Chapter 9
Share, Optimise, Closed-Loop for Food Waste (SOL4FoodWaste): The Case of Walmart-Mexico

John Rincón-Moreno, María-Laura Franco-García, Jorge Carlos Carpio-Aguilar, and Mauricio Hernández-Sarabia

Abstract The food waste in landfill decomposes into contaminated run-off (leachate) and methane (CH_4), which is considered a relevant greenhouse gas. This causes environmental liabilities, energy losses and problems in the food system. Currently, organic waste volumes are increasing dramatically converting this into a serious concern in both developed and developing countries. Zero waste to landfill (ZWTL) is one of the most promising concepts for solving organic waste problems. ZWTL when integrated into business processes can lead to innovative ways to identify, prevent and reduce waste. In that sense, the circular economy (CE) has also been considered regularly as an approach to the more appropriate waste management as it considers the business strategy part of the zero waste system**.** This circularity would increase productivity throughout the food value chain. In that manner, retail stores are proven to be a major market-driven force in the food system. Hence, one retail store located in the Metropolitan Area of Mexico City, part of Walmart-Mexico (Walmex), was selected to showcase a suitable strategy to tackle the food waste issue. Thus, this research aimed to explore how the organic waste management can be improved by combining CE business model and a ZWTL strategy. The findings of the combined framework (SOL4FoodWaste) showed that most of the food considered as waste can be recovered through different stages. Even further, 40% of the

J. Rincón-Moreno (✉)
University of Twente, alumni, Enschede, The Netherlands

M.-L. Franco-García
University of Twente, Enschede, The Netherlands
e-mail: ml.lfrancogarcia@utwente.nl

J. C. Carpio-Aguilar
Walmart Mexico, CDMX, Mexico
e-mail: jorge.carpio@walmart.com

M. Hernández-Sarabia
Faculty of Engineering, Universidad de Ibagué, Ibagué, Colombia
e-mail: mauricio.hernandez@unibague.edu.co

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food waste management costs can be saved through three business actions associated to those recovery stages. The proposed SOL4FoodWaste framework intends to collect all the sustainable concepts that might potentially be implemented or resembled in other industries with similar food waste challenges.

Keywords Organic waste management · Zero waste to landfill · Food waste hierarchy · Circular economy · ReSOLVE framework · SOL4FoodWaste

9.1 Introduction

At different stages (from harvest to consumption), the food is thrown away even if it is still appropriate for human intake. It is estimated that up to 30% of food produced for human consumption in the world is wasted throughout the food supply chain (FAO 2011). This fact is having significant impact on the current food system posing many uncertainties on environmental liabilities as in many countries organic waste is buried in landfill locations. The food landfilled decomposes into contaminated run-off (leachate) and methane (CH_4) greenhouse gas. Methane is 21 times more harmful than carbon dioxide (Forster et al. 2007) in terms of greenhouse effects. Thereby, CH_4 is linked to global warming but is also related to energy losses due to its heating and cooking properties (Moumen et al. 2016). Therefore, solutions on food waste burdens are essential to improve food security and the efficient use of resources as well. Ultimately, the food waste reduction and/or food waste elimination can enhance the entire food system (Koester 2015).

At the moment, countries are constantly dealing with the food waste issue; so far, the developed nations are regarded as the frontrunners, while the developing ones are still struggling with their waste management systems. As an example of the current situation in developing countries, it has been reported that about 96% of the municipal solid waste (MSW) in Mexico is still disposed of in landfills. Fifty percent of the total of the disposed MSW is attributed to organic components. It is worth mentioning that irregular dumping areas can be used to ‘dispose’ the waste. Likewise, recycling is not yet embedded in the Mexican culture, and the consumer awareness qualifies low due to lack of proper orientation and public policies at this regard (SEMARNAT 2015). Thus, Mexico’s current waste management system is considerably lagging in recycling and energy recovery and offers little regulatory incentive to avoid food being disposed of.

Even so, there are initiatives driven by the private sector that avoid waste disposal. Thereby, this research was focused in one of those practises done in the private sector, more exactly within Walmart-Mexico (Walmex). At present, Walmex’s objective is to avoid the generation of food waste whenever possible by seeking out a zero waste to landfill (ZWTL) strategy. Currently, the waste that cannot be recycled, reused or composted is disposed of in authorised site for either urban solid waste or hazardous waste. The waste landfilled still corresponds to 27% of the total waste produced (Walmart 2015), though this company has a sustainable waste management policy that stimulates the waste management efficiency in the retail stores with a special focus on food waste. Even further, it has multiple organisational areas that constantly review the regulatory frameworks in order to comply with permits and authorisations required to operate its sustainable waste management policy. Thus, an enhanced approach on waste management regarding food waste is needed to increase the up-to-date efficiency level. The reduction on the food waste burden is not only seen at the company as a sole environmental sustainable strategy but rather is expected to contribute in a sustainable business through a circular use of resources. Hence, it would generate economic benefits to the business in the midterm, fostering corporate sustainability, environmental awareness and society welfare.

A high potential in preventing food waste by managing resources at lower cost is seen as a promising advance towards a sustainable world (MacArthur 2013). By doing so, the organic waste might return to the natural systems via energy recovery or can be used again with slight loss of quality (Pitt and Heinemeyer 2015). Solutions on food waste such as donation, utilisation of by-products, livestock feeding, composting or bioenergy generation are put in consideration when dealing with food waste. These approaches not only offer social and environmental benefits but also economic advantages (Jurgilevich et al.2016). In this regard, circular economy (CE) is a new business model aiming to close the loop of resources (productive process spill overs and post consumption materials) by keeping their value as much as possible.

While the basic concept of the CE has been available for many years, the benefits of this business model are often misaligned with the core business strategies (Planing 2015). In fact, there are not sufficient case studies that currently reflect the necessity of going circular in business and even fewer examples of companies reporting food waste reductions aligned with their core business strategy. Hence, the reduction on food issues towards a CE model must entail a financial-feasible strategy where no organic resources become landfilled.

For this particular study, the focus is the circular management of food waste. Thus, this study aimed to elucidate a framework that can improve the organic waste management in Walmex by combining a circular business model and a ZWTL strategy. In this study, the (CE) principles applied to this type of organic materials were translated to four management streams: (1) reduction, (2) donation, (3) animal feeding and (4) anaerobic digestion. Later on, all of them were incorporated into a circular business model for the case study in hand.

The research is structured as follows: the steps needed to reach a CE business model through a ZWTL strategy was detailed in Sect. 9.2. Then the methodological approach undertaken was described in Sect. 9.3. The findings and discussion as a result of the methodology applied to the case study were explained in Sect. 9.4. Finally, conclusions and recommendations were placed in Sect. 9.5.

9.2 Literature Review

This section details the concept of organic waste management, especially focused in developing countries to provide an overview of the current situation. Then the ZWTL was explained in a food waste context. This could be possible by introducing the food waste hierarchy as an approach of targeting the ZWTL strategy. Finally, the CE principles were coupled into a suitable framework for this case study through the ReSOLVE framework.

9.2.1 Organic Waste Management

Organic waste volumes are increasing dramatically due to economic growth, rise in population and higher standards of living converting this into a serious concern in both developed and developing countries (Kothari et al. 2014). In developing countries, this has been one of the major problems on waste management today due to the lack of funding for waste treatment, insufficient land for disposal and low expertise coupled with weak policies and regulations interfering with the implementation of an appropriate system (Mohee et al. 2015).

Currently, five popular treatment methods are widely used in developing countries to treat organic waste: animal feeding, composting, anaerobic digestion, incineration and landfills. Illegal open dumps and landfills are primary methods due to their widely application for treating food waste (Adhikari et al. 2006). Food being disposed of in landfills represents 90% of use rate for food waste treatment, and the second most common method, composting, ranges from 1% to 6% of use rate. Anaerobic digestion (use rate of under 0.6%) and other treatments, such as livestock feeding or incineration, are rarely used (Adhikari et al. 2009).

In order to implement a different perspective on organic waste management, it is important to categorise the waste composition into different categories such as recyclability, combustibility or biodegradability opportunities so it can be used as a parameter to implement the most suitable waste management strategy. Nevertheless, when choosing the adequate system, some criteria needs to take into consideration several variables for an effective waste management such as the primary service and secondary services/coproducts provided such as food for donation, livestock, composting or anaerobic digestion (Villanueva and Wenzel 2007).

Although, those options seem to be the most feasible solution, it may not be convenient for technical or economic reasons in some cases (Jamasb and Nepal 2010). Overall, in essence, organic waste management must be focused into the principle of 'zero waste' which means no raw materials being disposed of to landfills throughout the food chain (Song et al. 2015).

9.2.2 Organic Waste Management in Mexico

In general, the Mexican organic waste recycling system ranks very poorly compared to similar economies (SEMARNAT 2015). This is due to incomplete legal frameworks and limited funding to improve the food waste systems. Another relevant factor is the little consumers' participation in the collection phase; inappropriate education programmes at this regard seem to be the cause. Thus, collection of recyclables remains very weak across most locations in the country (Thi et al. 2015).

According to SEMARNAT (2015), 96% of the municipal solid waste is sent to landfills; very insignificant portion (3.6%) receives some type of recycling. In addition, open dumps and inadequate landfills are the most common practise. At present, there are 12 active sanitary landfills in Mexico, but it is known that there are numerous undocumented landfills especially in rural areas. In any case many landfills in Mexico are reaching their capacity thresholds, and municipalities are seeking funds to provide new solutions. Despite the government's effort to support these initiatives to upgrade infrastructure, not substantial improvements have been observed.

A high percentage of organic waste (up to 52% of the solid waste) that is disposed in open dumps or quasi-controlled landfills (SEMARNAT 2015) is an indication of the inadequate waste management system. This generates an increasing environmental impact as no treatment is being developed to solve the problem on organic waste management. The environmental problems are associated with methane emissions, bad odours, leachates, etc. (Moumen et al. 2016). In addition to the issues associated with the large physical area required for the landfill facilities, in practice, the landfills' capacity is often surpassed. Although 48% of the municipal solid waste represents different types of waste that can be easily recovered, the focus is on the organic waste. It represents a twofold solution: feeding opportunities and energy recovery.

9.2.3 Waste Management at Walmex

Current Walmex's waste management actions are framed under the ZWTL strategy and the local environmental regulations. So far, the waste treatment methods at Walmex are determined according to the existing infrastructure and its potential; residues recovered with economic value are already sent to recycling. Composting is determined according to the available infrastructure at the region where shops are located. The residues that are not recycled, reused or composted are sent to authorised disposal sites for waste urban or hazardous solid waste. In general, 355,944 tonnes of waste are generated in Walmex, from which 73% is recycled and 27% is sent to landfill (Walmart 2015).

9.2.4 Zero Waste to Landfill (ZWTL)

Exhaustion of finite natural resources forces society to consider efficiency on their industrial outputs. Therefore, ZWTL is understood as a philosophy that inspires to reshape resource's life cycles so no junk is being disposed of either in landfills or incinerators (Song et al. 2015). Some scholars might consider that 'zero waste' management is an all-inclusive view of waste and resource treatment from a sustainable standpoint. Essentially, ZWTL aims to resemble the way resources are reused in a natural cycle. It promotes a transformation, where businesses minimise the burden on earth's raw materials and learn to do more with less natural resources (Song et al. 2015).

Certainly, the scope of ZWTL embraces concepts that have been settled for sustainable waste management systems which comprise avoiding, reducing, reusing, recycling and regenerating waste materials (Zaman and Lehmann 2013). However, ZWTL embodies integrated systems in which everything keeps its value. Thus, the material stream becomes circular meaning that the same materials are used again and again until they are exhausted. No materials are wasted or underused in a circular system (Colon and Fawcett 2006; Mason et al. 2003; Murphy and Pincetl 2013).

ZWTL is one of the most promising concepts for solving waste problems. Its concepts depict an ideal environment and resource utilisation. Irrespective of the social, economic and environmental benefits of ZWTL, the concept itself provides gains for an organisation or community if they channel the work in a clear and consistent manner (Song et al. 2015). When ZWTL is integrated into business processes, it can lead to innovative ways to identify, prevent and reduce waste of all kinds; albeit, in order to know whether they reach the ZWTL target, how to evaluate the process becomes very important.

9.2.5 Waste Hierarchy

Nowadays, there is no straightforward path for solving the current waste challenges. Hence, it cannot be expected to have a common framework on handling waste within industries, nations and households. Though, especial attention to managing waste has been placed on legislations, action programmes and setting the targets to embark on this problem. The Directive 2008/98/EC of the European Parliament (2008) presents a framework that aims to diminish the undesirable effects to health and environment of the production and management of waste.

Hitherto, the framework elaborated by the European Parliament stated that waste prevention shall be the main concern of waste management, then, reusing, material recycling and energy recovering shall be the least desired option. The EU directive layouts the waste hierarchy as an instrument on handling waste. However, it is highly ranked as a practice to not support landfilling.

9.2.6 Food Waste Hierarchy

Likewise, in the worldwide waste challenge, the increasingly food waste issue is drawing more attention. Hence, a conceptual framework depicting the waste hierarchy proposed by the European Parliament in the context of food waste is relevant in order to guide the most suitable options under this perspective. As an illustration, authors such as Papargyropoulou et al. (2014) proposed a framework for the management of waste all the way through the food supply chain by adopting the EU waste hierarchy framework. The authors suggested a twofold categorisation to distinguish what can be recovered as food surplus which in this scenario is considered as waste avoidance (e.g. reduction, donation and livestock feeding) and what can be used as food waste for the recovery step (energy recovery, e.g. biodigester). This definition was also studied by Parfitt et al. (2010), whose definition of food waste is related to the reduction in fit-for-human consumption organics at the end of the food supply chain (retailers and consumers), which means that it can no longer be eaten.

As previously mentioned, setting the priorities and ways of management is crucial as very often the main measure is the reuse of surplus food for human consumption to relieve food poverty. This latter is mainly organised through redistribution networks and food banks. Yet, the quality of food surplus might undermine those approaches, and other treatments might be included to process food waste. Those suitable solutions are explained in the following sections.

9.2.6.1 Reduction

The reduction of organic waste is being increasingly seen as a concern by corporations, organisations, governments and so on. This is due to the outrageous amount of food landfilled from farm to fork. For this reason, the target is firstly being set on preventing overproduction and oversupply of food beyond human diet requirements at all the stages of the food value chain. In the retail market, it also entails food surplus prevention (Papargyropoulou et al. 2014). Food waste could be easily reduced through inventory management to minimise surplus while maximising shelf replenishment and in-store shelf life times (Bond et al. 2013).

Some strategies directly affect food losses and food waste reduction, while others are indirectly affected by influencing people's behaviour in a long-term strategy. Hence, it is important to optimise the flow of perishable food at its very primary stage taking into account the expected shelf life of the food to prevent needless losses. This optimisation might bring minimisation of economic deficits, while consumers can be provided with high-quality products (Blackburn and Scudder 2009). Any sort of approach undertaken to address this issue must be particularly practical and cost-effective, so that the implementation could be performed relatively quickly and could achieve short-term gains once it has been stablished (Lipinski et al. 2013).

9.2.6.2 Food Donation

Food donation to those in need presents interesting opportunities since there are food networks that may contribute to this ideology by offering more easily controlled systems avoiding food loses. Therefore, a link is created to associate sustainability with food security and food safety. Though, there are always losses in the food chain no matter how close the loop is, it is also necessary to consider the obstacles when generating solutions for food waste management when donating (Jurgilevich et al. 2016).

9.2.6.3 Animal Feeding

It is based on the principle that the food waste can serve to feed the livestock to foster the agricultural output. In some Asian countries (Japan, south Korea, Taiwan) with high demand for animal feeding, it is promoted by law the use of food waste to feed animals, which accounts for almost half of the total food waste generation (Kim et al. 2011). Albeit, in developing countries it is not a common practise to separate and collect food waste to feed animals since almost all of generated food waste is mixed with municipal solid waste (Thi et al. 2015).

9.2.6.4 Anaerobic Digestion Technology

It refers to the biological decomposition of organic materials in the absence of oxygen to produce a biogas mainly methane and a fraction of carbon dioxide with an effluent of high nutrient value (Ray et al. 2013). Anaerobic digestion has been widely investigated for both its energy production and waste management potential. This is a well-known technology that has been implemented in various countries of the world (Thi et al. 2015). On the other hand, it is acknowledged in developing countries that anaerobic digestion is still hard to implement due to technical barriers, inappropriate operations or inadequate management (Müller 2007).

Food waste is well-fit to be converted into methane by anaerobic digestion, and some studies have been carried out evidencing its effectiveness (Wang et al. 2012). Under anaerobic conditions the food bacteriological content converts the food waste into biogas. Such application is attractive due to its potential for energy (heat and electricity) generation (Chiu and Lo 2016). Compared with other typical food waste treatment such as composting and incineration, anaerobic digestion is more appropriate for food waste treatment because it recovers more energy while it emits less environmental harm in the form of greenhouse gas emissions (Chiu et al. 2016).

The biogas derived from the anaerobic digestion can be used as an alternative energy source to substitute conventional fossil fuel consumption (Calabro 2009). On this manner, it can be used as various types of energy sources, such as heat and electricity produced from biogas combustion (Lin et al. 2013). The heat can be used to uphold the temperature of the anaerobic reactor and to provide heat for nearby areas. If electricity is generated, this can be internally consumed, and the excess of electricity could be delivered to the public grid (Møller et al. 2009).

In order to reach a 'ZWTL' strategy, a solution is not completed until all the factors affecting not only the environment but also the social and economic factors are counted. In consequence, the 'ZWTL' philosophy integrated into the food waste hierarchy is one approach that must be coupled with a way to create a cost-effective business with social benefits. Thereby, the CE principles offer a framework where the ZWTL strategy can be valued towards a circular business model as explained in the following section.

9.2.7 Circular Economy (CE)

CE is an approach that takes the concept of sustainability one step further and rethinks the future on how the current system can be reorganised, where growth is possible within a renewing economy involving materials science, design, engineering and systems design (Pitt and Heinemeyer 2015). In essence, CE is known as an industrial system that is meant to replace the end-of-life concept and the use of renewable energy and targets the elimination of waste through the new output of products, organisations and even business models.

This CE system is focused on few principles. The first principle of CE aims to preserve and improve natural resource management and renewable resource streams over finite stocks. The second principle introduces the optimisation of resource by circulating products, components and materials in use at the end-consumption utility in both technical and biological cycles. Finally, the third principle considers fostering system effectiveness by designing out externalities (MacArthur 2013).

Companies seeking for savings in circular systems need to increase the rate at which their products are collected and consequently reused or recuperated by applying CE principles. As it can be seen, a circular model fosters the need for innovation and growth and decreases the demand for resource consumption. Productivity can be threatened when natural resources become scarce; thus governments and companies have started considering the implementation of CE business models (Murray et al. 2015).

As it has been reported (MacArthur 2013), increasing circularity creates new opportunities for companies that could offer important benefits that would not otherwise be achievable without a CE model. Through different schemes, companies could create strategies to face business challenges by starting up new CE models so that bigger profits will appear, for example, by making use of by-products. As a result, there will be a lower energy and material intensity demand, thus reducing fossil fuel consumption (Murray et al. 2015). Moreover, the lower demand for resources will also slow current rates of natural erosion relieving environmental burdens and decreasing the need for landfill and charges for waste treatment.

According to the Ellen MacArthur Foundation (2013), the full benefits of the CE would avoid up to 340 million tons of waste from landfilling each year around the globe, more than 272 million tonnes would be from the elimination of food waste. This circularity would reduce the pressure on agricultural soils and the preservation of land productivity through less pressure on food production. Given that around one-third of the total food produced for human consumption is now lost or wasted (FAO 2011), using this 'waste' material has considerable potential to slow the demand for land.

CE has been considered regularly as an approach to more appropriate waste management through recycling, reuse or recovery methods. Hence, a complete view at the implementations of alternative solutions over the entire life cycle of any process as well as the interaction between the process, the environment and the economy must be considered (Ghisellini et al. 2016). After all, CE has the potential to implement new patterns and help stakeholders reach increased sustainability. Consequently, it is not only regarded as a waste or energy recovery, but rather it is about improvement of the entire system.

9.2.8 ReSOLVE Framework

According to the Ellen MacArthur Foundation (2013), the three principles of the CE above outlined can be applied into six business actions. Those actions might contribute to businesses and countries to generate circular strategies and growth initiatives. Thus, it represents circular business opportunity under the so-called ReSOLVE framework (Regenerate, Share, Optimise, Loop, Virtualise and Exchange). This conceptual framework displays a major role as it can be used to apply the principles of the CE towards the design, implementation and acceptance of circular business models (Lewandowski 2016; Planing 2015).

The ReSOLVE framework is briefly detailed as follows:

(1) Regenerate – primary use of renewable energy and materials, involving health regeneration of ecosystems such as return of the biological resources to the biosphere.
(2) Share – this means optimisation of resources by sharing them among users and reusing them throughout their lifetime through maintenance, repair or refurbishment.
(3) Optimise – this refers to a performance/efficiency of a product by removing waste in production throughout the supply chain.
(4) Loop – it is meant to keep components and materials in closed loops by prioritising inner loops.
(5) Virtualise – this is related to delivering goods and services virtually.
(6) Exchange – it replaces old materials with advanced non-renewable materials by trying to apply either new technologies or new products and services (MacArthur 2013).

9.3 Methodological Approach

As mentioned in the introduction, the main research question driving this work is how the organic waste management in Walmex can be improved by combining a CE business model and a ZWTL strategy. In order to study the CE business model and ZWTL frameworks, it was decided to use the case study approach. In addition to that, desk research, interviews with semi-structured questionnaires and expert's consultation were combined for data gathering. The analysis of the information was under the combination of those frameworks and the food waste hierarchy.

9.3.1 Case Study

This research aimed to provide a suitable strategy to closing the loop on food waste at Walmex. This was done by integrating the 'ZWTL' philosophy into the ReSOLVE framework proposed by the Ellen MacArthur Foundation (2013), as the conceptual framework method employed towards a circular business model. The showcase in this study was based in one Walmex located in the Metropolitan Area of Mexico City.

9.3.2 Data Collection

In order to receive a complete input of the performance mainly on food safety, food quality and food waste management, key staff members in the store were consulted. The authors conducted semi-structured questionnaires among staff members with positions such as store manager, reception supervisor, assets protector supervisor, IT supervisor, bakery supervisor, fruit and vegetable supervisor, maintenance leader, operations submanager, perishables submanager and canteen manager. In total, 12 respondents were selected due to their influence in the decision-making processes throughout the food value chain at the retail store level.

The questionnaire was applied to key staff enquiring the same questions to all of them but with slightly variations according to their level of involvement on each step of the current organic waste management practises (e.g. managerial decision questions, operational performance). Afterwards, this sort of outcome was coupled with information of daily food waste generated and the type of waste generated. Both characterisation and volumes were gathered through logbooks provided by the staff which served as the inventory baseline of the current practises. This methodology was selected and carried out due to its double character: qualitative and quantitative nature.

9.3.3 Data Analysis

The current organic waste management was analysed against the food waste hierarchy proposed by Papargyropoulou et al. (2014). This was done due to the practicality of using a framework to assess the practises that influenced the efficiency of the store. Given the different steps in the hierarchy before landfilling, the data collected was assessed in terms of food waste avoidance (reduce, feed people in need and feed livestock) followed by waste management (energy recovery, e.g. biodigester) as described in Sect. 9.3. However, the analysis of the information only through the waste hierarchy was limited to the evaluation of the environmental performance. Consequently, in order to integrate the technical, environmental and financial impacts, the information gathered was analysed through the CE principles set by MacArthur (2013) as described in Sect. 9.4.

9.3.4 Circular Business Model Analysis

The findings described in this study are seen as an input towards a circular business model. In that sense, the integrative approach to reach the aimed target was assessed under a multidimensional perspective, i.e. technical, environmental and financial. This integrative approach shed light on the benefits generated that can increase the acceptance of CE models and practises. The integrative perspective was offered by the ReSOLVE framework which provided the conceptual background from which the ZWTL is shifted into a business action, as it was presented in Sect. 9.4.

The two main steps followed during the ReSOLVE framework implementation are here indicated. Firstly, the strategy proposed was confronted between two scenarios carried out through the ReSOLVE framework, being the inner circle of the loop and the priority given because it guarantees a longer and more efficient use of resources towards an integrated circular business model. Then, the technical-environment-financial aspects were the ones that determined the decision-making variable in this study.

9.4 Findings

The interviews were carried out among 12 key responsible persons at the retail store. The enquiries on the subject of organic waste management activities provided evidence on how those activities influence the efficiency of the system. This resulted in an inventory of the current practises implemented at such location. Moreover, in order to keep details of food waste, logbooks were consulted to track the type of food and daily volumes of organic waste disposed of to landfill. Subsequently, the findings were used as baseline to be integrated to the ZWTL strategy with the purpose to improve the current organic waste management system.

9.4.1 Current State of Organic Waste Management at the Walmex's Store

At present, 'first-in, first-out' is the adopted systemic solution in the store which is based on the assumption that all food products arriving on a specific time have the same shelf life span. Even so, the store's policy regarding this issue stated that despite this fact, store shelves have to be well filled with a wide range of fresh products to anticipate customers' expectations. Although positively beneficial for sales statistics, continually replenished supplies mean that food stocks close to expiry are often overlooked by consumers (FAO 2011). This store's effort, however, resulted in a product display in store shelves that increased the amount of food wasted. Once the food is considered as waste, there are three different classification to manage organic waste: (a) stolen/distorted (products in good conditions but incomplete or altered due to thieves manipulation), (b) donation to those in need (products in good conditions but with aesthetically alterations in the package) and (c) food waste (rotten products, expiration date was passed, employees decided the landfilling of the food).

Two of them (stolen/distorted and donation) are regarded as second quality products as they are aimed to serve a different purpose in the food value chain. In this case, the destination of those second quality products is their distribution to multiple food charity organisations. In that sense, the Walmex store has been working on food donation especially with a national charity organisation that redistributes the food through their soup kitchens. Currently, they have been donating to this charity only packaged food with aesthetical alteration, placing aside vegetables, fruits, bakery and pastry. Since after the collecting time (11:00 am), food cannot be stored for the next day, it is then regarded as waste. This is mainly due to risks regarding food quality, cost of transport and preservation which also requires additional labour, storage, examining and monitoring efforts to redistribute the saved food.

However, the third category (food waste) has no declared purpose in the food value chain; in consequence it is directly landfilled without taking any benefit out of it. The 12 respondents mentioned that the food waste is managed by staff that follows technical criteria (texture, colour and odour) as well as subjective criteria. They discard products with no good appeal that are interpreted as low quality according to customers' demands. Once the organic products are taken away from the store shelves, a green bag is used to collect the food labelled as organic waste to be transported into a refrigerated room. This procedure takes place at least three times per day. After the collection phase of the food waste, its management passes to an external partner who is in charge of the daily disposal of the food waste in landfill sites.

According to the recorded information, two main groups of food waste at the organic end-of-life chain were identified: (1) fruits and vegetables and (2) bakery and pastry. Approximately 95% were fruits and vegetables mainly bananas, apples, watermelons, tomatoes and potatoes (see Fig. 9.1). On the other group, bakery and pastry were represented mainly by cakes, bread and crackers.

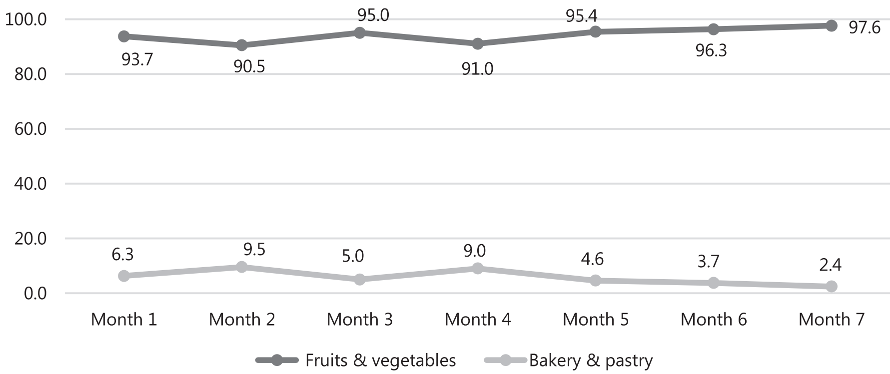

Fig. 9.1 Food waste landfilled per month (%)

As observed in Fig. 9.1, the daily amount of food discarded is not constant through the time. In fact, it can be stated that the gap between the lowest volumes landfilled and the highest volumes landfilled is significant. As indication, for fruits and vegetables in Month 2 (lowest volume of food waste landfilled) compared to Month 7 (highest volume of food waste landfilled), there is gap of more than 7%. The same occurred as to the group of bakery and pastry; the gap between the lowest volume landfilled (Month 7) and the highest volume landfilled (Month 2) was about 7%. There are some indications that this fluctuation might be caused by a poor supply chain management. However, the exact causes of having such fluctuation on the values were not mentioned during the interviews. Although, the proportion of food waste might not be significant during the retail operation; given the aim of this research, it is not only environmental and social wise to tackle this issue but also financially responsible to address the food waste problem as it was so far.

9.4.2 ZWTL Strategy at Walmex's Store

Prior to setting a ZWTL target, it is relevant to highlight all the possible scenarios that could reduce the food being landfilled. Also important to say is that these possible scenarios have to be firstly fully embedded into the environmental regulatory frameworks before any of them can be actually executed. In this case, a scenario was delivered prioritising food waste avoidance (reduce, feed people in need and feed livestock). The least desired option of the waste management approach corresponds to energy recovery, e.g. biodigester. This framework was completed according to the adaptation of the food waste hierarchy developed by Papargyropoulou et al. (2014). This provided a clear stance of the food conditions in the retail store, with the aim of creating a ZWTL landfill strategy under the food waste hierarchy principles. Therefore, we start with the most recommended one: reduction.

9.4.3 Reduction

At the retail store level, food waste can be attributed to two main factors: oversupply and reduction of shelf life. Those factors can be corrected by improving the supply chain management (Sciortino et al. 2016). At present some products in the store such as bananas, apples, watermelons, tomatoes, potatoes, cakes, bread and crackers have been identified as the products with less shelf life span. However, a data-driven supply network is required in the store to obtain more information about the shelf life of all entering products; this could ensure a better logistics approach to extend shelf life.

Consequently, the store's manager may then choose to sell food products based on their remaining shelf life. One major advantage of this strategy is that high-quality perishables can be sold to the customers at a premium cost by choosing the products with relatively long shelf lives (Jedermann et al. 2014). Upgrading these practices is important since employees' criteria to discard up food are ruled moderately by subjective standards as a decisive factor on whether to send the food or not to landfilling; by doing so, food stocks could be reduced as no high volumes of food are needed to be in store shelves. The 'first-expired, first-out' (FEFO) approach is one of the most applicable ways to deal with this issue. Although, FEFO is convenient for the store, it is important to mention that this approach is only possible by using robust inventories that enable accurate demand forecasting of those products (Hertog et al. 2014).

This approach is not only intended to treat with oversupply issues but also to an extent aimed to lengthen food shelf life. In the light of the benefits that this scenario might deliver, East (2011) proposed a system to predict storability performance testing FEFO compared to first-in, first-out (FIFO) and last-in, first-out inventory scheduling protocols. The author concluded that by using this approach, the improvement in storage capabilities is possible, so the reduction of fruit losses might rise up to 30% in comparison to other protocols. For more practical reasons, this research was focused in the postharvesting phase, especially at-harvest site. On the other hand, Sciortino et al. (2016) observed that 14% of food waste was reduced when decisions were made on a shelf-life-based analysis. This can be done by collecting accurate information about the daily flow of food, thus minimising food losses. Thereby, the volumes of food required to maintain the shelf full of high-quality food could be matched with costumers' demands and simultaneously cutting costs in storage, cooling and marketing (Sciortino et al. 2016).

9.4.4 Feed People in Need

At this point in time, there is no guarantee for the food stock to be completely sold out as the operations of forecasting and extending shelf life are also coupled with costumer's purchase behaviour which cannot be controlled. Hence, the 'fit-for-human-consumption' activity was enlisted as a 'second-best' solution in a context where there is still high-quality food in the retail store. Its purpose is to provide food to those unable to afford their own food. Thus, food banking emerged as non-governmental initiatives in the form of alliances saving food to distribute it to people in need (Schneider 2013). In conventional models of food banking, participants donate food that has little commercial value (overruns in production, excess supplies, past sell-by or stock that does not move on the shelves), but its nutritional properties remain for consumption purpose. At the retail level, operators can donate food that is too close to the expiring date losing its commercial value, or giving away unmarketable products such as bruised fruit and vegetables (Timmermans et al. 2014).

As a matter of fact, prior to this study, the store had previously defined its own target regarding food donation. The policy is set up to 30% of food losses and could be more as the managerial level considers it appropriate. Although, the target was set, an exact daily rate of food waste reduction after the previous phase (Reduction) is unknown. The Walmex's store must overcome potential barriers regarding logistics, information and legal concerns. Likewise, strengthening food banks and food bank networks throughout the country could be the sort of solution as a win-win situation that would benefit those in need without landfilling food. This situation implies less amount of food sent to donation but of a higher nutritional value due to the reduction-at-the-source strategy proposed for this study. So, it is worth to remark the relevance of a proper implementation of the food waste hierarchy used as a framework for this study, ever since if implemented properly, the amount of food meant to donation could be less but of at a higher nutritional value.

9.4.5 Feed Livestock

Another scenario of lesser value is to process food waste for animal feed. However, this is often not financially lucrative considering lower prices in that sector (MacArthur 2013). The livestock sector could use the retail flows of foods which cannot be redirected to human consumption either reduction through inventory management/extending shelf life span or food donations. The success of this scenario relies heavily on a number of practices, processes and policy parameters, such as safety, legislation on materials, operator rights and cost (Timmermans et al. 2014).

During the interview process, one person representing the livestock sector expressed his interest in the discarded food at the Walmex's store. According to this person, his sector may use for cattle-breeding up to 25% of bakery and pastry for the youngest group of animals. Then, this proportion could be raised up to 40% after 45 days of the animal lifetime. On the pig-breeding sector, after 25 days of the animal lifetime, their diet is a food mixture including among others bakery and pastry. After 45 days of the animal lifetime, fruits and vegetables conform part of their diet. Fruits and vegetables can be combined with bakery and pastry with portions between 35% and 15% of their diet. During the animal's adult life (e.g. pigs), the proportion of bakery and pastry can surpass 50% of the total amount of the food used to feed. The proportions on the diet were disclosed in order to indicate the livestock sector high demand of retail store's food losses which could close the loop of the ZWTL strategy.

As priory mentioned the livestock sector is highly interested in using the Walmex's food waste for cattle-breeding and pig-breeding. Indeed, the feeding method guarantees that fruits and vegetables are consumed immediately right after the food arrives to the farms. As for the food waste conformed by bakery and pastry, their intake was insured to a maximum of 3 days after their arrival. Even further in case the food might become not-fit-for-livestock consumption, the farms proved to have composting procedures for the no-longer-eatable food. Therefore, the farms themselves are not disposing of to landfill but rather closing the loop on food waste as well.

Setting quantifiable target for this scenario was not easy to define when comparing with the other two scenarios which are meant to close the loop on food waste. In any case, animal feeding remains as an option to achieve ZWTL through composting the remaining non-eatable portion. But due to the priority of reduction and donation streams, it seems irrelevant to fix a target for the feed livestock one. This latter depends on the quantity left after the two previous scenarios in the waste hierarchy. But in practise it is not a direct option for the remaining portion because this should comply with legislations associated to food safety and food quality standards at any time. Thus, not all the food is qualified to farm animals.

Even so, some numbers could be estimated aligning this strategy to the global target set by nations, regions and corporations on food waste avoidance. In that sense, the European Union and the United Nation target to decrease 50% of food waste (Lipinski et al. 2013). With regard to this scenario, feeding livestock as part of the food waste hierarchy framework might contribute up to 6% of the reduction once the two first scenarios have been exhausted (they account 44%) towards the ZWTL target (Fig. 9.2).

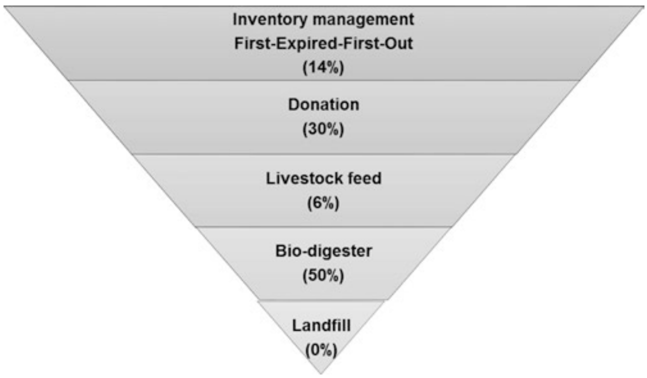

Fig. 9.2 ZWTL strategy. (Adapted from Papargyropoulou et al. (2014))

9.4.6 Biodigester and Energy Recovery

The final step to be undertaken, as it is illustrated in Fig. 9.2, is the recovering of energy by using a biogas system which appeared to be the suitable technology for this case study due to its advantages to treat food waste (MacArthur 2013). The nutritional richness of those materials is perfectly appropriate for any anaerobic digestion technologies to convert this influx into renewable energy and organic fertiliser (Leung and Wang 2016).

As explained here above, the three proposed scenarios must obey at least to a certain food safety standard for health reasons complying with the current Mexican legislation and ethical behaviour on social accountability. After all the three potential scenarios here studied, no additional option for reusing and recycling was feasible for some of the food becoming at that point waste, as no other option is feasible at present. Moreover, bearing in mind the inevitable biological decay of food quality, the organic waste must face the unavoidable act of being managed. This is because their natural decomposition creates odour, fast depletion on any physical surface, release of greenhouse gases and leachate percolation (Leung and Wang 2016). As observed in Fig. 9.2, 50% of the total food being disposed of by the retail store is available to be digested inasmuch as the former three scenarios have been already exhausted, and no other option is able to retain food quality and safety properties for either animal or human consumer any longer.

However, assuming that the remaining volume of food waste of the ZWTL scenario is still unknown, the biodigester system was designed by considering the complete daily amount of food wasted. From this assumption, the capabilities of the system were identified after some calculations. Furthermore, due to the existence of several Walmex stores in Mexico City, there is the possibility to bring their food waste to the biodigester system to reach the biodigester capacity.

The biodigester design can be daily fed by two groups of food waste (fruits and vegetable and bakery and pastry). The total substrate feeding the system was a water mix ratio of 1:3 which was calculated according to Arboleda and Salcedo (2009). Additionally, the volume substrate was estimated considering a density average of 1.3 kg/l at 35 Celsius degrees. After calculations were done, it was possible to estimate the methane production based on the theoretical value of 500 ml CH_4/g VSS. The outcome of this theoretical digestion process yielded on average 11054.27 CH_4 litres per day as observed in Table 9.1.

Theoretically, it is possible to say that all the amount of food wasted can be used to feed a biodigester to produce electricity. Yet care should be taken in the anaerobic digestion process as inhibition may occur when food waste is used as the main substrate. This inhibition is related to the disparity in the nutrient content of food waste. Therefore the biogas yield is affected by any variation in carbohydrate, protein and lipid content (Chiu and Lo 2016). Special attention is focused on the lipids and lignocellulosic concentration in food substrate. This could lead to process inhibition if food waste with high lipid content was digested (Zhang et al. 2014). In case of

Table 9.1 Biogas production from food waste food

Month	Volume substrate (l/day)	Kg VSS/day	CH_4 production (l/day)
Month 1	697.5	19.5	9730.1
Month 2	660.1	18.4	9208.8
Month 3	774.9	21.6	10810.3
Month 4	560.5	15.6	7819.4
Month 5	970.2	27.1	13534.8
Month 6	928.4	25.9	12951.4
Month 7	955.2	26.7	13325.0
Average			11054.27

excessive addition of lignocellulosic waste in the substrate mixture, this might result in poor biogas production (Chiu and Lo 2016).

According to the properties of the food wasted, there was no significant presence of lignocellulosic biomass (no rice proportion was characterised), and the lipid content coming from bakery and pastry represents only 5.8% of the total wasted (see Fig. 9.1). Hence, it is expected to have standard performance of the anaerobic digestion system since the ingoing food waste flow does not content representative number of components to inhibit the biogas production.

As priory outlined the conditions in anaerobic digestion made possible to use methane (CH_4) as a source to generate heat and electricity. From calculations it was possible to estimate the feasibility of using renewable energy to substitute (a) electricity currently supplied by the grid and (b) heat from natural gas consumption. As shown in Table 9.2, 394913.7 (KJ/day) is the total energy a biodigester was able to produce under similar conditions than this case study. This value is the result of the methane theoretically produced in anaerobic digestion (11.1 Nm^3/day) multiplied by the low heating value (LHW). This latter suggested by the low heating value (LHW), as suggested by Waldheim and Nilsson (2001). However, the energy requirement for pasteurisation was extracted from the total energy production since this energy requirement is a stage prior to the digestion process.

Once, the total energy available for electricity generation was estimated assuming a combined cycle gas turbine efficiency of 50% as recommended by Honorio (2003). This was done in order to determine the kilowatts per hour the system was capable to supply when substituting electricity provided by the grid. From those calculations, the electricity produced by anaerobic digestion can cover 0.8% of the total electricity consumed per month. This electricity share, from the biodigester, is neither technical nor economically feasible as it is not supplying significant electricity to the system, and therefore the payback time is foreseen as negative.

Furthermore, a second calculation was done taking into consideration the generation of biogas for heat and cooking utilities trying to find some economic value to the biodigester by-products. This resulted in 254.73 MJ/month of energy consumed for heat and cooking as observed in Table 9.2. This value was discounted of the total energy for electricity generation. This result considered an efficiency of heating of 80% (standard value) and an efficiency of combined cycle gas turbine of

Table 9.2 Energy recovery (power and heat) by biogas production

Power (electricity)	
CH_4 production (Nm^3/day)	11.1
Low heating value (MJ/ Nm^3 CH_4)	35.7
Total energy (KJ/day)	394913.7
Energy requirement for pasteurisation (KJ/day)	48512.2
Total energy for electricity generation (KJ/day)	346,401
Efficiency of combined cycle gas turbine (%)	50
Share in the total electricity consumption per month (%)	0.8
Heat (cooking)	
Higher heating value natural gas (MJ/Nm^3)	33.7
Energy consumed by heat and cooking (MJ/month)	254.7
Total energy for electricity generation (KJ/day)	346,401
Efficiency of heating (%)	80
Efficiency of combined cycle gas turbine (%)	50
Electricity produced by biogas after heat and cooking (KWh/ month)	1399.1
Savings in energy bills (%)	18.6
Payback time (years)	2.4

50%. Thus, it resulted in 1399.1 KWh/month of electricity produced by biogas after heat and cooking.

The electricity produced by biogas after heat and cooking covers the energy requirements for those operations in the retail store, and there can still be an energy value left for electricity generation. However, it does not directly mean that this amount of energy would replace the electricity consumed from the grid, but rather it implies that biogas can substitute (commercial) natural gas for heat and cooking operations.

The biodigester technical feasibility was confirmed through cost-benefit analysis. According to this analysis, a commercial biogas plant (only bioreactor system for heat and cooking) at a cost of 66,000 USD with a cost operation per year of 3800 USD is stablished at site. Thus, the savings in energy (electricity and heat and cooking) bills per month could be lowered in 18.6% (Table 9.2). Therefore, the payback time for this type of solution will take 2.4 years.

9.5 Discussion

In this section it is described the combination between ZWTL strategy and the ReSOLVE framework as the selected approach to reach a CE business model.

9.5.1 The ReSOLVE Framework Towards a Circular Business Model

Approaches to close the loops on food waste at Walmex were here analysed by using the ZWTL strategy as framework. The ultimate target was indeed 0% of waste for disposal in landfills (Fig. 9.2). This served indeed as a showcase to identify those waste (materials) streams that could jointly lead to the 0% waste to landfill. But due to the multinational character of Walmex, this case has proved to feature some patterns that could be replicated beyond the Mexican context if those patters fit into international frameworks such as those published by the Ellen McArthur Foundation (2013). Hence, in this section, the technical proposal, so far here discussed, is in this section coupled to the ReSOLVE conceptual framework (MacArthur Foundation 2013). By integrating the ReSOLVE and ZWTL frameworks, technical, environmental and financial benefits can be analysed at once and serve as a tool to be explored in other Walmex's stores in Mexico or in similar food waste generation and composition conditions. The final purpose is to deliver a general model that can deliver a closer approach to circular business models by deploying closing loops of food materials.

9.5.2 Closed-Loop System

The business action in the ReSOLVE framework called Loop was chosen as the first scenario to be assessed towards a CE business model. This is due to the principle of the Loop concept and the CE itself meant to keep a closed loop and prioritise inner loops (MacArthur 2013). As outlined in Sect. 9.3, the current management in the Walmex's store disposed of a relevant amount of food waste in landfills. Therefore, by using this framework, a fully closed Loop in a ZWTL strategy is proposed (Fig. 9.3).

In this scenario, the biodigester was displayed as the main/unique treatment; thus, the Closed- Loop system is considered from a technical and economical perspective. Technical-wise, the system can cover all the heat and cooking demand for the store as calculations showed (Table 9.2), while it provides a source of renewable fuel (CH_4) to replace the fossil fuel. At the same time, this system is avoiding the emission of greenhouse gases in open landfills by combusting the methane in a biogas plant. However, this system is lacking fully environmental awareness as it is fostering the production on food waste to feed the system. Hence it contradicts, to some extent, the facts shown in Sect. 9.3, where the food still edible for human consumption was highly recommended to not be biodigested first. Furthermore, the financial benefits can be easily recognised as shown in Table 9.1; the savings in energy bills might be up to 18%.

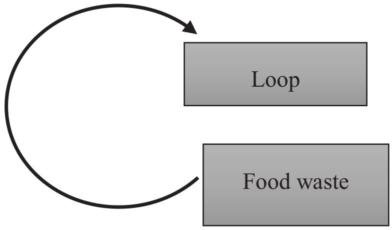

Fig. 9.3 Closed-loop system

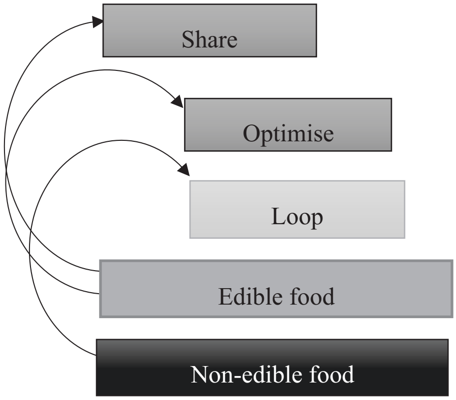

Fig. 9.4 Share, optimise and closed-loop system

9.5.3 Share, Optimise and Closed-Loop System

The Share, Optimise and Closed-Loop system does not follow the principles of CE of keeping a closed loop and prioritise inner loops as previously showed. Instead, it can be seen as an integrative approach by adapting the food waste hierarchy in the ReSOLVE framework (see Fig. 9.4). The share is meant for donations, but it can be referred to feeding livestock as well since both maximise product utilisation (MacArthur 2013). Optimise is related to the reduction phase as it removes waste by increasing efficiency (first expired, first out). And finally, the Loop referred to the anaerobic digestion process of recovering energy from the food waste stream.

From the technical standpoint, Share (donation and animal feeding) was accountable for approximately 36% of food waste reduction. Then, optimise could represent up to 14% food waste reduction. And lastly the Closed-Loop through the use of a biodigester represented 50% of the food waste stream (see Fig. 9.2). This technical system can also be regarded as a non-wasteful use of resources system, ever since it is focused in an intensive waste-reduction approach. The environmental externalities might be dramatically reduced as no food is wasted in landfills, the same as the Closed-Loop system. Albeit, the former system aimed to tackle food waste at its very primary stage, avoiding the necessity of generating food waste by cutting down the oversupplying of perishables at the Walmex's store.

On the financial aspect, the savings come from different sources. In Share, donation is seen as highly altruist, but it needs some compensation to be a suitable solution. Some fiscal incentives promote this initiative to compensate the economic losses in the business. Animal feeding although is not the ideal option for edible food; it also might recover some economic value while providing good-quality food to farm animals. In addition, increasing efficiency through Optimise (reduction) brings savings to the business.

When Share and Optimise are summed up, the savings reached 23% compared to the total cost of the food landfilled. The financial benefits were estimated taking into account the fiscal incentives for donating food, the cost of perishables for the livestock sector and the cost reduction by using first-expired, first-out approach. Nonetheless the savings can be higher by adding the energy bill savings in gas consumption through the use of the biodigester. Placing these elements together, the savings could be up to 41%. Yet, the biodigester system might need resources from other Walmex's stores, since in order to cover the heating and cooking demand, the system must work the closest to full capacity.

9.6 Conclusions and Recommendations

The main research question driving this research was: how the organic waste management in Walmex can be improved by combining a CE business model and a ZWTL strategy? To answer this question, the food waste hierarchy provided a suitable framework to target a ZWTL goal. It was noted that the current organic waste stream at the store has relevant opportunities to be optimised. The framework used showed that besides the clear oversupply issues diagnosed, most of the food can be recovered through different stages. Therefore, boosting managerial performance rather than implementing sophisticated technological developments on perishable foods seems feasible as this measure requires considerably involvement of a high number of staff members (e.g., operators should be skilled and knowledgeable) and low investment. Prior to implement any waste management action, the regulatory frameworks have to be considered to keep environmental compliance at all levels.

Businesses use different tools to assess their performance towards sustainability. Albeit, when it comes to specific sustainable issues, e.g. food waste, the literature is still scarce. Furthermore, a sustainable proposal must not only be effective but rather integrative due to its cross-cutting nature of sustainable practises. Therefore, for the purpose of this case study, several frameworks were integrated seeking for ZWTL strategies. In particular the ReSOLVE framework served to evaluate the CE principles which theoretically can be converted into six business actions. For this research three business actions were placed into consideration: Share, Optimise and (closed) Loop (SOL). Basing the analysis on two scenarios, the integrated system that appeared to be the most circular is the one using SOL. This system is clearly deep-rooted in the philosophy of the CE as it is handling the food waste by reducing the amount on nonedible organics. Thus, the SOL4FoodWaste framework is delivered as an attempt to collect applicable sustainable concepts and integrate them as one single framework that might potentially be implemented or resembled in similar retailer industries.

Although the key concepts and benefits of the ZWTL and CE principles have been available for many years, very often the technical-environment-financial relationship is misaligned that has resulted, so far, in not circular systems. The findings of the SOL4FoodWaste framework showed the benefits of managing the food waste through the three business actions, saving about 40% of the food waste management costs.

9.6.1 Recommendations for Further Research

Because in this study the main focus was the operations of food waste at one of the retailer stores of Walmex, the role of costumers on the ZWTL strategy was not analysed. Although, consumers' behaviour was not part of the study, scholars have agreed on consumers' power to influence product quality standards. There is a constant perception that consumers will not buy food which has the 'incorrect' dimension or poor appearance. At present there is weak existing factual information about consumer's preferences regarding the food appearance in connexion to quality and safety standards. Hence one of our recommendations for future research is to inquiry the consumers in order to explore the possibility to offer them a broader quality range of products in the retail stores not only based on good appeal. By influencing the costumers, a dramatic reduction of food losses can be foreseen. In addition to that, further research must be focused on verification procedures of the SOL4FoodWaste framework implementation. This type of integrative managerial approach can motivate the development of circular business models/actions for other type of discharged materials from the technical loops (MacArthur 2013), e.g. clothing, cleaning products and electronics, among others.

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