(Contract CG/67/31b)

Greenhouse gas emissions and material flows

PART II: Production and use of beverage packaging

J. Theunis

For the Federal Office of Scientific, Technical and Cultural Affairs
"Global Change and Sustainable Development - Sub-Program 2"

2001/IMS/R/131

Vito

June 2001

This report is a result of the research project *Greenhouse gas emissions and material flows*, a joint project of Institut Wallon, Institut pour un Développement Durable and Vito, co-ordinated by Institut Wallon. The project was financed by the Federal Office of Scientific, Technical and Cultural Affairs as a part of its research program on *Global Change and Sustainable Development - Sub-program 2*.

The approach, results and conclusions of the entire project can be found in the summary report *Greenhouse gas emission reduction and material flows. Final report*, edited by Institut Wallon.

The detailed results of the research of Vito are written down in three reports:

- *Greenhouse gas emissions and material flows. Part I: Analysis of the literature.*
- *Greenhouse gas emissions and material flows. Part II: Production and use of beverage packaging.*
- *Greenhouse gas emissions and material flows. Part III. Materials used for packaging and building: plastics, paper and cardboard, aluminium.*

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

0 EXECUTIVE SUMMARY

This report is a result of the research project *Greenhouse gas emissions and material flows*, a joint project of Institut Wallon, Institut pour un Développement Durable and Vito, co-ordinated by Institut Wallon. The approach, results and conclusions of the entire project can be found in the summary report *Greenhouse gas emission reduction and material flows. Final report*, edited by Institut Wallon.

The detailed results of the research of Vito are written down in three reports:

- *Greenhouse gas emissions and material flows. Part I: Analysis of the literature.*
- *Greenhouse gas emissions and material flows. Part II: Production and use of beverage packaging.*
- *Greenhouse gas emissions and material flows. Part III. Materials used for packaging and building: plastics, paper and cardboard, aluminium.*

This report gives an analysis of the packaging flows in Belgium in general, and of the use of beverage packaging in Belgium more specifically. The use of different packaging types for different groups of beverages is analysed quantitatively and qualitatively. Actual and future material use, energy use, transport requirements and costs of the specific beverage packaging types are estimated.

The results of these analyses are used for estimating the greenhouse gas emissions related to the end use of beverage packaging in Belgium over the entire life cycle, and the potential greenhouse gas emission reduction. Material-related greenhouse gas emissions can be reduced through decreases in packaging weight, increased recycling and changes in packaging choice.

Two complementary approaches were used: a scenario approach and a (partial) optimisation approach, based on costs.
It could be concluded that, except for beverage cartons, greenhouse gas emissions per litre of beverage packed are smaller for reuse packaging than for one way packaging. Greenhouse gas emissions related to materials use (including waste treatment) dominate greenhouse gas emissions during the use phase of the packaging.

Life cycle greenhouse gas emissions related to the end use of beverage packaging are estimated at 500-600 kton CO_2-eq in 2000. In the absence of measures to reduce greenhouse gas emissions they will increase by 50 to 100 kton in 2015.
Decreases in packaging weight, increased recycling and changes in packaging choice (mainly shifts to reuse PET) lead to potential emission reductions ranging from 250 to 300 kton CO_2-eq in 2015. Increased reuse gives significant additional benefits compared to increased recycling only.

The costs of these emission reductions have been calculated at 150 to 200 Euro/ton. However, cost data are quite uncertain. A decrease of 15% in specific packaging costs for reuse packaging reduces the emission reduction costs to 60 to 120 Euro/ton. These values should be interpreted as an upper limit.

Compared to the total greenhouse gas emissions reduction effort needed to comply with the Kyoto protocol, the emission reduction potential from the Belgian end use of beverage packaging is small. Moreover, a significant part of the life cycle emission reduction will be realised abroad. The potential for greenhouse gas emission reduction based on changes in consumption patterns will depend on the possibility to develop broad strategies that cover a large fraction of the Belgian consumption. Therefore, conclusions on beverage packaging should be compared to other product groups.

On the other hand, this analysis has only quantified the greenhouse gas emission reduction potential. Calculations of reduction potential should be broadened to other environmental impacts. Synergetic effects on other environmental impacts should also be taken into account when interpreting reduction costs.

This study is a first attempt to quantify the effects of changes in beverage packaging use in Belgium on specific emissions (in this case greenhouse gas emissions), on a macro level and for a long time period, taking into account the possibilities and constraints for substitution of different packaging options for specific groups of beverages. This macro level quantification of the emission reduction potential gives relevant additional information for evaluating product policies as compared to the results of LCA studies.

The approach that has been developed for greenhouse gas emissions can also be used to quantify the effects on e.g. waste streams. It can also be used for other product groups.
However, if the environmental impacts of (changes in) consumption patterns (e.g. towards sustainable consumption) are to be assessed or evaluated quantitatively, systematically recording consumption figures of key product groups in physical terms (weights) seems a necessity.

1 BACKGROUNDS

1.1 General

Packaging fulfils multiple functions: transporting, distributing and trading goods; storing goods; portioning bulk products; preserving perishable goods; marketing; etc. It is an activity that has a rather high visibility for the public. It is often related to environmental impacts (e.g. waste).
It is expected that in future packaging will still gain importance. There is an increase in sales of ready-to-eat microwave oven meals requiring adapted packaging. Controlled atmosphere, modified atmosphere and so-called "intelligent packaging"[1] are gaining importance.
In general, the rotation time of the materials used in packaging applications is rather short: most materials used for packaging end up as waste within months after being used for packing goods.

1.2 Legislation

1.2.1 European legislation

European Directive 94/62/EG on Packaging and Packaging waste deals with the whole life cycle of packaging. It describes preventive measures and gives quantitative targets for recycling and valorisation: at last in 2001 50-65 %[2] of packaging waste has to be valorised[3], 25-45 % has to be recycled[4], with a minimum of 15 % for each packaging material. At last in 2006 these targets will be raised.

The Directive also gives some essential requirements for packaging concerning the manufacture and the composition, the reuse and the valorisation of packaging. The European Normalisation and Standardisation Bureau, CEN, received a mandate to specify these vaguely described essential requirements.

The Packaging Directive is actually being revised. In this revision new targets for recycling will be fixed. In a discussion note the Directorate General Environment of the European Commission proposes two options for increasing the targets for recycling[i]:

1. at least 90 % of all packaging has to be valorised; of each packaging material at least 60 % has to be recycled;
2. at least 60 % of all packaging has to be recycled; per packaging material the following recycling rates have to be attained
   - glass 75 %
   - paper and cardboard 65 %
   - metals 55 %

---

[1] Active or 'smart' packaging systems : films impregnated with chemically reactive additives that absorb oxygen, ethylene and other agents of spoilage inside the package once it has been sealed.
[2] All percentages concern the weight of the packaging.
[3] reuse, material recycling, energy recovery
[4] reprocessing the waste material for its original purpose or for other purposes, including organic recycling, but excluding incineration with energy recovery

- plastics 20 % (mechanical recycling only)

In the discussion on this proposal the packaging industry called these options not funded and unrealistic.
The European Environmental Bureau (EEB) and environmental organisations ask for specific targets on reuse and for a higher target for plastics recycling.[ii]

1.2.2 Belgian legislation

Co-operation agreement on the prevention and management of packaging waste

In Belgium waste management is a regional competence. The three regions have developed a common legislation, called the "Co-operation agreement on the prevention and management of packaging waste"[iii], that entered into action on 5/3/1997. The targets for recycling and valorisation are more ambitious than those in the European Directive: 50 and 80 % respectively for 1999.

In the Co-operation agreement the "party responsible for packaging"[5] has three obligations:
1. prevention
2. take-back obligation: the party responsible for packaging has to take back a proportion of the packaging that he brought on the Belgian market in order to satisfy the legally required percentages of recycling and valorisation.
3. information: each year the party responsible for packaging has to provide quantitative data on the packaging he brought on the market and on the way he satisfied his take-back obligation.

In order to fulfil their take-back obligation the parties responsible for packaging can become member of an accredited organisation. The organisation will have to reach the legally required recycling and valorisation percentage for its members as a whole.
Two organisations have been accredited: FOST Plus for the household packaging waste, Val-I-Pac for the industrial packaging waste.[6]

The three regions have created a supervisory body: the Interregional Packaging Commission (Interregionale Verpakkingscommissie).

Ecotax on beverage packaging

The ecotax legislation, introduced in 1993 and adapted several times, put a tax of 15 BEF on each beverage packaging[7]. Exceptions were made for refillable packaging.
Recyclable packaging was exempted from the tax if increasingly stringent recycling percentages were attained for the corresponding year (Table 1).

---

[5] Party responsible for packaging: the party that brings packed products on the Belgian market; the products can have been packed in Belgium or they can have been imported in their packaging.
[6] Starting from 05/03/2000 small retailers also have a take-back obligation. Suppliers of service packaging can become member of FOST Plus and take over the take-back obligation from the retailers.
[7] Excluded are beverage packaging that are predominantly made out of wood, pottery, porcelain or crystal.

Table 1 Recycling percentages for recyclable beverage packaging exempted from ecotax

	1996	1997	1998	1999	2000
glass	55	62	67	73	80
metals	40	47.5	58	64	80
synthetic materials	20	30	43	56	70
beverage cartons	20	30	43	56	70

Recently, the federal government reached an agreement on a system of ecotaxes and tax reductions ("ecoboni") to promote the use of reuse packaging for beverages. The system does not apply to milk packaging.

1.3 Environmental concerns

Specific environmental concerns related to packaging use, are the waste problem, incineration of plastics related to dioxin emissions, the concerns about the use of PVC, the use of additives in plastics, migration, …

Especially beverage packaging has received a lot of attention, in legislation and in LCA studies. Partially this can be explained by the relative uniformity and comparability of the packed products, which makes beverage packaging more suitable for a simplified and standardized approach.

Another reason is probably the fact that waste statistics are often given in tons. Because glass and metal are important packaging materials for beverages, and because their weight per unit of packed product is high, they represent a proportionally large fraction in the total waste quantity (see 2.2.2).

Therefore, it seems *a priori* interesting to look at the total contribution of beverage packaging to specific emissions or environmental pressures, and the reduction in these emissions or pressures that can result from measures addressing the use and the composition of packaging, to see if the attention given to beverage packaging can result in significant environmental benefits. These benefits should then be weighed against eventual increases in costs related to changes in the use and the composition of packaging.

2 SYSTEM DEFINITION AND BOUNDARIES

2.1 Packaging

2.1.1 Definition and categories

Packages are part of larger packaging systems. In those packaging systems, a distinction can be made between primary, secondary and tertiary packaging. In the following analysis the definitions adopted in the Co-operation agreement will be used.

Packaging is defined as *"all products made of any materials of any nature to be used for the containment, protection, handling, delivery and presentation of goods, from raw materials to processed goods, from the producer to the user or consumer"*.

Packaging is further specified according to its function:
- sales packaging or primary packaging: packaging conceived so as to constitute a sales unit to the final user or consumer at the point of purchase
- grouped or secondary packaging: packaging conceived so as to constitute at the point of purchase a grouping of a certain number of sales units, whether the latter is sold as such to the final user or consumer or whether it serves only as a means to replenish the shelves at the point of sale; it may be removed from the product without affecting its characteristics (e.g. cardboard box)
- transport or tertiary packaging: packaging conceived so as to facilitate handling and transport of a number of sales units or grouped packaging in order to prevent physical handling and transport damage (e.g. pallet and stretch foil)

A last category of packaging, that is not explicitly mentioned in the Co-operation Agreement, but that is also subject to it, is so-called service packaging: packaging made and/or filled at the point of sale (e.g. carrying bags).

The Co-operation Agreement also defines different categories of packaging waste according to the end user of the packaging.
- household packaging waste: packaging waste originating from the normal functioning of households and packaging waste assimilated herewith.
- industrial packaging waste: any packaging waste which cannot be considered as household packaging waste

As such these definitions do not always result in a clear-cut distinction between specific packaging: commerce, catering and offices will sometimes use the same kind of products (packed in the same way) as households (e.g. beverage bottles).
In order to avoid the confusion that remains, the following specifications have been adopted:
- All tertiary packaging is considered to be industrial packaging.
- All secondary packaging is considered to be industrial packaging, unless grouping packaging with a volume of maximum 0,5m³ designed in such a way that they represent a sales unit.
- For primary packaging two situations are distinguished:

- the packed product is exclusively intended for industrial use; in that case the packaging is industrial packaging;
- the packed product is both sold to households and to companies; in that case the packaging responsible has to consult the list of 'Primary household and industrial packaging'[iv].

Another essential distinction is between reusable packaging and one-way packaging:

- <u>reusable packaging</u>: any packaging conceived and designed to accomplish within its lifecycle a minimum number of trips or rotations, in which it is refilled or used for the same purpose for which it was conceived
- <u>one-way packaging</u>: any packaging which is not reusable packaging in the sense of the definition above

Finally, packaging is often characterised according to the packed product: food packaging, beverage packaging, etc.

These definitions are illustrated in Table 2.

Table 2 Packaging categories

		household packaging	industrial packaging
one-way	primary		
	secondary		
	tertiary		
reusable			
in black : non existing in clear grey : categories covered by FOST Plus in dark grey : categories covered by Val-I-Pac			

In order to fulfil their take-back obligation the parties responsible for packaging can become member of an accredited organisation. The organisation will have to proof that it has reached the legally required recycling and valorisation percentage for its members as a whole.
Two organisations have been accredited: FOST Plus for the household packaging waste, Val-I-Pac for the industrial packaging waste.

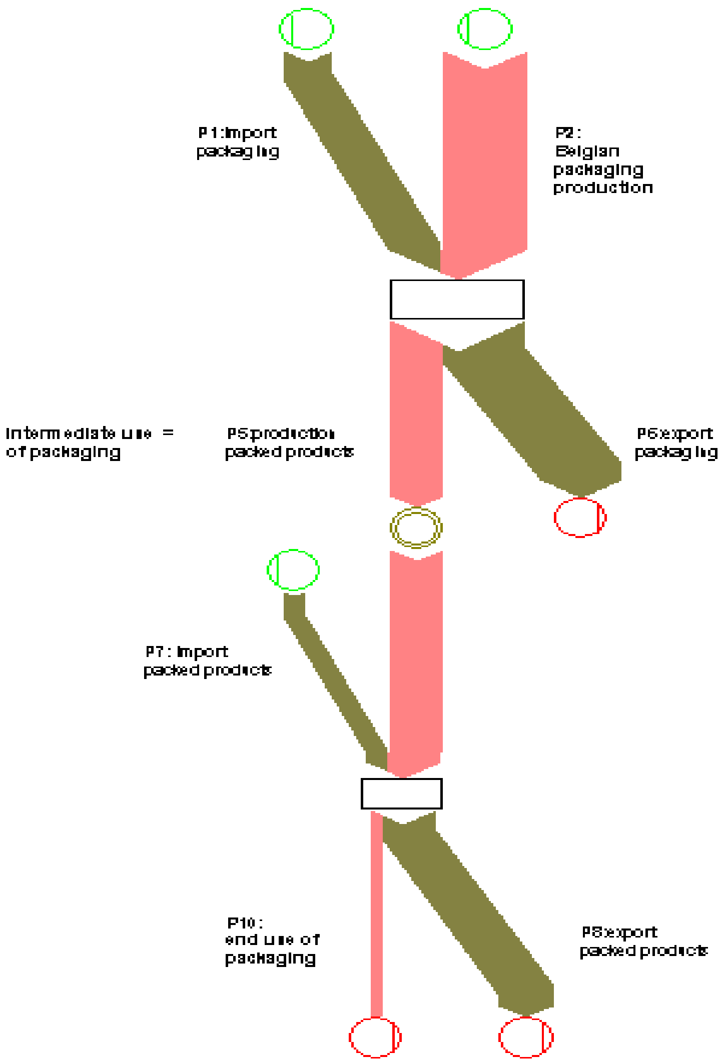
2.1.2 Packaging end use

This analysis deals with the Belgian end use of packaging by the final consumer, or, in other words, with packaging used for packed products brought on the Belgian market.

If we use "packaging brought on the Belgian market" or "Belgian end use of packaging by the consumer", this includes:

- import of packed products for Belgian end use
- Belgian production of packed products for Belgian end use:
  - import of products and subsequent packing in Belgium
  - Belgian production of product and subsequent packing
    - the packaging used to pack the product can in its turn be:
      - produced in Belgium
      - imported

Figure 1 Packaging flows and packaging end use



It excludes:

- Belgian production of packed products for export
- Belgian production of packaging for export

Figure 1 illustrates the concept. Although hypothetical it shows the discrepancies that can exits between the end use of packaging, the intermediate use of packaging by packers of products and the packaging production.

2.1.3 Packaging quantities

There is no direct statistical information on the quantities of packaging brought on the Belgian market. Data on production of packaging can be found in the statistics of the National Statistics Institute (NIS). Data on import and export of packaging can be found in the Belgian foreign trade statistics collected by the National Bank of Belgium (NBB). From these data the apparent consumption of packaging in Belgium can be calculated. But, these statistics do not give information on the quantities of packaging brought on the Belgian market through import of packed products, or on the quantities of packaging used to pack products that eventually will be exported (Figure 1).

In the co-operation agreement the same end use perspective as defined above, is used. Thus, the data provided by FOST Plus and Val-I-Pac members can be used to estimate the Belgian end use of packaging. These data will be used further in this document. Where possible and necessary they will be compared or completed with data from other sources.

End use of household packaging

In its annual report for 1999[v] FOST Plus gives data on the quantities of one-way household packaging that were declared by FOST Plus member companies to be brought on the market by them. According to FOST Plus the declarations represent 90 - 92 % of all domestic packaging brought on the market. However, for some materials coverage is higher than for others. Based on exact figures provided by FOST Plus the amounts were extrapolated for the total market (Table 3).

However, these figures only relate to one-way household packaging. The flows of reusable packaging (mainly glass bottles and plastic crates for glass bottles) are not included. The average quantity of reusable glass packaging brought on the market each year is estimated at 53 kton[8]. Together with the one-way glass packaging this brings the total amount of glass packaging brought on the market every year at 387 kton.

---

[8] The volume packed in reuse packaging (glass bottles for beverages) was estimated based on a combination of estimates of the total packed beverage consumption in 1999, FOST Plus data on one-way packaging, and figures for the use of reuse beverage packaging in 1992/1993[viii].
To calculate the corresponding average quantity of reusable packaging brought on the market each year assumptions had to be made on the number of cycles a bottle makes on average before it has to be replaced (because they are not returned, because they are rejected for further use or because they break during the refilling process), on the number of cycles it makes per year and on the total period that a specific packaging design or concept is in use before it is entirely replaced, e.g. in response to changing product quality, for marketing purposes, …
Whereas a uniform period of 10 years for entire replacement of the packaging concept has been taken, the number of times a reusable glass bottle is used on average before it has to be replaced and the number of cycles per year are different for different beverages (e.g. higher for small beer or soft drink bottles, lower for wine bottles). This has been taken into account in the calculations.

The average quantity of reuse beverage crates is estimated at 10 kton.

Within the category of household packaging different groups of packed products can be considered. More than 75 % of the household packaging consists of food and beverages packaging.

Table 3 Household packaging brought on the Belgian market in 1999: estimates per sector (based on FOST Plus figures and calculations).

kton	food	beverages	others	total	%
one-way glass reuse glass	103	216 53	15	387	*47.7*
paper-cardboard	47	7	87	142	*17.5*
steel	49	26	9	83	*10.2*
aluminium	5	5	2	12	*1.5*
plastics reuse crates	39	51 10	48	148	*18.2*
beverage carton[a]	4	16	0	20	*2.5*
others	6	1	11	19	*2.3*
total kton *%*	*253* *31*	*385* *47*	*173* *21*	*811*	*100*

[a] roughly 15 kT cardboard; 4 kT PE; 1 kT aluminium

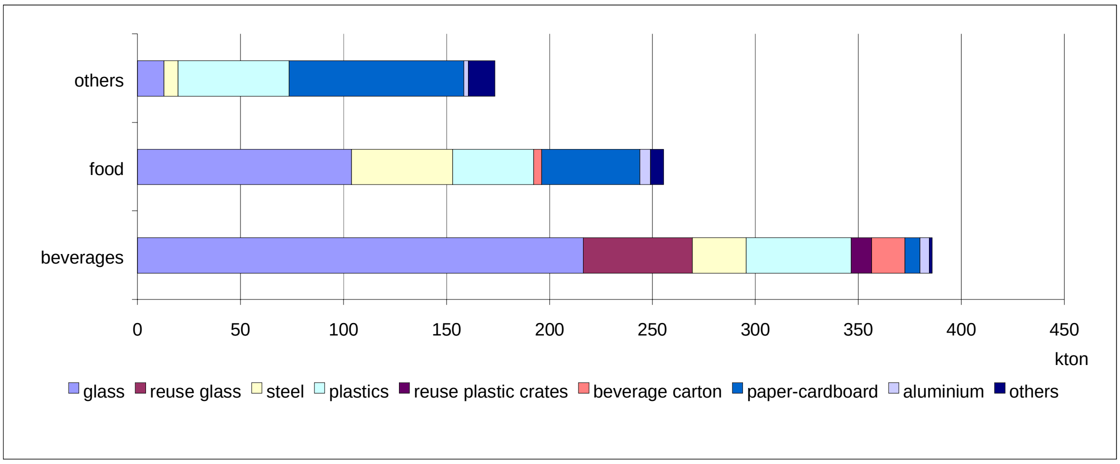


Figure 2: Household packaging brought on the Belgian market in 1999

The high tonnage for food and beverage packaging is mainly caused by the use of heavy packaging materials such as glass and steel. Food and beverage packaging accounts for 2/3 of all plastics used for packaging. Paper and cardboard is more important for non-food-or-beverage applications.[9]

End use of industrial packaging

In its accreditation file Val-I-Pac estimated the amount of industrial packaging brought on the market each year.[vi] The actually declared amounts for 1999 by the member companies (representing 64 % of the total market)[vii] were extrapolated (Table 4).

Table 4 Estimated quantities of one-way company packaging.

	1997		1999	
	kT	%	kT	%
paper-cardboard	366	53,4	369	53
metal	38	5,5	56	8
plastics	87	12,7	90	13
wood	142	20,7	167	24
glass	30	4,4	14	2
others	22	3,2		
total	685		695	

From these data it can be concluded that total quantities of one-way household and company packaging are roughly equal. However the composition of both differs. Glass packaging dominates for household packaging. Paper and cardboard dominate for company packaging. Wood is important for company packaging (crates and pallets), but is of very little importance for household packaging.

2.1.4 Focus on beverage packaging

The study area will be limited further to household packaging (the clear grey areas in Table 2). This includes some secondary packaging (e.g. crates for bottles, cardboard or plastic for joining cans or bottles, …).

Within this category of household packaging a further limitation is made to food and beverage packaging, representing the bulk of the materials used for household packaging. The detailed analysis of packaging options and alternatives will focus on beverage packaging only.
Most packaging types and packaging materials that are used for the other product categories are also used for food and beverage packaging (be it in a somewhat different form, e.g. PE bottles for detergents, …).

---

[9] TN Sofres/APME gives a figure of 200 kton for plastic packaging waste in MSW. This differs quite a lot from the FOST Plus figure. Normally, they should more or less match because packaging brought on the market ends up as waste within a year.

Finally, we will concentrate on the core package, but labels, caps and closures will be considered insofar as they represent important material flows that might influence the greenhouse gas balance of specific packaging options decisively.

2.2 Functions

2.2.1 Packaging in general

We can define the **function**[10], "**packaging service**" as the **quantity of specific goods to be packed in specific portions**.

> A demand for 1.000.000 litre of beverage packaging service corresponds to a certain number of packs each containing a certain amount of beverage (e.g. 1.000.000 bottles of 1 litre, or: 2.000.000 bottles of 1/2 litre).

The portion is explicitly mentioned in the function because
- the function of a large pack can be clearly different from the function of a small pack: family packs versus single servings;
- the portion determines the ratio packaging/packed product;
- the portion determines the packaging options that are technically and economically feasible (e.g. cans).

According to this definition some packaging types (products) are perfect substitutes: they can fulfil the same function (e.g. one litre of milk can be packed in a one litre glass bottle, in a one litre PE bottle, in a one litre beverage carton). In reality however, they seem to be imperfect substitutes. Different packaging types exist one next to the other fulfilling the same function as defined above.
Some reasons for this are consumers' preferences (e.g. ease of handling, carrying), influence of the packaging on the quality of the packed product (e.g. taste, shelve life, …), producers' preferences (cost of packaging, appealing to the consumer, …).
This is saying as much as that in reality the function is more complex than how it is defined here. These qualitative differences will be taken into account when identifying packaging options that can substitute one another.

2.2.2 Beverage packaging

In the case of beverage packaging two different markets (functions) can roughly be distinguished:
- large packs ("family packs"): 0,75 - 1 - 1,5 - 2 l
- small packs ("individual packs"): 0,2 - 0,25 - 0,33 l - 0,5 l[11]

Detailed figures on the consumption and the use of packaging for different beverage categories can be found in a study by Coopers and Lybrand[viii] (see also § 2.3.1). The total

[10] Function is used here as it is commonly used in LCA.
[11] Last years an intermediate category of 0,5 l packs is gaining importance. In some cases these are individual packs, e.g. 0,5 l beer cans, in other cases they might be a response to declining family size.

consumption of packed beverages (excluding draught beer) in 1993 was estimated at 3600 million litres. About one fifth of it was consumed in bars and restaurants. By 1999 this consumption has grown to about 3900 million litre.[ix,x]

For each group of beverages mentioned below roughly the same technical packaging options are available (see § 2.3). They also have a similar ratio large packs/small packs.

Table 5 Groups of beverages with their market shares in 1992/1993 and 2000

	1992/1993 C & L[viii]	1993 Canadean[ix]	2000 Projection[x]
Carbonated water and carbonated soft drinks	30,7	28,3	33
Non- carbonated water	22,0	21,2	23
Beer	18,2	17,9	15
Milk and milk drinks	17,4	19,7	16
Wine and spirits	7,1	8,2	8
Fruit juices and nectars	4,7	4,7	5
Total	*100*	*100*	*100*

Canadean data have been adapted:
- category 'special drinks' (iced tea, energy drinks) has been added to carbonated soft drinks
- category 'mineral water' has been split: 1/4 carbonated water, 3/4 non-carbonated water
- category ‘beer’: total consumption figure includes 40 % draught beer and has been corrected accordingly

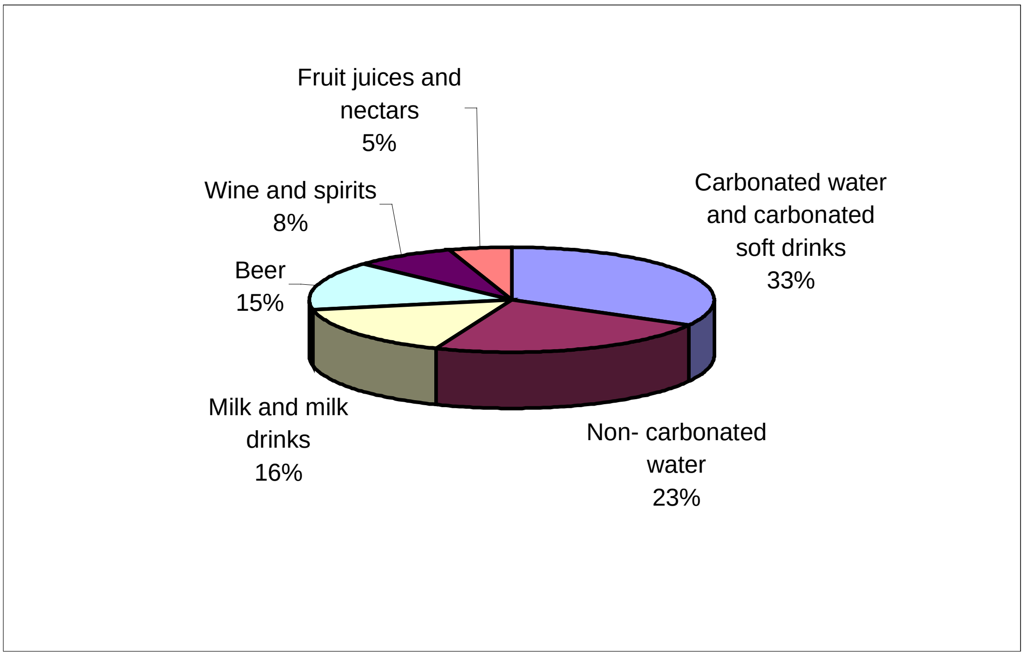


Figure 3: Groups of beverages with their market shares in 2000

The Coopers and Lybrand study also gives detailed figures from which the percentage of beverage types packed in specific portions can be calculated. The result is shown in Table 6.

Table 6 Percentage of beverage types packed in specific portions

content	*% of packed volume per beverage group*							
	milk and milk drinks	non-carbonated water	carbonated water	juices and nectars	lemonades	coke	beer	wine and spirits
large	84	96	86	72	60	70	8	100
small	16	4	14	28	40	30	92	0

Milk and water are mainly packed in large bottles (family packs). Beer is mainly (more than 90 %) packed in individual packs. For fruit juices and soft drinks a 70/30 ratio applies.

Combining groups of beverages and portioning gives rise to the following demand categories (functions):

Because of their small shares, the small packs of non-carbonated water and fruit juices, and the large beer packs will not be considered separately.

Table 7 Estimated market shares for beverage packaging functions in 2000

content	*% of total packed volume*						
	Carbonated water and soft drinks	Non-carbonated water	Milk and milk drinks	Beer	Wine and spirits	Fruit juices and nectars	Total
large	26	22	13	1	8	4	74
small	7	1	3	14		1	26

2.3 Beverage packaging options

2.3.1 Overview of the actual situation

According to the previously mentioned Coopers and Lybrand study[viii] (Table 8) 1/3 of all drinks (excluding draught beer) in 1992/1993 were packed in refillable glass packaging. Including one-way glass bottles 42 % of all beverages (excluding draught beer) was sold in glass bottles, 25 % in PET bottles (water and soft drinks) and another 16 % in beverage cartons (mainly milk and milk drinks, but also fruit juices). Together glass, PET and beverage cartons accounted for almost 85 % of the beverage packaging market.

The volume packed in PVC, although only used for non-carbonated water, represented 7 % of the total packed volume. It was as important as the total wine and spirits market, and more important than the total market share for cans.

Table 8 Beverage packaging options in 1993

% per packaging type	glass reuse	glass one-way	beverage carton	HDPE	PET	PVC	others PP and PS	cans	totals
carbonated water	40	2			56			3	100
lemonades	31	2	4		46			17	100
coke	35	1			45			18	100
non-carbonated water	17				50	32			100
milk and milk drinks	15		66	15			3		100
beer	86	7						7	100
wine and spirits	9	91							100
juices and nectars	6	7	87					1	100
totals	*34*	*9*	*16*	*3*	*26*	*7*	*0*	*6*	*100*

Volumes of beverages packed in one way packaging in 1999 were calculated from FOST Plus data on the declared use of different packaging materials, using assumptions on the average weight for each packaging material. The results are shown in Table 9.

In 1999 PET has gained a share of more than 33 % of the beverage packaging market and 50 % of the market for one-way beverage packaging. This is caused by the growth in soft drink and water consumption, two groups for which PET has become the most important packaging material, and by the fact that these two groups of beverages are increasingly packed in PET bottles, replacing reuse glass bottles. PET has almost entirely replaced PVC. Also PET or HDPE bottles are replacing beverage cartons.

Table 9 Beverage packaging options in 1999

% per packaging type	glass reuse	glass one way	beverage carton	HDPE	PET	PVC	others	cans	totals
carbonated water and soft drinks	25	2	1	1	55			16	100
non-carbonated water	24			4	69	2			99
milk	13	1	65	20					99
beer	83	4						13	100
wine and spirits	6	91	1		1			1	99
fruit juices	4	7	88					1	100
totals	*29*	*8*	*14*	*4*	*36*	*1*	*0*	*8*	*100*

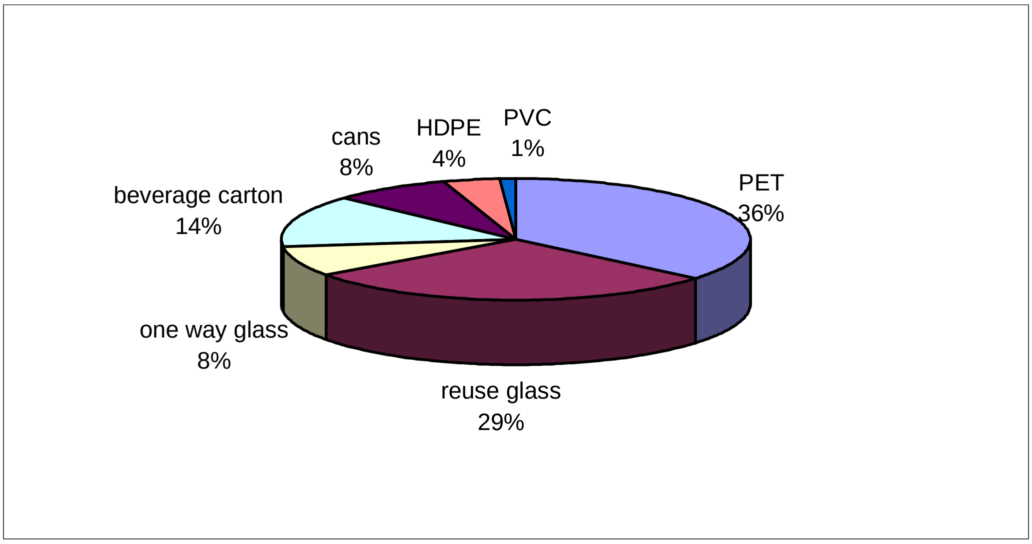


Figure 4: Beverage packaging options in 1999

The use of PET for packaging is increasing worldwide. Improved barrier properties have made it possible to pack beer and oxygen sensitive products, such as milk and fruit juice in PET bottles. Increased temperature resistance also allows hot filling and sterilising.
In the US PET has replaced glass bottles for carbonated soft drinks. PET bottles have taken an 80 % share of the US and Japanese bottled water market. In Western Europe its share of 35 % is expected to rise to more than 60 % by 2006. [xi] Experts expect that PET will have about 5 % of the beer market by the end of 2002 (Pack News, Dec2000). Even spirits have been packed already in PET (single serving bottles on airplanes).
Increased temperature resistance also allows cleaning at high temperatures, which led to the development of refillable PET.

According to the C&L study about one third of all beverages (excluding draught beer) were packed in refillable glass.[12] The study also gives figures on the shares of refillable and one-

[12] Data from a survey for 1992 (*Databank PRO, niet-alcoholische en alcoholische dranken, E. Van Looy, B.V.I.-PRO, 1994)* confirm that glass was by far the most important packaging material for alcoholic beverages (more than 95 %). For non-alcoholic beverages (excluding milk) the bulk of the market is shared by glass and plastic bottles. However in this study the share for glass (almost 1/2) is higher than that for plastics (42 %).
For comparison of market shares the figures for milk were left out of the Coopers & Lybrand data. This gives remarkable differences for the shares of reusable glass and plastics. Estimates of PRO for use of cans and beverage cartons are also lower.

	Coopers & Lybrand	PRO
glass refillable	37,6	52,5
glass one way	10,4	9,0
plastics	39,7	31,3
beverage carton	5,4	3,1
metal	6,9	4,0
total	100	100

For methodologies used see respective studies, for explanation of differences see PRO study.

way packaging in households and in the catering sector. The total volume packed in refillable bottles is almost the same for the household and the catering sector. But, the share of refillable packaging is much larger in the catering sector. About 20 % of household beverage consumption is packed in refillable bottles against almost 85 % in the catering sector.[13]

No recent data on the use of refillable beverage packaging were found. Volumes packed in refillable packaging for 1999 were calculated in two steps:
- the total consumption of packed beverages for each beverage group for 1999 was calculated using the 1993 Coopers & Lybrand figures and the average growth rate calculated from the Tetrapak consumption data;
- reuse packaging (glass) was calculated as the difference of the total packed volume and the total volume packed in one-way packaging, calculated from FOST Plus data.

The results show a decrease in the use of refillable packaging. However, the figure for non-carbonated water shows an increase, which seems not very probable.

In the Netherlands refillable plastic bottles are used for packaging water and soft drinks (PET) and milk (PC). They have almost entirely replaced the refillable glass bottle.

On the Belgian market the use of refillable PET is however negligible. According to Colruyt the introduction of ref-PET failed because of:
- the limited interest of the Belgian consumers;
- the competition against highly promoted recycling/collection schemes.[xii]

A technical obstacle to the use of ref-PET is that the bottles have to be sorted into two bottle types for soft drinks and water because of the aromatic infection problems. Flavour transfer to the PET material is a problem, also in other countries where ref-PET is used, e.g. in Denmark (technical requirements in pool contract, test to determine flavour transfer into the PET material).

According to a 1998 European study[xii] a detailed analysis of costs for one-way and reuse packaging among the fillers and retailers companies shows that:
- reuse packaging is the most profitable for the fillers
- one-way packaging gives the highest advantage to retailers by minimising their handling costs
- the investments for reuse packaging systems are 1,5 to 5 times higher than for one way packaging; unstable legal frameworks support one-way packaging
- the currently very low costs for energy and raw materials support one-way packaging; labour costs put reuse packaging at a disadvantage.

Within the last three decades most retailers have developed their distribution of industrially produced goods for use with one-way packaging. All of the costs for reuse related services have been reduced to a minimum.

In all of the countries were there are no legal laws restricting one-way packaging, discounters have become one of the catalysts in forcing reuse systems from the market.

---

[13] These figures exclude the wine and spirits consumption, that are for the largest part packed in one way glass bottles.

2.3.2 Carbonated water and soft drinks

In 1993, the market of carbonated water market was divided in PET and glass. No separate figures for carbonated and non-carbonated water are available for 1999. It is estimated that 2/3 is packed in PET bottles. The remainder is mainly packed in refillable glass.

Carbonated soft drinks are increasingly packed in PET (roughly 50 %). Refillable glass still accounted for about 1/3 in 1993, but this share has probably been halved. Cans represent the third important option for packaging carbonated soft drinks.

Last years all major water and soft drink producers have brought 0,5 litre PET bottles on the market. The share of 0,5 l bottles might have increased significantly compared to the figures in Table 6 and will probably still increase.

Carbonated water and carbonated soft drinks together represent about one third of the total beverage packaging market.
For large packs the main choice is between refillable glass, one-way PET and refillable PET. For small packs cans and refillable glass bottles are used. (Probably they do not fully compete: the largest market for small refillable bottles is the catering sector, whereas only 30 % of the cans are used in the catering sector.) PET is introduced for 0,5 l and 0,33 l bottles.

2.3.3 Non-carbonated water

In 1993, in the large market of non-carbonated water (25 % of the market) 50 % was packed in PET bottles, 1/3 in PVC bottles. No separate figures for carbonated and non-carbonated water are available for 1999. It is estimated that 2/3 is packed in PET bottles. The remainder is mainly packed in refillable glass. PVC bottles have almost entirely disappeared.
Non- carbonated water is mainly sold in 1 and 1,5 l bottles (95 %). Options for large packs are (refillable) PET and (refillable) glass.

Also 5 litre packs are actually in use for water (HDPE bottles). Large packs do not seem interesting for other beverages because of the limited shelf life after opening. For non-carbonated water 5 l bottles may present an interesting possibility to save on materials use.

2.3.4 Milk and milk drinks

In 1993 2/3 of all milk and milk drinks (16 % of the market) were packed in beverage cartons. The remainder was mainly packed in glass (15 %) or HDPE bottles (15 %). A small share was packed in PP and PS.
In the 1999 figures the share of HDPE bottles has risen. No data were available for the PP and PS packaging. PET has already been introduced for some fresh milk products (e.g. Campina[xiii]). Recent data from the Belgische Confederatie van de Zuivelindustrie give

shares of 20 %, 65 % and 14 % for HDPE, beverage cartons and reuse glass bottles respectively.
In the milk packaging market it is expected that beverage cartons will lose market shares to plastic bottles (HDPE, PET?). In Europe the relative share of beverage cartons compared to blown bottles has decreased between 1992 and 1997.[xv]

With the exception of Belgium and the UK all of the reuse primary packaging for drinking milk vanished from the EU market in the middle of the 1960's. The market was dominated by beverage cartons and in some countries by plastic bottles.
The refillable PC bottle was introduced in March 1996 on the Dutch market to replace the glass bottle for fresh milk (pasteurised milk). It can be reused about 30 times. It has not been introduced on the Belgian market. The share of fresh milk in the total milk consumption in Belgium is less than 5 %.
Oxygen barrier properties for the PC bottle are less favourable. This might give a constraint for longer shelf life. Hot filling and sterilising is theoretically possible for PC, but there is no experience yet.

The refillable PET bottle is actually not possible for long life milk products because high temperatures (> 80 °C) are needed for cleaning. However, research is going on increasing the temperature resistance of PET bottles. It can be expected that in future refillable PET bottles for milk will become available.

The cost of PE pouches (for milk or juice packaging) is very low and they present an obvious possibility of reducing materials use. However, they have not been introduced on the Belgian market. They are harder to handle than non-flexible packaging; after opening they have to be put into a multiple use can. They have been introduced in some European countries in the late 1970's but disappeared again because of declining consumer acceptance.

2.3.5 Beer

About 40 % of all the beer consumption is draught beer. The remainder (15 % of the beverage packaging market) is packed mainly in glass (about 90 %, the most of which reusable). More than 90 % is packed in small packs (in 1993, 84 % in small bottles, 6 % in cans). Between 1987 and 1997 cans have steadily replaced one-way bottles.
Beer in PET bottles has a clear potential. It has been launched already on several markets.

2.3.6 Wine and spirits

Wine and spirits (8 % of the beverage packaging market) are almost exclusively bottled in large size glass bottles (mainly one way glass; only some wine, imported and bottled by supermarkets, is in refillable glass).
Wine is also packed in beverage cartons and in bag-in-box systems that can easily be sealed again after opening. In 1993 the share was still considered negligible. However in the mean time, this market may have developed further.

Technical and market potential for wine and spirits in PET bottles is not clear. A long conservation period limits the use of materials with low barrier properties. This is especially the case with quality wines, aperitifs and spirits. However, particularly in France, inexpensive table wine is actually sold in one-way PET bottles.
Probably the largest part of the market will also in future be packed in glass, but it can be expected that a rising share will be packed in alternative packages (beverage cartons, bag-in-box systems and PET bottles).

2.3.7 Fruit juices and nectars

Fruit juices and nectars represent only about 5 % of the market. They were mainly packed in beverage cartons in 1993 (87 %). The remainder was packed mainly in glass (large one way bottles and small refillable bottles), a very small quantity in cans. For large packs the share of beverage cartons was even 95 %.
Absorption of flavours made plastic packaging less suitable for juice packaging. However, recently fruit juices packed in PET bottles have been successfully introduced on the Belgian market[xiii] but there are no separate figures for fruit juices in 1999.
For pouches the situation is similar to the one for milk and milk products.

Table 10 and Table 11 give the options for large and small beverage packages respectively that are quantitatively important or could become so. For each of these options a standard packaging system (primary and secondary packaging) has been defined.
Some questions remain regarding technical potential, e.g. for packaging fruit juices and milk in (refillable) PET bottles. It seems however that technical difficulties for these options will be overcome very soon.

Table 10 Packaging options for large size beverage packs

	glass bottle		PET bottle		HDPE	beverage
	one way	reuse	one way	reuse	bottle	carton
carbonated waters / soft drinks		A	A	P		
non-carbonated mineral waters		A	A	P		
fruit juices and nectars	A	(A)	R	(P)		A
milk and milk drinks		A	R	(P)	A	A
wine and spirits	A	A				(A)

A: actually commonly used; (A): actually used, but marginal; R: recently introduced; P: potentially used; (P): unclear potential

Table 11 Packaging options for small size beverage packs

	glass bottle		PET bottle		can
	one way	reuse	one way	reuse	
carbonated waters / soft drinks		A	A	P	A
beer	A	A	R	(P)	A

A: actually commonly used; R: recently introduced; P: potentially used; (P): unclear potential

3 PRODUCT SYSTEM DESCRIPTION

3.1 Beverage packaging products

In this paragraph standard beverage packaging products, that are representative for a specific packaging option, will be defined. Their future evolution (i.e. their weight) will be estimated. For caps a standard weight reduction of 10 % in the period 2000 - 2015 has been assumed. Labels have not been taken into account.
For each type of packaging a secondary packaging has been assumed. For these secondary packaging materials a standard weight reduction of 10 % in the period 2000 - 2015 has been assumed.
These data will serve as a basis for further calculations.

Two surveys from 1992 and 1993 give detailed information on the weight of beverage packaging on the Belgian market.[viii,xiv] These data were compared to more recent data from the study of Hekkert *et al* (that was the basis for the data used in the MATTER study)[xv], to examples found in various literature sources[xxv,xxviii] and to own data. Based on these data representative packaging systems were chosen (Table 14, Table 15).

3.1.1 Glass bottle

One way glass bottles

Large one-way glass bottles are used for fruit juices and for wine and spirits. Small one-way glass bottles are to some extent used for beer.
The 1992/1993 surveys give an average weight of 450 g for 1 l fruit juice bottles. Hekkert expects an average weight of 375 g for 1 l one way glass bottles in 2000. Recently, bottles of 285 - 290 g were introduced for fruit juices and vinegar. This can be seen as the long-term potential average.

Bottles for wine and spirits are heavier. Roughly the same values as mentioned for the 1 l fruit juice bottles applied to the average 0.75 l wine bottle in 1992/1993 and in 2000. Calculations based on the total volume of wine and spirits packed in one-way glass and the total declared quantity of glass used for wine and spirits suggest a higher average weight of 475 g.
In 1997 the company Geens Benelux introduced two types of 0.75 l wine bottles with weights respectively of 300 and 450 g. Verlipack reduced the weight of a 0.75 l wine bottle from 450 g to 370 g, a reduction of 18%.[xvi] The long-term potential average weight will be set at 350 g.

Since the volume of fruit juices packed in one way glass bottles is very small (less than 0,5 % of the total packed volume, no separate 1 l bottle will be included in the model.

Reuse glass bottles

The weight of 1 l reuse glass bottles differs also quite a lot depending on the packed beverage. In 1992/1993 it ranged from 600 g for milk bottles to 930 g for coke bottles. The average was about 750 g. 0,75 l reuse wine bottles weighed between 450 and 600 g.
Recent samples confirm these weights. For the long term we consider a 20 % weight reduction possible.

In 1992/1993 0,25 l beer bottles weighed between 250 and 275 g. For soft drink, milk and water bottles the average was 270 g (range 175 - 374 depending on beverage).
A weight reduction of 78 g is reported for a 0,33 l reuse beer bottle, resulting in a weight of 242 g (weight reduction of about 25 %).
If we apply a weight reduction of about 20 % to the 0,25 l bottle in the period from 1992/1993 to 2015 we arrive at a weight of 220 g.

The number of trips of a refillable glass bottle:

- some bottles are not returned; some bottles are returned, but discarded for further use;
- different for different beverages[xvii]: from 20 for lemonade and coke bottles, to 25 for water, 30 for beer and milk and even 45 for fruit juices. The number of trips is very high for small refillable bottles that are mainly used in the catering sector, as is the case for fruit juices.
- in the PRO study averages for alcoholic and non-alcoholic beverages are respectively 42 and 32[xiv];
- the previously cited report on reuse in Europe gives the following figures[xii]:
  - 25, 33 and 100 cl bottles for beer: 40 – 60 times
  - individual company brands: 20 times
  - milk and dairy products : 15 – 25
- for wine lower reuse figures are considered (wine is stored much longer); a Vito study[xviii] considers two scenarios: 5 and 10 times

The averages that will be used, are 25 for large reuse glass bottles and 30 for small reuse glass bottles. It is considered that each bottle is used 5 times per year, and that once in every 10 years the entire stock of reuse bottles is replaced because of changes in the design or in the packaging concept. These data allow calculating the average materials use for 1 litre of beverage packed in a refillable bottle[14].

Crates

1 l reuse glass bottles are transported and sold in crates of 12 or 6. These crates for 6 bottles weigh about 1,2 kg. Small reuse glass bottles are transported in crates of 24 bottles, weighing approximately 1,9 kg. We assume that they are reused about 75 times.
In some cases small glass bottles are additionally grouped per 4 or per 6 in a carton holder of about 25 g. This is mainly the case for luxury beer types. Their share is probably negligible.

---

[14] E.g. for packing 1 litre of beverage in a 1 litre reuse glass bottle of 750 g the average use of glass is 45 g per litre of packed beverage.

Caps

Typically large glass bottles are closed with HDPE screw caps, weighing on average 3 g. Small glass bottles are closed with crown caps, weighing about 2,3 g (2,1 g tinplate, 0,2 g LDPE).

3.1.2 PET bottle

One way PET bottles

In 1992/1993 the average 1,5 l PET bottle weighed about 40 g for non-carbonated beverages and 45 g for carbonated beverages. By 2000 these weights have been reduced to about 36 g and 42 g respectively. We will assume a typical average weight of 38 g. A further reduction of 10 % in the period 2000-2015 will be assumed.
Spadel and Coca-Cola introduced bottles containing up to 25 % recycled material. Manufacturers predict multi-layer bottles can contain at least 50 % recovered PET (PETCORE website)
There are a variety of processes now commercially operating that produce food grade PET resin. High quality recovered PET may be used to produce food grade PET, for use in primary packaging up to 100 %. The Swiss BAG and the US FDA recently approved the use of 100 % recycled PET for beverage packaging.[xix,xx]

After the introduction of the 0,5 l bottles, Spadel introduced a 0,33 l water bottle to replace the 0,33 l cans. A weight of 20 g and a further reduction of 10 % in the period 2000 - 2015 have been assumed.

HDPE cap of 3 g for the large bottles and 2 g for the small bottles.

Secondary packaging:
- large bottles: 6 bottles packed in a 22 g PE foil
- small bottles: 24 bottles wrapped in a 25 g foil and kept together in a 100 g carton tray

Reuse PET bottles

Increased temperature resistance made it possible to clean PET bottles (at 75 °C). Actually research is going on to improve the cleaning at higher temperatures (up to 85°C)[xxi].
A 1,5 litre refillable bottle weighs 103 grams. They are designed to be reused 25 times, but possibilities to reach a number of 30 have been reported. Many bottles make fewer trips because of the damage done during the refilling process.

The Danish LCA considers a 0,5 l refillable PET bottle weighing 53 g. For a 0,33 l bottle we will assume a weight of 45 g (85 % of the weight of the 0,5 l bottle).

The same assumptions as for glass bottles have been made on the number of trips per year and on the replacement of the entire stock. The same type of crates also has been considered[15].

HDPE cap of 3 g for the large bottles and 2 g for the small bottles will be considered.

3.1.3 HDPE bottle

A 1 l HDPE milk bottle typically weighs about 35 g. It has a closure weighing about 3,5 g. A weight reduction of 10 % is assumed for the period 2000 - 2015.

Secondary packaging:
- 6 bottles in a 18 g PE foil

3.1.4 Beverage carton

According to the Alliance for Beverage Cartons[xxii] the average one litre aseptic brick-shaped carton weighs 28 grams. Its weight has been reduced by 21% over the past 20 years. It might be further reduced to 23 g in the coming 10 to 15 years. A gable top carton weighs about 30 grams.
For use with fresh products, the carton is generally made out of 89% paper and approximately 11% polyethylene. For long life products, the carton consists of 70% paper, 25% polyethylene and has a 5% aluminium layer. The aluminium layer provides an extremely efficient oxygen barrier.

Because during pouring from cartons without cap the liquid content comes into contact with the fibres, the use of recycled fibres for the production of beverage cartons is in most countries still prohibited. (Packaging 2000, 2/99)

A PP lid of 2 g is assumed.

Secondary packaging:
- 6 bottles in an 18 g foil.

3.1.5 Steel can

About 90 % of the beverage cans used in Belgium are steel cans.
According to APEAL the average 0,33 l steel beverage can in 2000 (without the aluminium end) weighs about 24 g, the best available 22 g. The aluminium lid weighs 2,7 g.
The Danish LCA gives a weight for the entire can of 28,2 g.

---

[15] In the German and Danish LCAs weights for crates 1,5 l reuse PET bottles range from 183 to 227 g per bottle (crates for 10 and 12 bottles respectively). For 0,5 l reuse PET bottles the Danish LCA gives a weight of 1550 g for 24 bottles (65 g per bottle). Taking into account the high rate of reuse these differences are negligible.

Hekkert distinguishes a standard 0,33 l steel beverage can for the year 2000, weighing 23 g (without the aluminium end), and an improved ultra thin steel beverage can, weighing only 18 g. The latter does not seem to be on the market yet. It will be used as the long-term improvement option.

According to APEAL steel packaging contains up to 25% recycled material.

Secondary packaging:
- 24 bottles wrapped in a 25 g foil and kept together in a 100 g carton tray

3.1.6 Aluminium can

According to the European Aluminium Association a standard 0,33 l aluminium beverage can weighs 14 g[xxiii]. The Danish LCA gives an average weight of 14,5 g.
Hekkert cites sources indicating a further reduction to 10 g.

Secondary packaging:
- 24 bottles wrapped in a 25 g foil and kept together in a 100 g carton tray

3.2 Materials production

Relevant materials for beverage packaging are glass, folding carton (for beverage cartons and some secondary packaging), aluminium, steel and plastics (PET, HDPE, LDPE). The use of PVC for bottle production has become marginal. The use of PC does not seem to present large opportunities.
PP is sometimes used for caps or closures.

The detailed description of the production of the materials used in packaging production and the associated flows in Belgium are described in part III of this report and in the report of Institut Wallon [xxxiv].

3.3 Packaging production and use

3.3.1 Energy for packaging making and filling

The data for energy use for packaging making and filling were derived from a comparison of different literature sources[xxiv,xxv,xxvi,xxvii,xxviii] and own data.

Energy for packaging making includes all energy needed to transform materials into finished packaging. Energy for filling includes all energy directly associated to the processes of filling the packaging. In many cases (part of) packaging making and filling are one process.

The data that are found in the literature differ very much. To make them comparable, all literature data (electricity use, use of fossil fuels, use of process heat, …) were transformed in electricity use equivalents (MJe).

Energy use for making PET bottles differs from 9 to 12.2 MJe/kg for 1.5 l bottles. Data for filling differ from 33 to 202 MJe/l.
The following values will be used:

- packaging making: small bottles: 7.5 MJe/kg
  large bottles: 10 MJe/kg
- filling: 80 MJe/l

For HDPE bottles the same values will be used.

For refillable PET bottles an equivalent of 133 MJe/l has been added for cleaning returned bottles of 1,5 l. This value has been increased with 50 % for small bottles.

For glass bottles the same values for cleaning and for filling as for PET bottles will be used.

For steel cans energy use for packaging making differs from 0.7 to 5.3 MJe/kg. Data for filling differ from 85 to 240 MJe/l.
The following values will be used:

- packaging making: 2.1 MJe/kg
- filling: 190 MJe/l

For aluminium cans the same values will be used.

TetraPak gives a need of 25,1 MJe and 13,0 MJ propane for assembling 1000 packs starting from the materials for the different layers. Starting from these values we can calculate the equivalent energy needed for packaging making for 1 l beverage cartons.

- packaging making: 2.7 MJe/kg
- filling: 37 MJe/l

For secondary packaging the following data will be used for packaging making[xv,xxvii]:

- LDPE film: 2,6 MJe/kg pack
- HDPE caps: 6,8 MJe/kg pack
- steel caps: 2,0 MJe/kg pack
- HDPE crates: 3,2 MJe/kg pack

3.3.2 Transport

For transport of the filled packaging from the filler to the retailer the following procedure has been adopted:

- The beverage quantity transported is volume-restrained. It is not the weight of transported packaging and its content, but its volume, that will determine the number of trips to be done (Table 14, Table 15). Transport allocated to the packaging is the difference of the considered option and a hypothetical bulk transport (additional kilometres to be done because of the packaging choice).

- An average transport distance of 150 km has been assumed.
- It is assumed that the truck returns with empty bottles in the case of reuse bottles or otherwise empty. Hence, no additional transport for the return of empty bottles has been considered.

Transport of the filled packaging from the retailer to the final consumer has not been taken into account. It is assumed that the energy use related to this transport is not determined by the choice of the packaging. Even if for heavier packaging the customer would be more inclined to taking the car than e.g. a bicycle, the additional energy related to this transport is negligible.

3.3.3 Costs

Detailed cost data for packaging filling were found in a recent Austrian study.[xxvi] These data are based on surveys in existing plants in Austria. Some data were adapted because not all considered packaging options are the same. Costs for cleaning reuse bottles are included. Additional retail costs are costs for taking back the empty bottles in retail shops (Table 12). The latter are quite high, especially in the case of small reuse packaging.

Table 12: Costs for filling

EUR/1000 l		investments	variable costs	additional retail costs
one way PET	1,5 l	9.43	9.31	
reuse PET	1,5 l	14.52	13.84	36.34
one way glass	1 l	9.04	10.66	
reuse glass	1 l	13.56	15.99	54.51
beverage carton	1 l	6.03	25.29	
one way PET	0,33 l	11.79	11.64	
reuse PET	0,33 l	18.15	17.31	165.17
reuse glass	0,25 l	16.95	19.99	218.02
steel can	0,33 l	8.86	12.35	

The same study also gives "material" costs. Again some of these data had to be adapted (Table 13). These "material" costs are the costs of the delivered bottle, can or preform, the closure, foil, cardboard, … for one piece of packaging. They include secondary packaging (e.g. crates). Costs per piece of packaging are considerably higher for the reuse bottles than for their one-way equivalents. However, fewer pieces are used per litre of beverage (see §3.1.1 and 3.1.2).

Table 13: Packaging material cost

EUR/1000 pieces		material cost
one way PET	1,5 l	38.76
reuse PET	1,5 l	207.61
one way glass	1 l	121.41
reuse glass	1 l	202.76
beverage carton	1 l	56.69
one way PET	0,33 l	96.90
reuse PET	0,33 l	519.02
reuse glass	0,25 l	608.28
steel can	0,33 l	183.14

Table 14 Material use and transport for large packaging options

type	**PET bottle, one way**		**PET bottle, reuse**		**glass bottle, one-way**		**glass bottle, reuse**		**PE bottle**		**beverage carton**	
	2000	2015	2000	2015	2000	2015	2000	2015	2000	2015	2000	2015
primary packaging												
material	PET	PET	PET	PET	glass	glass	glass	glass	HDPE	HDPE	cardboard /LDPE /aluminium	cardboard /LDPE /aluminium
content (l)	1,5	1,5	1,5	1,5	0,75	0,75	1	1	1	1	1	1
weight (g)	38	34	103	92,7	475	350	750	600	35	31,5	28	23
closure												
material	HDPE	HDPE	HDPE	HDPE	cork	cork	HDPE	HDPE	HDPE	HDPE	PP	PP
weight (g)	3	2,7	3	2,7	5	4,5	3	2,7	3	2,7	2	1,8
secondary packaging												
content (N° bottles)	6	6	6	6	12	12	6	6	6	6	6	6
content (l)	9	9	9	9	12	12	6	6	6	6	6	6
material	LDPE	LDPE	HDPE	HDPE	cardboard	cardboard	HDPE	HDPE	LDPE	LDPE	LDPE	LDPE
weight (g)	22	19,8	1200	1080	650	585	1200	1080	18	16,2	18	16,2
transport												
content (l)	25700	25700	19800	19800	9900	9900	13200	13200	19800	19800	28500	28500

Table 15 Material use and transport for small packaging options

type	**PET bottle, one-way**		**PET bottle, reuse**		**glass bottle, reuse**		**steel can**		**aluminium can**	
	2000	2015	2000	2015	2000	2015	2000	2015	2000	2015
primary packaging										
material	PET	PET	PET	PET	glass	glass	steel can aluminium lid	steel can aluminium lid	aluminium	aluminium
content (l)	0,33	0,33	0,33	0,33	0,25	0,25	0,33	0,33	0,33	0,33
weight (g)	20	18	45	40,5	250	220	24	18	14	10
							2,7	2,43		
closure										
material	HDPE	HDPE	HDPE	HDPE	steel	steel				
weight (g)	2	1,8	2	1,8	2,3	2,07				
secondary packaging										
content (N° bottles)	24	24	24	24	24	24	24	24	24	24
content (l)	7,92	7,92	7,92	7,92	6	6	7,92	7,92	7,92	7,92
material	LDPE	LDPE	HDPE	HDPE	HDPE	HDPE	LDPE	LDPE	LDPE	LDPE
weight (g)	25	22,5	1900	1710	1900	1710	25	22,5	25	22,5
material	cardboard	cardboard					cardboard	cardboard	cardboard	cardboard
weight (g)	100	90					100	90	100	90
transport										
content (l)	25100	25100	10500	10500	7920	7920	25100	25100	25100	25100

3.4 Collection and sorting of household packaging waste

This chapter only deals with the specific processes for the collection and sorting for further treatment of packaging waste. The processes used in the further treatment of the selectively collected waste flows of each material (recycling, incineration, …) and the associated flows are described in part III of this report and in the report of Institut Wallon [xxxiv].

3.4.1 Collection and sorting

In the FOST Plus collection schemes the following fractions are collected:

- glass (mainly packaging glass): collection through decentralised glass containers and through container parks (bring system) and transport to the recycling company
- paper and cardboard (all paper and cardboard): kerbside collection and transport to the recycling company
- plastic bottles and flasks, metal packaging and drink cartons (PMD fraction): collection through blue PMD bags or through container parks (bring system); the content of the blue bags is sorted in sorting centres

Other plastic packaging (foils, cups, boxes, bags, …) is not collected. FOST Plus does not consider their collection and recycling economically or ecologically justified. According to a FOST Plus evaluation, changing the collection scheme fundamentally would lead to an inferior service and would lead to difficulties in reaching the objectives or to significant cost increases without improvement of the service or of the recycling results.[xxix]

At the end of 1999 the FOST Plus collection schemes covered 71 % of the population (7,2 million inhabitants) in intensified projects.

Glass

Glass is collected through decentralised glass containers ("bottle banks", 1 collection point per 1000 inhabitants, 85 %), sorted by colour, and through container parks (bring system, 15 %) and transported to the recycling company.
Operations in the recycling company are:

- manual separation of large impurities;
- reduction of the size to pieces of 6 to 60 mm;
- separation of ferro-metals through magnetic separators;
- separation of non-ferro metals through eddy current separators.

In all companies opto-electronical devices are in use to separate the glass by colour and to remove stoneware, sandstone and porcelain. The clean glass fractions are transported to the glass factory. In Belgium there are six companies for recovery of hollow glass.

Costs for glass collection have been steady for the last three years for which figures are actually available (Table 16).

Table 16 Costs for glass collection

	1997	1998	1999
BEF/ton	2076	2074	2068

In 1999 the average price at which the collected glass was sold at the recycling companies was 420 BEF/T. During the year it fluctuated between 410 and 480 BEF/T.
Kerbside collection is twice as expensive as collection through decentralised glass banks. It yields an inferior quality of glass because there is no colour separation.[xxx]

Paper and cardboard

In the FOST Plus collecting scheme paper and cardboard packaging is collected once per month together with newspapers and magazines (kerbside collection, 75 %), or in the container parks (25%), and transported to the recycling company.
It is assumed that 75 % of the collected paper and cardboard consists of newspapers and magazines. 25 % consists packaging. The recycling company sorts specific paper qualities and bales them.

Costs for paper and cardboard collection are given in Table 17.

Table 17 Costs for paper and cardboard collection

	1995	1996	1997	1998	1999
BEF/ton	1859	2314	2035	1780	1756

Prices paid by recycling companies for the waste paper and cardboard fluctuate strongly. They have risen from about -850 BEF/T in March 1998 to almost 500 BEF/T in December 1999. For new contracts in 2000 FOST Plus even expected a purchase price of 4300 BEF/T. (FOST Post nov2000)

Plastic bottles and flasks, metal packaging and beverage cartons (PMD fraction)

The PMD fraction is collected twice per month via kerbside collection in special blue PMD bags (89 %) or in container parks (bring system, 11 %). The content of the blue bags is sorted in sorting centres:
- separation of the fine residue;
- separation of the blue bags and plastic foils;
- magnetic separation of iron;
- manual sorting of the different plastic qualities, the beverage cartons and the aluminium fraction.

In 1997 there were 13 PMD sorting centres in Belgium.

The costs for PMD collection have constantly decreased since the start of the FOST Plus collection schemes. The costs for sorting have risen, but they have stabilised around 7800 BEF/T (Table 18).

Table 18 Costs for collecting and sorting PMD

EUR/ton	1995	1996	1997	1998	1999
PMD collection	242	214	210	189	177
PMD sorting	160	161	189	194	195
	402	376	399	383	372

In Germany the actual cost for sorting is about 600-700 DEM/ton (310 - 360 Euro/ton). The intention is to halve this cost. 320 manual sorting installations are to be replaced by fully automatic 'Kaktus' installations. [xxxi] This would result in a lower cost than the actual PMD sorting cost in Belgium. However, in Germany all plastic packaging is collected.

Recently, there have been impressive developments for the sorting of plastic containers. In 2000, there were approximately 200 process lines or separation units world wide equipped with automatic bottle sorting equipment.[xx] Automatic sorting equipment can sort bottles by polymer type and/or colour quickly. Research has shown that significant cost savings and improved quality can be attained by the use of these systems, where sufficient throughput can be achieved.

Automated bottle sort systems have been developed which use a combination of spectroscopic identification methods and/or colour cameras for sorting. The most sophisticated equipment available today is able to identify a wide range of polymer grades, including PVC, coloured and clear PET, natural HDPE and PP and coloured HDPE. These machines use either X-ray or near IR spectroscopy for polymer identification and optical sensors for colour identification.

According to PETCORE accuracies of better than 90% appear to be routine, with many users quoting figures of better than 99%. Research from Switzerland concluded that automated PET bottle sorting systems can reduce costs by up to 60 %.[xx]

We will assume a gradual increase of automatic sorting and a decrease in sorting costs of 20 % by 2005 and 30% by 2010.

Beverage cartons can be sorted automatically based on eddy currents that detect aluminium or IR techniques that detect the combination PE/carton.[xxxi]

In case a mixed plastic waste fraction is sorted out instead of single resins, the sorting costs will be lower. For manual sorting the non resin-specific capital cost can be estimated at about 70% of the total capital cost and the non-resin specific labour cost at about 20% of the total labour cost. For automatic sorting this is about 90% and 35% respectively. For manual sorting the capital cost is about 8% of the total cost, the labour cost about 82%. For automatic sorting this is about 32% and 58%.[xx]

Combining these results brings the total manual sorting cost for separating a mixed plastic waste fraction at about 30% of the cost for sorting out single resins; for automatic sorting the sorting cost for MPW is about 60 % of the sorting cost for single resins.

Table 19 Evolution of collection and sorting costs for PMD

EUR/tonne	2000	2005	2010	2015

collection	177	168	168	168
sorting				
- to single resin	195	156	137	137
- to MPW	59	78	82	82

For the collection of other waste PET we will assume a cost that is 1,5 times the cost of PMD collection and sorting. This accounts for the cost increase for collecting lighter and more contaminated fractions. On the other hand the residual waste PET fractions also contains industrial packaging waste (e.g. foils) that are easy to collect and sort.

Three groups of PET bottles can be distinguished:

- transparent, colourless bottles: the largest fraction having also the largest market value; they can be used for replacing primary PET;
- clear blue bottles: the colouring agent can be a problem in certain applications; a small fraction of clear blue bottles does not pose a problem when mixed with colourless bottles; however, the share of blue bottles for packing water increases;
- coloured bottles (green, mixed or not with blue bottles) for the strapping market.

3.4.2 Recycling results

In its annual report for 2000 FOST Plus gives recycling rates for areas that work for at least 12 months with the FOST Plus collection scheme. Table 20 also shows the recycling rate if the amounts recycled through the mediation of FOST Plus are compared to the total beverage packaging end use[16].

The recycling rates for paper and cardboard in the areas covered by FOST Plus collection schemes are over 100 %.
According to FOST Plus the high rate for paper and cardboard is explained by the amount of secondary packaging that is also collected. However, this figure is in all cases somewhat arbitrary. The selective collection of paper and cardboard does not distinguish between paper and cardboard from packaging and paper and cardboard from other sources (newspapers, magazines, …). The share of packaging paper and cardboard has been fixed at 25 % of the total collected quantity. It could be as well that this share of 25 % is too high.

The amounts of waste packaging that are selectively collected in areas that are not covered by FOST Plus collection schemes are limited (Figures of OVAM for those areas are less than 0,5 % of the total quantity of household packaging waste).

[16] These recycling rates are not to be confused with the recycling rates calculated in the FOST Plus annual report. The recycling rates in the annual report compare the amount recycled through the mediation of FOST Plus with the total amount of household packaging brought on the market by its members.

Table 20 Recycling rates for household packaging

	total end use one way household packaging [kt]	recycling result FOST Plus [kt]	recycling rate based on total end use [%]	recycling rate in areas covered by FOST Plus collection schemes [%]
	1999			2000
glass	333	245	74	92
paper-cardboard	139	152	109	120
metals	94	62	66	92
plastic bottles	63	35	56	80
other plastics	81	0	0	0
total plastics	144	35	24	
liquid carton	20	10	49	71
others	21	0	0	0
total	752	505		

The remaining quantities are not selectively collected. They end up in the rest fraction of the domestic waste.

The recycling rates for the areas covered by the FOST Plus collection schemes give an idea of the recycling rates that would theoretically be reached if the whole country were covered by a similar collection scheme.

4 GREENHOUSE GAS EMISSIONS RELATED TO THE END USE OF BEVERAGE PACKAGING IN BELGIUM

4.1 Method

4.1.1 Improvement options

Table 21 shows the improvement options that have been considered for the assessment of the greenhouse gas emission reduction potential from beverage packaging.

Table 21: Improvement options for the reduction of greenhouse gas emissions from beverage packaging

At the function level (consumption pattern changes)

- changes in beverage consumption pattern: not considered (unless econometrical projection of historical beverage consumption trends)
- changes in choice of packaging (end use)
  - includes reuse
  - substitution: potential and limits
    - technical
    - economical
    - ecological
    - sociological

At the product level

- weight reduction
- increased use of recycled materials

In the production chain and the treatment of the used product:

- increased recycling of used packaging
- improvement options in materials production: partially considered
- improvement options in waste treatment technologies: partially considered
- improvement options in energy production: not considered
- improvement options in transport system: not considered

4.1.2 Approaches

Two complementary approaches have been used (Table 22):

- a base model (PackBase) based on average emission factors for materials and energy production and fixed scenarios for changes in packaging use and recycling rates;
- a MARKAL partial optimisation model (PackMark) in which the choice of packaging and recycling rates is optimised on cost basis.

Table 22: Comparison of the PackBase model and the PackMark model

model definition	**PackMark**	**PackBase**
demand	exogenous demand for beverage packaging	
end use options (demand technologies)	BAU scenario	
	end use optimisation within specified ranges	end use scenarios based on technical and sociological potential for substitution
materials production	partial optimisation (focus on recycling) - partially fixed (average emission factors and costs)	scenarios – average emission factors
treatment of used products	partial optimisation - partially fixed (average emission factors and costs)	scenarios - average emission factors
energy production	average emission factors and costs (changing in time)	fixed average emission factors
supply of transport	fixed – average emission factors and costs	fixed – average emission factors
results	**PackMark**	**PackBase**
	- cost-effective improvement options - assessment of improvement potential through system optimisation under different greenhouse gas emission constraints	- comparison of reduction potential for individual packaging options - comparison of emissions of different phases (materials production, use phase, transport, waste treatment) - assessment of total improvement potential - no cost assessment

4.1.3 Demand

In both approaches the demand for beverage packaging (expressed in litre of packaging service) is calculated from the results of the Corelli model for beverage consumption.[x] For beer it has further been assumed that also in future 40 % is sold as draught beer (see 2.3.5). For carbonated beverages the demand has been split up for large and small packaging based on the actual shares and an assumed future increase of 3 % for small packaging in the period 2000 – 2015. The resulting data are given in Table 23.[17]

[17] For practical reasons the demand in the MARKAL model for the years 2005 and 2010 has been interpolated between the data for 2000 and 2015. This leads to minor changes as compared to the data presented in Table 23.

Table 23: Demand for beverage packaging in the period 2000 – 2015[x]

packed volume (x 10^6 l)	2000	2005	2010	2015
carbonated beverages				
large	995	1,069	1,129	1,179
small	264	301	337	372
non-carbonated water	977	1,104	1,217	1,318
milk and milk drinks	623	587	545	501
fruit juices and nectars	206	229	250	268
beer (excl. draught)	595	546	499	455
wine and spirits	276	282	286	290
total	3,936	4,118	4,263	4,383

4.1.4 Packaging production and use

The end use phase of the packaging includes packaging making (starting from the supplied base materials), filling, cleaning (in case of reuse packaging) and transport. For both models the same data on energy use, materials use and need for transport have been used. They are based on the analysis in §3.1.

The procedure for calculating the transport needs for a specific packaging option has been explained in §3.3.2.

A greenhouse gas emission factor for transport of 1341 g CO_2/km has been used. This emission factor is based on the emission factors for a 32-40 T truck in the MEET model developed by Vito, and an assumed typical route (Table 24). Costs for transport have been fixed at 62 BEF/km.

Table 24: Greenhouse gas emission factor for transport

	km	g CO_2/km
urban normal	7.5	1594
urban peak	2.5	2057
highway normal	90	1160
highway peak	30	1718
rural normal	15	1303
rural peak	5	1718
	150	1341

4.1.5 PackBase

End use options (demand technologies)

The considered packaging options are based on Table 10, Table 11, Table 14 and Table 15.

Table 25 summarises the end use scenarios that have been used in the PackBase model. They include a business-as usual scenario (BAU), a freeze in packaging choice (FR), and scenarios with moderate to drastic changes in choice of packaging. Changes in packaging choices in the scenarios are based on a gradual replacement of packaging with higher emission factor (g CO_2 eq/l) with packaging with lower emission factor (see Figure 5 and Figure 6), taking into account technical and sociological constraints. In most cases this comes back to an increase of reuse, and especially use of reuse PET bottles whereever possible (with the exception of the use of beverage cartons for milk). The detailed scenarios are given in Annex 1.

Table 25: End use scenarios for the PackBase model

BAU	• further decrease in reuse glass (-10 %) - replaced by one-way PET • small one-way PET partially replaces cans (-10%) • decrease beverage cartons (-5%) and reuse glass (-10%) for milk products – replaced by HDPE • one way PET for beer (+15%); replacing mainly one way and reuse glass, but also cans (-3%)
FR	• no changes in packaging choice
NIR	• no increase in reuse • replacement by "best option" (except for ± 5 %)
RU1	• increase of reuse (mainly reuse PET) • moderate use of PET and reuse PET for beer • wine and spirits : 90 % glass; 20 % reuse
RU2	• more drastic increase of reuse PET • increased use of (reuse) PET for beer • wine and spirits : 85 % glass; 20 % reuse
RU3	• maximum reuse (large: 90 %; small: 80 %, exc. wine: 30 %) • wine and spirits : 80 % glass

Materials production and waste treatment

In the PackBase model different materials production and waste treatment scenarios have been combined with the above-mentioned end use scenarios.

Table 26: Materials production and waste treatment scenarios

FEF (fixed emission factors)	no changes in emission factor
M	+ decrease in materials use (weight) per packaging type
M+RW	+ increasing % waste recycling
M+RW+RP	+ increasing % recycled material in production

Decreases in weight per packaging type are described in § 3.1 and summarised in Table 10 and
Table 11.

Emission factors found in literature for the production of the materials were corrected for the use of recycled material in the production process. The benefits from the use of recycled material were credited partially to the packaging (see Annex 2).

Calculations and estimates are based on the following sources:

- for glass and cardboard production: BUWAL, 1996[xxiv]
- for plastics: APME ecoprofiles, 1999[xxxii] and own calculations for recycling credits (see *Greenhouse gas emissions and material flows. Part III*).
- steel: Institut Wallon, 2001[xxxiii, xxxiv]
- aluminium: own calculations (see *Greenhouse gas emissions and material flows. Part III*).

For glass and cardboard production no changes in use of recycled materials were considered. Closed loop recycling is already accounted for completely in the production emission factors. A content of recycled material in the packaging of 20 % in 2000 and of 30 % in 2015 was assumed for steel and of 35 % and 45 % respectively for aluminium. For plastics a content of recycled material in the packaging of 0 % in 2000 and of 25 % in 2015 was assumed.

The resulting emission factors for the production of materials are given in Table 27.

Table 27: Greenhouse gas emission factors for the production of packaging materials

kg CO_2-eq/kg	2000	2015
glass	0,65	0,65
PE	1,80	1,64
PET	4,30	3,83
cardboard	0,50	0,50
steel	1,60	1,55
aluminium	10,96	10,32
beverage carton	1,28	1,22

The recycling rates in 2000 for packaging waste are based on the actual rates in the third column of Table 20. Only for paper and cardboard the rate has been adapted (to 86%). It is assumed that future recycling rates can be slightly higher than the rates in the last column of Table 20.

Table 28: Recycling rates used in the PackBase model

	2000	2015
glass	74%	95%
HDPE	56%	85%
PET	56%	85%
cardboard	86%	95%
steel	66%	95%
aluminium	66%	95%
beverage carton	49%	75%

The benefits from recycling of used packaging were credited partially to the packaging (see Annex 2: Allocation in case of recycling or in case of energy recovery).

Packaging that is not recycled is considered to be eliminated with the rest fraction of the domestic solid waste. In 2000 52 % is considered to be incinerated. The remaining 42 % is landfilled. It is assumed that by 2015 landfilling of domestic solid waste will have been abolished. All packaging waste that is not recycled is incinerated. The efficiency of electricity production from waste has been fixed at 10 % of the calorific value of the waste.

Emissions of waste incineration have been allocated fully to the packaging, even if a part of the energy is recovered (see Annex 2).

Energy production

A fixed emission factor of 83 kg CO_2 eq/GJ has been used (average emission factor for Belgian electricity production in 2000).[xxxv]
Because changes in use of electricity related to beverage packaging can be considered marginal, the effect of using the marginal electricity source, a STAG power plant, having an efficiency of about 50 %, was tested. An emission factor of 120 kg CO_2 eq/GJ has been used for this purpose.

For steam a fixed emission factor of 70 kg CO_2 eq/GJ has been used.

4.1.6 PackMark

End use options (demand technologies)

In the PackMark model the BAU end use scenario has also been used. In this scenario the evolution of the packaging use is fixed exogenously. In all other scenarios the possible shifts in end use were confined within specified ranges. The applied minimum and maximum percentages are given in Annex 1.
Reduction in materials use per packaging unit is part of an autonomous evolution. Through their reduction of cost of materials, these reductions are cost effective.

Table 29: Scenarios for the PackMark model

BAU	fixed packaging end use
OPT	end use optimisation no greenhouse gas emission limit
RE-15	end use optimisation greenhouse gas emission limit at 85 % of the level of 2000
RE-30	end use optimisation greenhouse gas emission limit at 70 % of the level of 2000
RE-MAX	end use optimisation greenhouse gas emission limit at minimum possible[18]

Because quite some uncertainty exists on the packaging cost data, and because the main shift in packaging choice is between one way and reuse packaging (see below), the effect of the difference in specific packaging costs between one way and reuse options was tested by reducing the specific packaging cost for one way options by 15 % for all scenarios.

To complicate the modelling work not too much, the considered packaging options were somewhat simplified compared to the PackBase model. All milk was considered to be packed in large packs. The error made in this way is small because the same packaging options are available for small and large milk packs. For wine the standard 1 l reuse glass bottle was used instead of the 0,75 l bottle.

Materials production and waste treatment

The focus of the optimisation is on the choice of the packaging type and on the waste treatment options (recycling versus treatment with the rest fraction of the solid domestic waste). Other improvement options are included through changes in weights, energy use, emission factors or costs but they are not optimised (no alternative options). Optimisation of the materials production processes based on end use of packaging only is not realistic.

[18] For determining the lowest attainable greenhouse gas emission level an emission tax of 9999 Euro/ton CO_2 eq was applied to the OPT scenario.

The input data for the materials production processes (virgin and recycled materials) are based on the detailed analyses by Vito (*Greenhouse gas emissions and material flows. Part III*) and Institut Wallon[xxxiv].

- ***Materials production***

Plastics

The production of plastics, and of the necessary intermediate organic chemicals, is a part of the much larger, highly integrated petrochemical complex. Crucial petrochemical processes, such as the production of ethylene or aromatics, have multiple inputs and outputs. Due to the complexity of the petrochemical processes calculating greenhouse gas emission factors for plastics is tedious. This is clearly shown by the striking differences in CO_2 emissions in the older and the more recent versions of the APME ecoprofiles, which in their turn differ quite a lot from other detailed studies (see *Greenhouse gas emissions and material flows. Part III*).

Production of PET and of PE have been represented by a fixed emission factor, based on the APME ecoprofiles, 1999[xxxii], and a fixed cost, based on the average market prices for PET and PE over the last years (Table 30). The impact of the choice of these emission factors on the results is discussed below (§0).

Table 30: Average greenhouse gas emission factors and costs for PET and PE production

	PET	PE
emission factor (ton CO_2/ton)	4.3	1.8
cost (Euro/ton)	1000	750

A re-extrusion process for producing recycled plastics from sorted waste plastics has been defined. Input data for this process are based on the detailed analysis of plastics production (see *Greenhouse gas emissions and material flows. Part III*).

Glass

For modelling hollow glass production the data from the MATTER database have been used. Two processes have been modelled: hollow glass production from virgin raw materials and hollow glass production from recycled cullet, both in gasoil fired furnaces.

Steel

For steel production two production routes have been modelled: the basic oxygen furnace route and the electric arc furnace route. Data for these production routes were provided by Institut Wallon (based on an analysis of the Belgian steel production and on cost data of the MATTER database).[xxxiii, xxxiv]

Cardboard
Modelling the production of packaging cardboard has been based on the detailed analysis of paper and cardboard production (see *Greenhouse gas emissions and material flows. Part III*). Integrated and non-integrated cardboard production from wood pulping, and recovered paper pulping have been modelled. A fixed share of 30% integrated and 70 % non-integrated packaging board production has been assumed.
The use of recycled paper pulp has been excluded for board production for beverage cartons.

Aluminium
The use of aluminium is very limited for the considered beverage packaging options. Therefore aluminium production has not been modelled in detail. It has been represented by the same emission factor that is used in the PackBase model. A cost of 2500 Euro/ton has been used (average price for sheet aluminium in 1999-2000).

- ***Recycling***

Selective collection and sorting of packaging waste has been modelled as described in §3.4.1. Transport requirements have been calculated based on assumptions on the average distance from the collection point to a recycling centre.

The same future recycling rates as in the PackBase model were considered as the potential maximum rates for selective collection for 2015.[19] Minimum rates were fixed at 60% for each packaging type. The actual rates are the outcome of the optimisation.

After selective collection and sorting, steel cans, glass and cardboard can be used in the material production processes described above.[20] Although they will not always be recycled back to packaging materials, it is assumed recycling is not constrained by a limited demand for recycled material for the production of new products. Hence, recycling has been modelled in closed loops. This also means that all the recycling benefits are allocated to the packaging system (which is different from the allocation procedure in the PackBase model). (see also Annex 3)

Waste plastic bottles can be collected and sorted to unmixed plastic waste (as is the case actually in the FOST Plus collection scheme).[21] A re-extrusion process for unmixed plastic wastes has been modelled in a closed loop. A constraint has been put on the maximum use of recycled plastics in new plastic bottles (a maximum of 25% in 2015). For these recycled plastics the full recycling benefit goes to the beverage packaging system.
All plastics that can not be recycled in a closed loop, are "exported" from the system. For these "exported" sorted plastic waste the emission credit has been calculated according to the formula in Annex 2. (see also Annex 3)

An alternative to this scheme has been included in the model: waste plastic packaging is collected and sorted to mixed plastic waste. This mixed plastic waste can be incinerated

[19] All changes in model take place gradually. Maximum or minimum values evolve linearly between the values of 2000 and 2015.
[20] Waste glass from discarded reuse glass bottles goes back directly to the recycling process.
[21] Discarded reuse PET bottles and HDPE crates go back directly to the recycling process.

with recovery of energy or can be used in a feedstock recycling process. As a typical example of a feedstock recycling process the BASF pyrolysis process has been used (see *Greenhouse gas emissions and material flows. Part III*).

For recycling of beverage cartons it is assumed that all of them are repulped. It is not always clear what happens to the aluminium and polyethylene. According to FOST Plus, actually three possibilities exist: landfilling (but this practice disappears), energetic valorisation at the pulping site or in cement ovens or, finally, material recycling (mainly in the larger pulping plants). In the model they are treated in a similar way as the rest fraction of the domestic solid waste, which includes a gradual phase out of landfilling and energetic recovery of 20% of the energetic value of the polyethylene (see next paragraph).
For the costs of repulping beverage cartons the difference in sales price, reported in the FOST Plus annual reports, between waste beverage cartons and waste paper and cardboard was added to the costs for repulping waste paper.

- ***Incineration and landfilling***

For landfilling, the same evolution as in the PackBase model has been used. However, in this case a gradual increase of the energy recovery efficiency from 10 to 20% by 2010 is assumed.
Costs have been fixed at 87 Euro/ton for incineration[xxxvi] and at 105 Euro/ton for landfilling. An average transport distance of 45 km from the point of collection has been used.

Energy

The energy supply system has not been modelled in detail. For electricity production a changing emission factor and cost have been used. They are representative for electricity from the grid produced by centralised power plants in Belgium under base case assumptions on economic growth and evolution of international prices of gas, coal and oil.[xxxv]

Table 31: Average greenhouse gas emission factor and cost for electricity production

	2000	2015
emission factor (kg CO_2/GJe)	0.083	0.052
cost (Euro/GJe)	10.2	11.0

For steam production a gas boiler with an efficiency of 92% has been modelled.

4.2 PackBase results

4.2.1 Greenhouse gas emissions for beverage packaging options

Based on the above-mentioned data greenhouse gas emissions were calculated for packing 1 litre of beverage in different types of packaging in 2000 and 2015. The results are shown in Figure 5 and Figure 6. The results for 2015 include reduction in packaging weight and increased recycling (*M+RW+RP*). The total value has been split up in a part related to materials use (production and waste treatment of the materials), a part related to making and filling the packaging (and cleaning in the case of reuse bottles) and a part related to transport. As mentioned previously the part related to transport only includes the additional kilometres caused by the choice of a specific packaging option.

These results were used further to calculate the greenhouse gas emission reduction related to the entire packaging system and the potential greenhouse gas emission reduction (§ 4.2.2). They should not be interpreted as absolute values, but rather as rough indications. However, some clear conclusions can be drawn from them.

In most cases reuse packaging perform better than one way packaging. This is clearly the case if we compare reuse glass to one way glass or reuse PET to one way PET. Differences in energy use and related greenhouse gas emissions caused by cleaning or transport are small compared to the differences related to the materials use. The only one way packaging type that can compete with the reuse packaging for greenhouse gas emission reduction is the beverage carton.

Hence, with the exception of the beverage carton the difference is made by the choice between reuse or one way. The reuse PET bottle performs better than the reuse glass bottle.

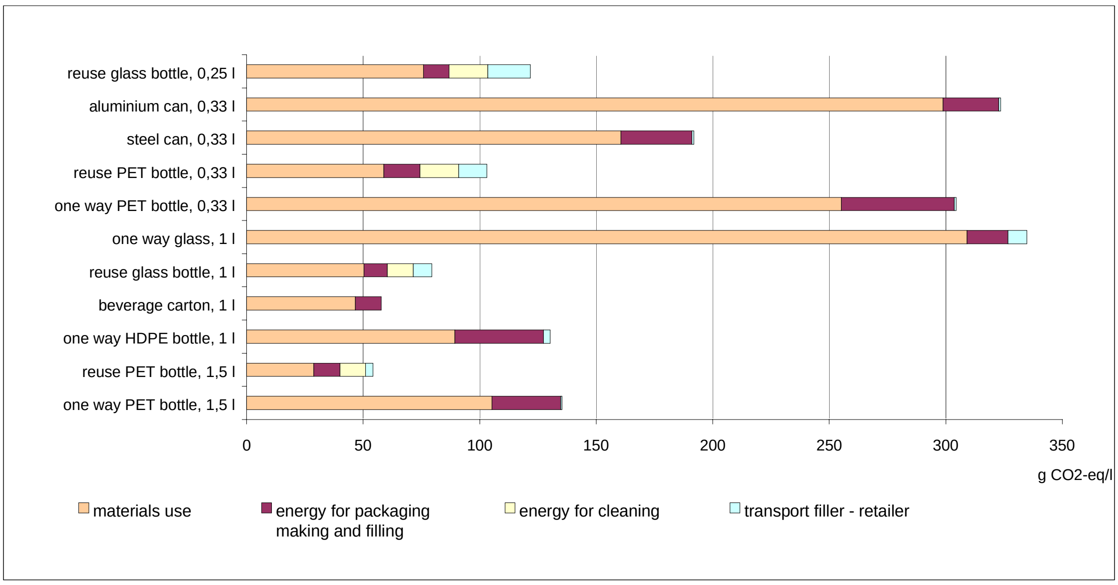


Figure 5: Greenhouse gas emissions for packaging 1 litre of beverage for different types of beverage packaging in 2000

The difference between the packaging is mainly caused by the materials use (including waste treatment), which largely outweighs differences in greenhouse gas emissions during the use phase of the packaging (making, filling, cleaning, transport).

Comparison of the results for 2000 and 2015 shows that material related greenhouse gas emissions can be reduced significantly through decreases in packaging weight and increased recycling.

It has to be stressed that these results are intended to be used further in macro-scenarios on greenhouse gas emissions related to the total use of beverage packaging in Belgium. They do not apply to each specific case. Moreover, they only apply to greenhouse gas emissions. Other environmental aspects have not explicitly been taken into account.

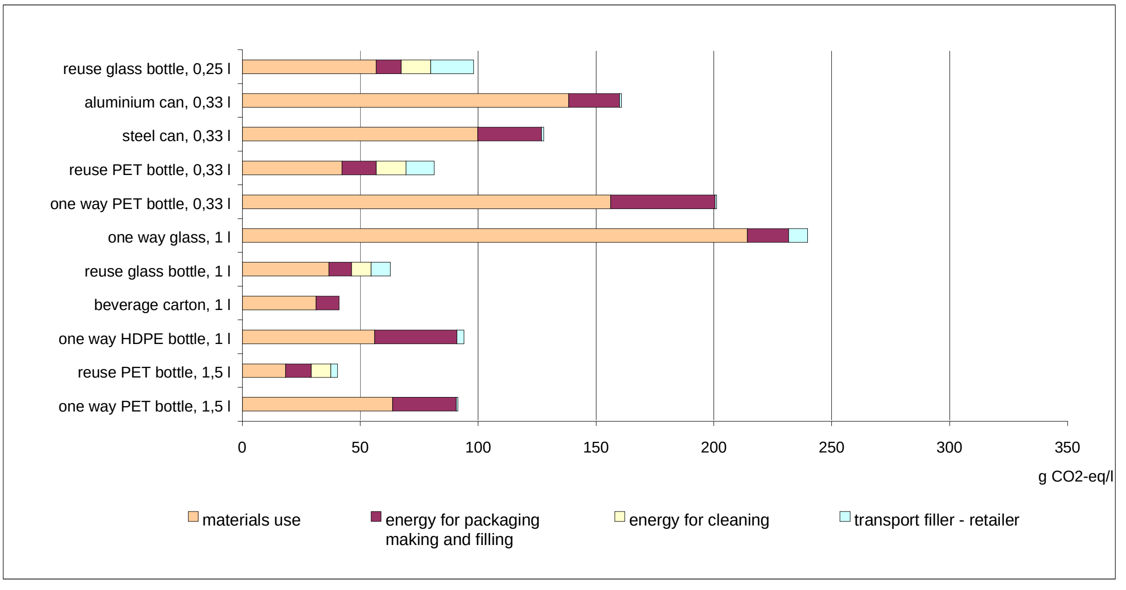


Figure 6: Greenhouse gas emissions for packaging 1 litre of beverage for different types of beverage packaging in 2015

4.2.2 Greenhouse gas emissions and possible reduction for the entire beverage packaging system

The actual amount of greenhouse gas emissions (over the entire life cycle) caused by the end use of all beverage packaging in Belgium was estimated at 581 kton CO_2-equivalents per year.

Table 32 shows the results of the calculations of the actual and future greenhouse gas emissions.[22]

[22] These results differ on some points from the preliminary results that were presented during a symposium organised by OSTC in March 2001 (Nemry F., Lopez P., Theunis J., Bréchet T. *Greenhouse gas emissions reduction and material flows*). Meanwhile recycling rates, emission factors for electricity production and for production of some materials, and energy data for packaging production have been adapted to new findings.

The actual amount of greenhouse gas emissions (over the entire life cycle) caused by the end use of all beverage packaging in Belgium was estimated at 581 kton CO_2-equivalents[23] per year.

Table 32: Greenhouse gas emissions of combined end use scenarios and materials production and waste treatment scenarios

kton CO_2 eq	2000	2015					
		BAU	FR	NIR	RU1	RU2	RU3
FEF	581	672	643	587	511	444	393
M		624	585	539	471	406	359
M+RW		513	492	449	396	347	310
M+RW+RP		478	463	418	370	326	293

When the choice of packaging, the weight per packaging and the rate of recycling remain unchanged (*FR-FEF*), emissions will rise to 643 kton in 2015 as a result of the increase in beverage demand. In the *BAU-FEF* scenario they will rise to 672 kton. Through decreases in packaging weight (*BAU-M*) this amount can be reduced by 48 kton. Increased recycling can lead to an additional reduction of 146 kton.

Figure 7 shows the greenhouse gas emission reduction that is realised in 2015 in the different scenarios compared to *BAU-FEF* scenario.

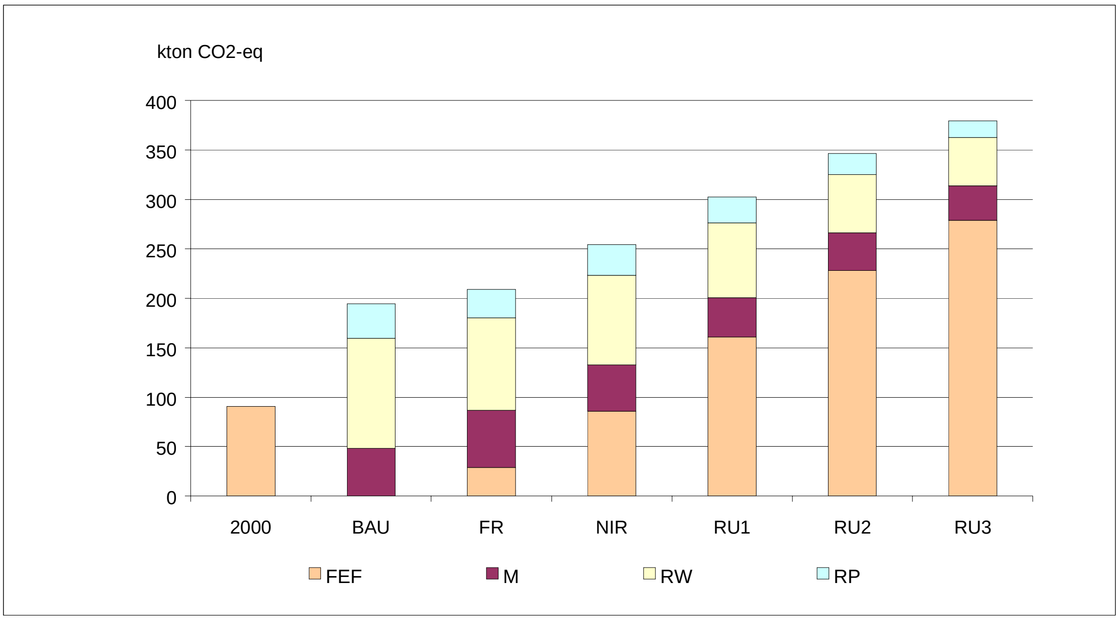


Figure 7: Greenhouse gas emission reduction of combined end use scenarios and materials production and waste treatment scenarios

[23] When giving greenhouse gas emission figures further in the text, *kton CO_2-equivalent* will be shortened to *kton*.

Without increased use of reuse packaging the reduction potential in 2015 can rise to 133 kton as a result of changes in the choice of packaging (*NIR-M*) and to 254 kton if an increase in recycling rate[24] is also considered (*NIR-M+RW+RP*).
With increases in reuse the reduction potential in 2015 can increase to 346 kton in a moderate scenario (*RU2- M+RW+RP*), and 379 kton in a more ambitious scenario (*RU3-M+RW+RP*). The latter means a decrease of 56 % compared to the *BAU-FEF* scenario.

Comparison of the results of the scenarios with changed packaging use with the *BAU-M+RW+RC* scenario gives an idea of the additional reduction that can be expected from changes in packaging use as compared to a scenario in which only changes in packaging weight and recycling rates occur. This additional reduction increases from 60 kton for the *NIR* scenario to 185 kton in the most drastic scenario. (If the recycling rate stays at the actual level, the difference between the *BAU* scenario and the most drastic scenario is even more pronounced: 265 kton.)

Clearly, the benefits of increased recycling are less in a scenario with reuse than in a scenario without reuse. But even with increased recycling benefits, the reduction potential in the *BAU* scenario is only as high as what can be obtained from moderate changes in packaging use without any increase in recycling efforts (*RU1-M*).

Hence, increased recycling leads to additional emission reduction, but it can not attain the same reduction as what can be obtained with changes in the choice of packaging (mainly reuse). Even when materials weight per unit of packaging is reduced and high recycling targets are obtained, changes in the choice of packaging can still lead to an additional emission reduction of 150 to 185 kton.
Changes in packaging choice without increases in recycling lead to higher greenhouse gas emission reductions than the *BAU* or the *FEU* scenario with increases in recycling.

Table 33 summarises the reductions that can be realised compared to the 2000 emission level. Three strategies are compared: *packaging weight reduction* (M), *increased recycling* (M+RW+RP) and *changing end use* (RU2). Clearly, the three strategies interact. With reductions in packaging weight only emissions will still increase. When adding an *increased recycling* strategy (without changes in end use) emissions can be reduced by 20 %. When adding a *changing end use* strategy (without changes in recycling), emissions can be reduced by 30%. Finally, combining all three strategies, emissions can be reduced by 44 %.

Table 33 Potential emission reduction of different strategies compared to the 2000 emission level

	BAU	changes in end use (RU2)
no changes in packaging production and waste treatment (FEF)	+16%	-24%
packaging weight reduction (M)	+7%	-30%
increased recycling (M+RW+RP)	-18%	-44%

[24] both an increase in the use of recycled material in the production of packaging, as an increase in the recycling rate of used packaging

4.2.3 Sensitivity

The impact of some crucial parameters on the final results was tested.

- When using an emission factor for plastics that is half way between the values proposed by APME and by Patel *et al* (see *Greenhouse gas emissions and material flows. Part III*) total emissions decrease by 60 kton (-10%). The emission reduction potential decreases by 25 kton.
- If all electricity is assumed to be produced from gas (marginal electricity production, average greenhouse gas emission factor of 0.120 kg CO_2/GJe) total emissions increase by 47 kton (+8%), but the emission reduction potential is hardly affected.
- If the final recycling rates in 2015 are decreased by 5 %, the emission reduction potential decreases by 15 kton (-5%).
- Changing the average transport distance to 250 km has a negligible influence (+15 kton).

It seems that individual changes in some crucial parameters do not affect the results fundamentally.

4.3 PackMark results

4.3.1 Emissions

Table 34 shows the greenhouse gas emissions and the potential reduction for the different scenarios. Emissions for 2000 and for the 2015 BAU, OPT and MAX scenarios are the outcome of the model calculations. Emissions for RE-15 and RE-30 have been put as an external constraint on the model.

Emissions in 2000 are at 515 kton CO_2-equivalents. In the BAU scenario these emissions increase to 530 kton. This moderate increase is a combination of the increased packaging demand, the changing end use and changes recycling rates. Recycling rates increase for glass and cardboard, but not for plastics and steel (§ 4.3.3).

In the OPT scenario emissions are 89 kton higher than in the BAU scenario. The minimum emission level that can be achieved is 289 kton, a reduction of 241 kton compared to the BAU scenario and 329 kton compared to the OPT scenario.

Table 34: Greenhouse gas emissions and reduction in the different scenarios

kton CO_2 eq	2000	2015				
		BAU	OPT	RE-15	RE-30	RE-MAX
emissions	515	530	618	437	360	289
emission reduction						
compared to BAU			-89	93	170	241
compared to OPT			0	181	258	329

4.3.2 Changes in packaging use

Figure 8 shows the evolutions in beverage packaging use that take place in the BAU scenario. Note that these evolutions have been fixed exogenously. They are not the outcome of an optimisation.

In the OPT scenario (Figure 9) the decline in reuse packaging is more pronounced than what was put forward in the BAU scenario. Part of the reuse glass packaging is replaced by reuse PET. Reuse glass is only used for wine. The shift to one way PET packaging is also more pronounced. It replaces reuse glass and cans, and is also used for milk products and fruit juice packaging to the extent possible. HDPE bottles gradually replace beverage cartons for milk packaging.

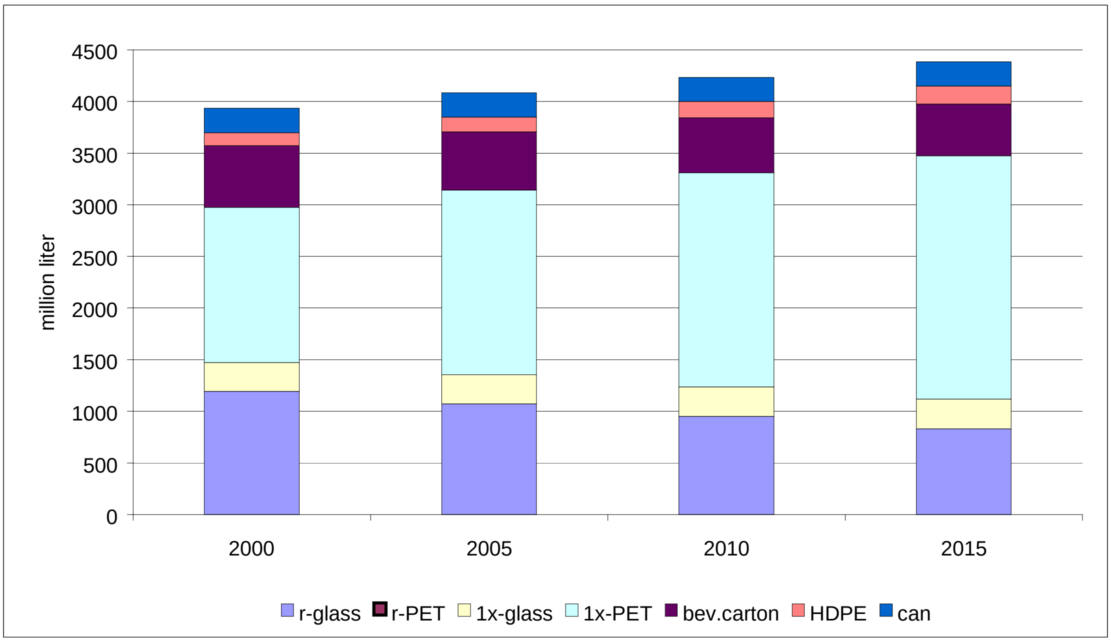


Figure 8: End use of beverage packaging – BAU scenario

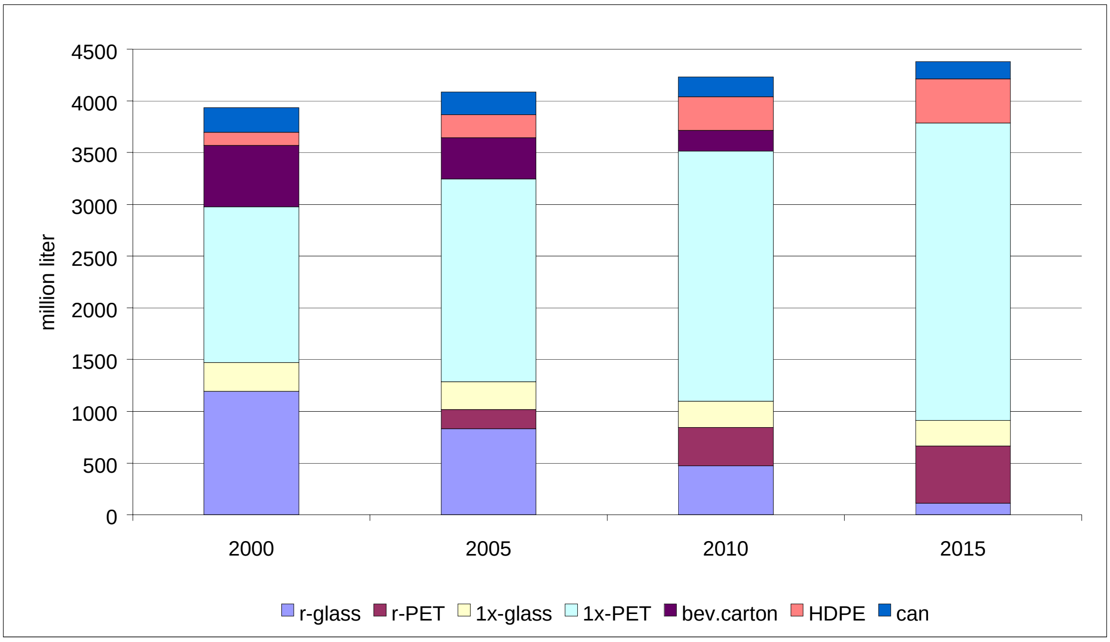


Figure 9: End use of beverage packaging – OPT scenario

When limiting greenhouse gas emissions in 2015 at 85% of the level in 2000, the use of reuse PET bottles will drastically increase (Figure 10). Again reuse glass disappears almost entirely. The use of one way PET also increases. It replaces HDPE for milk packaging to the extent possible.

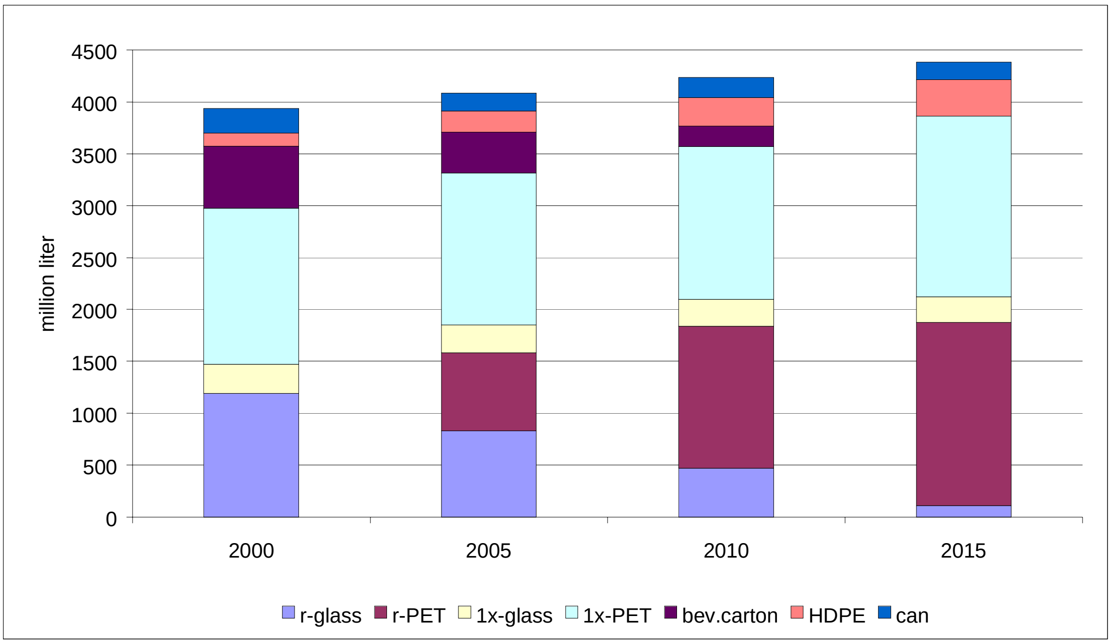


Figure 10: End use of beverage packaging – 15% reduction scenario

Figure 11 shows the evolution in case of a 30% reduction of the emission level in 2000. The use of reuse PET bottles increases further (further replacement of large one way PET bottles by reuse PET bottles; small reuse PET bottles replace cans and one way PET bottles for beer and soft drinks). Also in this case HDPE bottles replace beverage cartons, although emissions per litre packed are higher for HDPE bottles than for beverage cartons. Only in the maximal reduction scenario beverage cartons keep their market share (Figure 12). Cans also disappear in the more drastic reduction scenarios.

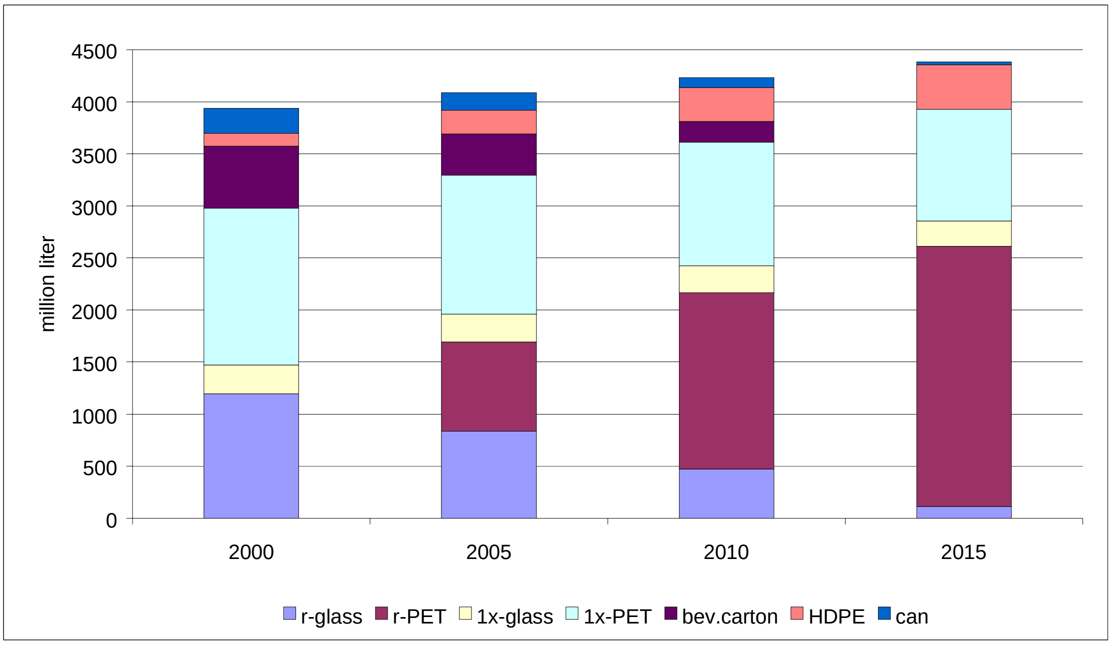


Figure 11: End use of beverage packaging – 30% reduction scenario

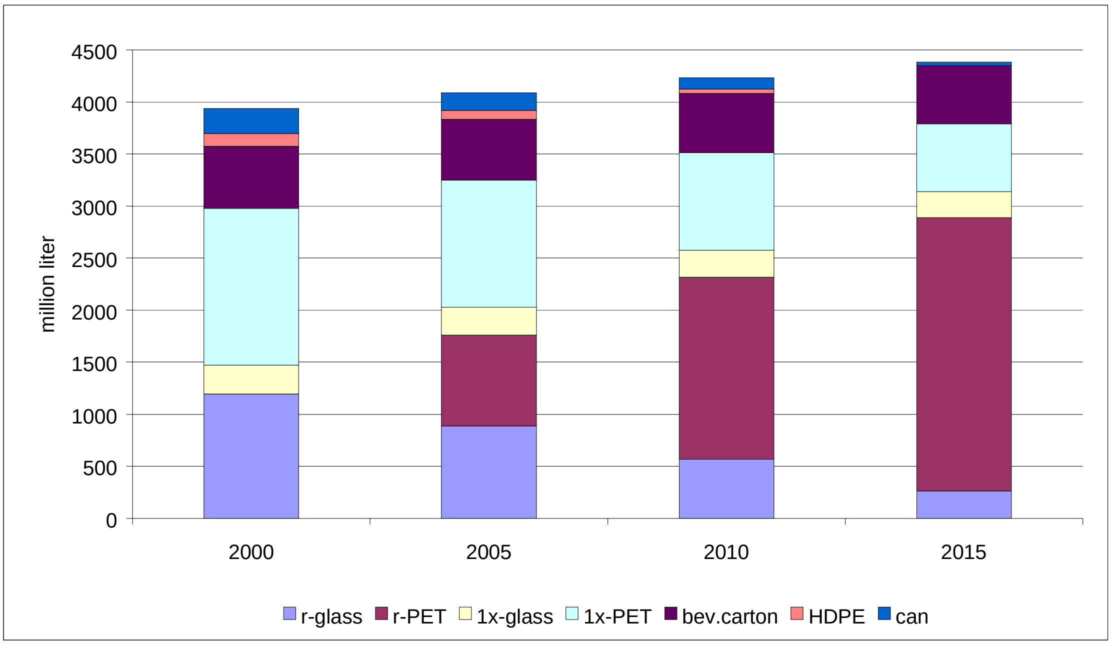


Figure 12: End use of beverage packaging – maximum reduction scenario

4.3.3 Evolutions of recycling rates

In the BAU and the OPT scenarios recycling rates only increase for cardboard packaging and for glass packaging. For plastic packaging and cans they remain at the lowest allowed level. This indicates that without additional emission constraints increased recycling of plastics and steel is not cost effective.

Both in the RE-15 and the RE-30 scenario recycling rates increase to the maximum level for all materials. The fact that already in the RE15 scenario the full potential of recycling for greenhouse gas emission reduction is exploited indicates that increased recycling is a cheaper strategy for reducing greenhouse gas emissions than increased reuse.

For plastics a feedstock recycling option had been defined, but in none of the scenarios this option is used. For the considered plastic waste streams mechanical recycling seems to offer better results for greenhouse gas emissions. This is in line with the conclusions from recent German studies (see *Greenhouse gas emissions and material flows. Part III*).

4.3.4 Costs of greenhouse gas emission reduction

Table 35 shows the average packaging cost for the different scenarios. This cost includes costs for treating the waste packaging. The average cost decreases between 2000 and 2015. Logically the decrease is more pronounced in the OPT scenario than in the BAU scenario.
However, also in case of a 15 or 30 % reduction in greenhouse gas emissions (compared to 2000) the packaging cost is lower than in the BAU scenario. This result and the result of the cost optimisation without emission limits (OPT scenario) suggest the BAU scenario is sub-optimal, both in cost terms and in terms of greenhouse gas emission reduction.
Therefore, we will further compare the costs and the reductions of the reduction scenarios with the OPT scenario. However, it should be kept in mind that this is a scenario in which packaging use has been optimised for least costs without greenhouse gas emission reduction. Most probably it gives a too drastic view:

- Costs are minimised for the system as a whole. Costs and benefits are not allocated to specific actors, although in reality they will be.
- Although upper limits have been put on the possible substitution of packaging options, in reality markets, technical requirements, consumer wishes, … will be much more diverse.

Table 35: Comparison of packaging costs for the different scenarios

EUR/litre	2000	2015				
		BAU	OPT	RE-15	RE-30	RE-MAX
packaging cost	0.134	0.110	0.091	0.096	0.104	0.119

Figure 13 shows both the average emission reduction cost and the packaging cost per litre when increasing greenhouse gas emission reductions are aimed for. Increases in packaging cost are in the order of 0.005 to 0.013 Euro/litre.
The cost for emission reduction increases from 130 Euro/ton CO_2 eq in the 15% reduction case to 228 Euro/ton in the 30% reduction case, and finally to 371 Euro/ton in the maximum emission reduction case.

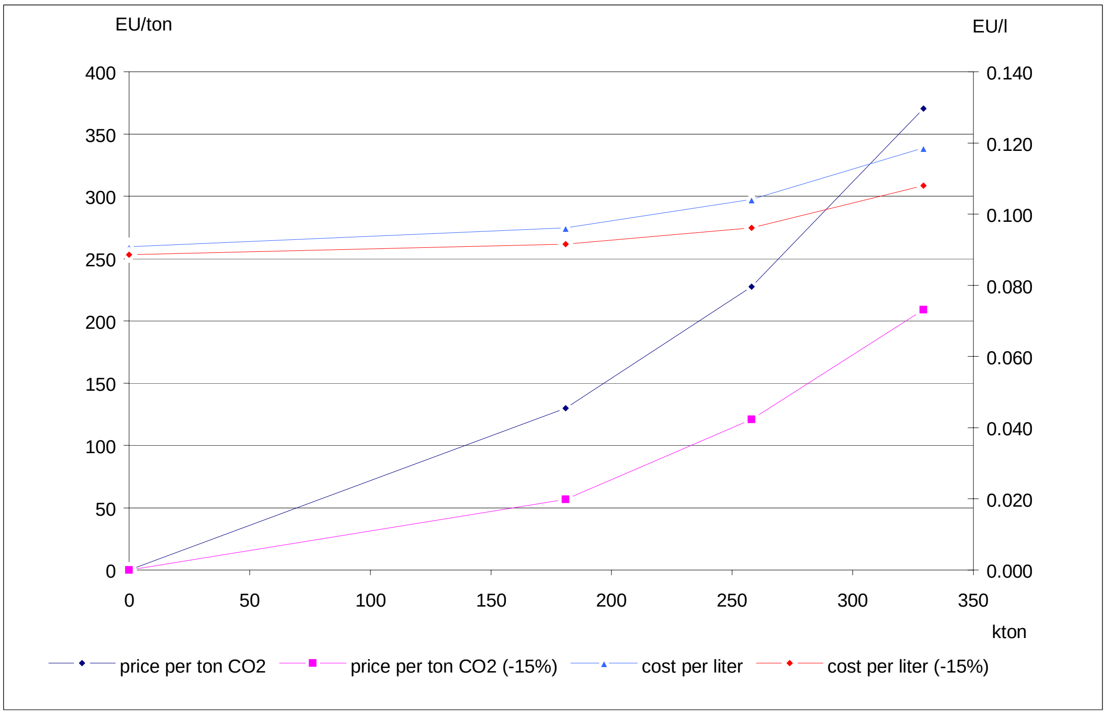


Figure 13: Cost of greenhouse gas emissions reduction (compared to OPT scenario)

To have an idea of the effect of the price differences between one way and reuse packaging, the specific costs of packaging making and handling for the reuse options was decreased by 15 %, while all the other costs remained unchanged. In that case the cost for emission reduction decreases to 57 Euro/ton CO_2 eq in the 15% reduction case, to 121 Euro/ton in the 30% reduction case, and to 209 Euro/ton in the maximum emission reduction case.

4.4 Conclusions

Two complementary approaches have been used to calculate the life cycle greenhouse gas emissions and the emission reduction potential related to the end use of beverage packaging in Belgium: a scenario approach and a (partial) optimisation approach, based on costs.

When comparing the results of both models some differences appear. Calculated emissions for 2000 are 66 kton lower for the PackMark model. This difference can partially be explained by differences in the choice of boundaries. They can also be explained by the way both models have been set up and by their level of detail.

In the PackMark-BAU scenario increased recycling takes place for cardboard and glass, but not for plastics and steel. Hence, there is no simple comparison between results of the PackMark-BAU scenario and the BAU-scenarios in the PackBase model.

Emissions in the most drastic scenario in the PackBase model are comparable to the emissions in the PackMark scenario with maximum emission reduction. The corresponding emission reduction potentials are 329 and 379 kton respectively. Hence, taking into account the different points of comparison, the reduction potentials calculated in both models are comparable.

Greenhouse gas emissions per packed litre of beverage are smaller for reuse packaging (reuse glass and reuse PET) than for most one way packaging options. Beverage cartons are the exception.
Greenhouse gas emissions related to materials use (including waste treatment) dominate greenhouse gas emissions during the use phase of the packaging (making, filling, cleaning, transport). They can be reduced significantly through decreases in packaging weight and increased recycling.

Based on the results of both exercises the **total greenhouse gas emissions** related to the end use of beverage packaging in Belgium can be estimated at 500 - 600 kton. In the absence of measures to reduce greenhouse gas emissions these emissions will increase by 50 to 100 kton.
Some changes that come into effect when packaging cost is minimised (OPT scenario), lead to reductions in greenhouse gas emissions (e.g. replacement of reuse glass by reuse PET, replacement of one way glass by reuse glass for wine). Reduced use of materials per packaging unit (reduced packaging weight) will also lead to lower greenhouse gas emissions. But, on the whole greenhouse gas emissions increase, because of the increase in beverage consumption and the gradual replacement of reuse packaging by one way PET bottles.

Material related greenhouse gas emissions can be reduced through decreases in packaging weight, increased recycling and increased reuse of packaging.
Calculations of the **emission reduction potential** show a maximum reduction potential of 300 to 350 kton. However, this implies drastic changes in the use of beverage packaging. More realistic estimates show a reduction potential of 250 to 300 kton.

Increased recycling is a cheaper option for greenhouse gas emission reduction than changes in packaging choice, but it has a limited potential. Changes in packaging choice (i.e. increased the use of reuse PET bottles) give significant additional benefits compared to increased recycling only (up to more than 150 kton).

Increasing the use of reuse bottles (mainly PET reuse) seems the most powerful strategy for reducing greenhouse gas emissions related to beverage packaging. However, the actual trend goes in the opposite direction. In the absence of greenhouse gas emission limits model results show an accelerated decline in reuse glass, that is only partially replaced by reuse

PET, and an increase in one way PET bottles. Only when imposing greenhouse gas emission limits, reuse PET becomes an attractive option.

The influence of some crucial parameters on the emissions and the emission reduction potential was tested. Although total emissions can change by 10%, the influence on the reduction potential is limited.

Compared to the actual situation and compared to the assumed BAU scenario there is quite some potential for greenhouse gas reduction without additional **cost**. The changes in recycling rate and packaging choice taking place in the 15% and 30% reduction scenarios lead to a reduction in packaging cost.

However, when comparing emissions and costs of reduction scenarios to a scenario in which packaging cost is minimised (without emission limits), the average **emission reduction cost** was estimated at 130 Euro/ton in case of a 15% emission reduction (compared to the 2000 level), and 228 Euro/ton in case of a 30% emission reduction.
This result is very sensible to the price difference between one way and reuse packaging options. If the specific costs for reuse are reduced by 15%, the emission reduction cost reduces by 45% to 55%. However, most probably, the average packaging cost will not fully reduce to the level of this minimised cost. Hence, these emission reduction costs should be interpreted as upper limits.[25]

The advantage of a recycling strategy depends on the constraints on both the use of recycled material in the new products and on the recycling of waste packaging because they will determine the demand and the supply of recycled material. The success of a recycling strategy in the packaging system can depend on the supply or the demand from other systems.

Comparison to Belgian greenhouse gas emissions

Life cycle greenhouse gas emissions related to the end use of beverage packaging in Belgium represent about 0,3 to 0,4% of the total Belgian greenhouse gas emissions. The calculated emission reduction potential corresponds to 1,1 to 1,4% of the total emission reduction effort that Belgium has to realise in the period 2000 – 2010 (approximately 22 Mton).

The comparison is however not fully correct because a significant part of the life cycle greenhouse gas emissions are related to imported materials or products, and will occur abroad. Hence, a significant part of the emission reduction potential will be realised abroad, and will not help Belgium in reaching its emission reduction targets. Similarly, Belgian

[25] The essential point of this analysis is the estimation of the reduction potential and the associated costs of changes in beverage packaging use. It does not allow to draw detailed conclusions on specific evolutions. Cost data are too general and too uncertain to allow detailed conclusions, e.g. on the shifts that are observed between HDPE and beverage cartons.

production of (packaging) materials for export will contribute to the life cycle greenhouse gas emissions related to the end use of beverage packaging abroad.

It is not clear which part of this emission reduction will be realised in Belgium. Taking into account the large imports of intermediates in material production, materials and packaging itself, and the export of waste materials (see *Greenhouse gas emissions and material flows. Part III*), the share of the "imported" emissions and "exported" emission credits will probably be at least 50 %.

5 CONCLUSIONS

Objectives and method

This study is a first attempt to quantify the effects of changes in beverage packaging use in Belgium on specific emissions (in this case greenhouse gas emissions), on a macro level and for a long time period, taking into account the possibilities and constraints for substitution of different packaging options for specific groups of beverages. Future technological evolutions are included in the analysis. This macro level quantification of the emission reduction potential gives relevant additional information for evaluating product policies as compared to the results of LCA studies.
The approach that has been developed for greenhouse gas emissions can also be used to quantify the effects on e.g. waste streams. It can also be used for other product groups.

To be able to take into account the cost factor, a MARKAL model was developed. MARKAL optimises the entire system based on cost minimisation, and provides a structured framework for evaluating costs, taking into account technical evolutions over a long time period. However, the system based on end use of beverage packaging is not a closed system: the same materials and energy carriers are used for other applications; waste materials are recycled to other kinds of products; waste energy is recovered and sometimes used for other applications. Moreover, foreign trade flows dominate the picture. In these circumstances, an optimisation of all production processes based on the end use of beverage packaging only does not make sense.

Therefore, the focus of the optimisation was on those parts of the packaging system that are really influenced by the choices in packaging: the choice of packaging type itself and the treatment of the waste packaging. For the treatment of the waste packaging the implicit assumption is that markets for recycled materials are not constrained.

Packaging flows

There is no direct statistical information on the quantities of packaging brought on the Belgian market. Estimating final use was only possible because the Interregional Co-operation Agreement compels producers and importers of packed products to declare the amounts they have put on the Belgian market.
If the environmental impacts of (changes in) consumption patterns (e.g. towards sustainable consumption) are to be assessed or evaluated quantitatively, systematically recording consumption figures of key product groups in physical terms (weights) seems a necessity.

More than 75 % of the household packaging (by weight) consists of food and beverages packaging. Food and beverage packaging accounts for more than 90 % of all glass and steel and 2/3 of all plastics used for packaging.
Beverage packaging represent more than 40 % of the total end use of household packaging in Belgium. This is mainly due to the fact that 67 % of all beverage packaging are glass bottles. Because their weight per unit of packed product is high, beverage packaging

represent a proportionally large fraction in the total packaging waste quantity. In terms of packed volumes food packaging is more important.

Major trends in beverage packaging: decline in reuse, increase of the use of PET, also for applications from which it was excluded until now because of technical constraints (beer, fruit juices, milk). Reuse PET bottles have been developed, but are not in use in Belgium.

Greenhouse gas emissions related to beverage packaging

Except for beverage cartons, greenhouse gas emissions per litre of beverage packed are smaller for reuse packaging (reuse glass and reuse PET) than for one way packaging.

Greenhouse gas emissions related to materials use (including waste treatment) dominate greenhouse gas emissions during the use phase of the packaging (making, filling, cleaning, transport). They can be reduced significantly through decreases in packaging weight and increased recycling.

Life cycle greenhouse gas emissions related to the end use of beverage packaging in Belgium are small compared to the total Belgian greenhouse gas emissions: 500-600 kton CO_2-eq in 2000. In the absence of measures to reduce greenhouse gas emissions they will increase by 50 to 100 kton.

Decreases in packaging weight, increased recycling and changes in packaging choice (mainly shifts to reuse PET) lead to potential reductions in life cycle greenhouse gas emissions ranging from 250 to 300 kton CO_2-eq in 2015. Increased reuse gives significant additional benefits compared to increased recycling only.

The costs of these emission reductions have been calculated at 150 to 200 Euro/ton. However, cost data are quite uncertain. A decrease of 15% in specific packaging costs for reuse packaging reduces the emission reduction costs to 60 to 120 Euro/ton. In both cases costs were compared to a scenario in which packaging cost is fully minimised. Hence, they should be interpreted as an upper limit.

Compared to the total greenhouse gas emissions reduction effort needed to comply with the Kyoto protocol, the emission reduction potential from the Belgian end use of beverage packaging is small (1,1 to 1,4% of the total emission reduction effort). Moreover, a significant part of the life cycle emission reduction will be realised abroad. Calculating this share was not possible in the framework of this project. However, it can be estimated at at least 50 % of the total emission reduction potential.

The potential for greenhouse gas emission reduction based on changes in consumption patterns will depend on the possibility to develop broad strategies that cover a large fraction of the Belgian consumption. Therefore, conclusions on beverage packaging should be compared to other product groups.

On the other hand, this analysis has only quantified the greenhouse gas emission reduction potential. In the case of packaging strategies aiming at reducing greenhouse gas emissions seem to be the same as strategies aiming at reducing waste production. Hence, calculations of reduction potential should be broadened to other environmental impacts. Synergetic effects on other environmental impacts should also be taken into account when interpreting reduction costs.

Annex 1: Shares of packaging options in the different end use scenarios

Table 36: FR scenario: share of packaging options per beverage group

	Carbonated water/ soft drinks		Non-carbon. water	Fruit juices and nectars	Milk and milk drinks		Wine/ spirits	Beer
	large	small	large	large	large	small	large	small
One way glass bottle				7			95	4
reuse glass bottle	25	30	25	4	15	15	5	83
One way PET bottle	75	10	75					
reuse PET bottle								
HDPE bottle					20	20		
beverage carton				88	65	65		
Can		60		1				13

Table 37: BAU scenario: share of packaging options per beverage group

	Carbonated water/ soft drinks		Non-carbon. water	Fruit juices and nectars	Milk and milk drinks		Wine/ spirits	Beer
	large	small	large	large	large	small	large	small
one way glass bottle				5			95	
reuse glass bottle	15	20	15		5	5	5	75
one way PET bottle	85	30	85	20				15
reuse PET bottle								
HDPE bottle					35	35		
beverage carton				75	60	60		
Can		50						10

Table 38: NIR scenario: share of packaging options per beverage group

	Carbonated water/ soft drinks		Non-carbon. water	Fruit juices and nectars	Milk and milk drinks		Wine/ spirits	Beer
	large	small	large	large	large	small	Large	small
one way glass bottle							85	
Reuse glass bottle					5	5	5	83
one way PET bottle	75	5	75	4	5	5		4
Reuse PET bottle	25	30	25					
HDPE bottle					5	5		
beverage carton				96	85	85	10	
Can		65						13

Table 39: RU1 scenario: share of packaging options per beverage group

	Carbonated water/ soft drinks		Non-carbon. water	Fruit juices and nectars	Milk and milk drinks		Wine/ spirits	Beer
	large	small	large	large	large	small	Large	small
one way glass bottle							72	
reuse glass bottle							18	60
one way PET bottle	50	5	50				4	10
reuse PET bottle	50	60	50	25	15	15	2	25
HDPE bottle					10	10		
beverage carton				75	75	75	4	
Can		35						5

Table 40: RU2 scenario: share of packaging options per beverage group

	Carbonated water/ soft drinks		Non-carbon. water	Fruit juices and nectars	Milk and milk drinks		Wine/ spirits	Beer
	large	small	large	large	large	small	Large	small
one way glass bottle							68	
reuse glass bottle							17	15
one way PET bottle	25	5	25				6	15
reuse PET bottle	75	75	75	50	15	15	3	70
HDPE bottle								
beverage carton				50	85	85	6	
Can		20						

Table 41: RU3 scenario: share of packaging options per beverage group

	Carbonated water/ soft drinks		Non-carbon. water	Fruit juices and nectars	Milk and milk drinks		Wine/ spirits	Beer
	large	small	large	large	large	small	Large	small
one way glass bottle							56	
reuse glass bottle							24	10
one way PET bottle	10	5	10				7	10
reuse PET bottle	90	80	90	90	15	15	6	80
HDPE bottle								
beverage carton				10	85	85	7	
Can		15						

Table 42: OPT, RE-15, RE-30 and RE-MAX scenarios: maximum share of packaging options per beverage group

	Carbonated water/ soft drinks		Non-carbon. water	Fruit juices and nectars	Milk and milk drinks		Wine/ spirits	Beer
	large	small	large	large	large	small	large	small
one way glass bottle	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	100	n.a.
reuse glass bottle	75	85	75	75	15	15	15	85
one way PET bottle	85	85	85	50	15	15	n.a.	85
reuse PET bottle	75	85	75	50	15	15	n.a.	70
HDPE bottle	n.a.	n.a.	n.a.	n.a.	85	85	n.a.	n.a.
beverage carton	n.a.	n.a.	n.a.	85	85	85	n.a.	n.a.
Can	n.a.	75	n.a.	n.a.	n.a.	n.a.	n.a.	50
Max. reuse	75	85	75	75	15	15	15	85

Table 43: OPT, RE-15, RE-30 and RE-MAX scenarios: minimum share of packaging options per beverage group

	Carbonated water/ soft drinks		Non-carbon. water	Fruit juices and nectars	Milk and milk drinks		Wine/ spirits	Beer
	large	small	large	large	large	small	large	small
one way glass bottle	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0	n.a.
reuse glass bottle	0	0	0	0	0	0	0	15
one way PET bottle	25	7.5	25	0	0	0	n.a.	0
reuse PET bottle	0	0	0	0	0	0	n.a.	0
HDPE bottle	n.a.	n.a.	n.a.	n.a.	0	0	n.a.	n.a.
beverage carton	n.a.	n.a.	n.a.	0	0	0	n.a.	n.a.
Can	n.a.	7.5	n.a.	n.a.	n.a.	n.a.	n.a.	0

Annex 2: Allocation in case of recycling or in case of energy recovery

Recycling can lead to reduced emissions compared to a system in which recycling is not considered. The emission credit for recycling is the difference between the emissions resulting from production of virgin material and the emissions resulting from the recycling process.

An allocation problem arises if, as a result of recycling, an amount of material passes from one product system to another (e.g. PET bottles recycled to PET fibre), and we want to know the emissions related to a specific product system. Does the emission credit have to be allocated to the recycled product or to the product made out of the recycled material?
A similar problem arises with waste incineration with energy recovery.

To avoid allocation problems, the ISO guidelines for LCA put system expansion as the first option. E.g. when the incineration of plastic packaging waste leads to the production of an amount of electricity, this will be compared to the production of electricity in a reference system. The consequence is that any figure given for the emissions for a given packaging option will include emissions (or emission credits) related to other products. Hence, the absolute value of the greenhouse gas emission (or other impact) figures becomes less relevant. It is the difference between different options that counts.

For our purpose, we are interested in relative values, for comparing different options and for assessing the improvement potential related to improvement options, but also in absolute values for calculating the absolute emission level related to beverage packaging. This means that avoiding allocation is not always an option.

Two cases have to be distinguished: recycling of used products and use of recycled material for new products.

1. Both emission credits from use of recycled material for making a product, and emission credits from recycling that same used product, can be allocated fully to the product system under consideration. The benefits for the whole system are fully allocated to the packaging system. However, the result of such an approach has to be interpreted carefully.
   Suppose emission credits for recycling of PET bottles to PET fibre for textiles are fully allocated to the PET bottle. If the same approach were taken for PET fibre, adding the results for both product systems would lead to double counting. The overall gain for the two product systems would be overestimated.

2. To avoid this risk of double-counting different options are possible.

a. Allocating the emission credit to the new product:
   If the emission reduction caused by an increased use of recycled material is fully allocated to the new product, it is only logic not to credit the same product for the fact that it is recycled after use. This benefit would also go to the new product.
   However, in that case increasing the recycling of used products would not lead to a reduction of the emissions allocated to the considered product system. Part of the

reduction potential that can be realised through changes in the considered product system would be missed.

b. Allocating the full emission credit to the used product:
   In that case increasing the use of recycled material in new products would not reduce the emissions of the product system under consideration. Again part of the improvement potential of the considered product system would be missed.

Only in case of closed-loop recycling it does not make any difference if you allocate the emission credit fully to the old or to the new product, because they are part of the same product system.

None of both solutions is satisfying. For this project the following pragmatic approach has been adopted for calculating the emissions from packaging in the PackBase model:
Half of the emission credits for recycling of used products and half of the emission credits for use of recycled material are allocated to the considered product system. The other half is allocated to the product systems providing the waste material for producing the recycled material and to the product system using the waste product.

This leads to the following formulas for emission factors:

emission factor for materials partially made out of recycled materials:

$$EF_M = EF_N - \%R * (EF_N - EF_R) * 0.5$$

EF_N = emission factor for production of virgin materials
EF_R = emission factor for production of recycled materials to be used for the production of product1
%R = percentage use of recycled material

emission factor (credit) for recycling of waste products:

$$EF_A = -(EF_N - EF_S) * 0.5$$

EF_S = emission factor for production of recycled materials for the production of product2

emission factor for products taking into account benefits of recycling:

$$EF_{P1} = EF_M + EF_A * \%S$$
$$= EF_N - (EF_N - EF_R) * \%R * 0.5 - (EF_N - EF_S) * \%S$$

%S = percentage of waste products recycled

In case of closed loop recycling %R = %S and $EF_R = EF_S$, and the formula reduces to:

$$EF_P = (1 - \%R) * EF_N + EF_R$$

In practice, however, recycling is sometimes highly integrated in the normal material production process (e.g. use of recycled paper, use of scrap metals), and it is not always obvious to find values for EF_N and EF_R or EF_S.

In case of energy recovery from the incineration of waste materials, this approach can lead to inconsistencies. E.g. because of the low energy recovery efficiency of incineration of waste plastics in municipal solid waste, the emission factor for electricity production increases, if the CO_2 emissions from incineration of plastics would be allocated to the electricity production as described above. Therefore, both emissions of waste incineration and the emission credit for the production of electricity have been allocated fully to the packaging.

Annex 3: Modelling recycling

The advantage of a recycling strategy depends on the constraints on both the use of recycled material in the new products and the recycling of waste products. They will determine the demand for and the supply of recycled material. (In the PackBase model we have considered both independent of each other.)

Different cases can be considered:

- The use of recycled material in new products (as well packaging as non-packaging) is constrained by technical limits. In other words demand for recycled material is limited. In this case increasing the potential recycling of waste packaging will yield environmental benefits as long as the demand is not satisfied. If the demand, at the given technical limits, is satisfied, further benefits can only be realised if the technical limits for use of recycled material are lifted first.

- Recycling of waste products is constrained (e.g. maximum on selective collection of waste). In other words, supply of recycled material is limited. In this case increasing the potential use of recycled material in new products will yield environmental benefits as long as the demand is lower than the supply. If, at a given rate of recycling of waste products, demand equals supply, lifting the constraints on increasing this rate is a prerequisite for obtaining further benefits from an increase in the technical limits for use of recycled material in new products.

Hence, the success of a recycling strategy in the packaging system can depend on the supply by or the demand from other systems, and by the technical constraints on recycling in these other systems.

If there are no technical constraints (in other words potential demand is not constrained), and the constraint for increased recycling depends on the potential recycling rate for used packaging only, recycling can be modelled as closed-loop recycling. In case of glass, steel and cardboard production, this seems to be the case.

In case of plastics recycling, technical constraints on increasing the use of recycled material in new products exist. In this case, ideally limits would have to be fixed both for packaging products and non-packaging products. The sum of both will give the maximum potential demand for recycled product (or the maximum potential supply). In that case residual demand for non-packaging products has to be included in the form of a demand for the material concerned. As a consequence the total greenhouse gas emissions calculated by the PackMark model would not have any meaning because the emissions related to this residual demand will also be included.
Therefore, an intermediate solution was implemented. A constraint has been put on the maximum use of recycled plastics in new plastic bottles. For these recycled plastics the full recycling benefit goes to the beverage packaging system.
All plastics that can not be recycled in a closed loop, are "exported" from the system. For these "exported" sorted plastic waste the emission credit has been calculated according to the formula in Annex 2.

REFERENCES

[i] DG ENV (1999) *Discussion paper on the revision of the packaging and packaging waste directive 94/62/EC. 1/12/1999.*

[ii] Borgo E., Claeys S., Martens B., Niemegeers J. (2000) *Retour of wegwerp? Wetgeving, beleid en milieuaspecten van drankverpakkingen*, Bond Beter Leefmilieu Vlaanderen, Brussel.

[iii] *Samenwerkingsakkoord betreffende de preventie en het beheer van verpakkingsafval*, Belgisch Staatsblad 05/03/1997.

[iv] Interregionale Verpakkingscommissie. *Handleiding bij het aangifte formulier 1998, Bijlage 1.*

[v] FOST Plus (1999) *Jaarverslag 1998*, FOST Plus, Brussel

[vi] I.V.C., *Jaarboek 98*, Brussel, 1999.

[vii] VAL-I-PAC (2000) *Valorisatie en recyclage. Resultaten VAL-I-PAC 1999.*

[viii] Les emballages de boissons et leur déchets : radiographie de la situation en Belgique, Coopers & Lybrand, 1995.

[ix] Tetra Pak, Info market data Belgium, 1999. Data source : Canadean.

[x] Bréchet T. (2000) *Réduction des émissions de gaz à effet de serre et flux de matières.* Rapport final aux Services Fédéraux des Affaires Scientifiques, Techniques et Culturelles (SSTC), Institut pour un Développement Durable, 2000.

[xi] Gunning P., (PET packaging growth in new markets), In : Verpack.Berat, Vol. 43, n° 6, 1999

[xii] Golding A. (1999) *Reuse of primary packaging. Final report. Part I – Main report*, Abfallberatung, Müllvermeidung & Recycling, Tübingen

Golding A. (1999) *Reuse of primary packaging. Final report. Part II - Country reports*, Abfallberatung, Müllvermeidung & Recycling, Tübingen

[xiii] Pack News, several issues 1998 - 2000.

[xiv] Van Looy E. (1994) *Databank PRO. Niet-alcoholische en alcoholische dranken*, PRO v.z.w., Brussel.

[xv] Hekkert M.P., Joosten L.A.J., Worell E. (1997), *Packaging tomorrow. Modelling the material input for European packaging in the 21st century*, Utrecht University, Utrecht.

[xvi] FOST Plus (1997) *Zo weinig mogelijk, zo veel als noodzakelijk. recente initiatieven op het gebied van preventie van verpakkingen en verpakkingsafval*, FOST Plus, Brussel.

[xvii] Equivalence entre emballages boissons reremplissables et valorisables en Belgique. Etude réalisée par Ecobilan sur la base d'une étude de marché de Coopers & Lybrand pour la société FOST Plus, Ecobilan, 1995.

[xviii] Ceuterick D., Huybrechts D. (1994) *Vergelijkende levenscyclusanalyse van verpakkingsalternatieven voor wijn*. Vito, Mol.

[xix] Pack News, Maart 2001.

[xx] PETCORE (2000) *Collecting and sorting plastic bottles. A comprehensive guide. 2000 Edition Update*, PETCORE, Amsterdam.

[xxi] Multon J-L., Bureau G. (1998), *L'emballage des denbrées alimentaires de grande consommation*, Lavoisier Technique & Documentation, Paris.

[xxii] www.ace.be

[xxiii] www.aluminium.org

[xxiv] Habersatter K. *et al* (1996), *Ökoinventare für Verpackungen Band II*, Bundesamt für Umwelt, Wald und Landschaft (BUWAL), Bern.

[xxv] Danish Environmental Protection Agency (1998) *Lifecycle assessment of packaging systems for beer and soft drinks. Technical reports 1, 2, 3, 4, 5 and 6*, Danish Environmental Protection Agency, Ministry of Environment and Energy, Danmark.

[xxvi] Früwirth W., Hutterer H., Pilz H., Stoiber H. (2000) *Volkswirtschaftlicher Vergleich von Einweg- und Mehrwegsystemen für ausgewählte Getränke- und Gebindeartne einschliesslich der Beurteilung der Erfassungs- und Recyclingraten. Analyse von Veränderungen des Getränkemarktes und Schlussfolgerungen für die Getränkequoten der Zielverordnung*, GUA/IFIP, Wien.

[xxvii] RDC/Coopers & Lybrand (1997) *Eco-balances for policy-making in the domain of packaging and packaging waste*. *Final report*, RDC/Coopers & Lybrand, Brussels.

[xxviii] Plincke E. *et al* (2000), *Ökobilanz für Getränkeverpackungen II*, Umweltbundesamt, Berlin.

[xxix] FOST Plus (2000) *Jaarverslag1999*, FOST Plus , Brussel.

[xxx] FOST Post, juni 2000

[xxxi] Packaging 2000, Nr. 4/1999

[xxxii] Boustead, I. (1999), *Ecoprofiles of plastics and related intermediates*, APME, Brussels.

[xxxiii] Nemry F., Lopez P. (2001) *Reduction of greenhouse gas emissions and material flows, Housing system analysis –Part I - Detailed description of the system and evaluation of the potential of emissions reduction,* Institut Wallon, Namur.
[xxxiv] Nemry F., Lopez P. (2001) *Reduction of greenhouse gas emissions and material flows, Housing system analysis – Part II - Description of processes,* Institut Wallon, Namur.
[xxxv] Vito (2000) *Lange termijn scenarios, voor Electrabel-SPE*, Vito, Mol.
[xxxvi] Vrancken K., Torfs R., Van der Linden A., Vercaemst P., Geuzens P. (2001) *Vergelijking van verwerkingsscenario's van HHA en niet-specifiek categorie II bedrijfsafval,* Vito, Mol.