ReCiPe Midpoint Hierarchist, which identifies 18 impact categories, including climate change on a 10-year scale, land use and water depletion. The results obtained

will be shared with the emporiums themselves, and with ARPAV, to highlight the issue of food waste, supporting the recovery of surpluses through scientific data.

MOTIVATIONS AND OBJECTIVES

Food waste is a phenomenon that affects all stages of the food chain, from primary production to domestic consumption, with effects not only economic and social aspects but also environmental ones.

For this reason, fighting against food waste must concern not only international and national institutions but also supervisory bodies, such as regional ARPAs (Agenzie Regionali per la Protezione dell'Ambiente), and citizens.

In fact, within the Veneto region, the Regional Social Services Directorate has established a collaboration with ARPAV (ARPA Veneto) to promote awareness of the amount of food wasted and to encourage virtuous behaviour in the recovery of food surpluses. Among the activities operating in the field of food surplus recovery, this thesis takes into account the "Empori della Solidarietà", an established but constantly expanding reality, which receives regional funding for its work.

In agreement with ARPAV, the motivations behind this study were not only to highlight a virtuous regional practice, but also to estimate whether its activity brings benefits from the environmental point of view. Therefore, this study aims to support the donation of food surpluses with scientific evidence, with a view to sustainable development, since the donation of food surplus allows to avoid waste and the environmental consequences associated with its disposal.

In this thesis, the objective was therefore to assess the environmental impacts (though the Life Cycle Assessment (LCA) methodology) of the recovery activity of the "Empori della Solidarietà" within the Veneto region, in comparison with a basic scenario in which food waste is treated through a combination of composting, anaerobic digestion and incineration processes.

This pilot study could serve as a basis for future studies, as food recovery activities are varied and distributed all over the country, and it will support raising awareness about avoided environmental impacts associated to such activities.

THESIS' STRUCTURE

The thesis is structured in the following eight chapters, each of which is divided into some subchapters.

- Chapter 1 introduces the issue of food waste, and its subchapters contain the definition of food waste and surpluses, a description of the causes of food waste and the quantities involved, the indication of its environmental implications and finally the description of which strategies could reduce them;
- Chapter 2 describes policies and action plans related to food waste and to distribution of food surplus;
- Chapter 3 presents the case study of "Empori della Solidarietà", explaining what they are and what they do;
- Chapter 4 presents the materials and methods used in the thesis work, including the bibliographic search and the application of the Life Cycle Assessment (LCA) approach to the selected case study;
- Chapter 5 illustrates the results of the bibliographic search on LCA studies addressing food waste and food surplus donation systems;
- Chapter 6 presents and discusses the results of LCA application to the case study; and finally,
- Chapter 7 reports the conclusions of the thesis work.

1. FOOD WASTE THROUGH THE WORLD: THE NUMBER OF AN INCREASING PHENOMENON AND ITS CONSEQUENCES

According to the Food and Agriculture Organization of the United Nations (FAO) "one third of all food produced globally is either lost or wasted" (*FAO, 2019*).

In an age where about 2 billion people in the world can't have an easy access to food, about 800 millions starve because of undernourishment and chronic malnutrition and approximately 40% of the worldwide population fight against water scarcity (*Vulcano et al., 2018*), it is evident that reducing food waste and food loss is fundamental to a purpose of sustainability. In fact, the fight against food waste has been included among the Sustainable Development Goals of Agenda 2030, an action program signed by the governments of the UN member countries (*UNric, 2019*).

1.1 Definition of the problem

Despite the worldwide importance of food waste, there is not yet a common and shared definition of what food waste is and what it concerns (*Vulcano et al., 2018*). FAO distinguishes between *food loss* and *food waste*, taking into consideration the phase of the food value chain in which the phenomenon is verified (*Vulcano et al., 2018)*: "food loss" refers to the food lost due to problems in the production, processing and distribution stages or due to technical limitations in the storage or packaging (*Lipinski et al., 2013*). "Food waste" instead, usually occurs at retail and consumption stages and refers to food that is thrown away either before or after it spoils (*Lipinski et al., 2013*) as well as to the alternative use (non-food) of food that is edible and safe for the human consumption (*FAO, 2019*).

The Italian law L. 19 August 2016, n. 166, with regard to "Disposizioni concernenti la donazione e la distribuzione di prodotti alimentari e farmaceutici a fini di solidarietà sociale e per la limitazione degli sprechi", distinguishes between *food surplus* and *food waste*. The first one refers to agro-food products that remain unsold although they are still safe and they still respond to the hygiene requirements: the causes of this no-sale are usually weather damages, packaging alterations, remaining of promotional activities, lack of demand, errors in production planning and the nearby to the expiration date. *Food waste* instead refers to products still edible that leave the food value chain due to commercial (e.g. the proximity to the expiry date) or aesthetic reasons, and which, in the absence of an alternative fate, are destined for disposal.

As reported by *Vulcano et al. (2018), s*ome academics include in their definition of food waste also the human overfeeding, and the use of cultivations for animal feed or energetic purposes, when such cultivations could be suitable for human nutrition.
The European Commission (*2017b*) refers to *food surplus* as "food and beverages that have not been sold or are not marketable but are still suitable for human consumption" while *Albizzati et al. (2019) refer* to *food waste* as the share of surplus food directly sent to disposal. These latter two definitions are also adopted in this thesis work.

1.2 Causes and scale of the problem

From the 30's of the past century, the waste of food has grown until it has reached one third of the food produced; this escalation has gone simultaneously with the growth of the population, the increase of the urbanization and the exploitation of fossil sources (*Vulcano, et al., 2018).* The causes of the waste of food are different between developing and developed countries: in the first ones there is a strong connection with the lack of decent conservation and transport systems whereas in the second ones the phenomenon of the waste of food is mainly connected to an increased demand of perishable products and to an arising of food transformation levels (*Vulcano, et al., 2018*).
FAO estimated, as reported above, that the food lost or wasted in 2009 represents the 32% of the food produced; this datum is based on weight and does not consider the difference in water and caloric content per kilogram of different food types. *Lipinski et al. (2013)* using the FAO Food Balance Sheets, made an estimate based on calories; as shown in *Figure 1*, there is a clear difference between cereals and fruit and vegetable lost or wasted with reference to their weight and the same products lost or wasted in terms of calories and this is because fruit and vegetable contain more water.
Along the food supply chain, food is wasted due to various reasons: as *Vulcano et al. (2018)* report, in the stage of the primary production, "unpredictable factors" can occur such as weather damages, diseases and environmental pollution, but also the transformation of the customers preferences and the market trends.
Next, during the production and the transformation phases, the causes can be: bad storage, inefficient harvesting methods, technical and budgetary problems.

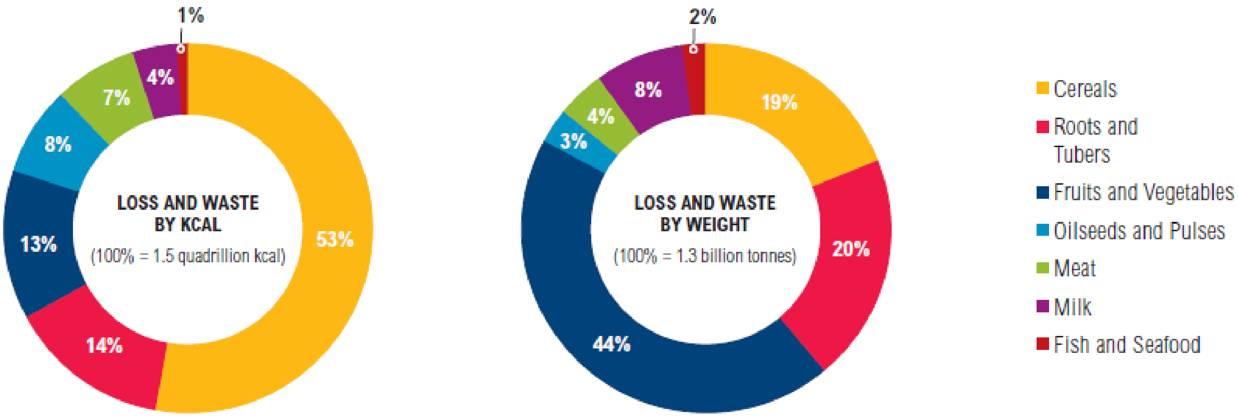

Figure 1, Global food losses and food waste by calories and by weight, Lipinsky et al., 2013

Parfitt et al. (2010) conducted a review for post-harvest losses, both for perishable and non-perishable food: they state that grain is lost for about 15% whilst one third of the production of fruits and vegetables (FFVs) is lost "before it reaches consumers".

The quantification of how much every stage affect the food loss and waste is reported in *Figure 2*, with a differentiation between developing and developed countries. This figure, taken by the study of *Lipinski et al. (2013)*, shows that the production and the storage phases weight 24% each, with no significant difference between developing and developed countries. Consumption phase instead burden for 35% with a significant 28% caused by the developed countries.

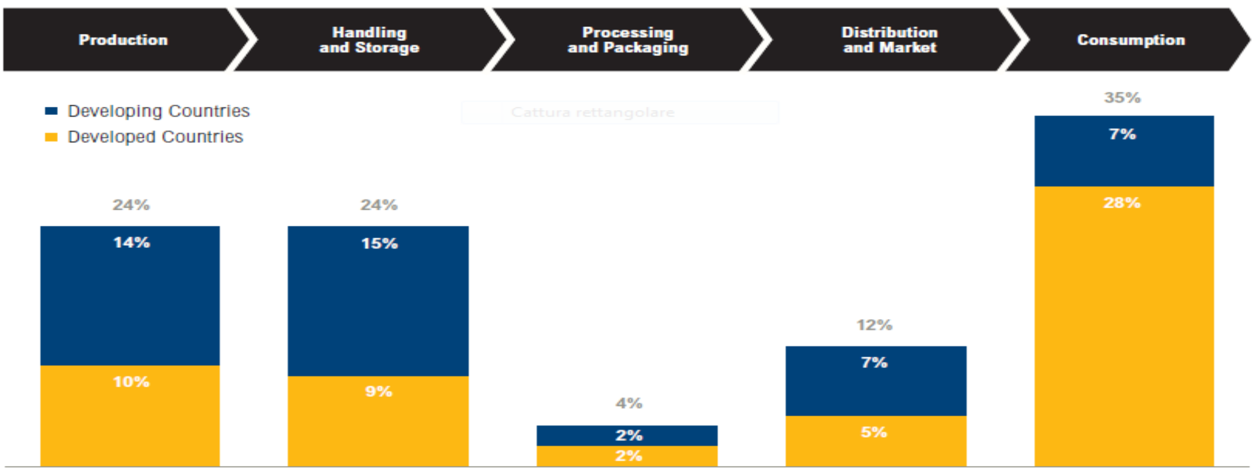

Figure 2, Global food waste within food supply chain, Lipinski et al., 2013

Household food waste is defined as" food and drinks consumed within the home", including home-grown and takeaways (*Parfitt et al., 2010*). It can be distinguished in *unavoidable* and *avoidable*: the first one refers to food wasted during the preparation, such as peels, bones and shell; avoidable part instead is the excess food cooked or prepared and not consumed (*Schott et al., xxx*) or food that exceed the expiry date. The amount of avoidable food waste is a consequence of consumers behaviours and attitudes but also family size and culture of origin (*Vulcano et al.*, 2018). As reported by *Parfitt et al. (2013),* in UK household food waste amount for 8.3 Mt per year, whereas in the United States it is estimated to be 211 kilograms per year, with a cost of $589,76 for a family of four.

The huge contribution of household consumption to the waste of food is validated also by the FUSIONS (Food Use for Social Innovation by Optimising Waste Prevention Strategies) project (https://www.eu-fusions.org/index.php): in 2012, in Europe, household consumption accounted for 53% of the total and together with processing phase represented 72% of the food waste, including edible and inedible parts associated with food (*Figure 3*).

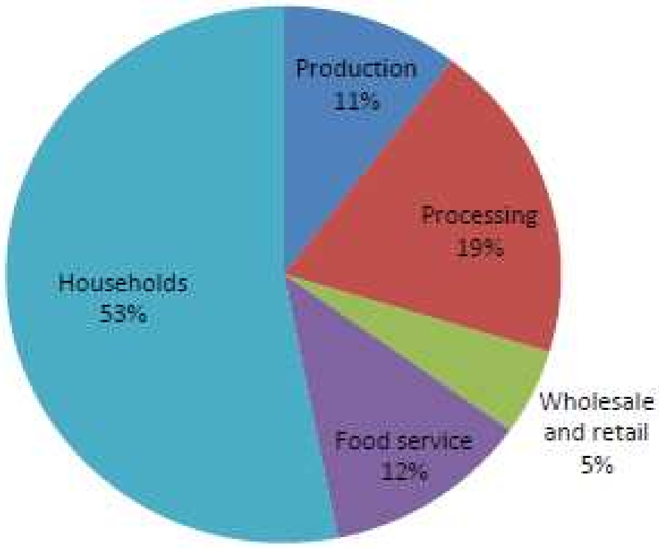

Figure 3, Percentage of the food waste within the stage of food supply chain (FUSIONS)

In Italy, different studies quantified food waste. According to *Vulcano, et al. (2018)*, about 2 Mt of food was wasted in 2005-2006 by agro-food industry with the higher quotes in the processing and conservation of fruit and in the dairy industry. Approximately 400.000 ton of food was wasted by the distribution stage, 40% of whom is represented by FFVs. In addition, specific statistical surveys were conducted about the household contribution: in 2014, 1.19 Mt of food was wasted, and an Italian family threw away an average of 49kg of food every year. Perishable food such as FFVs represented the major fraction of waste, unlike most expensive food like meat, cheese and fish.

Supermarkets waste 18.8 kilograms per m^2 per year, whereas school canteens throw away one meal out of three. Nonetheless, Italy is on the fourth step of the podium in fighting food waste, following France, Germany and Spain: during 2017, almost 71% of Italians reduced or avoided the waste of food (*ANSA, 2018*).

1.3 Environmental implications

Food and agriculture systems cause environmental impacts which can be direct and indirect (*Vulcano et al., 2018*).

The first ones involve the exploitation of water, energy, fossil and natural sources, such as the soil degradation and transformation (especially for cereal crops) or mining, the alteration of nitrogen and phosphorus cycles and the loss of biodiversity, but also the emission of pollutants and greenhouse gases (*Vulcano et al., 2018*).

The environmental indirect impacts instead, are related to the waste management stage and they include the impacts generated from the landfill or incineration disposal or from composting and anaerobic digestion plants. Furthermore, indirect impacts are caused also by the food recovery activities (*Vulcano et al., 2018*) but in a smaller size, as reported by *Albizzati et al. (2019),* in agreement with *Eriksson et al. (2017).*

In 2012, the ecological footprint of the food system was globally 2.8 global hectares per capita while in Italy it amounted to 4.6 global hectares per capita (*Vulcano et al., 2018*).

Globally, FAO calculated the carbon footprint of food wastage in 2011 and it accounted for 4.4 GtCO2 eq per year: the highest contribution was given by consumption stage and, among different types of food, cereals and meat contributed the most (*FAO, 2013*).

As reported by *Vulcano et al. (2018),* the land use change impacts for 11% on the emissions of greenhouse gases. It can be considered as a consequence of the growth of the population, which requires more productive agricultural areas that are by the way exploited and at risk of desertification. Moreover, regarding direct impacts, the food-agricultural systems are responsible for the global loss of 60% of biodiversity, caused mainly by habitat destruction, invasive alien species and the exploitation of few crops. It has also a huge impact on the use of water sources since 87% of freshwater is used for irrigation and animal husbandry and from 2000 to 5000 liters are needed to feed a person every day (*Vulcano et al., 2018*).

As cited above, the direct impacts generated from the waste of food are mainly attributable to their end of life in landfill or incinerator, which generates biogas and percolate and harmful air pollutants, respectively (*Vulcano et al., 2018*). The REDUCE (Research, Education, Communication: an integrated approach for food waste prevention) project carried out an investigation about the food waste found in the disposal facilities in the north of Italy and according to that, estimated that, among municipal solid waste, 5,9Mt are food waste, out of which 1,6Mt are still edible (*Tua et al., 2017*). Therefore, if such food would not be wasted, it would not contribute to the environmental emissions associated with its end of life: 830,5 ton of avoided food waste, would allow to avoid the emission of 1,719 ton CO2 and of 9,16 ton CH4 and the consumption of 7 million hl of water (*Lapi et al., 2017*).

In line with the data reported so far, it is evident that a general reduction of food waste in all its facets will help to fight the impacts on the environment and also on human health, and solutions that addresses prevention of food waste and recovery of surpluses are to be preferred (*Albizzati et al., 2019* and *Eriksson et al., 2017*).

1.4 Approaches and strategies to reduce food waste

As reported by *Vulcano et al. (2018)*, the approaches to reduce food waste can be classified in structural and non-structural measures.

Structural measures focus on the causes that generates food waste; thereby they include strategies as shortening of the food supply chain and promoting awareness about the food waste issue.

Short agro-food chain is in contrast with the model of the large-scale distribution, which levels up the food transformation, increasing in this way the risk of wasting food. In Italy, about 90% of food products pass through the 5 largest chains of large-scale retailing (*Vulcano et al.,* 2018).

It is evident that the first step to shorten the agro-food chain is to reduce the distance between producers and consumers, facilitating local farmers' markets or the direct sale from the place of production. Nowadays, in line with the custom of on-line shopping, digital food hub is growing, in which consumers can order the products directly from their home. An example is given by *Cortilia, Biosolidale, Zolle* and others (*Vulcano et al.,* 2018). It is evident that localizing the food supply chain allows to reduce the transport time, thus preventing spoilage (*Hegnsholt et al., 2018*).

As a second structural measure, raising awareness about food waste and how it can be prevented is crucial; companies play a central role on it. As reported by *Hegnsholt et al. (2018),* companies can train employees so that they have skills to manage the inventory properly: some companies, in collaboration with the Lean Path company, have developed a tracking system that can track waste but also identify its causes, such as overproduction.

Non-structural measures instead, focus on the enhancement of technologies in the phase of storage, transport and commercial supply (*Vulcano et al.,* 2018). An example is reported by *Lipinski et al. (2013)* in which they suggest the use of evaporative coolers, a technique to keep the temperature low without using electricity, to provide "an opportunity to store perishable foods longer in areas that lack electricity infrastructure". They also suggest to stock cereals and other crops in metal silos, to prevent disease due to a bad conservation.

Another example of non-structural measures is food recovery. As pointed out by *Vulcano et al. (2018),* food still edible can be shared between citizens, thanks to online and mobile applications, such as *iFood*, *NextDoorHelp*, or "*Ratatouille*", the latter being a virtual fridge used in the Veneto region to notify that you are willing to donate food: it is a mobile phone application that allows people to tell their neighbors that they have food surplus to donate.

Additionally, food surpluses can be recovered and redistributed to help people who are in need. Food redistribution is defined as a process by which food surplus is "recovered, collected and provided to people" (*European Commission, 2017*). Examples of such activities in Italy are: "*Siticibo*", a food recovery program promoted by Banco Alimentare, that recover food surplus only from catering and canteens and redistribute it to charity organizations (*Banco Alimentare, 2019*); and "*+cibo -spreco*", a project that involves points of sale of large-scale retail trade, promoting continuous solidarity donations: this activity is promoted by Etra spa, a multiutility providing waste service in the Veneto region, and it is the first case in Italy in which a public utility promotes solidarity project (*Favero, 2014*). Finally, one of the most widespread realities is the network of "Empori della Solidarietà", which is active in Italy since 2008 and homogeneously distributed in the national territory. This work focuses on this type of food recovering activity, which is hence presented in detail in chapter 3.

Restaurant and catering are widely responsible for the waste of food, usually because of the large portions served or of the food prepared in advance and never consumed. In order to reduce food waste, many projects have been launched, including the "family bag" (financed by the Ministry of

the Environment and CONAI) and "Il buono che avanza" (supported by the association Cena dell'Amicizia Onlus): in both cases, the aim is to promote the practice of the "doggy-bag", encouraging consumers to take their leftovers home (*Vulcano et al.*, 2018).
Lastly, the production of food waste can be reduced by recycling food, that is no longer available for human consumption, as animal feeding or as ; furthermore, there is the possibility to recycle food components to produce ecological and vegan materials (*Vulcano et al.*, 2018) as substitutes for plastic and leather.

2. REGULATORY FRAMEWORK

The environmental and economic implications related to the waste of food have encouraged nations to draw up laws and tools to contrast this phenomenon.

In 2014, before the Sustainable Development Goals, the 54 member countries of the African Union signed the "Malabo Declaration", to try to halve post-harvest losses by 2025 (*Vulcano et al., 2018*; *FAO, 2019*).

Globally, the *Agenda 2030* is the latest action program drafted by United Nations pursuing a sustainable development. It was signed in September 2015 (*UNric, 2019*) and included seventeen Sustainable Development Goals (SDG's). Among them, the theme of food waste and its related implications are included in goals 2 and 12 (*UN, 2019*).

Goal 2, i.e. *Zero Hunger*, addresses the issues of the world hunger and the growth of population, and state that the global food and agriculture systems must be reconsidered if we want to provide food for "2 billion of people expected to be undernourished by 2050" (*UN, 2019*). Goal 12, i.e. *Responsible Consumption and Production*, includes the target 12.3 "to halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses" by 2030 (*UN, 2019*).

2.1 European framework

The most recent European Waste Framework Directive is dated 19th November 2008 and subsequent additions. The article number 4 defines a waste hierarchy, which puts prevention in the first place and disposal only at the end of the pyramid (*Figure 4*). Article number 9 deepens waste prevention, recommending Member States to take action; in particular, section *g)* reports the target of the Agenda 2030, that is to reduce by 50% global food waste per capita, whilst section *h)* encourages food donation for human consumption (*EC, 2008*).

More specifically, with regard to food surplus, European Union has implemented the "*UE guide lines for food donation*", (*EC, 2017*) which defines roles and obligations of the actors, pointing out that organizations that recover and redistribute food surplus are compared to food business operators: they "should apply good hygiene practices and have an auto-control system (HACCP)30 in place"; they must refuse products that could present a risk for the consumers, such as abnormal aspect of food; moreover, they have to trace the food itinerary, from whom they receive food and to whom they donate it (*EC, 2017*).

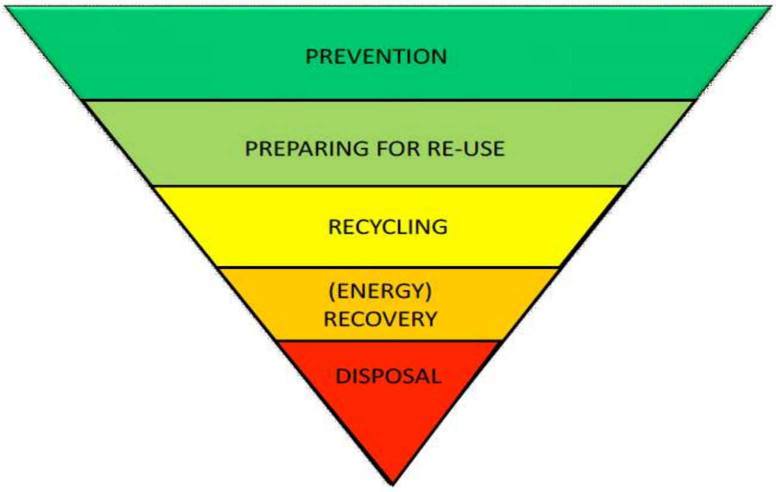

Figure 4, Waste Hierarchy, (EC, 2008)

2.2 Italian framework

One of the first legislative act about food surplus and food waste was the law 155 of 25th June 2003, known as "Good Samaritan Law" (L. 155/03). The sole article of this law equalizes the non-profit organizations to final consumers as regard the correct conservation, transport, storage and use of food and this means a bureaucratic simplification that have facilitated charities in helping indigent people.

Then, in 2013, the European Waste Framework Directive led to the publications of the *National Waste Prevention Program* which contains prevention measures for the waste priority streams, including biodegradable waste. Out of 5 measures, measure two is about the distribution of food surplus from the large-scale retail trade to social canteens and "solidarity supermarkets", measure three promotes a short supply chain, whilst measure five concerns the household waste (*DD, 2013*).

On the 5th of June 2014, Andrea Segrè (president of Last Minute Market and coordinator of PINPAS in Italy) presented the *National Plan for the Prevention of Food Waste* (PINPAS), which summarize ten priority actions to fight food waste, including food education, awareness, research, social innovation and green public procurement, facilitating, within public invitations to tender, catering and restoration services that redistribute food surplus (*Segrè, 2014*).

The most recent law about food surplus is the number 166 of 19th August 2016, known as "Legge Gadda" (L. 166/16) which regulates the donation of foodstuffs and pharmaceuticals. Its article one reports the priority objectives for food waste reduction, among which the redistribution of food surplus for human nutrition is mentioned. Article four establishes that donations are allowed also after the date of minimum durability, as long as packaging integrity and conservation conditions are guaranteed, whereas article seventeen addresses tax reductions: to those who donates food surplus for free, the municipality can apply a reduction on waste tax, proportional to the donated quantity.

3. CASE STUDY: THE NETWORK OF "EMPORI DELLA SOLIDARIETA'", A TOOL FOR RECOVERING FOOD SURPLUS AND PROMOTING SOCIAL INTEGRATION

Like a supermarket but without paying at the checkout: an "Emporio della Solidarietà" can be shortly defined in this way. However, as reported by *Midena*, (*2017*) (Social Services Department) in her presentation "*L'esperienza degli Empori Solidali nella Regione Veneto*", the definition is more detailed: an "Emporio della Solidarietà" is a social project that redistributes basic necessities to indigent, according to their needs and creates an accompanying path to promote personal autonomy. In this way, there is a marriage between tackling food poverty and social integration.
Such "Empori solidali" are addressing families with economic distress, especially those composed by children under 24 months; the access to aid is subordinated to an interview at an assistance centre in which socio-economic conditions are taken into account (e.g. by checking the Indicatore della Situazione Economica Equivalente, ISEE), and if a family results in need of assistance, the head of the family receives a points card, that represents the currency exchange to be used at "Empori solidali" (*Figure 5)* (*Veneto Region, Decree n.11, Annex A)*.

Figure 5: points as currency exchange in an "Emporio della Solidarietà", 2019

This thesis work is focused on the "Empori della Solidarietà" located in the Veneto Region; in 2017, needy people who took advantage form this initiative were about 133 thousand (*Veneto Region, release n. 1376, 2017*). From a legislative point of view, after the regional law 11/2011, in 2013 the Veneto Region approved a three-year program to promote the recover and redistribution of food surplus (*Midena,* 2017). These charities activities, promoted by private citizens and more often by clerical associations, receive a cash financing support, which in 2017 amounted to 490 thousand € (*Veneto Region, Release n. 1376, 2017*).
From an organizational point of view, "Empori della Solidarietà" can be classified as "direct" and "indirect": the first ones are like little supermarkets, where people can directly "buy" food, whereas the second ones are like storage locations that redistribute food surplus to other emporiums or charities.

In the Veneto Region there are thirteen "Empori della Solidarietà" plus "Banco Alimentare", located as follows:

- 5 direct Empori plus Banco Alimentare, in the province of Verona;
- 1 indirect Emporio, in the province of Padova;
- 3 Empori, two direct and one indirect, in the province of Venezia;
- 3 Empori, two direct and one indirect, in the province of Treviso.

Banco Alimentare is a national ONLUS that promotes food surplus recovery and organizes the national "food collection" day. The central direction in Veneto is based in Verona (*Figure 6*) and there are also two support warehouses, located in Vigonza (Padova) and Verona. Banco Alimentare can be considered as a huge indirect emporium which collect food surplus from large-scale retail trade, fruit and vegetable markets and producer companies. In the province of Verona there are also five direct Empori that have *Caritas* as lead partner, but they are smaller than Banco Alimentare.
The indirect Emporio in the province of Padova is based in Cittadella: it uses a storage provided by a clerical association, by paying a forfeit for electricity and rent. At first it was born as a meals recovery activity and then it developed as an emporium in March 2017 (*Figure 7*).
The three Empori in the province of Venice are located in Chioggia (*Figure 8*), San Donà di Piave (*Figure 9*) and Mirano (*Figure 10*). The first two are direct, their lead partners are clerical

associations and they redistribute food to needy people resident in the municipality, whilst Mirano is an indirect emporium, whose lead partner is a group of social cooperatives.
One of the biggest indirect emporium is located in the municipality of Montebelluna (*Figure 11*), in the province of Treviso and it receives fruit and vegetables mainly from market organizations located all around Italy, from Cuneo to Ragusa including Latina and Chieti. In the province of Treviso there are also two direct emporiums: one is located just outside the city walls and uses a former monastery as headquarter (*Figure 12*). The second one instead, is based inside the headquarter of the Province of Treviso and it is the only one in Veneto located into a public organization; it is physically located into a former theater and it differs from the other emporiums because it redistributes also clothes, books and toys (*Figure 13*).

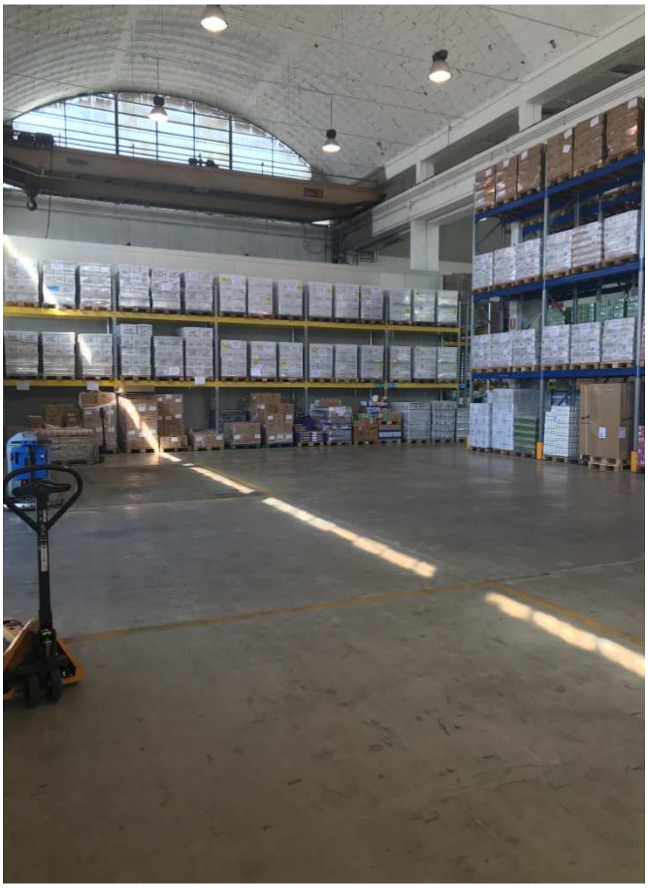

Figure 6, Banco Alimentare

Figure 7, Cittadella

Figure 8, Chioggia

Figure 9, San Donà di Piave

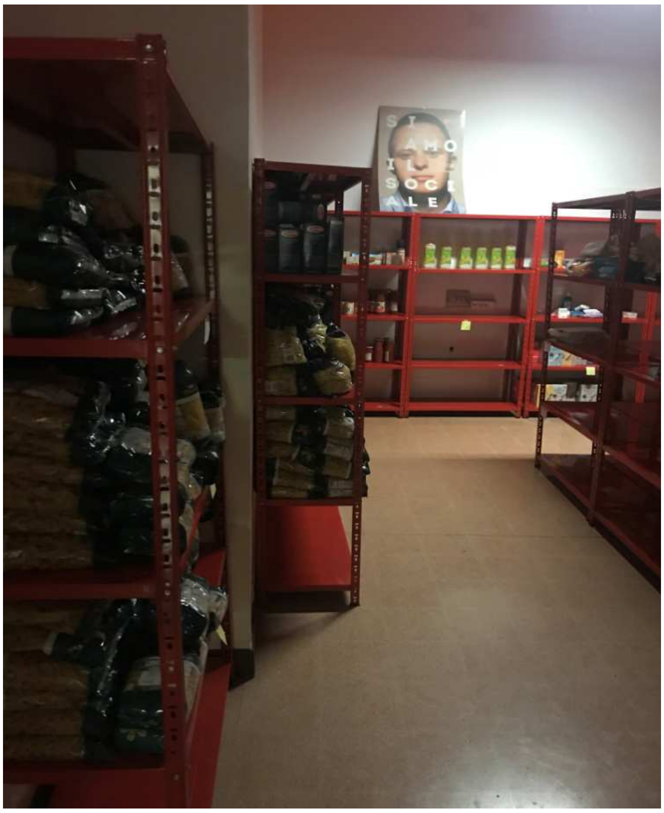

Figure 10, Mirano

Figure 11, Montebelluna

Figure 12, Treviso, inside the city wall

Figure 13, Treviso, inside the ex-theatre

4. MATERIALS AND METHODS

4.1 Bibliographic search

To understand the state of the art of LCA studies applied to the food, food waste and food redistribution sector, a bibliographic search was conducted using Scopus as databases. The keywords used have become increasingly specific, leading to a reduction in the number of documents found: for example, by entering "LCA food production" as a keyword, 1031 documents were found, which were drastically reduced to 2 using specific keywords such as "LCA food donation system". The other keywords used were "LCA food sector", "LCA food waste management" and "LCA food surplus”. The results of this research are presented and discussed in chapter 5.

4.2 Life Cycle Assessment

Life cycle assessment (LCA) is an objective method for assessing the potential environmental impacts and resources used during the life cycle of a product, which may be a good or a service (*ISO, 2006a*). The process goes from the extraction and treatment of raw materials, through production, use and transport, up to the final disposal or recycling of the product (*Society of Environmental Toxicology and Chemistry – SETAC, 1993*). The LCA is a standardized method according to International Standard Organizations – ISO 14040 and 14044:2006 (*ILCD Handbook: General guide for Life Cycle Assessment – Detailed guidance*) and consists of four distinct phases (*Figure 14)*:

1. Goal and Scope Definition
2. Life Cycle Inventory
3. Life Cycle Impact Assessment
4. Interpretation

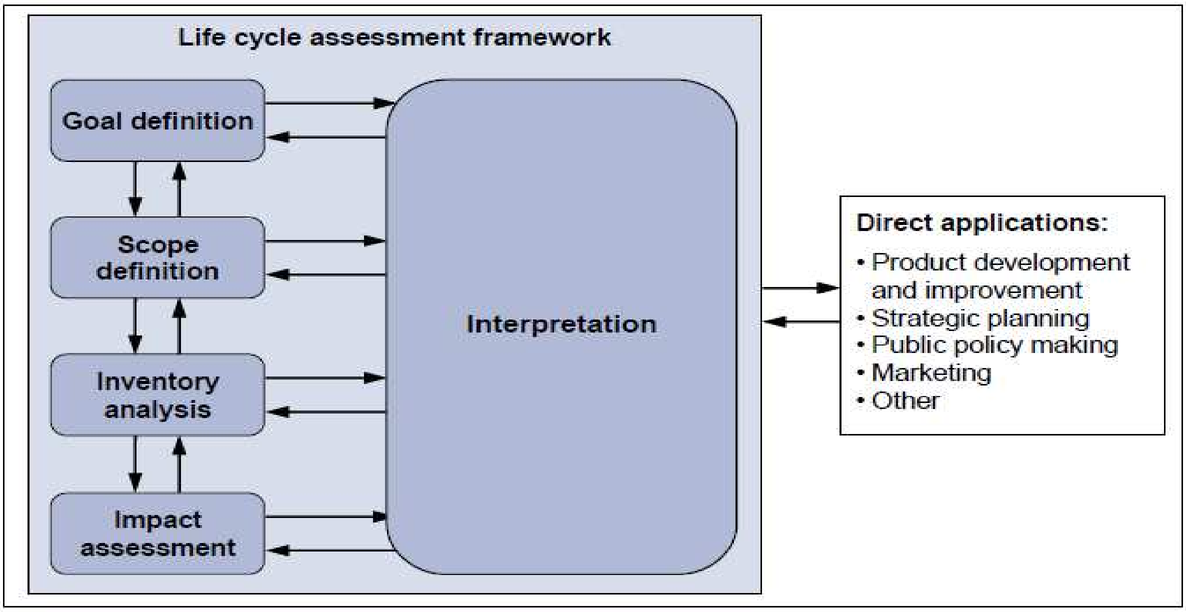

Figure 14, LCA phases (ILCD Handbook: General guide for Life Cycle Assessment – Detailed guidance)

In the first phase, the objectives of the study are clearly defined, establishing the intended application, the starting motivation and the audience to which the results are to be communicated (*ISO, 2006a*). Furthermore, in this phase the system boundaries and the functional unit are defined. In order to define the boundaries of the system, it is necessary to represent them in a schematic diagram that highlights which parts of the life cycle are included in the study, and which parts are excluded (*ILCD Handbook: General guide for Life Cycle Assessment – Detailed guidance*). The term functional unit is used to define a quantitative measure "of the function that the goods (or service) provide", to which the results obtained are referred (*Finnveden et al., 2009*). In order to choose the functional unit of many products, it is sufficient to distinguish between two fundamental aspects such as the duration of use over time and the extent of the actual function provided (*ILCD Handbook: General guide for Life Cycle Assessment – Detailed guidance*).

Life cycle inventory involves the compilation and quantification of material and energy inputs (resources) and outputs (emissions) through the various phases of the life cycle of a product or service, thus constructing a flow diagram of the system to be analyzed (*ISO 2006a*).

At this stage, data collection takes place. Most of the data should be collected directly in the field but very often the data for the system under study are missing. For this reason, over the years, several databases have been built, in order to facilitate the inventory phase, replacing the missing data (*Finnveden et al., 2009*). Public databases available are national, regional, industrial or consultants'; national and regional databases are used in each Life Cycle Assessment, as they provide data on electricity, raw materials, transport and waste services, often based on average data, “representing average production and supply conditions for goods and services” (*Finnveden et al., 2009*).

The available databases are already included in the software used to conduct the life cycle analysis. The software used for this thesis is SimaPro, released in 1990 by PRé Consultants and now sold worldwide (*Herrmann et al., 2014*). Among the databases contained in SimaPro, we have chosen to work with Ecoinvent v 3.3, LCA food and Agrifootprint.

The main phase of a life cycle assessment is the impacts analysis. At this stage, the data from the previous stage are characterized on the basis of their potential effects on the environment and “aggregated in support of interpretation” (*Finnveden et al., 2009, ILCD Handbook: General guide for Life Cycle Assessment – Detailed guidance*): inventory data are "compressed" into a shorter list of impact categories, which can be differentiated on two levels, midpoint and endpoint. Midpoint assessment includes a longer list of impact categories while endpoint assessment refers to three protection areas, which are human health, natural environment and natural resources (*Figure 15*).

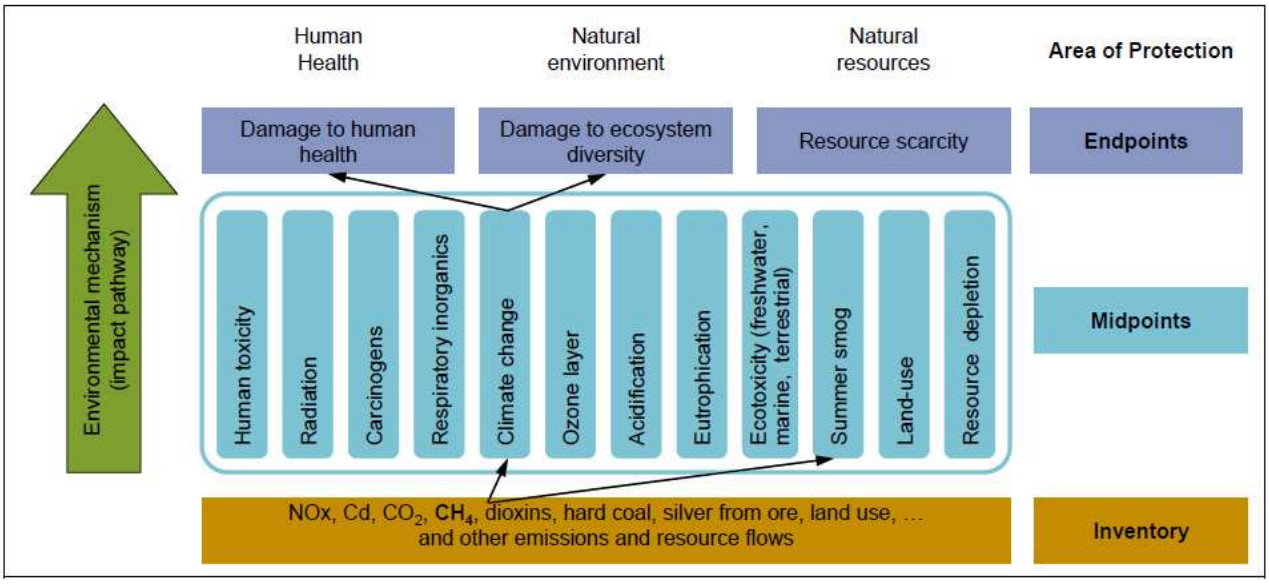

Figure 15, Life Cycle Impact Assessment, ILCD Handbook: General guide for Life Cycle Assessment – Detailed guidance

The mandatory steps included in the analysis of impacts are the selection of impact categories and their classification and the selection of the method of characterization (*ISO 2006a, b*). There are several possible methods for the analysis of impacts; among those available, in this thesis ReCiPe 2016 has been used. This method was chosen because it includes impact categories at both midpoint and endpoint levels, with characterization factors based on a global scale. The impact categories contained in the midpoint level are 18, unlike the 14 contained in the IMPACT 2002+ method: a higher number of impact categories allows to obtain more accurate and precise results (*ILCD Handbook: General guide for Life Cycle Assessment – Detailed guidance*) and also for this reason the use of the ReCiPe method was preferred. Of the three perspectives proposed by the method, the hierarchical one was chosen since it refers to the most common policy principles. In addition, as far as climate change is concerned, it is based on a time horizon of 100 years. The individualist perspective instead, is based on a time horizon of 20 years, whilst the egalitarian one on a time horizon of 1000 years: unlike the time horizon considered by the hierarchical perspective, the former is too short, the latter too long.

Finally, in the last phase, the results are considered all together and analyzed on the basis of the accuracy of the data and on the basis of the assumptions made in the previous phases; the interpretation phase therefore allows the questions posed in the goal and scope definition phase to be answered (*ILCD Handbook: General guide for Life Cycle Assessment – Detailed guidance*).

5. LIFE CYCLE ASSESSMENT FOR FOOD WASTE AND FOR RECOVERING STRATEGIES: THE STATE OF THE ART

“LCA food production" was the first keyword used in the bibliographic search which led to 1031 documents, reduced to 700 by limiting the search to the area of "environmental science". The articles found present various and sometimes unrelated topics: from the environmental impacts of Canadian cherries production to a study supporting the choice of omega 3 fats for a more nutritionally and environmentally healthy diet.

To refine the search, the second keyword used was "LCA food sector", which allowed to find 251 documents, then reduced to 186 by limiting the search to "environmental science". Again, the articles addresses different topics, ranging from water footprint to social implications of the production of palm oil, up to a full LCA study comparing the environmental impacts of catering services and ready-made meals.

Therefore, by using general keywords, a large amount of bibliographic documents can be found, which covers various topics, sometimes not even remotely related to the topic of this thesis work.

As far as food waste management is concerned, the bibliographic search led to 277 studies, then reduced to 222 by limiting the search to "environmental science". These studies are mainly aimed at investigating the environmental impacts related to the treatment of food waste, such as anaerobic digestion and composting, often compared to incineration, and focus on the last stages of the waste hierarchy; as an example, according to *Salemdeeb et al., 2018,* composting is the least environmentally damaging process followed by anaerobic digestion and incineration.

End of life scenarios such as composting or incineration are also considered in LCA studies addressing the (avoided) environmental impacts of food donation systems. Using “LCA of food donation system” as keywords, only two papers were found, published in 2017 by *Eriksson et al.*, and in 2019 by *Albizzati et al*. The first one focuses on a carbon footprint of food waste management options for fruit and vegetables, comparing four different scenarios: incineration with energy recovery, anaerobic digestion, conversion to chutney and donation. The second one instead, considers not only global warming but a total of ten impact categories, among which human toxicity and water depletion; it compares four scenarios as well: donation/animal feed, incineration, anaerobic digestion and a scenario called “prevention” in which it is assumed that food is not wasted at all. Both agree that food surplus management focusing on the priority levels of waste hierarchy (prevention, donation and conversion) impact less than anaerobic digestion and incineration.

There are other studies that concern food donation systems but they are not assessing environmental impacts. For example, *Moggi et al. (2018)* and *Garrone et al. (2014)* present and promote food surplus recovery, suggesting what can be done to improve donation systems. More specifically, *Moggi* and colleagues stress the importance of Corporate Social Responsibility in reducing food waste, suggesting that farmers market organizations work together for a common purpose, whilst *Garrone and colleagues* enlighten the process through which the food supply chain firms come to donate surplus food-to-food banks.

Finally, by using "LCA food surplus" as a keyword in the bibliographic search, 13 articles were found, which however mainly refer to crops used to produce biomass for energy purposes, therefore not relevant for the topic of this thesis work.

To sum up, the bibliographic search conducted using general keywords related to the food sector has led to numerous results addressing various topics. By refining the search using keywords more directly related to the issue of recovery and redistribution of food, it emerges that the studies conducted so far are few: most of them investigate the environmental impacts of food treated as waste, and only a couple of very recent studies includes the priority stages of the waste hierarchy, such as prevention and donation. There is therefore a need to further investigate the environmental impacts of these initiatives in order to better understand how much they can support improving sustainability in the food value chain.

This thesis work can therefore represent a first step in this direction.

6. LIFE CYCLE ASSESSMENT OF THE NETWORK “EMPORI DELLA SOLIDARIETA’”

6.1 Goal and scope definition

The study conducted in this thesis is a "cradle to grave" LCA of the "Empori della Solidarietà" in the Veneto region. The study used emporiums' data for 2017 to allow the comparison with the data on Veneto’s municipal waste, available for the same year; indeed data collection started in early 2019 and ARPAV reports on municipal waste in 2017 were not yet available at that time.

Two scenarios were analyzed: a scenario 0 in which surpluses were treated as waste and a scenario 1 in which surpluses were recovered thanks to emporium activity. The goal was to identify the environmental impacts generated by the surplus recovery activity, and to compared them with those generated by the surplus treated as waste.

The functional unit was the management of 1 kg of recovered food (wet weight basis), the packaging of which was not been considered since, in terms of weight, it accounts for only 2% (as reported by *Albizzati et al., 2019*).

As described in chapter 4.2, Ecoinvent v.3.3, LCA Food DK and Agrifootprint 2.0 databases were used.

The method used for the impacts assessment was ReciPe Midpoint H, which includes 18 impact categories namely: Climate change, Ozone depletion, Terrestrial acidification, Freshwater eutrophication, Marine eutrophication, Human toxicity, Photochemical oxidant formation, Particulate matter formation, Terrestrial ecotoxicity, Marine ecotoxicity, Ionising radiation, Agricultural land occupation, Urban land occupation, Natural land transformation, Water depletion, Metal depletion and Fossil depletion.

6.2 Life Cycle Inventory

As mentioned in the previous chapter, two scenarios were analyzed: a scenario 0 in which surpluses are treated as waste and sent for disposal (called also disposal scenario) (*Figure 16*) and a scenario 1 in which surplus food is recovered and redistributed (called also recovery scenario) (*Figure 17*).

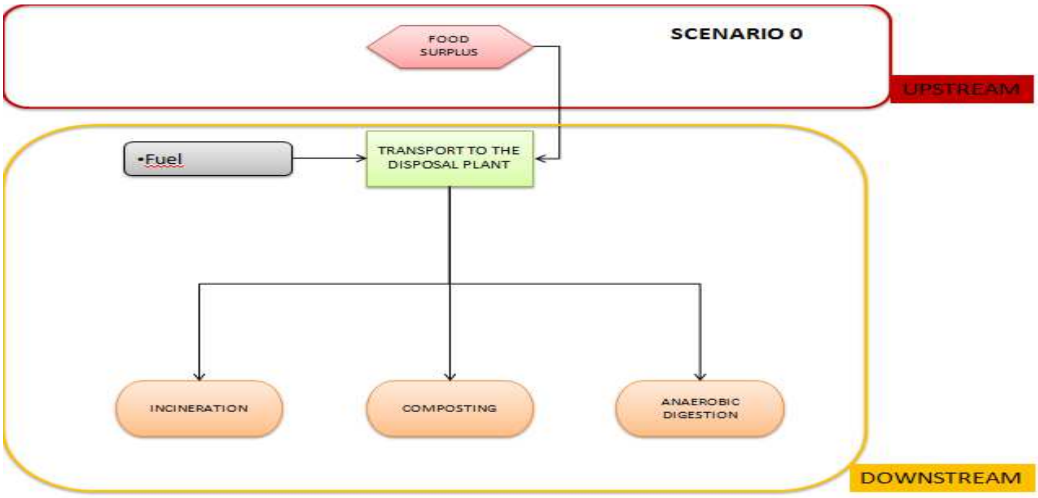

Figure 16, scenario 0

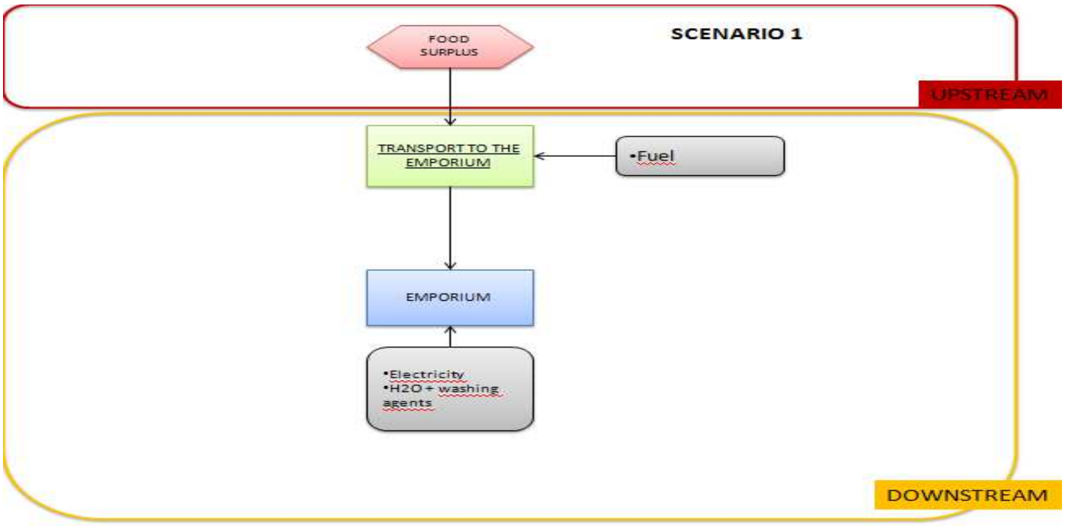

Figure 17, scenario 1

For the modelling of the recovery scenario, the following data were requested: voltage, supplier and consumption of electricity; consumption of heating fuel; water consumption; type and quantity of detergents used to clean the emporium; number of cold rooms, refrigerant gas used and reintegrated quantity; mode of transport of surpluses and characteristics of the vehicles used; quantity and type of surpluses recovered and their place of origin. In the absence of the latter data, the kilometres travelled or the total fuel consumption were requested.

The necessary data were collected in the field (i.e. primary data), through direct interviews with representatives of the emporiums or by sending them an excel questionnaire to be completed. The latter was the case with the emporiums located in the province of Verona, as it was not possible to agree on a day for an interview that would suit both parties.

In addition, as the emporium's staff is made up of volunteers who devote their free time to the activity of the emporiums, data collection has proved to be difficult, especially with regard to technical data, such as electricity consumption or the amount of energy replenished by the cold rooms. Another limitation was the fact that many emporiums use buildings made available by municipalities, religious associations and public bodies and therefore have not been able to retrieve the requested information directly. For this reason, five emporiums were excluded from the LCA study and specifically: two emporiums located in Treviso, one for providing data about 2018 (because in previous years they did not keep an account of consumption and quantities managed) and the other one for not providing data on energy consumption and transport, and the emporiums of Mirano (VE) Villafranca (VR), and Montebelluna (TV) again for not providing data on energy consumption and transport.
Some difficulties were also encountered in the collection of data related to the type of food surplus; while some emporiums indicated quantities of specific products, most of them indicated quantities related to macro categories of food, such as "fruit and vegetables" or "fresh and dairy products", without specifically reporting the type of products.
Others, such as the emporiums Casa del Colle (VR) and Don Giacomelli, (VR) did not indicate the macro categories; it was impossible to even estimate the macro category of products recovered by them and for this reason these two emporiums were excluded.

To sum up, the emporiums considered in this study are: the direct ones of Chioggia (VE), San Donà di Piave (VE) San Martino Buonalbergo (VR) and Legnago (VR); the indirect one of Cittadella (PD) and Banco Alimentare (VR).

In case of lack of data or data only partially provided, some assumptions have was made as follows.

<u>Cold rooms and quantity of refrigerant gas replenished</u>. Only Banco Alimentare was able to indicate all the information requested, asserting that the reintegrated quantity was zero. Out of the remaining emporiums some have no refrigerated cells, in some others such cells are not used or are small, i.e. containing less than 3 kg of refrigerant gas, and therefore not subject to the F-gas regulations, which concerns the containment, use, recovery and distribution of fluorinated greenhouse gases contained in refrigeration systems that requires annual checks starting from 3 kg

(CE 842/2006). As a result of these considerations, it was decided to use the data provided by Banco Alimentare also for all the other emporiums, and therefore, since a reintegrated quantity equal to 0 does not generate any kind of environmental impact, cold rooms were not included in the LCA modeling.

Electricity consumption. The database Ecoinvent v3.3 contains data for 2014, provided by the International Energy Agency (IEA): these are old data, not referred to specific sites. For this reason, it was decided to create a new process using the data of the energy mix indicated by the energy suppliers, taking into account the latest preliminary and precautionary data for 2017 (as reported in *Figure* 18). When emporiums did not provide information on their electricity suppliers, or when it was not possible to retrieve data on the operator's energy mix, data from the Gestore Servizi Energetici (GSE) have been used. This was the case of Chioggia (VE).

The data provided by the GSE and other operators concern high voltage energy mix, while emporiums receive energy in low voltage. For this reason, it was necessary to create a specific process. Specifically, the percentage data provided by the national operators have been partitioned between the various electricity production processes present in SimaPro (*Figure* 19), with specific considerations regarding electricity from nuclear sources and from photovoltaics.

Fonti primarie utilizzate	Composizione del mix iniziale nazionale utilizzato per la produzione di energia elettrica immessa nel sistema elettrico italiano	
	2016*	2017**
Fonti rinnovabili	38,85%	36,60%
Carbone	15,47%	13,75%
Gas naturale	37,97%	42,34%
Prodotti petroliferi	0,79%	0,75%
Nucleare	3,78%	3,68%
Altre fonti	3,14%	2,88%

*dato consuntivo
**dato pre-consuntivo

Figure 18, energetic mix provided by GSE

	SIMAPRO	GSE	
Electricity, high voltage {IT}| electricity production, deep geothermal | Alloc Def, U	0.0203	0.0233	
Electricity, high voltage {IT}| electricity production, hydro, pumped storage | Alloc Def, U	0.0074	0.0085	
Electricity, high voltage {IT}| electricity production, hydro, reservoir, alpine region | Alloc Def, U	0.1004	0.1154	
Electricity, high voltage {IT}| electricity production, hydro, run-of-river | Alloc Def, U	0.0565	0.0649	
Electricity, high voltage {IT}| electricity production, wind, <1MW turbine, onshore | Alloc Def, U	0.0141	0.0162	
Electricity, high voltage {IT}| electricity production, wind, >3MW turbine, onshore | Alloc Def, U	0.0043	0.0049	
Electricity, high voltage {IT}| electricity production, wind, 1-3MW turbine, onshore | Alloc Def, U	0.0318	0.0366	0.2699
Electricity, **low voltage** {IT}| electricity production, photovoltaic, 3kWp slanted-roof installation, multi-Si, panel, mounted | Alloc Def, U	0.01684219	0.0194	
Electricity, **low voltage** {IT}| electricity production, photovoltaic, 3kWp slanted-roof installation, single-Si, panel, mounted | Alloc Def, U	0.01347376	0.0155	
Electricity, **low voltage** {IT}| electricity production, photovoltaic, 570kWp open ground installation, multi-Si | Alloc Def, U	0.05326953	0.0612	
	0.3183	0.3660	
Electricity, high voltage {IT}| electricity production, hard coal | Alloc Def, U	0.1736	0.1352	
Electricity, high voltage {IT}| electricity production, lignite | Alloc Def, U	0.0030	0.0023	
	0.1766	0.1375	
Electricity, high voltage {IT}| electricity production, natural gas, combined cycle power plant | Alloc Def, U	0.1499	0.3338	
Electricity, high voltage {IT}| electricity production, natural gas, conventional power plant | Alloc Def, U	0.0403	0.0896	
	0.1902	0.4234	
Electricity, high voltage {IT}| electricity production, oil | Alloc Def, U	0.01272259	0.0075	
Electricity, high voltage {IT}| import from FR | Alloc Def, U	0	0.0368	
Electricity, high voltage {IT}| heat and power co-generation, biogas, gas engine | Alloc Def, U	0.0293	0.0022	
Electricity, high voltage {IT}| heat and power co-generation, natural gas, combined cycle power plant, 400MW electrical | Alloc Def, U	0.1693	0.0126	
Electricity, high voltage {IT}| heat and power co-generation, natural gas, conventional power plant, 100MW electrical | Alloc Def, U	0.1043	0.0078	
Electricity, high voltage {IT}| heat and power co-generation, oil | Alloc Def, U	0.0552	0.0041	
Electricity, high voltage {IT}| heat and power co-generation, wood chips, 6667 kW, state-of-the-art 2014 | Alloc Def, U	0.0098	0.0007	
Electricity, high voltage {IT}| treatment of blast furnace gas, in power plant | Alloc Def, U	0.0111	0.0008	
Electricity, high voltage {IT}| treatment of coal gas, in power plant | Alloc Def, U	0.0068	0.0005	
	0.3857	0.0288	
			0.9039

Figure 19, examples of the data partitioning between the ones provided by SimaPro and the ones provided by GSE

Fuel consumption. For all the emporiums analyzed, the heating system is connected to the electrical system. The data of the heating fuel were therefore included in the electricity consumption.

Use of detergents and water consumption. The emporiums of San Donà di Piave and Cittadella did not provide data on water consumption, as it was considered negligible and therefore irrelevant. Banco Alimentare and Legnago were unable to find information on the detergents used. In this case, it was decided to proceed as follows: the emporiums that provided the data for the consumption of water and detergents were first modeled and the impact was found to be actually insignificant on the total. For this reason, the modelling of the remaining emporiums was carried out in the same way, as consumption of water and use of detergents pointed out to be not relevant on total impacts.

Type of food surpluses recovered. The emporiums of Chioggia which is active mainly in the recovery of fruit and vegetables, reported specific data for the types of food products recovered and therefore it was not necessary to make any assumption. Chioggia recovered peaches, nectarines, plums, apricots, oranges, pears, carrots, salads, peppers, tomatoes, watermelons, apples, kiwis, cucumbers, with the addition of potatoes, onions and radicchio, for a total of 5510,5 kilos in 2017.

Banco Alimentare recovered products for an amount of 1896239,3 kilos. It provided an excellent level of detail, with a high number of macro-categories, including "meat", "fish", "oils and seasonings", "fresh and dairy products". However, there were also items that did not refer to any macro-categories, such as "other food", "mixed fresh food", "other frozen food" or "vegetable fats". The following assumptions were made to make up for this lack of data:

- "fresh meat - other" and "frozen meat - other" were modeled as poultry, since the remaining surpluses of the macro- category "meat" concerned only pork and beef;
- "other frozen" have been split in half between frozen fish and frozen bread;
- "mixed fresh food" have been distributed equally between the products listed under the category "fresh and dairy products";
- the amount of "other food" was considered as "candies", since the two items were listed together;
- for "vegetable fats" the choice went to sunflower seed oil, as it was found to be the most consumed by Italians in 2015, as reported by *Repubblica* in an article of 22 October 2016. Since the database does not contain the Italian production process, it was decided to use the Ukrainian process, as it is one of the largest producers, together with the Russian Federation (*FAOSTAT. © FAO Statistics Division, 2009*).

The remaining data on the type of food recovered, despite being very accurate, still required a series of assumptions because within the databases it was not always possible to find the reference process.

For example, "dry pasta", "fresh pasta", "tortellini", "pizza", "biscuits", "pastries" and "other cereal derivatives" were modeled as "bread". "Spices" was modelled as "coffee", partly because it was listed together with coffee and partly because it was not possible to find any process for a specific spice. Within the macro category "fruit", some types of product were clearly indicated (e.g. apples, clementines, pears, peaches and kiwis) while others were simply reported as "fresh fruit". To include the latter, it was decided to use a mix of fruits recovered from the emporium of Montebelluna,(peaches, nectarines, plums, apricots, oranges, pears, watermelons, apples, kiwis), modeling a category called “fruit mix”. "Fruit juices" and "preserved fruit" were modelled as "fruit mix". The same reasoning has been made for the macro category vegetables and legumes. For the first one, it was decided to use a mix of vegetables recovered again from Montebelluna (carrots, salads, peppers, tomatoes, cucumbers). For the second one, the most consumed legumes in Italy were chosen (lentils, beans, chickpeas and peas) as reported by an article in the "Corriere Ortofrutticolo" which mentions data from the Institute of Services for the Agricultural Food Market (ISMEA) (*Corriere Ortofrutticolo, 2016*). These products have been used to model the macro category "vegetables and legumes".

"Soft drinks" and "spirits" were modeled as “bottled water”. As far as “eggs” are concerned, in the software the unit of measure is "pieces". Since the data provided by the emporiums were in kilos, it was decided to model this process using another source of protein, namely cheese, as done by *Albizzati et al. (2019)*.

Finally, quantities of "ready-to-serve soups" and "homogenized" (usually composed of dried pasta and legumes and fruit or chicken, respectively), were equally divided in and modelled as fruit, vegetables and legumes, chicken and bread.

The emporium of San Donà di Piave has provided data regarding the recovery of frozen chickens, eggs, fresh and dairy products, fish, flour, biscuits and snacks, fruit and vegetables, for a total of 34473 kilos. The same assumptions made for Banco Alimentare were applied to this emporium.

The surplus recovered by the emporium of San Martino Buonalbergo was modeled in the same way. This emporium recovered: pasta, rice, legumes, canned tuna, tomato puree, milk and dairy products, soft drinks, coffee, confectionery, olive oil and seed oil and related bread products, for a total of 63600 kilos.

Cittadella emporium recovered a total of 15147.8 kilos, including fruit, vegetables, flour, potatoes, beverages, rice and turkey. Products received from Caritas was excluded from the modelling, as these associations receive mainly from private donors, and these donations do not constitute a surplus (*Federica Germani, ARPAV, personal communication*). For the emporium of Cittadella, multiple assumptions were necessary, since for some products data were provided only as "outgoing donation" and not as "recovered surplus". In this case, the outgoing quantity was considered equivalent to the recovered quantity.

In addition, there were difficulties with the units of measurement, since most of the data were provided in "packages" or "cassettes". Only in the case of apples and pears it was reported that 15 packages were equivalent to a weight of 225 kilos and in the case of tomatoes, 1 package was 1,5 kilos. Such conversion factors were used also for “fruit” and “vegetables”, respectively. When the unit of measurement provided was "cassettes", it was assumed that they were equivalent to "packages".

Finally, the emporium of Legnago provided data for the recovery of fruit and vegetables only, for a total of 9000 kilos.

It is important to underline that the Banco Alimentare supply the direct emporiums. To avoid double counting of the quantities recovered, the products that the direct emporiums have received from the Banco were excluded from the final count.

Transport. Only Chioggia reported the quantities transported in each trip from the place of origin of the surplus to the emporium; in this case, it was possible to adequately calculate the kgkm.

Cittadella, Legnago, San Donà di Piave e San Martino Buonalbergo provided data on the amount of fuel consumed in 2017 and on how many kilometres can be covered with a litre. In this way it was possible to calculate the kilometres travelled by each emporium during 2017. The emporium of Legnago pointed out that the number of kilometres travelled also includes the journeys that the vehicle has made for Caritas canteen services, an activity that is not part of the recovery of surpluses. As a result, the transport figure for the Legnago emporium was overestimated.

Banco Alimentare was a special case. The Banco used three means of transport to recover surpluses, and for each mean it indicated the total fuel consumption and how many kilometers it can travel with one litre. However, it did not indicate the quantity of food that can be transported by each mean. Therefore, to calculate the kgkm it was assumed that the heaviest vehicle carried 60% of the surplus recovered, and the remaining 40% was equally divided between the remaining two (equally weighting) vehicles.

Disposal scenario. Disposal scenario consists of a single scenario in which three types of disposal are included: incineration, anaerobic digestion and composting. The waste streams are divided as follows: 15% is sent to incineration, while the rest is divided into 49% anaerobic digestion and 51%

composting. The percentages used for composting and anaerobic digestion are those reported by ARPA Veneto in the "*Rapporto rifiuti urbani*" of 2018; while 15% refers to the percentage of food waste in incinerators in Northern Italy, as reported by *Tua et al., (2017*). For modelling this scenario it was assumed that the surpluses with packaging goes directly to the incinerator, while the surpluses without packaging are sent to anaerobic digestion and composting (*Stefania Tesser, ARPAV, personal communication*). In order to calculate the kilometers travelled to the disposal site, it was assumed that most of the surpluses occurred in supermarkets, which are mainly located in provincial capitals. An average of the distances between disposal plants (the list of which was provided by ARPAV for composting and anaerobic digestion, and Ispra for incineration) and related provincial capitals was then calculated and used.

In the recovery scenario, no disposal option was taken into consideration, as the end of life is represented by the arrival of surpluses at the emporium.

6.3 Impact Assessment and Interpretation

This chapter presents and discusses the results of the impact assessment. In particular, *Figure 20* shows, for each emporium, the overall impacts of both scenarios for each midpoint. This graph was obtained by normalizing to 100% the highest value obtained (among emporiums and scenarios) for each midpoint and reporting the other values as relative percentage with respect to it.

The next figures, from "a" to "n", represent, in percentage values, the contribution of each process used in the modelling of scenarios, such as the type of food recovered, electricity consumption, transport and disposal processes. There are 12 figures, two for each emporium, representing scenario 1 and scenario 0, respectively.

As a general comment about the results reported in *Figure 20*, it can be noticed that in 13 midpoints out of 18 the emporium of Legnago shows in scenario 1 the highest value among all the emporiums and scenarios. This is due, as shown in *Figure g*, to the contribution of the transport activity, for which overestimated data have been provided (0.4 kilometers travelled for FU, i.e. 1 kilogram of recovered food).

In the following paragraphs, the results will be described and discussed in more details at midpoint level.

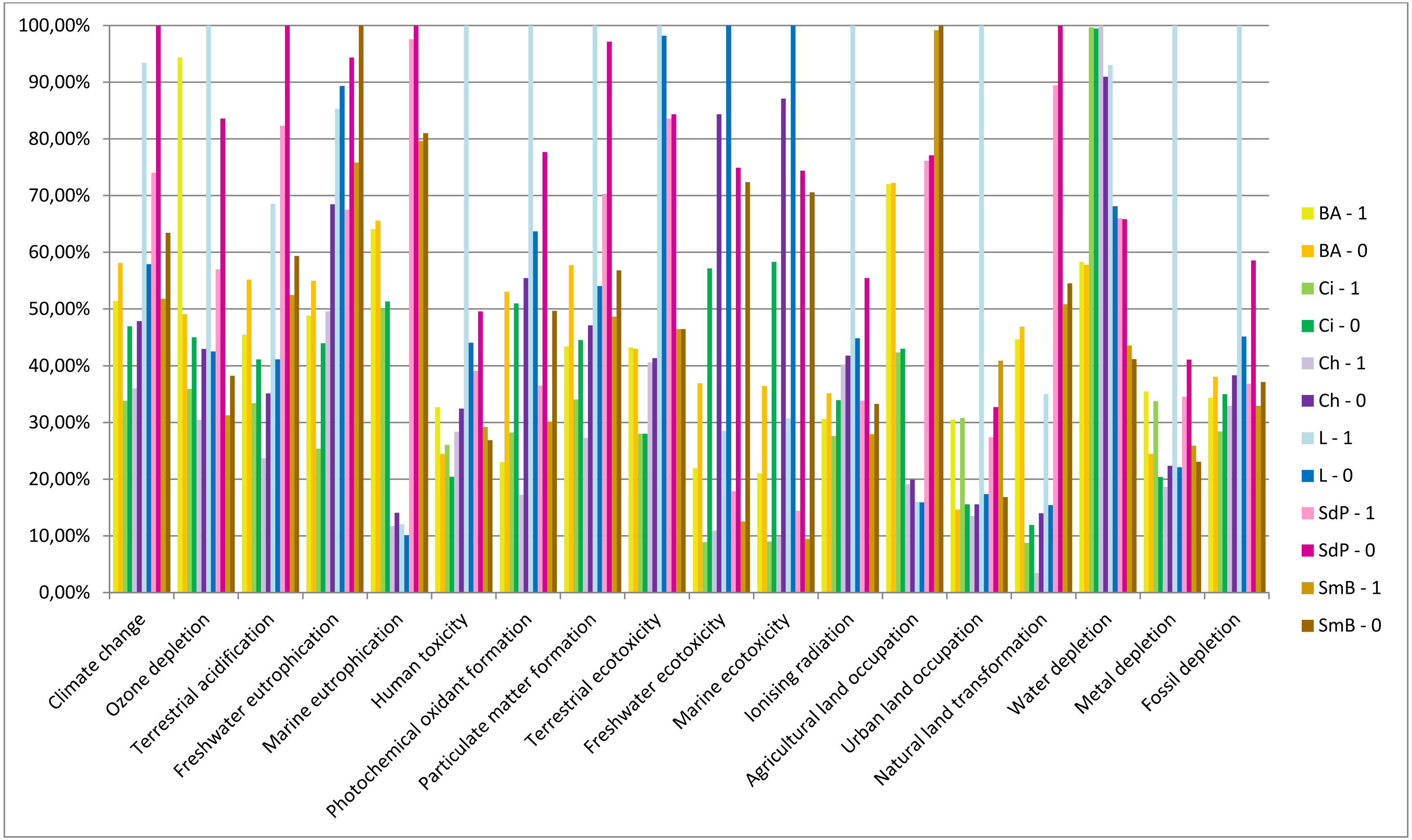

Figure 20, Overall impacts

Legends: BA, Banco Alimentare; Ci, Cittadella; Ch, Chioggia; L, Legnago; SdP, San Donà di Piave; SmB, San Martino Buonalbergo.

BANCO ALIMENTARE

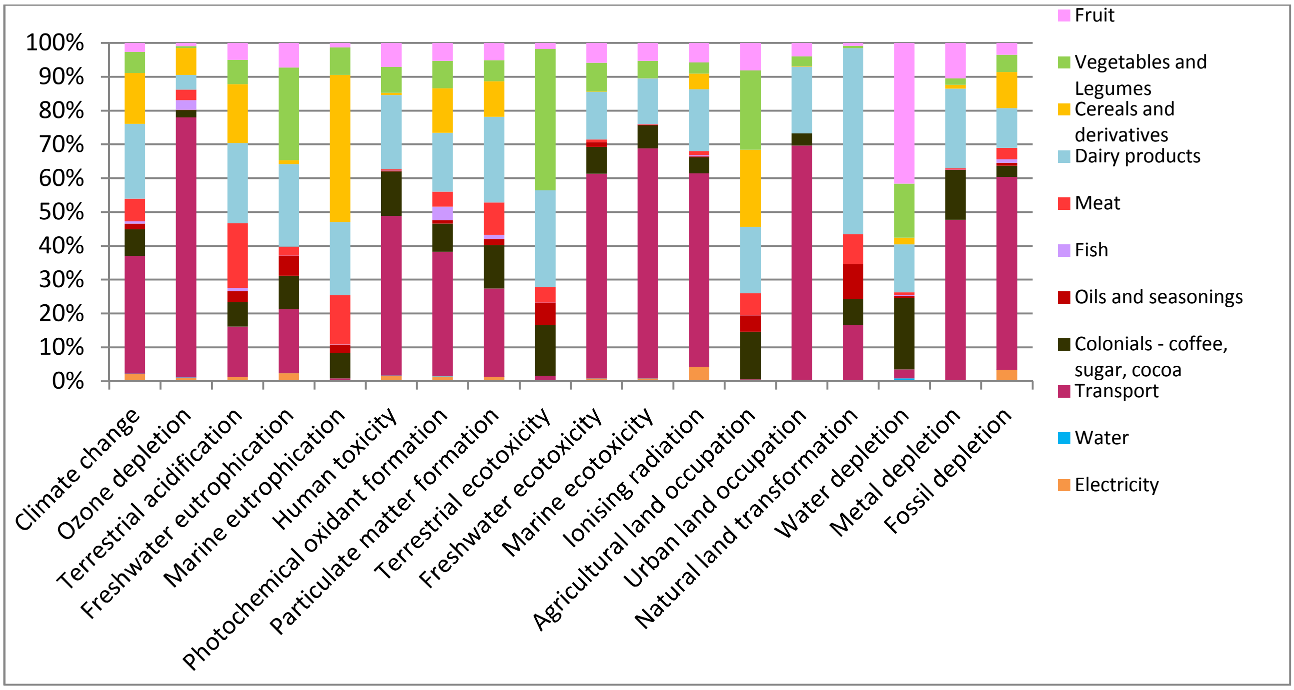

Figure a, BancoAlimentare, scenario 1

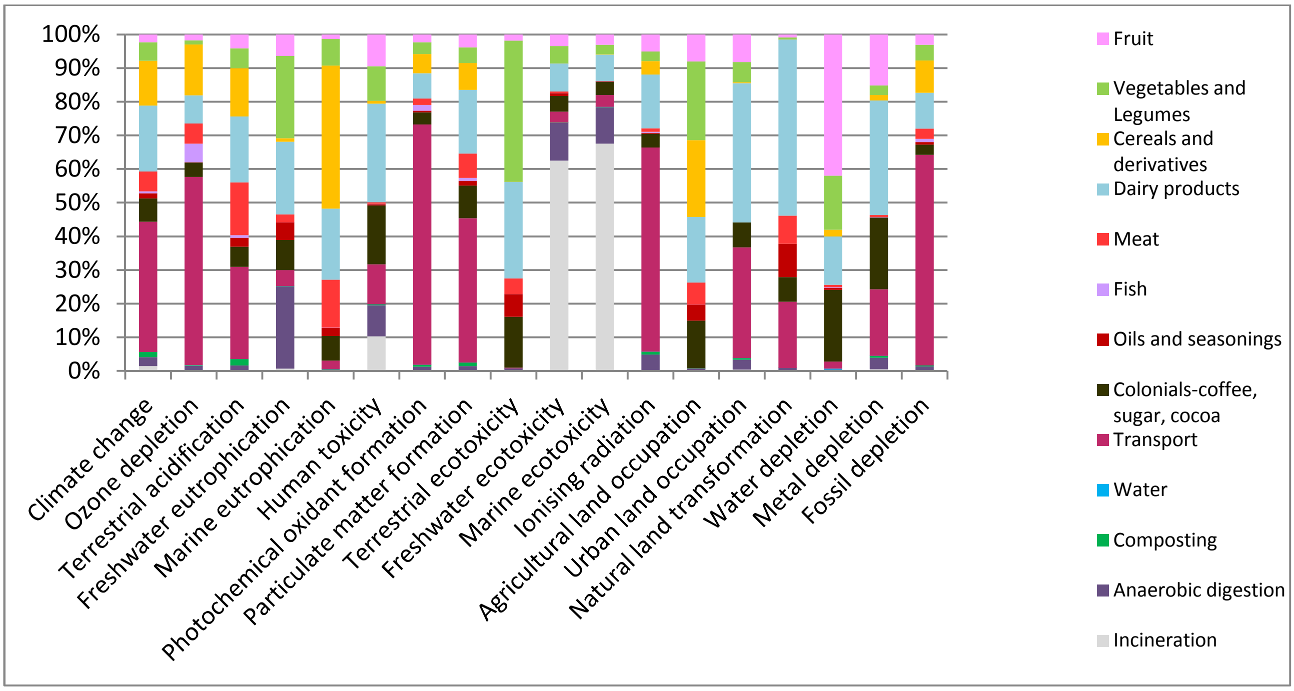

Figure b, BancoAlimentare, scenario 0

CITTADELLA

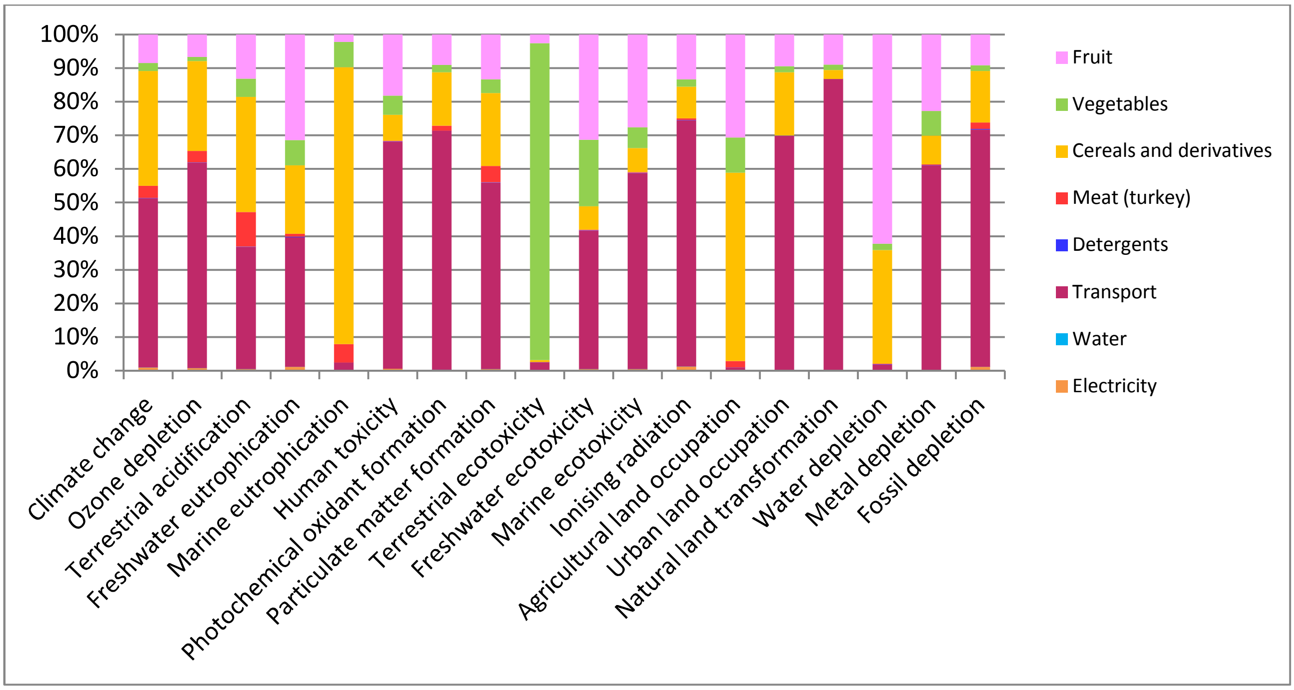

Figure c, Cittadella, scenario 1

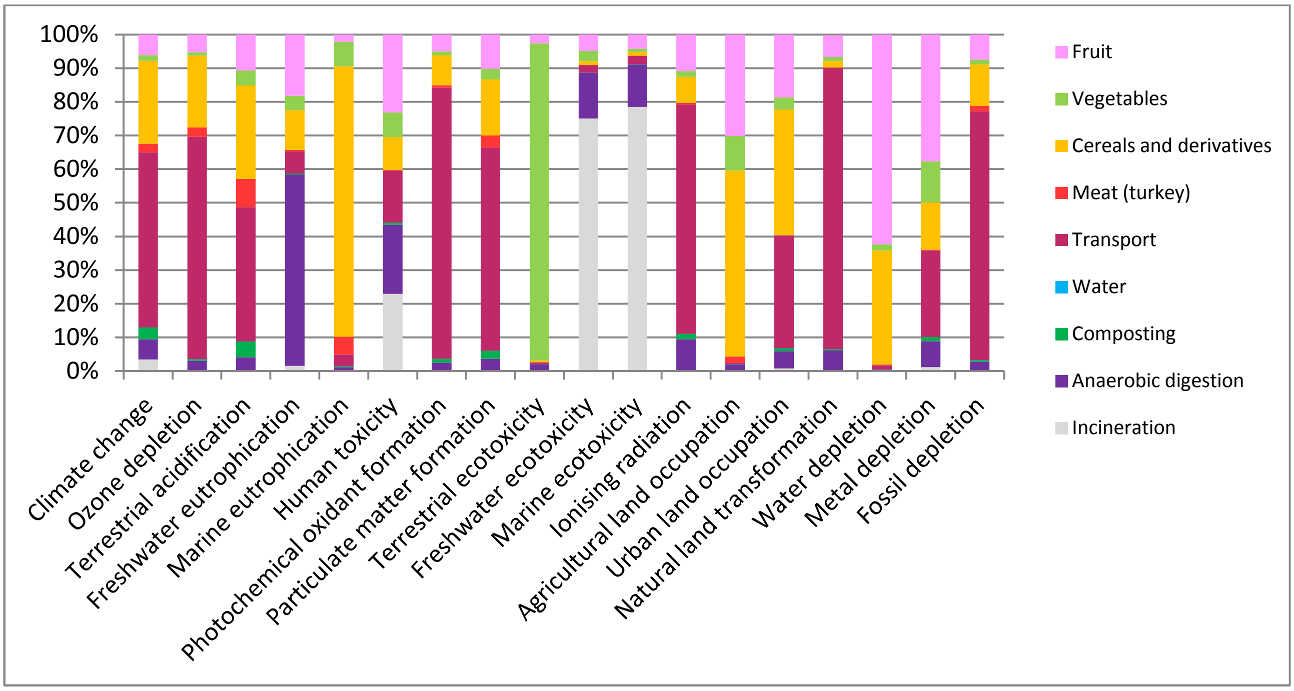

Figure d, Cittadella scenario 0

CHIOGGIA

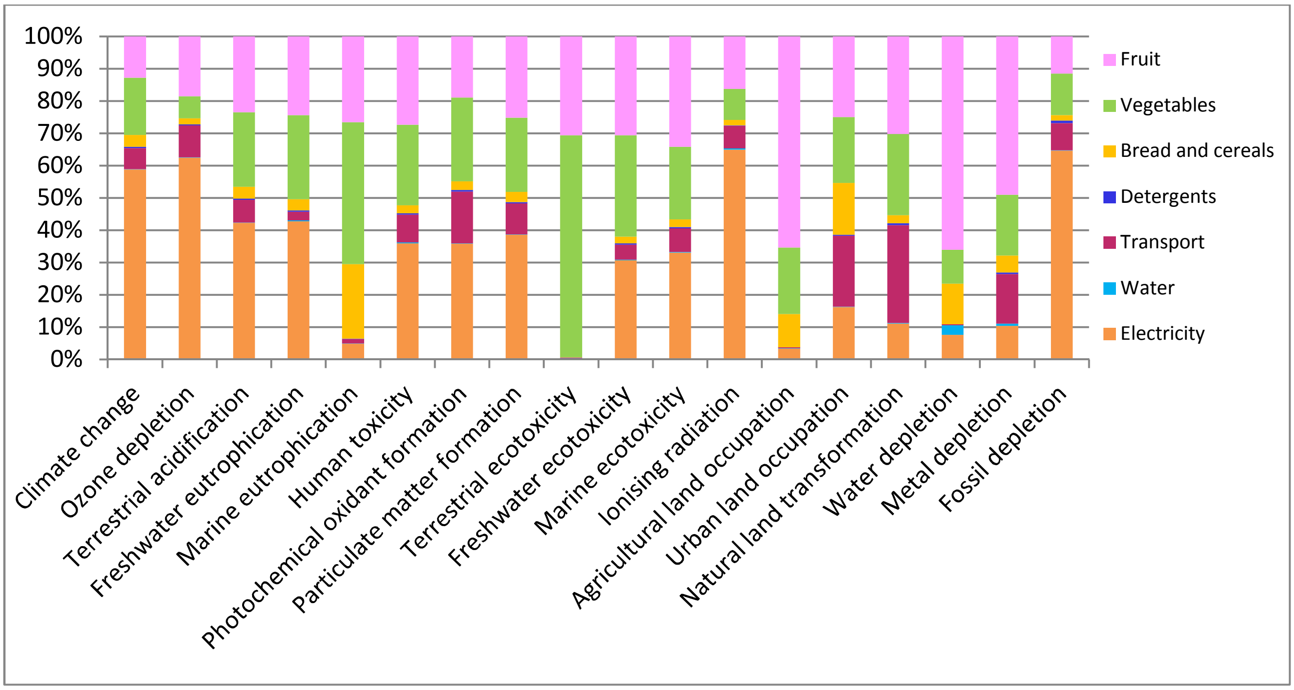

Figure e, Chioggia, scenario 1

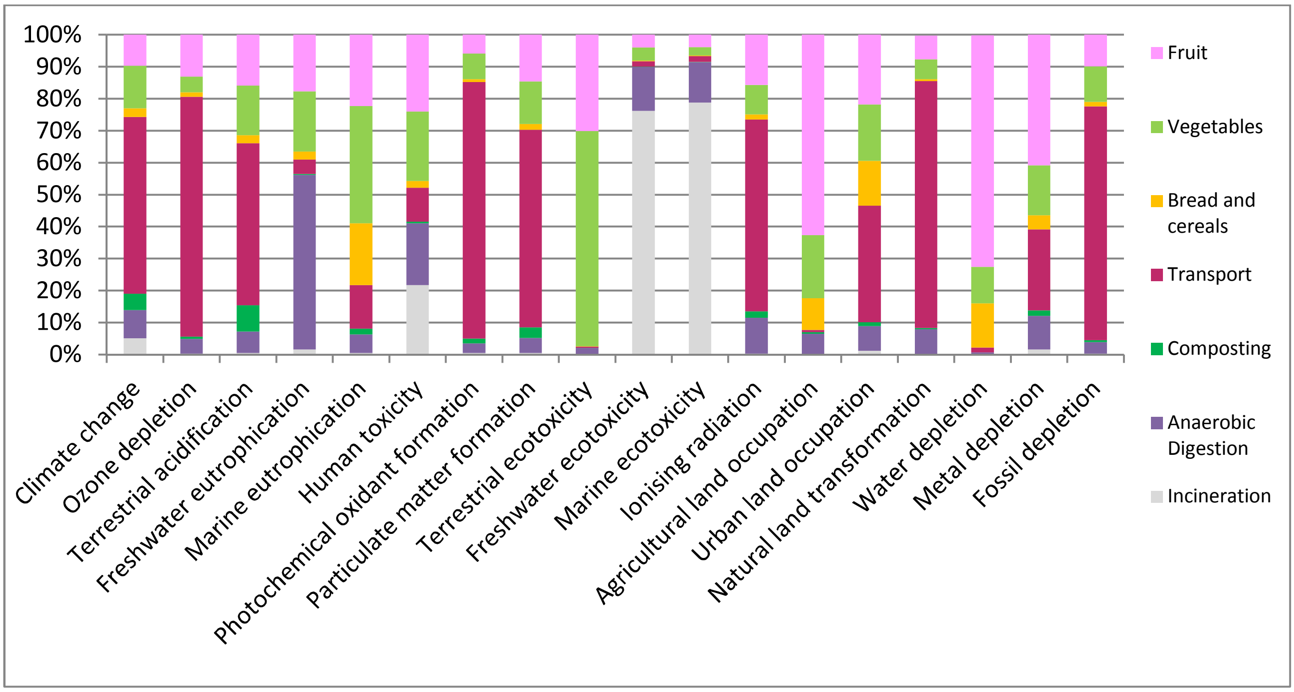

Figure f, Chioggia, scenario 0

LEGNAGO

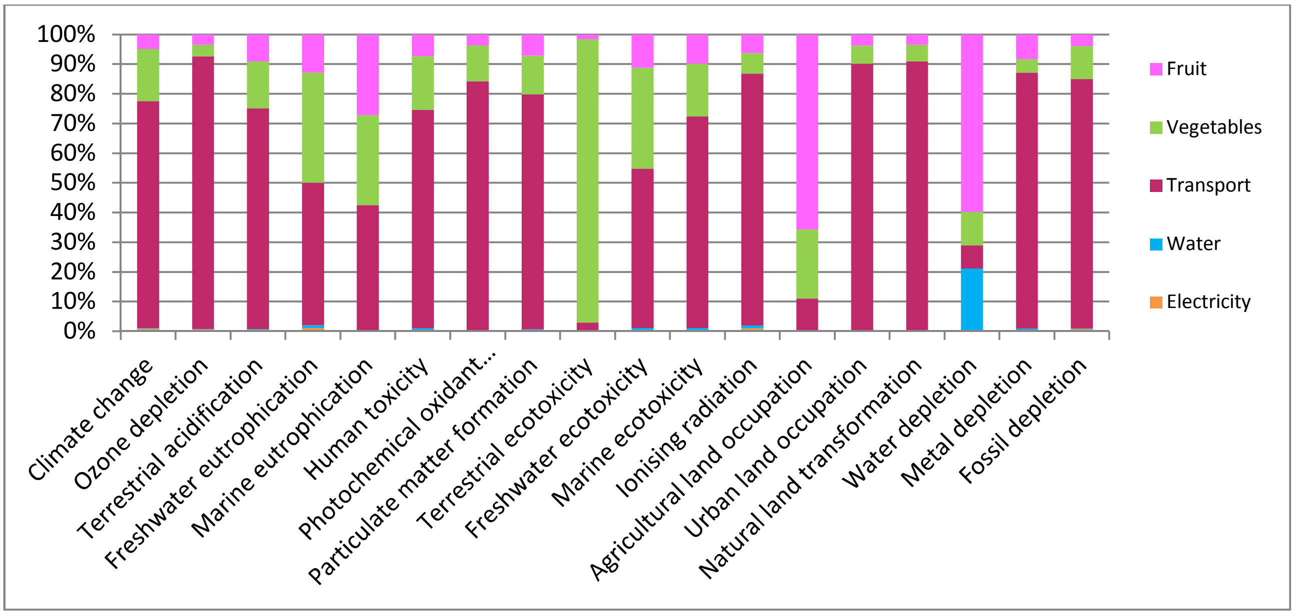

Figure g, Legnago, scenario 1

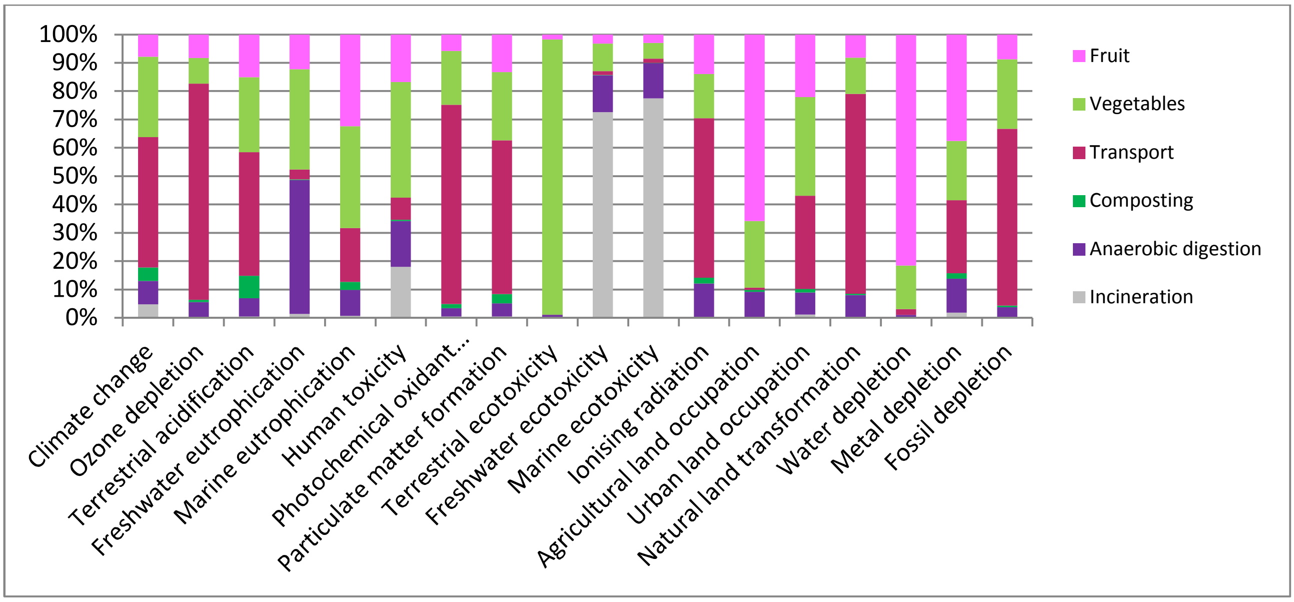

Figure h, Legnago, scenario 0

SAN DONA' DI PIAVE

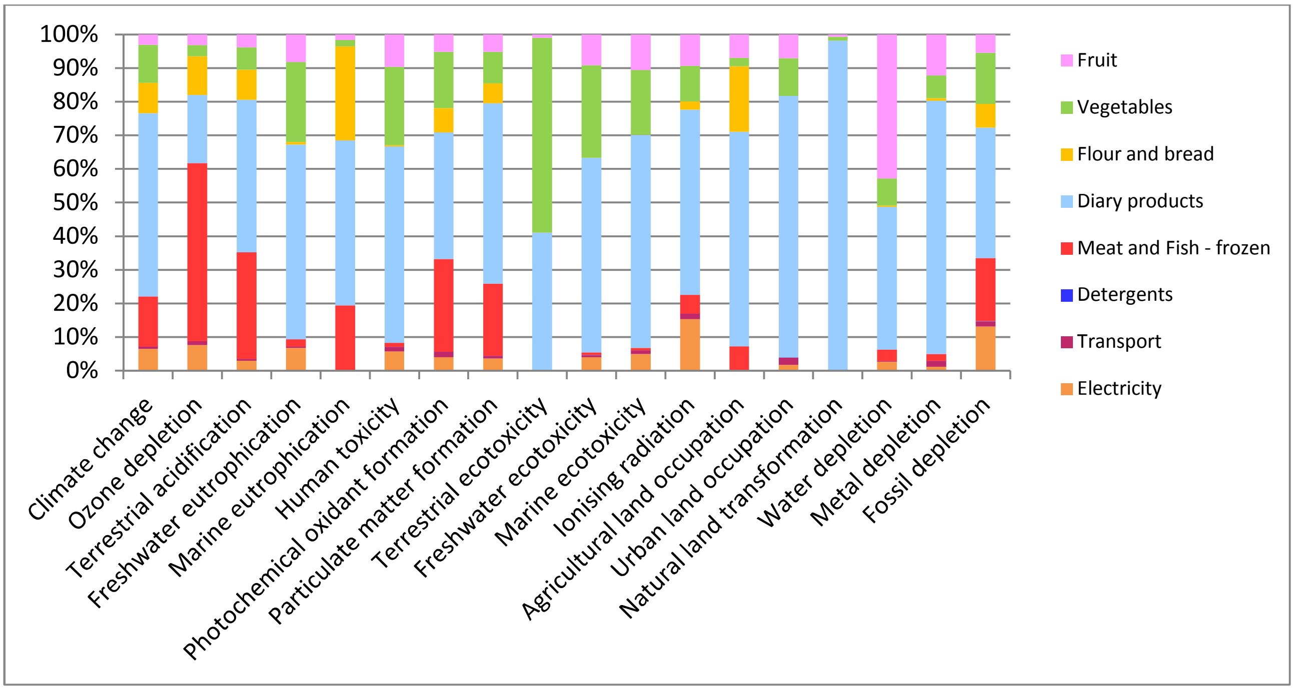

Figure i, San Donà di Piave scenario 1

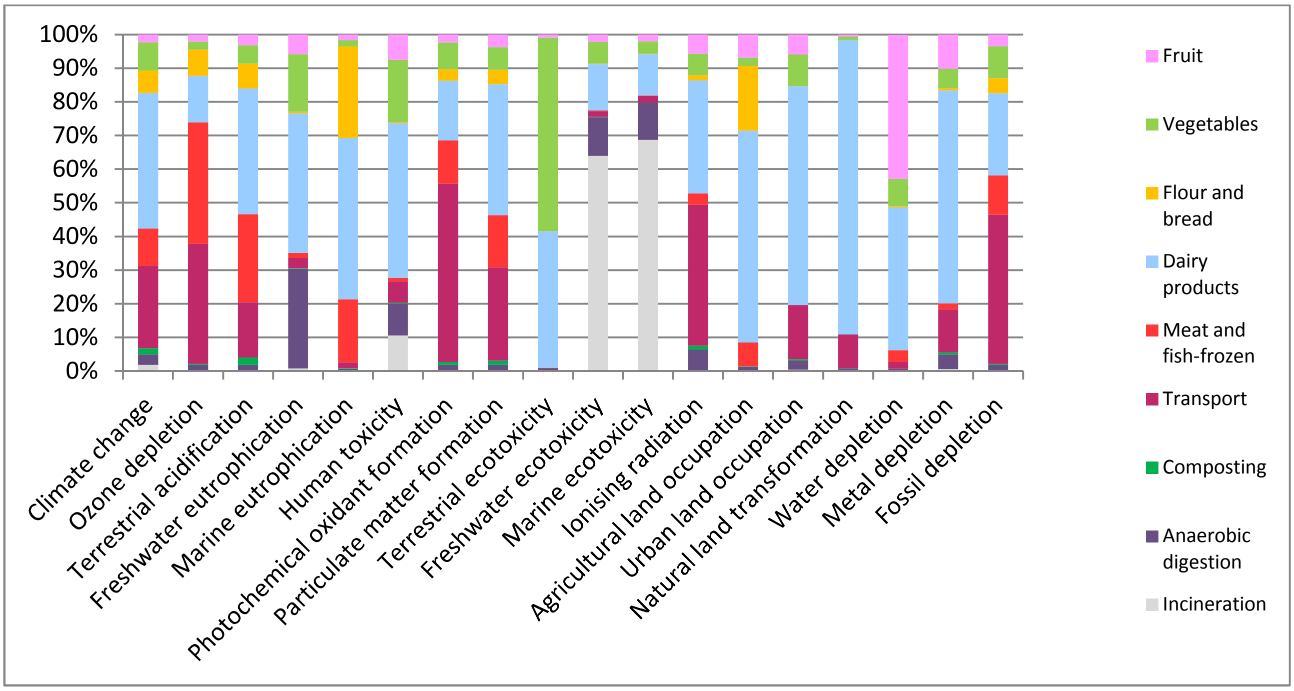

Figure l, San Donà di Piave, scenario 0

SAN MARTINO BUONALBERGO

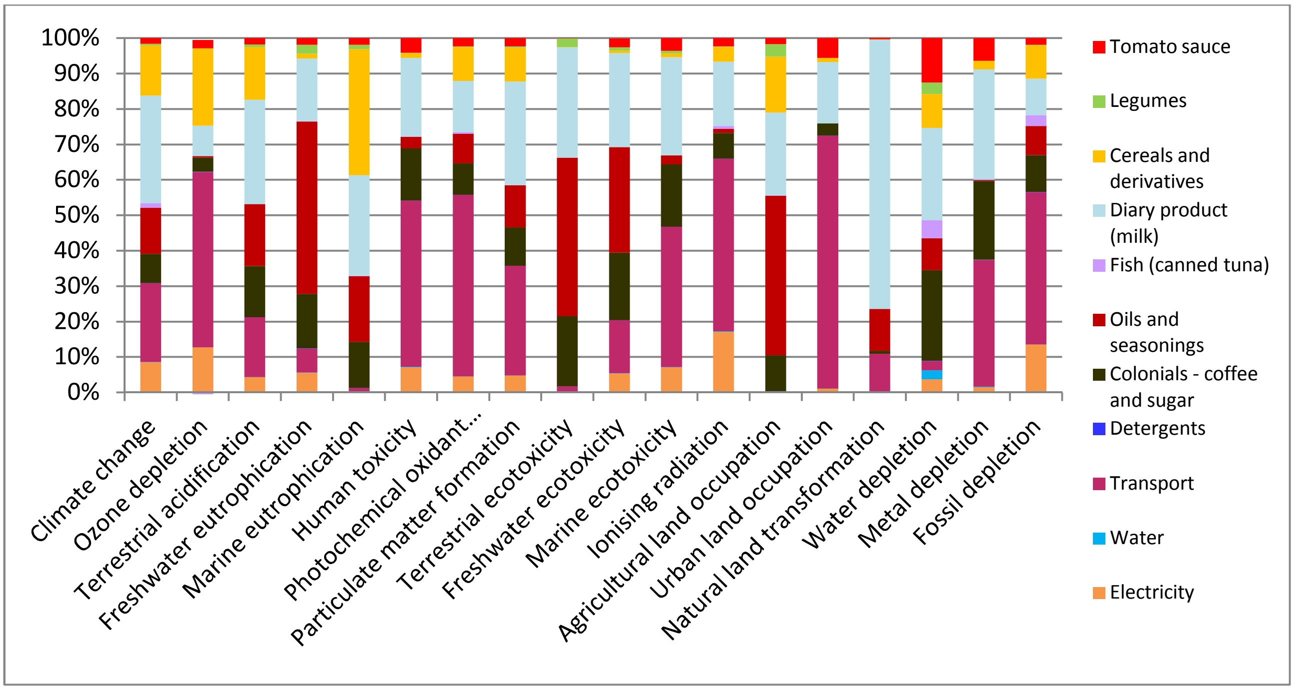

Figure m, San Martino Buonalbergo, scenario 1

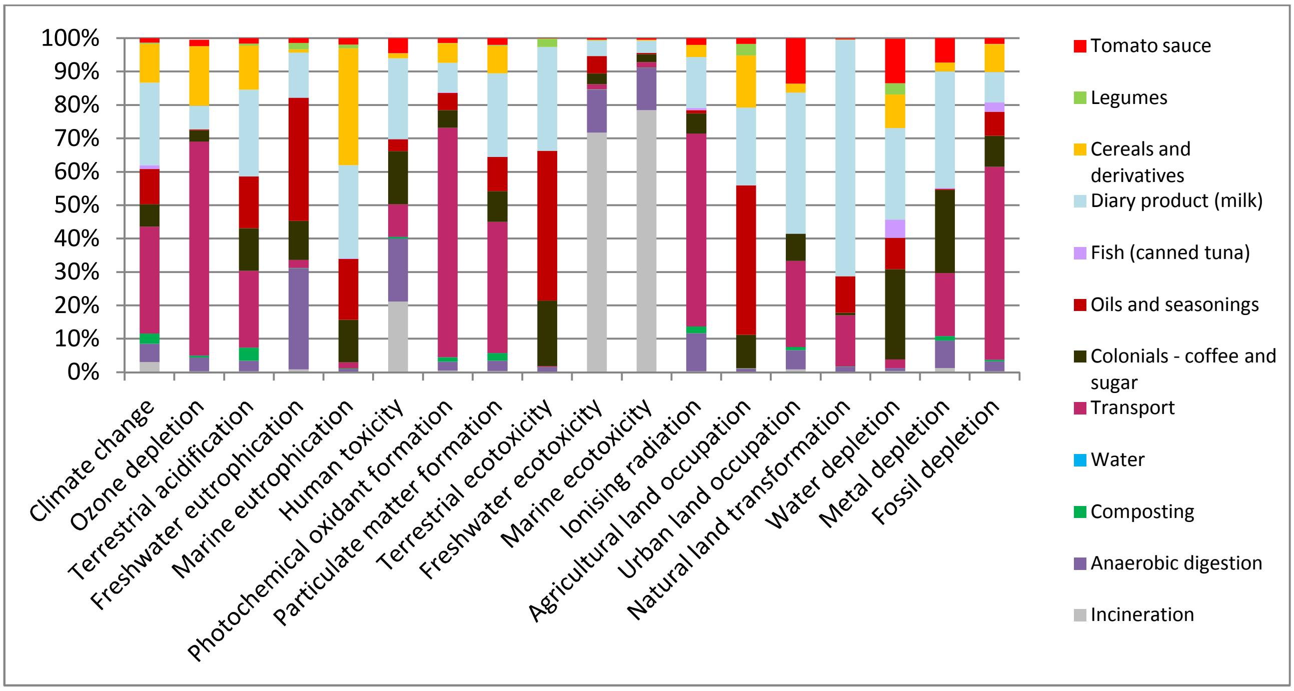

Figure n, San Martino Buonalbergo, scenario

Climate change

In all the emporiums, as regards the impact category "Climate change", scenario 1 performs better than scenario 0 (*Figure 20*), except for Legnago (as anticipated and explained before).

The highest value (the one equal to 100%) refers to scenario 0 of San Donà di Piave. In this case (*Figure l*), 60% of the contribution is given by the dairy production process and by transport to the disposal plant. Direct emissions from transport and livestock farms, are in fact among the main sources of greenhouse gases. The substantial difference with scenario 1 lies in *Figure i*: in the recovery scenario, transport accounts for only 0.6% (in fact, this emporium covers only 0.37 km to recover 1 kg of surplus).

The second highest percentage is in scenario 1 of Legnago (93%), where the greatest contribution is given by transport to recover food surpluses (76%) as previously explained (*Figura g*).

For the emporium of Cittadella, the greatest contribution is given by transport and cereals, both in scenario 1 (*Figure c*) and in scenario 0 (*Figure d*). The same applies to San Martino Buonalbergo where impacts deriving from dairy production are also relevant and the main difference between the two scenarios is given by the disposal processes which contribute to 10-12% in scenario 0.

Similar results are obtained by Banco Alimentare, although in this case the contribution of disposal processes is less than the above-mentioned emporiums (6%), (*Figure b*).

Finally, in Chioggia, in scenario 1, electricity weighs the most (58%), due to the emissions produced by the plants that produce it (*Figure e*). Only for this emporium electricity consumption has a significant weight. This is because, if we compare the energy consumption with the functional unit (1 kg of food surplus recovered), the value obtained is the highest of all the emporiums.

The reason could therefore be related to the fact that Chioggia is a young emporium; having settled only at the end of 2016, probably the activity was not yet well started in 2017.

This reason could explain why consumption has such a high impact when related to the amount of surplus recovered and allocated by the emporium.

Ozone depletion

As far as "Ozone depletion" is concerned, once again scenario 0 is performing worse than scenario 1 in all the emporiums, except for Legnago and Banco Alimentare (*Figure 20*). As far as Legnago is concerned, scenario 1 is the one with the highest value among all emporia. Here, transport accounts for 91% of the total (*Figure g*), and the same considerations formulated for "Climate change" are valid. In the case of Banco Alimentare, the high percentage of scenario 1 (94%) can be explained by the fact that this emporium uses refrigerated trucks and refrigerant gases are among the primary causes of ozone depletion; in fact, in scenario 1, transport contributes for the 76% (*Figures a*).

The use of refrigerant gases also affects the value of scenario 1 at San Donà di Piave (*Figure i*): in this case, however, this percentage (53%) is not directly linked to the emporium's activity, but to the production process of a type of recovered food, i.e. "Meat and Fish - frozen".

For the emporiums of Cittadella and San Martino Buonalbergo, transport weighs most on the total both in scenario 1 and scenario 0 (*Figures c, d and Figures m, n*). All other types of recovered food (such as fruit, vegetables, bread and cereals, etc...) weigh equally between the two scenarios. In scenario 0, however, disposal processes are included, and that is what makes the difference between the two scenarios.

In scenario 1 of Chioggia, 65% is given by the consumption of electricity (*Figure e*) for which the same considerations seen in Climate change are applicable. Electricity consumption and transport, in scenario 1, together account for about 75%. This percentage is the same for transport in the disposal scenario. What makes this scenario worse is therefore the presence of disposal processes (*Figure f*) which do not weigh in the recovery scenario.

Terrestrial acidification

The trend obtained for the impact category "Terrestrial acidification" shows that the recovery scenario performs better than the disposal scenario (*Figure 20*) except for Legnago, for which the same considerations reported above can be taken into account.

The highest value refers to the scenario 0 of San Donà di Piave. In San Donà di Piave, the production process of dairy and frozen meat (responsible for nitrogen and phosphorus emissions) weighs 80% in scenario 1 (*Figure i*) and 63% in scenario 0 (*Figure l*); however, what makes scenario 0 worse is transport, which accounts for 16%, compared to only 0.4% in the recovery scenario.

In the case of San Martino Buonalbergo, the categories of recovered food and transport have the same impact in between the recovery and disposal scenario. However, scenario 0 is still worse, due to the impact of disposal processes (which together account for 7%, *Figure n*), responsible for the emission of phosphorus and nitrogen. The same situation occurs also in Cittadella (*Figure c and Figure d*).

Once again, as far as the emporium of Chioggia is concerned, electricity accounts for a greater percentage (42%) in scenario 1 (*Figure e*), while in scenario 0 the greatest impact derives mainly from the emissions connected to the transport (50%) and to disposal processes (14%) (*Figure f*).

Freshwater eutrophication

For the Freshwater eutrophication the trend is the same for all the emporiums, where the recovery scenario performs better than the disposal scenario (*Figure 20*).

The highest value is represented by the scenario 0 of San Martino Buonalbergo, where the process of cultivation of sunflower oil ("Oils and seasonings") weighs 36%, to which is added the impact of anaerobic digestion (30%) (*Figure n*). Both processes contribute to the phenomenon of eutrophication, on the one hand because of the use of fertilizers that can reach surface waters by runoff processes, and on the other hand because of the use of nitrogen and phosphorus during the anaerobic digestion of biomass.

The second highest value (94%) is for scenario 0 of San Donà di Piave (*Figure 20*). In this case, the main impacts are from dairy production (41%) and again from anaerobic digestion (29%) (*Figure l*).

In scenario 1 of the Food Bank, dairy products and vegetables together account for 40%, as well as in scenario 0. However, in the latter case, the impact of anaerobic digestion (24%) is added, which makes the disposal scenario worse. For the emporiums of Chioggia and Cittadella, the difference between scenario 1 and scenario 0 is about 20%. In both cases, this difference is due to the impact of anaerobic digestion, which is high for both emporiums (about 50%).

For the emporium of Legnago, this is one of the few cases in which scenario 1 performs better than scenario 0, in where anaerobic digestion impacts for about 50% of the total (*Figure h*).

Marine eutrophication

For the Marine eutrophication the trend is the same for all the emporiums, where the recovery scenario performs better than the disposal scenario (*Figure 20*).

The greatest impact is given by scenario 0 of San Donà di Piave, where the main contribution is given by dairy products (45%) and frozen meat (20%) (*Figure l*).

Second, scenario 0 of San Martino Buonalbergo weighs 81% (*Figure 20*). In this case, the greatest contribution is from dairy products and cereals (*Figure n*). The situation is also the same for Banco Alimentare e Cittadella, where the same type of product contributes about 60% and 80%. In these cases, scenario 0 is worse because the impacts from disposal activities are added.

Finally, for the emporiums of Chioggia and Legnago, the greatest contribution is given by vegetables (about 40% in both cases), due to the wide use of fertilizers.

Human Toxicity

For this impact category, only the emporiums of Chioggia and San Donà di Piave present scenario 1 performing better than scenario 0, in which emissions from incineration and anaerobic digestion have a fairly significant impact on the total (almost 40% in Chioggia and 20% in San Donà di Piave) The highest value is that of scenario 1 of the emporium of Legnago, in which transport contributes 73%, and for which the considerations expressed at the beginning of the chapter can be applied.

In scenario 1 of Banco Alimentare, San Martino Buonalbergo and Cittadella, the percentage that weighs the most is the one related to transport.

For San Donà di Piave, on the other hand, the greatest contribution comes from dairy products, in both scenarios.

Photochemical oxidant formation

The trend shows that scenario 1 performs better than scenario 0, for all the considered emporia, except for Legnago (which also has the highest value), where transport weighs 86% in scenario 1, due to overestimation.

Also in scenario 1 of Banco Alimentare, San Martino Buonalbergo and Cittadella, the greatest contribution comes from transport, the percentage of which is in any case lower than that of scenario 0.

On the contrary, in Chioggia, electricity has a greater impact on scenario 1 (35%), while in scenario 0 the greatest contribution is given by the transport to the disposal plants, which accounts for 80%.

In San Donà di Piave, on the other hand, the percentage that weighs the most in scenario 1 is related to the production of dairy products because of upstream farming activities and industrial production of dairy products. In scenario 0, on the other hand, the greatest contribution is made by transport.

Particulate matter formation

The trend shows that scenario 1 performs better than scenario 0, for all the considered emporia, except for Legnago (which also has the highest value), where transport weighs 80% in scenario 1, due to overestimation.

In scenario 0 of the Banco Alimentare, the largest contribution is determined by transport and dairy products, which together account for 60%; in scenario 1, however, these two processes account for 50%, since transport has a smaller contribution.

For the emporium of Cittadella, as it does not recover dairy products, the greatest weight is due to transport, both in scenario 1 and in scenario 0.

In San Donà di Piave it is exactly the opposite: the percentage that weighs most in scenario 1 is the one linked to the production of fresh and dairy products, thanks to a transport activity that takes place within the municipal boundaries. In scenario 0, on the other hand, transport accounts for a larger share (27%).

Finally, Chioggia in scenario 1 the largest contribution comes from electricity, while in scenario 0 the greatest contribution comes from transport.

Terrestrial ecotoxicity

In this impact category there's no substantial differences between scenario 0 and scenario 1, since vegetables is the group that impacts the most (90% in all the scenarios for every emporium), due to the use of pesticides and herbicides.

Freshwater ecotoxicity

For this impact category, scenario 1 performs better than scenario 0, with differences up to 70-80%, as in the case of Chioggia and Legnago.

In scenario 0, the process of incineration impacts for 70% of the total, due to the emissions released. This situation is repeated for each emporium.

Marine ecotoxicity

Also in this case, scenario 1 performes better than scenario 0 (*Figure* 20). In this case, the substantial difference comes from the waste incineration activity, whose percentage of impact in the disposal scenarios is around 70% for all the emporiums.

Ionising radiation

In this midpoint, scenario 1 is better than scenario 0, with the exception of the emporium of Legnago, for which the considerations already seen can be applied.

In the scenario 1 of Chioggia electricity has the greatest impact, while for San Donà di Piave the main contribution is coming by the production of dairy products. In both cases, the recovery scenario is still better than the disposal scenario, since in scenario 0 transport accounts for a higher percentage. Also with regard to the Banco Alimentare, San Martino Buonalbergo and Cittadella, the transport of scenario 0 impacts more on the total.

Agricultural land occupation

As far as this midpoint is concerned, the differences between the scenarios of each emporium are so small that it is not possible to establish a trend.

For the Banco Alimentare, the contributions of fruit, vegetables, dairy products and cereals are equivalent between the two scenarios.

In Chioggia, fruit accounts for 60% in both scenarios. In Cittadella, fruit and cereals together account for about 80%, both in the recovery and disposal scenarios. In San Martino Buonalbergo, the greatest contribution is given by the cultivation of sunflower oil (oils and seasoning) in both scenarios. In San Donà di Piave, on the other hand, the greatest contribution comes from dairy products, which account for 60% in both scenarios.

In the same way, also in the emporium of Legnago what contributes the most is fruit and vegetables: together they contribute for 80% of the total, both in the recovery scenario and in the disposal scenario.

Urban land occupation

In this impact category, the scenario 1 of Banco Alimentare, Cittadella, San Martino Buonalbergo and Legnago (which has the highest value) performs worse than scenario 0. This is the result of transport for the recovery of surpluses, which in scenario 1 of all the above mentioned emporiums

has an impact of at least 70%. Road transport is the process that, among those considered, contributes most to this midpoint, due to routes construction.
In San Donà di Piave, scenario 1 is better than scenario 0. In this case, dairy products contribute 70% in both scenarios; the difference lies in transport: in scenario 0 it contributes 16%, while in scenario 1 it contributes 2%. Also in the emporium of Chioggia scenario 1 is better than scenario 0. Also in the emporium of Chioggia scenario 1 is better than scenario 0 and also in this case the difference lies in transport (21% in scenario 1 and 36% in scenario 0).

Natural land transformation

Also in this midpoint the results show that scenario 1 is better than scenario 0, with the exception of the emporium of Legnago.
The highest value for this midpoint is represented by scenario 0 of San Donà di Piave, in which dairy products contribute 87% and transport to the disposal plant 10%. In scenario 1, on the other hand, the greatest contribution is made by dairy products (97%); transport accounts for less than 1% as the collection of surpluses takes place within a few kilometres.
The transformation of the natural environment is a direct consequence of the production of dairy products, due to the land-use change for breeding; it is a consequence also of road transport because of the construction of roads. In scenario 0 of Legnago, this activity contributes to 70% of the total, while in scenario 1 it contributes to 90%, due to the overestimation expressed at the beginning.
Also in Banco Alimentare and in Cittadella the greatest contribution in both scenarios comes from dairy products and transport. Same situation for San Martino Buonalbergo.
Transport contributes 70% in scenario 0 of Chioggia while in scenario 1 it contributes only 30%.

Water depletion

As far as this midpoint is concerned, the recovery scenario has higher values than scenario 0. However, in 4 out of 6 emporiums, this difference does not even reach 3%: these values are therefore too small to be considered significant.
In Banco Alimentare, fruit, vegetables and dairy products are the most significant, due to the large use of water for irrigation of fields and orchards and for washing the stables. They weigh 40%, 16% and 15% respectively in both scenarios.

The same situation for both scenarios is repeated in San Donà di Piave with different percentages: fruit has a contribution of 40%, as well as dairy products.

The results are the same for Cittadella, where, however, not having recovered dairy products in 2017, their contribution is replaced by cereals, crops that need constant irrigation.

Metal depletion

In this case, the results show that scenario 1 is worse than scenario 0, with the exception of Chioggia and San Donà di Piave.

As shown in the Figure, the highest impact is in scenario 1 of Legnago, where transport accounts for 80%. For this case, the considerations already expressed at the beginning can be applied.

For Banco Alimentare, Cittadella and San Martino Buonalbergo, in scenario 1, what weighs most is fruit and transport, as shown in the corresponding figures. For this midpoint, the cultivation of fruit impacts due to the large use of fertilizers used in orchards, while transport due to the construction of roads and vehicles. In these three cases, the proportion of transport in the disposal scenarios is 20-30% less than in the recovery scenario, making the latter performs worse.

Fossil depletion

In this midpoint, the trend is positive for all recovery scenarios as they have less impact than disposal one. The only exception is Legnago (which also has the highest value among the emporiums), because of the overestimation made for transport.

Transport affects this midpoint because of the asphalting of the road and because of the production of fuels that feed the means of transport (all emporiums have diesel vehicles).

The second highest value is that of scenario 0 of the emporium of San Donà di Piave. In this case, dairy products account for 24%, compared to 38% in scenario 1. However, transport makes the difference. In the recovery scenario it impacts only 1.5%, while in the disposal scenario it impacts 44%.

In Cittadella, transport accounts for 70% in the recovery scenario and 73% in the disposal scenario. What makes scenario 0 worse is the addition of disposal processes, although the differences remain minimal.

7. CONCLUSIONS

The study initially covered 12 emporiums located in the Veneto region, then reduced to 6 due to lack of data, for which it was not possible to make any kind of estimate. It is also important to point out how the lack of data or the data lack of precision, has led to the need for assumptions that, in all probability, resulted in overestimated or underestimated results.

In spite of that, the results obtained show an almost constant trend in considering the recovery scenario as better than the disposal scenario for all impact categories, with some exceptions.

The only recurrent one is represented by Legnago, which, as already widely pointed out, presented overtaken data regarding the transport of surplus, since the kilometres provided also included activities different from the recovery one.

Even in other cases where scenario 0 is better than scenario 1, this is due to transport to recover food surpluses. It is therefore important to underline that the recovery activity must be carried out within a limited kilometer radius, in order not to have negative environmental impacts due to emissions generated by transport.

There are cases where the impact is related to fruit, vegetable and dairy production processes and therefore not directly related to emporium activities. In these cases, however, recovery is even more important in order to avoid adding the impacts of disposal activities.

Since Chioggia has provided the most accurate data it can be assumed that its results are also the most accurate. Since they are the ones that most clearly show how scenario 1 is better than 0 (except for water depletion), it can be concluded that recovery is preferable to disposal from an environmental point of view. However, in order to make these conclusions more robust, it would be desirable in the future to collect data with the same level of accuracy also in other emporiums.

BIBLIOGRAPHY

- Albizzati, P.F., Tonini, D., Chammard, C. B., & Astrup, T. F. (2019). "Valorisation of surplus food in the French retail sector: Environmental and economic impacts". *Waste Management, 90, 141-151.* https://doi.org/10.1016/j.wasman.2019.04.034
- ANSA (2018). "Oggi la giornata per la lotta allo spreco alimentare"
- Bernard Saraiva Schott, A., & Andersson, T. (2014). "Food waste minimization from a life cycle perspective". *Journal of Environmental Management, 147, 219-226.*
- Comission, A.S. et al for E. (2016). "Reducing food waste through social innovation"
- Decreto Dittatoriale (7/10/2013). Adozione e approvazione del Programma nazionale di prevenzione dei rifiuti. *Gazzetta Ufficiale Serie Generale n. 245 del 18 ottobre 2013.* https://www.gazzettaufficiale.it/eli/gu/2013/10/18/245/sg/pdf
- EC, 2008. Directive 2008/98/EC of the European Parlament and of the Council of 19 November 2008 on Waste and Repealing Certain Directives. *Official Journal of the European Union*, Strasbourg.
- EC, 2010. Commission - Joint Research Centre - Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook - General guide for Life Cycle Assessment - Detailed guidance. First edition March 2010. EUR 24708 EN. Luxembourg. Publications Office of the European Union
- EC, 2017. Commission Notice 16.10.2017 of European Commission. EU guidelines on food donation. Available at https://ec.europa.eu/food/sites/food/files/safety/docs/fw_eu-actions_food-donation_eu-guidelines_en.pdf
- Eriksson, M. & Spångberg, J. (2017). "Carbon footprint and energy use of food waste management options for fresh fruit and vegetables from supermarkets". *Waste Management, 60, 786-799*. https://doi.org/10.1016/j.wasman.2017.01.008
- FAO (2013). "Global food loss and waste". *Food Wastage Footprint & Climate Change, 1(1-4).*
- Favero, C., (2014). "Le buone pratiche della lotta allo spreco". *Ecoscienza, 5, 38-44*
- Finnveden G., Hauschild M. Z., Ekvall T., Guinée J., Heijungs R., Hellweg S., Koehler A., Pennington D., Suh S., (2009)."Recent developments in Life Cycle Assessment", *Journal of Environmental Management, 91 (1), 1-21.* https://doi.org/10.1016/j.jenvman.2009.06.018

- Food and Agriculture Organization of the United Nations (2011). Global Food Losses and Food waste – Extent Causes and Prevention
- Hegnsholt, E., Unnikrishnan, S., Pollman-Larsen, M., Askelsdottir, B. & Gerard, M. (2018), "Tackling the 1.6-billion-ton food loss and waste crisis". The Boston Consulting Group, Food Nation, State of Green.
- ILCD Handbook (2010)."General guide for Life Cycle Assessment – Detailed guidance", European Union https://eplca.jrc.ec.europa.eu/uploads/ILCD-Handbook-General-guide-for-LCA-DETAILED-GUIDANCE-12March2010-ISBN-fin-v1.0-EN.pdf
- Legge 25 giugno 2003, n. 155. Disciplina della distribuzione dei prodotti alimentari a fini di solidarietà sociale. *Gazzetta Ufficiale Serie Generale n. 150 del 1 luglio 2003.* https://www.gazzettaufficiale.it/eli/gu/2003/07/01/150/sg/pdf
- Legge 19 agosto 2016, n. 166. Disposizioni concernenti la donazione e la distribuzione di prodotti alimentari e farmaceutici a fini di solidarieta' sociale e per la limitazione degli sprechi. *Gazzetta Ufficiale Serie Generale n.202 del 30 agosto 2016.* https://www.gazzettaufficiale.it/eli/gu/2016/08/30/202/sg/pdf
- Lapi, M., Zoboli, R., Fontana, S., Fraschini, F., Colombo, S. & Santi, M. (2017). "Reti di collaborazione contro lo spreco alimentare", Rapporto finale del progetto.
- Lipinski B., et al., 2013, "Reducing Food Loss and Waste." Working Paper, Installment 2 of *Creating a Sustainable Food Future*. Washington, DC: World Resources Institute. Available online at http://www.worldresourcesreport.org.
- Midena, M. C., 2017, "*L'esperienza degli Empori Solidali nella Regione Veneto*"
- Moggi, S., Bonomi, S., & Ricciardi, F. (2018). "Against food waste: CSR for the social and environmental impact through a network-based organizational model". *Sustainability (Switzerland), 10(10), 1-19.* https://doi.org/10.3390/su10103515
- Paola Garrone, Marco Melacini, Alessandro Perego, (2014) "Surplus food recovery and donation in Italy: the upstream process". *British Food Journal, 116(9), pp.1460-1477* https://doi.org/10.1108/BFJ-02-2014-0076
- Parfitt, J., Barthel, M., & Macnaughton, S. (2010). "Food waste within food supply chains: quantification and potential for change to 2050". *The Royal Society Publishing, pp. 3065-3081* https://doi.org/10.1098/rstb.2010.0126

- Papargyropoulou, E., Lozano, R., Steinberg, J. K., & Wright, N. (2014). "The food waste hierarchy as a framework for the management of food surplus and food waste."*76, 106-115.* https://doi.org/10.1016/j.clepro.2014.04.020
- Regolamento (CE) 17 maggio 2006, n. 842 del Parlamento europeo e del Consiglio su taluni gas fluorurati ad effetto serra. http://data.europa.eu/eli/reg/2006/842/oj
- Salemdeeb, R., Bin Daina, M., Reynolds, C., & Al-Tabbaa, A., (2018). "An environmental evaluation of food waste downstream management options: a hybrid LCA approach", *International Journal of Recycling of Organic Waste in Agriculture. 7(3), pp.217-229* https://doi.org/10.1007/s40093-018-0208-8
- Stenmark, Å., Jensen, C., Quested, T., & Moates, G., (2016). "Estimates of European food waste levels", *Fusions.* https://www.eufusions.org/phocadownload/Publications/Estimates%20of%20European%20food%20waste%20levels.pdf
- Tonini, D., Albizzati, P. F., & Astrup, T. F. (2018). "Environmental impacts of food waste: Learnings and challenges from a case study on UK", *Waste Management, 76, 744-766*. https://doi.org/10.1016/j.wasman.2018.03.032
- Tua, C., & Nessi, S. (2017). "The "REDUCE" project: definition of a methodology for quantifying food waste by means of targeted waste composition analysis", *Rivista Di Economia Agraria, Anno LXXII, 289-301.* https://doi.org/10.13128/REA-22804
- Veneto Region (12/10/2017). Release n. 1376, "Povertà: Regione Veneto finanzia con 490mila euro il banco alimentare e la rete degli Empori di Solidarietà",
- Veneto Region (31/01/2017), Decree n.11, Annex A, "Linee Guida Empori della Solidarietà",
- Vulcano G., Ciccarese L., (2018). "Food wastage: a systemic approach for structural prevention and reduction", ISPRA – Institute for Environmental Protection and Research, Rapporti 279/2018, ISBN 978-88-448-0882-2, 364 p.

SITOGRAPHY

- https://www.bancoalimentare.it/it
- http://www.corriereortofrutticolo.it/2016/05/11/ismea-crescono-consumi-legumi-litalia-dipende-dallimport/#prettyPhoto
- https://www.eniday.com/it/
- https://www.eu-fusions.org/index.php
- http://www.fao.org/food-loss-and-food-waste/en/
- https://www.repubblica.it/economia/rapporti/osserva-italia/conad/2016/10/22/news/olio_di_semi-150275121/
- https://www.un.org/sustainabledevelopment/sustainable-development-goals/