



# **Food loss and packaging**



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## **Food loss and packaging**



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Voedselverspilling: literatuurstudie. Mechelen : OVAM, 2011.

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# Summary

## What is the relationship between packaging and food loss?

The optimal packaging of foodstuffs means that unnecessary packaging is avoided without bringing the safety of the food into danger and to incur the minimal amount of food loss as possible. This process deals with finding a balance between the adjustment of food packaging to a changing lifestyle, such as smaller portions for smaller families in order to have less food waste, and at the same time to prevent the environmental impact of extra packaging material and waste becoming a burden as a result. Especially in recent years, there is more attention also brought to viewing food loss in light of the environmental impact and the relationship with packaging, whereas in the past, the focus was primarily on the prevention, and the recycling, of packaging waste. Nevertheless, the protection of the product is the primary function of packaging, and the total life-cycle environmental impact of the packaged foodstuff is, in most cases, higher than the packaging itself. Ideally, an optimal packaging will have no added environmental impact. However, sometimes that is not possible, and an assessment must be made. If an innovative packaging can contribute to less food loss, then from a certain standpoint this avoided environmental impact shall compensate for the extra environmental impact of the packaging. The goal of this study is to develop a method for reaching this trade-off point and to demonstrate this metric for a number of selected foodstuffs with regards to possible packaging innovations.

## How can packaging contribute to less food loss?

Well-designed packaging for foodstuffs, such as smaller portions, can thereby contribute to the fact that the consumer purchases the quantity of foodstuff that is better in accordance with his needs. Foodstuffs can also be preserved longer by better-designed, re-sealable packaging, packaging with separate compartments (mini portions), air-tight packaging with an adjusted protected atmosphere, active packaging that creates the ideal atmosphere for the product, intelligent packaging, and so forth.

The following 5 foodstuffs were selected and for these packaging measures, the trade-off points were calculated:

Category	Subcategory	Packaging
Meat and meat-products	Fresh beef	Vacuum Skin Packaging (VSP)
	Cooked ham	Portioned Sizes
Fruits and Vegetables	Fresh lettuce	Pre-cut and washed lettuce Portioned Sizes
	Green beans	Canned Portioned Sizes
Dairy Produce	Cheese spreads	Mini portions
Bread	Fresh bread	Portioned sizes, packaging suited for freezing, conversion to pre-packaged bread with longer preservability, conversion to bake-off bread packaged in protected atmosphere
Drinks	Carbonated soft drinks	Portioned Sizes

These trade-off points are achieved on the basis of sample surveys of various packaging. The highest obtained trade-off points are used rather than the median. These values are intended to be concept guidelines: if a new packaging can yield at least this percentage of food loss according to this principle, then in most cases the total environmental impact of the new product packaging system will be even better.

#### **Bread (losses represent 18% of the total climate impact)**

- **Conversion to smaller breads.** The environmental impact of the extra packaging is already compensated when there is at least one-half slice less waste.
- **Freezing bread.** The additional environmental impacts are already compensated when there is at least two slices less loss (from 800g bread).
- **Conversion to pre-packaged bread with a long expiration date.** This system doesn't necessarily have any additional impact with respect to fresh bread, and there is thus no discussion about *"compensated when there is at least 'x' slices less bread loss"*. The benefit with regards to the option of freezing bread is that with this option the energy use related to preservation is not a significant factor.
- **Conversion to bake-off breads in MAP (Modified Atmosphere Packaging)** to be baked at home is, theoretically, only interesting in the event that on average the consumer wastes a third of the bread. In praxis, however, it is unlikely that this will occur.
- **Bake-off baking at the place of retail** in combination with an adjusted inventory management has indeed lead to a reduction of bread loss in the production-distribution chain. More recent studies on bread loss in the chain mention a range of 2-6 percent, average 4 percent, in contrast to an average of 7 percent in previously published research where little or no mention was made of deep-freeze or bake-off distribution chains.

#### **Meat and meat-products (losses represent 15 to 19% of the total climate impact)**

- **Conversion to VSP (Vacuum Skin Packaging) for fresh meat** is to be justified if the extension of the expiration date effectively produces less loss with this type of packaging, either in the distribution phase, or with the consumer. The largest and heaviest Vacuum Skin Packaging (VSP) from the test samples has somewhat of a higher environmental impact than an MAP packaging for the same portion size, but is already compensated for with at least 2% less of the beef being lost. In most cases, the environmental impact of a VSP packaging will even be more beneficial than an MAP packaging. A VSP packaging can be smaller in volume and this will have a positive effect on the impact related to storage and transport.
- **Conversion to smaller packaging for cooked ham** definitely makes sense. If one can prevent the loss of at least a third of a slice of ham by converting to a smaller packaging; then the environmental impact of the extra packaging is compensated.
- **Conversion from packaging under normal atmosphere (i.e. fresh foil) to an MAP packaging** is compensated for starting at one third of a slice of ham. Thus, don't buy too much at a deli counter. Moreover, if the pre-packaged portions in the refrigerated counters are too large, then it is better to buy the proper portion at the deli counter.

### **Cheese spreads (losses represent 10% of the total climate impact)**

- **Conversion from regular packaging to mini-portions:** starting with at least 2-3% less loss of cheese spreads/goat cheese, the extra impact of the mini-portions packaging is already compensated for. The quantity of cheese spread is less than the quantity needed for a quarter of a sandwich (i.e. 5g of a 200g cup)
- **Conversion from a large family packaging (i.e. 300g) to a standard-sized packaging:** starting with at least 1,5% less loss of cheese spreads/goat cheese, the extra impact of the normal packaging in relation to the large, family size is already compensated for.

### **Lettuce (losses represent 16-36% environmental impact) and string beans**

- **Conversion from a full head of lettuce to a bag of pre-cut and washed lettuce** is reasonable beginning at 15% less loss of lettuce. This is primarily interesting for smaller households if the head of lettuce is too large. There will also be less water used. The lettuce is already washed and does not need to be washed again. This is more efficient in the industry than at home.
- **Conversion to smaller packaging of pre-cut lettuce**, for example, of a large re-sealable or non-resealable bag of 300-400g to bags of 100-200g, or from 100-200g to the smallest portions of 40-80g, is reasonable with at least 5% less loss of lettuce. For doubts as to how much lettuce one will need and consume at a meal, this can offer a solution. A larger, re-sealable bag will, after the initial opening, also still protect the lettuce. After the initial opening, the bag protects the lettuce against humidity loss, however, the protective atmosphere is gone, by which the remaining preservation time is rather short. The environmental impact of a re-sealable bag, usually made with a heavier foil and the added sealing mechanism, is more or less the same and in some cases even higher than the smaller, thinner bags with a protected atmosphere (EMAP).
- **Conversion to smaller cans of green beans**, for example, from large cans of 400g net (this is circa 220g drained) to smaller cans of 200g net, is reasonable beginning with 15% less loss of green beans. This comes to about 34 grams of green beans (drained weight).

### **Carbonated soft drinks (losses represent 8% of the total climate impact)**

- **Conversion from large to smaller packaging for home usage** is reasonable from the environmental standpoint in situations where the user frequently throws away large quantities of drinks from large 1,5 to 2 liter PET bottles. According to research, this is the leading cause of loss of carbonated water and soft drinks. Starting from at least 20% less loss from large 1,5 to 2 liter PET bottles, (this is circa 1 large consumption of 33cl), the environmental impact is compensated for with respect to the usage of the smaller 0,5 PET bottles, or 33cl cans.

### **How do the Flemish Government and its chain partners proceed with this?**

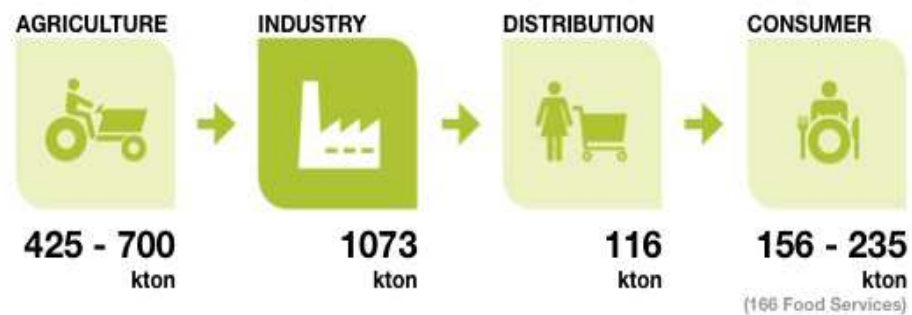
The fight against food loss is a community and shared responsibility. In this regard, on 31 March 2014, the Flemish Government and its chain partners, amongst which are Fevia Vlaanderen and Comeos Vlaanderen, who were also involved in the focus group of this study, have signed the engagement declaration 'Vlaanderen in Actie: Samen tegen voedselverlies' (Flanders in Action: Together against Food loss). In recent years, there have been various initiatives taken to address food loss with prevention and valorisation. The study at hand, which delves deeper into the aspect of food loss in relation to packaging, is an initiative of the Flemish Government and

Fost Plus, the private organisation that guarantees the promotion, coordination and financing of the selective collection, sorting and recycling of household packaging waste in Belgium. The study can build further upon previous studies. A few examples of this are: 'Food loss in chain perspective' (OVAM, 2012), where an estimation was made by the loss across the entire foodstuff chain in Flanders; a 'Baseline of food waste in Flemish families via sorting analysis of refuse' (OVAM); and the 'Food Loss Project' (Fevia Vlaanderen, 2013) on the loss in the food industry in Flanders. The packaging data in all of these studies is available, and concerning this the study at hand can provide additional insights.

With the results of this study, the Flemish Government wishes to engage in a constructive dialog in the Flemish Consultation Between Chain Partners on Food Loss, where links of the chain and the Flemish Government are represented, and from which future actions shall be coordinated. Central to this consultation and further collaboration is the departure point to help each other in a positive manner and to look further than the specific challenges within the individual links. The chain is, however, a dynamic entity: what one of the links undertakes can have a positive or negative impact on the other links in the chain ahead or behind. It is the communal and shared responsibility to implement solutions that, both at the chain and the corporate level, create win-win possibilities and to continue the fight against food loss as efficiently and effectively as possible.

# 1 Introduction

## 1.1 Relevance



*Figure 1 : Food losses and by-products in the chain, quantitative estimate for Flanders (OVAM, 2012)*

Packaging has a 'positive' role to fulfil in the reduction of food losses. In most cases, the 'negative' environmental impact of the packaging itself is rather limited with regards to the packaged food commodities. This places things into perspective. Moreover, food loss is not only ecological, but is also a relevant ethical and economic problem. There is a strong link between food loss and packaging. By means of packaging, one strives to preserve food products for as long as possible and to prevent the loss of products. The quality of the packaging thus has a direct impact upon food loss. According to the FAO, the majority, some 40%, is lost in industrialised countries after the purchase by the consumer. An intensive exercise has led to figures for Flanders (OVAM, 2012). The estimation contains the food loss and accompanying side effects that come about in the complete food supply chain. In agriculture and food companies, significant possibilities arise of 'non-edible' side effects that are somewhat yet to be assessed, such as animal feed. In the distribution and with the consumer, the portion of 'edible' food loss is greater. The total production is estimated at around 2,1 million tons or 345 kg per inhabitant. In the meantime, food loss sits high up on the European agenda and Flanders has also signed on to this ambition and is carrying out a set of 25 measures to realise this intention. This project, with a specific focus on innovative packaging, is coordinated by OVAM and Fost Plus, and receives the support of various stakeholders involved in the food supply chain.

## 1.2 Definition of food loss

The following working definition of the Interdepartmental Food Loss Workgroup of the Flemish Government is used in this study:

**'Food loss is every reduction of foodstuff available for human consumption, which occurs in the food chain, from harvest up to and including consumption'** Foodstuff raw materials and products also contain a portion of non-edible biomass, which is freed up during the production/processing of food products or from consumption. We call these by-products. Both food loss, in the event that it cannot be avoided, as well as by-products, can still be assessed in some way with preservation of quality in mind. For more explanation on this definition and the conceptual framework of food loss and by-products, see the synoptic document of the Flemish Government 'Food Loss in Flanders' (2012). Thus, whenever there is

mention of percentages of food losses or loss, it is only dealing with the edible portion conforming to the abovementioned definition and not about the by-products. This study focuses on the role of packaging for the prevention of food losses.

## **1.3 Objective and Methodology**

### **1.3.1 Objective**

The goal of the project is to address clearly the question about how and in what capacity packaging can contribute to the prevention of food loss and how one must factor this in with respect to potential extra packaging material or refuse. The result being that these issues must later be able to be clearly communicated. Food losses place the packaging of foodstuff in a different environmental perspective. More packaging can lead to less food loss, but aggravates the refuse problem. A question arises regarding a balance between less food waste on the one hand and more packaging waste on the other (Wikström, 2009). A way out of that dilemma is to put the emphasis on optimising packaging rather than simply reducing the packaging. New innovative technologies can play a role in this here. In the context of the Retail Innovation Programme, the British WRAP investigated packaging technologies that can deliver a possible contribution to the fight against food loss (Scott & Butler, 2006). In Flanders, the role of packaging and food loss already recently offered in the first reference study of OVAM (OVAM, 2012). In this project, the theme is further elaborated.

### **1.3.2 Project team and Steering Committee**

A project team consisting of experts from Studio Spark, Pack4Food and VITO carried out this project by commission from OVAM and FOST PLUS. The project team were thereby actively supported by a steering committee of representatives from sector organisations COMEOS and FEVIA Vlaanderen and the Flemish Government (Interdepartmental Food Loss Workgroup).

## **1.4 Food loss and packaging in the chain perspective**

The fight against food loss is a common and shared responsibility. In this regard, on 31 March 2014, the Flemish Government and Boerenbond, Fevia Vlaanderen, Comeos Vlaanderen, Unie Belgische Catering and Horeca Vlaanderen signed the engagement declaration 'Vlaanderen in Actie: Samen tegen voedselverlies' (Flanders in Action: Together against Food Loss). In recent years, initiatives have already been taken to address food loss with prevention and food waste valorisation. This study is an example of this. These projects occur in close collaboration with chain partners, the government and the stakeholders. With this declaration of intention, the initiators agree to be willing to go further together, and they also want to announce their engagement to European policy makers. The signees are calling for businesses and organisations in the chain as well as stakeholders to underwrite the declaration of engagement and to undertake action to reduce food losses as much as possible. The role that the Flemish Government is taking on is a facilitating and supporting role and is taking them up in its policy and actions. For all information, you can go directly to the website of the Interdepartmental Food Loss Workgroup, which coordinates and adjusts the activities on food loss by the various policy domains. The departure point of the chain approach is to help each other in a positive manner and to look further than the specific links within the individual sector. The chain is, however, a dynamic entity: what one link undertakes can have a positive or negative impact on the other links in the chain ahead or behind. For example, significant food loss takes place at the



consumer level. To take up the responsibility in a shared and community way implies that the businesses in the chain, with their directed innovation, as well as the consumers, with adjusted purchasing and consumption behaviour, both contribute their part. The goal of the collaboration and the deliberation amongst the various links of the chain, both at the chain and corporate level, is to identify win-win possibilities in the fight against food losses and to proceed as efficiently and effectively as possible as well as implementing a structural evolution. The challenge with chain collaboration regarding packaging and food loss is also to arrive at innovative solutions for a number of apparent paradoxes that are at play in the system. The innovations should go further than mere product, process or packaging technique innovations. Regarding this, we are considering new collaborative and business models. These paradoxes can be:

- **Paradox 1** : *'the less the food loss, the less turnover in the chain'*. Within a chain link, the food that is not sold and is lost is a form of value loss. One experiences the consequences and puts the stimulus in action. Less loss further up in the chain has a logical consequence that there will be less sales realised further on down in the subsequent steps of the chain. In order to arrive at a win-win situation in all steps of the chain, this values must be created thus in another manner.
- **Paradox 2** : *'the preceding link(s) the costs, the following links the profits'* It is not always the party that does the investing that directly has the most advantage. Clear, mutual chain agreements and new forms of collaboration are essential in this case, but in praxis, it seems to be rather difficult: the retailer should permit a portion of his profit to flow back to the packager. Moreover, those who are responsible and who decide about the purchase, investment, sales and loss also do not have the same incentives.
- **Paradox 3** : *'the preceding link(s) the cause, the following links the consequences'*. The former reasoning also works in the opposite direction. The adjusting of a packaging that causes more food loss can be advantageous for the involved link (i.e. lower cost price), but the subsequent link(s) are stuck with the consequences of more food loss.
- **Paradox 4** : *'everyone is all in, or nothing'*. All links in the chain must be convinced by a (packaging) measure, accept it, and to be willing to implement it. Foodstuffs in innovative packaging are only effective as the efforts put into it with respect to available packaging. Moreover, if they are not accepted and are consequently sold with difficulty, then the loss from this can be even greater. The most well-known 'Packaging Paradox' deals with consumers who perceive some better performing packaging as over-packaging (see also section 3.1.3.3).

The study at hand shall provide no solutions for the above mentioned paradoxes, but will indeed serve as incentive for a discussion and collaboration in the chain consultation about it. With new insights on the impact and the possible role of packaging to combat food loss, this will be put into perspective.

In the platform 'Vlaams Ketenoverleg Voedselverlies' (Flemish Chain Consultation Food Loss') all links of the chain and the Flemish Government are represented and from this all actions will be coordinated. The following six actions are further elaborated, and within a few of these themes possible concrete actions regarding packaging are presented.

**Establish a Chain Roadmap** For example, strategy objectives and actions for packaging, on the sector and chain level;

**Build up a Knowledge Base** For example, quantitative analyses on the impact of packaging and the relation to food loss, possible packaging measures and innovations;

**Raise Awareness** For example, raising awareness on the role of packaging for the prevention of food losses in the chain; raising awareness on the necessity for a total system approach on the impact of packaging and food (in contrast to a biased focus on the impact of packaging);

**Call for a Food Loss Coalition** For example, a call to businesses, the proactive approach and involvement of companies to investigate and implement potential packaging measures;

**Engaging the Consumer** For example, a coordinated effort to sensitise the consumer to more conscientious choices of proper portion sizes, certain types of packaging that combat food loss, and so forth.

**Social Initiative** For example, gifts of food of which the expiration date is (nearly) expired to food banks or other charity institutions.

## 1.5 Reader's Guide

This report is constructed around 10 main chapters. In chapter 2, the selection of 5 case studies of food categories for closer investigation is introduced. In chapter 3, the research methodology is explained. In the five sequential chapters 4 thru 8, the research, results and conclusions are summarised per category: 'bread', 'fresh beef and meat-products', 'vegetables', 'spreadable cheese' and 'carbonated soft drinks'. Each of these chapters follows the same structure: an introduction on that food category with respect to known and less known packaging options are available to combat loss; likewise an overview of what system options there are to combat loss; the inventory of data; the research results; and the conclusions and recommendations that can be made for that food category. In chapter 9, the results and a general conclusion are given. In the last chapter 10, a word of explanation is given regarding the appeal that is made in the context of this project and the on-line inspiration platform 'pack2savefood' that is a result of this. There are also recommendations given regarding further communication.

## 2 Selection of food products and packaging methods

The number of food products is significantly large. For this study, a selection of 5 case studies is made, taking a number of criteria into consideration, and agreed with the project commissioners and steering committee of this study.

### 2.1 Criteria

The following 10 criteria were taken into consideration:

1. demonstrative character with regards to the role of the packaging;
2. sufficient diversity in packaging measures (portion size, mini-portions, various packaging techniques, packaging materials with specific qualities, re-sealability, and so forth) and/or options regarding system innovation;
3. sufficient diversity in foodstuff categories;
4. with sufficient relevance with respect to volume consumption;
5. with sufficient relevance with respect to volume of food loss;
6. with sufficient relevance with respect to environmental impact of food (loss);
7. with sufficient relevance for sectors in Flanders (economic agricultural and horticultural activities, food industry and/or packaging industry);
8. where sufficient influence is possible by, for example, actors in the Flemish industry or distribution (some matters are difficult to change because the decisions are not made or influenced in Flanders);
9. sufficiently new: this is not the first study on packaging and the relationship to food loss. In this report, frequent references to this are made. With the selection of cases, we are attempting to add to available knowledge.
10. sufficiently surprising: cases that add little environmental impact to the packaging system and simultaneously to reducing food loss are in fact no brainers. Innovations that do, however, add to the packaging system and that can be perceived as over-packaging are interesting to investigate. Sustainability is often counter-intuitive.

### 2.2 Selection of Case Studies

On the basis of these ten criteria, the following five case studies were selected. In the study Food Loss in the Perspective of the Chain (OVAM, 2012), the figures for Flanders were estimated on the basis of available research with respect to the total quantities in the various links in the chain. For the selection of specific product groups, more detailed figures are sought after on this level. An overview of this is given here in the following sections of 2.3 thru 2.5.

### **2.2.1 Brood**

Bread is the largest fraction of food loss that was found via a measurement of waste in Flanders (OVAM, 2011)(criterion 5). This is logical because the usage is large (criterion 4) and loss sensitive due to limited preservability and consumer preferences. For many, bread must be 'oven fresh'. Per unit (kg), bread is less significant with regards to environmental impact in comparison with some other food products, but in combination with the quantity of consumption and loss per person, it is indeed relevant (criterion 6). Economic activities of producers of raw materials, independent bakeries and industrial bakeries are significant in Flanders (criterion 7) and they can exert a clear influence on choices in connection with packaging (criterion 8). LCA's of other environmental studies in connection with bread are internationally available, but not for the typical bread of this region or the specific chains in Flanders. Existing environmental studies also do not specifically investigate the relationship with food loss (criterion 9). Projects regarding the combating of loss are indeed there, and here we are thinking about projects such as SHELFLIFE I & II, which were carried out by the laboratory for LevensMiddelenChemie en – biochemie (LMCB) of K.U. Leuven. These and other projects focus primarily on innovations in the bread-preparation process, and/or on the supply chains of bread such as deep-freeze technology and bake-off or parbaking. From studies on consumer behaviour and food loss, it appears that the wasting of bread is not a priority: it is deemed logical and, for example, old bread given to animals is not viewed as food loss. The options for innovative packaging that could combat bread loss are rather limited and the question is indeed whether greater breakthroughs could not be realised by a systematic approach (criterion 2). Options such as mini-packaging or plastic packaging with a modified atmosphere are readily perceived as over-packaging. If we can show in this study that this can be compensated for by less bread loss, then that will counter preconceived ideas (criterion 10).

### **2.2.2 Meat and Meat-products**

Within meat and meat-products, a case study is chosen for fresh beef and pre-cooked ham (pork). They are both categories that represent a large consumption quantity (criterion 4). The impact per kg of meat is relatively high in comparison with other food categories and is per kg the highest for beef in comparison with other types of meats (criterion 6). Flemish actors in the agricultural, food industry and distribution sectors (criterion 7) can exercise a clear influence on choices in relation to packaging (criterion 8). With attention to quality and food safety there is already very much being done; for example, the reducing of initial contamination, the monitoring and optimising of the cold chain, and the packaging of meat in a protected atmosphere. In addition to the existing efforts, the further tackling of loss in the chain and with the consumer remains relevant, but certainly not evident for meat (WRAP, 2013). Potential packaging measures are situated on the level of other packaging technologies and sensitising of portion sizes. For red beef, Vacuum Skin Packaging (VSP) is an option that is provided in adjacent countries, but in Belgium is rather rare. Acceptance by the consumer here forms one of the most important barriers with regards to colouring and form of the fresh beef. The chances for the implementation of VSP and the known barriers are summarised in this study. The VSP packaging and the advantages for preservation are already seen in other studies (Van Velzen, 2011; Rabobank, 2014). In this study, the trade-off point is calculated from how much percentage less food loss VSP delivers in relation to current MAP packaging for red beef (criterion 9). The same is done for smaller portion packaging for ham that can be subject to the perception of over-packaging (criterion 10).

### 2.2.3 Spreadable Cheese

This is primarily the demonstrative character of the packaging measure of mini portions to combat food loss (criteria 1 and 2) and the perception of over-packaging that remains with the consumer regarding mini portions, which makes spreadable cheese with a limited expiration very interesting as a case study (criteria 9 and 10). The usage of spreadable cheese made with cow, goat and sheep milk and so forth and with limited expiration is rather limited in relation to other types of cheeses such as semi-hard and hard cheeses (criterion 4). However, with these pre-packaged pieces of cheese, the same principle can be applied such as packaging in two, separate compartments. When the first pieces are consumed, only then does one open the second compartment. The second compartment is packaged longer within a protected atmosphere whereby it also stays fresh longer. Actually, this is the same basic principle as with mini portions of spreadable cheese. With small portions and mini portions of spreadable cheese, the packaging can be viewed as excessive. Consumers view packaging as excessive when they encounter the quantity of packaging is not in relation to the packaged product or when they experience it as an obligation because there exists no other alternative for less packaging material (Fost Plus, 2012). In this study, the balance point is calculated: starting with how much less loss of cheese is the excess packaging material compensated for (criterion 9)? Is the feeling of excessiveness from an environmental viewpoint correct (criterion 10)? Cheeses in general are also a product category with no small environmental impact (criterion 6). In Flanders, there are no large food-industry companies that make such spreadable cheeses. Small-scale producers of plain cheeses, fresh cheeses, goat cheeses and so forth, however, are present in Flanders. Here we are thinking primarily about farmer's markets. These producers have an influence on the choice of packaging. Retailers can also exert, to a limited degree, influence on their suppliers, and primarily the consumer in the store has the choice between the available large or mini-portion packaging that are usually offered alongside each other (criterion 8).

### 2.2.4 Vegetables

Fresh vegetables are a category in which all links of the chain incur substantial losses. Both the quantity of usage as well as loss (criteria 4 and 5) are greater in relation to fruit. Chains are in large part local and chain actors in Flanders exercise a large influence on the efficiency and the management of the chain, amongst which is also the losses (criteria 7 and 8). Specific attention is paid to the case study of fresh lettuce. It is available both fresh, unprocessed, and pre-cut, -washed, -mixed, etc. Bagged salad is a category that is used in the study of Tesco and has a loss of 68% in the United Kingdom in the chain (see FIGURE). This indeed had significant press coverage in the United Kingdom and opened up the discussion on food losses. From both the perspective of packaging as well as a broader system perspective, this is an interesting case to study closer (criterion 10).

## Bagged Salad

- We will not offer multi-buys on larger packs and are developing an intelligent promotion strategy to allow customers to 'mix and match' products
- Introducing re-sealable bags across the range following a trial on shredded iceberg lettuce
- Twin packs offer 'eat me now, eat me later' opportunities for customers

Total  
Production  
Wasted:  
**68%**

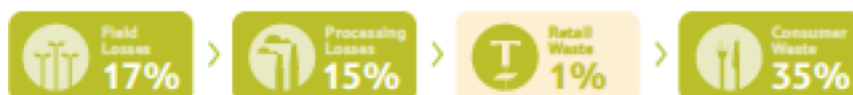


Figure 2 : Tesco (2013)

### 2.2.5 Carbonated soft drinks and bottled water

Various available LCA and Carbon Footprint studies on carbonated soft drinks and bottled water (including non-carbonated) point out that the impact of the packaging is a heavy burden in the total environmental impact, and in some situations is even greater than the production and distribution of the soft drink itself (Amienyo et al., 2013). This is the case because the impact of, for example, light soft drinks or drinking water is itself rather limited. This makes the trade-off exercise and the research question of whether a choice for another packaging indeed can be compensated for by the avoided impact of less loss of liquids quite challenging and interesting (criteria 9 and 10). Hereby we are primarily thinking about the choice for smaller packaging, going from 15 to 50 centilitres, in relation to the large bottles of 1,5 or 2 litres. The most important cause of loss is 'flat' soft drinks in large bottles, followed by the remains and 'dregs' that remain in smaller packaging or discarded bottles or glasses (WRAP, 2009), and to a lesser degree, closed soft-drink packaging past expiration dates (criteria 1 and 2). With the consumption of soft drinks and bottled water, Belgium belongs to the top 3 leaders in Europe (criterion 4). Measurements in Holland and the United Kingdom also point out that the waste of soft drinks and bottled water via the kitchen sink is also relevant. Regarding the percentage of the purchased quantity, there is not so much lost via the kitchen sink, between 2-7% (CREM, 2013 and DEFRA, 2010). However, with the combination of the total usage, drinks indeed make up a significant portion of the total food loss with consumers, approximately 9% in Holland (CREM, 2010) and 17% in the UK (WRAP, 2013). In the UK, the greatest portion is from carbonated soft drinks. Given that the consumption of soft drinks and bottled water in Holland and the UK is lower in comparison to Belgium, then here too the loss should make up a significant amount (criterion 5).

## 2.3 Data consumption

On 1 January 2013, there were 6.381.859 Flemish people (FOD Economie—ADSEI). This number is used in the report when there is mention about the total number of people in Flanders. In the Food Footprint study that was carried out by the Department of Agriculture and Fishing (Danckaert et al., 2013), the total food consumption in Flanders is brought into focus. In Table 3 of that report (p.25), the daily intake per person per product group is given. The figures in this report are based upon the Belgian 'Voedselconsumptiepeiling' (VCP) of 2004 (De Vriese et al.,

2006). These figures are ten years old and are currently being updated in a running study. The results of this will be published in the coming years. The study at hand uses these figures as a departure point and is only updated for a few of the case studies (bread, soft drinks and bottled water). In the table, the product groups to which the selected case studies belong are underlined. Good databases on the usage of foodstuffs are essential. The VCP brought the food intake of Belgian into focus, on a very detailed level, and on the basis of a large representative test survey. VLAM annually publishes current figures on the household usage in Belgium and Flanders (originating from market research office of GfK Panel Services Benelux). Other sources such as professional unions also make figures available.

There are a number of important differences between the figures for household usage and that of the VCP. With the VCP, there is a unit 'kg per person intake', or in other words, the portion that is actually eaten. With household usage, it is 'kg per person purchased'. Figures for the VCP thus do not contain the quantity that is not eaten, including both the preventable food loss as well as the unavoidable portion, such as, for example, the wax crust of cheese, potato peelings, and so forth. The weight unit of the VCP takes into account water release, for example, evaporation while cooking vegetables or baking meat; and water intake, for example, with flour, rice, potatoes, and so forth. Household usage entails no usage via other channels outside of the home such as restaurants, or personal production such as greens from one's own garden. Although both databases are thus very welcome within the context of this subject, they cannot be merely methodologically combined. It is, however, indeed an interesting route for further research into food loss by consumers in Flanders. For the reference year 2013-14, detailed figures will soon be produced for the intake (VCP), household usage (VLAM, GfK and potentially other sources), and a measurement of the food loss in waste (OVAM). Primarily for the usage outside the home, home production, and the routes for food losses other than waste, there is currently no proper data available or subject of a running study.

Product(groep)	Dagelijkse inname (kg/pp/jaar)	Totale voedselinname in Vlaanderen (ton/jaar)
<b>Potatoes and grain products</b>	<b>95</b>	<b>603.793</b>
Potatoes and potato products	39	251.806
Pasta, rice and grains (dry weight)	6 [1]	35.686
<u>Bread (excluding pastry)</u>	<u>45 [2]</u>	<u>287.184</u>
Other	5	29.117
<b><u>Vegetables</u></b>	<b><u>53</u></b>	<b><u>338.226</u></b>
<b>Vegetable soups and juices</b>	<b>37</b>	<b>233.171</b>
<b>Fruit</b>	<b>44</b>	<b>282.088</b>
<b>Milk and calcium-enriched soy products</b>	<b>58</b>	<b>370.138</b>
<b><u>Cheese</u></b>	<b><u>11</u></b>	<b><u>67.086</u></b>
<b>Meat, fish, eggs, meat substitutes</b>	<b>59</b>	<b>379.689</b>
<u>Meat and meat-products</u>	<u>44</u>	<u>278.128</u>
Fish, shellfish and crustaceans	10	61.030
Eggs	4	26.555
Meat substitutes	2	13.976
<b>Spreadable and cooking fats</b>	<b>9</b>	<b>58.933</b>
<b>Category, other [3]</b>	<b>51</b>	<b>323.676</b>
Sauces	11	71.046
Sugar and sweets	13	84.210
Baked goods-cakes-pastry	26	168.420
<b>Subtotal foodstuffs</b>	<b>416</b>	<b>2.656.799</b>
<b>Drinks, alcoholic [3]</b>	<b>68</b>	<b>434.895</b>
<b>Drinks, non-alcoholic</b>	<b>287</b>	<b>1.830.353</b>
<u>Soft drinks (sweetened and light)</u>	<u>136 [4]</u>	<u>865.048</u>
<u>Bottled water</u>	<u>124 [4]</u>	<u>791.351</u>
Fruit juices and nectar	21 [4]	130.911
Tea and coffee (dry weight)	6 [1]	38.291
Bouillon (dry weight)	<1 [1]	4.752
<b>Subtotal drinks</b>	<b>355</b>	<b>2.265.248</b>
<b>Total foodstuffs and drinks</b>	<b>771</b>	<b>4.922.047</b>

*Table 1: Annual usage of foodstuffs per person (kg/pp/year) and the total usage in Flanders 2013 (ton/year)*

Notes for table 1:

General: due to rounding off, some totals may deviate. The tonnage of food intake per year in Flanders is based upon the population in 2013. In the original table, this was on the basis of 2011. [1] In the original table, the weights are inclusive of moisture intake from preparation. For the following categories the original weights are calculated from dry weight: pasta and rice (60% moisture); 50-75 gram coffee; 10-15 gram tea; and 10 gram bouillon per litre. [2] Communication



with VLAM (2014). In the Food Consumption Survey of 2004, this was still 50 kg/pp/year. The domestic usage is now 38 kg/pp/year of bread items. According to GfK, the home usage of bread in Flanders has decreased by 20% in a ten-year span! The consumption is probably somewhat shifted from home usage to usage outside the home, but certainly not to the degree that the 20% is completely compensated for. For the study, 10% in ten years time for the remainder is reached and for a shift to consumption outside of the home. [3] The chief categories 'Remainder' and 'Drinks' from the original table are partially amended. 'Alcoholic drinks' are removed from the 'Remainder' group and are now a separate main category. 'Sweetened drinks' is taken from 'Remainder' and is now under 'Non-alcoholic drinks'. 'Fruit juices', a main category in the original table, is now under 'Non-alcoholic drinks'. This is more consistent with the way in which market data is made available. [4] This is 'Bottled water' (124 litres) excluding tap water (collectively 227 litres 'Water' in the original table). [5] Press release VIWF, 8 June 2012 (market Figures 2011) and website VIWF, figures and trends of soft drinks and water.

## 2.4 Figures of food losses with consumers

The following Table 2 provides an overview of food losses as a percentage of the *edible* purchased quantity. This takes into account the definition of food loss and deals only with the edible portion. Non-edible food remains are not viewed as loss. The results on the basis of the OVAM baseline (2011) were compared with the results from other studies in Holland and the United Kingdom.

The figures for Flanders deviate greatly from the percentages of food losses such as those measured in Holland or the United Kingdom. In addition to the limited scope of 'waste' for the baseline in Flanders, every research uses a different methodology for inventory and analysis. A possible investigative approach for Flanders is to combine the results of the new Food Consumption Survey (2104 measurement) with market figures on the purchases of families (i.e. GfK or Nielsen) for the reference year 2014. Data on the purchase of food (in place of losses) in the hospitality industry and food services need to then again be inventoried separately. The premises that are made on the losses with consumers by the five case studies are introduced in the respective chapters. For bread, 18% is taken in line with the most recent figure of bread loss in Holland and is the same figure for loss of whole-grain bread in the United Kingdom. For soft drinks and bottled water, 7% is taken because of the more robust research methods that were used in the WRAP studies for drink loss. For spreadable cheese, 8% is taken. This is the average of 3% to 13% according to various studies. For cheeses, with limited expiration dates after opening the packaging, this is perhaps an underestimate. For the case studies of fresh meat (pork and beef) and meat-products (cooked ham) 10% is taken. This agrees with the lowest value of the study in the United Kingdom and that of the Dutch study. According to the British study, this is an underestimate for meat products and non-red meat. For the case study for lettuce, a range of 20% to 30% is used.

Product (group)	UK 2009 (DEFRA, 2010)	NL 2010 (CREM, 2010 & 2013)	VL 2010 (OVAM, 2011)
Potatoes	11 – 29%	23% 10% – 15% (2013)	
Pasta and rice	29%	24% resp. 39% 18% resp. 31% (2013)	1,3%
Bread (excluding pastry)	18 – 40%	20% 18% (2013)	2,2% incl. 'bakery...'
Grain products, other	7 – 18%	-	
Vegetables	24% (15 – 39%)	14%	2,4%
Fruit	20% (11 – 38%)	14%	1,8%
Milk and soy products	8 – 12%	13%	0,6% incl. 'cheese'
Cheese	12 – 13%	3%	
Meat and meat-products	10 – 15%	6% 9% (2013)	1,2%
Fish	10 – 13%	4%	
Eggs	10%	2%	
Spreadable and cooking fats	7%	23%	
Sauces	29%	23%	1,2%
Sugar and sweets	4%	4%	2,7%
Baked goods, cakes, pastry (chips)	15% (16%)	4% 10 – 15% (2013)	
Alcoholic drinks	6%	2%	
Soft drinks	6 – 7%	2%	
Fruit juices	14%	14%	
<b>Total foodstuffs (excluding drinks)</b>	<b>17%</b>	<b>14%</b>	<b>1,3%</b> (5,9 kg/pp/jaar)

*Table 2 : Food losses by the consumer (% of edible fraction of the purchased quantity)*

Notes for table 2:

DEFRA, 2010 The DEFRA study combines the results of the WRAP consumer survey 'Household Food and Drink Waste in the UK' (2009) with statistics on the food purchases by families 'Family Food Report' (2008). For some food products, the average weight is not mentioned in the table, on the basis of the usage figures in the UK, but rather the range (min.—max.). For example, for bread, 32% loss is the average weight in the UK. This is primarily due to the high usage of white bread, of which 40% is lost. In the case of whole-grain bread, there is 18% loss and 31% in the case of special breads. For potatoes, the loss for fresh is 29% and processed 11%. For vegetables, the average is 24%, but the differences are great from one category to the next, as for example with salads 39%, beans and greens 29—31%, processed vegetables 18%, carrots 17% and for onions, garlic, herbs and mushrooms 15%. For fruit, the average is 20%, but here too there are big differences: exotic fruits 38%, apples, pears, pitted fruits and citrus 22—29%; bananas 18%; grapes and soft fruit 11%-16%. With meat and meat-products, red meat is on the lower end of the range with 10% loss, while all other fresh meat categories and processed meat are on the upper end of the range with 14-15%. CREM, 2013 The CREM study combines the results of physical measurements of food in waste and GFT with the purchase figures of GfK. The losses of drinks via the kitchen sink are an estimate based upon what respondents have provided in the resident survey (CREM, 2010). This is a less

robust deviation than for the (solid) food. Of the 368 kg/pp/year that households have purchased for solid food (source: GfK), it ultimately appears that 66 kg are not consumed. 19kg is unavoidable and thus loss is 47 kg, or 13,6%, of edible food. OVAM, 2011 This deals with a baseline here of food loss in the fraction of waste. The quantity 'per year per inhabitant in kg' of Table 9, p. 39 of the study 'Food Loss in the Perspective of the Chain' (OVAM, 2012) are expressed as a percentage with respect to the intake of food in Table 2 above (loss divided by intake + loss). In the baseline, potatoes are included in 'vegetables'. 0,58 kg/pp/year 'Prepared meals' are allotted 45% for 'potatoes', 26% to 'vegetables' and 29% to 'meat' and 'fish', according to the configuration of these categories in the food consumption figures of Table 2. For food loss via other routes, such as GFT, kitchen sink, animal feed, no figures are available. VLACO controls the Figures for vegetables and fruit in the GFT portion (VLACO, 2010), though greatly diverge and make no distinction between loss and by-product.

## 2.5 Figures of Food Losses in Production and Distribution

Figures on food losses per product category are not available for Flanders or Belgium. According to reports by Comeos, the losses are limited in Belgium in the distribution sector to 2,5%. Example (see Figure): Colruyt recent published on its sustainability platform, [www.simplysustainable.be](http://www.simplysustainable.be), figures on food loss in its chain stores Colruyt, Okay and Bio-planet and on the concrete actions that it undertakes to limit this. In 2013, 97,6% of its fresh products was effectively sold. The 2,4% of unsold fresh products were further evaluated, of which 2,1% were still destined for human consumption (and thus according to the definition, no food loss).



Figure 3: Example of food loss evaluation for Colruyt (source: [www.simplysustainable.be](http://www.simplysustainable.be))

For figures on losses in distribution on the level of product categories, studies in other countries were thus also consulted. Comeos, as a member of the advisory committee, asked a number of its members whether these figures are also representative for supermarkets present in Flanders. The Table 3 below provides an overview of these figures. With the following, it is necessary to take into account the interpretation or comparison of the figures. Often one uses the definition of loss in place food loss. Under the term of loss is understood: (euro—not kg) value loss of fresh products in the chain by way of quality loss. Within this definition, loss is the discarding of non-longer saleable stock or the reduction of preventing this. Something could be completely lost with regards to value, for example, when it is given away at no charge, but is not

food loss because it is still eaten. Percentages of loss are thus always higher than percentages of food loss. The figures in the studies of Mena, et al. (2011) and INCPEN (2013) deal with loss. With Eriksson, et al. (2012), it deals with the percentage of food loss. The figures that the retailer Tesco (2013) reports in the United Kingdom are for food loss. The studies all have a different scope. Both geographically as well as the limitation of the chain: Mena, et al. (2011) is based upon a measurement with actors in the chain producing up to and including retail in the United Kingdom and Spain, INCPEN (2013) is a measurement of various retailers in the United Kingdom, and Eriksson, et al. (2012) is with various retailers in Sweden. The study by Eriksson, et al. (2012) communicates the most detailed figures on the level of various products. The expert T. den Hertog of 'Q-Point' gives the following global estimation of the percentages of loss of a number of important product groups: potatoes, fruits and vegetables 7%, fresh meat 5%, meat-products, cheese and dairy 3 to 4%. According to den Hertog, 5% of the food goes to waste by the retailer itself and some 10 to 15% in the preceding links of the retail chain (source: [www.q-point-bv.nl](http://www.q-point-bv.nl), article 'Derving in voedsel; hoe los je het op', 2006). The figures that the retailer Tesco has brought out have caused quite a commotion. Not so much over their own contribution to the chain, but rather over the higher contributions elsewhere in the chain by certain food products. Outside of bread, of which Tesco loses 4%, the percentage of loss for all other food products at Tesco is 1% or less. Primarily, the loss of pre-cut lettuce of which more than 2/3 is lost in the chain, has caused a stir. After the initiative of Tesco in the United Kingdom, four other large supermarket chains in the United Kingdom have announced that beginning in 2015, they will also publish food losses with their suppliers of food products up to the store itself (The Guardian, 29 January 2014).

Product (group)	FEVIA, NIB (2013) <i>Belgium Step: food industry % loss</i>	Mena, et al (2011) <i>United Kingdom and Spain Step: retail and delivery % spoilage</i>	INCPEN (2013) <i>United Kingdom Step: retail % spoilage</i>	Eriksson, et al (2012) <i>Sweden Step: retail % loss</i>
Pasta en rijst				
Bread (excluding pastry)	8,6% milling 2,31% bakery	>7%	4,00%	
Grain products, other				
Potatoes	0,77% processed	3 – 7% fresh <1% processed <1% frozen >7% pre-cut		2,2% fresh
Vegetables				5,0% fresh
Fruit			2% bananas 2% citrus 4% tomatoes	3,8% apples 5,5% citrus 5,7% bananas 6,6% tomatoes 10,4% paprika 10,7% lettuce
Milk and soy products	1,41% dairy	1 – 3% dairy >7% yoghurt		0,15%
Cheese			0,3 – 0,8%	0,2 - 0,8%
Meat and meat-products	0,85% meat and fish	>7%	2% chicken	1,5 – 2% pork 0,33 – 1% ground beef 0,5 – 0,6% chicken 1 – 2% sausage
Fish		5 – 7% fresh <1% frozen	3% salmon 12% tuna	
Eggs			2%	0,4%
Spreadable and cooking fats		3 – 5% margarine		
Sauces		>7% vinaigrettes		
Sugar and sweets	1,11% chocolade 2,78% suikerwaren			
Baked goods, cakes, pastry				
Alcoholic drinks	7% bier			
Soft drinks	0,69%	<1%		
Prepared meals	6%	>7% 1 – 3% pasta sauce 1 – 3% frozen pizza	6% pizza fresh	

*Table 3: Losses in the Chain of Production and Distribution*



## 3 Methodology

### 3.1 Food loss and packaging in the perspective of the chain

A calculation model was developed that allows for:

- presenting the cumulative climate impact of the portion of food losses in all steps of the chain as a separate cluster in the results (symbol 'L');
- presenting the cumulative climate impact of the portion of food that is eaten as a separate cluster in the results (symbol 'F');
- presenting the climate impact of packaging (symbol 'P') in relation to the food intake and loss in the results;
- and, whereby the complete life cycle of the food product is viewed, from the 'Agriculture and Horticulture' phase up to and including the 'Consumer' phase; including the impacts connected to transport by the consumers, the preservation, preparation and the food loss that takes place with the consumers;
- to evaluate the conversion of one food-packaging system (1) to an alternative food-packaging system (2) with properties that can reduce food loss (i.e. extended expiration date), yet with a higher environmental impact connected to the packaging itself.

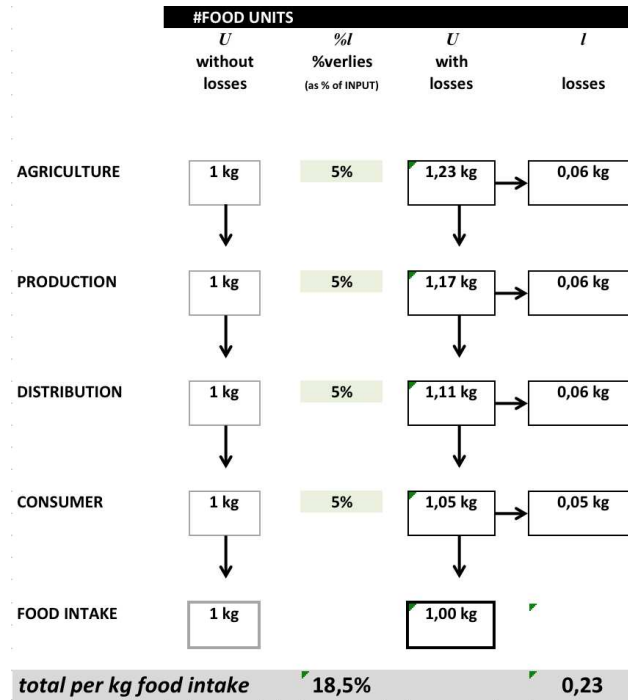
This is further worked out in the following sections of the chapter.

#### 3.1.1 Perspective of food loss in the entire chain (Life Cycle)

Food loss occurs in every step of the chain of a product. In existing LCA studies of food, one finds, moreover, data again in the report, usually in the chapter 'Inventory' of the inputs and outputs connected to the steps in the process. The percentage of fall-out or loss of a step in the process is inventoried as an output factor or as a measurable by-product of the step. Publications of existing LCA's of food are not always as transparent or as how one has inventoried the food losses. In the reporting of existing LCA studies, in the chapter 'Results', the impacts are then given per cluster of the process steps, life-cycle phases, or product components and packaging. One manner of presenting is chosen that is most meaningful in the function of the objective of the LCA study involved. The impacts related to the food portions that are lost in the chain are for the most part no longer visible as a separate cluster in the presentation of the results. In the current study, there is a calculation model that allows for presenting the cumulative climate impact of food losses in the chain as a separate cluster in the results. The specific objective of this study is primarily intended to make the relationship between the related impacts to food intake, related to food loss and related to packaging more comprehensible, rather than the relationship amongst the various life-cycle phases. The 'functional unit' in LCA studies of food is usually determined to be 'per kg produced product' or 'per kg sold product', whereby in the latter case, the losses in the distribution chain and retail points are indeed taken into account, whereas they are not in the former. Very seldom is the functional unit 'per kg consumed product', whereby the losses at the consumer level are also accounted for. As the scope of an LCA study does not contain the consumer, then also the related impacts, for example, refrigerated storage at home and transport by the consumer for shopping, are not factored in.

### Illustrative example:

In the following Figure 4, an illustrative example is seen. The division in the phases of the life cycle are vertical. Horizontal is the following in the columns: the number of food units (U) in a chain without loss; an estimate of the percentage of loss (%I) in this step of the chain as a percentage of the input in this step; the number of food units (U) in the chain with losses; and the loss (I) per step.



*Figure 4: illustrative example, food losses in chain perspective*

In the example, in each step of the chain 5% of the input in the step involved is lost. In the phase 'Agriculture and Horticulture' one needs to produce 18,5% more crops than necessary for the final demand (intake), knowing that here in each step of the chain 5% is lost. The total food loss in the chain is calculated according to the following formula:

$$\prod_{i=1}^n \left( \frac{1}{1 - \%I_i} \right)$$

The cumulative climate impact of the portion of food losses in all steps of the chain (symbol 'L') is the difference between the total impact of the chain with losses and the total impact of the chain without losses. In the example, this is the sum of the impact of 0,23 kg food units that one has to produce extra in the phase of A&H; 0,17 kg that one has to process in the food industry; 0,11 kg that one has to provide for in the distribution; and 0,05 kg extra that the consumer must purchase in order to ultimately consume 1 kg. In addition to this comes the climate impact of the processing of stream of losses from each phase.



### 3.1.2 Perspective relation of food loss and packaging

Because the objective of this study contains all phases of the life cycle, up to and including food intake and loss by the consumer, and because the specific inquiry of this study is, 'what is the relationship between food loss and packaging in the perspective of the chain?'; it has been chosen to present the results as the total impact related to food intake (symbol 'F') to food loss (symbol 'L') and to packaging (symbol 'P').

The sum of all 3 factors: 'F + L + P', is the total life-cycle impact of a food product, including food losses.

The sum of the food intake and packaging: 'F+P' is the total life-cycle impact of a food product, without losses in the chain. This is, in other words, a theoretical optimum for a chain in which all food losses, which per definition are 'avoidable', are eliminated. In the following Table 4, a more detailed overview is given on the combination of the components F, L and P.

Related to food intake (F)	Related to food loss (L)	Related to packaging (P)
Foodstuffs, portion consumed, complete chain (including possible steps of food processing, for example, to extend the expiration period)	Foodstuffs, portion of food loss, complete chain up to and including the step where the loss occurs	
	Foodstuffs, portion of food loss, impact of process and avoidable impact valorisation as animal feed, compost, etc.	
	Packaging, related to portion of food lost, up to and including the step in the chain where the loss occurs (including impact of production, recycling, energetic valorisation)	Packaging, related to portion consumed, complete chain including packaging in intermediate steps of the chain (including impact of production, recycling, energetic valorisation)
Transport, related to weight/volume*food (portion of food intake)	Transport, related to weight/volume*packaging and food product (portion of food loss)	Transport, related to weight/volume*packaging (portion of food intake)

*Table 4: Combination of the components F, L and P*

The impact of food loss ('L') consists of two components: the impact related to the quantity of food that is lost, indicated as 'L(F)', and the impact of the amount of packaging that also could be avoided should there not be food loss, is further designated by 'L(P)'.

#### Illustrative example:

Imagine a food product with an environmental impact of 100 kg CO<sub>2</sub>e per kg (F) and an environmental impact of the packaging of 10 kg CO<sub>2</sub>e per kg of packaged product (P). In a situation without loss, the total environmental impact of the product packaging system F + P = 110 kg CO<sub>2</sub>e. Suppose that a consumer eats an average of 80% of the product, 20% is lost. In order to consume 1 kg, the consumer thus need to purchase 1,25 kg (or 1/80%) of this food product. By a functional unit 'per 1 kg intake' 0,25 kg of the food is lost. The impact of the system is 110 kg CO<sub>2</sub>e per kg intake without loss, and 137,5 kg CO<sub>2</sub>e per kg intake by 20% loss, or  $1/(1/20\%)*(100+10)$ . The impact related to loss (L) is 27,5 kg CO<sub>2</sub>e per kg intake, and 2,5 kg CO<sub>2</sub>e per kg intake related to the avoidable quantity of packaging.

### 3.1.3 Trade-off point

#### 3.1.3.1 General Principle

The trade-off is the lessening of food loss that must at least be realised so that the total life-cycle impact of the existing system is equal to the total life-cycle impact of another system (for the same type of food product). Or, in a formula with the components F, L and P, and whereby 1 stands for the existing system and 2 for the new system (F is the same in both systems):

$$F + L1 + P1 \geq F + L2 + P2$$

In this comparison, it is thus most likely that the impact of the packaging in the second system is greater than that of the reference system ( $P2 > P1$ ), but that from this total system approach is to justify as that that can be compensated for by a minimal reduction of the impact of the food loss:

$$L1 - L2 \geq P2 - P1$$

#### 3.1.3.2 Communication on the basis of calculated trade-off

For example for bread, this translates into the following result and communication example directed at citizens:

'Buying smaller loaves of 400g more frequently than larger ones of 800g is justified from an environmental standpoint when it leads to at least 1/2 slice less loss (per 800g loaf, approximately 22 slices), and on the condition that this does not lead to extra automobile usage'.

Arguments for this method of communication are various.

- In this manner, one speaks to the consumer personally, taking into account his own lifestyle and user context. The one consumer will lose more than a half of a slice, while the other consumer has a larger family or the average bread consumption is higher and shall lose less than a half of a slice. Measurements are, however, context dependent and not to be generalised.
- We view a statement as robust if there are hardly any exceptions possible that could counter the provision. In the example used of buying smaller breads in place of larger ones:
  - the trade-off points are achieved on the basis of sample surveys of various large and small bread packaging. For the general design guideline; the highest obtained trade-off point is used rather than the median. Moreover, if a new bread packaging design can yield at least this percentage of bread loss reduction, then the total environmental impact of the new product packaging system is likely to be even lower.
  - one can clearly identify and communicate about possible negative side-effects (or rebound effects) and translate this to undesired behavioural changes. In the current example, a possible rebound effect of buying smaller breads is an increase in purchasing frequency, possibly automobile usage and thereby related impacts, thus the guideline is complemented with: '*...and on the condition that this does not lead to extra automobile usage*'.

- The message is primarily intended as activating and presents concrete provisions, in the sense of: 'if this is the case with you, there is perhaps then a possibility for you to do something'. By placing various options alongside each other, one gives the consumer the choice that can determine what the most ideal solution is to implement in the case of his or her situation. For example, the consumer does not have the time to go buy bread several times a week and if he or she can then accept the difference in quality with fresh bread, then he/she can choose for the option: 'buying bread for one week and freezing it is from an environmental standpoint to justify as that leads to at least one quarter of a slice less loss (per bread loaf of 800 g, average 22 slices)'.

### 3.1.3.3 Calculating the trade-off point

Sufficient packaging that fulfils its function to protect the product is quickly perceived as over-packaging, and the focus switches to the packaging waste. With too little packaging that inadequately fulfils its function, the focus turns to, in this case, food loss. This is what one understands as 'the packaging paradox'. The optimal packaging design lies at the trade-off of where just enough packaging is used to adequately protect the product. This can be illustrated with the 'Soras Curve'. This principle was also discussed in the study Food Loss on the Perspective of the Chain (OVAM, 2013).

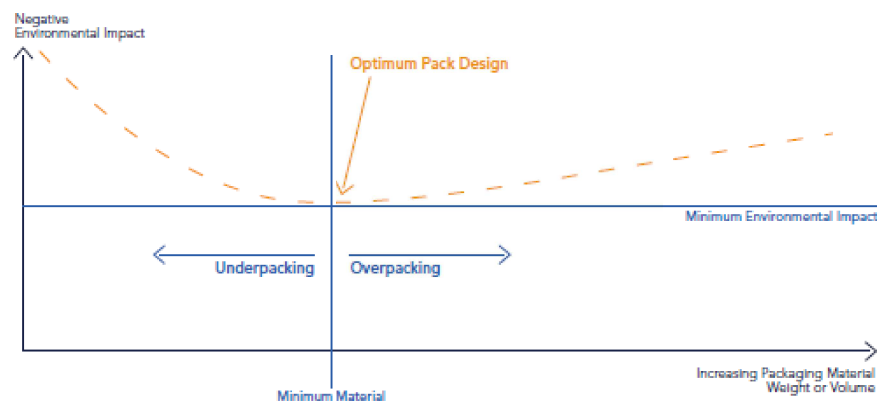
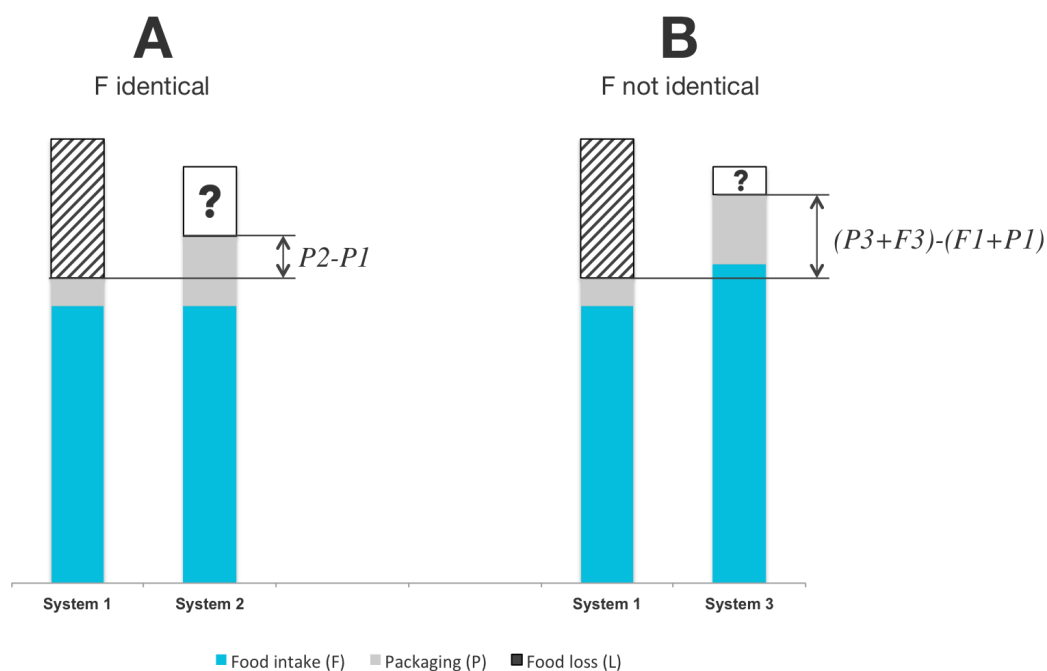


Figure 5 : Soras Curve (bron: Innventia AB)

Calculating the optimal packaging amount for food products according to this principle is, however, a difficult task. In order to calculate a point on the curve, it is necessary to be able to plot a measurable relationship between the packaging metric on the one hand and the degree in which this shall add or reduce the food loss on the other hand. This relationship, however, is not unequivocal. For food loss has more causes than expiration date alone and also consumer behaviour plays a large role in this. The connection is thus only able to be determined empirically with large, representative consumer panels and existing options. New innovations are difficult to test on a large scale.

In the formula  $F + L + P$ , the impacts of  $F$ ,  $P1$  and  $P2$  are to be determined and calculated. Regarding food loss  $L$ , studies and measurements in various countries are available. For Flanders, an overview is given in the report 'Voedselverlies in ketenperspectief' ('Food Loss in the Perspective of the Chain') (OVAM, 2013). Nevertheless, numbers on food loss ( $L$ ) are general by nature (i.e. percentage loss per food category) and there is no distinction made between packaging methods. In order to avoid poorly supported assumptions in the sense of: 'the estimated food loss with large packaging is 10% and with small packaging 5%, and thus a yield of 5%', another approach is chosen in which these unknown parameters are eliminated.



*Figure 6: Illustrative example*

With the aid of an illustrative example (see figure, left side, 'situation A'): system 1 and 2 are two different packaging systems for the same food product. The impact of the packaging of system 2 ( $P2$ ) is more than the double of system 1 ( $P1$ ). The food loss of system 1 (shaded) is based upon generally available figures, and is, moreover, strongly dependent upon situation to situation. The loss of system 2 is, on the basis of a qualitative judgement, less, but by how much exactly is difficult to determine. The difference in estimate between  $(P1 + L1)$  and  $(P2 + L2)$  is thus not reliable. The difference  $(P2 - P1)$  is indeed to be calculated. This is the difference that, in absolute terms, MINIMALLY must be compensated for by an equivalent to avoid the impact of food loss. In relative terms, this is calculated as the following:

$$1 - \frac{(F + P1)}{(F + P2)}$$

Illustrative example:

The same food product is available in a large or in a smaller portion of packaging. Per kg of food product smaller portion sizes implies more packaging material per kg of packaged product. This results in the following environmental impacts F and P.

	F (impact 1 kg food product)	P (impact of packaging per kg packed product)
Product in large package P1	10	5
Product in small package P2	10	10

In the example, the impact (per kg of food product) of the smaller packaging (P2) is double the amount of that of the larger packaging (P1). The user indeed encounters more loss of product from the larger packaging and experiences as good as no loss with the usage of the smaller packaging. Is it now then of interest for the user to convert to the smaller packaging? The total impact per kg intake (effectively consumed) in the case of the smaller packaging without loss is 20 per kg. The total impact per 1 kg intake in the case of the larger packaging, by which 25% is lost, is also 20 since the user must purchase 1,33 kg of food product (25% of 1,33 kg or 0,33 kg is lost). 1,33 times the impact of the food product in the larger packaging, or 1,33 x (10 + 5), is also 20. Starting with at least 25% less loss it is thus of interest for the consumer to switch over to the alternative, smaller packaging. In the case that that can be achieved, then the total impact of the product-packaging system with smaller packaging is smaller than in the original situation with larger packaging. If in the original situation the loss is less than 25%, then consequently switching to the smaller packaging will increase the total impact.

### **Interpretation of the Food Product (and System Approach)**

Discussions may arise with the comparison of various system options or packaging options for the 'same' food product. However, what is the 'same' food product? For example, can one really compare carrots in bulk (unprocessed), carrots in the can or jar (processed), pre-cut carrots from a deep-freeze pack (processed, deep-frozen), fresh, pre-cut and washed carrots in a plastic packaging, or cooked carrots in a vacuum-sealed plastic packaging on the level of food loss and impact as if this is dealing with the same end product? The type of carrots is often different (i.e. 'extra fine' in can or jar). By the processing that the product undergoes, the taste changes and thus the end product as well. For example, Green Beans in a jar or can from the deep freezer can indeed be eaten without cooking, because these are already cooked. In case of products already mixed and washed (i.e. wok vegetables), the consumer not only purchases the products themselves, but also buys himself time and taste. In people's perception, such a 'ready-made dish' is not the same as a dish that is 'completely self-made'. All of the options are also not available for the consumer out of season: in place of fresh, locally produced, one has the choice of imported, or processed in a can or jar with a longer expiration date on the basis of locally produced products, and so forth. For other categories this is also true. Can the taste of bake-off bread baked at home be compared to a fresh loaf of bread from the baker? Other purchasing considerations are at play here.

The determining of a trade-off is, in principle, also possible with system innovations that are more disruptive for a value chain (and go further than an other packaging system with logistical consequences). In such a case, the impact of the packaged food (F) is not the same, and it is necessary to differentiate between F1 and F2 (see figure, right side, 'situation B'):

$$1 - \frac{(F1 + P1)}{(F2 + P2)}$$

A concrete example is the water usage related to lettuce in bulk and pre-packaged, cut and washed lettuce. In the food industry, water usage is about 0.4 litre of water per kg of lettuce and is greatly dependent upon the techniques that are applied (Stoessel, et al., 2012). The washing of the lettuce at home under a running tap or a 5 to 10 cm-deep filled sink is easily five to ten times that amount. The impact not only shifts to another phase in the life cycle, but it also has to do with other quantities. On the other hand, the loss in the store of vegetables in bulk should be lower than with pre-packaged vegetables (Mena, et al., 2011). In the study at hand, the difference between the systems is primarily dealt with qualitatively, and where figures are available, quantitatively.

### **3.1.4 Perspective of the Life Cycle**

This study makes use of the figures and results of other LCA studies on food products and packaging. For the most part, this deals with the scope of 'cradle to gate', for example, from the field up to and including production. Because the goal of this study encompasses all phases of the life cycle, the scope is inclusive of the phases of distribution, retail point and consumer. The most important impacts related to the phases of distribution up to and including the consumer are refrigerated storage, transportation, food preparation and the refuse processing of the food losses and used packaging. In the chapters dealing with the case studies (chapters 4 thru 8), under the subtitle 'Inventory', an overview of data from the most important sources dealing with the product category is always given. In the chapter, an overview is given regarding the most important data sources dealing with the consumer transport steps, refrigerated and freezer storage in retail and at the consumer's home, and the phase of refuse processing of household

refuse (food losses and packaging). Because the geographical and time frame of available LCA studies of packaging and food can deviate from the situation in Flanders, as much usage as possible is made with local sources and studies, or, in the event they are not available, studies that are as representative as possible for the situation in Flanders.

#### 3.1.4.1 Packaging

The impact of packaging encompasses the production of the packaging materials and the refuse processing after use (recycling and recovery). The impacts are calculated on the basis of various LCA databanks and software such as Ecoinvent (version 2.2) and Simapro (PRé Consultants). Data for the production of plastic and metal packaging were obtained, when available for the specific materials, from Plastics Europe and World Steel. In addition to the LCA software Simapro, for some case studies, the same calculations were made with the Instant LCA software (RDC Environment) and the results were compared for consistency. For household packaging waste, the contemporary recycling and necessary use as reported in the annual report of Fost Plus 2013 (see table) were used. The impacts and avoided impacts related to recycling and energy recuperation were calculated by VITO for OVAM in the project Ecolizer (2013).

Material	% market (estimate)
<b>Paper-cardboard</b>	<b>89%</b>
Paper-cardboard	89%
Drink cartons	88%
<b>Glass</b>	<b>104%</b>
<b>Plastic</b>	<b>35%</b>
Bottles and jars	71%
<b>Metals</b>	<b>98%</b>
<b>Others, namely PE, PP and (E)PS</b>	<b>1%</b>
<b>Total Recycling</b>	<b>81%</b>

Table 5: Recycling Percentages (Fost Plus annual report 2013)

#### 3.1.4.2 Retail Phase

##### Cooling Equipment

The most important impacts related to the retail phase are the energy usage and loss of coolant by cooling equipment. Most recent factors for the energy use of cooling equipment can be found in the European study in the context of the Ecodesign Directive (2009/125/EC) for commercial cooling equipment (JRC, 2014). Cooling equipment typically contain the coolant R404A (GWP 3922 kg CO<sub>2</sub>e) or R134a (GWP 1430 kg CO<sub>2</sub>e). Since the beginning of 2000, there are consistently more coolants used with a lower GWP (i.e. R744 is CO<sub>2</sub> with GWP of 1) and this will likely increase because of legal and other incentives. ERM and the University of Ghent (2011) calculated for the distribution over approximately 100 km (including secondary packaging), the temporary cooled storage in a distribution centre and the cooled storage in a warehouse (3 days) a climate impact estimated at 0,17 kg CO<sub>2</sub>e/kg meat on the basis of generic data. For the distribution over approximately 100 km (including secondary packaging), the

temporary storage in a distribution centre and the storage in a warehouse (7 days), the climate impact is estimate at 0,05 kg CO<sub>2</sub>eq/litre milk based on generic data. These figures are used for the case studies for beef, ham and spreadable cheese.

### 3.1.4.3 Consumer Phase

#### Consumer Transport

The distance that the consumer covers going to the store and the mode of transportation used are based upon the 'Onderzoek Verplaatsingsgedrag Vlaanderen' (Departement Mobiliteit and Openbare Werken, 2013). This report contains the average number of kilometres covered per person per day, divided up according to the chief mode of transportation and pattern. One of the patterns seen is 'shopping, running errands'. The Onderzoek Verplaatsingsgedrag Vlaanderen provides no information on the portion that falls on the purchasing of food. The distinction between purchasing food or non-food items is made by JRC (2008) on the basis of the transportation statistics of the United Kingdom. Here too, figures are given per primary mode of transport. We use this division to apply to a portion of the displacement made for 'shopping, running errands' from the Onderzoek Verplaatsingsgedrag Vlaanderen. The results of this calculation are reproduced in the table below. With shopping with the auto while underway to or from another destination (i.e. home-to/from-work traffic), the impacts related to auto usage are attributed to the primary destination and not on shopping. The total climate impact of this transportation is 85 kg CO<sub>2</sub>e per person per year.

Mode of transport	Grocery shopping (A) km/pp/year	Climate impact factors (B) g g CO <sub>2</sub> e/km	Climate impact (A x B) kg CO <sub>2</sub> e/pp/year
On foot or by bike	50 (11%)	0	0
Moped/scooter	<1	108	<1
Automobile	308 (71%)	274	84
Automobile (passenger or other destination)	66 (15%)	0	0
Public transportation	13 (3%)	26 – 104	1
<b>Total</b>	<b>436</b>		<b>85</b>

*Table 6: Climate impact for consumer transport for food shopping*

#### Food storage

An environmental impact is only calculated for storage in the refrigerator or deep freezer. An average deep freezer with the capacity of 200 litres uses approximately 250 kWh per year. In the event that this deep freezer is half full, this comes to about 0,00685 kWh/litre\*day. An average refrigerator (without freezer) with a capacity for 200 litres uses approximately 150 kWh per year, which comes to (being half full) 0,00411 kWh/litre\*day. The environmental impact of Belgian electricity (low voltage) is calculated with the help of the Ecoinvent v2.2 database and the ReCiPe impact assessment method. ERM and the University of Ghent (2011) calculated that for a litre of milk, which after opening stands in a refrigerator for approximately 3 days, the climate impact is more or less 0,02 kgCO<sub>2</sub>eq/product. For meat (1 kg) that is kept for 3 days in a refrigerator and prepared for 30 minutes, the impact would be about 0,12 kgCO<sub>2</sub>e/kg. These figures are used for the case studies of fresh meat, ham and spreadable cheese.



### **Food Preparation**

The environmental impact of preparation by the consumer is strongly dependent upon the food product. In order to calculate this, the electricity or natural gas used during the preparation is estimated first. The table below gives a few figures.

Method of preparation	Electricity usage (kWh)
Pre-heated oven	0,4 kWh
Keeping oven at temperature for 1 hour	0,5 kWh
Bread machine	0,35 kWh per kg bread
Toaster oven	0,012 kWh per minute

*Table 7: Energy usage related to food preparation*

The environmental impact of Belgian electricity (low voltage) and natural gas (including emissions with use) is calculated with the help of the Ecoinvent v2.2 database and the ReCiPe impact assessment method.

#### **3.1.4.4 Phase waste processing of food losses**

There were four routes investigated for the processing of food waste: via refuse, via fraction GFT (this is vegetable, fruit and garden waste), home composting and the kitchen sink.

It is herein accepted that the refuse is incinerated. Data from the average emissions and waste of Flemish household waste incinerators come from the 'Inventaris van de Vlaamse afvalverbrandingssector' (OVAM, 2006). It is taken into account with the energy production. We surmise that 7% of the caloric input in household waste incinerators is rendered as electricity and 52% as steam.

The GFT and home composting routes are applicable for the case studies for fruit and vegetables, and we assume, although it is not permitted, that a share of bread and meat (products) also end up in the GFT. It is presumed that 17% of the GFT-waste is processed in a GFT-digesting installation with post-composting and 83% in a GFT-composter installation (current mix at GFT-processing installations). The figures on energy consumption, emissions to the air and materials and waste that are released during the composting/digesting of GFT-waste come from University of Ghent (2006), Vlaco (2009) and OVAM (2006, 2009). It is accepted that natural materials are economised thanks to the intervention of the produced compost and energy. The calculation for home composting is based upon that of the GFT-composting installation with only a few differences: there is no electricity needed, and the average emissions of ammonia and nitrous oxide are higher (adapted according to Martínez-Blanco, et al., 2010). For food waste that ends up in the kitchen sink (case studies of soft drinks and bottled water), it is presumed that this is diluted 100 times, and consequently the treatment of wastewater with average waste load is used from the Ecoinvent 2.2 database. ERM and the University of Ghent (2011) put forth that the waste processing of non-consumed food shall cause little greenhouse gas emissions. It is primarily the production and distribution of the quantity of non-consumed product that has an important influence on the results in the case of the impact calculated per functional unit '1 kg intake'. To illustrate: in the case that 15% of the sold meat products (such as in the case study of ham) are thrown away by the consumer, than  $1/(1-15\%)$  or 1,18 kg ham needs to be bought in order to arrive at the functional unit of '1 kg intake of ham'. The impact of

the production and the distribution of 180 grams of ham could have been avoided and is a much heavier burden than the 180 grams of ham going to the rubbish bin.

## 3.2 Climate Impact

There are various methods that are each directed at a specific environmental-impact category, such as: land use, water consumption (Water Footprint), climate impact (Carbon Footprint), smog, cumulative energy consumption, acidification, eutrophication, emissions from hydro-fluorocarbons, ozone layer depletion and so forth. In addition, there are methods that integrate all of these impact categories into a single score, such as the RECIPE-method. This last one is used, for example, in the eco-design tool, the OVAM Ecolizer. In the best-case scenario, it is possible to present packaging solutions that both reduce the impact of packaging as well as food loss. However, in some situations, an addition of the impact of the packaging can be justified if it reduces more impact related to food loss. Specific packaging measures, presented in this study, are paired with an addition to the environmental impact of packaging. In order to weigh the addition of the impact of the packaging against a reduction of the impact of food loss, two core indicators are calculated in this study (see chapter 3.1.1):

1. The environmental effect of the packaging with respect to the packaged food product;
2. The minimal reduction of food loss needed to compensate for the additional environmental impact of the packaging (trade off). In this case, the impact of the total system packaging and packaged product is lower than the original situation.

The choice of the impact categories also needs to be meaningful in the function of these core indicators. With the calculation of the trade off point based upon environmental-impact categories that are chiefly related to agricultural processes and in lesser degree to industrial processes and packaging materials (i.e. land usage), each packaging measure should be accountable. The relationship between various impact categories and the ratio impact of packaging with respect to food was also the subject of the study by Williams and Wikström (2011). This concluded that if a packaging measure can cause a reduction of the cumulative energy consumption of the total system of food and packaging, then relatively this will mean a yet even greater reduction of other impact categories such as climate impact, acidification and eutrophication. Therefore, this can be sufficient in studies on packaging measures to use the cumulative energy consumption as the only impact category. The study (Williams and Wikström, 2011) distinguished this somewhat in the sense that an addition of energy consumption or climate impact of the total system of food and packaging sometimes can be justified if this can mean a substantial reduction from another relevant environmental impact such as eutrophication or land use. This appeals for methods with impact categories factoring in relevance such as the RECIPE-method. This study makes use of the results of other available LCA studies on food products and packaging. What is worth noting is that in nearly every available LCA study on food and packaging, results are to be found on climate impact, and results on the cumulative energy consumption are much less common. Therefore in the study at hand, climate impact has been chosen to be used as a category. Every study on food currently uses its own choice and set of impact categories. This is because a standard for the carrying out of LCA studies for these products does not yet exist. Product Environmental Footprinting (PEF) of food products currently in full development and for nine food products there are PEF pilots begun in June 2014 (see the website of the European Commission, DG Environment<sup>1</sup> for more information about this).

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1 <http://ec.europa.eu/environment/eussd/smgp/>

Further support for the choice of climate impact as an impact category:

- The adaptation to the current importance for climate impact and the suppression of greenhouse emissions.
- CO<sub>2</sub> equivalent (CO<sub>2</sub>e) is, on the one hand, strongly related to the emission of CO<sub>2</sub> as a consequence of the burning of fossil fuels or carbon-based materials. There is thus a strong correlation of this with other impact categories such as cumulative fossil energy consumption, and other important effects related to the burning of fossil materials.
- On the other hand, CO<sub>2</sub>e also indicates to the forming of greenhouse gases such as methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O), which are important emissions from cattle ranching, among others. One gram of nitrous oxide yields an even greater contribution to the warming of the climate than approximately 300 grams of CO<sub>2</sub>; and with methane, this is around 25 CO<sub>2</sub>e.
- The impact of Land Use Change (LUC) can also be taken in the determination of the climate impact of food products. The calculation method is accepted by the current standards and guidelines (PAS2050, ISO14047, and so forth). The references for food products in these products take into account the climate impact of land use change.

The quantitative inventory figures and consequent results from this are held up to scrutiny for a number of quality criteria such as the data on which the figures are involved and the applicability for the local context: consumption of food products in Flanders, agriculture and horticulture sectors and the food industry in Flanders. The life cycle of climate impact of a food product and packaging differs per country

- *Electricity production:* a process that uses electricity coming from windmills and nuclear power plants produces less CO<sub>2</sub>e than that which comes from coal and gas power plants. Identical products with the same underlying processes and energy consumption can thus have a different climate impact because there is the question of another electricity mix, and this is primarily land and supplier dependent.
- *Transport methods and distances:* product chains contain many steps, amongst which is transport. An LCA study shows that Spanish tomatoes consumed in the United Kingdom have a different climate impact than Spanish tomatoes on the store shelf in Flanders. Or, consider, beans imported from Kenya by aeroplane rather than those imported by ship, for example. Lettuce heads bought via the short chain have a different impact than via the retail chain. For an identical product, these differences can be very chain-specific.
- *Waste processing:* this varies greatly from country to country. For example, in the United Kingdom, much is still dumped, while in Belgium and Holland, the waste is incinerated and recovers energy. In the latter countries, the total percentage of collection and recycling is high, yet the manner of collection and recycling for specific type of packaging, is again a different story.

### 3.2.1 Inventory (Reference Studies)

Figures on the climate impact related to meat and milk, specifically coming from Belgian (or Flemish) farms, can be found in two studies. The first study is the European study, 'Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions' (JRC, 2010). The specific situation per member state, including Belgium, is illuminated in detail. The second study is the Carbon Footprint study by ERM and the University of Ghent (2011) upon commission by the Department of Agriculture and Fishing, Monitoring and Study division. The figures of the latter are used as a reference and encompass both the agricultural phase as well as the processing phase of meat and milk. These figures were used in the case studies of spreadable cheese, cooked ham and fresh beef. An overview of these figures is given in the table below.

<b>kg CO<sub>2</sub>e</b>	<b>Milk</b>	<b>Beef</b>	<b>Pork</b>
<b>JRC, 2010</b>			
Per kg carcass		19,76 18,01 – 28,64	7,12 6,37 – 11,07
<b>ERM &amp; UGent, 2011</b>			
Per kg unprocessed milk, carcass	1,02 0,9 – 1,23 0,8	17,9 16,3 – 20,5 15,8	4,7 4 – 5,3
Per kg UHT milk, meat	1,04 1,03 – 1,36	22,2 22,2 – 25,4 19	5,7 4,8 – 6,4
Additional processing, per kg UHT milk, meat	0,13 (13%)	0,19 (0,01%)	0,22 (4%)

*Table 8: Figures for Climate Impact of Milk and Meat*

#### Notes for the table:

*ERM & University of Ghent, 2011* First figure is the result for a conventional system, second is the range on the basis of the sensitivity analysis. Third figure in the case of beef is the result for a specific feed trajectory. Third figure in the case of milk is for biological trajectory.

*JRC, 2010* First figure is the result, including average Scenario (II) for land use change. Second figure is the range on the basis of the minimum and maximum scenarios (I & II) for land use change. The degree to which the Belgian average differs from the European average varies from 9% lower to 5% higher in the case of pork, dependent upon the scenario that one uses the climate impact related to land use change to calculate (see table). In the case of beef, this varies from 14,5% lower to 3,5% higher. The differences between the member states are also sometimes mutually substantial. Pork and beef consumed in Belgium is primarily produced in Belgium or comes from nearby Western European countries (Holland, France, UK).

	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub> Energy	CO <sub>2</sub> LULUC (kg/kg)			Total GHG fluxes without LULUC (kg/kg)	Total GHG fluxes with LULUC (kg/kg)		
				Scenario				Scenario		
				I	II	III		I	II	III
Belgium <sup>1</sup>	0.81	2.01	1.18	2.38	3.14	7.04	3.97	6.37	7.12	11.07
Denmark	0.70	2.24	2.10	2.22	2.98	6.64	5.04	7.25	8.02	11.70
Germany	0.81	2.19	2.10	2.25	2.54	4.06	5.11	7.34	7.66	9.17
Greece	0.94	1.22	0.97	2.11	2.79	6.29	3.13	5.23	5.92	9.45
Spain	0.91	1.31	2.10	3.06	3.95	8.51	4.32	7.37	8.28	12.87
France	0.73	1.12	1.94	1.77	2.20	4.30	3.78	5.56	5.98	8.11
Ireland	0.72	1.05	0.87	1.68	2.08	4.33	2.65	4.31	4.75	6.98
Italy	0.94	1.50	1.56	2.77	3.71	8.57	4.00	6.77	7.71	12.61
Netherlands	0.73	2.94	2.31	2.25	3.13	7.59	5.98	8.22	9.11	13.61
Austria	0.82	1.13	2.26	1.70	1.71	1.87	4.20	5.91	5.92	6.08
Portugal	1.03	1.30	2.58	2.84	3.87	9.19	4.90	7.75	8.77	14.15
Sweden	0.71	1.63	2.05	2.13	2.47	4.03	4.41	6.52	6.87	8.44
Finland	0.76	2.59	2.46	8.60	8.71	9.35	5.81	14.41	14.52	15.16
United Kingdom	0.72	1.15	1.98	1.92	2.34	4.45	3.84	5.77	6.19	8.32
Cyprus <sup>+</sup>	0.76	1.54	2.51	5.03	6.24	13.68	4.79	9.83	11.05	18.55
Czech Republic	0.48	1.49	1.89	2.18	2.20	2.34	3.86	6.05	6.07	6.21
Estonia	0.43	1.68	2.54	6.62	6.74	9.39	4.63	11.27	11.37	14.06
Hungary	0.50	2.08	2.70	4.44	5.04	7.81	5.27	9.72	10.31	13.12
Lithuania	0.44	1.21	2.31	2.88	2.97	4.24	3.96	6.83	6.93	8.20
Latvia	0.48	1.66	3.31	14.68	14.83	17.75	5.46	20.13	20.29	23.22
Malta	0.75	1.10	2.90	3.00	3.46	6.97	4.74	7.74	8.20	11.74
Poland	0.43	1.24	2.14	2.51	2.73	3.81	3.81	6.32	6.55	7.63
Slovenia	0.49	1.50	2.92	2.80	3.48	6.78	4.91	7.71	8.40	11.72
Slovakia	0.42	0.93	1.93	2.37	2.49	3.11	3.29	5.65	5.78	6.40
Bulgaria	0.46	1.20	1.09	3.21	3.48	4.86	2.74	5.96	6.23	7.62
Romania	0.43	1.04	1.41	2.98	3.14	3.87	2.89	5.86	6.02	6.76
EU27	0.74	1.71	2.01	2.52	3.06	5.83	4.45	6.98	7.53	10.31

Figure 7 : Climate impact of pork, per kg carcass weight (JRC, 2010)



## 4 Bread

Fresh bread primarily makes up in volume a great portion of food loss. The quality of bread dissipates quickly via desiccation, retrograding of starch and mould. The most important causes of loss in the various phases of the chain are:

### **producer:**

- bread that is not sufficient to specifications and is unfit for sale.

### **distribution:**

- to what degree one makes an effort for bread sales to the closing time;
- the proper estimate of the size of the offer (choice) and stock management;

### **consumer:**

- purchased more than necessary ('to be sure to have enough at home');
- many find that bread older than 1 or 2 days is no longer good and the last of the previous bread is no longer consumed as soon as a new one is bought;
- personal choices, i.e. bread crusts or sides;
- specific living situations such as a busy life or (young) children at home, aggravate a good estimate of the quantity of use (also of the relationship of eating home and away) so that more is wasted; DEFRA (2010) investigated the connection between household sizes and loss. With bread, this difference is the greatest: single-person households lose some 60% more bread in comparison to multiple-person households;
- bread is a product where there is less awareness about it. DEFRA (2010) investigated the relationship between price per kg and the highest percentages of loss. Bread, apples, pears, bananas, root vegetables and fresh potatoes belong to this group.

### 4.1 Bread options

For bread, achieving a reduction of food loss, outside of optimising packaging, it is rather limited. Primarily on the system level there are a number of developments around that are interesting from a chain perspective. With this, we are thinking about, among others, bake-off, or pre-baked bread that is packaged in MAP with a protected atmosphere or can be distributed via the deep-freezer chain. These measures indeed add impacts to the system (i.e. extra packaging materials and the energy consumption related to freezing) and in the research, the question is asked, 'Starting with how many fewer slices of bread loss are these extra (system) impacts then compensated for?'

## 4.1.1 Packaging

### Packaging Materials

Packaging with a better water barrier can partially offer a solution here. However, hereby precaution needs to be taken that there is no condensation forming in the packaging because this leads to swifter mould growth. A too-high humidity in the sack can also lead to less-crisp crusts. Current types of packaging materials are the paraffin-lined paper bread sacks, paper-plastic laminates, or a 100% plastic sack, with or without (micro) perforations for preserving a crisp crust. The cellophane foil or sack is a bio-based alternative that has been around for a while. The Belgian packaging firm ACE Packaging in Wevelgem developed a bread sack whereby the petroleum-based paraffin layer is replaced by a natural coating. Innovations that situate themselves on the level of bio-based materials must in principle satisfy the requirements for packaging bread such as a proper humidity barrier to prevent drying out, but that have no additional qualities that improve the preservation of bread with regards to the non-bio-based alternatives.



*Figure 8: Compopack from ACE Packaging*

### Re-sealable bread packaging

Primarily the stiffer, plastic bread sacks are more difficult to close without a closure system. Solutions exist, such as a corded sack or a supplied clip.



*Figure 9: Corded sack for fresh bread by Albert Heijn (photo: Bunzl Retail & Industry)*

Pre-packaged breads in a foil are difficult to close again for storage. In order to combat drying out, the consumer must consequently provide a (i.e. used) bread sack or bread bin. A simple sticker (see FIGURE) can also offer a solution here.





*Figure 10: pre-packaged bread, re-sealable*

### **Portion size, bread weight**

Smaller portions, or even bought by the slice, or requested weight could offer a solution for single and elderly persons, for example, for whom the existing standard portions are too large. Some bakers in Flanders are already adopting this system as well as such projects going on abroad. Smaller portions imply more packaging material per kg of sold bread. According to the bakers involved, families are also purchasing slices of bread. In this way, each family member can choose his or her favourite bread. The sale according to this principle remains rather limited with respect to the sale of standard portions.



*Figure 11: baker Dirk Vertriest (photo) from Nazereth has been selling 'bread by the slice' for 10 years already (photo: vandaag.be, 4/11/2010)*

According to a Dutch test project on mini portions of bread of 4 slices, the 'Brammetje Bammetje', the extra packaging should be quickly compensated for by less bread loss. However, after the test period, it was not carried out further because, according to the producer involved, Beko Verpakkingen: 'Bakers don't get it completely, but we indeed see a trend towards smaller packaging. The consumer is not interested in the environmental-technical background, but happily purchases apportioned packaging. An (environmentally) aware choice appears to be difficult to enforce, but the result is indeed there.'



*Figure 12: Four slices of bread per package (photo and more information: [brammetjebammetje.nl](http://brammetjebammetje.nl))*

### **Modified Atmosphere Packaging, MAP**

An MAP-packaging, or the packaging under a protected atmosphere, is adopted more for bake-off, pre-baked breads, though also in niches for baked breads. We are thinking here of, for example, gluten-free bread (see FIGURE). In combination with other measures, such as bread composition and treatment, this packaging method adds the fact that the bread stays good for a months.



*Figure 13: gluten-free bread in MAP packaging*

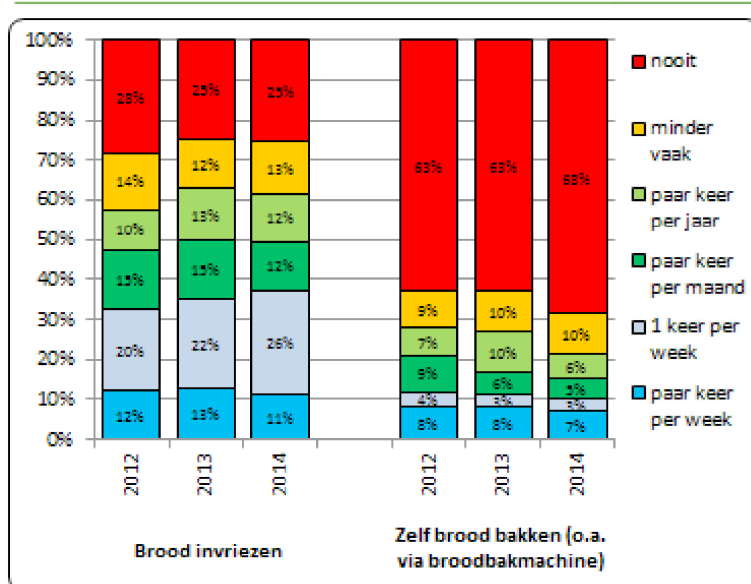
## **4.1.2 System options**

On the level of the system, there are various possibilities and the following options were investigated for this study.

**Freezing Bread** is an oft-heard recommendation for preserving bread longer and to combat loss. However, the freezing process adds extra impact to the system and in the study, it is calculated for when the amount of avoided quantity of bread loss evens this out. Freezing the bread in the bread sack in an extra plastic sack and to thaw out at room temperature should yield the best results. On the other hand, once thawed, the bread is best consumed within 24 hours. Thawing out too large of portions also has consequences of loss. Better still is thus to freeze the necessary daily quantity in separate deep-freeze bags. In order to demonstrate the advantage in terms of the environment with regards to not freezing bread, it is hereby taken into account in the study as a frequency of 1 purchase per week, whereby the the first bread is eaten

fresh, and then the remaining bread is frozen for use later in the week. Bread can, according to guidelines, be frozen for a maximum of 2 weeks. VLAM more recently investigated the usage frequency of freezing bread and also for baking bread. Freezing is experiencing a growing trend. In June 2014, some 37% of the respondents would freeze bread at least one time per week, in relation to 22% two years prior. One quarter of the respondents never do this. Baking bread at home is seeing a slightly decreasing trend with the respondents who regularly, at least 1 time per week, bake homemade bread, from 12% in 2012 to 10% in 2014. The number that never does this is currently 68%, which suggests that this was rather a temporary trend. Nevertheless, 10% that does this regularly is a significant target group.

## Gebruiksfrequenties



Wetenschappelijk Centrum voor Agri- en Visserijmarketing vzw



Figure 14: Usage frequency of freezing bread and baking it—  
Source: iVox as requested by VLAM (2014)

Koopt u graag brood voor een hele week? Geen probleem, u kan het gewoon **invriezen**:

► Stop de broodzak met het brood nog eens in een **plastic zak** voor u het in de diepvries steekt.

► Brood **ontdooien** doet u het best op **kamertemperatuur**. Neem het gewenste aantal sneetjes uit de zak en leg ze op een bord. Steek ze in een plastic zakje of dek af tegen het uitdrogen. 20 minuten later zijn ze helemaal klaar.

*Figure 15: Communication from retailer Colruyt on freezing bread*

#### **Switching to pre-packaged bread**

In this case we are not dealing with fresh bread, packaged after it is baked by the store or bakery and with a limited expiration date of 3 days. With fresh bread, there is usual no expiration date, but rather a 'packaged date'. We are concerned here with the industrial-made breads with an expiration date of a week or longer. On this packaging, there is indeed an expiration date. These breads have longer expiration dates because of an adjusted combination of ingredients, the usage of preservatives or thermal pasteurisation. Just as with the option of freezing bread, the advantage is translated to the expiration date in the study to a frequency of 1 purchase per week, and whereby the breads are stored in a pantry at room temperature.

#### **Switching to pre-baked breads**

These are available in packaging with protected atmosphere so that an expiration date of a few months to a half of a year can be achieved, but also in packaging without a protected atmosphere with an expiration period of 1 to 2 weeks. Once an MAP-package is opened, the non-fully baked breads are good for a limited time and must be stored refrigerated (max. 7°C) or frozen and used within 1 month. The advantage for expiration time for pre-baked breads in MAP-packaging is translated in this study into a user scenario with a frequency of 1 purchase per month and whereby the bread is stored in a pantry at room temperature.

#### **Bake-off and Deep-freezer chain**

In addition to the bake-off breads provided for the consumer, the aspect of bake-off in the supply chain is also taken into consideration. A consumer will not always realize it, but when fresh baguettes, loaves... are sold in the shop or at the baker, it often is with baked-off breads.



*Figure 16: Bake-off products finished off in the retail point (photo: dauphinebakery.com)*

The big advantage of bake-off for the shop, baker or bread shop is that the inventory management becomes easier. One can store more varieties of bake-off bread products in the deep freezer and meet the daily demand easier. In other words, one can bake the necessary quantity of bread 'just in time'. From the perspective of the chain, this technology is also seen as the breakthrough innovation for combatting stock shortages and losses. Thanks to the bake-off and deep-freeze technology, the possibility arose for industrial bakeries to supply their clients less frequently and with smaller quantities (less transport) and to export their bread products to markets that are further away. Innovations of bake-off products are mostly situated around the further bettering of the quality and the shortening of the running time for final baking. An example of this is Dauphine, who first developed on the Belgian market the 'Fully Baked' products. One places these deep-frozen in a pre-heated oven for 3 minutes. After merely 5 minutes of cooling off, the product is ready for sale, whereas generally the running baking time is 45 minutes (15 minutes thawing, 15 minutes baking and 15 minutes finishing). Indirectly, the shortening of the baking time also has advantages for the environmental impact.

### **Other options**

A bread sack is the ideal medium for printing. Tips for avoiding bread loss or using leftovers can thus be communicated on a bread sack (or mentioning a site or QR-code by which the tips can be found). In addition to this, some bakers already show this to customers via film clips on TV screens in the shop. Baking bread at home. According to the research of VITO, baking bread at home in a bread machine has the lowest climate impact (not in the oven because of energy consumption and energy-efficiency differences with the other systems). There exist very nice reusable bread sacks or bread bins to store bread. With these (i.e. textile) sacks, it needs to be heeded that they have sufficient humidity barriers in order to combat desiccation. Cutting bread at home. A non-cut loaf of bread dries out more slowly. The consumer who invests in a bread-slicing machine can also determine the thickness of the slices for himself.

## 4.2 Data inventory

In 2012, the average Fleming purchased: 45 loaves of bread, 4 baguettes, and 107 smaller bread items. Taking into account the figures on the market share of the various bread weights, the home consumption came to about 31kg/pp/per year of bread and 7 kg/pp/per year of smaller bread items and baguettes, with a total of 38 kg/pp/year. Regarding the consumption outside the home there is no data, but there is indeed a switching over towards more consumption outside the home and a general decline in bread consumption. 38 kg per person per year is indeed quite lower than the 50 kg/pp/year of the food consumption survey of 2004, but the home consumption of bread in Flanders has, according to GfK, declined as well by 20% in 10 years time. The consumption has shifted somewhat from home consumption to outside the home, but certainly not to the extent that fully compensates for the 20%. Furthermore, it is known that the relationship between the sales of pre-packaged and not is 40—60%. People in Flanders buy their bread, in comparison with the rest of Belgium, more at the baker. 40% of pre-packaged is still a large portion and should be because the supermarkets have a much larger proportion of pre-packaged breads than non-packaged. In recent times, there is consistently more in supermarkets the option to self-slice and package fresh bread, but this has not been going on long enough that it is already apparent in these figures. The hard discount stores, such as Aldi and Lidl, are also recently selling non-pre-packaged breads (source: publications of figures and personal communications with VLAM).

Figures for the loss of bread in the chain are centred around 1% yield and 2% stock losses in the agriculture phase (Danckaert, et al., 2013), 1-2% in the production phase, 3-7% in the distribution phase, and 18% at the consumer level. Very high levels of loss at the consumer level are registered in the United Kingdom (32% average loss), primarily by the very high loss of the typical white Chorleywood bread there. This is not representative for the bread that is consumed most in Flanders. In the figures from CREM (2010 and 2013) for Holland and the figures from DEFRA (2010) for whole-grain bread in the United Kingdom, the loss of bread is around 18%.

Moreover, from the baseline measurement study by OVAM, it seems that bread is the largest fraction of the disposed food in the mixed-waste stream: 1,6 kg/pp/year. A baseline measurement of this fraction in GFT has not yet been made. In addition, figures on the quantity of bread that goes to animal feed (both in the chain and with the consumer) are not available. If we begin with the 18% loss by the consumer, then this would mean that in addition to the 1,6 kg in mixed-waste stream, another 5 kg ends up with GFT and/or animals. According to a recent panel research of VLAM, consumers do not count the leftovers that go to chickens, dogs or other pets or onto the compost pile, as waste, and the panel confirms that there is indeed much to be done with this, or find another creative solution for bread leftovers.

*"You can toast old bread, or make toasties, French toast, bread pudding or croutons."*

(quote consumer panel Marktmakers, VLAM)

Figures on the climate impact of bread were calculated by VITO. In this study, consumer transportation for the purchasing is also taken into account (see chapter 3.1.4.3). Primarily the climate impact of this step weighs heavily in the case of bread. VITO also calculated the impacts of various system options such as bake-off and self-baked bread with LCA software. Results on



the climate impact of packaging were calculated on the basis of a measurement of the weight of various consumer packaging, of various types and sizes of bread, originating from various supermarkets and bakers (n=12). In available studies, figures were recovered for the usage of packaging in the distribution chain. The impacts of the packaging were calculated with respect to the various LCA databanks and software (see chapter 3.1.4.1). For the study, it was presumed that all packaging was evaluated energetically via the waste route, as well as if there comes about the actuality for a portion of bread sacks by separately assembled paper or from elsewhere.

## 4.3 Results for Bread

If we bring in the figures regarding loss in connection with the household consumption in Flanders, then we arrive at a total of annual production including loss at 270 kt, of which 25% of 69 kt goes lost in the chain. The largest portion, some 44 kt, is lost at the consumer level, followed by the distribution with circa 11 kt. The packaging that is paired with bread is 4 kt. The annual bread loss in the chain represented a climate impact of 46 kt CO<sub>2</sub>e (compared to the climate impact of driving around the world 4150 times with the auto). Of the total climate impact, the loss in the chain (L) is 18%, the consumed bread (F) 80%, and the packaging for the portion of consumed bread (P) 2%. The climate impact of the packaging with regards to that of fresh bread is 1% to 4%, dependent upon differences in the production and distribution system for fresh bread. The packaging system encompasses the bread sack as well as the packaging in the intermediate steps in the chain. The climate impact of the packaging system is equal to the climate impact of less than 1 slice from a loaf of fresh bread (of 800 grams). In the case of pre-packaged, industrial bread in a plastic bag or foil, the relationship of climate impact and packaging system with regards to bread in the range of 4-6%, dependent upon the weight of the plastic bag or foil. Thus, the bags that are re-sealable with a clip are in general larger and therefore heavier. The climate impact of the packaging system is equal to the climate impact of more or less one and a half slices of pre-packaged loaf of bread (of 800 grams). The MAP-packaging of pre-baked breads is relatively heavy in relation to the packaged contents. The relation of climate impact and MAP-packaging with respect to pre-packaged pre-baked bread is 15-17%. This is lower by pre-baked breads in a non-MAP plastic packaging. The climate impact of the MAP-packaging system is equal to the climate impact of approximately 4 slices of bake-off bread (of 800 grams).

## 4.4 Conclusions and recommendations

**Conversion to smaller breads** certainly makes sense. Beginning with at least one half slice less bread loss, the climate impact of the extra packaging is already compensated for. There is, however, one important condition: if the consumer makes more trip(s) to the baker, store or bread dispenser, this quickly threatens to nullify the advantage. A larger offering, and thereby the number of bread types, multiplied with the number of portion sizes, makes stock management and the estimation of the proper sales numbers more difficult for the baker or store, and the risk of more loss at this step. Herein lies the advantage for cutting slices 'on demand' in place of offering additional small, standard portions. There are a few bakers in Flanders that have invested in a special bread-slicing machine and sell bread per slice or weight (such as at the butcher).

**Freezing bread** (maximum 2 weeks because of quality loss) makes sense on the condition that the consumer accepts the quality difference with fresh bread. The additional climate impact that is brought along for one week freezing, a plastic deep-freeze bag, and a potential accelerated thawing, would already be compensated for starting at two slices less loss (of a bread loaf of 800 grams). In a scenario in which one goes to the store only 1 time a week in place of 3 times a week for fresh bread compensates the avoided climate impact of less transportation, even with the additional impact of freezing. Freezing bread is a double win situation: the avoided impact of less loss and less transit with the automobile to the baker, store or bread dispenser. This, of course, does not apply with transit on foot or with the bike, or with the auto en route to another destination.

**Conversion to pre-packaged bread with a long expiration date** In this system there need not be any additional impact with respect to fresh bread, and there is thus no discussion about 'compensated for beginning ... slices less bread loss'. The climate impact of industrial breads can be more advantageous, dependent upon the specific situation and taking everything into consideration: scale of production, energy efficiency of machines, personal energy incentives with CHP, for example, transport and packaging. In the event that the consumer hereby goes less frequently to the shop with the auto or freezes less bread, this reduces the climate impact. The advantage with respect to the option of freezing bread is that with this option, the preservation aspect is not a significant factor. An additional advantage with regards to freezing bread is ease of use (the time or management necessary for thawing) and that people in principle only open a new package when the previous one is done. In the retail place as well one can offer pre-packaged bread somewhat longer for sale, than with daily, fresh bread—such as the name implies—is only good for 24 hours. The advantage with respect to pre-baked breads is that these breads, directly after baking, can be packaged in their definitive packaging. With bake-off breads, often there is yet another packaging used in the distribution chain.

**Conversion to pre-baked breads in MAP packaging** with a protected atmosphere and with a very long expiration date makes less sense as an option for combatting loss of bread at home. The climate impact connected with the plastic packaging and primarily the finishing baking at home nullifies the climate-impact reductions of less loss. It is, theoretically, only interesting in the event that on average the consumer wastes a third of the bread, that a complete conversion to bake-off bread would balance out, but in praxis, this is purely unthinkable in light of this consideration. Bake-off for the home segment is mostly with special breads such as ciabatta, panini, or special moments, holidays...; or, for example, also not having anything in the home for emergencies (when one cannot, or does not want to, go to the store). This type of bread thus has a very specific target group and application.

**Bake-off baking at the place of retail** in combination with an adjusted inventory management can indeed lead to a reduction of bread loss in the production-distribution chain. More recent studies on bread loss in the chain mention a range of 2—6 %, average 4 %, in contrast to an average of 7 % in previously published research where little or no mention was made of deep-freeze or bake-off distribution chains.



## 5 Meat and Meat-products

Expiration as the cause of food loss is central with meat, primarily in the distribution and consumer chain. The role of packaging, portion sizes, is for the most part found in this part of the chain. In the production chain, generally other factors play a part, such as the quality and safety of the cold chain and the processing methods.

Food losses in the distribution and with the consumer are in principle two connected events. If one keeps the meat longer in the store, then its expiration time is shorter for the consumer. If one buys the meat quicker from the store, then there is the risk of more quality loss or loss for the butcher or retailer. However much longer one can extend the expiration time of meat in its packaging, then this gives that much more time for the distribution to sell a quality product, and for the consumer to be able to enjoy a quality piece of meat. The greatest challenge for packaging of fresh meat deals with the counter-intuitiveness of packaging for many consumers. People will generally choose a nice, red piece of meat, preferably freshly cut. This engenders trust. Packaging that can drastically extend the expiration date of meat, colours the meat purple or mashes it together (in the case of vacuum-packed), and a small portion of meat in a plastic dish creates the perception of over-packaging and so forth. In addition, reports that packaging artificially colours meat red, sitting packed in a special gas, stimulates distrust. People are equipped with their senses to be able to determine the freshness of meat (seeing, smelling, tasting, etc.) and do not want to be misled there by technological innovation. Moreover, consumers are picky, and one searches in the store for the packaging with the longest expiration date (scavenging behaviour). All of these aspects make for the fact that the packaging of meat with attention to reducing food loss in the distribution and with the consumer is a difficult exercise in trade-off. The ideal packaging is a rational solution on the one hand (longer expiration) and a subjective solution on the other hand (can be nicely presented and acceptable for the consumer).

### Distribution (butcher, store,...)

- With a good running inventory management, the quantity of loss is as low as possible. Dealing with the expiration date is the most important cause of loss for meat, along with holidays and promotions (WUR, 2012).

### Consumer

- From the baseline of OVAM (2011), it appears that 1,5% of the average rubbish bag in Flanders consists of unopened packaging. Of this fraction, it was checked to see if the expiration date had already passed or not. Apart from the 24% that was difficult to determine, it appears that 21% of the unopened packaging had not passed its expiration date. In 55%, it was indeed the case ('Use By' date: 17%--'Best Before' date: 37%). Of the unopened packages of 'meat, fish and fowl' (18%) and 'dairy products' (22%) were the 2 largest portions.
- CREM (2010) investigated the reasons for food loss for diverse product groups amongst which were meat/fish. In addition to the 15% 'other' of undefined reasons, all reasons had to do with the freshness of the product. In 27% of the cases, the expiration date was passed, and in all remaining cases, the product tasted or smelled suspicious (25%), looked suspicious or no longer appetising (19%) or people found it no longer fresh enough (14%). Reasons given, such as: 'prepared too many times'; 'leftover after baking/cooking' or 'too little to keep', were not mentioned by the Dutch respondents. These results do not completely agree with a similar research study in the United

Kingdom: one third of the respondents gave as one of the most important reasons, 'Cooked, prepared or served too much'.

- DEFRA (2010) investigated the relationship between household size and loss. Single-person households lost circa 8% more meat in comparison with multiple-person households.
- In the volume of product loss, it is a relevant category, with 9 to 15% loss with the consumer, but it is certainly not an easy one to take on. This also seems to be so from a study in the United Kingdom where people have measured the trend between 2007 and 2012 regarding the decline of food loss for different product categories. For meat and fish, this appeared to be as good as unchanged, despite various sensitising measures in the meantime (WRAP, 2013). The study concluded that for fresh meat, one does best with following the measures: sell the proper portion sizes and inform and sensitise consumers about the proper portion sizes; create more clarity about the meaning of the expiration dates; make more usage of the freezer for storing meat at the consumer's home as well as innovative packaging that extends the expiration date of fresh meat.

## 5.1 Options for Meat and Meat-products

### 5.1.1 Packaging

Regarding the packaging of meat and meat-products, four types are distinguished:

- Packed under normal atmosphere (wrapping paper or dishes with wrapping foil)
- Modified Atmosphere Packaging, or packed under a protected atmosphere with a high concentration of Oxygen (further designated with 'HiOx MAP'); this is exclusively for fresh meat;
- Modified Atmosphere Packaging, without Oxygen (<0,5%) and with elevated CO<sub>2</sub> concentration (further designated with 'LowOx MAP'); primarily for meat-products and can be applied in combination with N<sub>2</sub> for fresh meat;
- Vacuum Skin Packaging (VPS), whereby all Oxygen is removed from the packaging and the foil is sealed around the product on the dish as a second skin.

The potential energy savings related to the reduction of the loss of meat by innovative packaging has already been investigated in a Dutch study (van Velzen, 2011). Based upon the results of this study the packaging related measures mentioned above are considered. The results are shown in the following overview table.

Measure	Energy usage for packaging (MJ)	Estimated loss (%)	Energy loss through loss (MJ, for pork)	Total packaging + loss (MJ)
<i>Per packaging unit 350—500g fresh meat</i>				
Packed under normal atmosphere (NA) (absolute qty.)	0,7	9,00%	7	7,7
From NA to MAP	1,5	-5,00%	-4,3	-2,8 (-37%)
From HiOx MAP to VSP	-1,1	-3,00%	-1,7	-2,8 (-36%)
From HiOx MAP to LowOx MAP	0	-3,00%	-0,4	-0,4 (-5%)
From MAP PET to rPET	-1,1	0,00%	-1,4	-2,4 (-31%)

*Table 9: Average reduction (-) or addition (+) of energy usage and percentage of loss per packaging option for fresh meat, calculated on the basis of the results (Van Velzen, 2011).*

From here it seems that there is already a large reduction of loss and energy saving has taken place by the MAP packaging in place of air packaging. With the conversion from HiOx MAP to VSP, according to the study, an energy savings is possible that is just as substantial as the switching from air to MAP packaging. With the conversion of HiOx MAP to LowOx MAP for fresh meat, the savings is less substantial, though still relevant. The study (Van Velzen, 2011) also looked at the effect of the application of more recycled materials (such as rPET). This measure can also combat the energy usage of the total system still further.

In Belgium, HiOX MAP is most often applied to consumer packaging of fresh, red meat, and LowOX MAP and VSP less so. These two alternative packaging techniques for fresh, red meat at the focus of the case study on fresh meat. Other packaging techniques for fresh meat are briefly taken up in this chapter. For meat-products, specifically ham, portion sizes are the subject of the case study. Other packaging options for meat-products are also offered in this chapter.

#### 5.1.1.1 Air Packaging with Wrapping Paper or Dishes with Wrapping Foil

These packaging methods are generally found with independent butchers, specialty shops with fresh goods, supermarkets with their own butcher department or that are supplied daily by a butcher with freshly cut meat.

Wrapping paper, the typical Edelpack butcher paper with an HDPE layer of foil, is always a current packaging method in the line of independent butchers because of its artisanal character, its cost and ease of use. The short expiration date with this packaging method is a disadvantage, but the cutting of a quantity of meat needed by the client is, however, an advantage for this route and this packaging method. If the meat is consumed directly, there is essentially also no difference from an opened MAP or vacuum-sealed packaging. The packaging and conditions (temperature, hygiene, and so forth) primarily make a difference in the period of storing between the moment of purchase and that of consumption. Later on in this chapter, a number of options and examples are further worked out for the retail channel of butchers.

An other known example of an air packaging is the EPS dish with a PVC stretched wrapping foil. These dishes are often provided with a perforated, absorbent base, or there are humidity absorbers (or 'nappies' in the jargon) present to capture draining liquid from the meat. Fresh meat stays in contact with air as an environmental atmosphere, whereby the desired red colour remains for a few days, though after 4-6 days, an undesired brown colouring will occur. The microbiological growth is not halted. The precise expiration time with air packaging is dependent upon the distribution temperature, the type of meat and the initial contamination, and it is limited

to a maximum of 5 days. The estimated loss in the chain up to and including the speciality shop, excluding the consumer, via this packaging method is 10%, or two to three times as high in comparison with MAP, and five times as high in comparison with vacuum skin packaging (Van Velzen, 2011).

#### **5.1.1.2 MAP with elevated Oxygen levels (HiOx MAP)**

This is not a new technique and has been used since the mid 1970's. It is also now still the most applied packaging technology for pre-packaged, fresh meat. The meat is placed in a dish, and the desired gas combination with high Oxygen concentration is introduced and sealed tightly. Typical combinations are 60-85% O<sub>2</sub> with 15-40% CO<sub>2</sub>. O<sub>2</sub> is the component that ensures that the red colour of the fresh meat is preserved and the CO<sub>2</sub> is the component that halts the microbiological growth. The expiration time that one achieves with this technology is dependent upon the type of meat as well as the raising of the entrance quality of the fresh meat (the 'beginning contamination') and the cold chain: 5 to 10 days and in some cases even up to 12 days. For ground meat, this average is shorter.

#### **5.1.1.3 MAP with low-Oxygen Atmosphere (LowOx MAP)**

Meat-products (ham, turkey ham, smoked ham,...) are contaminated during the slicing process in places with decaying flora. In order to be able to guarantee the expiration date of these products for a sufficiently long time, they are often packed under a protected atmosphere: the air in the packaging is replaced by a mixture of gas without O<sub>2</sub> and with as high of CO<sub>2</sub> and N<sub>2</sub> concentration as possible. Cooked meat-products are treated with nitrates by which they obtain the pink colouring. Under the influence of Oxidised radicals, they turn an ashen grey. With LowOx MAP, an expiration time of 5 to 6 weeks can be achieved. In theory, it is also possible to package fresh, red meat with LowOx MAP, but in praxis, this seems to be very difficult. The remaining Oxygen level must be lower than 0,05% or the brown colouring will occur. With CO<sub>2</sub> concentrations higher than 25%, a purplish colouring occurs (for example, with a gas combination of 70% N<sub>2</sub> and 30% CO<sub>2</sub>). However, with 25% CO<sub>2</sub> or lower, this has little or no effect any longer on the microorganisms. Purplish colouring at any rate means no loss of quality. On the contrary, regarding HiOx MAP, the expiration date will be longer. The colouring, however, repels the consumer from purchasing the meat, and thus in praxis it is currently not applied.

#### **5.1.1.4 MAP with Carbon Monoxide (MAP CO)**

This deals with the packaging of fresh meat under a protected atmosphere with Carbon Monoxide, which is added in small quantities to the gas combination. This CO ensures for the preservation of the red colour of fresh meat, so that no more Oxygen must be added for the benefit of the consumer's perception. Hereby the oxidation is strongly decreased and as a consequence the expiration time is increased. What is indeed very important is that this is not permitted within the European Union. For example, it is, however, permitted in the United States. Up until 2004, it was permitted in Norway. At the beginning of 2004, the Norwegian laws were harmonised with the EU, by which the Norse permission of Carbon Monoxide to be used as an additive for foodstuff was rescinded. For many reasons, a new approval request from the EU was then relinquished. One of the reasons was that Carbon Monoxide reacts with the meat, whereby the stable dark-red Carbonylmyoglobine is formed. One could not refute that Carbonylmyoglobine could cause cancer and masked the spoilage of the packaged meat, through which the risk of consuming spoilt meat could be added.

#### 5.1.1.5 Vacuum Skin Packaging (VSP)

The packaging is sealed shut as it is made devoid of air by means of a vacuum machine. Traditional vacuum packaging has a number of disadvantages, such as the hard, protruding sealed corners and the unattractive seams. The vacuum technique has further evolved such as with the shrink-wrap packaging. The vacuum packaging is then made of a shrinkable material. After brief contact with hot water, the foil or bag then shrinks and closes itself 'skin-tight' around the meat. A sealing seam can then scarcely be detected any longer. With vacuum skin packaging (VSP), the product is first placed in a pre-formed dish. After the evacuation of the air, the dish is closed off with a special skin foil. A few applications of vacuum for meat are deep-freeze meat, entire chickens, ribs, sausages and game. As consumer packaging for meat vacuum-packing is applied much less frequently than HiOx MAP, though in the supply of fresh meat for Horeca and butchers, this is more common. Just as LowOx MAP is vacuum packing an interesting technique with regards to the expiration date of fresh meat. After the sealing, there is still a minimal quantity of space with Oxygen present in the bag. By oxidation of the fresh meat, or by microbial activity, this diminishes, and a small quantity of Carbon Dioxide gas is released in the meat and halts the microbiological growth. Where traditional vacuum packaging reduces the air in the packaging to a maximum of 3%, VSP lowers this level still further, to less than 1%. On the condition of a good entrance quality of the meat and a good cooling chain, an expiration date of 3 to 4 weeks can be achieved. This longer expiration date of fresh meat in VSP (circa 21 to 28 days) with respect to HiOx MAP (circa 5 to 10 days), can in principle lead to a lower loss in the distribution chain and with the consumer, and can thus from a business standpoint and sustainability be an interesting alternative for HiOx MAP. However, just as with the alternative of LowOx MAP, for which likewise an extended expiration date has an effect on fresh meat, also with the VSP the reddish purple colouring of the fresh meat is indeed a disadvantage for sales.



*Figure 17: Example of Vacuum Skin Packaging (VSP)*

#### 5.1.1.6 Evaluation of alternatives LowOx MAP and VSP for red meat

The table below provides an overview of the most important advantages and disadvantages or limitations that hinder the players in the chain. The most important aspects are mentioned and provided here is which new developments are being prepared.

<i>From fresh red meat in:</i>	<b>HiOx MAP to</b>	<b>LowOx MAP</b>	<b>VSP</b>
Expiration period	5 – 10 days	+ 1 tot 2 weeks	+ 1 tot 2 weeks
Meat discolouration	+	–	–
Compression of meat	+	+	–
Humidity release	(–)	(–)	+
Additional cost per packaging (regarding MAP)			EUR 0,07 dependent upon volume
Investment	circa EUR 100.000	circa EUR 100.000	circa EUR 200.000
Communication	+	+	–
Vertical presentation	–	–	+
Transport volume	–	–	(+)

**Tabel 10: Advantages and Disadvantages of LowOx MAP and VSP with respect to HiOx MAP**

### *Consumer Acceptance*

This is the greatest limitation. A meat purveyor or store does not want to risk that consumers do not trust the product and consequently decide on purchasing the meat elsewhere. The dark-red colour of the fresh meat and the packaging are the two most important visual aspects that determine the perception of quality for the consumer (Vermeulen, 2010). Therein lies the problem for VSP and LowOx MAP because the meat by nature colours to reddish purple. New innovations regarding the packaging of red meat in a low-Oxygen atmosphere factor in on this aspect the most as a result (see section on examples). Another visual disadvantage of VSP is that the meat sits in the packaging mashed together. What is indeed an advantage of VSP is that there is less moisture release from the fresh meat. In an MAP packaging, this is captured by moisture absorbers.

### **Examples: Innovations that combat the undesired colouring in VSP**

*A few examples found are FreshCase® that approaches this colouring phenomenon in VSP with Sodium-Nitrate crystals in the foil layer that is in contact with the meat, and which migrate to the meat. However, Sodium Nitrate may not be added to fresh meat according to the European additive law (2008/1333). Thus, such foil cannot be used in Europe. Another example is Cryovac Darfresh® Bloom packaging. This is the combination of a VSP packaging within a HiOx MAP (see FIGURE). The external MAP packaging film prevents gas from escaping or light coming in. The internal VSP film in contact with the meat as well as the high O<sub>2</sub> concentration of the gas combination, however, is penetrable and ensures that the red colour of the meat is preserved. More information about this and other examples found is to be found on the Pinterest site: Pack2savefood (see the banner '2save meat').*



*Figure 18 Example of Cryovac Darfresh® packaging with separate VSP and HiOx MAP compartments (source: <http://mestro.nl/darfresh-on-tray/> ).*

### *Supply-chain Acceptance*

Economic limitations and chances with new packaging and processing technologies for meat are offered in a recent study by Rabobank (2104). The study concludes that technologies such as VSP have a surcharge and that the investments will increase (see Table 10). Given this, and the current margin pressure in the chain cause the meat processors to hesitate on making these investments. Yet, if they still invest, then the question is whether the consumer will accept the higher price for a longer expiration date. According to the Rabobank study, chances arise primarily for producing more efficiently, to combat the spoilage on the shop floor, and new undertaking chances to create consolidation and chain integration by means of more collaboration (Rabobank, 2014). In addition, there are still a number of technical and practical advantages and disadvantages connected to VSP in comparison with MAP. One of these disadvantages is communication, or the difficulty to provide a printed surface (with logo, text, FIGUREs). Solutions exist such as an extra surrounding packaging of printable cardboard or foil, or a greater façade with a sticker positioned next to the meat, and so forth. This, however, raises the variable costs of this method. Skin packaging, however, does offer a vertical-presentation possibility (FIGURE). With skin packaging, the meat is fixed on the dish, where as with MAP the packaging must lay flat because the meat can move around in the dish. With a vertical presentation, the consumer can make his choice in a natural standing position and the supermarket will be able to display more meat per square metre in the vertical-oriented refrigerators. An addition advantage of the vertical presentation is that the ‘grabbing behaviour’ of the consumer is thwarted, by which it becomes easier for the supermarket to sell packaging with the shortest remaining expiration time first (Van Velzen, 2011).



VSP can deliver a smaller product with the usage of shallower dishes. The dish of an MAP packaging is usually deeper than the piece of meat to prevent contact between the top foil and the meat. This cause undesired colouring from the contact surface. With the use of shallow dishes for VSP, the packaging in principle is just as high as the height of the piece of pressed meat. This permits the transport volume per packaging unit to be reduced and the freight load is indeed better for the ecological and cost efficiency of the logistics chain. However, taller dishes are better to neatly stack. For VSP then, taller dishes are thus also frequently used.

#### **5.1.1.7 Packaging Materials, Barrier Qualities**

An MAP packaging for fresh meat or meat-products consists mostly of a pre-formed or thermoformed dish, sealed with a top seal. In addition to 'Topseal' packaging, meat-products are also packed in 'Flowpack' packaging. The meat is placed on a shallow dish and next the foil is folded around the product and sealed shut along the short and long sides. The proper materials combination of the packaging foil is closely connected to the product to be packaged and the desired expiration date presented. Mono-layer and multi-layer combinations can be chosen, by which the following can be achieved:

- Mechanical strength
- Water barrier
- Gas barrier
- Anti-fog qualities
- Seal qualities

The following base materials and their primary function can be distinguished:



Base material	Abbreviation	Primary function
Aluminium	Alu	High gas and water barrier
Amorphous or Crystalline polyethylene terephthalate	APET, CPET	Gas barrier, high temperature resistant
Ethylene vinyl acetate	EVA	Sealant layer
Ethylene vinyl alcohol	EVOH	Gas barrier
High density polyethylene	HDPE	Water barrier and sealant layer
Low density polyethylene	LDPE	Sealant layer
(Oriented) Polyamide	(O)PA	Gas barrier, high temperature resistant, high peak load
Oriented or Crystalline-Polypropylene	OPP, CPP	Water barrier (CPP is crystal clear)
Polystyrene	PS	Holds form
Polyvinylidene chloride	PVdC	Water barrier, gas barrier

*Table 11: Base materials and their primary function.*

In praxis, mono-material PP dishes are still widely used, because of the cost among other reasons. With respect to other multi-layer options (i.e. with EVOH layer), this scores lower on the level of gas permeability. Here too, the desired presented expiration date plays an important role; it is highly possible that for an expiration date of 1 to 2 weeks PP dishes offer sufficient protection for MAP-packaged products. PVdC is nearly no longer used as a gas-barrier layer for packaging meat. The most recent generation of PET top seals and dishes no longer have a PE-seal layer necessary, which is beneficial for the recyclability of this mono-material packaging. It was investigated specifically for meat-products in this study whether it is possible to switch over from a multi-layered barrier packaging to a mono-layer PP or PET packaging, without sacrificing too much with regards to expiration. Thereby a few were looked at for the Oxygen permeability, but in this context still other factors naturally play a part. A non-transparent alternative is aluminium-laminate foil that is completely impermeable by gas, water and light. This, however, is applied less frequently because it is not possible to visibly judge the reduction in the quality of the meat. Moreover, this is a form of over-packaging: this is more of a barrier than is necessary in principle.

#### 5.1.1.8 Nanomaterials

Such as described before, high-barrier qualities currently are coming about through the application of EVOH, for example, in multi-layered foils. New developments are geared in the direction of the application of nanotechnology (Azeredo, 2009). With the addition of nano additives to the base material, one hopes to be able to develop such a mono-material packaging with sufficiently good barrier qualities. The technology is not yet fully developed at this point, and one expects breakthroughs on short, middle-length terms. This is not so technologically evident: the nano parts namely serve very well to be intermixed in the plastic matrix and moreover nicely distributed. Various articles under the rubric of 'inspiration' from the pack2savefood platform are aimed at developments in this area. Such nanomaterials are currently also not allowed by law (EU 10/2011), except when there are behind a functional barrier, but that is in this application not very practical.

#### **5.1.1.9 Re-sealable packaging for meat-products**

Nearly for all packaging implementations for meat-products, there exist possibilities for re-sealability. The meat-product still remains good for a limited time with respect to the microbial shelf life, but it does prevent desiccation, odour and taste loss, ... and these are also causes of food loss.

#### **5.1.1.10 Oxygen absorbers**

Oxygen absorbers ensure for the residual O<sub>2</sub> is eliminated from the packaging. By way of this, no oxidation occurs and the pink colour is better preserved. In the recent past, the issue was for separate, small bags that had to be introduced into the packaging. Costs and complicated production logistics held the implementation of this back. And, despite the warnings on the bags of 'do not eat', the risk existed that the consumer confused the sack with salt, for example. Meanwhile, there are now indeed many alternatives on the market: labels, integrated into the foil, ... so that this argument is no longer as valid.

#### **5.1.1.11 Oxygen emitters**

These were developed by the firm EMCO and have the name OxyFresh™. Primarily the possibilities for this technology are investigated for packaging fruit: high O<sub>2</sub> concentrations can combat mould growth. OxyFresh™ absorbs CO<sub>2</sub> at the same time, by which CO<sub>2</sub> accumulation in the packaging of fruit is combatted. There are applications for meat as well: high O<sub>2</sub> concentration ensures for a longer preservation of the colour of red meat. There was also a version developed that generates CO<sub>2</sub>, which is again a good combination for the preservation of fresh meat (Ragaert, 2013).

#### **5.1.1.12 Intelligent Packaging (sensors, indicators)**

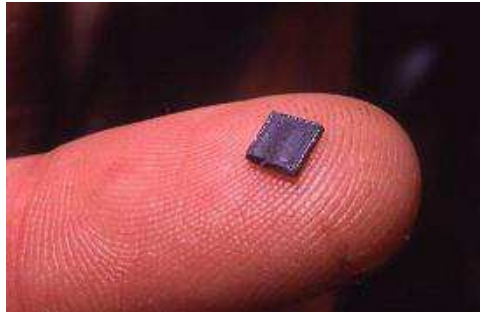
Intelligent packaging monitors the condition of the packaged food product or the environment around the food product. Such sensors, indicators on the consumer packaging for fresh meat or meat-products are for the time being not yet applied in praxis. Whether this will be so in the near future is thus the question. Reliability, limited applicability and cost price currently impede the implementation of them.



*Figure 20: Example of Intelligent Packaging*

In a production environment and the cold distribution chain, sensors and monitoring systems indeed have their worth with product quality, guarantee of product safety, optimising product process concerning the use of raw materials and energy and less food loss. To measure is to know! When an irregularity is noticed, interventions can occur faster during the production or distribution by which fallout and recalls can be avoided. There are various on-going research projects in Flanders. In the logistics chain, the temperature is surely tracked, but not on the individual packaging. It is on this aspect of individual packaging that various research projects are focussing. This can primarily offer a logistical benefit. Currently, the 'FIFO' (First in First Out) principle is used. By tracking individual packaging (or per group of products of the same product batch), one can decide on this level, for example, to place the product quicker in the store.

The goal of the SBO-research project CheckPack (<http://www.pack4food.be/project/sbo-checkpack>) is the development of an optical sensor in packaging foils, that on the one hand, via capturing and detecting air-borne components, tracks the microbiological and chemical putrefaction of foodstuffs that are packed within a protected atmosphere. On the other hand, this sensor also measures the quantity of CO<sub>2</sub> present in packaging. In the first place, this project is geared towards the meat and fish industry, two important food sectors in Flanders with products that because of their intrinsic qualities are very vulnerable to microbiological and chemical putrefaction. The majority of these products are packaged within a protected atmosphere. A large disadvantage of this packaging methodology is that the quality based upon sensory, microbiological or chemical analyses cannot be judged with opening the packaging. Both this industry and the distribution sector also serve their logistics chain to discourage random samples and tests for expiration quality, frequently with 'worst-case' scenarios. This can result in large product volumes that are lost and thus are also important economic losses for these sectors. This research projects seeks to make a developed sensor available as an industrial tool that allows for a expedient, accurate and non-destructive analysis of packaged meat and fish products at each stage of the distribution chain, beginning with the packaging process.



*Figure 21: CheckPack sensor*

A specific example of intelligent packaging with possible application for meat is one with Time-temperature indicators. These TTI's consist of, in many cases, a mixture of a substrate and an enzyme, installed on the surface level by a sticker, which react with each other depending upon time and temperature, whereby a colour change occurs. Primarily, they find their application in the tracking of the temperature profile during storage of packaged foodstuffs (i.e. cold-storage chain). TTI's can be divided into two categories: those that only react to temperature above or below a specific limit ('partial history indicators') and those that react to all temperatures ('full history indicators'), and thus gradually continue to change colour, whereby the speed of which is determined by temperature. The control of a specific temperature trajectory is the most important value of a TTI (for example, whether the cold chain is respected during the distribution). Placing the link between the signal of a TTI and the quality of the packaged product must always be handled very carefully. It is not that a TTI changes colour because of something that is a temporary misuse of temperature occurs, for example, and therefore the product can no longer be consumed. In order to be able to correctly make pronouncements about this, other types of indicators are necessary (i.e. those that measure putrefaction odours, such as those developed in the CheckPack project).

#### **5.1.1.13 Packaging Techniques for other Meat-products**

With deep-freeze meat products, the packaging requirements are limited to a good deep-freeze durability and a low moisture permeability of the bag (usually special PE grades). For dried sausages and related products, the packaging requirements are usually limited to moisture-barrier packaging, such as a PE flowpack, in order to prevent the moisture intake and re-contamination. In addition, there is also packaging for dried sausages with an aluminium layer, because in many cases these products are sensitive to light and oxygen. In a number of cases, this is also combined with MAP (i.e. with 100% N<sub>2</sub>). Meat snacks such as moist sausages must be protected mainly against mould growth. This can be done by packaging in an LowOx MAP or vacuum packaging, as an alternative to a can or jar. The expiration time of packaging in MAP or vacuum can amount to several weeks, dependent upon the moisture level of the meat snacks and the ingredients, but in general have a shorter expiration time than being packaged in a can or jar. Pre-cooked meat and/or meals in which pre-cooked meat is processed can best be packaged in a LowOx MAP or vacuum packaging. Additional packaging requirements primarily come forth from the expected preparation manner. In the case of microwave preparation then PP is the best choice; for example, a PP flowpack. For oven meals, aluminium dishes are more appropriate. CPET dishes are also beginning to be seen more. Fresh steam-and-cook meals in which fresh meat and fresh vegetables are combined actually call for contradictory packaging requirements because fresh meat ideally calls for a protected atmosphere, and fresh vegetables ideally need a controlled atmosphere. The most ideal solution to prolong expiration time seems to be to optimise the packaging for the fresh vegetables (actively controlled atmosphere), whereby the preservation of the sliced vegetable components can be maximised to 10-12 days. By use of marinades, the brown discolouration of the fresh meat component can be retarded (van Velzen, 2011).

### 5.1.2 System Options

In this section a number of options for packaging meat (fresh, meat-products, prepared meat-products) are discussed, specifically aimed at the sales channel of butchers, specialty shops and small-scale producers. The butcher has it rough and every year loses a share. In 2013, 26,5% of the volume of fresh meat went over their counter. The large supermarkets ('DIS 1') remain the most important channel for sales with the volume share of 39,6%, but their share remained relatively stable for the past 5 years. It is primarily the smaller neighbourhood markets and the hard discount stores that compensate for the declining share of the butchers. Hard discount rose from 30% of the market share in 2012 to 32% in 2013. In the meat-products market, the butchers represent a much smaller portion of 12% of the sold volume (VLAM, Figures 2008—2013). Packaging options geared to the sales channel of independent butchers focuses primarily on the preparation and storage of the meat by the butchers themselves. The fresh slicing of the meat and packaging within the store is that very thing that distinguishes the independent butcher from the supermarket and is the reason why the clients consciously chose the butcher. A vacuum machine has long belonged to the standard equipment of a butcher and purchased fresh meat or meat products can be thus divided up, a portion for the sale in the cool counter and the remaining portion vacuum packed again for cold storage in stock. Clients can also in some cases have their meat vacuum packed upon request. There are examples of specialty stores for fresh goods and supermarkets with their own butchery department that invest in smaller, half-automatic machines to package self-sliced meat-products and fresh meat. An example is the Klappack machine and foil. The foil crackles like cellophane and can be layered with paper so that it takes on a more artisanal appearance (see FIGURE).



*Figure 22: Klappack packaging with 'paper look'.*

Because the Klappack is a foil packaging sealed on three sides, with a relatively high surface-volume proportion, the O<sub>2</sub> permeability of the packaging can be critical. Klappack innovations are therefore primarily aimed at new multi-layer foils with a higher barrier. Another example is with butchers and small-scale producers that invest in a semi-automatic MAP packaging machine (see FIGURE). This is an interesting solution for prepared meat-products such as stewed meat, which usually are offered in a dish with a lid or foil. Thus, the prepared meat lasts longer in the cold counter, and the butcher can prepare a greater quantity at once.



*Figure 23: Semi-automatic MAP packaging machine  
(photo: DECATECHNIC, Herentals)*

## 5.2 Data inventory

In 2013, on average a Belgian bought 21,6 kg meat per person (incl. deep-freeze) and 10,2 kg of fowl and game (incl. deep-freeze). Within fresh meat, pork is the second largest category with a home usage of 6,1 kg per person, after meat combinations with a home consumption of 7,6 kg per capita, and for beef with 5,3 kg per capita. In recent years, the home usage of meat-products remained stable at 11,3 to 11,4 kg per capita. Salted products (dried and smoked ham, etc.) are the frontrunner with 23,3% of the volume share of meat-products, for cooked ham (21,7%), salami (14,4%) and cooked sausages (11,3%) (VLAM, Figures 2013). Figures on the loss of fresh meat in the chain are situated around 1,66—2,54% (mortality rates of cattle and hogs) in the agriculture phase; 0,84% in the meat-processing industry; 5% in the supply chain (from slaughter up to and including sales) of fresh meat; 3—4% in the supply chain of meat-products; and between 9—15% with the consumer. Red meat is on the low end of this range and pork and meat-products are at the high end (for figures and sources, see chapters 2.5 thru 2.7). Figures on the climate impact related to fresh meat come from the studies 'Applications of the Carbon Footprint methodology to Flemish Stock Farming (ERM & University of Ghent, 2011). The figures include the agricultural phase and the processing phases of meat. See chapter 3.2 for the figures from these studies. Results on the climate impact of packaging were calculated on the basis of a measurement of the weight of various consumer packaging, various meat and meat-products, coming from different supermarkets and bakers (n=24). The impacts of the packaging were calculated with regard to the various LCA databanks and software (see chapter 3.1.4.1). For the study, it was assumed that all packaging was evaluated energetically via the route of waste. In order to investigate the difference between an MAP and a skin packaging, 3 existing examples were studied. Only in the case of 1 retailer was there a brand of fresh meat found with VSP. This deals here with imported Irish beef packaged in a 'Cryovac Darfresh® Bloom' (see FIGURE in chapter 5.1.1.6), though, in fact, the combination is a vacuum-skin packaging with HiOx MAP. The expiration date on the skin packaging did not differ with respect to the expiration date on the HiOx MAP packaging nearby with beef in the shop in question. The date 'packaged on' did not appear on the packaging mentioned, thus the expiration data could not be compared. With another retailer, no beef was sold in VSP, though there was a brand of



pork ribs from Belgium. Horsemeat and exotic meats were also sold there in VSP. With a lack of other examples of fresh beef in VSP, a few of these products in PSP were also taken for the sampling. In the case of the fresh pork, the expiration data can indeed be compared with that of the pork in the HiOx MAP packaging (in the same shop) because the 'packaged on' date was also present on the packaging. The pork in VSP is good for 3 days longer than with HiOx MAP according to this information (from 7 to 10 days). In order to investigate to what degree the multi-layer packaging can be replaced by mono-layer packaging, simulations were carried out with PredOxyPack by Pack4Food. This software allows for making an estimation of the quantity of Oxygen that comes into the packaging during the storage of the packaged product. Hereby the software calculates: (i) the packaging configuration (bag, dish with top seal,...) (ii) the gas-product relationship, (iii) the surface exchange, (iv) the barrier qualities of the material, and (v) the time-temperature profile to which the packaged product is exposed.

## 5.3 Results for Fresh Beef and Cooked Ham

### Fresh Beef

When we connect the figures concerning the loss of fresh beef in Flanders with home consumption, then we arrive at an annual total production including loss of 36 kt, of which 15% is lost in the chain. The largest portion of that, about 3 kilotons, is lost with the consumer, and the remainder in the supply chain. The packaging that is paired with fresh meat is 2 kt. The annual loss of fresh beef in the chain represented a climate impact of 117 kt CO<sub>2</sub>e (10.650 times around the world with an automobile, as the crow flies). From the total climate impact, the loss in the chain of product and packaging (L) is 15%, the portion of consumed beef (F) 84%, and the packaging of the portion of consumed ham (P) 1%. The climate impact of a typical MAP packaging with respect to the packaged beef itself varies from 1 to 2,5%, primarily dependent upon the packaged portion size. The difference in the weight between the MAP packaging studied and the vacuum-skin packaging varied greatly (for the same portion size of fresh meat, between 200 and 300 grams). In one case, the VSP packaging weighed nearly one and a half times as much as the MAP packaging, but the trade-off point was reached with at least 2% avoided loss of beef. In the 2 other cases, the weight of the VSP packaging was comparable with the MAP packaging. A VSP packaging has no 'inlay' in order to absorb run-off moisture from the meat. The VSP packaging, on the contrary, contains additional packaging material, printed with information, such as in the studied cases, a paper wrapper and labels, and in the other case a printed, plastic flowpack.

### Cooked Ham

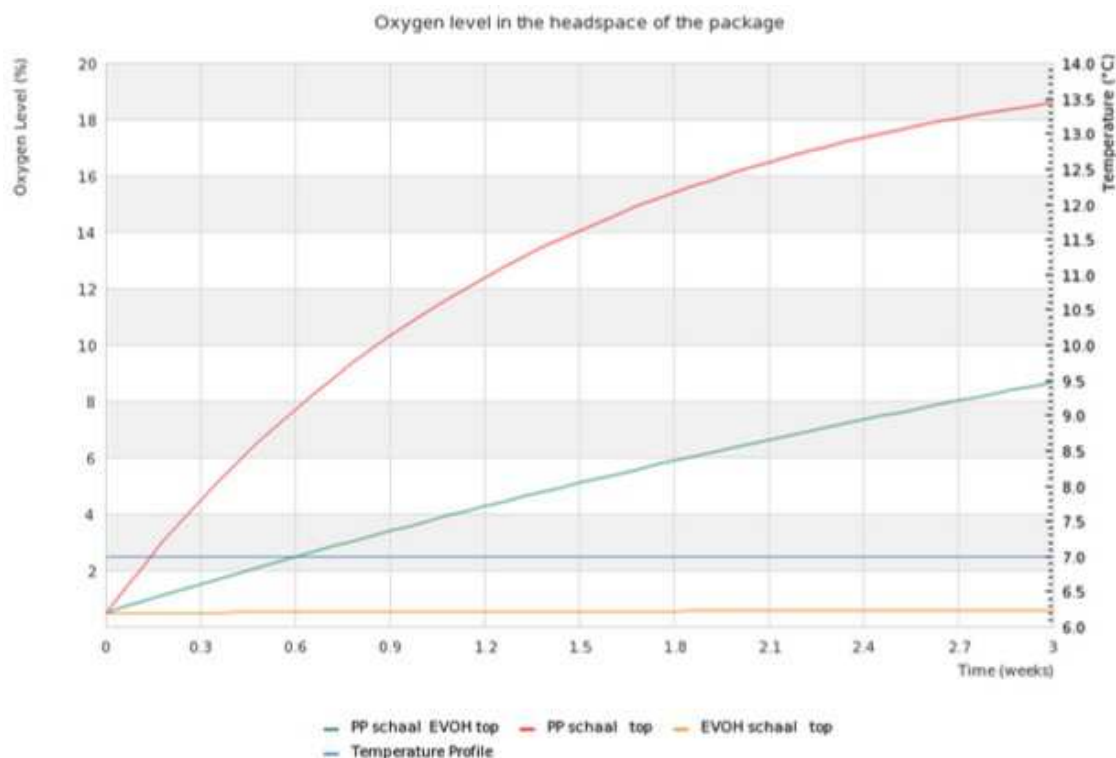
When we connect the Figures concerning loss with the home consumption of cooked ham in Flanders, then we arrive at a total annual production including loss of 17 kt, of which 20% is lost in the chain. The largest portion of that, about 2 kilotons, is lost with the consumer, and the remainder in the supply chain. The packaging that is paired with cooked ham amounts to 2 kt. The annual loss of ham in the chain represented a climate impact of 19 kt CO<sub>2</sub>e (1.700 times around the world with an automobile, as the crow flies). From the total climate impact, the loss in the chain of product and packaging (L) 19%, the portion of consumed ham (F) 75%, and the packaging of the portion of consumed ham (P) 6%. The climate impact of a typical MAP packaging with respect to the ham itself varies from 3 to 14 per cent, primarily dependent upon the packaged portion size and type of packaging (dish with top seal or lighter flowpack). A paper wrapper for freshly cut ham weighs less than an MAP packaging, but the trade-off point is already obtained with at least 6% avoided loss of ham. By switching from a packaging of 200—250 grams content to a smaller packaging of 80—100 grams, the climate impact of the extra impact is already compensated for with at least 6% less loss of ham. 6% comes out to be one-third of a slice of ham in a packaging of 200 grams with circa 6 slices. By switching from a 300—

400 gram large family or promotion packaging to 200—250 grams, the impact of the extra packaging is already compensated for with at least 3—3,5% less loss. Here too 3,5% of a larger packaging with 10-12 slices comes out to one-third of a slice of ham.

### Simulation of multi-layered and mono-material applications

Here below the simulations are reproduced for a dish of 18,5 x 13,5 x 5 cm (1250 cc volume):

- Multi-layered PP/EVOH/PP dish (150/4/150  $\mu\text{m}$ ) + PP/EVOH/PP top seal (20.4/20  $\mu\text{m}$ )
- Mono-layered PP dish (thickness 300  $\mu\text{m}$ ) + multi-layered PP/EVOH/PP top seal (20/4/20  $\mu\text{m}$ )
- Mono-layered PP dish (thickness 300  $\mu\text{m}$ ) + mono-layered PP top seal (thickness 45  $\mu\text{m}$ )
- Mono-layered PET dish (thickness 300  $\mu\text{m}$ ) + PET top seal (thickness 45  $\mu\text{m}$ )

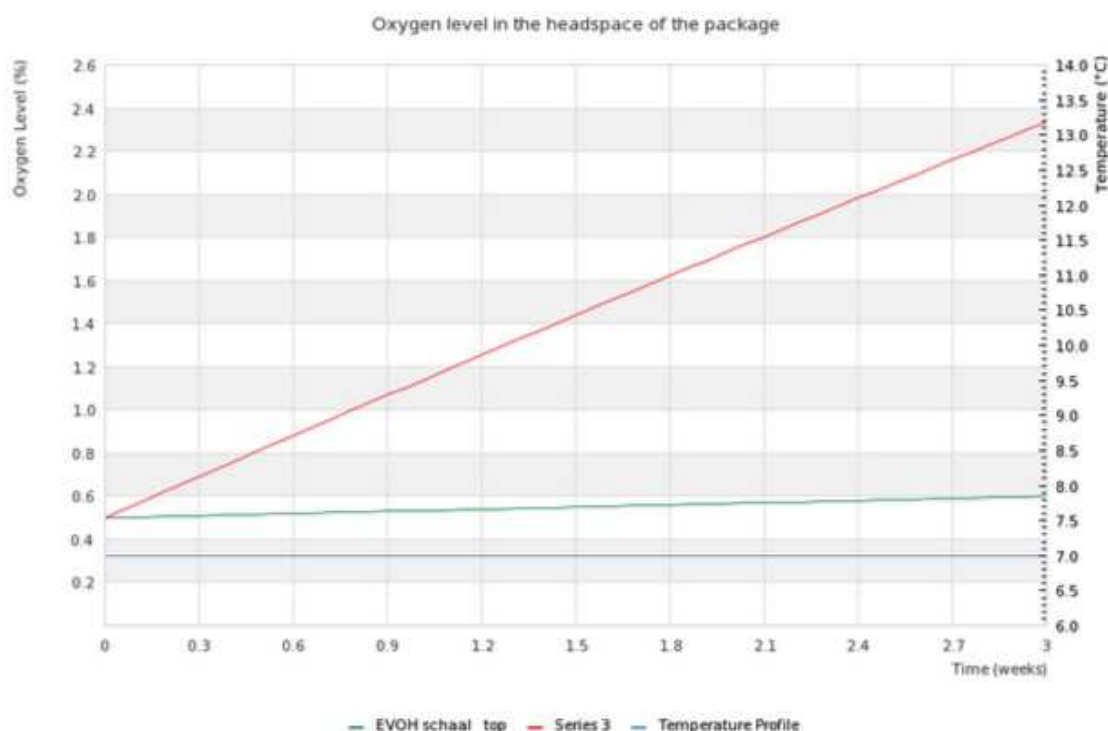


**Figure 24: Simulation of multi-layered PP/EVOH and mono-material PP packaging system for meat**

From the simulations, it seems clear that whenever both the dish and the top seal are made out of a multi-layered material (i.e. PP/EVOH/PP), there is no change in the O<sub>2</sub> concentrations during a typical storage of sliced meat products (namely 3 weeks at 7°C). When the multi-layered dish is replaced by a mono-layered PP dish of the same thickness, there is a significant increase in the O<sub>2</sub> concentration, up to about 9%. The conversion of both the dish and the top seal by a mono-layered PP of the same thickness as the multi-layered, is in this case not an option. From the simulations, however, it seems that at the end of the expiration period there is



nearly the same amount of O<sub>2</sub> in the packaging as in the air. The added thickness of the PP layer in this manner to obtain the same barrier as the multi-layered packaging is, in this case, not an option because in this way an unrealistically thick packaging would be needed. Another option is to work with a mono-layered PET dish. The simulation below shows that here in this case, there is indeed an increase of O<sub>2</sub> during the expiration period, but that this is limited (to about 2.4% O<sub>2</sub>, departing from an initial 0.5% O<sub>2</sub>). This increase of O<sub>2</sub> is perhaps negligible with respect to the effect on the expiration period of the sliced meat products.



*Figure 25: Simulation of mono-material PET packaging system for meat*

Beginning with the same material thickness such as in the simulation above, the weight of a mono-material PET packaging will be about one and a half times as much as a multi-layered PP/EVOH-based packaging because of the difference in the specific weight of these materials. In the case of the same current scenario of waste processing (this is incineration with energy recuperation), this will mean a slight increase of the impact of the packaging. If we here calculate for the trade-off, then this increase would be compensated for by at least 1% less loss of fresh beef, or 3% in the case of fresh pork. However, this positive connection between the expiration period of the meat and the applied packaging is not present in this case. In the case of mono-material meat packaging, the potential avoidable impact is in the recycling of the mono-material packaging or the usage of the recycled material. This latter situation we see in praxis already happening: in the market of PET dishes for fresh fruits and vegetables as well as in PET dishes for MAP packaging of fresh meat, there are examples where in fact up to 70% rPET (coming from recycled PET bottles) is processed in the dishes. In such a case, the environmental impact is lower in comparison with multi-layered dishes and top seals. Because there is no positive connection with the food losses being avoided, there are no further conclusions or recommendations formulated in this study.

## 5.4 Conclusions and Recommendations

**Conversion to other packaging technologies for fresh meat such as VSP** is to be justified if the extension of the expiration date effectively produces less loss with this type of packaging either in the distribution phase, or with the consumer. The largest and heaviest Vacuum Skin Packaging (VSP) from the test samples has somewhat of a higher environmental impact than an MAP packaging for the same portion size, but is already compensated for with at least 2% less of the beef being lost. In many cases, the environmental impact of a VSP packaging will even be more beneficial than an MAP packaging. Thus, a VSP packaging can be smaller in volume and this will have a positive effect on the impact related to storage and transport. The biggest limitation for the application of this packaging system for fresh meat is the discolouring of the meat. Red meat sells, purple meat does not. In addition, in the case of VSP, there are still other economic, aesthetic and practical obstacles that must be overcome with innovations in order to convince the consumer, the production and the distribution chain of this packaging method (see chapter 5.1.1 for an overview).

**Conversion to smaller packaging for cooked ham** definitely makes sense. If one can prevent the loss of at least a third of a slice of ham by converting to a smaller packaging, then the environmental impact of the extra packaging is compensated. The most important limitations are price and perception. A smaller packaging with only 3 slices creates the perception of over-packaging. In this sense, foil packages (flowpack) are slimmer than the relatively heavier (thermoform) sealed dishes.

**Conversion from packaging under normal atmosphere** (i.e. fresh foil) to an MAP packaging is compensated for starting at one third of a slice of ham. Thus, don't buy too much at a deli counter. However, if the pre-packaged portions in the refrigerated counters are too large, then it is better to buy the proper portion at the deli counter.

## 6 Vegetables

Vegetables are sold as fresh and attractive as possible. This means that the chain must pay attention to strict, as well as aesthetic, norms before the fruits and vegetables end up in the store. Packaging can also play a role in extending the expiration period of the vegetables, and portion sizes can offer that these are better directed to the needs of the consumer. All consumer studies show that the placing of value on freshness, or the lack of it, is the most important causes for loss at the consumer level. In the British study, personal preferences ('don't like it') would also play a part in about 10% of the cases, and in about one third of the cases it was the case that the portion sizes offered were too large (WRAP, 2012). DEFRA (2010) investigated the connection between household size and loss. With vegetables and potatoes, this difference is large: single-person homes lose circa 70% more vegetables in comparison with multi-person homes (with fruit, the difference is 55%). An important cause of losses in the supermarket is the 'grabbing behaviour' of consumers: people search for the packaging with the longest expiration date and the packaging with the shorter expirations remain unpurchased.

### 6.1 Options for Vegetables

For Vegetables, the existing division into five grades is used. For each of these grades, the production and distribution system is very different, such as the value chain and the involved actors, the processes and activities, the type of packaging that is being used, and so forth. The first grade is that of the unprocessed, fresh products. The second grade is that of canned goods. The third grade is that of deep-freeze products. The fourth grade includes the pre-cut, washed, mixed, ... vegetables. Lastly, the fifth grade contains blanched, pre-cooked and vacuum-packed fruits or vegetables. First-grade fruits and vegetables do not mean that they are unpackaged, for example, a head of lettuce for sale can also be packaged in a plastic bag. Several examples of packaged fruits and vegetables were treated by Pack4Food in this study; packaged cucumbers and packaged bananas. These are discussed under the options for 'Packaging'. Under the options for 'Systems' the following 2 concrete examples were discussed: 1st, 2nd and 3rd grades of string beans on the basis of the existing research in Holland; and 1st and 4th grades of lettuces. 'Bagged salad' is mentioned in the study from Tesco and 68% (in the United Kingdom) of this would be lost in the chain. This indeed caused quite a commotion. These are treated from a broader system perspective in this study.

#### 6.1.1 Packaging

With fresh fruits and vegetables, packaging usually has a primarily logistics function. Fresh fruit and vegetables that are packaged in the multi-packs (of 6 or 8 pieces) have advantages as well as disadvantages. On the one hand, the stackable aspect is increased and provides protection during transport, but on the other hand, the quantity of packaging materials is higher in comparison with bulk. If one product begins to spoil, in the case of bulk, the risk exists that still a greater fraction will be infected, while with multi-packs, this is limited by the packaging. Packaging innovations for the extending of the expiration period are packaging that are used to optimise the ripening of the fruit (not too slow, nor too fast). Also, products such as cucumbers are frequently packaged individually. This is primarily done to prevent drying out by which the expiration period can be extended. For sliced fruits and vegetables, there are always still a great many developments in the field of packaging to extend the expiration period of these products, and consequently to reduce food loss. Hereby the study focuses primarily on the ideal gas combination and the usage of breathable foils.

#### 6.1.1.1 Fresh (unprocessed) fruits or vegetables packaged in foil

Two examples were investigated more closely by Pack4Food. Cucumbers were the case study for vegetables and bananas for fruit.

*Example 1: The Cucumber* A study from India (Dhall & Sharma, 2012) on green cucumbers showed that cucumbers packaged in a shrinkable packaging have a longer expiration period than unpackaged cucumbers and this goes for ambient temperature (29°C) and cooling (12°C). Spoilage of cucumbers is primarily blamed on yellow colouring, desiccation, leading to shrivelling and damage due to too cold of storage, pests or growth of microorganisms. For an optimal storage, the cucumbers should best be kept in 10-15°C and in a high relative humidity of 90-95%. In the Indian study, the cucumbers were packaged in a Cryovac D955 shrink-wrap. This foil consists out of bi-axial orientated, high-density polyethylene with a limited O<sub>2</sub> and H<sub>2</sub>O permeability. The packaging was shrunk around the cucumbers by heating (5 to 7 seconds at 165°C). Various parameters were tracked during storage at 12°C (90-95% relative humidity) and 29°C (65-70% relative humidity). By the packaging of the cucumbers in a shrink-wrap packaging, the expiration period of up to 15 days was achieved at 12°C, while for the unpackaged cucumbers at 29°C, only 5 days was obtained.

The leading advantages of the individually packaging of cucumbers:

- **Lowered weight loss** The most significant weight loss of 10% occurred in the unpackaged cucumbers after 4 days storage at 29°C, while the packaged cucumbers at the same temperature showed a weight loss of only 1% after 6 days of storage. At 12°C and a higher humidity level, the weight loss of 11% occurred after 15 days for the unpackaged cucumbers while only 0,66% weight loss was incurred with the packaged cucumbers.
- **Less deformation of the cucumbers** After 9 days of storage and 6% weight loss, the unpackaged cucumbers already displayed a strong showing of shrivelling and could no longer be marketed.
- **Less damage from cooling** The loss of robustness was the greatest with the unpackaged cucumbers. At 12°C, the difference between the packaged and the unpackaged cucumbers occurred after 4 days. The desired robustness could be retained here for up to 12 days for the unpackaged and 18 days for the packaged cucumber. At 29°C, the difference showed up immediately and the extended expiration period obtained was effectively 2 days (up from 4 to 6 days). With the unpackaged cucumbers, there was a much more rapid yellowing than with the packaged cucumbers.
- **Less loss by infections from pests and/or microorganisms** An additional advantage of the individually packaged cucumbers is that the microbial spoilage that can possibly limited stays at one cucumber (on the inside) and is not spread out over the entire batch

#### *Example 2: Bananas*

The ripening of bananas is divided into a pre-climacteric and a post-climacteric storage. The pre-climacteric period is always in bulk and in this period by regulating the level of ethylene the ripening of the bananas is optimised. During the post-climacteric period, the level of the ethylene must always be kept as low as possible because this can lead to a too-rapid ripening (rotting). The expiration period of the ethylene-ripened bananas at 20°C in a PE sack is limited (3 to 5 days), primarily also from the accumulation of anaerobic metabolites (ethanol and acetaldehyde). The introduction of micro-perforations can already greatly extend the expiration

period. The best results were achieved by the number of micro-perforations that ensured that the equilibrium concentrations of O<sub>2</sub> and CO<sub>2</sub> amounted to 5-7% respectively. This led to a better retention of the robustness, a nice yellow colour of the bananas, a layer of sugar content in the peel, which indicates that the banana is not overripe and contains a high concentration of decomposable components in the pulp. The addition of ethylene absorbers is yet an extra benefit of the packaged bananas. Through the absence of ethylene, the further ripening is retarded. This also leads to a high level of decomposable components in the pulp, which indicates a normal ripening. An overview study (2011) by which bananas were stored at their optimal storage temperature (12°C) showed that for the optimally ripened bananas packaged under MAP in an LDPE film or MAP in an LDPE film with an ethylene absorber, the expiration period of the bananas was extended 5 and 7 weeks respectively with respect to the unpackaged bananas stored at 25°C. This better storage technique of the packaged bananas led to less weight loss and a better robustness of the fruit.

### 6.1.1.2 EMAP and AMAP

Freshly harvested fruits and vegetables respire. Certain types respire more quickly, and are therefor more vulnerable to spoiling, while others respire relatively slowly, and are thus less vulnerable. The respiration rate varies also by season and per region, even for the same sorts of fruits and vegetables. The goal is to keep the amount of Oxygen in the controlled packaging low and in an optimal balance with the quantity of CO<sub>2</sub>. This extends the expiration time and increases the quality of the products. The Oxygen level must be high enough in order for it to ensure that minimal aerobic breathing can take place. With the lack of Oxygen, anaerobic respiration occurs by which spoilage is more rapid. This also explains why a gas-tight MAP packaging is not ideal for fresh fruits or vegetables.

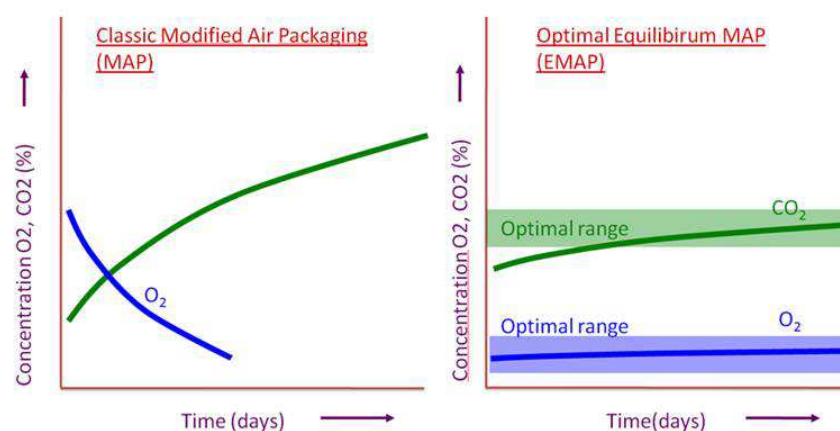


Figure 26 (source: Perfotec)

EMAP makes use of the natural respiration of fruits and vegetables for the regulating of the atmosphere in the packaging. EMAP is a technique by which the air in the packaging is also adjusted, but where there are small perforations in the foil ensuring for a controlled air-permeability, with which the combination in the packaging can be kept constant for a longer time. The required transference rate of the packaging is obtained by the proper number of micro-perforations. The difference between AMAP (Active Modified Atmosphere Packaging) and EMAP is that AMAP is an actively controlled process by which the air permeability of the packaging is actively adjusted by the measured respiration rate of the vegetables, and actively corrected for measured variations in the foil thickness. This ensures for a still longer expiration period. The difference between MAP and E- or AMAP is that MAP makes usage of the inert gasses and an static atmosphere and that E- or AMAP only adjust the permeability of the packaging via micro-perforations in order to achieve the balance in the atmosphere within the packaging. The foil's air permeability is a critical control point for the quality and the preservability of fresh products. One perforation more or less can make the difference between 1-3 days of extra expiration time.

## 6.1.2 System Options

### 6.1.2.1 Vegetables in the can or jar and deepfreeze (2<sup>nd</sup> and 3<sup>rd</sup> grades)

There are different LCA studies abroad that are available on vegetables in these various packaging options and processing systems: for carrots (Ligthart, Ansems & Jetten, 2005); and for spinach and green beans in various packaging systems (Broekema & Blonk, 2010). Environmental studies on the subject in Flanders are not known. In this part, we provide a description of the results of the Dutch study for green beans and use the applicability of these results for the market in Flanders. The scope of this study is from cultivation up to and including preparation by the consumer. The functional unit is per kg prepared product. According to variants that were offered in the Dutch study are discussed here more closely as well as the results on climate impact. A few of the products from the input parameters that have a large influence on the results and the mutual differences are reproduced in the following table.

	1st grade (fresh)				2 <sup>nd</sup> grade		3 <sup>rd</sup> grade
	Kenya Senegal, open-field	Spain, open- field	Holland, open-field	Holland, greenhouse	Holland, open-field, glass jar	Holland, open-field, can	Holland, open-field, deep-freeze
Agricultural Phase							
1/ yield (ton/ha)	7,4 – 7,5	14,6	12,5	55	13,9		
2/ Electricity (kWh/ha)	2500	1250	–	8000	–		
3/ Natural Gas	-			56364	–		
4/ Method of transport	6700 Aeroplane / 4700 ship	Lorry 1400 km	Lorry 100 km	Lorry 100 km	Lorry 100 km	Lorry 100 km	Lorry 100 km
Processing & Packaging Phase							
5/ Method of conservation	–				Heat	Heat	Frozen
6/ Ton output per ton input	0,85						
7/ Electricity (kWh/ton output)	–				204,3		
8/ Natural Gas (kg/ton output)	–				62,3		
9/ Packaging (kg/ton output)	8kg PE bag				778 kg Glass +28 kg Steel	187 kg Can	49 kg Carton
Distribution & Supermarket Phase							
10/ Loss (%)	5,00%				1,00%		
11/ Electricity distribution (kWh/ton)	62,5				–		98,4
12/ Electricity supermarket (kWh/ton)	34,2				46,1		134,6
Consumer phase							
13/ Electricity (kwh/ton)	380				–		440
14/ Natural Gas (m3/ton)	76,9						

Table 12: Inventory of LCA study on string beans Broekema & Blonk, 2010

#### **Relation between losses in the chain and packaging**

Losses in the various steps of the chain are considered, distinct from plate-related losses after the preparation by the consumer. The scope of the study is up to and including the prepared product. In the study, it is not literally discussed regarding the food losses in the 'agriculture and horticulture' phases and 'processing', but in the inventory data this is an aspect of the 'yield' (ton/ha) and of the 'ton output per ton input' with processing. Hereby it is interesting that the yield per hectare, for the same product of green beans from cultivation, is higher with the processed and deep-freeze vegetables than by fresh vegetables (see table 12 input parameters, row with reference number 1). In the processing phase the same input/output factor is used for all systems. Per ton input of green beans, this yields 0,85 tons of product. (See table 12 input parameters, row with reference number 6). Fall-out during transport steps is considered minimal with cooled transport and one goes from here that the transportation, by which the risk exists that the products do not stay cooled, is well organised. In the supermarket phase, there is 5% fall-out of fresh green beans, and only 1% fall-out of processed and deep-freeze green beans. (See table 12 input parameters, row with reference number 10).

The study considers that the loss at the consumer during storage is negligible (WRAP, 2008). At the same time, however, one does accept that the packaging size can indeed have an influence on the loss at the consumer level. With packaging that is too large, there is loss. With preservatives this can play a bigger role than with fresh or deep-freeze because the content of preservatives, once opened, is very limited in terms of expiration time. The content of a deep-freeze packaging can, in principle, also be prepared in separate, smaller portions at different times.

The study considers the same energy consumption (see table, column 14 'Natural Gas') for the preparation by the consumer at home. Green beans of the 2nd and 3rd grades have, however, already undergone a heated treatment in the industry and thus the consumer at home can prepare the beans with less energy consumption in a short time.

## Results

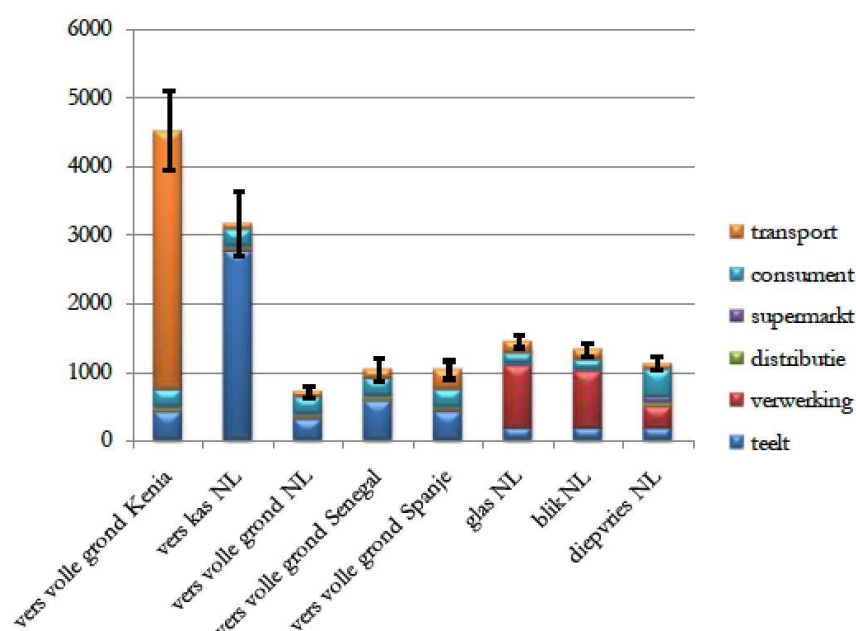


Figure 27: Climate impact kg CO<sub>2</sub>e/ton of green beans for the Dutch market (Broekema, et al., 2010).

The general conclusion of this Dutch study (Broekema, 2010) is that during the season (August up to and including September), fresh green beans from the soil and cultivated, have the lowest climate impact. The climate impact of fresh green beans from greenhouses is a factor of 4—5 times higher, for more than 75% attributed to the usage of natural gas during cultivation. To what degree the figures are related to representative energy consumption for greenhouses in Flanders, with a high portion of CHP, for example, is not clear (see table input parameters, rows with references 2 and 3). From out this viewpoint, the results must certainly be discerned and further research on this is recommended.

The impact of imported green beans is primarily related to the cultivation yield in these countries of origin and the transport. The scenario with beans from Kenya has a very high climate impact, for more that 80% attributed to transport via aeroplane. Beans from Kenya (outside of season) are to be found in the store shelves in Belgium, but these are not imported by aeroplane, but by ship. The scenario with beans from Senegal, imported by boat, do not differ much from those from Spain, transported with lorries. Despite the greater distance, transport per boat is relatively more efficient in comparison with transport on the roads. The yield in lands such as Senegal and Kenya is very low in comparison with Holland. The yield in greenhouses is also much higher than in comparison with local cultivation in open-field.

Fresh, or 1st grade, by the 2nd and 3rd grades, processed and deep-freeze. The climate impact from the can, jar and deep-freeze is at the same level. The 2nd grade has a higher climate impact during the processing, but no impact related to the cold storage. Conversely, the 3rd grade, deep-freeze has a higher climate impact because they are stored in cold storage. Fevia points out that in principle, a difference is in the energy consumption for the preparation: products in cans or jars already have undergone a heated treatment and shall be able to be prepared faster and with less energy consumption. This is now presumed (see table input



parameters, row with reference number 14). Another point is the addition of the packaging and the difference between Holland and Flanders.

The production of glass and metal packaging has a rather much larger climate impact than the PE sacks for fresh green beans. In the case of glass and can, the addition is 50-60% to the climate impact, and in the case of PE sacks, the addition is only 1%. The addition of the packaging on the climate impact is estimated to be lower in Flanders because of the higher recycling percentages for glass and metal. The figures for packaging in the study are based on the study by Sevenster, et al., 2007. In the study, in the case of glass, a recycling percentage of 78% and recycled content of 59% are used. The surplus leaves out the difference between primary usage and secondary. These figures are lower than the current recycling percentages for the market in Flanders: this is more than 100% for glass and 98% for metal packaging. (Fost Plus, 2013; see chapter 3.1.2.2). Through these higher recycling percentages, the greenhouse gas emissions from these types of packaging are reduced by 25—40%! This results in a decrease from the total climate impact of green beans in the 2nd grade (jars and preserves) by about 12—13%.

#### **6.1.2.2 Smaller portions for cans and jars (2nd grade)**

This was already mentioned in the section above regarding green beans. Products of the 2nd grade, thanks to preservation techniques and this manner of packaging, remain good for a very long time, even up to years, and this is without refrigerated storage. A disadvantage of that, once the packaging is opened, they have a very limited expiration period and must be consumed as soon as possible. Whatever is left over after preparation, thus for the most part is lost. A simple solution is to choose for a smaller portion size. This indeed implies more packaging material per unit kg, and to this end, the trade-off point is calculated: *'with at least ... % less loss of product in cans or jars, the impact of the smaller packaging is compensated for'*.

#### **6.1.2.3 Fresh pre-cut and washed vegetables in a bag (4th grade)**

'Salad/lettuce' is a category that is to be found both in the 1st grade and also is experiencing a light growth in the 4th grade. The volume share of pre-packaged (4th grade) lettuce amounted to 20% of the total fresh lettuce market (VLAM) in 2013. Retailer Tesco in the United Kingdom came out with surprising Figures on the loss of 'bagged salad' in the total chain: more than 2/3 of the lettuce would be lost. Studies abroad indeed confirmed that the loss of the pre-packaged lettuce, primarily in the distribution, is higher than the lettuce sold in bulk (Mena, et al., 2010). Figures for the local market in Flanders are not available. Lettuce in the 4th grade, however, cannot be compared with lettuce from the 1st grade, sold in bulk or also packaged. The differences are qualitatively evaluated from a broader system perspective, with respect to aspect of loss and climate impact.

#### **6.1.2.4 Smaller or mini-portions of pre-packaged vegetables (1st grade) and pre-cut lettuce (4th grade)**

Accordingly, for the previous section on pre-cooked lettuce from the 4th grade, the trade-off point is calculated for the conversion to smaller packaging. The consumer can choose from various portion sizes; from mini-portions (1—1,5 servings) and the larger format (4—6 servings), and sometimes offered in a re-sealable bag (with Zip-lock). The advantage of buying more, smaller mini-packages in place of one, larger package is that at the time of the meal itself, one can decide how many packages to open. The advantage of leftovers in an unopened, small packaging is that the lettuce is still always packaged in a protected atmosphere (EMAP). With

large, re-closable bags, this is no longer the case. Once the bag is opened, the protecting atmosphere disappears and the brown colouring and spoilage of the lettuce will occur sooner.



*Figure 28 : Left, lettuce in closed mini-bags (1,5 portions); Right, lettuce in opened, large non-reclosable bag (4 portions)—1 week after sale.*

#### **6.1.2.5 Blanched, vacuum-packaged potatoes and vegetables (5th grade)**

Potatoes are primarily a product known in the 5th grade, and slowly the selection is expanding out with others such as endives, Brussels sprouts, carrots, cauliflower, and so forth. The potatoes or vegetables are first vacuum packed and then steamed cooked. The potatoes or vegetables have an expiration period of at least 4 weeks. This is shorter than the expiration period that can be achieved with processed products in the 2nd or 3rd grades, such as previously mentioned, and thus these cannot be compared: the end-product differs in taste, preparation method, and so forth.

## **6.2 Data inventory**

In 2013, the average home consumption of vegetables was 49,4 kg per person, including deep-freeze and processed vegetables. Fresh vegetables (1st grade, unprocessed and 4th grade pre-cut, washed...) account for 82% of the total home consumption of vegetables; preservatives and jars (2nd grade) 11%; and deep-freeze vegetables (3rd grade) 7%. The following to 5 series of fresh vegetables is representative of 82% of the total home consumption of fresh vegetables. This is all of the vegetables that can be counted in Flanders.

Top 5 fresh vegetables, household consumption	Kg per person per year
Tomatoes	6,3
Carrots	6,3
Onions	4,6
Endives	3,7
Lettuce, of which Fresh (1 <sup>st</sup> grade), Bagged (4 <sup>th</sup> grade)	2,6 80% 20%
<b>Total fresh vegetables</b>	<b>40,5</b>

*Table 13: VLAM, Figures 2013*

Figures on the loss of lettuce (heads) in the chain are to be found in various sources: 20% loss in the agriculture and horticulture phase (Roels and Van Gijsegheem, 2011); 9—15% in the production and distribution chain; and 14—39% at the consumer level (see chapters 2.5 and 2.6). According to a study on the loss at the retail level (Mena, et al., 2010), this percentage should be higher with pre-packaged lettuce than with non-packaged, fresh lettuce. In this study, we work with a range on the basis of the minimum and maximum values above. The loss over the total chain is then between 37% minimum and 59% maximum. Figures on the climate impact come from various studies. Van Hauwermeiren, Coene, Engelen, & Mathijs (2007) calculated the climate impact for local and conventional distribution chains (see table 14). AMS, L&V (2014) calculated in the context of this study a climate impact of 0,44 kg CO<sub>2</sub>e per kg for lettuce produced in the Flemish greenhouses on the basis of recent figures on the energy consumption in the Flemish greenhouses and specifically for lettuce cultivation. For the packaging analysis, measurements are carried out on packaging of pre-cut lettuce in the 4th grade (n=15) and green beans packaged in different portion-sized cans (n=4).

Food item	Local food systems			Mainstream food systems		
	Transport	processing & storage	total	Transport	processing & storage	Total
	g CO <sub>2</sub> /kg	g CO <sub>2</sub> /kg	g CO <sub>2</sub> /kg	g CO <sub>2</sub> /kg	g CO <sub>2</sub> /kg	g CO <sub>2</sub> /kg
Beef	285.73	56.74	342.47	25.01	56.74	81.75
Potatoes	200.05	0.00	200.05	78.53	negligible	78.53
Cabbage lettuce	177.33	21.79	199.12	78.53	22.08	100.61
Tomatoes	198.70	5.19	203.89	78.53	4.73	83.26
Carrots	233.40	11.33	244.73	78.53	10.09	88.62
Apples	36.69	40.72	77.41	39.77	27.02	66.79
Gouda cheese	1557.14	841.71	2398.85	443.56	1389.10	1832.66
Average	384.15	139.64	523.79	117.49	215.68	333.17

*Tabel 14 : Climate impact of local and conventional distribution system (Van Hauwermeiren, et al., 2006)*

## 6.3 Results of case studies for lettuce and green beans

Amongst the green vegetables, green beans in the can and fresh lettuce; 1<sup>st</sup> grade (full head, unprocessed) and 4<sup>th</sup> grade (pre-cut and washed), are investigated as specific case studies.

The case study on green beans in the can was limited with a supplement from existing, available research (see chapter 6.1.2.1). The specific objective was to calculate the trade-off point for the conversion of large cans (400g net) to smaller portions in the can (200g net). The result is a

broad range: from at least 15% less loss in the worst case to a case in which the impact of the system with smaller packaging was even more advantageous than with the larger packaging.

When we bring the figures regarding loss of lettuce in relation to the home consumption of lettuce in Flanders, then we arrive at a total annual production (1st and 4th grades), including loss, of 23—25 kt, of which 37—59% or 9—14 kt is lost in the chain. The largest portion, circa 2—7 kt, is lost at the consumer level, and the agricultural sector with circa 5 kt. The packaging that is paired with lettuce is <0,5 kt. The annual loss of lettuce in the chain represented a climate impact of 2—4 kt CO<sub>2</sub>e (equal to driving 150—350 times around the world with an automobile).

In comparison with the other case studies, this climate impact is rather limited (see chapter 9, 'General Conclusions').

Because the climate impact of the lettuce is so low, the climate impact of the plastic bag or tray varies greatly with respect to the lettuce itself. On the basis of a random sampling of 10 different packaging and portion sizes for lettuce, this goes from 14% to 166%, average for the sampling is 54%. In comparison with other case studies (i.e. soft drinks), this is on the high end, but that mainly come from the relatively low impact of the product of lettuce itself. The consequence of this is also that the trade-off point varies greatly in the function of the weight of the packaging. By heavier packaging for lettuce, such as dishes, the trade-off point is very high. If we only look at plastic bags for lettuce, then with the trade-off point, for example, of switching from a large, re-closable or non-closable bag of 300-400 grams to smaller bags of 100—200 grams, or from 100—200 grams to the smallest portions of 40—80 grams, then starting at 2—5% less loss, that point is already obtained. With the subject of small portions of lettuce, attention is given to a light-weight implementation of importance on the trade-off point with regards to keeping large portions low.

### **System Perspective, Lettuce 1st and 4th grades**

In the 3 Figures below, the differences in the value chains, the processes and the aspects of losses, water usage and climate impact are presented.

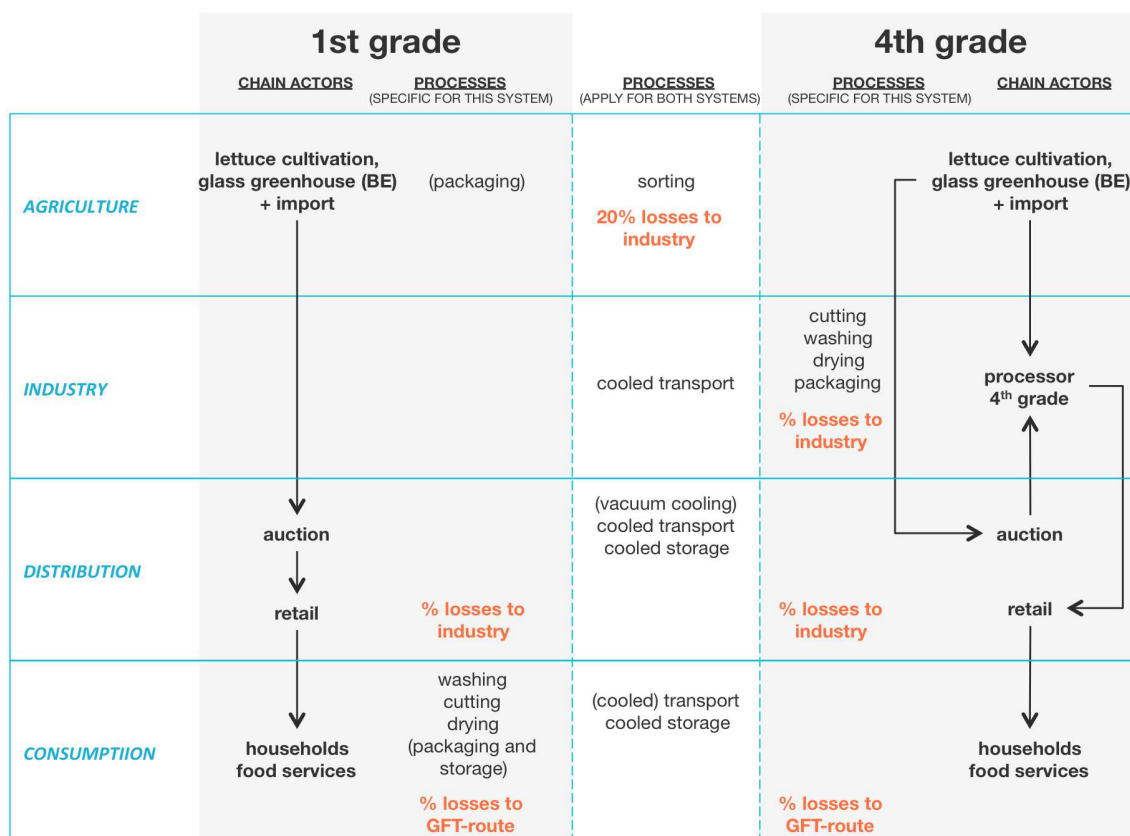


Figure 29: System Perspective, Losses aspect

#### Losses in the chain

- Losses in the agricultural sector are not related to differences between 1st and 4th grades.
- The processing of the lettuce (portions discarded, not fit for consumption) shift from the consumer phase to the producer stage.
- Losses and by-products that come about in the industry are evaluated as fodder, or for energy incentive; losses and by-products that occur at the consumer level are evaluated in the GFT route. Well-presented channels from the industry can be valued at a higher worth.
- Losses in distribution (supermarket phase) should be higher for pre-packaged lettuce than lettuce in bulk. In the study by Mena, et al. (2010), the value decline of pre-packaged lettuce should be '>7%' and in bulk '<7%'.
- Additional disadvantage is that loss from packaged lettuce in the retail (unopened packaging) is no longer a fraction of pure biomass.
- Pre-cut lettuce has, in principle, a shorter expiration period than non-cut lettuce. In order to prevent and slow down brown discolouring on cut edges, freshly cut lettuce is rinsed in ice-cold water.

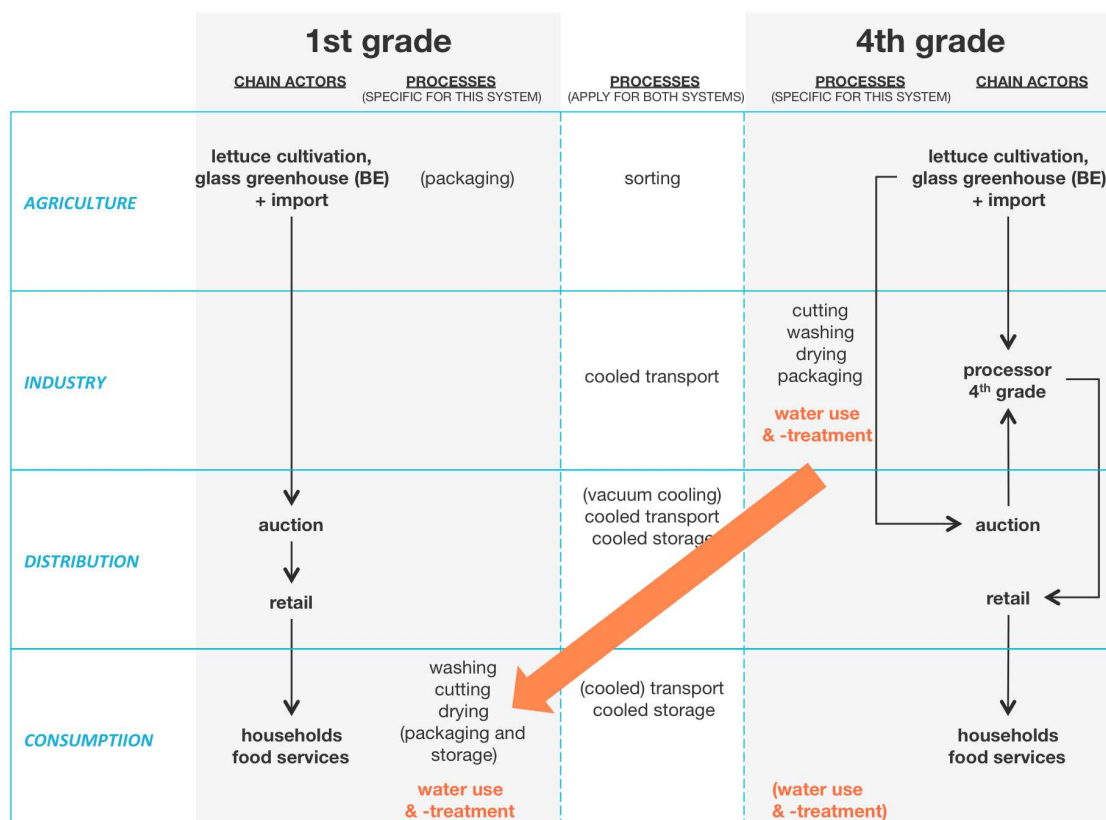


Figure 30: System Perspective, Water usage aspect

#### Water Usage:

- Water usage in agriculture is not related to the differences between 1st and 4th grades.
- Water usage shifts from the consumer phase to the producer phase (fresh cutting). This water usage is significant and strongly dependent upon the (Best Available) Techniques that one applies, such as the number of washing steps and the application of a closed system with the re-usage of water. In the study by Stoessel, et al., (2010), there is mention of a water usage of 0,4 litres per kg end product for the washing of vegetables in the industry. 1 kg of lettuces is 2—3 heads. Washing at home, under a running tap, or partially filled sinks, will result in many times this water usage.

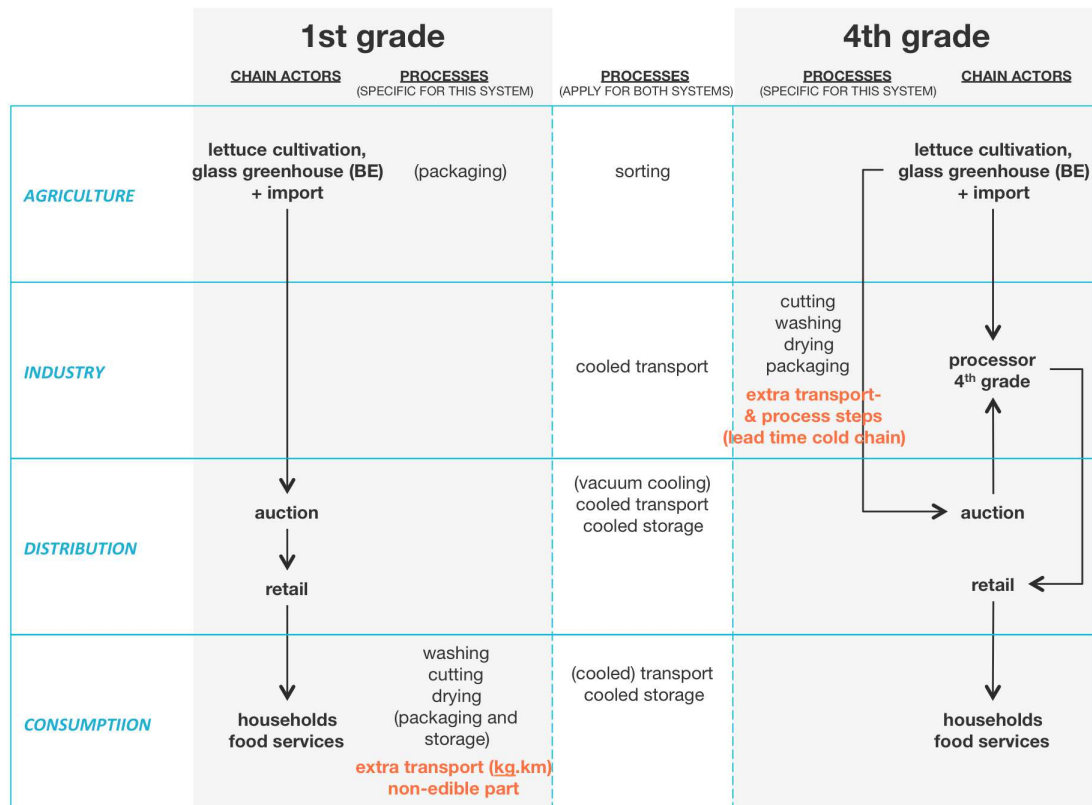


Figure 31: System Perspective, Climate Impact Aspect

#### Climate Impact:

- To a large extent, this is determined by the distance travelled and the number of transport steps in the 2 different chains. With lettuce in bulk, one can, in principle, keep the chain shorter, but much is dependent upon how efficiently the chain is organised. Best-practice examples of auctions also allow that for vegetables in the 4th grade chains can be organised to be very short and efficient.
- In an LCA study of carrots in bulk and pre-cut and packaged in a plastic bag (Ligthart, Ansems & Jetten, 2005), it was concluded that the impact of the transport by the consumer is lower than with pre-cut carrots. This is because the consumer has proportionally less weight traveling with the auto. With unprocessed carrots, as well as in the case with lettuce in bulk, the non-edible fraction is transported over more transport kilometres, which has an influence on the climate impact. This difference is, however, very minimal. In the case of longer chains (time, distance), for example, export products or exotic import products can also play a role.

A detailed LCA analysis can quantitatively bring into focus these different chains and weigh the environmental differences. There are pros and cons connected to both systems and one-sided reports on the high losses of 'bagged salad' must be weighted in this broader system perspective. Further research is recommended.

## 6.4 Conclusions and Recommendations

### **Conversion from a full head of lettuce (1st grade) to a smaller sack of lettuce (4th grade)**

is reasonable beginning at 15% less loss of lettuce. This is primarily interesting for smaller households if the head of lettuce is too large. There will also be less water used. The lettuce is already washed and does not need to be washed again. This is more efficient in the industry than at home.

**Conversion to smaller packaging of pre-cut lettuce (4th grade)**, for example, of a large re-sealable or non-resealable bag of 300-400g to bags of 100-200g, or from 100-200g to the smallest portions of 40-80g, is reasonable beginning with 5% less loss of lettuce. For doubts as to how much lettuce one will need and consume at a meal, this can offer a solution. A larger, re-sealable bag will, after the initial opening, also still protect the lettuce. After the initial opening, the bag protects the lettuce against humidity loss, however, the protective atmosphere is gone, by which the remaining preservation time is rather short. The environmental impact of a re-sealable bag, usually made with a heavier foil and the added sealing mechanism present, is more or less the same and in some cases even higher than the smaller, thinner bags with a protected atmosphere (EMAP)

**Conversion to smaller cans of green beans (2nd grade)**, for example, from large cans of 400g net (this is circa 220g drained) to smaller cans of 200g net, is reasonable beginning with 15% less loss of green beans. This comes to about 34 grams of green beans (drained weight).



## 7 Spreadable Cheese

The case study for spreadable cheese is focused completely upon the losses in the retail—consumer chain because of the limited expiration time for the product in combination with the packaging. A well-closed packaging creates a good condition for the preservability. However, once the packaging is opened, the cheese must be consumed quickly; for example, 150 grams of fresh goat cheese should be within days, or at least 1 person from the family at least 1 portion per day. Sometimes the consumer has the choice from still smaller packaging or mini-portions, but that is not always the case. The BAT study on dairy products (Derden, et al., 2007) provides a good overview of the causes, and the Best Available Techniques in order to prevent product losses in this production step of the chain. These are all primarily process-related.

### 7.1 Options for spreadable cheese

#### 7.1.1 Packaging

##### Smaller portions and mini-portions packaging

Spreadable cheese is usually packaged in a plastic polypropylene (PP) small cup, sealed with an aluminium foil or cover or, if it involves somewhat more solid spreadable cheese, then in small aluminium foil wrappers or dishes within a cardboard outer packaging. The latter is a known example of mini-portions where the consumer is already familiar with for a long time. The most well-known example of this is perhaps indeed ‘La Vache Qui Rit’. There are also spreadable cheeses and spreadable goat cheeses, typically packaged in plastic PP cups with available portions varying from 150—200 grams to the large cups of 300 grams.



*Figure 32: Mini-portions in plastic cups or aluminium foil wrappers and cardboard*

For these products, one can always choose more often for mini-portions (see FIGURE) in the store. Mini-portions are primarily intended for small portions and usage outside of the home, for

example at work or school. Sometimes the consumer has no other choice than the packaging with mini-portions for the same product. On the contrary, in the same way, sometimes the consumer has no other choice for the same product than a normal or large portion in a cup. If the consumer indeed has the choice between these various packaging options for the same product, the conceptualisation and perception of over-packaging arises. This is strengthened by the message that 'less packaging is always better for the environment'. This demonstrates the packaging Paradox (see chapter 3.1.2). Mini-portions can prevent food loss, especially with smaller portions of spreadable cheeses or goat cheeses with limited expiration time, and thus avoid the impact of the production, the transport, cold storage, and so forth of the portion of the spreadable cheese that is lost. Conversely, the packaging of mini-portions is relatively heavier (kg packaging per kg product) and the impact of the packaging is usually higher. In this case study, it is investigated after what point this extra packaging impact becomes compensated for by less loss of spreadable cheese or goat cheese:

*'With at least ...% less loss of spreadable cheese/goat cheese, the extra impact of the packaging for mini-portions compensated for'.*

With this message, it is still always up to the user to determine whether this can make a difference based upon his or her personal lifestyle and environment.

#### **Mini-portions and smaller portion sizes, also for other types of cheeses!**

Processed and goat cheeses have but a limited market share in the total cheese usage, circa 12,5% of the total home usage (source: VLAM on the basis of Figures from GfK). The packaging principle of dividing the cheese content into different compartments, and to package within a protected atmosphere, is perfectly applicable and scalable to the other types of cheese. A good example of this is the pre-packaged slices of cheese in different compartments.



*Figure 33: Slices of cheese in compartmentalised packaging (source: Cheese Import Jan Dupont, Bruges)*

An important point with hard and semi-soft cheeses is the quality of the seal. Cheeses are frequently packaged by vacuum or within a protected atmosphere. In principle, this has to do with the same packaging options as with meat-products (see chapter 5). However, cheese will always begin to mould quickly as soon as there is a (micro) leak in the packaging. Special cheese, and mostly those with a limited expiration time are also more sensitive for loss within the production—retail chain. Adjusting the offer for demand is more difficult because they are primarily purchased for special occasions. Here too there are always more cheeses in mini-portions and smaller portion sizes to be found.

In general, one can imagine that with cheeses, the packaging (even more so today this is the case) can play an enormous role in combatting losses. In the segment of spreadable cheeses,

fresh cheeses, hard and semi-soft cheeses, one can thereby exert more force on more choice for small packaging, and with this, compartments (mini-portions).

### **Packaging of other liquid dairy products**

Packaging of other liquid dairy products such as milk, yogurt, farmer's cheeses and so forth, are always very well packaged (above all with a strong light barrier). The largest losses at the consumer level are consequent to packaging sizes (leftovers). Technologically seen, these products can be packaged in all possible packaging types, so long as the light barrier is guaranteed. Re-sealable packaging and sufficient choice for the consumer and the availability of smaller portion sizes and mini-portions are therefore also in this case the packaging strategy that is being promoted. These vary already now in commercially available packaging. This deals with here then primarily with raising awareness for the consumer. Yet, still for certain types of milk products of specific brands or house brands, only the normal portion sizes, between 100—200 grams, are available. Here, we are thinking about farmer's cheeses, mascarpone, special yogurts such as Greek, fresh cheese specialties, and so on.

### **Re-sealable Packaging**

Slices of sandwich preparations were previously offered exclusively in plastic disposable packaging. Many consumers took out what they needed and left the rest alone. But, the opened packaging no longer closed very well, thus the foodstuffs dried out more quickly. There are now different systems in usage. The most well-known are the cups with click or glue closures and the bags with zip or ribbed closures. The dairy product remains good for a limited time still with regards to the microbial preservability, but one does indeed prevent desiccation, aroma and taste loss, ... and those are also causes of food loss. 'Bag in a box' is also a packaging option to extend the expiration period of liquid and semi-liquid dairy products. In place of a bottle, now you buy a box of 3 litres, and thanks to the closure and dispense system, the foodstuff remains good longer.

### **Easy to (completely) empty**

Further in chapter 9, there is an example of this described: the Tetra Top®, presented by Tetra Pak as an answer to the call that has gone out to companies. This packaging makes it possible to more easily empty them and to consumer the entire content. This is a flaw with various packaging types of semi-liquid and somewhat solid dairy products and desserts: ribbings, difficult hooks in the form of the packaging, a too-narrow opening, and so forth, prevent the consumer from consuming the product completely. This student also made innovations, not on the packaging, but the spoon (see FIGURE).



Figure 34: Innovation example for leftovers in yogurt pots.

This and still other innovations for innovative packaging for dairy products and cheeses that can combat loss are to be found on the inspiration board '2save zuivel | dairy' on: <http://www.pinterest.com/pack2savefood>.

## 7.2 Data inventory

Spreadable cheese is prepared from melted cheese with an addition of salt and a small amount of water, by which it becomes spreadable. There can be other ingredients added such as herbs or pieces of ham. The home usage of melted cheese, including other types of melting cheese such as 'smelly' cheese, is 1,1 kg/pp/year. The home consumption of goat and sheep cheese is 0,4 kg/pp/year (VLAM, Figures 2013). The portion of the spreadable cheeses within the melting and goat cheeses is not known. The result is calculated on an estimate of 50—66% of this quantity (0,75—1 kg/pp/year). Figures for the losses of cheese at the consumer level vary between the 3% of the edible purchased quantity (CREM, 2013) and 13% (DEFRA, 2010). With the baseline of food loss in the refuse in Flanders (OVAM, 2011), the portion of dairy products is 0,41 kg/pp/year or 0,36% with respect to the quantity of household waste. The baseline study makes no further distinction between the 0,2—0,8% for the hard and semi-soft cheeses and around 2% for soft cheeses such as Brie (Eriksson, et al., 2013). Similar Figures in the INCPEN study (2013) for hard and semi-soft cheeses are 0,3—0,8%. Losses in the dairy industry are 1,41% (FEVIA, 2014). Milk losses in the agricultural sector account for 0,95% (Roels and Van Gijsegheem, 2011). Figures on the climate impact related to (standardised) milk are based upon the Carbon Footprint study by ERM & University of Ghent (2013) on the products of the Flemish cattle farming. The climate impact related to the production of cheese on the basis of cow milk or goat milk is based upon a Dutch LCA study of these products (CE Delft, 2011). For the allocation of the impacts on the final cheese product and the by-products, the IDF (2010) standard was applied, consistent with the methodology such as in the ERM and University of Ghent Carbon Footprint study and the Dutch LCA study. This method takes into account the production of milk and cheese by-products (milk fat, whey,...) and a portion of the impact is attributed to the by-products such as cream, butter, whey powder, lactose, and so forth. The impact of the packaging is based upon a sampling of 3 known types of spreadable cheeses and goat cheese that can be purchased by the consumer in normal cup (150—200 grams) or in mini-portions. One of these spreadable cheeses is also available in a larger packaging of 300 grams. In this one case, it is also calculated from what percentage of less loss the switch from a normal portion of 200 grams is compensated for.

## 7.3 Results for Spreadable Cheeses

When we bring the Figures concerning loss in connection with the (home) consumption of spreadable cheeses in Flanders, then we arrive at a total annual production including loss of 5 to 7 kt, of which 11% is lost in the chain. The largest portion, approximately a half of a kiloton, is lost with the consumer, the remainder in the supply chain. The packaging that is paired with spreadable cheeses is 0,5—0,6 kt. The annual loss of spreadable cheeses in the chain represented a climate impact of 4 to 5 kt CO<sub>2</sub>e (300 to 400 times around the world in an automobile). Of the total climate impact, the loss in the chain (L) 10%, the portion of consumed spreadable cheese (F) 84%, and the packaging of the portion of consumed spreadable cheese (P) 5%. The climate impact of the packaging with respect to the spreadable cheese varies from 4% to 9%, dependent upon the content of the packaging, the type of packaging material, and the extra weight of mini-portions with respect to normal cups. The packaging weight difference between mini-portions and the normal packaging was in 2 out of three of the cases only 5—6% per unity kg of packaged product. In the third case, the difference was in fact greater than 45%. In the case of mini-portions, if the thickness of the wall of the cup and the aluminium foil is thinner, and they also do not have a lid, then it is more comparable to the normal cup. In two of the three cases, this makes the difference in weight rather limited. For one brand, for which the consumer also has the choice of a larger, family-sized packaging, the weight of this larger packaging is circa 25% lighter per unit kg of packaged product.

## 7.4 Conclusions and Recommendations

### Conversion from normal packaging to mini-portions

*Starting with at least 2-3% less loss of cheese spreads/goat cheese, the extra impact of the mini-portions packaging is already compensated for. The quantity of cheese spread is less than the quantity needed for a quarter of a sandwich (i.e. 5g of a 200g cup).*

Also, if the consumer only throws away a little bit, if mini-portions in his or her life situation can make a small difference, then mini-portions are a responsible choice from an environmental perspective.

### Conversion from a large, family-size packaging to smaller, standard packaging

*With at least 1,5% less loss of cheese spreads/goat cheese, the extra impact of the normal packaging in relation to the large, family-size is already compensated for.*



## 8 Carbonated Soft Drinks

By volume, soft drinks and bottled water constitute a significant portion of food loss. Not so much as percentage loss of the processed quantity (less than 1% per step in the production-distribution chain), or as a percentage of the purchased quantity by the consumer (2—7%). Primarily it is through the quantity of consumption that this category forms an important portion of the total loss with households. In Holland and the United Kingdom, drinks make up 9—15% respectively of the food loss in households. Knowing that the consumption of soft drinks and bottled water per person in these countries is lower than in Belgium, then it should also constitute a significant amount in Flanders.

The decrease of flavour from an unopened packaging of carbonated soft drink or water is the most important cause of loss ('the soft drink is flat'). With other drinks, there are other causes that dominate such as sitting too long and (also) the quick regression of flavour with coffee and tea; typical for wine are the preference of cork and (also) the quick regression of flavour once a bottle is opened. The expiration of the expiration date is for fruit juices and beer the main reason (CREM, 2010 and 2013; WRAP, 2013).

From research in the United Kingdom, it often seems that large quantities of carbonated soft drinks are disposed of at one time in the kitchen sink: 45% of the discarded volume are quantities of more than a half of a litre at a time, and more than 50% between 5 and 50 cl at a time. Also for bottled water, the situation is comparable: 35% of the discarded volume is quantities of more than one half of a litre at a time. Other categories where this is between 30—35% of the discarded volume are cases of milk, soup and wine (WRAP, 'Down the drain', 2009). An overview of the causes of loss of soft drinks and bottled water in the chain:

### **production:**

- Losses during the syrup preparation and the filling process (for example, batch process, cleaning, installations, spills and overflows...); however, negligible percentage of loss (<1%).

### **consumer:**

- Too large portions of bottles or cans of soft drinks;
- Pouring out too large of portions of soft drinks or water in glasses, cups;
- Warming of a poured soft drink (or non-reclosable packaging);
- The last 'dregs' are no longer finished;
- Loss of flavour from soft drinks from large bottles (soft drink is 'flat');
- Too large of purchased quantity (for example too large of group packaging) by which the expiration date is reached or the taste has gone bad by loss of CO<sub>2</sub>;
- Light-weight packaging are thin-walled by which the barrier for CO<sub>2</sub> is also lowered (this can be the case in cheaper products, for example);

- Consumption outside of the home, for example, with kids going to school, youths going out, events, parties and receptions, and so forth, primarily through excesses ('drinks belong with it, even if you aren't thirsty', 'glasses are set down and no longer found again'), time lapse for finishing the soft drink (i.e. the break at the event is over, the school bell...);
- Water with an odour. This comes about from drinking directly from the bottle. Bacteria are responsible for the odour of water in an opened bottle and can even cause diarrhoea;
- Water is just water' and the consumer is less aware of it.

#### **horeca and food services:**

- Too large of portions are offered;
- The client is no longer satisfied with the soft drink from large bottles, which were opened the day(s) before and are already somewhat 'flatter';
- Expired soft drinks. The long expiration period of soft drinks is mainly determined by the CO<sub>2</sub> content and the barrier qualities of the packaging. With a quick stock rotation, this does not pose a problem, but whenever certain carbonated drinks stay in stock longer, then it can still prevent the expiration date from being met. The same problem can occur in retail, but because of the stock-management systems that are being applied there, this is less the case.

## **8.1 Options for Carbonated Soft Drinks and Bottled Water**

With carbonated soft drinks there are three trends at the level of packaging materials that are separate from the striving for less food loss, but in fact (can) have an influence: the development of thin-walled, light-weight packaging, the development of new, bio-based materials and an addition of the recycled content in plastic bottles. The respecting, or ever improving, of the gas barrier holds the carbonation in better within a not-yet-opened packaging. A number of these developments are discussed in further detail. However, such as already mentioned above, the loss of CO<sub>2</sub> from a non-opened packaging is not the most important cause of loss with the consumer. Portions that are adjusted better to everyone's needs seem here to be the most presented strategy to combat loss. Smaller portions indeed imply an addition of packaging per litre of consumed unity. This shall be investigated more closely with respect to the trade-off point: 'With at least how many glasses (of 25 cl) less loss of soft drinks is the addition of packaging material compensated for?' Loss of soft drinks alone is not the most important consequence of this loss at the consumer level. The climate impact of the soft drink itself is in some cases even less than the climate impact of the packaging. With regards to cases of the largest contribution, it depends heavily upon the collection of the soft drink, the packaging material, the portion size, the percentage of recycling used in the packaging, and it is thus not simple. An important contribution to the impact is the transport by the consumer to the store for his food and drink purchases. Yet, we can still say that the impact of the loss of soft drinks, as well as the impact of the loss of the portion of packaging and transport, to a large extent could be avoided should the soft drinks be completely consumed.



### 8.1.1 Packaging

#### Packaging Materials

The current packaging forms and materials are small cans (steel and/or aluminium), PET bottles, grouped together with carton trays and/or PE foil wraps, and returnable, glass bottles in HDPE crates.

#### *Development of bio-based bottles*

Currently there are various biotech firms working on developing the 100% bio-based bottle. The Dutch firm Avantium is focused then on PEF (polyethylene-furanoate) in place of PET (polyethylene-terephthalate). Others, such as the American firms Virent and Gevo are focused on the development of bio-based PET. The foundation for PEF is furan-dicarboxylic acid. Furanoates are molecularly based upon carbohydrates. The carbohydrates are not only able to be taken from living organisms such as corn or sugarcane, but also from wood chips, agricultural waste or old newspapers. In addition to the fact that PEF bottles can be 100% bio-based, there are also other advantages. PEF allows less light, water and Carbon in, by which the product is good longer in the bottle. In proportion, there is mention of less spillage. PEF is very strong, by which the packaging can be produced thinner. With this, there are fewer raw materials needed and the production costs will go down. The development of PEF is going along at full steam. At this moment, it is a bit more expensive to produce. In addition, it also needs to be investigated regarding the recycling possibilities of PEF bottles. The collection and recycling system in Belgium is adjusted to a high-valued recuperation of PET. It is yet unclear in what capacity PET and PEF can easily be distinguished from one another and if PEF does not influence the purity and quality of the PET.

#### *Development of airtight PET bottles (barrier technology)*

The disadvantage of PET with respect to glass and cans is that PET is not completely airtight. Oxygen and Carbon Dioxide are small enough to slip through the holes of the polymer networks. Leave a PET soft-drink bottle for a few years in the cellar and the carbonation will be gone. With a thick-walled 1,5 litre bottle, in four months time some 10% of the carbonation is gone. A moot point, because just at 15% less, people would notice a difference. With individual, thin bottles, this goes more rapidly. The expiration time of these bottles hovers around a half of a year. Only by way of the light permeability of the PET, smaller PET bottles are respectively bulkier in relation to large bottles. For, the smaller the bottle, the greater the relative surface area and how much faster the bubbles are lost. The permeability and incoming Oxygen is also the most important obstacle for beer, juice and wine in PET. Beer goes stale with exposure to air, wine goes sour and fruit juices lose Vitamin C. It is chiefly for reasons of these adaptations that technological solutions in the meantime are developed to make the walls of the bottle impenetrable for incoming Oxygen (rather than for escaping Carbon Dioxide). A solution is for bottles with more plastic layers (multi-layer). Between the PET inner and out layer, then for example, there is a thin layer of nylon. A barrier of three to sometimes five different plastic layers of PET and EVOH ensure for a very strict Carbon Dioxide permeability. The production of a multi-layered bottle is difficult from a technical standpoint. Multi-layer barrier technology also presents problems with the recycling of PET and the quality of the output production by the risk of a mixing of the materials. PET recycling firms are also increasing providing services for specialising in the distinguishing of the various mono- and multi-layer channels. Another solution is that of oxygen scavengers. These materials are mixed by the PET-granulate (or other base material) before the bottle is made. The capture the Oxygen that comes in from the outside air, by which juice, beer or wine stay good longer. As soon as they are saturated with Oxygen, then the Oxygen permeability of the bottle will again be dependent upon the thickness and surface

area of the bottle. However, with this solution for longer expiration time also poses a problem for the recycling of PET. The binding components such as iron or nylon mix with the re-cycled PET and the quality of the output decreases. There are indeed continued further developments in this field that result in a lower impact on the recycling quality. Two other methods exist to strongly decrease the permeability of PET bottles, both for the incoming Oxygen as well as the escaping of Carbon, and the recycling of PET is not influenced. Both are based upon plasma enhanced chemical vapour deposition—abbreviated to PECVD. The first method ensures for an internal Diamond Like Coating (DLC, or Carbon coating) in the PET bottle, via a plasma treatment by introduction of methane traces or acetylene gas. This coating decreases the Oxygen permeability with a factor of thirty, while the loss of Carbon Dioxide decreases by a factor of seven. The second method ensures for an internal silicon-oxide coating on the PET bottle, by which the barrier qualities are substantially increased. According to the producers, SiOx coatings should not influence the recyclability of PET or other SiOx-coated plastic materials such as foils.

### *Recycled PET heavier?*

It is not true that bottles or other foodstuff packaging with recycled rPET are heavier than their counterparts from new PET. This is, however, true for multi-layer applications, with a layer of new PET in contact with the foodstuff and rPET in the intermediate or external layer, but this technology is practically no longer applied for bottle-to-bottle recycling. Recycled bottles now come about as hygienic granulate that is mixed with new PET, from which then the bottles are made. In order to comply with strict regulations regarding food safety, a thin layer of the surface of the ground PET chips is removed, in which the potential impurities are found. The heart of the cuttings stays intact and forms the basis of the hygienic granulate. There are both chemical and mechanical procedures to make hygienic PET recycled material (source: PET recycling firms Cleanaway and Wellman). Since these developments in rPET technology, there are constantly more applications of recycled rPET coming onto the market of packaging for foodstuffs. Bottles for water, soft drinks, shell packaging for fresh fruit, and so forth, are adapted, whereby the quantity of PET is decreased in combination with an increase of the level of rPET. Taking all of these material developments into consideration, the greatest challenge is not so much on the level of risk for material addition of plastic packaging, focused on the reduction of the food loss or other matters such as bio-based aspects, but rather on the level of risks for high-valued (PET) recycling. How this will further develop is difficult to determine. Innovations in the past that have made recycling more difficult, such as multi-layer materials, are consequently welcomed back and improved by other technologies such as barrier-coating techniques that do not influence the recycling.

### **Closable Packaging**

In principle, the consumer can always choose for the packaging form of re-closable PET or glass bottle in addition to other packaging possibilities. All house brands and virtually all major brands offer PET bottles with a number of exceptions. However, certain consumers still choose cans due to personal preferences, also for home consumption. This may have to do with rational arguments such as longer expiration periods or more efficient usage of storage space, or with more subjective arguments such as a difference in taste or experience with freshness. Some swear by cans, and if the 33 cl can is too large, then with some brands there is the choice for a smaller format such as 25 cl or 15 cl (see below in this chapter, option 'portions size'). In the segment of consumption outside of the home, there are also the half-litre PET bottles, mainly the can and in the Horeca also the glass bottles are popular. This is also for various reasons, for example, the load grade of a soft-drink automat or refrigerator is higher with cans than with PET bottles, cans are colder sooner than PET bottles, a Horeca business will give a certain appearance and thus choose for the nice, glass bottles, and so forth. Mainly in the segment of outside the home, there are a number of innovations that are adaptable, for example, the PRIKIT, primarily intended for children, or the BRE closable can, primarily intended for the

energy drinks in the grey channel such as petrol stations (more examples can be found on the inspiration board '2savedrinks' on [www.pinterest.com/pack2savefood](http://www.pinterest.com/pack2savefood)).



*Figure 35: PRIKIT (Mol) is an invention to keep the bees out and the straw in the bottle or can. Less spilling also occurs with bottles that fall over.*



*Figure 36: Ball Resealable End (BRE) closable cans (source: [www.ball-europe.com](http://www.ball-europe.com)).*

### **Portion Size**

The market portion of the carbonated soft drinks in packaging of 1 litre up to 2 litres was circa 60% in 2006 (OIVO, 2007 on the basis of figures by ACNielsen), by which the 1,5 litre bottle had the largest market share. In the range of small packaging up to and including a half-litre container, the 33 cl cans had the largest market share. The trend towards smaller packaging has carried on continuously since then. The choice possibilities are also constantly increasing. For the trade-off exercise, it is calculated for how many soft drinks at the minimum must be less lost in order to compensate for the switching over from the largest PET bottles in the assortment of a brand or house brand (1,5 or 2 litres) to the half-litre PET bottles.

## **8.2 Data inventory**

According to the Food Consumption Survey of 2004, the average intake per person per year is 82 litres of soft drinks (sweetened and light) and 227 litres of water, including tap water. According to the figures of VIWF, the sector association of the Belgian water and soft drink industry, the purchases per Belgian in 2011 are: 132 litres of soft drinks and 124 litres of bottled water (source figures: Canadean, Nielsen). The majority of the soft drinks are carbonated (circa 92%). With bottled water, it is a bit less than a third that are carbonated (26,8%). Figures from the VIWF also indicate that the consumption of bottled water saw a decreasing trend, and soft drinks an increasing one between 2000 and 2011. For soft drinks, that is an increase of some 25%. This increase is attributed for the most part to the light soft drinks. Between 2000 and 2011, the consumption of regular soft drinks rose with 7,8% while that of the light soft drinks was no less than 110%! The market share of the light soft drinks in 2011 is 28,4% (source: VIWF

website). With regards to the consumption (litre per person) of bottled water as well as with soft drinks, Belgians belong amongst the top 3 consumers in Europe.

	<b>Intake (2004)</b> <i>litre/pp</i>	<b>Purchase (2011)</b> <i>litre/pp (% Market Share)</i>
<b>Water (including tap)</b>	<b>226,7</b>	
<b>Bottled water</b>		124 (43,8% MA)
Carbonated		33,2
<b>Soft drinks</b>	<b>81,7</b>	<b>131,6 (46,6% MA)</b>
Carbonated		120,7
Sugar	50,4	94,2
Light	31,3	37,4
<b>Fruit juices and nectars`</b>	<b>20,5</b>	<b>21 (7,5% MA)</b>

*Table 15: Intake and purchases of soft drinks and bottled water.*

As it can be noticed, there is an enormous difference between the figures dealing with the intake (82 litres per person) and the purchases of soft drinks in 2004 (circa 120 litres per person in the period of 2003-2005). The VCP figures are not based upon measurements, but on self-reporting by people in a test group. Respondents might be inclined to underestimate their consumption of less healthy products such as snacks, sweets and soft drinks. The figures by the research firm Canadean on the purchases by families are measured values.

Loss of drinks by the consumer was also investigated in various foreign studies. In Holland (CREM, 2010 and 2013), the loss of drinks (excluding dairy) is 2% of the purchased quantity. Drinks account for 9% of the total food losses by consumers; herein coffee, tea, soft drinks, fruit juices and wine have a portion of a comparable order of amount. In the United Kingdom, the portion of drinks is greater, as it constitutes 15% of the food loss by consumers there. The largest portion, one third of this, is from carbonated soft drinks (WRAP, 2013). 7% of the purchased amount is lost there (DEFRA, 2010). Both in Dutch and the British study, the absolute loss of bottled water is less in comparison with soft drinks. The consumption of bottled water in these countries is about 5 times lower than in Belgium (see Figure). The consumption of soft drinks is also 14—18% lower in these countries, but the difference is less than that with bottled water.

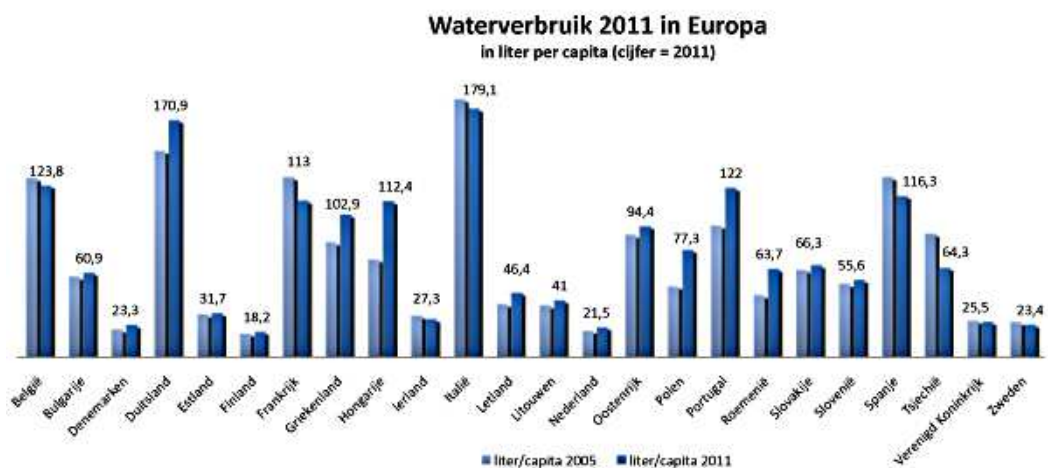


Figure 37: Bottled water consumption in European member states.

The climate impact related to soft drinks is primarily with the production of the raw material sugar (on the basis of beets or cane sugar), the acidifier and carbonation, the energy consumption in the production and distribution phases, and the energy consumption and the emissions of the cooling apparatus in the retail or Horeca phase. The latter is for the most part to be attributed to the drinks that were sold for usage outside of the home. Figures on the climate impact of the raw materials and the production and distribution are to be found in an LCA study for the UK market (Amienyo, et al., 2013). In addition, Carbon Footprint studies were also carried out and published by various (large) producers and retailers. The results on the climate impact of the packaging were calculated on the basis of a measurement of the weight of the various one-time soft drinks and water packaging of different types (i.e. can, PET) and sizes. There was a sampling taken of the soft drinks and water of brands and of house brands of different supermarkets (n=20). Secondary and tertiary packaging was also taken into account. The impacts of the packaging were calculated by various LCA databanks and software. For the study, it was assumed that packaging for all drinks is evaluated via the PMD route (see chapter 3.1.4.1).

## 8.3 Results for Carbonated Soft Drinks

When we bring the figures concerning loss in connection with the consumption of carbonated soft drinks in Flanders, then we arrive at a total annual production of 796 kt, of which 7%, or 54 kt, is lost at the consumer level. Losses in the production and distribution phases are negligible (less than 1%). The loss in the agricultural phase is 3% with sugar derived from beets. The plastic and metal packaging that is paired with the soft drinks is 29 kt (glass is left outside of consideration in the study).

The annual loss of soft drinks has a climate impact of 24 kt CO<sub>2</sub>e (2150 times around the world in an automobile). Of this, 17 kt CO<sub>2</sub>e is because the soft drinks are lost, and 7 kt CO<sub>2</sub>e because of the share of packaging that also could have been avoided. Of the total climate

impact, the loss in the chain (L) is 7%, the portion of soft drinks consumed (F) 64%, and the packaging of the portion of consumed drink (P) 28%. The climate impact of the soft-drink packaging with respect to the packaged soft drink varies greatly depending heavily upon the content and the type of packaging, for example, approximately 70 to 90% in the case of bottles and cans of a half-litre or less, sold not-chilled, and 35 to 60% in the case of being sold chilled. For PET bottles of 1 to 2 litres, the climate impact of the packaging is 30 to 40% with regards to the climate impact of the (usually not sold, chilled) soft drink. In no single specific case was it true that the climate impact of the packaging was higher than the soft drink itself. In the study, an average soft drink (60% sweetened and 40% light) is assumed. A determining factor for the climate impact of a soft drink is the sugar content as well as the type of sugar (beets or cane), among other things. In the case of light soft drinks, the impact of the packaging with respect to the soft drink shall increase. This is surely also the case with bottled water, where the climate impact of the water itself is as good as negligible, and is nearly exclusively related to the operational production and distribution activities. The order of magnitude of consumption is the same (see table 15) as for the carbonated soft drink. The packaging is similar by nature, but with a smaller number of can in comparison with soft drinks. The climate impact of the packaging with respect to mineral water varies here from 90% to 110%, primarily dependent upon the size of the bottle.

## 8.4 Conclusions and recommendations

**Conversion from larger to smaller packaging** for home usage is reasonable from the environmental standpoint in situations where the user frequently throws away large quantities of drinks from large 1,5 to 2 liter PET bottles. According to research, this is the leading cause of loss of carbonated water and soft drinks. With at least 20% less loss from large 1,5 to 2 liter PET bottles, (this is circa 1 large consumption of 33cl), the environmental impact is compensated for with respect to the usage of the smaller 0,5 PET bottles, or 33cl cans. We can draw this conclusion for the situation in Flanders, where PET bottles and cans are recycled to a large extent. In countries where this does not happen or on a lesser scale, then the impact of the packaging with respect to the packaged product will increase and it then becomes that much more difficult to likewise compensate the additional packaging with less loss.

## 9 Results and general conclusions

In the chain, food is lost before, during and after the packaging phase. An estimate for the 6 case studies of the total 'food loss' in the chain as a percentage of the total quantity of produced food varies from 10% for carbonated soft drinks to 48% for lettuce. Thus, 52% to 90% is 'intake', or is actually consumed (figure 38). In the 6 case studies investigated, the weight of the primary sales packaging is 1% to 10% of the weight of the total quantity of food that is produced, taking into account losses (figure 38). A portion of this packaging also could have been avoided and is indirectly a consequence of food losses ('packaging loss' in the figure).

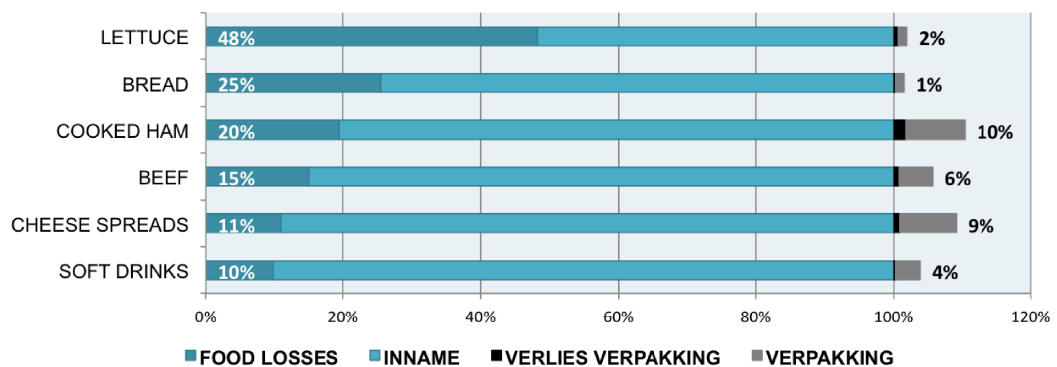
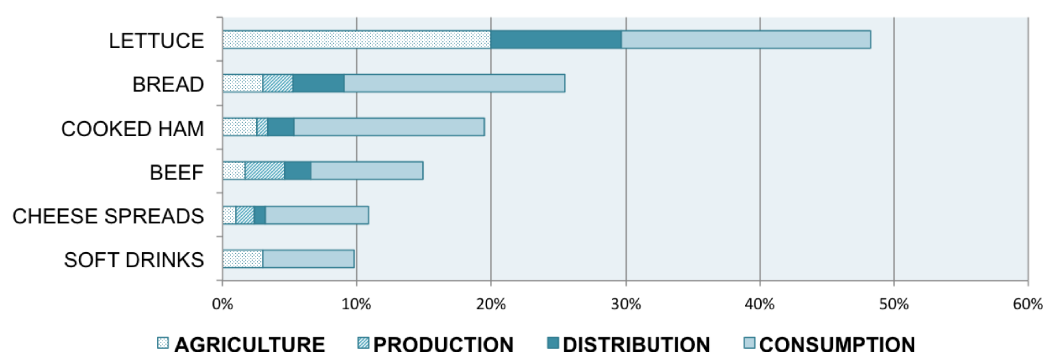


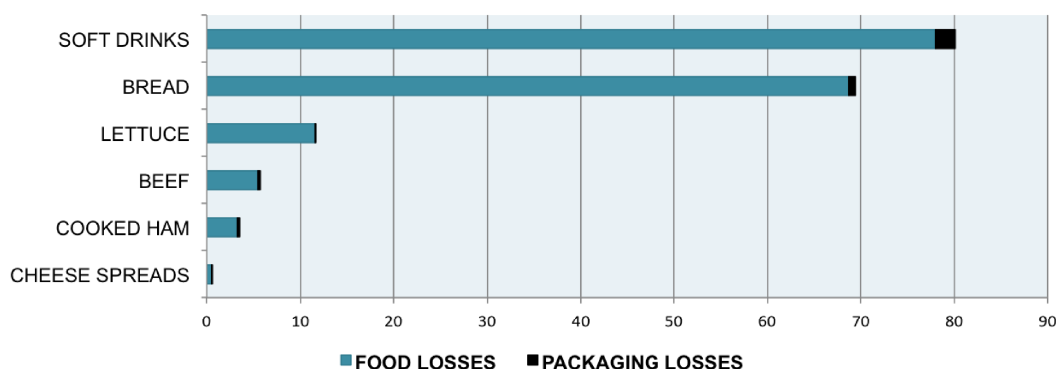
Figure 38 : Weight perspective of food, loss and packaging

If we look at the phases in the chain where the food loss occurs, then the relationships lie elsewhere per study, but the consumer phase dominates (figure 39). The role of packaging in reducing food loss in the various links of the chain is dependent upon the specific causes and also packaging only has an influence from the moment that the product is packaged. The role is rather limited in the agricultural phase. The average 2,3% of losses in the food companies is also primarily related to factors that are separate from the qualities of the packaging itself, such as for example: losses with production changes, interruptions and human error. Operational errors such as labelling errors, non-closed packaging, or damaged packaging are also causes of loss with food companies (Fevia Flanders, 2013). Some causes are possible to treat through packaging, for example, not being able to fulfil contractual conditions with clients because the remaining expiration period is too short. Packaging options, usually taken by producers on their own initiative, or by request of their clients, will mainly have effects further up in the chain; in the distribution phase and with the consumer. Losses in the distribution phase are limited; average 2,5% (source, Comeos). For the case studies involving bread and lettuce, this is higher. The loss at the consumer level is 7% to 19% in the 6 case studies looked at (figure 39).



*Figure 39 : Weight perspective, food loss in the chain*

Another perspective is taking into account the consumption of these products in Flanders. Figure 40 shows the food loss in the chain related to the consumption in Flanders for the 6 case studies. Soft drinks and bread, both categories with which the daily consumption is high, come then to the forefront.



*Figure 40 : Weight perspective, kiloton food loss related to consumption in Flanders, 2013.*

If we view these relationships now from the perspective of climate impact, then a completely different image is formed (figure 41). The climate impact of the packaging with respect to the food type varies in the case studies from 1% for fresh beef to 44% for carbonated soft drinks. The portion of climate impact of the food type that is lost in the total chain varies from 8% for carbonated soft drinks to 15—34% for lettuce (average 24%). In all case studies, the climate impact of the food quantity that is lost is greater than the impact of the quantity of packaging, except for carbonated soft drinks. The climate impact of a product increases respectively the further up the chain it is found and the more process and transportation steps it has undergone: a percentage of loss in the consumer phase weighs heavier than a percentage of loss in the agricultural phase. For these reasons, the portion of 'food loss' is relatively lower than from the perspective of weight (figure 38). The climate impact of the primary sales packaging varies from 1% for beef to 44% for carbonated soft drinks with respect to the climate impact of the food product itself. The climate impact of the packaging that also could have been avoided by less food loss mainly shows up in the forefront with lettuce and carbonated soft drinks.

In absolute terms, the climate impact as a consequence of the loss of beef is the highest of the 6 case studies. Lettuce, despite the high percentage of loss, has the lowest climate impact (figure 42). On the one hand, this has to do with the different quantities of consumption per year, and on the other hand, with the difference in the impact per kg of the food product itself.



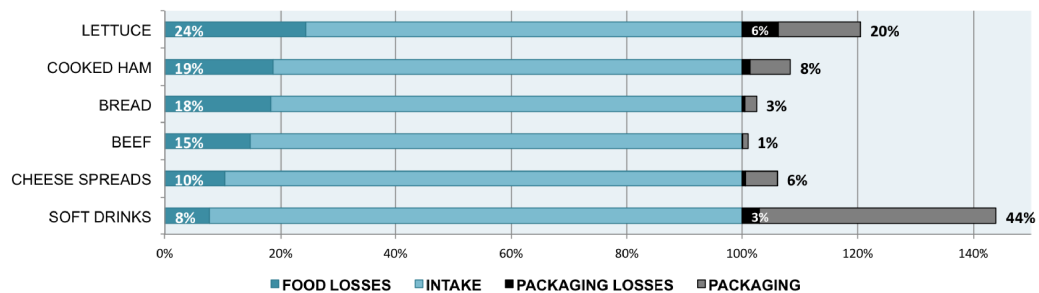


Figure 41 : Perspective of Climate Impact, Food, Loss and Packaging

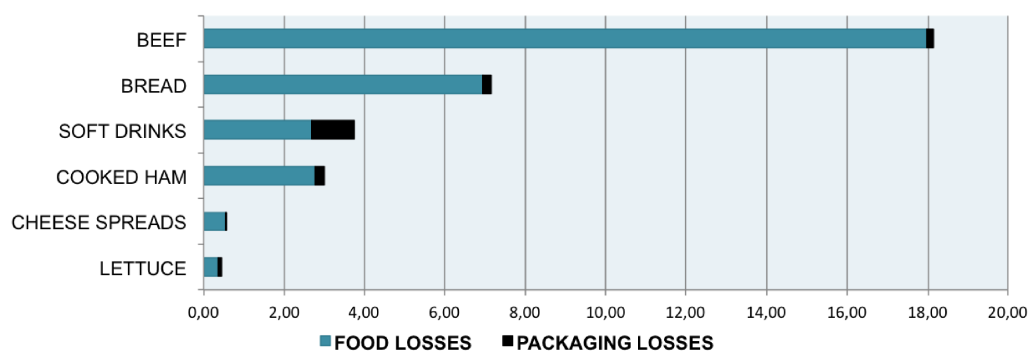


Figure 42 : CO2 kg equivalents per person per year (Flanders 2013).

For the 6 case studies, there are then various options viewed and the trade-off point is calculated beginning from the least amount of less food loss that will compensate for an increase of the climate impact related to the packaging (Figure 43).

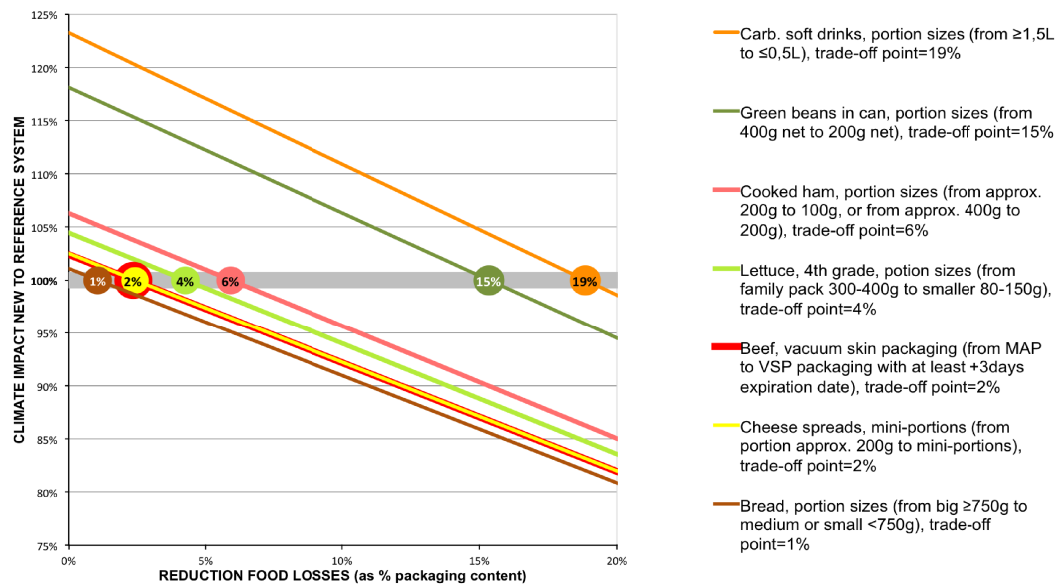


Figure 43 : Trade-off points (notice that the trade-off point for beef and spreadable cheese is the same)

Figure 43 shows on the Y-axis the difference between the climate impact of the new system (E2) with respect to the current one (E1) and whereby the system is the packaging and the product. The X-axis shows the difference in food loss between the new system (v1) and the current one (v2). An example: convert a user from the purchase of a family pack of lettuce, 400 grams, to smaller bags of 100 grams, then the climate impact of both is the same if the user wastes at least 4% less of the content. The impact of a head of lettuce, 400 grams, of which 16 grams (4% content) is not consumed, then is the same impact of 4 smaller bags of lettuce of 100 grams each, of which all is consumed. If there, however, is no difference in food loss (0% on the X-axis), then the impact of the system with 100-gram bags is about 5% higher. If in reality there is still a greater difference in food loss, i.e. 10% of 40 grams of a larger bag of lettuce, then the climate impact of the system with the 100-gram bags is 6% lower (94% on the Y-axis). These trade-off points are explained in closer detail below.

#### Bread (the impact of loss represents 18% of the total climate impact)

- **Conversion to smaller breads** The environmental impact of the extra packaging is already compensated for with at least one-half slice less loss.
- **Freezing bread** The additional environmental impacts are already compensated for with at least two slices less loss (from large, 800g bread).
- **Conversion to pre-packaged bread with a long expiration date** In this system there need not be any additional impact with respect to fresh bread, and there is thus no discussion about 'compensated for with at least ... slices less bread loss'. The benefit with regards to the option of freezing bread is that with this option the preservation aspect is not a significant factor.
- **Conversion to pre-baked breads in a packaging with a protected atmosphere** to be baked at home is, theoretically, only interesting in the event that on average the consumer wastes a third of the bread. In praxis, however, it is unlikely that this will occur.

- **Bake-off baking at the place of retail** in combination with an adjusted inventory management has indeed lead to a reduction of bread loss in the production-distribution chain. More recent studies on bread loss in the chain mention a range of 2-6%, average 4%, in contrast to an average of 7% in previously published research where little or no mention was made of deep-freeze or bake-off distribution chains.

#### **Meat and meat-products (loss represents 15 to 19% of the total climate impact)**

- **Conversion to other packaging technologies for fresh meat** such as VSP is to be justified if the extension of the expiration date effectively produces less loss with this type of packaging either in the distribution phase, or with the consumer. The largest and heaviest Vacuum Skin Packaging (VSP) from the test samples has somewhat of a higher environmental impact than an MAP packaging for the same portion size, but is already compensated for with at least 2% less of the beef being lost. In most cases, the environmental impact of a VSP packaging will even be more beneficial than an MAP packaging. Thus, a VSP packaging can be smaller in volume and this will have a positive effect on the impact related to storage and transport.
- **Conversion to smaller packaging for cooked ham** definitely makes sense. One can prevent the loss of at least a third of a slice of ham by converting to a smaller packaging; then the environmental impact of the extra packaging is compensated.
- **Conversion from packaging under normal atmosphere to an MAP** packaging is compensated for starting at one third of a slice of ham. Thus, don't buy too much at a deli counter. Conversely, if the pre-packaged portions in the refrigerated counters are too large, then it is better to buy the proper portion at the deli counter.

#### **Cheese spreads (loss represents 10% of the total climate impact)**

- **Conversion from regular packaging to mini-portions:** with at least 2-3% less loss of cheese spreads/goat cheese, the extra impact of the mini-portions packaging is already compensated for. The quantity of cheese spread is less than the quantity needed for a quarter of a sandwich.
- **Conversion from a large family packaging to a smaller, standard-sized packaging:** with at least 1,5% less loss of cheese spreads/goat cheese, the extra impact of the normal packaging in relation to the large, family size is already compensated for.

#### **Lettuce (loss represents 16 to 36% of the total climate impact)**

- **Conversion to a full head of lettuce to a sack of pre-cut and washed lettuce** is reasonable with at 15% less loss of lettuce. This is primarily interesting for smaller households if the head of lettuce is too large. There will also be less water used. The lettuce is already washed and does not need to be washed again. This is more efficient in the industry than at home.
- **Conversion to smaller packaging of pre-cut lettuce**, for example, of a large re-sealable or non-resealable bag of 300—400g to bags of 100—200g, or from 100—200g to the smallest portions of 40—80g, is reasonable with at least 5% less loss of lettuce. For doubts as to how much lettuce one will need and consume at a meal, this can offer

a solution. A larger, re-sealable bag will, after the initial opening, also still protect the lettuce. After the initial opening, the bag protects the lettuce against humidity loss, however, the protective atmosphere is gone, by which the remaining preservation time is rather short. The environmental impact of a re-sealable bag, usually made with a heavier foil and the added sealing mechanism present, is more or less the same and in some cases even higher than the smaller, thinner bags with a protected atmosphere (EMAP).

- **Conversion to smaller cans of green beans**, for example, from large cans of 400g net (this is circa 220g drained) to smaller cans of 200g net, is reasonable beginning with 15% less loss of green beans. This comes to about 34 grams of green beans (drained weight).

### **Carbonated soft drinks (loss is 7% of the total climate impact)**

- **Conversion from large to smaller packaging** for home usage is reasonable from the environmental standpoint in situations where the user frequently throws away large quantities of drinks from large 1,5 to 2 litre PET bottles. According to research, this is the leading cause of loss of carbonated water and soft drinks. Starting from at least 20% less loss from large 1,5 to 2 litre PET bottles, (this is circa 1 large consumption of 33cl), the environmental impact is compensated for with respect to the usage of the smaller 0,5 PET bottles, or 33cl cans.

We can draw this conclusion for the situation in Flanders, where PET bottles and cans are recycled to a large extent. In countries where this does not happen or on a lesser scale, then the impact of the packaging with respect to the packaged product will increase and it then becomes that much more difficult to likewise compensate the additional packaging with less loss.

Following are general conclusions stemming from this research:

#### **1/Packaging can prevent food loss.** To what extent is dependent upon:

1. A proper adjustment with the changing market needs (i.e. portion sizes);
2. The technical properties of the packaging (i.e. barrier characteristics);
3. A proper application in all links of the chain (i.e. a minimal initial contamination of meat and an unbroken cold chain), and;
4. The acceptance by all links of the chain (i.e. acceptance by the consumer of coloured meat in a type of packaging that extends the expiration time of fresh meat).

Innovations of packaging that can further reduce food loss play a role in all of the factors mentioned above. A technically superior packaging needs to be handled well in order to be able to valorise the benefit of the improved packaging. The role of all links in the food chain remains important.

#### **2/ Each type of food, type of producer, type of distribution channel, type of end client demands a specific innovation approach and solutions.** For example, innovations for fresh

meat or prepared meals with meat are different for a small-scale producer or butcher who is providing for a local market, than for a large-scale producer that serves chain stores and export markets. The same goes for bread of local bakers versus industrial bakers, for a fresh head of lettuce sold in bulk or a pre-cut salad mix in a bag. Each product and value chain has its idiosyncrasies, with respect to the role and the acceptance of pre-packaged products. Nevertheless, respecting this diversity, there are within each type of chain optimising options indeed possible for further reducing food loss, and ...

**3/ ...innovative packaging can play a role in this, however, as a part within a broader, total packet** such as improved stock-management systems, food technology, conservation techniques, cooling techniques, application of sensors and monitoring systems, methods to capture and evaluate higher-valued food losses, and so forth. A focus that is too one-sided on innovative packaging to reduce food loss, and therein a focus that is too one-sided on technological aspects and solutions, however, is a small part of the potential under the broader term of 'innovation'.

**4/ An increase of the impact of packaging can be justified if this can prevent food loss and the impacts related to this can be avoided.** Each gram of food that is no longer lost also does not need to be produced. The environmental gain that can be won by avoiding food loss is quickly greater than an increase of the impact from the packaging. The acceptable increase of the packaging material differs, however, according to the category of food product.

- Bread: conversion to smaller bread loaves is already compensated for after a half of a slice less bread loss; • Meat: meat needs more packaging and thus preventing food loss is almost always to be justified. Even for the heaviest vacuum skin packaging, this is already compensated for with at least 1,2% less loss;
- Cheeses: generally speaking, packaging with cheeses can play an important role. Thus, switching to smaller mini-portions for spreadable cheeses is already compensated for if there is at least 2% less food loss;
- Vegetables: in the example of lettuce, switching over from a head of lettuce to a sack of lettuce is reasonable after about 15% less loss;
- Drinks: the conversion of large to smaller packaging is only justifiable if frequently there are large quantities of drink from 1,5 to 2 litre bottles being discarded (from about 33 cl loss from larger bottles).

**5/ The swift evolution in packaging solutions makes it necessary that there is more information in order to proceed with it correctly.** This information is best offered and developed in consultation with the entire food chain. In Flanders, there are already various initiatives and platforms such as Pack4Food, a consortium of research institutions and firms that have as an objective the innovation of foodstuff packaging in order to stimulate food companies and suppliers. Another recent initiative is the Platform Duurzaamheid van Flanders' FOOD that also is geared towards companies in the agricultural food chain by means of supplying information, consultation, networking, collaboration with concrete research projects, and so forth. All of these initiatives are primarily targeted at the large and KMO companies in the chain and the initiatives also usually originate from the industry and the research world itself. Here, new initiatives find the best affiliation in order to prevent fragmentation.

**6/ Specific support and stimulation of innovation is essential.** In this context the Pinterest website is relevant with inspiring examples of innovations, and the result is that the project is further maintained. But also here, there is a better affiliation and there are more synergetic examples possible with existing information channels regarding innovation in the packaging and food sectors, such as: the website with examples and the Preventpack newsletters from Fost

Plus; the articles and Radar newsletters from Flanders 'FOOD'; the newsletters and publications on the site of Pack4Food; the articles and newsletters on the site of the Inter-departmental workgroup Food Loos of the Flemish Government; the Ecodesign link site and the many other sites that have innovation as their objective (broader than packaging alone) in order to stimulate the prevention of food loss. The Pinterest website is not targeted at specialists, but rather on novices and interested people, students. It is intended to be a collection bank of existing articles (from other sites) and does not have as an objective the production of new articles. In order to become efficiently maintained, it is important to form a good network with the other suppliers of information and to become well informed about new and relevant articles. If that can be arranged, then it demands relatively little effort to further maintain the Pinterest page (in the order of a half day of man hours per week).

**7/ Food loss can be more explicitly offered as a theme within existing awards.** An example of this is the existing category (food) 'preventing loss by means of innovative packaging' for the Greener Packaging Award. One can make a call to food companies, suppliers of packaging, and retailers in order to offer suggestions that are more specific to this theme. More generally, one can strive to bring the theme of 'food loss' more to the fore with existing awards for innovation in the food industry. Alongside, or within the available themes of food quality, safety and health, food loss is offered less explicitly.

# 10 Communication Proposal

## 10.1 Communication Recommendations

In order to communicate about the problematic of 'food loss and packaging' the following suggestions are provided. The talking points of the communication are reproduced here. Legio studies in the past highlight the (negative) impact of packaging by regarding the packaging as waste that was to be avoided. Packaging, however, can also deliver a positive contribution. Considering food and packaging together creates possibilities. The calculations of this study make it clear that, with the margins of the food-packaging trade-off point, there is still room for improvement and innovation to both lower the environmental impact and to prevent food loss. The central point of the communication ('against the perception') must be a positive story: by means of a good usage of well-designed packaging, it is possible to prevent food loss so long as it respects the trade-off point. This communication must be targeted at all links of the food chain. Better, more innovative packaging can prevent food loss, but this on the condition that it is carried out correctly either within distribution or at the consumer level. The introduction of better packaging requires communication throughout the entire chain. With this, it must be considered with regards to other considerations than the environmental impact of food loss and packaging, which were the scope of this study. Environmental awareness, price consciousness, and still other considerations such as health, social engagement (for example, support for local producers) goes together. Options that are both a solution for the consumer to be more price-conscious with food and that can prevent food loss will be the easiest to push through. Many of the mentioned solutions are, however, not this, such as the mini-portions and smaller packaging can indeed be a solution for smaller household to prevent food loss, but they are in fact more expensive. Two-way communication is thus necessary: people are curious about the environmental impact of packaging and often have many unanswered questions. However, a large target group is open for a rational discussion. In order to break through certain misconceptions and perceptions, it is important to integrate the questions of the people and to proceed proactively. A chain approach is thus the best solution for this. Information that is too one-sided coming from only one link of the chain comes over as being prejudiced. With the goal of breaking through certain misconceptions and perceptions, it is necessary to not underestimate the factor of distrust. From a chain perspective, information that is both professional and based upon praxis can be supplied as not being prejudiced. Direct communication to the people on the results must best happen in consultation. This communication must also take into account the individual lifestyle and context of the people and families. There are no universal solutions that will be valid for everyone, but one recommendation can, however, be given—where there is doubt between being able to prevent food loss and the prevention of extraneous packaging, people would best choose for the prevention of food loss. Food loss nearly always is a greater burden. Hereby, people must realise that many of the recommendations in the case studies described are counter-intuitive and do not mesh with prevailing perceptions. Combatting prevailing perceptions is not easy and calls for persistence and cautious communication. An example of a communication platform that is targeted at civilians is the Meldpunt Verpakkingen. It is one of the projects of the 'Kennisinstituut Duurzaam Verpakken' in Holland, since January 2013, established on the occasion of the new Raamovereenkomst Verpakkingen (website, <http://www.kidv.nl>). Here, consumers can be online with questions, announcements, ideas and suggestions about the sustainability of packaging. The Meldpunt provides these announcements, ideas and suggestions to factories, businesses and/or branch organisations and publishes their reactions on the website of Meldpunt. Meldpunt manages questions from people about packaging in the broadest sense, as well as other types of packaging. A similar initiative is also conceivable in Flanders. The various stakeholders in Flanders already work together on projects. Since 31 March 2013, there is also the declaration of engagement, 'Flanders in Action: Together against

food loss'. An information platform that is directed at civilians could be a concrete initiative from this Chain consultation and a future collaboration. Also, in other countries, there are similar constructs such as WRAP in the United Kingdom, which develops expertise and shares it, both aimed at the companies and the consumers. The on-line platform, which is positioned as a brand, to reach people is 'LoveFoodHateWaste'.



Figure 44: Melpunt Verpakkingen of the Kennisinstituut Duurzaam Verpakken (Holland).

## 10.2 Platform Pack2SaveFood

The Pack2SaveFood platform will be further explained with inspiring examples. This platform is set up in the context of this project in order to inventory all possible innovations with regards to packaging and food loss and to further disseminate them. This platform is targeted at novices, interested in the subject of food loss and packaging. In this way, via the platform [www.pack2savefood.org](http://www.pack2savefood.org), a call was launched, targeted at students, designers, companies and research institutions, to think about innovative packaging that combat food loss. The website, [www.pack2savefood.org](http://www.pack2savefood.org), with information on the call, will be dissolved after the course of the project. The material that was collected during the course of the project; inspiring examples, articles, innovation ideas of (mainly) students, were collected on the Pinterest site: <http://www.pinterest.com/pack2savefood/> and this platform will be further maintained after the completion of the project. It was primarily students who answered the call. A number of schools were thereby proactively approached with the question to integrate a design or research project around this subject in the 2013-2014 academic programme. A number of schools, such as the University of Antwerp, the University of Ghent and Thomas More Mechelen loaned their cooperation to some fifty 'pins' on the inspiration board of Pack2SaveFood regarding the results of these student projects (collected on the Pinterest board 'student ideas | students'). Various students also entered their ideas for the OVAM Ecodesign Award 2014. The 'Bready' (see figure) even earned a nomination. Other schools also approached (such as the University of Hasselt) responded positively to the call, but could not take up any additional projects in their programme



for the 2013-2014 academic calendar. The assignments had to in fact be amenable to the curriculum of the schools involved. Concretely this meant that the innovation scope must go broader than only packaging innovation and the most frequent ideas dealt then also primarily with product, ICT and system innovations. Two groups working at the University of Ghent even incorporated ideas for combatting food loss in the restaurant of their school.



*Figure 45: Idea from a University of Ghent student in response to the call.*

On the occasion of the call, a group of 17 students of Product Development from the University of Antwerp, kept a journal for 2 weeks on drinks spillage. After the term, it was asked how they could themselves adapt their behaviour and to which product or packaging innovations would one agree with. Because the sampling is very small, and the period is very short, one needs to interpret the figures carefully. The spillage of carbonated soft drinks for these students was between 20 cl and a half of a litre per week. The most common causes are leftovers in glass where the carbonation is gone, leftovers in larger bottles where the carbonation is gone, and five students had an accident with a can or a glass that was knocked over. Larger losses were noted for water from bottles, up to 70 cl per week. The two most important causes are portions that were too large and poured out and water in bottles with an odour or where the carbonation is gone. Options that the students are considering themselves: buying smaller packages, no longer pouring water out but directly drinking from the bottles, buying re-closable bottles instead of cans, using smaller glasses for soft drinks, innovative glasses or packaging that keep soft drinks cool longer and the carbonation longer after opening the packaging, and the provision of a tap system in the student room to be used by more students.



*Figure 46: Seventeen students of Product Development kept a journal of drink spillage for 2 weeks.*

A number of companies also submitted an idea or recent innovation on the occasion of the call, such as the Tetra Top® by Tetra Pak, which is to be simply separated by the user into different material components. Because the packaging is completely open, it is easier to make them completely empty (see figure). Other inspiring examples by companies were investigated by the research team; companies proactively approached, and the output of this was also placed on the boards. In total, there are 370 Pins posted on 24 thematically divided boards.



*Figure 47: Tetra Top®, submitted by Tetra Pak.*

ON 22/04/2014, Flanders' FOOD published an overview of all research and project initiatives in the food industry concerning food loss as an opportunity for innovation and also published the call in the context of this project. (<http://www.flandersfood.com/artikel/2014/04/22/voedselverlies-als-opportuniteit-voor-innovatie>) The call made to the research centres was answered by Food2Know. As a contribution for this project, they made a survey at the Horeca Expo 2013. At a booth at the expo, visitors were asked to fill out the survey on the spot. The survey was answered by some 300 respondents, primarily students. The results are not representative as a sampling for the Flemish population but still delivered a number of qualitative insights on the consumer perceptions regarding packaging and food loss. Other parties also showed readiness to possibly be willing to work together in later stages for research on the subject (for example, Test Aankoop, VLAM).

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