Integrating Sustainability in the Food Supply Chain - Two Measures to Reduce the Food Wastage in a Swedish Retail Store

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ABSTRACT: Due to the growing world population, the environmental impact from the food supply chain is currently increasing in a global perspective, essentially because the global food consumption is increasing in general. The UN *Food and Agriculture Organization* (FAO) estimates that about one third of the edible portions of the food produced globally is lost or wasted along the way from raw materials to the dinner plate. When food is produced, transported, stored, treated and processed in different ways it consumes a lot of resources and energy and causes large negative impact on the environment due to emissions of pollutants affecting waters, soil and air. When food is wasted somewhere in the food supply chain, it implies unnecessary emissions of greenhouse gases and other pollutants and also entails a pointless extraction and use of natural resources: each since the production is made in vain.

Sustainable development has been generally accepted as *development that meets the needs of the present without compromising the ability of future generations to meet their own needs*. Quite simple, this means that humanity of today needs to conserve the remaining resources on Earth and sharply reduce the anthropogenic environmental impact. In order to attain a state where man can live in equilibrium with the natural world, humanity must pursue sustainability in every activity and every movement. According to the Swedish Environmental Protection Agency (SEPA) a reduction of food loss within the food supply chain could facilitate society's quest to develop in a sustainable manner.

The retail store is one place where large numbers of food items are gathered at the same location and where a lot of food is discarded, many times completely in vain. It is thus a suitable place to take actions to reduce the food loss in a quite effective way. In a Swedish retail store located in Uppsala, two product specific measures have been introduced; a new display table intended to reduce the loss bananas and a new price reduction routine intended to reduce the loss of grilled chicken. This thesis aims to investigate whether the measures put in place actually have resulted in reduced losses or not. The goal of the study was to examine how much unnecessary environmental impact (in terms of contribution to global warming) that hence has been avoided. The research questions are studied through a combination of data analyses, interviews and life-cycle assessments. SWOT-analyses have also been conducted in order to evaluate the introduced measures in terms of contribution to sustainable development within the food sector.

The results of the study concluded that the measure based on price reduction has reduced the losses of grilled chicken with approximately 200 kg per annum. This implies that an annual climate impact of around 430 kg CO_2-equivalents has not been caused in vain, which should be the case if the 200 kg of chickens had instead been discarded. The study however shows that the measure is not particularly effective and could be improved in order to further reduce the daily losses.

The data analysis show that the banana waste that arises during the exposure in the store has decreased with 1 200 kg per year, implying that around 1 400 CO_2-equivalents has not been caused in vain. However, the study also shows that a rather complex system containing economic routines for handling food waste, most likely is wrongly used. Unfortunately, the routines may affect the registered waste outcome from the new display table due to a relocation of the waste from one waste category to another. The new display table's effect on the total waste quantity is therefore difficult to evaluate.

The conducted SWOT-analyses finally concluded that both introduced measures had strong environmental and economic benefits (and also favorable social benefits in the case of the display table), making them good and useful interdisciplinary solutions in terms of sustainability: thus contributing to a sustainable development within the food sector.

Keywords: Food loss, Food Supply Chain, Climate Impact, Resource Depletion, Sustainable Development.

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POPULAR SUMMARY: Due to the growing world population, the environmental impact from the food sector is currently increasing in a global perspective, essentially because the global food consumption is increasing in general. The UN *Food and Agriculture Organization* (FAO) estimates that about one third of the edible portions of the food produced globally is lost or wasted along the way from raw materials to the dinner plate. When food is produced, transported, stored, treated and processed in different ways it consumes a lot of resources and energy and causes large negative impact on the environment due to emissions of pollutants affecting waters, soil and air. When food is wasted somewhere on its way towards the dinner plate, it implies unnecessary emissions of greenhouse gases and other pollutants and also entails a pointless extraction and use of natural resources: each since the production is made in vain.

Sustainable development has been generally accepted as *development that meets the needs of the present without compromising the ability of future generations to meet their own needs*. Quite simple, this means that humanity of today needs to conserve the remaining resources on Earth and sharply reduce the environmental impact caused by humans. In order to attain a state where man can live in equilibrium with the natural world, humanity must pursue sustainability in every activity and every movement. According to the Swedish Environmental Protection Agency (SEPA) a reduction of food loss within the food sector could facilitate society's quest to develop in a sustainable manner.

The retail store is one place where large numbers of food items are gathered at the same location and where a lot of food is discarded, many times completely in vain. It is thus a suitable place to take actions to reduce the food loss in a quite effective way. In a Swedish retail store located in Uppsala, two specific measures have been introduced; a new display table intended to reduce the loss of bananas and a new price reduction routine intended to reduce the loss of grilled chicken. This thesis aims to investigate whether the measures put in place actually have resulted in reduced losses or not. Another aim of the study was to examine how much unnecessary environmental impact (in terms of contribution to global warming) that hence has been avoided, since the food hopefully is consumed rather than discarded. The research questions are studied through a combination of data analyses, interviews and life-cycle assessments; where the latter is a way of analyzing a products environmental impact during its time of existence. Analyses intended to determine potential strengths and weaknesses of the measures and to examine if there are any opportunities and hidden threats connected to them have also been conducted to evaluate if the introduced measures contributes to sustainable development within the food sector.

The results of the study concluded that the measure based on price reduction has reduced the losses of grilled chicken with approximately 200 kg per annum. This implies that an annual climate impact equal to the combustion of approximately 185 liters of gasoline has not been caused in vain, which should be the case if the 200 kg of chickens had instead been discarded. The study however shows that the measure is not particularly effective and could be improved in order to further reduce the daily losses.

The data analysis show that the banana waste that arises during the exposure in the store has decreased with 1 200 kg per year, implying that an annual climate impact equal to the combustion of around 600 liters of gasoline has not been caused in vain. However, the study also shows that economic routines for handling food waste most likely is wrongly used; unfortunately affecting the registered waste outcome from the new display table .The new display table's effect on the total waste quantity is therefore difficult to evaluate.

The study finally concluded that both introduced measures have strengths and opportunities that imply strong environmental and economic benefits (and also favorable social benefits in the case of the bananas), making them good and useful solutions in terms of sustainability: thus contributing to a sustainable development within the food sector.

Keywords: Food loss, Food Supply Chain, Climate Impact, Resource Depletion, Sustainable Development.

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Herman Nilsson

1. INTRODUCTION

”Human beings and the natural world are on a collision course. Human activities inflict harsh and often irreversible damage on the environment and on critical resources. If not checked, many of our current practices put at risk the future we wish for human society and the plant and animal kingdoms, and may so alter the living world that it will be unable to sustain life in the manner that we know. Fundamental changes are urgent if we are to avoid the collision our present course will bring”

- The World Scientists’ Warning to Humanity *(Kendall, 1992)*

To produce large quantities of food is necessary to feed the world’s population, but today’s global food production consumes resources and adversely affects the environment (Nellemann et al., 2009). When food is wasted somewhere in the food supply chain it implies unnecessary emissions of greenhouse gases and other pollutants and also entails a pointless extraction and use of natural resources: each since the production is made in vain.

The size of the food loss in the food supply chain has not been defined, but the UN *Food and Agriculture Organization* (FAO) estimates that about one third of the edible portions[1] of the food produced globally is lost or wasted along the way from raw materials to the dinner plate (FAO, 2011). Quite simple, this means that a significantly larger amount of food is produced than actually is consumed: a state that cannot be regarded as sustainable.

1.1. Project Aim and Purpose

Humanity must pursue sustainability in every activity and every movement, in order to attain a state where man can live in equilibrium with the natural world. We need to conserve the remaining resources and sharply reduce our environmental impact. The Swedish Environmental Protection Agency (SEPA) argues that a reduction of the food losses within the food supply chain has potential to support the achievement of such a commitment (Rytterstedt et al., 2008).

In a Swedish retail store, two product specific measures have been introduced; measures intended to reduce the loss of grilled chicken and bananas. This thesis aims to investigate whether the measures put in place actually have resulted in reduced losses or not. The purpose of the study is to examine how much unnecessary environmental impact[2] that has been avoided, due to the introduction of the two product-specific measures aiming at reducing the food loss.

[1] i.e. food excluding parts that normally is thrown in the garbage, such as bones and husks and so on
[2] in terms of contribution to global warming

1.2. Introducing Background – Sustainability and Sustainable Development

"Our biggest challenge in this new century is to take an idea that sounds abstract – sustainable development – and turn it into reality for all the world's people"

- Kofi Annan (UNIS, 2001)

In his book *Timeless Cityland* the Swedish professor Per G. Berg said that "*Sustainability is the call of our time*" (Berg, 2010). He insinuates that mankind currently faces the massive challenge to implement sustainability in every level of the human society and in all of our activities and movements; for instance, to make a society, that produces more food than actually is needed, more efficient. The expression *sustainability* invokes hope of a better future and is widely used over the world. It tends to pop up everywhere: in political agendas and business descriptions as well as in TV commercials and daily discussions around the dining table. Sustainability has its origins in the concept of *sustainable development* and its essential meaning of which rose from the environmental struggles and early negotiations connected to the first large UN Conference on the Human Environment, held in the Swedish capital Stockholm in 1972. At that time, an understanding of the relationship between the environment and economic growth as central factors for development had started to emerge (Kjellén, 2007), and scientists, politicians and decision makers soon realized that a development in itself, required an interdisciplinary approach in order to become sustainable. Thus, in the early stages after the UN Conference in 1972, sustainability became an incipient instrument in the framework of problem solving and investigation of limits and planetary boundaries. It was seen as an imaginative aspiration to resolve the conflicts between environmental and economic values (Dryzek, 1997).

In the mid-80s, a new organization was created, called the *Bruntland Commision,* formally known as the World Commission on Environment and Development (WCED). Its essential purpose was to address environmental problems connected to growth and development, and to raise awareness of the need for sustainable development (Kjellén, 2007). The organization aimed at establishing a sense of global companionship in order to encourage a united endeavor for achieving a more sustainable future. In 1987 WCED gave out their main publication *Our Common Future*, in which the definition of sustainable development used today was coined:

Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

– Our Common Future (WCED, 1987)

This definition implies that sustainable development as a concept accommodates a whole spectrum of moral and ethical questions about human attitudes, human livelihood and our appropriate relationship to other entities on the planet. With this in mind, Dryzek (1997) (among others) categorize *sustainability* as an environmental discourse, which indirectly is justified by Waddel (1998) in the sense that the concept evokes sentiment and also is something that the general public can relate to. WCED hints that development towards a sustainable society is a common responsibility with a general interest. It requires commitment from the industrial sector, such as the food sector, as well as from ordinary people. Furthermore, sustainability and sustainable development consists of different arguments and perceptions of how things can be done in a logical or proper way, which according to Lindseth (2006) is something that is characteristic for a discourse in that sense. Hence, it is reasonable that WCED (1987) points out *sustainable development* as a key element in environmental politics.

1.2.1. The Need of an Interdisciplinary Approach When Designing a Sustainable Future

The fundamental purpose of development is to satisfy human needs (WCED, 1987). However, the development has to be performed in a manner that does not "*endanger the natural systems that supports life on Earth: the atmosphere, the waters, the soils and the living beings*" (WCED, 1987). Hence, in order to be sustainable, development requires an interdisciplinary approach that takes different viewpoints into consideration, thus finding a balance between different interests which mainly fall within three basic categories – natural sustainability, economic sustainability, and social sustainability (figure 1) (Böhringer et al., 2007). Thus, efforts for a sustainable development should take this trinity into account and preferably be beneficial from all three viewpoints.

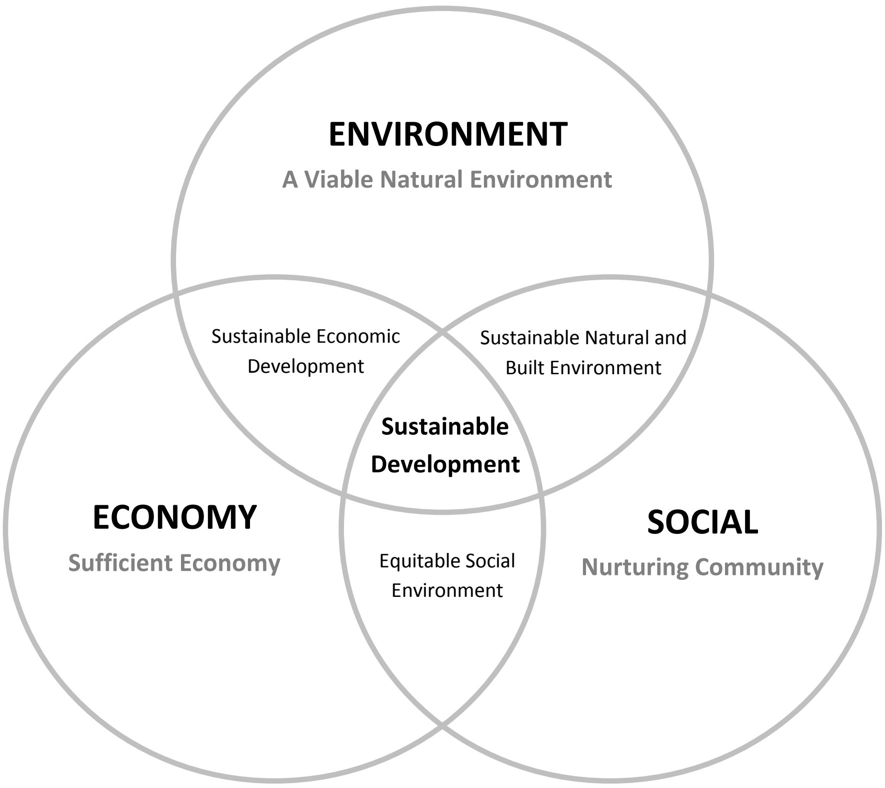

Figure 1. *Sustainable development requires an interdisciplinary approach that takes different viewpoints into consideration.*

Quite simple, a sustainable development requires that man and his technological and socio-economic systems can coexist with nature and its biogeochemical and ecological systems. However, the implementation of this elegant, holistic approach is often tempered by practical constraints when theory hits the 'reality of practice' in which budgetary, professional, political and other hindrances intended to serve the 'common good' are in fact channeled into serving a more limited range of interests (Campbell, 1996; Hempel, 2009). Nevertheless, the sustainability concept as a symbol in planning a sustainable society is "*sufficiently ambiguous to be embraced by diverse interests, yet coherent enough to inspire movement in a particular direction*" (Hempel, 2009). In this sense, sustainability as a concept does have a strong strategic function when it is related to longer-term visions open to change (Campbell, 1996; Berg, 2010).

The basic definition of *sustainability*, based on the above mentioned trinity (figure 1), has been generally accepted (Kjellén, 2007). Currently, effort is focused on developing a deeper and more nuanced analysis of sustainability with the intention of understanding the nature of the concept and the relationship between its interacting components. Illustrations like the 'Diamond' (figure 2) have been created in order to further illuminate the concept as a matter of interdisciplinarity. The 'Diamond' shows the fundamental relationships between the three basic components and several other essential parameters in this more nuanced picture of sustainability.

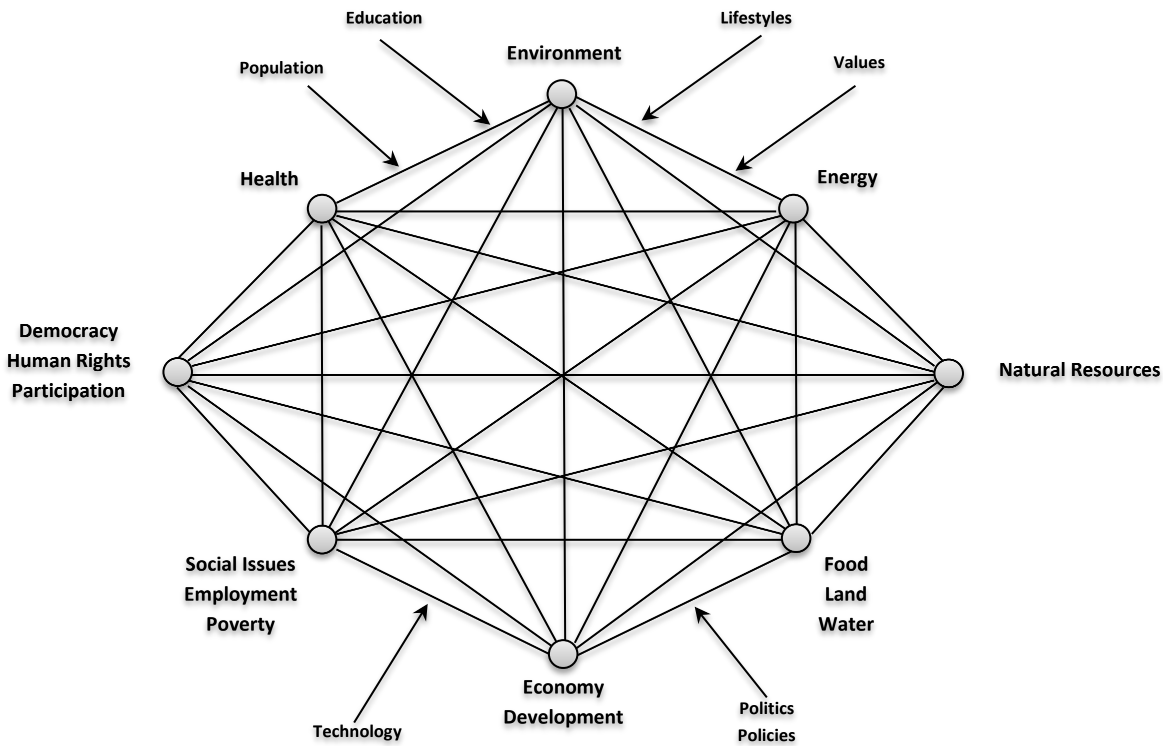

Figure 2. *The 'Diamond' showing the elements of sustainability (Kjellén, 2007).*

1.2.2. Sustainable Development – Dealing with Global Problems such as Climate Change and Resource Depletion

"Sustainable development seeks to reconcile environmental protection and development; it means nothing more than using resources no faster than they can regenerate themselves, and releasing pollutants to no greater extent than natural resources can assimilate them."

- Angela Merkel (Merkel, 2008)

Merkel (1998) refers to a condition where the human race is in harmony with nature and its natural systems, but at present this is a utopia. However, the huge and massive exploitation of the resources on Earth has laid the foundation for our modern and developed society. Wolfgang Sachs (1999) means that this era is therefore based on a "*robber economy*", in the sense that we are actually stealing the resources from Earth and using them faster than they are replenished. Modern society has large impact on nature and the timescale of modernity collides with the timescale that governs life and the earth, which the depletion of non-renewable resources is a clear example of. Our present consumption rate is unsustainable. According to WWF, humanity and its activities currently consumes resources at a rate equivalent to 1.5 planets (WWF, 2012). They argue that it is urgent to "*find ways to do more with less*". The overproduction of food that is being wasted instead of being consumed is indeed an unnecessary depletion of resources in general and a clear example of unsustainability.

Another example of colliding timescales is *global warming*. Human activities have resulted in an unbalance in the carbon cycle. There is no longer a natural equilibrium between the release of CO_2 into the atmosphere and the absorption of CO_2 through vegetation and oceans. More CO_2 is released into the atmosphere than what is absorbed, which results in an unnatural (*anthropogenic*) raise in global average temperature. Because of this, ecosystems and their species are not capable of adapting quickly enough to the changing living conditions.

The attempt to achieve sustainability brings us one step closer to a utopian situation in which we live in perfect harmony with our planet. All the same, sustainable development as such is not a fixed state of harmony (WECD, 1987), but rather a process of change where our efforts to develop still allow us to coexist with the natural environment in a way that does not compromise the needs of future generations. Sustainable development implies that every part of society and every human activity must be permeated by sustainability in order to overcome global problems such as climate change and resource depletion. Since food is vital for our survival and the food sector is such a large and important sector in the society it is necessary to integrate sustainability in the whole sector.

1.2.2.1. Anthropogenic Climate Change

Before the modern human civilization had begun to ascend, develop, and flourish, Earth's environment was in a particularly rare state of stability which had lasted for about ten thousand years: an era known as the *Holocene* (Rockström et al., 2009; Kjellén, 2007). The industrial revolution when fossil fuels first being used marked the beginning of the end of this period of environmental stability. Since then, human actions have triggered a global process which changes the climate throughout the world; since then, a new era, the *Anthropocene*, has begun (Rockström et al., 2009).

In 1988 the American atmospheric physicist James E. Hansen raised his voice and presented his views and theories about a changing climate and that it most likely was caused by humanity (The New York Times, 1988), a so called *anthropogenic climate change*. The same year that Hansen made the remarks, the UN agency IPCC (Intergovernmental Panel on Climate Change) was established as an international organization of climate scientists worldwide. The researchers' first task was to compile the causes and consequences of the climate change in an initial comprehensive evaluation, which was published in 1990 (IPCC, 2012). Since then, the debate around the world has been extensive, but most scientists currently agree that humans and their activities have most likely been the cause of the global warming that is observed on Earth (IPCC, 2007c).

There are several reasons to accept that it is man who causes the global warming, through his emissions and his land use (SEPA, 2007). Some reasons are our better understanding of the climate and its behavior; increased knowledge about the relationship between the atmospheric composition and the radiation balance; old and new measurements of temperature; sea level rising; and amounts of carbon dioxide in the atmosphere. Regarding the latter, the concentrations of carbon dioxide in the atmosphere has risen from 280 ppm (parts per million of the total air volume) before the industrialization (Eklund, 2009), to 391.8 ppm, at the present (NOAA, 2012). In other words, the amount of carbon dioxide in the atmosphere has increased by 40 percent since the beginning of the industrial era.

The effects of the global warming can already be observed. Since the temperature has started to rise, the glaciers have started to melt and retreat, weather patterns have been changing, extreme temperatures have been measured, more powerful tropical storms and severe droughts have occurred, and sea levels have begun to rise at a fast rate compared to the last few thousand years (Lynas, 2004). In addition, there are also a number of 'hidden threats' which could arise as a result of the more obvious effects due to the changing climate (Swain, 2012; Miller et al., 2009): economic crisis, food scarcity, population displacement, political conflicts, and social upheavals.

The emission of greenhouse gases have increased by 70 percent since the 1970s, and there is a risk that it will increase considerably more in the near future if there are no further incentives introduced, or if measures are not taken to reduce the human enhancement of the greenhouse effect (IPCC, 2007b). If no significant actions are taken to reduce the global emissions of greenhouse gases, climate scientists believe that the emissions will have increased by between 25 and 90 percent within two decades (IPCC, 2007a). In many countries, emissions have been reduced by environmental measures and work towards sustainable development. However, due to an ongoing industrialization in many developing countries, emissions are not reduced in a global perspective.

In order to prevent global warming from exceeding a limit of 2-3 degrees Celsius, the concentration of greenhouse gases (primarily CO_2) in the atmosphere must be stabilized in the relatively near future. For that to happen, the global emissions must peak within the next decade and then begin to decline. The effects of global warming have already had a significant impact on society as well as the ecosystems and if the warming continues, and the global average temperature increase with more than 3-4 degrees, there is an imminent risk that the consequences will become even more widespread and severe (Lynas, 2007) . Humanity faces a common problem, a problem that has been described as more and more urgent and whose consequences could be disastrous.

1.2.2.2. Depletion of Earth's Natural Resources

"Sustainable consumption is the use of goods and services to meet basic needs and to bring a better quality of life, while minimizing the use of natural resources, toxic materials and emissions of waste and pollution over the life-cycle, so as not to jeopardize the needs of future generations."

- ***Michael Carley and Philippe Spapens*** *(Carley et al., 1998)*

Some decades ago, a common belief was that the natural resources on our planet are more or less unlimited and that the natural systems are robust enough to absorb human waste mostly by itself (Stenmark, 2007; Gowdy, 1994). This worldview is, however, firmly outdated. The resources, i.e. Earth's natural capital, are not inexhaustible and some of them are also likely to run out in the nearest future (Miller et al., 2009; Stenmark, 2007). The new worldview is more about carful and efficient usage of resources. Nevertheless, as a result of a rapidly increasing population and a development towards greater welfare around the world, global consumption still increases and the resource depletion continues at an accelerating rate. We burden the natural systems and their functions to such a great extent that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted (Millennium Ecosystem Assessment, 2005). Present resource withdrawal exceeds the carrying capacity of nature, and a continued accelerating extraction of this proportion puts Earth's natural balance at risk, hence resulting in a potential system collapse (figure 3). An overexploitation like this endangers Earth's ability to meet the basic needs of future generations: therefore making such a development unsustainable.

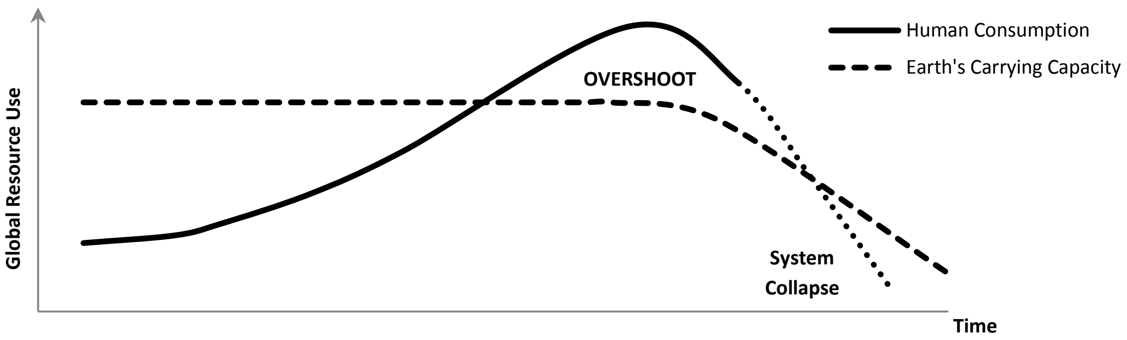

Figure 3. *Unsustainable development. Sustainability demands that society stays within the carrying capacity of Nature. It is estimated that the carrying capacity of the natural systems was exceeded around the 1970's.*

Carley and Spapens (1998) describe 'sustainable consumption' as resource use only to meet 'basic needs' and to bring a better quality of life while minimizing emissions of pollutants and waste production. They further argue that basic needs go hand in hand with 'necessary consumption', but that it is still very difficult to define necessary consumption and determine where overconsumption begins. However, humanity needs to limit its resource exploitation and diminish the losses of materials and energy throughout the life-cycle of goods and services in order to ensure a sustainable consumption pattern that take long-term sustainability into account.

1.3. Project Background

When food is produced, transported, stored, treated and processed in different ways it consumes a lot of resources and energy and causes large negative impact on the environment due to emissions of pollutants affecting waters, soil and air (Berlin, 2005). The impact differs during a product's life cycle. A simple classification of products is to divide them into two basic categories – *active products* and *passive products* – depending on whether the product needs an infusion of energy to operate (Hanssen, 1998). An active product like a car or a television needs energy to operate while a passive product like a chair or a food item does not. Hence, passive products mainly causes its environmental impact during the initial stages of the life cycle[3], while an active product mainly affects the environment during the industrial manufacturing and usage of the product (Angervall et al., 2008) As an illustration, the environmental impact from the life cycles of passive and active products is displayed in figure 4.

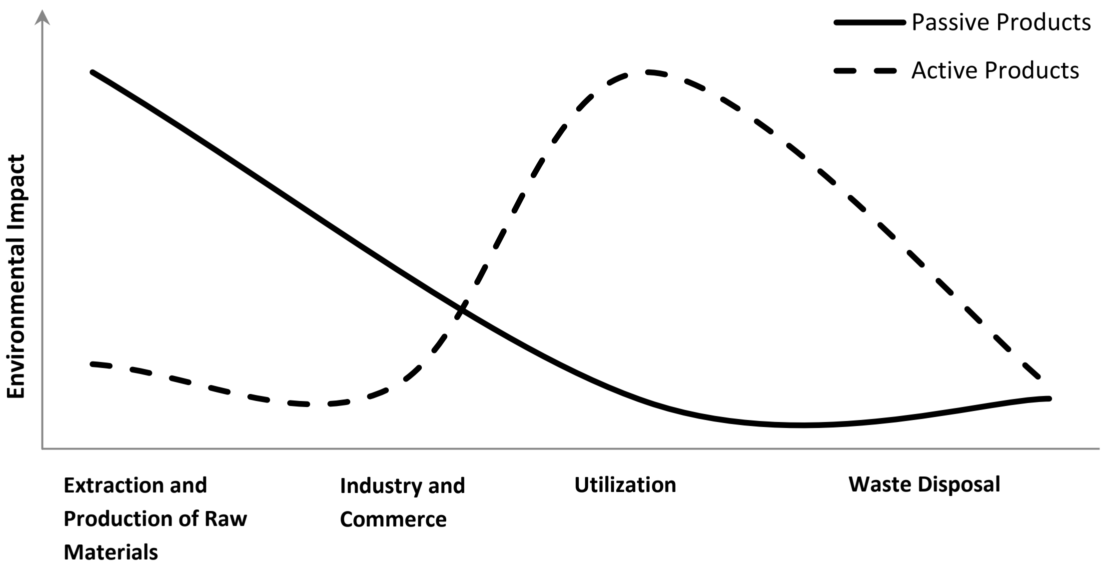

Figure 4*. The environmental impact from active and passive products from a life-cycle perspective (Angervall et al., 2008).*

A major part of the food produced globally originates from the agricultural sector, and according to IPCC (2007b) this business causes about 10-12 percent of the global emissions of greenhouse gases, thus having a significant contribution to the global warming. In Sweden, this sector accounts for an even larger share of the total emissions of such gases – 20-25 percent accordingly to Sonesson (2008) – making it one of Sweden's major contributors to climate change. This impact is mainly due to animal holding and the process of growing crops, and the most common emitted greenhouse gases are in this case methane and nitrous oxide (Ahlmén, 2002). One way to reduce the environmental impact discussed above is to reduce the food loss within the food supply chain (figure 5).

[3] i.e. extraction and processing of materials

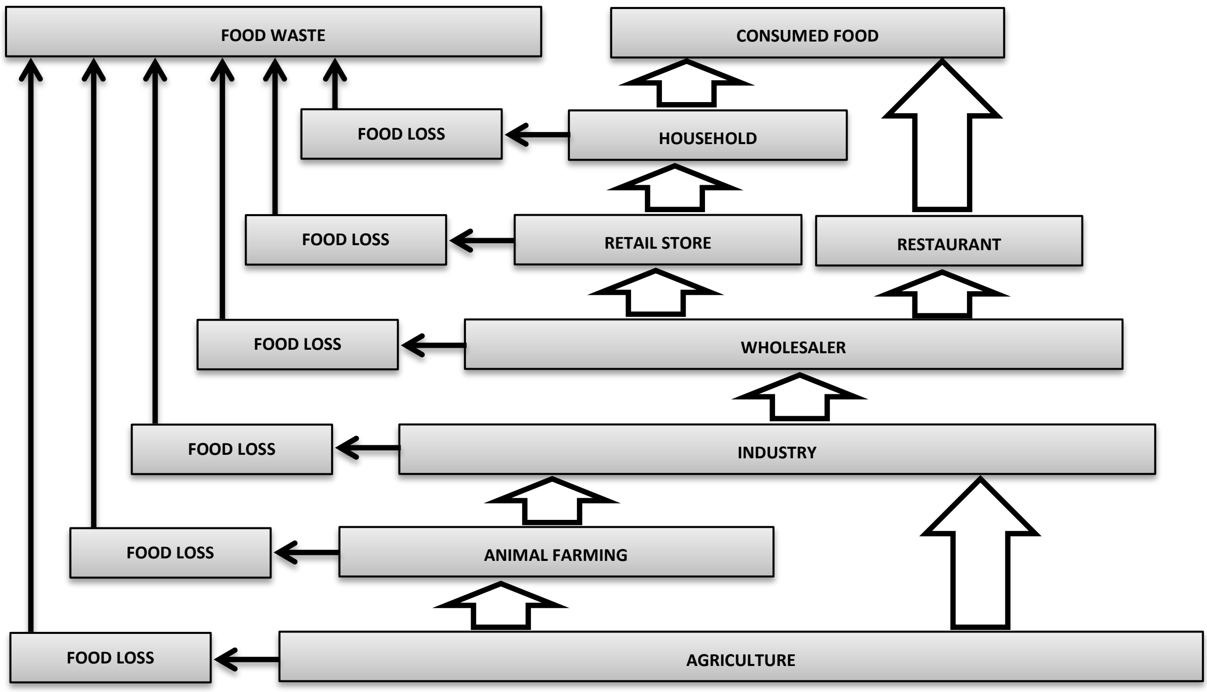

Figure 5. *The food supply chain displayed as a flowchart (Eriksson et al, 2011).*

Food loss has been defined as the proportion of the food waste that could have been used for consumption if it was handled in a different way (Andersson et al., 2011). Food is wasted at all levels of the chain; at some, losses occur to a greater extent than in others (FAO, 2011). If losses occur at a later stage within the chain, a greater number of sub-processes have been performed in vain, compared to if losses takes place in an early stage. Thus, the strain on nature and its natural capital becomes larger if losses take place later in the chain. Hence, measures would be of greater value if they are introduced at a later stage in the chain compared to if same measures were introduced in an earlier stage. The retail sector is one later level within the food supply chain where large amounts of food waste is piled up; amounts that could be regarded as fairly controllable compared to food waste at the household level. The food waste at the retail level is gathered on a single certain spot which makes it more manageable than food waste at the household level where it is far more scattered in smaller amounts at numerous of different locations.

1.3.1. The Flow of Goods in a Store

The products' path through a store mainly consists of three steps: delivery at the loading dock; passage through the store via store shelves; and out of the store through the sales counters. This path generates income and is therefore important to optimize and make as efficient as possible. The retailer and its employees determine the size of the incoming flow of goods, which usually are decided based upon predictions of potential sales; i.e. the amount of goods that are needed to satisfy the demand (Hernant et al., 2010).

However, there are a few divergent side paths which the goods unfortunately tend to enter, which results in food losses.

1.3.1.1. Different Categories of Food Loss within the Retail Sector

At the retail level, there are some different ways of which food can be lost or become waste. Eriksson et al. (2012) has divided the losses into four categories of waste essentially based upon how they are handled (figure 6).

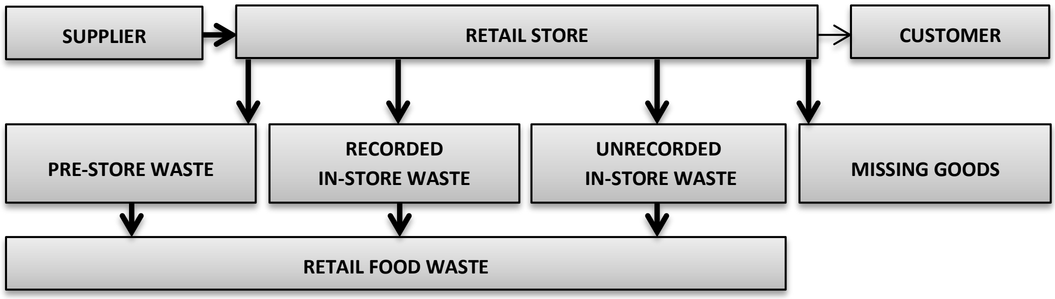

Figure 6. *Flow chart showing mass flows of food and the different categories of waste according to definitions made by Eriksson et al. (2012).*

Firstly there is *pre-store waste*, which basically is goods that are rejected by the store immediately at the loading dock, due to unsatisfactory quality. These rejected products are not paid for by the store. Eriksson et al. (2012) argue that this type of loss in theory belongs to the supplier delivering the certain goods, but is in reality handled as waste at the store. According to earlier studies made by Eriksson et al. (2011) this category of waste is fairly common in the section for fruit and vegetables and could amount up to approximately 6 percent of delivered quantities. The second category of waste is *recorded in-store waste*, which is food that is paid for, recorded as waste, and finally discarded by the retailer. The food ending up in this category is usually food items that have exceeded their best-before dates or items whose quality has been significantly reduced.

The third category determined by Eriksson et al. (2012) is *unrecorded in-store waste*, which simply are discarded food items that have not been recorded as waste. This may be due to errors in the process of recording in-store waste, where human mistakes or negligence generally are the main reasons. According to Eriksson et al. (2012) these types of losses normally occurs when the store's employees are about to record waste, and the actual quantity is wrongly recorded because of round ups or misjudged weight estimates. The last category of studied flows at the retail level is *missing quantities*, which includes food items that e.g. become stolen. For fresh fruits and vegetables 'missing quantities' essentially is likely to be due to evaporations (Eriksson et al., 2012).

1.3.2. Factors Affecting the Rate of Food Loss

As mentioned in the introduction, FAO has estimated the size of the food loss within the food supply chain to about one third of the edible portions of the food produced globally (FAO, 2011). This therefore indicates that a lot more food is produced than actually is consumed. The food loss is, however, primarily depending on fundamental factors in the society such as living standards, livelihood, consumption patterns and attitudes (Rytterstedt et al., 2008). These factors basically control the public demand of goods, and thus also the supply at retailers. In addition, the amount of food that is wasted at retailers also depends on several internal factors. One such factor is lack of planning which could lead to over-ordering and oversupplying (Åhnberg, 2010), and if the retailer cannot manage to sell everything that has been ordered the surpluses is discarded and registered as in-store waste.

Seasonality is also a factor that affects the food loss in the retail sector, since holidays and external happenings such as changing weather conditions could change the consumer's behavior (Alexander et al., 2008; Kantor et al., 1997). One of the most obvious such happenings are the barbeque season which in Sweden mainly occurs during the summer season. Christmas and eastern are two events that complicates the routines at the retailers since it is difficult to predict and specify the exact amount of goods that is required (Andersson et al., 2010; Eriksson et al., 2011). The fact that retailers does not want to run out of goods and always endeavors shelves that are fully loaded, makes the situation rather problematic since it may result in unsold surpluses that will be wasted. When the shelves are filled with new products, there is an imminent risk that the old products will be left over, since the customers tend to choose the newer ones. Today, goods are expected to be fresh and customers are probably afraid of buying products with a short time left to the *best-before date* and most likely avoid such ones. In order to get a good price, many suppliers demands that the retailer order and manage to sell many of their different goods (Rytterstedt et al., 2008). At the same time, customers expect the retailer to offer a wide range of different products and labels. These two aforementioned factors further complicate the retailer's situation since they more or less are forced to have a wide assortment of many diverse articles with many different brands and varieties of the same type of goods, preferably without having any food losses.

The most common reason that food is wasted at the retail level is an expired best-before date (Andersson et al., 2011). Ordering miscalculations; selling campaigns by competitors or the own store; customer's irregular purchasing pattern; and unfavorable product placement in the store, may be examples of underlying causes (Andersson et al., 2011).

With this background it is understandable that it is an important task to reduce the food losses in order to both reduce the environmental impact and the wastage of resources. The retailers are one level where there are economic incentives and also a great potential to reduce the overall food loss. Previous studies (Eriksson et al., 2011; Eriksson et al., 2012) show that large quantities of fresh fruit and vegetables and large proportion of meat are lost at the retail level. Thus, it might be possible to take measures to perform significant loss reductions in these two departments.

1.4. Significance of Project Topic

The importance of a sustainable development has been extensively addressed in the introduction of this paper. According to the Swedish Environmental Protection Agency (SEPA) a reduction of food loss within the food supply chain could facilitate society's quest to develop in a sustainable manner (Rytterstedt et al., 2008).

The SEPA further claims that various studies shows that the overall environmental impact during a life-cycle of food products are of great importance (Rytterstedt et al., 2008). The environmental impact from the food supply chain is currently increasing in a global perspective, essentially due to increased global food consumption in general. Factors that are of great significance for the food supply chain's environmental impact are enhanced import of exotic fruits and intensified meat consumption (Carlsson-Kanyama et al., 2003). Since the production and distribution of food, significantly contributes to the global warming, the food supply chain is vastly affected by the first national environmental quality objective in Sweden – *Reduced Climate Impact* (SEPA, 2011) – which seeks to diminish the climate impact caused by human activities. It is therefore important to identify sources of greenhouse gas emissions, to be able to reduce them. Thus, it seems highly relevant to analyze the effect of product-specific measures aiming at reducing food losses, in order to investigate their ability to ease the climate impact.

Furthermore, the European Union has given high priority to measures aiming at preventing or reducing waste production (European Commission, 2008). Thus, actions to reduce the loss of food within the food supply chain are highly prioritized and are of general concern.

The environmental impact from a single store might not cause a significant footprint in terms of the whole, but as the proverb says; '*many a little makes a mickle*'[4]. If a major part of the stores in a country manage to reduce the food loss thanks to certain measures, the overall effects from an environmental and economic perspective may be of great importance.

1.5. Scope

The following delimitations have been set within the framework of the project:

- The project will include a study of a specific grocery store in the Uppsala-Stockholm region, Sweden.
- The information used in the data analysis has already been collected by the grocery store and a researcher at the Swedish University of Agricultural Science.
- A data analysis will be performed based on data that extends two years into the past. The study will compare the store's food losses before and after the measures were introduced.
- A life-cycle assessment (LCA) of the type 'screening LCA' will be performed regarding the products concerned, instead of a full LCA.
- The investigation of the environmental impact will be limited to the contribution to global warming in terms of emitted greenhouse gases.
- The discarded products are assessed with respect to waste disposal.

[4] in Swedish: '*många bäckar små bildar stor å*'

2. METHODOLOGY

All methods used for solving complex problems are based on a simplified model of the problem situation (Liljenström, 2005). A simplification mean that certain information could have been left out, since it does not have any significant effects on the final results. This does not automatically imply that the quality of the results deteriorates. Despite ignorance of certain information, results can still be of enough quality to answer the research question (Rydh, 2002), which in this study are about the evaluation of two measures intended to reduce the food loss in a Swedish retail store and to examine if there are any possibilities to avoid unnecessary impact on the environment.

2.1. Choice of Waste Reducing Measures

A research project on food waste at the Swedish University of Agricultural Sciences has revealed that bananas and chicken are two products in grocery stores that have proven to be two areas of concern with regards to retail food waste. Bananas are one of the products discarded at greatest volumes within the department of fruits and vegetables and chicken is the most discarded product in terms of weight at the section of meat. The research project has been collaborating with a number of grocery stores in the region of Uppsala and Stockholm. Through interviews held with these stores, it appeared that one of the stores had already introduced measures to reduce the waste of bananas and chicken, since both products had been documented to be two particular problem areas. Because the grocery store had a need to get the measures and its effects analyzed, the measures were chosen as subjects for this study.

2.2. Interviews

Personal interviews were performed by phone with key workers at the grocery store in order to collect information about the introduced measures, and with responsible persons at different companies and facilities in order to gather data and information needed in the life-cycle assessment. The interviews were semi structured, meaning that they were very adaptable in a way that allows the interviewer to pilot the interview more spontaneously if needed, even though the questions have been decided in advance (Denscombe, 1998). Dynamism is an important factor in interviewing techniques according to Esaiasson (2007). Thus, in order to make the interviewee feel secure and motivated and understand that there is time to develop the response, questions were constructed in a manner that provided a sense of flow to the interview. The questions are listed in Appendix 1.

Personal interviews are considered to provide high validity since data and information could be controlled while the interview is carried through, so that possible mistakes or errors could be avoided or solved immediately (Denscombe, 1998).

2.3. Data Collection and Data Analysis of Retail Food Wastage

In order to investigate whether the introduced measures have resulted in reduced losses or not, data over delivered quantities and specific losses of grilled chicken and bananas have been collected. The data was mainly used to analyze and compare the losses of grilled chicken and bananas before and after the measures were introduced. The collection of specific food loss data needed in this study, have been performed by the grocery store itself in cooperation with researchers at the Swedish University of Agricultural Science (SLU). Quantities of deliveries and sales, and magnitude of pre-store waste and recorded in-store waste regarding chicken and bananas has been daily registered by the grocery store and the data extends two years into the past; the data has been recorded during 104 weeks from the first week of January 2010, until the last week of December 2011. The collected data applied for bulk sales and were expressed in kilograms. The numbers were used to calculate the relative loss; i.e. the wastage of the two products in relation to the quantity supplied.

Regarding fresh fruits and vegetables, Eriksson et al. (2012) show that pre-store waste is the largest food waste category: being three times as large as the amount of recorded in-store waste in relation to delivered quantities. Eriksson et al. (2011) argues that a store that presents low rates of food waste in terms of recorded in-store waste instead might have a higher rate of pre-store waste in the case of fruit and vegetables. Considering these facts and statements, this study examined the pre-store waste of bananas in order to determine its size and its possible impact on the introduced measure.

2.3.1. The Surveyed Grocery Store

The surveyed grocery store, which is located in the city of Uppsala, is owned and has been selected for the study by the Swedish retail company Willy:s AB. The store is classified as a low price market store, which is characterized by large volumes, high turnover, relatively few articles and external locations (Axfood, 2011). The low price sector accounts for approximately 11 percent of the Swedish food market (Axfood, 2011).

2.4. Life-Cycle Assessment (LCA)

The life cycle of a product describes a product's life, beginning with extraction of raw materials and energy from nature, and ends with material's reunification with the natural systems (figure 7). In brief, the life-cycle mainly consists of four stages; extraction of raw materials, manufacturing, usage, and waste management (Baumann et al., 2004). During these stages the product is treated differently in many diverse processes, usually and especially during the stage of manufacturing. All these processes involve large flows of materials and energy, and altogether there has most likely been a significant environmental impact.

Life-cycle assessment (LCA) is a method which essentially is used to assess the overall environmental impact during a product's entire life-cycle from cradle to grave (Baumann et al., 2004). To carry out an LCA is like performing a system analysis from an environmental point of view. The method implies investigation and understanding of how different elements are interrelated and influence each other in order to make it possible to tackle environmental problems from a holistic perspective (Rydh et al., 2002). Understanding the life cycle perspective provides a broader view that facilitates problem identification and definition, as well as problem solving. The implementation of life cycle assessments can provide decision support that result in avoiding problem relocation and sub-optimization[5]. LCA is a

[5] i.e. the performance of a single part of the system is improved but the performance of the system as a whole deteriorate

comprehensive analytical method with environmental focus, which may include all material and energy flows within the selected system boundaries. In order to make the life cycle assessment comprehensible, different levels of system boundaries (i.e. delimitations) must be decided. Boundary levels such as: delimitations in contrast to the natural systems, geographical delimitations, and delimitations in time (Rydh et al., 2002).

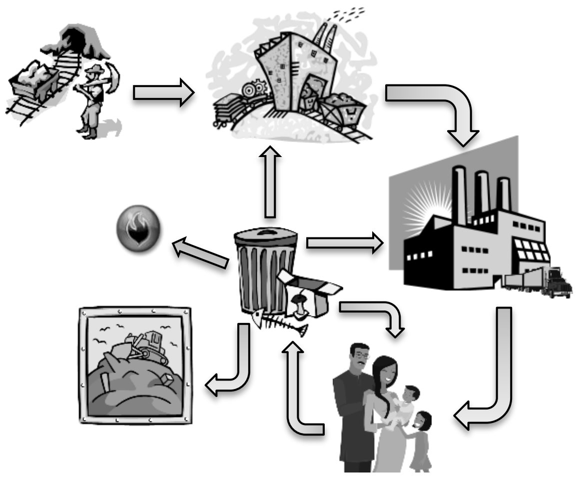

Figure 7. Illustration of a product's life-cycle, where the four main stages are: extraction of raw materials, manufacturing, usage, and waste

This study intended to examine how much extra environmental impact that has been avoided, due to the introduction of the product-specific measures aiming at reducing the food loss. The environmental impact was assessed as GWP (*global warming potential*). In order to evaluate the environmental effect of the measures introduced at the grocery store, life-cycle assessments were performed for each of the two products concerned: chicken and bananas. The LCAs performed were of the type *screening LCA*, which are conducted on a level containing fewer details compared to an ordinary LCA (Dantes, 2006). The assessments included all production steps contributing to climate change, from initial agricultural cultivation and extraction of raw materials to final waste management. In order to map the fundamental background stages between cradle and production gate in the product's life-cycles, findings from other LCAs (Cederberg, 2009; Widheden, 2001; Tynelius, 2008; Dole, 2012a) have been used. Distribution processes, store handling, and waste management processes have, however, been examined and mapped. Data on greenhouse gas emissions within the system boundaries were collected, characterized[6], and finally expressed as CO_2-equivalents emissions, in order to show its contribution to the climate impact.

2.4.1. Global Warming Potential (GWP)

Global Warming Potential is a metric enabling comparison of future climate impacts of long-lived greenhouse gases emitted into the atmosphere. The emission of 1 kg of a compound is related to 1 kg of the reference gas, CO_2, and expressed as kg CO_2-equivalents. The emissions of climate gases in this study were calculated according to characterization factors published in the latest IPCC report (IPCC, 2007c) (table 1).

Table 1. *Global Warming Potentials, GWPs, used in the study.*

Compound	GWP, time horizon 100 years
Carbon dioxide, CO_2	1
Methane, CH_4	25
Nitrous oxide, N_2O	298

[6] weighted according to potential contribution to global warming

2.5. SWOT-Analysis

SWOT-analyses were performed in order to determine the sustainability aspects of the introduced measures; i.e. to critically review the strengths and weaknesses of the measures and to more clearly identify eventual problems, opportunities, and possible threats. Systemic thinking is an important part in the concept of sustainability (Kjellén, 2007), which thus makes a SWOT-analysis to an appropriate analytical tool to manage the complex network of interrelationships within a system. The "Diamond" visualized in figure 2 has been used as a basic concept for systemic thinking when the SWOT-analyses were conducted in this study, in order to take as many factors as possible into consideration.

SWOT looks at *Strengths*, *Weaknesses*, *Opportunities*, and *Threats,* and is a strategic planning and evaluation method commonly used to evaluate businesses corporations, but also used widely to aid decision making in a range of organizational projects and planning connected to development (Hatch, 2006).

3. LIFE CYCLE INVENTORY

3.1. Life Cycle Assessment (LCA) of Grilled Chicken

3.1.1. System Modeling and Description

The system studied comprises all essential steps from cradle to grave in the product's life-cycle, starting at the rearing of the so called 'grandparents' and 'parents'. A grilled chicken basically undergoes six stages throughout its life-cycle: hatchery, rearing, slaughter and processing, distribution, refinement in retail store and finally consuming or waste management depending on if the product is sold or discarded at the retail store. These stages are also the basis for the LCA. In addition, a number of underlying processes related to these aforementioned stages are also taken into account. Transports and production of materials and energy are also included. An illustration of the studied system and its system boundaries is displayed in figure 8 and a more detailed description of the involved processes is made in table 2.

The life-cycle assessment on chicken meat made by Cederberg et al. (2009) has been used as a basis for the assessment made in this study. The assessment done by Cederberg et al. (2009) is of the type 'cradle to farm gate' and includes the two initial main stages of a chicken's life-cycle (breeding of ascendants and rearing of slaughter chickens) and the processes related to them: processes such as production of fodder and fertilizers.

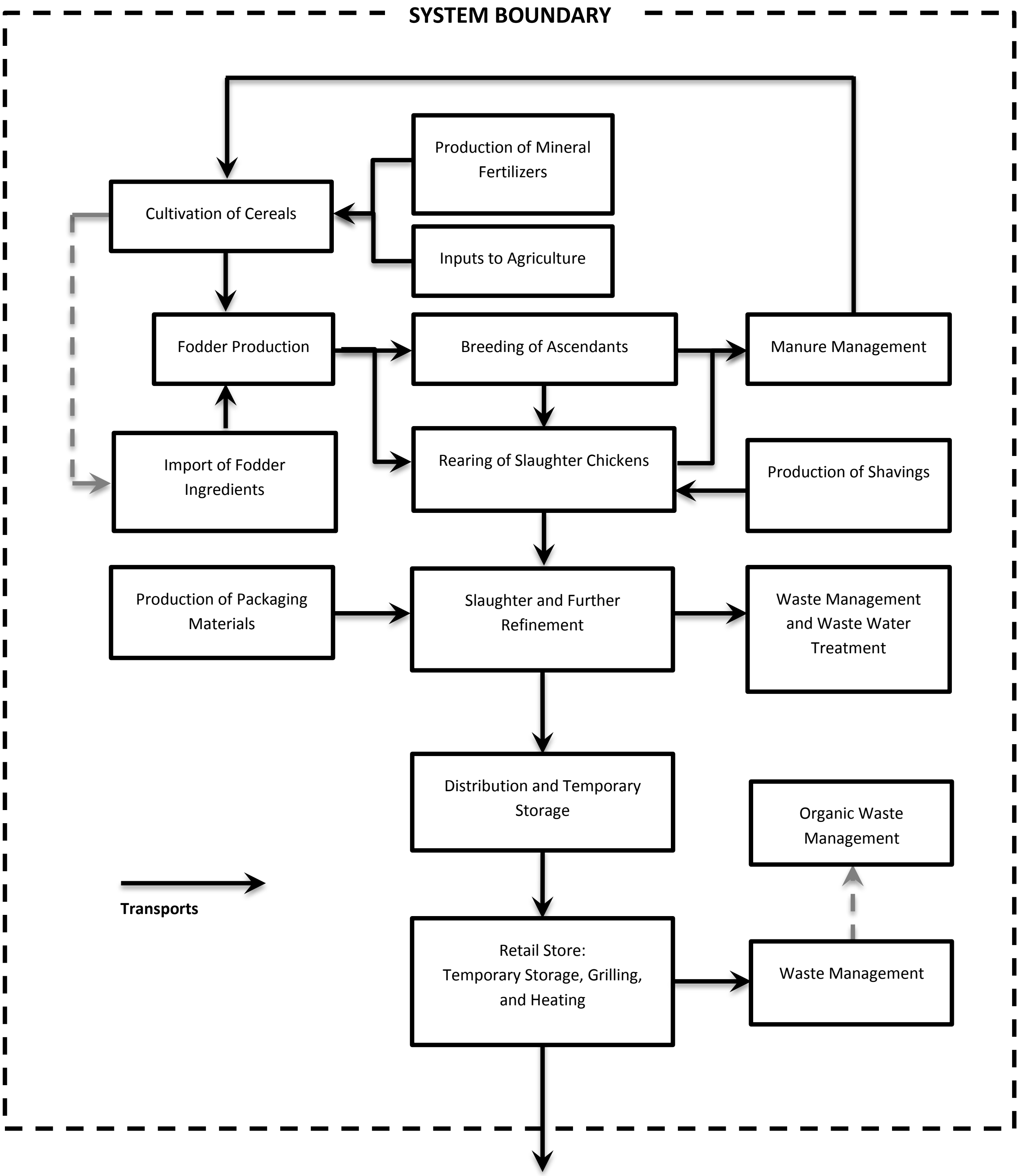

Figure 8. *The system studied*

Table 2. *The involved processes in the assessment*

Stage in the Life-cycle	Involved Processes
Breeding of Ascendants	• Rearing of first generation chickens (‘grandparents’), hatching and rearing of second generation chickens (‘parents’), and hatching of third generation chickens (slaughter chickens) • Production, transportation, and consumption of fodder • Manure management • Transportation of newly hatched slaughter chickens to a rearing farm
Rearing of Slaughter Chickens	• Rearing of slaughter chickens. • Production, transportation, and consumption of fodder • Manure management • Production and transportation of shavings • Transportation of slaughter chickens to the slaughter facility

Slaughter and Further Refinements	• Slaughter
	• Refinement
	• Energy consumption
	• Packaging material
	    o Production of materials
	    o Combustion and recycling of packaging materials
	    o Reduced need of energy production
	    o Reduced need of fiber production
	• Waste water treatment
	• Organic waste as raw material for new products
	    o Production of biogas
	    o Production of district heat
	    o Production of mineral fertilizer
	• Transport of chicken products to the wholesaler/logistic company

Distribution	• Short time storage in warehouse facilities o Energy consumption • Transportation between different warehouses • Transport of chicken products to retail store
The Retail Store	• Short storage in stockroom • Energy and heat consumption in the store • Energy consumption due to grilling and heating processes

Waste Management	• Transportation of food waste from retail store to waste management facility
	• Waste management
	    o Production of windrows
	    o Composting process
	    o Production of restoring soil

3.1.2. Delimitations

- Greenhouse gas emissions from the production of capital goods and infrastructure are not in included in this assessment.
- Land use change is a major source of greenhouse gas emissions worldwide; however, there is no consensus on methodology of how to make allocations between different land-based products. In addition, uncertainty and inadequate data are a common problem related to land use changes. Thus, emissions due to land use changes on national as well as on international level are excluded from this study.
- The environmental impact due to traveling of employees to and from place of work is not included in the assessment.
- Energy requirements for humans and animals providing transport services are excluded from the study.
- Climate impact from the production of pesticides is not included in the study.
- The utilization of waste management byproducts, i.e. compost soil, has been excluded from the study.

3.1.3. Functional Unit

The functional unit used in this study was '1 kg carcass weight' (CW): i.e. meat with bone.

3.1.4. Data Inventory

Breeding of Ascendants

Production and rearing of first and second generation chicken ('grandparents' and 'parents') and hatchery of third generation, i.e. the slaughter chicken, is done in one large facility in southern Sweden.

The initial stage of the life-cycle is breeding of ascendants, which begins with import of so called 'grandparents' to Sweden. This first generation of chickens is raised during 24 weeks and will afterwards produce eggs during the following 40 weeks (Widheden et al., 2001). These eggs hatches after three weeks and becomes the so called 'parents', who also are reared during 24 weeks before they start to produce eggs. The 'parents' produce eggs during 40 weeks and the slaughter chickens hatches after three weeks (Widheden et al., 2001). The newly hatched slaughter chickens are about one day old when they are transferred to a rearing farm somewhere in the southern half of Sweden (Widheden et al., 2001).

Rearing of Slaughter Chickens

Rearing farms usually raise seven batches of chickens per annum; every batch consisting of approximately 96 000 heads (Tynelius, 2008). The chickens are generally raised under suitable conditions with unlimited access to food and water during their 36 days on the rearing farm (Svensk Fågel, 2012) before being transported to the chicken meat producer for slaughter and further refinements.

Many rearing farms also have an internal production of cereals which partly is sold and partly used as fodder for the chicken production. Straw is a byproduct from the cereal production and it is used by many rearing farms as fuel for heating the stables and the ashes is returned to the fields afterwards (Widheden et al., 2001).

Fodder Production and Consumption

The ascendants and the slaughter chickens receive food composition that slightly differs depending on which part of the life cycle they are in (Widheden et al., 2001). Cederberg et al. (2009) estimated the total feed consumption per parent animal to 63 kg per head during the whole life-cycle. Cederberg et al. (2009) further estimated the feed consumption for slaughter chickens to 1.75 kg feed per kg live weight (including feed waste). The feed mainly consist of winter wheat mixed with concentrate feed comprising primarily of proteins (Brazilian soymeal) and some wheat from the feed industry. The ingredients used in fodder for slaughter chicken production is displayed in table 3. The composition shown in table 3 is a general composition of ingredients in fodder used for rearing of both ascendants and slaughter chickens. However, there are some differences between food given to slaughter chickens and food used for raising the ascendants. The most important fodder ingredient from an environmental point of view is soy meal, which normally is made out of soy beans cultivated in Brazil. The farming of soy beans usually occurs on land areas that have once been covered by tropical rain forests. When the forests have been cut down, a lot of carbon stored in the biomass and in the soil is released into the atmosphere, negatively affecting the environment through an enhanced global warming. According to Tynelius (2008) the soymeal content differs quite a lot; the fodder intended for slaughter chickens contains 20-30 percent soymeal while feed used to rear ascendants only consist of 5-15 percent soymeal. Instead, the latter feed composition has a larger share of barley and oats (Tynelius, 2008). According to *Lantmännen* a common fodder product normally used for non-commercial purposes contains 24 percent soymeal (Månsson, personal communication, 2012).

Table 3. *General composition of ingredients in fodder used for rearing slaughter chickens and their ascendants (Data from Cederberg et al. (2009).).*

Ingredient	Share (%)
Wheat	58.6
Soymeal	18.2
Grain Bran	4.3
Minerals	3.4
Peas/Horsebean	3.3
Rapeseed (whole and meal)	3.0
Barely	1.7
Oats	1.7
Others	5.8

Manure handling

According to Cederberg et al. (2009) the production of manure during a life-cycle was 1.09 kg per slaughter chicken and the dry matter content is generally between 60 and 70 percent. Methane and nitrous oxide emissions from manure management were calculated with emission factors according to recommendations from IPCC (2006).

Slaughter and Refinement

Lantmännen Kronfågel is Sweden's largest producer of chicken meat with a market share of about 50 percent (Kronfågel, 2012). In Sweden the company has one production facility, located in *Valla* in the county *Södermanland*. 46 rearing farms provide the company with chickens and approximately 38 million heads are slaughtered at the facility each year: which gives a production that amounts to about 55 million tons chicken meat per annum (Borg, personal communication, 2012). Kronfågel uses two sizes of chickens for slaughter at their facility: 1 650 gram and 2 325 gram (Borg, personal communication, 2012). The slaughter yield at the facility is 70 percent according to Borg (personal communication, 2012), at Kronfågel. The facility in *Valla* has an annual energy consumption of 23 197 MWh of electricity and 1 607 m^3 of heating oil (Borg, personal communication, 2012).

74 percent of the total production is fresh (refrigerated) products and the remaining 26 percent is frozen products. The amount of energy required in the freezing process has been subtracted from the total before allocating the energy consumption between fresh and frozen products. 23 percent of the total production is whole chickens that are going to be grilled in the retail stores (Borg, personal communication, 2012). The waste and residues created at the facility is used as byproducts to produce other products such as biogas, fertilizers, and district heat; giving a negative outcome that reduces the global warming potential from this life-cycle stage. The negative outcome per kilogram chicken meat is consistent with Tynelius (2008).

Distribution

Dagab is a logistic company owned by *Axfood AB*, and it is responsible for a major part of the distribution of goods within the corporate group. *Kronfågel* transport products to *Dagab*'s central warehouse in Jönköping where they are marshaled and then further distributed to retail stores all over the country.

An order is sent by the *Willys* store directly to Kronfågel in the morning (day one). Kronfågel handles it and transport the products from the facility in Valla to Jönköping where they arrive during the night. At lunchtime day two the goods are further transferred to Dagab's warehouse in Jordbro, Stockholm, where they are marshaled. In the morning at day three, the goods are transported to the retail store in Uppsala (Sörenssen, personal communication, 2012). The loss of chicken is assumed to be negligible during the distribution.

The warehouse in Jönköping consists of two sections. The section handling chicken products has a daily flow of about 12 000 parcels (Engblom, personal communication, 2012). Chicken products are the second most common article at the particular warehouse section and constitute 20-25 percent of the total amount of goods (Engblom, personal communication, 2012). The warehouse has a daily energy consumption of approximately 7 000 kWh (Engblom, personal communication, 2012).

The warehouse in Jordbro consists of three sections. The section handling chicken products has a daily flow of about 36 000 parcels (Lindén, personal communication, 2012). The warehouse has a daily energy consumption of approximately 8 500 kWh (Lindén, personal communication, 2012).

Transports

The *Network for Transport and Environment* (NTM) has a database that has been used in order to calculate the climate impact from the transports used in the life-cycle stages after the rearing of the slaughter chickens. Distances and transport data is presented in table 4 and table 5.

Table 4. *Transportation data – Type of transportation*

Type of Transport	Loading Capacity (tons)	Fuel Consumption (liter/(ton*km))	GWP (kg CO_2-eq/liter)	Refrigeration supplement (kWh/(ton*km))
Heavy Truck	15	0.03-0.04	2.9	0.05
Truck with Semi Trailer	40	0.012-0.02	2.9	0.05

Table 5. *Transport data – Distances and environmental impact*

Transport Objective	Route	Distance (km)	Type of Transportation	Loading Ratio (%)	g CO_2-eq/F.U.
Distribution from Kronfågel to Dagab's central warehouse	Valla – Jönköping	223	Heavy Truck	70	22.7
Distribution from Dagab's terminal in Jönköping to the terminal in Jordbro	Jönköping – Jordbro	341	Truck with Semi Trailer	85-100	42.4
Distribution from Dagab's terminal in Jordbro to the retail store	Jordbro – Uppsala	94	Truck with Semi Trailer	85-100	11.6
Transport of food waste from the retail store to the waste management facility	Uppsala – Högbytorp	51	Heavy Truck	70-100	5.2

The Retail Store

At the retail store, the studied chicken products are usually stored a couple of days in the stockroom before being grilled and hopefully sold (Manager of the meat section, personal communication, 2012). The chicken is grilled during 30 minutes and is then put into a heating cabinet in order to stay warm. If a grilled chicken have spent three hours in the heating cabinet without being sold it has to be discarded and treated as waste. The discarded grilled chicken products are thrown into a container for food waste.

The grill and the heating cabinet have an energy consumption that amounts to 19 kW per hour and 3 kW per hour respectively (The store manager, personal communication, 2012). The retail store's annual energy consumption is approximately 1 921 MWh (The store manager, personal communication, 2012).

The energy consumption has been allocated to the grilled chicken products with respect to its share of the store's gross revenue. The energy consumption of the grill and the heating cabinet has been subtracted from the total energy consumption and assigned to the grilled chicken.

Waste Management

The food waste from the store is picked up by *Ragn-Sells*, a company specialized on waste management and recycling. The food waste is composted in windrow composts at their facility in Högbytorp and the compost outcome is used internally as restoring soil in landfills. 1 ton organic waste is needed to produce 300-400 kg compost dirt (Gustavsson, personal communication, 2012). Because of constitutional restrictions, the compost dirt cannot be used for agricultural purposes such as fertilizers since it might contain potential contaminants from different meat products. Hence, the use of the compost soil has been excluded from the study.

Energy

Vattenfall is one of Sweden's largest producers of electricity and they got an energy mix consisting of: 53 percent renewable electricity (e.g. hydro power), 46.5 percent nuclear power, and 0.5 percent fossil power (Vattenfall, 2012). Their energy mix and data for emissions has been used in order to calculate the climate impact from the energy use occurring in the 'slaughter and refinement' stage and forward. According to *Vattenfall* (2012), 1 kWh of their electricity causes emissions of 9 grams CO_2 and 0.019 grams NO_x.

3.2. Life Cycle Assessment (LCA) of Bananas

3.2.1. System Modeling and Description

The assessment covers all essential steps from cradle to grave in the product's life-cycle, starting at extraction of raw materials and production of inputs. A banana mainly undergoes seven stages throughout its life-cycle: farming, processing, shipping, ripening, distribution, exposure in retail store, and finally consumption or waste management depending on if the banana is sold or discarded at the retail store. In addition, the assessment also comprises a number of underlying processes related to these aforementioned stages; processes such as transports and production of materials and energy.

This life-cycle assessment is based on a study made by *Dole* which examines the carbon footprint from bananas cultivated on Dole farms in Costa-Rica. Dole's study is of the type 'cradle to gate' and includes all stages in the life-cycle except from the user phase and waste management of the bananas (Dole, 2012a). This assessment uses Dole's study and its results up to and including the ripening process. The subsequent stages in the life-cycle, i.e. distribution and exposure in retail store, correspond to German conditions in the original study but are in this assessment modified for Swedish conditions. Unlike Dole's study, this assessment takes waste management into account.

An illustration of the studied system and its system boundaries is displayed in figure 9 and a more detailed description of the involved processes is made in table 6.

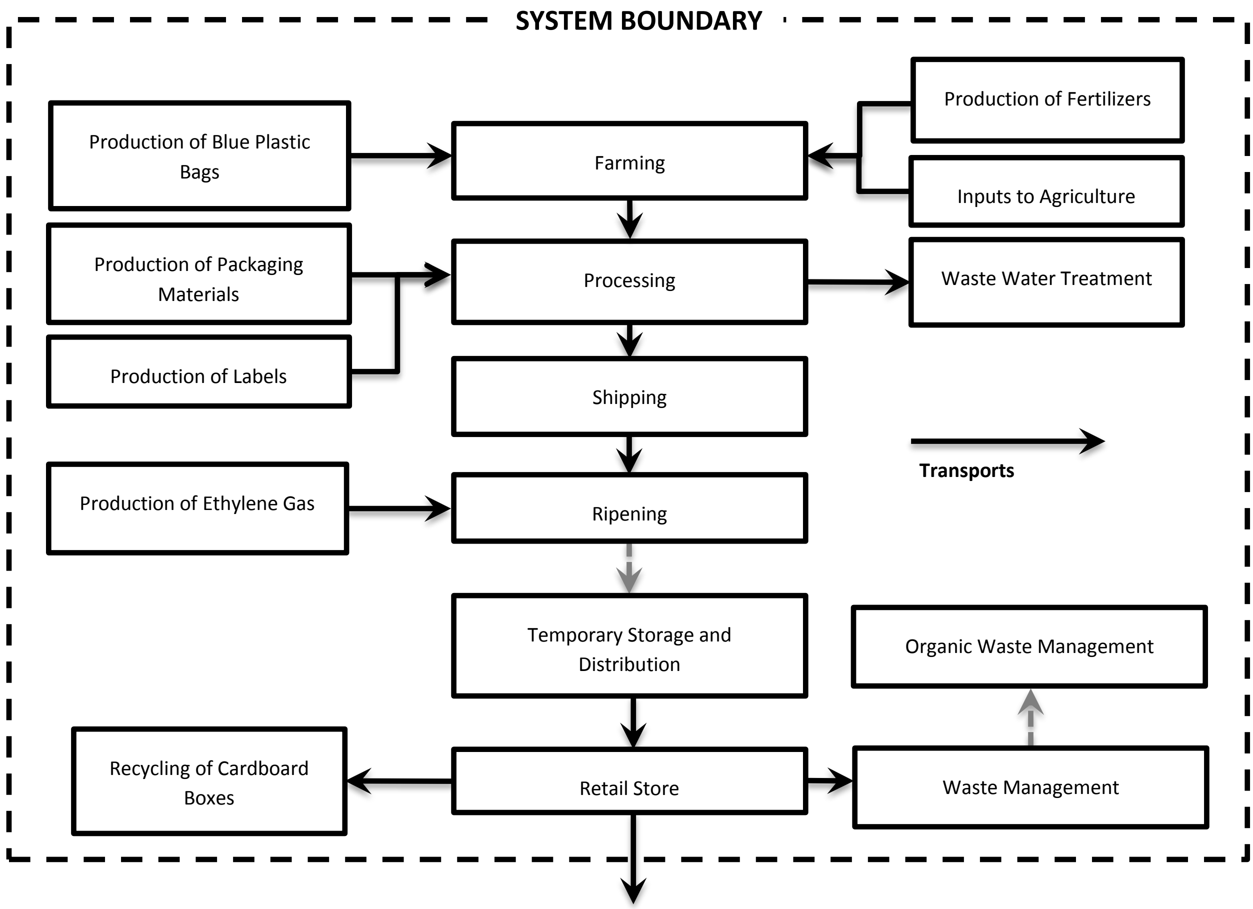

Figure 9. *The system studied*

Table 6. *The involved processes in the assessment*

Stage in the Life-cycle	Involved Processes
Farming	• Production, transportation, and usage of fertilizers • Production and transportation of blue plastic bags • Soil emissions • Usage of fossil fuels and electricity due to usage of tractors and other machinery and equipment
Processing	• Production and transportation of packaging materials • Loading of containers • Transports to port terminal • Waste water treatment
Shipping	• Refrigerated storage at port terminals • Operations at port terminals • Oversea transportation o Refrigerated storage in cargo holds
Ripening	• Transportation from port terminal to central warehouse • Ripening process • Short time storage in warehouse facilities
Distribution	• Transport of bananas to retail store
The Retail Store	• Energy and heat consumption in the store

Waste Management	• Transportation of food waste from retail store to waste management facility
	• Waste management
	  o Production of windrows
	  o Composting process
	  o Production of restoring soil
	• Transport of cardboard boxes to a paper mill in Trondheim, Norway, via Stockholm.
	• Recycling of cardboard boxes

3.2.2. Delimitations

- Greenhouse gas emissions from the production of capital goods and infrastructure are not in included in this assessment.
- Land use change is a major source of greenhouse gas emissions worldwide; however, there is no consensus on methodology of how to make allocations between different land-based products. In addition, uncertainty and inadequate data are a common problem related to land use changes. Thus, emissions due to land use changes are excluded from this study.
- The environmental impact due to traveling of employees to and from place of work is not included in the assessment.
- Energy requirements for humans and animals providing transport services are excluded from the study.
- The assessment includes production in Costa-Rica, overseas transportation and distribution in Sweden.

- The utilization of waste management byproducts, i.e. compost soil, has been excluded from the study.

3.2.3. Functional Unit

The functional unit used in this study was ‘1 kg bananas with peel’.

3.2.4. Data Inventory

Farming

Bananas are cultivated on large plantations in equatorial areas such as Costa-Rica. The banana plant is considered as a perennial herb even though it looks quite similar to a palm tree (NE, 2012). The plant essentially consists of two parts: one underground growing stem and one apparent stem (often regarded as a ‘shoot’) (Banana.com, 2012) that grows above the ground surface. The shoot ends with the banana bunch which normally carries up to 200 bananas (NE, 2012). After each period of carrying fruits the plant dies back or is partly cut down whereupon it starts to produce a new ‘shoot’ for the next generation of bananas.

Fertilizers are used during the cultivation, and the work on the plantation is eased by using tractors and other kinds of machinery and equipment. The banana bunches are covered by blue plastic bags used for pest mitigation or in order to prevent birds and dust from reaching the fruits (Dole, 2012b). The bananas are harvested while they still are green.

Processing

When the bananas are harvested they are washed and divided into smaller bunches suitable for market sales. The bananas then undergo a series of systematically performed procedures where they are sorted, labeled and thoroughly packed in cardboard boxes before being loaded into refrigerated containers that are transported to the port terminal (Dole, 2012b).

Shipping

The bananas are transferred to *Puerto Moín’s* port terminal on the east coast. The refrigerated containers are connected to an electric power source at the terminal in order to maintain the cold climate in the containers, thus delaying the ripening process of the bananas. When a cargo ship from Europe arrives, it is loaded with containers. The oversea transportation takes about 10-12 days and during the voyage the containers are kept in refrigerated cargo holds of the ship at a temperature of 13.3 degrees Celsius (Kotrell, personal communication, 2012). The transatlantic transportation ends up in the Swedish city Helsingborg (Kotrell, personal communication, 2012). Once in Sweden the containers containing bananas are unloaded from the cargo ship and placed in a cargo area at the port terminal. To keep the bananas cold and further delay the ripening process, the containers are once again connected to an electric power source (Kotrell, personal communication, 2012).

Ripening

Saba is a wholesaler of fruit and vegetables and is an affiliated company in the *Dole* group. Saba provides *Willys* with fresh fruits and vegetables and has its central warehouse about four kilometers from the port terminal in Helsingborg (Graneskog, personal communication, 2012). The warehouse consists of different sections with different temperatures and has one large ‘ripening facility’ for bananas; a storage room with space for up to 40 000 cardboard boxes with bananas (Graneskog, personal communication, 2012).

The containers stored at the port terminal are picked up by Saba and transferred to the warehouse where the bananas are loaded into the ripening facility. By increasing the temperature to approximately 16 degrees Celsius (Graneskog, personal communication, 2012) the ripening process is initiated; a process that continues for about 6-10 days (Dole, 2012b). The ripening process is accelerated by adding of ethylene gas (Graneskog, personal communication, 2012).

When the ripening is completed the bananas are relocated to another storage room that is refrigerated, where the specific orders are made ready for delivery.

Distribution

The bananas are transported from Helsingborg to the retail store in Uppsala without interruption. The transportation is done by trucks using semitrailers.

Exposure in Retail Store

After arriving to the retail store, the bananas are handled by the employees and exposed to the customers by being put up on a display table.

The retail store's annual energy consumption is approximately 1 921 MWh (The store manager, personal communication, 2012). The energy consumption has been allocated to the bananas with respect to its share of the store's gross revenue.

Bananas that is not sold due to crushing and compression damages and to deteriorated visual attractiveness are discarded and treated like waste by being thrown into a container for food waste (Manager of the fruit and vegetables section, personal communication 2012).

Waste Management

The food waste from the store is picked up by *Ragn-Sells*, a company specialized on waste management and recycling. The food waste is composted in windrow composts at their facility in Högbytorp and the compost outcome is used internally as restoring soil in landfills. 1 ton organic waste is needed to produce 300-400 kg compost dirt (Gustavsson, personal communication, 2012). Because of constitutional restrictions, the compost dirt cannot be used for agricultural purposes such as fertilizers since it might contain potential contaminants from different meat products. Hence, the use of the compost soil has been excluded from the study.

The cardboard boxes are recycled in order to produce new cardboard material (The store manager, personal communication, 2012). The cardboard boxes are picked up at the retail store and transferred to *Returpapperscentralen* in Uppsala where they are compressed into a larger bulk together with other cardboard material (Pettersson, personal communication, 2012). The cardboard bulks are transported to *Hans Andersson Recycling* in Stockholm where they are marshaled and loaded onto a train for transport to a paper mill in the Norwegian city Trondheim (Carlström, personal communication, 2012).

Energy

Vattenfall is one of Sweden's largest producers of electricity; having an energy mix consisting of: 53 percent renewable electricity (e.g. hydro power), 46.5 percent nuclear power, and 0.5 percent fossil power (Vattenfall, 2012). Their energy mix and data for emissions has been used in order to calculate the climate impact from the energy use occurring in the distribution stage and forward. According to *Vattenfall* (2012), 1 kWh of their electricity causes emissions of 9 grams CO_2 and 0.019 grams NO_x.

Transports

The *Network for Transport and Environment* (NTM) has a database containing information about transport alternatives and related emissions. This database has been used in order to calculate the climate impact from the transports used in the life-cycle stages after arriving in Sweden. Distances and transport data is presented in table 7, table 8 and table 9.

Table 7. *Transportation data – Type of transportation: Truck (Source: NTM, no date; Bruce et al., 1997)*

Type of Transport	Loading Capacity (tons)	Fuel Consumption (liter/(ton*km))	GWP (kg CO_2-eq/liter)	Refrigeration supplement (kWh/(ton*km))
Heavy Truck	15	0.03-0.04	2.9	0.05
Truck with Semi Trailer	40	0.012-0.02	2.9	0.05

Table 8. *Transportation data – Type of transportation: Electric train (Source: NTM, no date)*

Type of Transportation	Emissions (kg CO_2/(ton*km)	Emissions (g NO_x/(ton*km)	GWP (kg CO_2-eq/(ton*km)
Electric train, bulk, EU	< 0.01	0.03	< 0.01

Table 9. *Transport data – Distances and environmental impact*

Transport Objective	Route	Distance (km)	Type of Transportation	Loading Ratio (%)	g CO_2-eq/F.U.
Transport from port terminal in Helsingborg to central warehouse	Port terminal – Central Warehouse	4	Heavy Truck	100	0.4
Distribution from Saba's central warehouse to retail store.	Helsingborg – Uppsala	623	Truck with Semi Trailer	85-100	77.3
Transport of food waste from the retail store to the waste management facility	Uppsala – Högbytorp	51	Heavy Truck	70-100	5.2
Transport of cardboard boxes from the retail store to Hans Andersson Recycling via Returpapperscentralen.	Uppsala – Stockholm	73	Heavy Truck	85-100	3.4
Transport from Hans Andersson Recycling to a paper mill in Trondheim, Norway.	Stockholm – Trondheim	781	Electric train	100	0.2

4. RESULTS

4.1. Description of the two Product-specific Measures Introduced with Purpose to Reduce the Food Loss

4.1.1. Grilled Chicken – Sale of Grilled Chicken to a Reduced Price

Chicken is the most discarded product, in terms of weight, at the section of meat according to recorded data from the retail store. The store buys whole pre-marinated chickens and pre-marinated chicken drumsticks and grills them in the store in order to be able to sell recently grilled chicken to the customers. The employees usually turn on the grill in the morning and the first grilled chickens are ready for sale at 9 a.m. During the day the employees ensure that grilled chicken always is ready for sale; more or less meaning that new chickens periodically are being prepared in the grill. The grilling process takes about half an hour and when it is finished the chickens are placed in a heating cabinet to stay warm. The grill and the heating cabinet are displayed in figure 10. According to the manager of the meat section (personal communication, 2012) the store sell about 16-24 grilled chickens a typical day.

Figure 10. *The grill*
To the right; the heating cabinet
Photo by Herman Nilsson

Within two hours after the grilling process is completed there is in theory a possibility to cool the newly grilled chicken and sell them as cold grilled chicken the upcoming day. Unfortunately, the surveyed store cannot do this due to a lack of time and certain equipment. Thus, a lot of unsold grilled chickens had to be discarded during the day. In order to reduce the daily loss of chicken a measure was introduced in the beginning of 2011: a measure based on price reduction. At the end of the day, the workers turn off the grill about one hour before closing time and then start to sell out the remaining chickens that have been grilled after 6 p.m. to half price. The measure only implies a slightly change in the daily routines as the employees have to mark the remaining unsold chickens with a new price at the end of the day. However, this change in routines does not require a significant effort according to the manager of the meat section (personal communication, 2012). The manager of the meat section also says that the exact date for introducing the measure is not known, but she argues that it must have happened in the first months of 2011.

4.1.2. Bananas – A New Display table for Better Exposure and Product Handling

Bananas are a product which stands for a relatively high rate of loss in the section for fruit and vegetables according to recorded data from the grocery store. The losses are mainly due to crushing and compression damages and to deteriorated visual attractiveness; the latter due to color change towards a brown nuance or appearance of dark spots. The store had a desire to reduce the losses, improve the exposure, and to optimize the handling routines regarding the bananas. Of a coincident, the store became aware of a solution that could satisfy their needs; a new type of display table allowing better exposure of the bananas and facilitated handling procedures. The new way of putting up bananas should also result in reduced losses.

The solution consisted of a new kind of display table, shown in figure 11. The old table was similar to an ordinary flat table, and the bananas were stacked on top of each other in a single pile directly on the table, after first having been removed from their original cardboard boxes. The new table is actually not a ‘table’, but rather a construction where the employees place the original cardboard boxes next to each other in a sloping angel. This variant of lay-up implies a better exposure towards the customers, as they get the experience that the bananas ‘stretch towards them’. The construction allows eight boxes of ordinary bananas to be placed – four in high and two in width – and the employees then takes the content from three more boxes and stacks them on top of the other bananas in the boxes already placed, for it to look more attractive. In addition, four more boxes of ecological/fair trade bananas could be placed next to the ordinary bananas.

Figure 11. *The new display table for bananas*
Photo by Herman Nilsson

The bananas are well-packed in their boxes at the beginning; usually not more than two clusters on top of each other. If one more cluster then is put on top of them at ‘the table’, it is commonly not more than three stacked clusters. At the old display table, 4-6 clusters usually were stacked and the bananas did not have any protection in terms of boxes, which often caused a lot of crushing damages and compression damages since they were moved around a lot by the customers. Since the bananas now are left untouched in their original boxes, most of the aforementioned damages are prevented.

The new display table has also led to new procedures in the handling process. In the past, the old table had to be refilled five times a day. Each time all bananas had to be removed from their boxes and stacked directly on the table; a rather time consuming procedure. The new table must be refilled three times a day, which implies the replacement of eight boxes. The bananas left in the old boxes are then put on top of the new ones. According to the manager of the fruit and vegetables section (personal communication, 2012) the new routines save a lot of time and effort each day. The manager also says that he is uncertain of the exact timing of the measure's introduction but claims that it happened sometime in the beginning of April 2011.

4.2. Results of the Food Waste Analysis

The retail store daily register data on sales and eventual losses. Data on delivered quantities and losses of bananas and grilled chicken during the period 2010-2011 was collected and analyzed. The overall results are presented in the following sections.

4.2.1. Loss of Grilled Chicken in the Retail Store

The collected data were examined in order to map the weekly losses of grilled chicken and how they vary during the period. The delivered quantity and the losses differ from week to week, but the weekly average was calculated to 167 kg delivered amount and 15 kg losses which equals to a weekly loss proportion of 9 percent. The standard deviation was calculated to 5.73 percent. Pre-store waste does not occur in the case of chicken meat that is going to be grilled at the retail store.

How the losses vary during the studied period is displayed in figure 12. Due to the uncertainties about the timing for the introduction of the measure, a probable estimation has been made. The estimated period for the introduction of the measure has been marked in the figure.

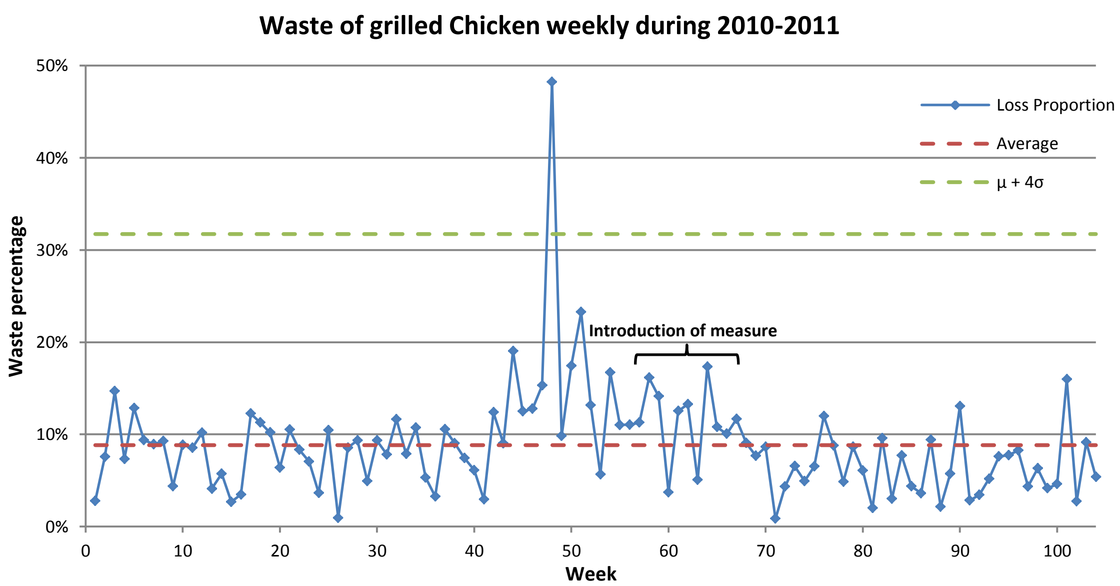

Figure 12. *Waste of grilled chicken weekly during 2010-2011*

The figure show that the losses generally have declined after the measure was introduced. There is an anomaly occurring in week 48. It is a value that is far outside the range of four standard deviations. In a case where the values are normally distributed, 99.73 percent of the values should fall within the range of three standard deviations and 99.99 percent of the values should fall within the range of four standard deviations. Thus, the found anomaly could not be considered as a normal random error or variation and must therefore most likely be due to an obvious mistake in the daily routines. This anomaly is further discussed in section 5.1.2.

In order to investigate if there is a significant difference between the loss proportions before and after the measure was introduced two *one-way ANOVAs* (Analysis of Variance) was conducted; one including the extreme value outside three standard deviations and one excluding that value. The tests are displayed in figure 13 and 14.

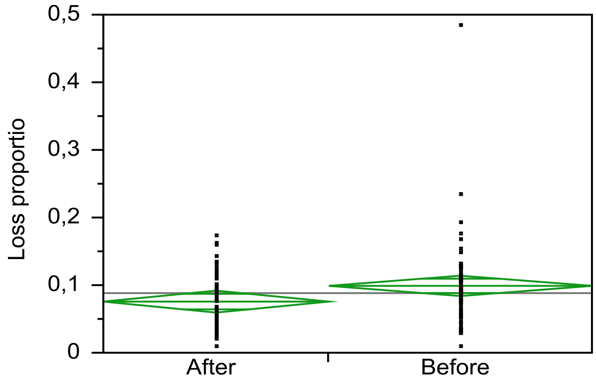

Figure 13*. One-way ANOVA of loss proportions before and after the measure was introduced: including the extreme value outside three standard deviations*

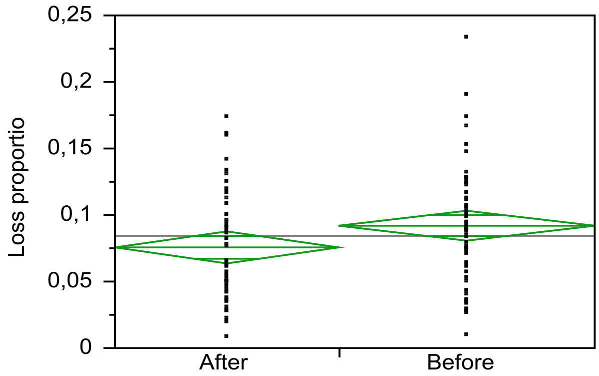

Figure 14. *One-way ANOVA of loss proportions before and after the measure was introduced: excluding the extreme value outside three standard deviations*

The first *one-way ANOVA* including the extreme value resulted in a P-value (*probability*) of 0.0393, showing that there is an approximately 96 percent probability that the loss proportion differs before and after the measure was introduced. With a 95 percent confidence level it thus means that the difference is significant. However, the *one-way ANOVA* excluding the extreme value resulted in a P-value of 0.0521which implies that the loss proportions differs with a 94.8 percent probability and with a 95 percent confidence level the difference is not significant. Nevertheless, the probability is almost 95 percent and if the confidence level is lowered to 90 percent, the difference should be significant. The extreme value will therefore be included in this study and the difference will be regarded as significant, because it actually is an existing value and it does not matter if it is excluded or not since there anyhow is a difference that most likely could be regarded as significant.

4.2.2. Loss of Bananas in the Retail Store

The collected data were examined in order to map the weekly losses of bananas and how they vary during the period. The delivered quantity and the losses differ from week to week, but the weekly average was calculated to 2 350 kg delivered amount and 15.8 kg losses which equals to a weekly loss proportion of 0.670 percent. The standard deviation was calculated to 1.02 percent.

How the losses vary during the studied period is displayed in figure 15. Due to the uncertainties about the timing for the introduction of the measure, a probable estimation has been made. The estimated period for the introduction of the measure has been marked in the figure.

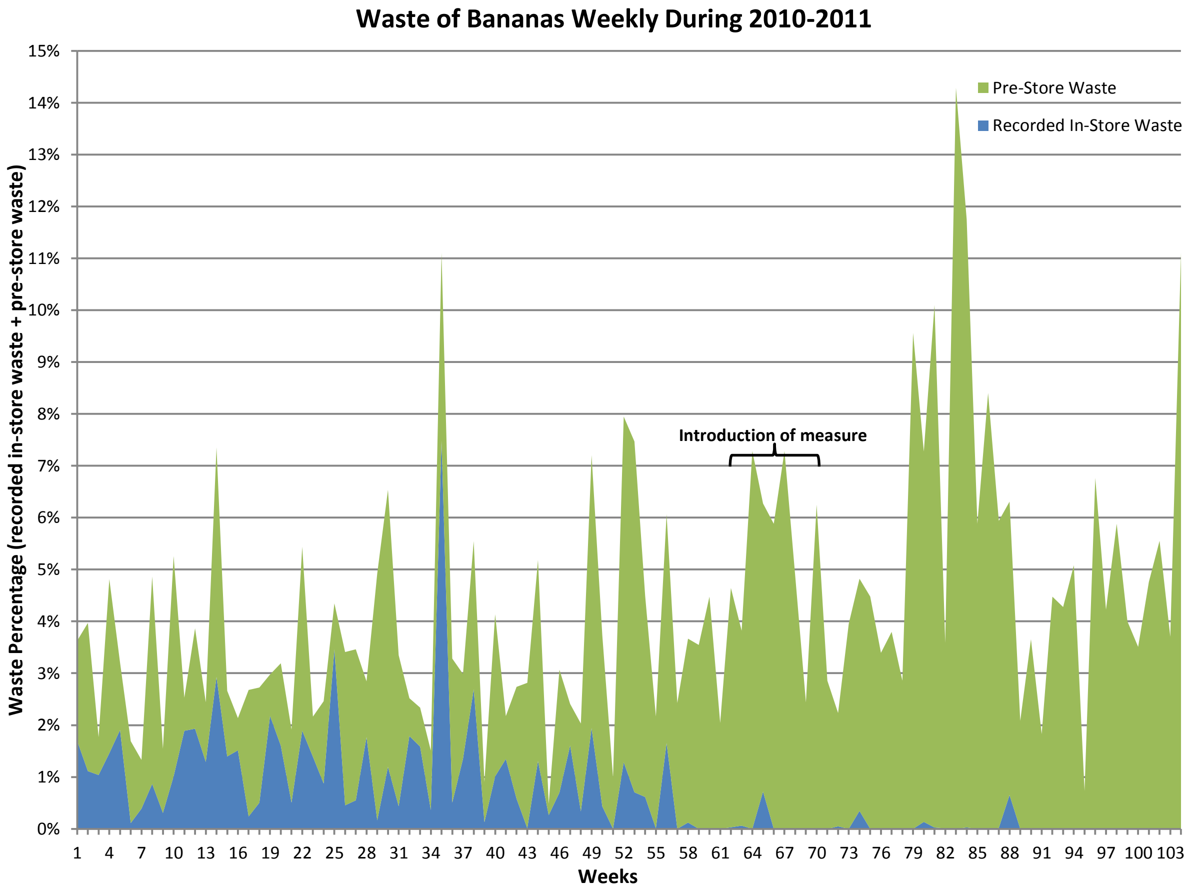

Figure 15. *Waste of bananas weekly during 2010-2011*

The figure show that the amount of recorded in-store waste has more or less ceased after the measure was introduced. Nevertheless, if the manager of the fruit and vegetables section was correct in his interpretation of the time for the measure's introduction (see section 4.1.2.), the figure also indicate that losses already had declined to a minimum, even before the measure was introduced. At the same time, the amount of pre-store waste started to increase in the end of 2010. The weekly average of pre-store waste has more than doubled during 2011 (see table 10). As shown in figure 15, the data analysis reveals that the total wastage of bananas each week is higher during 2011 than during 2010, mostly due to an increased amount of pre-store waste.

Table 10. *Loss of bananas - average numbers - registered pre-store waste data.*

Year	Delivered Quantities (kg/week)	Pre-Store Waste (kg/week)	Loss Proportion (%)	SD (%)
2010-2011	2 350	85.4	3.64	2.56
2010	2 440	53.0	2.17	1.45
2011	2 260	118	5.22	2.64

A *one-way ANOVA* (Analysis of Variance) was conducted to investigate if there is a significant difference between the loss proportions before and after the measure was introduced. The result is visualized in figure 16.

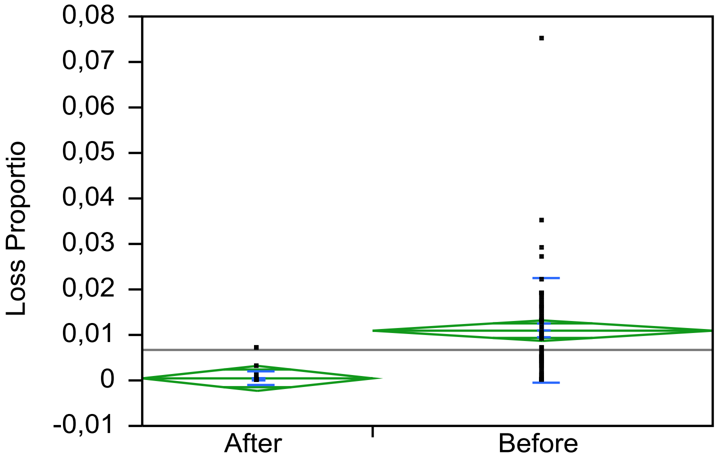

Figure 16. *One-way ANOVA of loss proportions before and after the measure was introduced*

The *one-way ANOVA* resulted in a P-value (*probability*) of 0.00001, showing that the loss proportion almost certainly (with 99.99999 percent probability) differs before and after the measure was introduced. The difference could thus be regarded as significant.

4.2.3. Outcome of the Introduced Measures

Further analysis of the losses before and after the measures were introduced had to be done in order to evaluate the measures more thoroughly: the results are presented in table 11 and 12.

Table 11*. Grilled chicken – Comparison of delivered quantities and losses before and after the measures was introduced*

	GRILLED CHICKEN	Delivered Quantities (kg)	Recorded In-Store Waste (kg)	Loss Proportion (%)
Before measure was introduced	Total during studied period	9 470	954	10.1
	Weekly average	169	17.0	
	Annual results based on weekly average	8 800	886	
After measure was introduced	Total during studied period	7 860	607	7.72
	Weekly average	164	12.6	
	Annual results based on weekly average	8 520	657	

Table 12. *Bananas – Comparison of delivered quantities and losses before and after the measures was introduced*

	BANANAS	Delivered Quantities (kg)	Recorded In-Store Waste (kg)	Loss Proportion (%)
Before measure was introduced	Total during studied period	150 700	1 593	1.06
	Weekly average	2 431	25.69	
	Annual results based on weekly average	126 400	1 335	
After measure was introduced	Total during studied period	86 300	46.0	0.05
	Weekly average	2 050	1.10	
	Annual results based on weekly average	107 000	57.0	

The comparisons made in table 11 and 12 indicate that the introduced measures in both cases have resulted in reduced amounts of waste. The loss proportion of grilled chicken has declined approximately two percentages from about 10 percent to below 8 percent which corresponds to a 20 percent decrease while the loss proportion of bananas have dropped to a minimum: from 1 percent to less than 0.05 percent which is corresponding to a 96 percent decrease.

The annual savings (in terms of reduced losses) that is possible to make by using the measures had to be estimated so that the potentially reduced environmental impact could be determined at a later stage. The estimated savings due to introduced measures are presented in table 13 and table 14.

Table 13. *Grilled chicken – Annual savings due to introduced measure. The recorded in-store waste has been calculated based on annual average delivered quantities*

GRILLED CHICKEN	Average Delivered Quantities (kg)	Recorded In-Store Waste (kg)	Annual savings due to introduced measure (kg)
Before measure was introduced	8 660	872	
After measure was introduced		668	204

Table 14. *Bananas – Annual savings due to introduced measure. The recorded in-store waste has been calculated based on annual average delivered quantities*

BANANAS	Average Delivered Quantities (kg)	Recorded In-Store Waste (kg)	Annual savings due to introduced measure (kg)
Before measure was introduced	121 000	1 280	
After measure was introduced		59.0	1 220

The figures in table 13 and 14 show that around 200 kg of chicken and roughly 1 200 kg of bananas could be saved from going to waste each year as a result of the introduced measures.

4.3. Results of the Life-Cycle Assessments (LCA)

4.3.1. Global Warming Potential (GWP) of the Studied Grilled Chicken

The life-cycle assessment showed that the climate impact from 1 kg of grilled chicken was slightly 2.1 kg CO_2-equivalents. The climate impact from the different life-cycle stages examined in this study is visualized in figure 17. The results in absolute numbers could be found in Appendix 2.

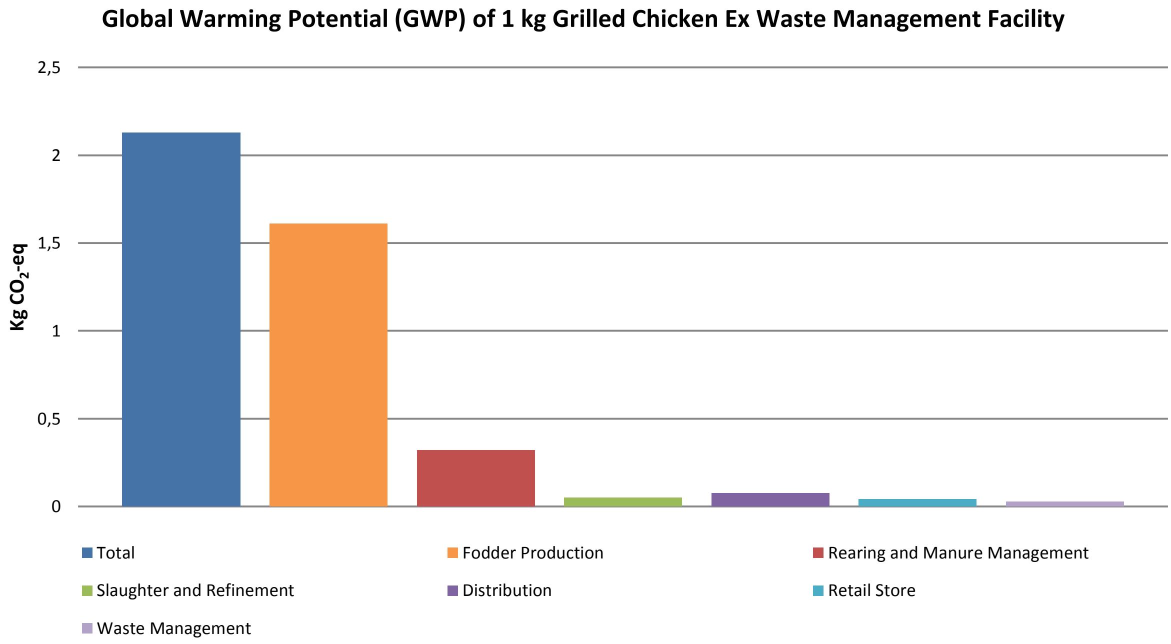

Figure 17. *Global Warming Potential (GWP) of 1 kg grilled chicken*

The fodder production had the largest climate impact and accounted for 1.61 kg CO2-equivalents, i.e. more than three thirds of the total. Rearing and manure management had the second largest impact with 15 percent of the total. The other life-cycle stages had just a smaller contribution to the total GWP, which is showed in figure 18.

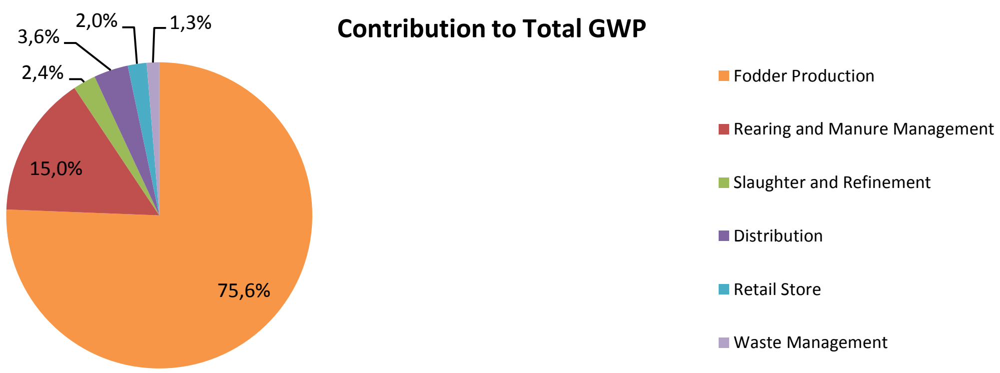

Figure 18. *The different life-cycle stages' contribution to the total global warming potential (GWP)*

The whole environmental burden caused by the grilled chickens and their life-cycle must be carried by the grilled chickens that actually are being sold; i.e. the environmental burden from products that are discarded must in theory be added to the products that are being sold, thus exiting the retail in the proper way. Figure 19 displays the 'real' climate impact caused by 1 kg grilled chicken exiting the store through the sales counters. The figure contains three bars; one showing the impact value attained in the LCA (cradle to grave of 1 kg discarded grilled chicken), and two bars showing the impact ex retail, before and after the measures was introduced.

Figure 19. *Comparison of the GWP of 1 kg grilled chicken ex retail before and after the measure was introduced*

Figure 19 shows that the GWP per kg grilled chicken has decreased a little bit after the measure was introduced. However, if the climate burden from all grilled chickens that are being wasted annually is added together and the impact caused by those chickens is separated from the impact caused only by the chickens that actually are being sold, the effect of the measure is much easier to visualize (figure 20).

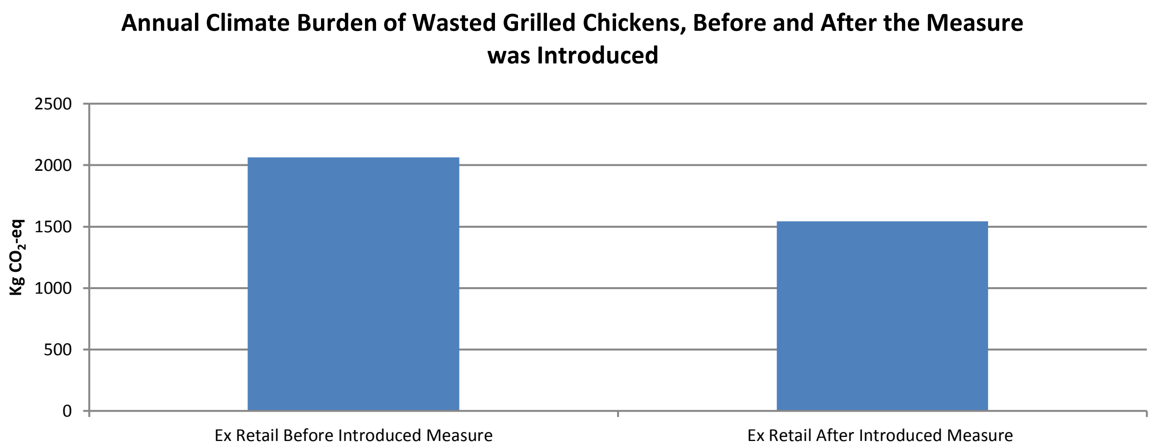

Figure 20. *Comparison of the annual climate burden caused by the wasted grilled chickens before and after the measure was introduced.*

The climate impact showed in figure 20 could be regarded as 'an extra burden' because it in theory should be added to those chickens that are being bought by customers.

4.3.2. Global Warming Potential (GWP) of the Studied Bananas

The life-cycle assessment showed that the climate impact from 1 kg bananas was a1most 1.2 kg CO_2-equivalents. The climate impact from the different life-cycle stages examined in this study is visualized in figure 21. The results in absolute numbers could be found in Appendix 2.

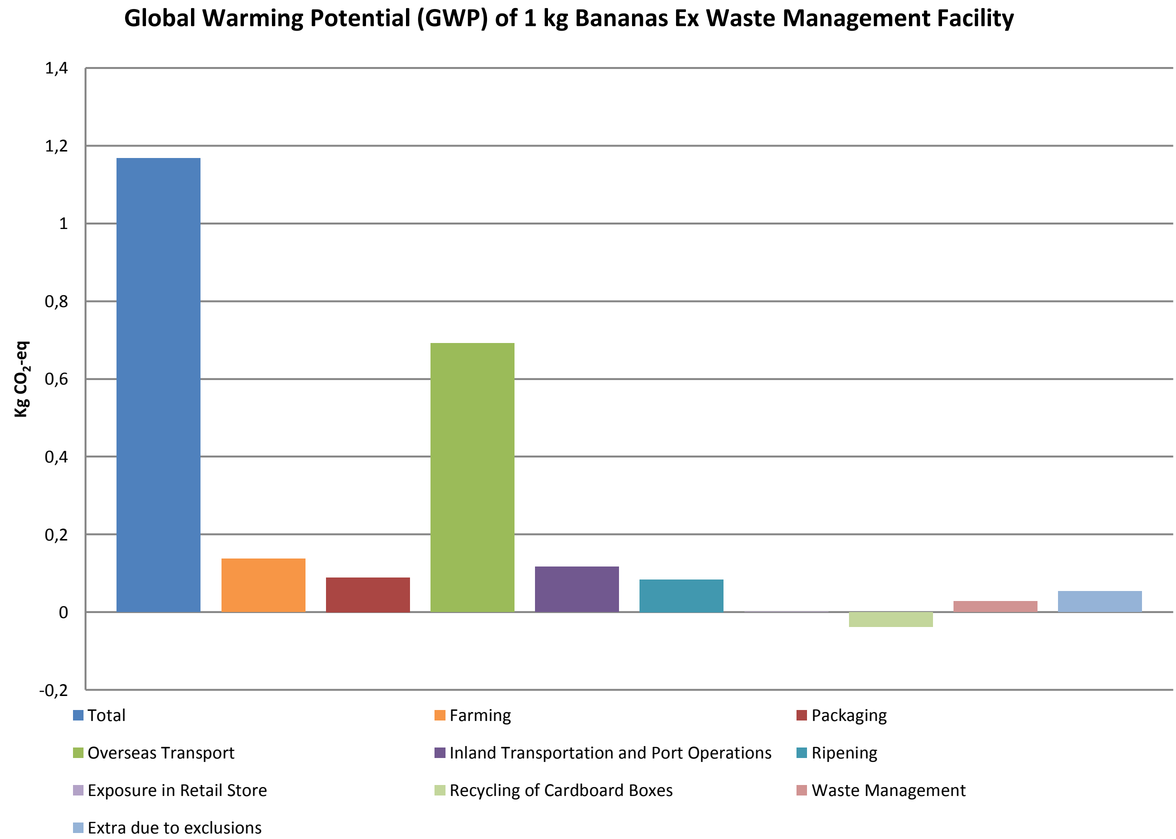

Figure 21. *Global Warming Potential (GWP) of 1 kg bananas*

The transatlantic transportation had the largest climate impact and accounted for 0.69 kg CO2-equivalents, i.e. more than half of the total. Farming, packaging, inland transportations, and ripening all had approximately the same impact: about 10 percent each of the total GWP; which can be seen in figure 22.

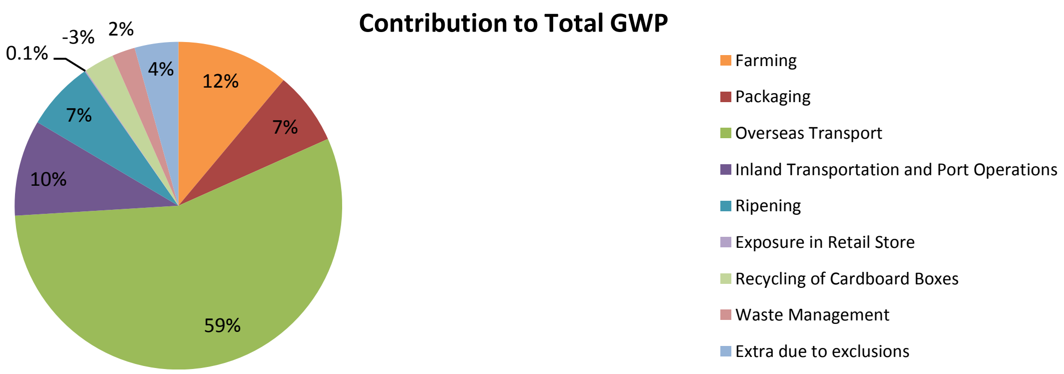

Figure 22. *The different life-cycle stages' contribution to the total global warming potential (GWP)*

As in the case with grilled chicken, the whole environmental burden caused by the bananas and their life-cycle must be carried by the bananas that actually are being sold. The GWP per kg banana is displayed in figure 23. The first bar shows the impact value attained in the LCA (cradle to grave of 1 kg discarded bananas).

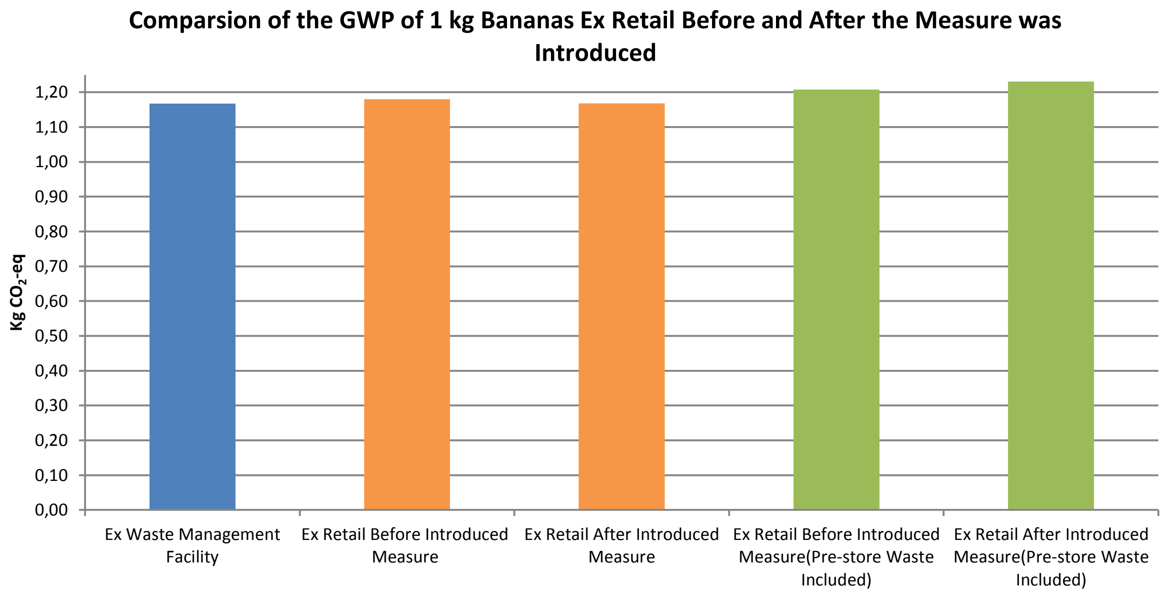

Figure 23. *Comparison of the GWP of 1 kg bananas ex retail before and after the measure was introduced*

Figure 23 show that the measure slightly has reduced the GWP of one kg bananas exiting the grocery store through the sales counters. However, if the climate burden from the pre-store waste also is included, the GWP for 1 kg bananas being sold is instead increased. As been stated earlier, the amount of pre-store waste started to increase about the same time as the measure was introduced. Consequently, the GWP of one kg bananas leaving the retail through the sales counters has thus increased. The annual implication of this is visualized in figure 24, which displays the difference of the climate burden caused by the discarded bananas, before and after the time period when the measure was introduced.

Figure 24. *Comparison of the annual climate burden of the discarded bananas before and after the measure was introduced*

4.3.3. Annual Environmental Savings in Terms of Avoided Climate Impact

The final outcome from the introduced measures and the results of the life-cycle assessment are used in order to determine the size of the unnecessary climate impact that is annually avoided due to reduced losses of food at the studied retail store. The climate impact that is avoided is presented in table 15.

Table 15. *Annual environmental savings due to introduced measures*

Product	Reduced Losses per Year (kg)	Climate Impact (kg CO_2-eq/kg)	Climate Impact that is Annually Avoided (kg CO_2-eq)
Grilled Chicken	204.0	2.129	434.3
Bananas	1 200	1.167	1 400

The measures introduced entails that 1 400 and 434 kg CO2-equivalents are avoided each annum due to reduced losses of bananas and grilled chicken.

4.3.4. Sensitivity Analyses

4.3.4.1. Climate Impact from Land Use Changes in Production of Brazilian Soy Meal

Land use change is a major source of greenhouse gas emissions worldwide; especially in regions where tropical rainforests are cut down and replaced by farmland. Brazil is a large producer of soy products such as soymeal and most areas where soybeans are cultivated have originally been covered by rainforests. A rather large part (around 20 percent; see section 3.1.4.) of the poultry fodder consists of Brazilian soymeal and climate impact from land use change should hence be a consequence of fodder production. However, as mentioned earlier there is no consensus on methodology of how to include environmental impact from land use changes and handle necessary allocations between different land-based products. In addition, uncertainty and inadequate data are a common problem related to land use changes. As stated in section 3.1.2, climate impact caused by land use changes is therefore excluded from the life-cycle assessment of grilled chicken. Nevertheless, a sensitivity analysis have been made in order to analyze how the global warming potential is affected if climate impact due to land use changes are added to the life-cycle assessment. Values from the *ecoinvent unit process* in the LCA-software *SimaPro* have been used as default value for addition of climate impact from land use changes in soymeal production. The results are visualized in figure 25.

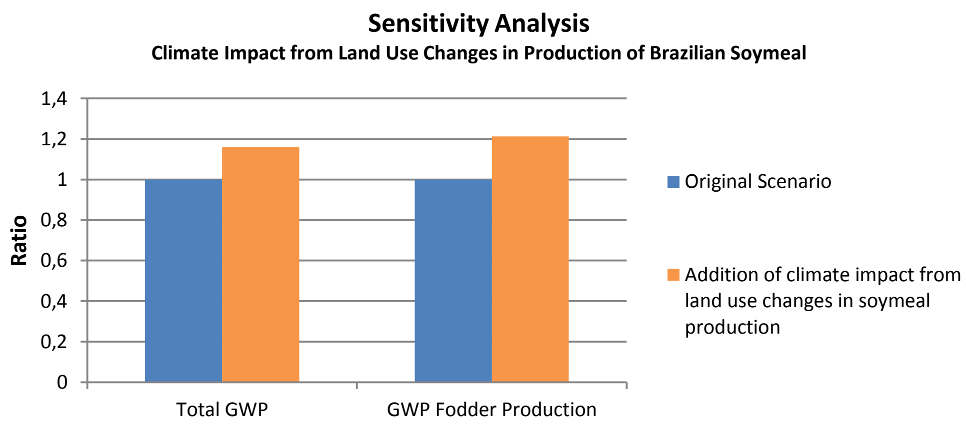

Figure 25. *Sensitivity analysis of the life-cycle assessment of the studied grilled chicken*

The sensitivity analysis showed that the total GWP and the GWP of fodder production is affected considerably if emissions due to land use changes also are taken into account. The GWP of fodder production increased with a little bit more than twenty percent which implies a 16 percent increase of the total GWP. The climate impact caused by land use changes can thus be regarded as an important factor when determining the carbon footprint of products containing ingredients cultivated on land that once has been covered by tropical rainforests.

4.3.4.2. Banana Farming on Iceland Results in a Shorter Overseas Transport

Banana farming occurs in Iceland despite the cold environment (Klose, 2010; Gardner et al., 2009). Geothermal energy can be utilized to heat up the greenhouses and increase the humidity by placing greenhouses over geysers, thus creating a rather tropical climate indoors; making it possible to grow bananas and other tropical fruits. At present, an Icelandic banana production is most likely not commercially viable. However, if bananas from Iceland could be imported to the European continent, the transport distances at sea could be reduced and some emissions of greenhouse gases could almost certainly be avoided.

A scenario where bananas are produced in Iceland has been examined in the performed life-cycle assessment in order to investigate how the total GWP of one kg bananas is affected by a shorter overseas transport. The results are visualized in figure 26.

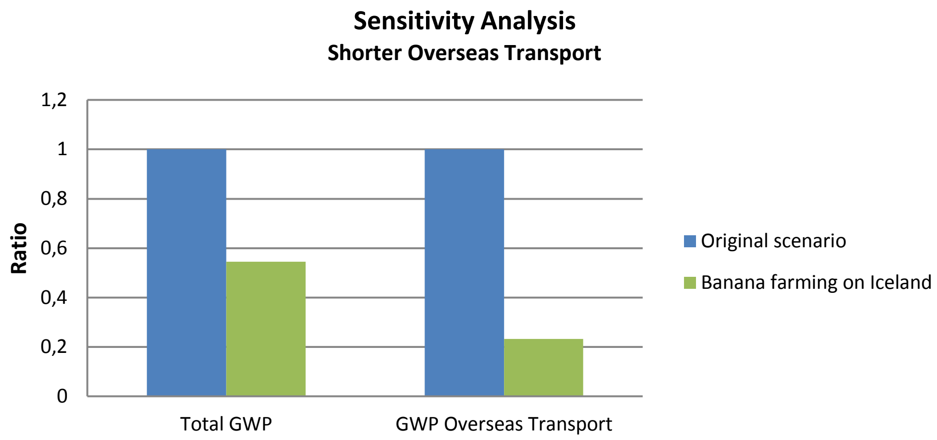

Figure 26. *Sensitivity analysis of the life-cycle assessment of the studied bananas*

The outcome of the sensitivity analysis showed that the climate impact from the overseas transport dropped 77 percent. In total, the GWP for 1 kg bananas from the studied system declined with almost 46 percent; clearly showing the significance of transatlantic transports' environmental impact.

4.4. SWOT-Analyses

To critically analyze the two introduced measures, SWOT analyses have been conducted. This was done to evaluate if the measures suffered from any hidden weaknesses or threats that would make them infeasible or inappropriate as solutions to the problem of food wastage. It was also done to point out certain strengths and possible opportunities. The SWOT analysis displayed in figure 27 and 28 identifies and summarizes current strengths and weaknesses, and future opportunities and threats, for the two product specific measures intended to reduce the food loss.

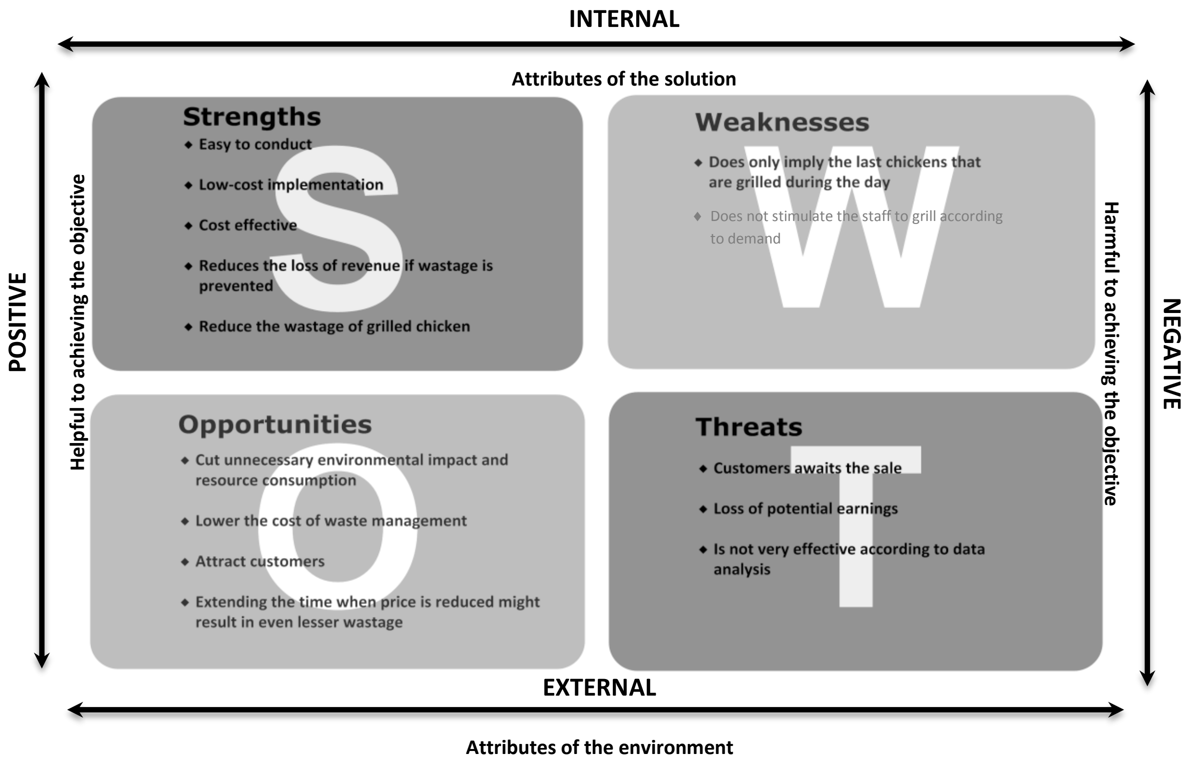

Figure 27. *SWOT-analysis of the measure where grilled chicken is sold to a reduced price*

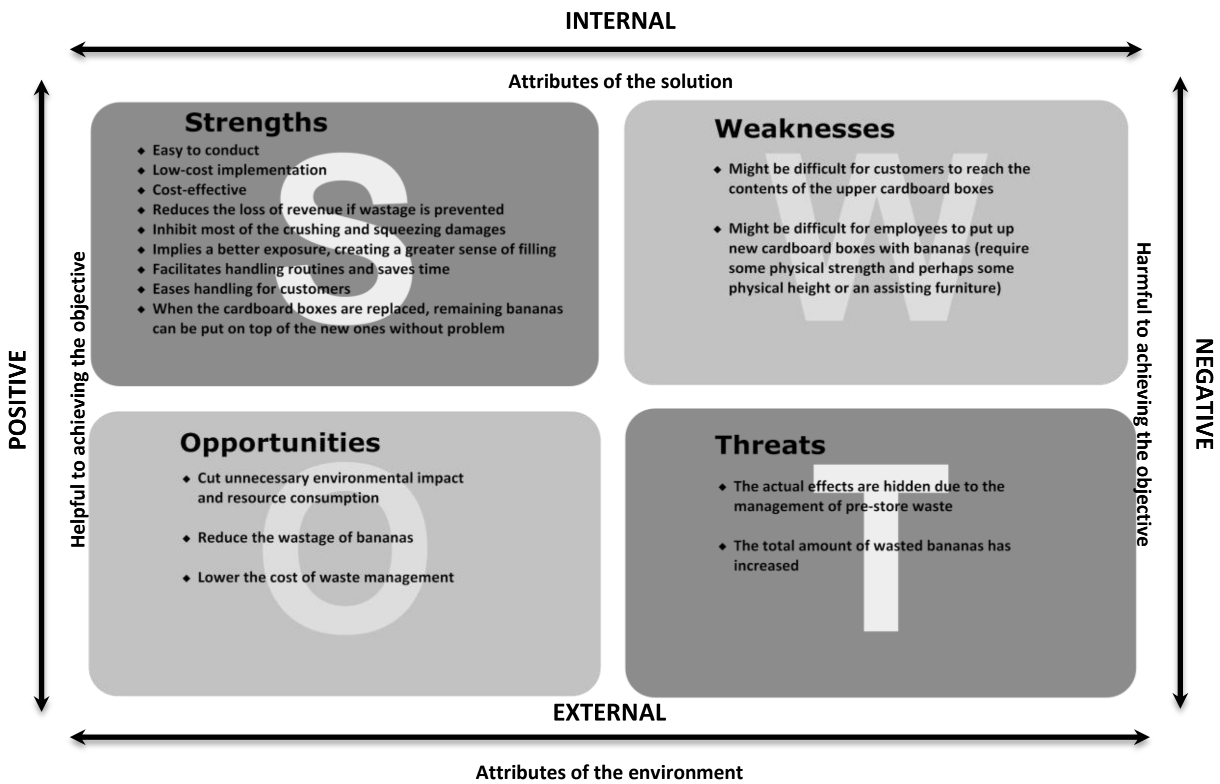

Figure 28. *SWOT-analysis of the new display table for bananas*

5. DISCUSSION

5.1. Grilled Chicken

5.1.1. Sensitivity Analysis

The sensitivity analysis shows that the climate impact from fodder production is affected significantly if a potential impact due to land use changes also is taken into account; thus implying that land use changes is an important factor when determining the environmental footprint of food production. Since there is no consensus on methodology of how to include environmental impact from land use changes and handle necessary allocations between different land-based products, this important factor is often excluded in life-cycle assessment on food products. There is therefore a risk that the theoretical impact values are lower than in reality. This analysis shows that this parameter most likely should be included to show the real environmental impact from goods containing soy products.

5.1.2. The Outcome of Introduced Measure

The introduced measure has shown a positive result since the loss of grilled chicken (in terms of recorded in-store waste) has declined almost 20 percent according to the data analysis. As mentioned before, there is no pre-store waste regarding grilled chicken, which explains why the whole decrease in losses is made in the waste category 'recorded in-store waste'. By comparing the losses before and after the price reduction and its related routines was implemented, it was calculated that around 200 kg of chicken is saved from going to waste each year. By using the results of the life-cycle assessment it was calculated that 434 kg CO_2-equivalents have not been released into the atmosphere in vain. In order to be able to compare this figure with something more concrete, 434 kg CO_2-equivalents is equal to the combustion of almost 49 gallons (approximately 185 liters) of gasoline (US EPA, 2012).

The diagram displayed in figure 12 shows that the recorded in-store waste started to decline during the early months of 2011, which is fairly consistent with the period when the measure actually was introduced. The figure shows an upturn in the loss ratio during the winter starting in 2010, which most likely depends on a decreased demand due to the assumption that grilled chicken is more popular during the warmer seasons. However, the loss ratio is not as high during the end of 2011 as it was in the end of 2010, but this is most likely due to an increased demand of chicken meat in general rather than being an effect of the introduced measure.

As could be seen in figure 12, there is an anomaly occurring in week 48 in 2010: an anomaly that is far greater than three standard deviations. This kind of deviation is called an 'outlier' in statistics, meaning that it is an observation that is numerically distant from the rest of the studied data. The found outlier is an indication of a potential error in the daily routines. Further investigations showed that the anomaly was due to a human mistake. Back then, the retail store had fewer deliveries of chicken products and had therefore a stock of chickens that should be grilled during the week. Usually there used to be two separated piles of chickens in the stockroom: one with chickens from the latest delivery and one with chickens that had been delivered even earlier. When the chickens should be prepared in the grill, the employees took chickens from the 'oldest' pile before taking from the newer one. In week 48 in 2010, the employees had unfortunately taken chickens from the latest delivery before the old ones had been used. Consequently, all remaining chickens from the earlier delivery had to be discarded before usage due to an expired best-before date.

One can argue that an anomaly of this kind should be excluded from the study. During 2010, the average weekly losses amounted to around 17 kg including the outlier. When the outlier is instead excluded the losses amounted to almost 15 kg per week during the same period. The weekly losses declined to approximately 12.5 kg after the measure had been introduced. The conducted ANOVA-test showed that there most certainly is a difference before and after the measure was introduced even if the outlier is excluded, showing that the measure most likely has had an effect.

5.1.3. SWOT-Analysis – Determining Sustainability Aspects

A quick glance at the SWOT-analysis made in figure 27 indicates that the advantages outweigh the disadvantages. There are some strong beneficial factors from an environmental and economic point of view, making it a viable option in a company's endeavor to become sustainable. The economic aspects are of great importance in a business perspective and the measure should therefore imply a good way of improving the economy by reducing the costs and increasing the profits. The measure will most likely reduce the loss of grilled chicken and thereby also the cost of waste management and loss of earnings, where the latter happens if the chickens have to be discarded instead of being sold. At the same time, the measure is a cheap and easy way to cut those economic expenses since it implies a low-cost implementation that is easily performed, thus also making it cost-effective. Moreover, favorable pricing of grilled chicken has an opportunity to attract customers. One can argue that there will be a loss of income due to the reduced price and that there is a risk that customers await the price reduction instead of buying the product to full price. However, once in place at the store to buy grilled chicken, the customers almost certainly purchase other products as well; thereby increasing the retail's total profit, which possibly can compensate for the economic loss from the sale of low-price chickens.

The SWOT-analysis further displays a couple of opportunities to approach an environmental sustainability. The measure could reduce the loss of grilled chicken, thus reducing the need of waste management and thereby preventing a certain climate impact resulting from transports to the waste treatment facility and from the compost processes. By reducing the unnecessary wastage, the climate impact caused in the production chain has not been in vain. As mentioned in the previous section, a pointless climate impact equal to the combustion of almost 185 liters of gasoline per annum is avoided due to the introduced measure.

The SWOT-analysis has also pointed out a significant weakness in the introduced measure, namely the fact that only the last chickens that are grilled during a day are covered by the measure and its new routines. A recently grilled chicken are placed in a heating cabinet where it can be stored for a maximum of three hours while awaiting an eventual sale. After spending three hours in the heating cabinet it has to be discarded, since the store has internal policies preventing the grilled chicken from spending more than three hours in the heating cabinet and since the store lacks equipment to cool it down in a proper way. This means that quite many grilled chickens that have not been sold to full price are wasted during the day. The measure implies that all remaining chickens in the heating cabinet that have been grilled after 6 p.m. obtains a reduced price during the last hour before closing time (which is 9 p.m. seven days a week). According to the conducted ANOVA-tests, there is a significant difference in the loss ratio before and after the measure was introduced, meaning that the measure has had an effect. However, the data analysis shows that the weekly average savings due to the measure is only about 4 kg of chicken which approximately is equal to four grilled chickens. One can thus argue that the measure is not particularly effective, which most likely is something that goes hand in hand with the measure's designing. So, in order to improve the measure's efficiency and further cut the wastage of grilled chicken, a reconfiguration of the measure should be performed in a way that include all chickens that are grilled during a day. All grilled chicken that have spent two hours in the heating cabinet should obtain a lower priced during the final hour, regardless of what time of the day it is. During the third hour in the heating cabinet when the price is reduced, new chickens should be prepared in the grill to be ready to replace the chickens in the heating cabinet that are either sold during the final hour or are discarded when the third hour has ended. This redesigned measure would mean that more work is required by the employees who have to spend some more time performing a regular price reduction during the whole day. However, the wastage will hopefully be further reduced, thus also reducing the economic losses even more.

From a social perspective, there are no particular aspects to take into account when evaluating the introduced measure. Nevertheless, the introduced measure still have environmental as well as economic benefits, making it a useful interdisciplinary solution in terms of sustainability: thus contributing to a sustainable development within the food sector.

5.2. Bananas

5.2.1. Sensitivity Analysis

The life-cycle assessment and its related sensitivity analysis clearly show the importance of overseas transports which accounted for a major part of the climate impact in the studied banana system. The sensitivity analysis clarifies that the impact may vary a lot with changed transportation distances. Thus it is possible to conclude that much of the climate impact of bananas could be avoided if the banana farming occurred closer to the consumers. From an environmental perspective it would hence be optimal if bananas consumed in Europe were cultivated on the European continent. However, growing bananas requires certain climatic conditions, and there are not many places in Europe that meet these requirements. Some places on the Mediterranean are warm enough during the summer season, but normally suffer from water a shortage, complicating the establishment of large-scale banana plantations. There is however a commercial banana production in the Canary Islands. The distance to Sweden is about half as long as the distance between Central America and Sweden, making import of bananas from Spain better from an environmental point of view compared to import from across the Atlantic Ocean. Still, import of Icelandic bananas would nevertheless be even more beneficial from a green perspective, due to even shorter traveling distances. A closer production system would also be more resource effective and would overall contribute to sustainable development.

5.2.2. The Outcome of Introduced Measure

The amount of recorded in-store waste has, according to the data analysis, more or less ceased since the measure was introduced. A quick look at the numbers confirms that the measure actually works. During the studied period before the measure was introduced, the weekly losses amounted to about 26 kg (1.1 percent) and after the measure had been introduced, the same numbers have dropped to approximately 1 kg (0.05 percent). By comparing the losses before and after the new display table was introduced, it was calculated that roughly 1 200 kg of bananas could be saved from going to waste per annum. According to the life-cycle assessment this means that 1 400 kg CO_2-equivalents have not been released into the atmosphere in vain. A simple comparison can put this in contrast to something more concrete in order to understand the magnitude of the avoided unnecessary climate impact: 1 400 kg CO_2-equivalents is equal to the combustion of 157 gallons (approximately 600 liters) of gasoline (US EPA, 2012).

In theory, this 'environmental benefit' should logically be a result of the introduced measure, but the fact that the recorded in-store waste has more or less stopped means that nearly every banana that is put at the display table is sold. This seems quite unlikely however. The new handling routines related to the new display table allow the remaining bananas from the old cardboard boxes to be put on top of the new bananas when the boxes are replaced, thus preventing bananas from being wasted. However, it is likely that at least some bananas have become unsalable due to incurred crushing damages or the appearance of brown spots. Yet, there is no recorded in-store waste. Either the new table is brilliant, or there are other underlying reasons why there is no recorded in-store waste. One such reason might be the adjacent small box of free bananas intended for children. In this box the employees put bananas that are considered to be unsalable. The fact that recorded in-store waste is zero means that all the bananas put in the box are either eaten or that the surplus is not being registered as waste when they are discarded (i.e. unrecorded in-store waste).

Another theory of why there is no recorded in-store waste appears at a closer glance at the data (visualized in figure 15), which reveals that the recorded in-store waste had declined to almost zero even before the measure was introduced. The manager of the fruit and vegetable section was uncertain about the exact date of the introduction – "sometime in the spring of 2011, in April I believe" (personal communication, 2012) – so there is a possibility that the new display table was established earlier than April. However, with regard to the manager's statement it seems unlikely that the measure was introduced as early as the beginning of February, when the recorded in-store waste actually started to decline. Almost certainly, something else has happened. There has not been an upturn in sales in relation to delivered quantities which makes it quite likely that the handling routines in the store were changed at the beginning of 2011.

Some procedures that clearly have been changed according to the data analysis are the routines for management of pre-store waste. During 2011 the amount of pre-store waste has more than doubled compared to 2010, implying that more bananas are considered to be of unsatisfactory quality at delivery. Fruit and vegetables are delivered to all Willys stores by *Saba* which transports the goods by truck from a central warehouse in Helsingborg. The deliveries to the various stores in Uppsala are made by the same truck; hence, basically all bananas distributed during a day come from the same supply and have the same origin. To investigate whether the bananas had been of inferior quality at delivery during 2011 a comparison with another Willys store in Uppsala was made. The data concerning pre-store waste and recorded in-store waste regarding bananas in the other retail store are presented in appendix 3. Those figures show that the proportion of pre-store waste in 2010 was approximately the same as in the studied store. The proportion of pre-store waste has however decreased to less than half in the other Willys store during 2011 while the same waste category has more than doubled in the studied store during 2011. This simple comparison most likely rejects the possible theory that the increased rate of pre-store waste in the studied retail store would be due to decreased quality at delivery. The proportion of pre-store waste would otherwise be of about the same magnitude in both stores since they got deliveries from the same truck.

So, the question about the increased proportion of pre-store waste and the decreased amount of recorded in-store waste still remains. One possible explanation may be that the management of pre-store waste is not performed according to the fundamental rules of pre-store waste, i.e. pre-store waste is only goods that have been rejected immediately at the loading dock due to unsatisfactory quality. Instead, there is a probability that bananas are treated as pre-store waste at a later stage; for instance when the display table is refilled with new bananas and there are some remaining bananas left that are considered to be unsalable. Those bananas should normally either be put into the adjacent box with bananas for children or discarded and registered as in-store waste, but due to a lack of control from the suppliers the employees can carry them back to the store's stockroom and register them as pre-store waste. In this way the store can save some money because the delivering company pays for the products that are of 'unsatisfactory quality at delivery' and they cannot check if the products actually were of inferior quality at delivery or if the quality has deteriorated later on. Therefore, the store can withdraw unsalable bananas when replacing the cardboard boxes and register them as pre-store waste and thus get a refund from the delivering company. This could be a potential explanation to why the recorded in-store waste have ceased.

However, the amount of pre-store waste is rather large and it seems unlikely that so many bananas would have gone bad during the relatively short time when they are exposed at the display table, despite the introduced measure and its theoretical strengths. It is therefore likely that the registered pre-store waste not only consists of bananas that have either been removed from the table or that regularly can be treated as pre-store waste. Logically, there should not be any particular losses from the table if the strengths of the introduced measure and the adjacent box with bananas for donation are taken into consideration. If the general routines for the store as such are taken into account, another reasonable explanation to the increased pre-store waste appears. As was mentioned in the background section, retailers do not want to run out of goods and always endeavor to have shelves that are fully loaded, which in the worst case may result in an unsold surplus that is wasted. With this fact in mind, it is fairly likely that this is the case for bananas as well. It would imply that the store orders with a certain margin of safety to ensure that they do not run out of bananas. This safety margin of bananas might be kept in the stockroom during the day and if they are not needed they are probably registered as pre-store waste at closing time or in the morning the day after. This kind of routine is feasible because of the great circulation of bananas and the procedure is good for the store from an economical perspective, since they can have a safety margin without any significant costs. The extra cost for waste treatment that may occur is not important in this context and does not affect the store's economy significantly.

It is difficult to determine whether the introduced measure has reduced the recorded in-store waste or not since its effect might be disguised by the changed routines for management of pre-store waste. However, the strengths of the new display table and the daily routines connected to it hints that it actually works, implying that the losses from the stage of exposure logically have declined. The theory that the remaining surplus that is considered to be unsalable when the table is refilled is treated as pre-store waste, explains why there is no recorded in-store waste. The increased rate of registered pre-store waste most likely depends on over-ordering intended to function as a margin of safety; thus, there is a risk that a number of bananas are discarded unnecessarily. It is hence likely that the outcome of the introduced measure is good, but changed routines regarding pre-store waste has probably resulted in increased losses of bananas on the total scale.

5.2.3. SWOT-Analysis – Determining Sustainability Aspects

The SWOT-analysis made in figure 28 shows that the advantages of the introduced measure outweigh the disadvantages. Firstly, the new display table brings opportunities to reduce the unnecessary waste of bananas in a simple and cheap way, with a possible outcome that prevents a pointless climate impact equal to the combustion of almost 600 liters of gasoline per annum. Part of the reduction of in-store waste is probably due to a relocation of waste between different waste categories, but this portion should not be too large with regard to the strengths of the measure, still making it beneficial from an environmental perspective. Secondly, the measure has some benefits from a business point of view since it is cheap to conduct, cost-effective and is less time consuming with regard to handling routines. Furthermore, it has the possibility to reduce the loss of revenue if fewer bananas are wasted thus enhancing the financial health of the company.

The new table also has social benefits since it improves the working conditions for the employees by making it easier and less time consuming to refill the display table with new bananas. The new routines imply less physical strain since there is a smaller need for movements that putting strain on the back, hopefully reducing the risk for repetitive strain injuries (*RSI*). However, the new table requires that whole boxes are lifted and placed on it which might necessitate a certain level of physical strength, limiting the refilling work to those who are physically suited to perform it. Otherwise, there is an imminent risk for back injuries for an employee lacking the physical strength that is needed. Another limiting factor is the physical height of the employee. A short person may not be able to arrange the upper boxes without using a pallet or similar furniture.

There are also some social and aesthetic advantages from customer perspective. The fact that the bananas are kept in their original boxes makes it easier to handle them since there is no particular need to move around the different banana clusters and dig in the boxes to find fresh and uncrushed bananas. Nearly every banana on the table should be as fresh and undamaged as the other ones due to the rapid circulation rate and the protection they acquired from the cardboard boxes and the certain way they are packed. So, the customers should more or less be able to pick the top bananas without the risk of getting a bad one. The sloping angle gives the whole construction a more eye-catching look that attracts customers by improving the visual attractiveness without having as many bananas at the table at once as previously. One weakness with the new table is that some customers may not be tall enough to reach the content in the upper boxes, but this is not a significant problem since the remaining bananas are put on top of the new ones when the table is refilled.

The introduced measure seems to have strong environmental, economic and social benefits, making it a good and useful interdisciplinary solution in terms of sustainability: thus contributing to a sustainable development within the food sector.

6. CONCLUSIONS

This thesis aimed to investigate whether two product-specific measures introduced with purpose to reduce the retail wastage of bananas and grilled chicken actually has resulted in reduced losses. The goal of the study was also to examine how much unnecessary climate impact that has been avoided, due to the introduction of the two measures.

The results of the study concluded that the measure based on price reduction has reduced the losses of grilled chicken with approximately 200 kg per annum. This implies that an annual climate impact of around 430 kg CO_2-equivalents has not been caused in vain, which should be the case if the 200 kg of chickens had instead been discarded. The study however shows that the measure is not particularly effective and could be improved in order to further reduce the daily losses.

In the case of bananas, the study concluded that the new display table in itself most likely has contributed to reduced losses in terms of recorded in-store waste. From the time when the new display table was introduced, the quantity of recorded in-store waste has decreased with 1 200 kg per annum, implying that an annual climate impact of around 1 400 kg CO_2-equivalents has not been caused in vain. The total amount of losses has however increased after the measure was introduced; an increase that is due to changed routines regarding the handling of pre-store waste which has resulted in a doubling of the pre-store waste. The recorded in-store waste has more or less ceased during 2011, but the decline started to occur even before the measure actually was introduced; making it difficult to determine whether the introduced measure actually works or not and how effective it is in reality. The study however indicates that the increased amount of pre-store waste for the most part consists of bananas that never enters the display table and likely is a result of over-ordering in order to create a ‘margin of safety’ to ensure that the store never run out of bananas during a day. The ‘extra bananas’ are discarded and treated as pre-store waste if they are not needed during a day. It is thus likely to believe that the measure put in place actually has reduced the loss of bananas caused at the exposure.

The conducted SWOT-analyses finally concluded that both introduced measures have strong environmental and economic benefits (and also favorable social benefits in the case of the display table), making them good and useful interdisciplinary solutions in terms of sustainability: thus contributing to a sustainable development within the food sector.

6.1. Final Remarks

The introduction extensively addressed the importance of finding a balance where humans can live in equilibrium with the natural world so as not to endanger the natural habitats for the organisms currently living on the planet and not jeopardize the natural systems’ future ability to sustain life in a manner that we know. Mankind needs to change our way of living in order to stop our negative impact on the living environment. Every human being has to take his or her responsibility in the transformation towards a sustainable society to ensure a livable future for generations to come. A lot of work and effort still remains until our present society can be regarded as sustainable. In the beginning of the century, the Secretary-General of the UN, Kofi Annan, said that “*our biggest challenge in this new century is to take an idea that sounds abstract – sustainable development – and turn it into reality for all the world’s people*”

(Annan, 2001), and to be successful we need to implement sustainability in all human activities, one step at the time.

The studied Willys store has taken some small steps in the right direction by introducing measures that have proven to reduce the unnecessary wastage of food, and by that also prevented resources from being extracted in vain and hindered adverse and unnecessary impact on the climate. The store has hence taken its responsibility and contributed to a sustainable development among food retailers in particular and within the food sector in general. However, bananas and grilled chicken are just two products out of thousands, and there are still a lot more to be done regarding food losses before they can be considered to fully assume their responsibility for sustainable development and it is not only about reducing the unnecessary wastage of other food items. As been revealed in the study, there are economic routines for handling waste that are actually increasing the total proportion of unnecessary food waste. The meaning of having such routines when there is an overall goal to reduce the food waste is indeed questionable. There might be some economic incentives from a business point of view since the store minimizes the risk of running out of goods without any significant costs. Those routines are, however, not justifiable from a sustainability perspective.

The world's scientists have gathered under a common banner and addressed that "*human beings and the natural world are on a collision course*" and that "*human activities inflict harsh and often irreversible damage on the environment and on critical resources*" (Kendall, 1992). They further argue that "*fundamental changes are urgent if we are to avoid the collision our present course will bring*" (Kendall, 1992). The introduced measures evaluated in this study are examples of solutions that are needed to achieve the higher purpose of pushing humanity out of the just mentioned collision course. The measures perhaps just imply a few small steps in the right direction, but those small steps are necessary if we should be able to ensure a sustainable future.

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APPENDIX 1

The New Display table for Bananas – Interview with the Manager of the fruit and vegetable section at the Surveyed Grocery Store

1. When was the new display table introduced and what did it cost you?
The new table construction was introduced sometime in the spring of 2011, in April I believe. It did not cost that much; approximately 1000-2000 Swedish crowns.

2. Why have you changed your display table?
We got a tip from a coworker at another department of the company, who works with establishment and renovation. The guy visited us and gave us the hint that you should have a table design that allows one to keep bananas in the original boxes instead of the letting the bananas lay loose on the table in a single mountain. The old table did not allow us to place the boxes in a proper way. According to our coworker, the new table with the new type of approach would result in better exposure and that fewer bananas had to be discarded. We wanted a more grand solution that could provide a decent exposure while reducing wastage.

3. What advantages did you expect that the new display table would bring and have the table fulfilled your expectations? Why is the new one better than the old one?
The idea was that we could reduce wastage on bananas and getting better and more apparent exposure, at the same time as it had a well-ordered and inviting appearance. With the old table, we put the bananas directly on the table and stack them in a single pile. This meant that it could be 4-6 clusters on each other, which resulted in a lot of discarded bananas due to crushing and compression damages. With the new table where the bananas are kept in their original cardboard boxes and where maximum 3 clusters are stacked, those kinds of damages can be avoided to a great extent.

4. How much can be accommodated on the new table compared to the old?
Now we have a table that is designed to tilt in order to let us stack the cardboard boxes as they come, in a sloping angle. We are able to set up four boxes in height and two boxes in width, i.e. a total of eight boxes. Furthermore, we tend to take the contents of three more boxes and put it loosely on top of the bananas in the already placed boxes to make it look more well-filled and inviting. Altogether, you can say that we have space for eleven boxes at once.

5. Has the new display table shown any drawbacks?
The only disadvantage is probably that the person refilling the table has to be a little taller in order to be able to reach up and place the top boxes in the tilt, without having to pick anything to stand on. Some customers have also indicated that it may be difficult to reach up and pick the top bananas. If necessary, we'll be happy to help them to pick from the top boxes if they wish to do so.

6. What are your feelings about the new table in comparison with the old one?
Very good! First, it got a lot more selling attractiveness, and we have also reduced the losses of bananas to a great extent. Moreover, it takes much less time to handle the bananas and refilling procedure has been facilitated a lot.

7. How often do you perform inventories and refilling procedures?
We normally refill the table three times a day and when we do, the boxes usually are quit empty. During the refilling procedure we shift all boxes and add remaining bananas at the top of the new ones in the new boxes, in order to expose them. Usually, there may be some bananas left in the boxes that were placed at the top of the slope, but we put then on top of the new bananas.

8. How much bananas do you estimate are thrown away each day since the new table was introduced?
Generally no more than one box of bananas is thrown away each day. The bananas are discarded due to deteriorated quality and they have been sorted out during the refilling procedure.

9. Have the routines been changed since the new table was introduced? What are the differences in the handling procedures?
We are now able to refill the bananas twice as fast as before, since we now are allowed to just place the original cardboard boxes right at the display table. Before we had to pick up bananas by hand and stack them in a single, good looking pile; a procedure which were pretty time consuming. I would guess that it takes about 15 minutes to do a refill today. With the old board we had to refill the table about five times a day, so the new table really allows us to save quite a lot of time and effort.

Sale of Grilled Chicken at a Reduced Price – Interview with the Manager of the meat section at the Surveyed Grocery Store

1. You have introduced a measure that has reduced the losses of chicken. How does this measure look like?
We buy whole chickens that have been pre-marinated, grill them in the store and then sell grilled chicken to our customers. The measure introduced is based on that the grilling procedure is stopped around 8 p.m. every day, which is about an hour before the store closes, and the grilled chickens that are left are sold out at half price.

2. How did you do before this measure was introduced?
We grilled chickens in the same way, but we did not sell them at a reduced price when the day was nearing its end, which resulted in that grilled chicken being unsold had to be discarded. There is a possibility to cool the newly grilled chicken within two hours after the grilling procedure is completed and sell them as cold grilled chicken the upcoming day, but this store cannot unfortunately do this. This is due to a lack of time and certain equipment. Thus, we had to throw away a lot of grilled chicken before the measure was introduced.

3. When did you introduce the measure?
The measure was introduced in the beginning of 2011. I can’t remember the exact date or week.

4. What are your feelings about the new measure?
Very good! We think it is great that we do not have to throw so much chicken anymore. We will be happy if do not have to throw food, and our customers that happen to shop in the final opening hours will be satisfied when they can buy grilled chicken at half price.

5. Does the measure have any drawbacks?
No.

6. Isn't there a risk that the customer's needs cannot be met if you run out of grilled chicken during the last hour because you have stopped the grill and sold out the remaining grilled chickens at a reduced price?
No, there is no such risk. In our assortment we have cold, pre-packaged, grilled chicken, which we refer our customers to, if they want grilled chicken during the last hour and we have sold out of our own grilled chicken that have been grilled in the store.

7. How much chicken do you estimate were discarded before the measure was introduced and how much is thrown in the current situation?
Sales of grilled chicken depend a lot on the weather conditions outside. If there is weather for a picnic outdoors, more grilled chicken are generally sold than if the weather is bad.

8. What does the daily routines for grilling generally look like?
We usually turn on the grill in the morning and have the first grilled chickens ready at 9 o'clock in the morning. Then we ensure that there always is grilled chicken ready for sale during the day, which more or less means that we grill chickens periodically with approximately an hour in between each grilling procedure. The grilling process takes about half an hour and when they are finished they are placed in a heating cabinet in order to stay warm. A typical day, we sell about 16-24 grilled chicken.

9. Have the daily routines changed since the measure was introduced?
The routines are still the same, except for the fact that we mark the remaining grilled chicken with a new price tag. The measure has not created an increased workload and is not more time consuming than before.

10. Where does the chicken come from?
Everything originates from Sweden and is delivered by *Kronfågel*.

11. Do you only grill whole chickens?
No, we grill chicken drumsticks as well.

APPENDIX 2

Grilled Chicken – GWP Data

Life-Cycle Stage	Global Warming Potential (GWP) (g CO_2-eq/F.U.)	Contribution to Total GWP (%)
Fodder Production	1 610	75.6
Rearing and Manure Management	320	15.0
Slaughter and Refinement	51.3	2.40
Distribution	77.5	3.60
Retail Store	42.3	2.00
Waste Management	28.3	1.30
Total	**2 129**	**100**

Bananas – GWP Data

Life-Cycle Stage	Global Warming Potential (GWP) (g CO_2-eq/F.U.)	Contribution to Total GWP (%)
Farming	138	12
Packaging	89.6	7.7
Overseas Transport	692	59
Inland Transportation and Port Operations	118	10
Ripening	84.5	7.2
Exposure in Retail Store	1.43	0.12
Recycling of Cardboard Boxes	- 37.1	- 3.2
Waste Management	28.3	2.4
Extra due to Exclusions	53.5	4.6
Total	**1 167**	**100**

APPENDIX 3

Loss of Bananas in another Willys Store in Uppsala

Registered data on delivered quantities and losses of bananas during 2010-2011.

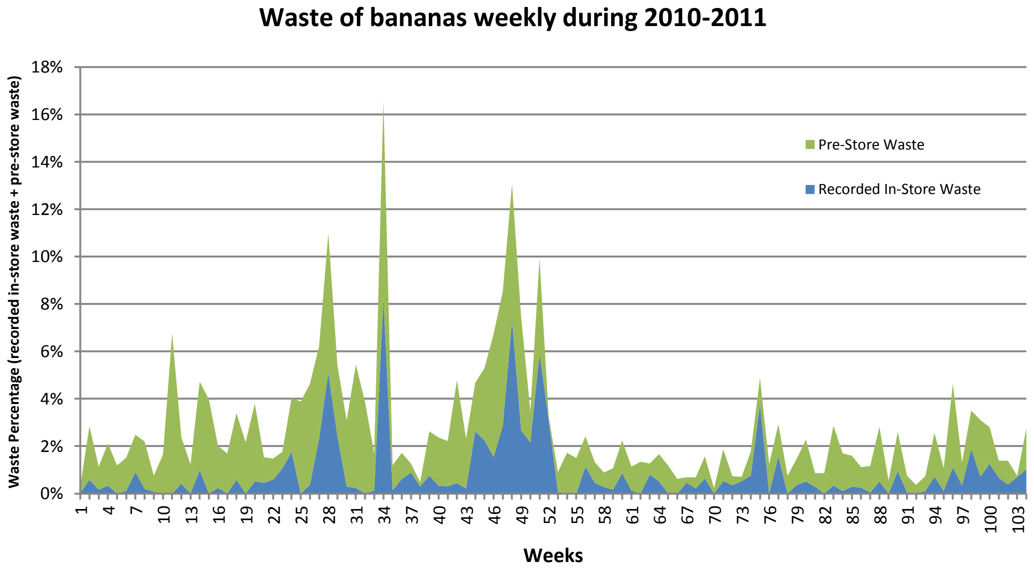
Product	Year	Delivered Quantities (ton)	Losses (ton)	Loss Proportion (%)
Bananas	2010-2011	219	5.49	2.51
	2010	114	3.84	3.37
	2011	105	1.66	1.58

Loss of bananas - average numbers – recorded in-store waste data.

Year	Delivered Quantities (kg/week)	Recorded In-Store Waste (kg/week)	Loss Proportion (%)	SD (%)
2010-2011	2 110	14.6	0.690	1.40
2010	2 190	19.7	0.900	1.82
2011	2 020	9.41	0.470	0.63

Loss of bananas - average numbers - registered pre-store waste data.

Year	Delivered Quantities (kg/week)	Pre-Store Waste (kg/week)	Loss Proportion (%)	SD (%)
2010-2011	2 110	38.2	1.89	1.56
2010	2 190	54.0	2.47	1.82
2011	2 020	22.5	1.11	0.65



Waste of bananas weekly during 2010-2011