

Waste Prevention

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Life Cycle Assessment on alimentation packaging systems for waste prevention



Àrea Metropolitana
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SUMMARY VERSION

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INTRODUCTION

Nowadays, society is responsible for an excessive waste production. In particular, packaging represents one of the current challenges in the prevention of municipal solid waste (MSW). Most part of the acquired products are packaged and in a short time become waste. The environmental, economic and social consequences of excessive packaging waste make the prevention essential. As a responds to the need for the reduction of MSW, this research addressed the packaging containers associated with home consumption.

Over their life-time, packaging containers can contribute to various environmental impacts such depletion of abiotic resources, global warming, eutrophication, ecosystem toxicity, and many others. Generally, reducing the amount of waste generated at source and reducing the hazardous content of that waste (waste prevention), will lead to the most resource efficient and environmentally save choice. However, care needs to be taken to avoid shifting problems from one stage to another. Reducing the environmental impact of a product at the production stage may lead to a greater environmental impact further down the line. Therefore, for this research, the waste prevention of packaging containers will be analysed from a life cycle perspective, by means of Life Cycle Assessment (LCA). LCA is a methodology that assesses the environmental impacts of a product or activity over its entire life cycle. LCA quantifies a range of impacts by assessing the emissions, resources consumed and pressures on health and the environment that can be attributed to a product. It takes the different life cycles stages into account, like, the extraction of natural resources, the material processing, the product manufacturing, distribution and use, but also the re-use, recycling, energy recovery and the disposal of remaining waste. This LCA provides quality data on packaging containers, based on specific local conditions. The goal is to assist decision-makers, like the AMB, in their waste prevention choices and to ensure that the best outcome for the environment can be identified and put into place, hereby reducing the overall environmental impacts.

Objective

The purpose of this research was to use LCA methodology to quantify and evaluate the environmental impacts related to different packaging systems alternatives. Different products and solutions were assessed, using average data of different packaging solutions in the Catalan market. This study aimed to identify, analyse, and quantify the environmental impacts of the product packaging containers with an elevated contribution level to the MSW of the AMB. Hereby comparing the selected products, as well as allocating different environmental impacts to each considered life cycle phase. To achieve this objective, the following steps where executed in this study:

- Relocate the waste generated by packaging in the product packaging market
- Identify the most common packaging containers for different products
- Quantify the potential environmental impact
- Create a total overview and propose the best scenario for each product

PRODUCT PROPOSAL

The market study on food and beverages distribution for home consumption in Spain and the data concerning waste generated by the alimentation sector, showed that the beverage sector has an elevated level in the production of the total packaging waste generated. The beverages selected were beers, soft drinks, milk, juices, and yogurts. In total this research focused on the products representing 28% of the total food and beverages home consumption in Spain in the year 2011.

Product inventory

Each selected products was analysed in detail, mainly focusing on the kind of materials used for different packaging types. The data gave information on the share of different packaging in each category of house consumption in Catalonia. The shares referred to the amount of product units sold over the total units sold in the category, for home consumption. The product containers have been selected based on their high presence in the Municipal Solid Waste, and therefore identified as being of interest to AMB for the prevention of waste. For an accurate comparison they were divided into three types of groups. These groups are made to only compare the results with other products from the same group, due to their differences in function. The beverage and yogurt containers were identified as high packaging waste producers, from which the following three separate study groups were defined:

- Group A: 1000 ml containers for the beverage products milk, juice, and beer
- Group B: 330 ml containers for the beverage products soda and beer
- Group C: 125 ml containers for the food product yogurt

Category	Type of packaging	Size	Functional unit	Total units
Group A	Carton containers	1000 ML	1000 L	1000,0
	Glass containers	1000 ML	1000 L	1000,0
	Plastic containers	1000 ML	1000 L	1000,0
Group B	Tin steel containers	330 ML	1000 L	3030,3
	Aluminium containers	330 ML	1000 L	3030,3
Group C	Glass container	135 ML	1000 L	7406,4
	Plastic container	125 ML	1000 L	8000,0



- Table 1: Selected product containers for research

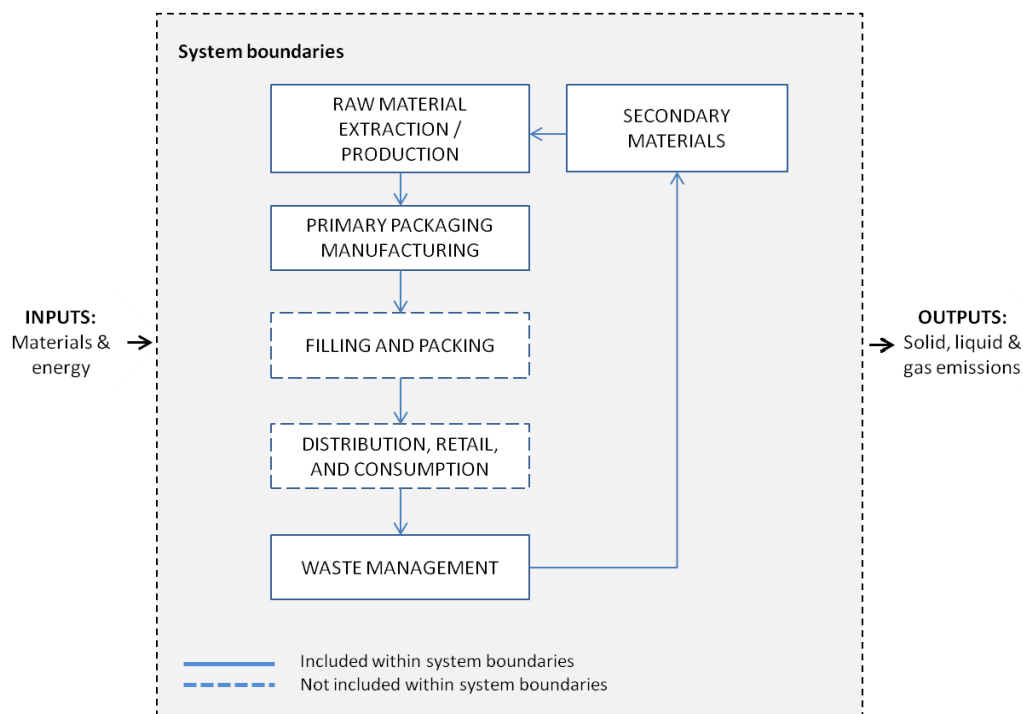
LIFE CYCLE ASSESSMENT (LCA)

By means of a Life Cycle Assessment (LCA), the environmental impacts of the different packaging systems were quantified and compared. Comparisons between systems have been made based on the basis of the same function. The function of the packaging systems is to facilitate the containment, protection, handling, delivery, and presentation of the alimentation products from the producer to the customers. This research only includes the functions of the primary packaging, which is the wrapping or containers handled by the consumer.

Goal and scope definition

For the comparability of LCA results, the functional unit defines the quantification of the identified functions of the product. Comparability of LCA results is particularly critical when different systems are being assessed, to ensure that such comparisons are made on a common basis. Therefore, the functional unit for this study is a standard packaging system for the one time containment of 1000 litres of product for home consumption in Catalonia, Spain.

The system boundaries determine which unit processes are included in the LCA. In the figure below, the full life cycle of the packaging systems from raw material production to end-of-life management is shown. Not every stage will be investigated in this study, marked with dashed lines in the figure. However, the processes of raw material extraction, packaging manufacturing and waste management, have been selected due to their expected contribution to the environmental impacts of the system investigated. Distribution, retail, and consumption were also expected to have great impact, yet could not be included due to the time limitations of the research.



- Figure 1: System boundaries for the Life Cycle Analysis of the packaging industry

Impact Assessment

Based on the data concerning composition, production and disposal of the product containers the environmental impact can be assessed. The impact assessment identifies and analyses all the corresponding environmental impacts and compares the results between the different product containers. Therefore the products in this research were divided into three groups (A, B, and C). Group A includes carton (LPB), glass (white and brown), and plastic containers (PET/HDPE) of 1000 ML, used to contain beverages like milk, juice, and beer. Group B compares the two different kinds of cans of 330 ML, namely tin steel containers and aluminium containers, for the containment of sodas and beer. The last group includes the smallest containers (125/135 ml) made from glass and plastic (PS), used for the preservation of yogurts.

Group A: 1000 ml containers for beverage products (milk, juice and beer)

Group A, exists out of six different containers for the products juice, milk and also beer. The comparison is made between the different types of juice containers, however these containers are representable for the other product containers made out of the same type of material (glass, plastic, liquid packaging board).

Type of packaging	Product	Size	Weight	Material
Carton container	Juice	1000 ML	32,34 g	Liquid packaging board
Plastic container	Juice	1000 ML	37,54 g	PET
Glass container	Juice	1000 ML	436,00 g	Glass white

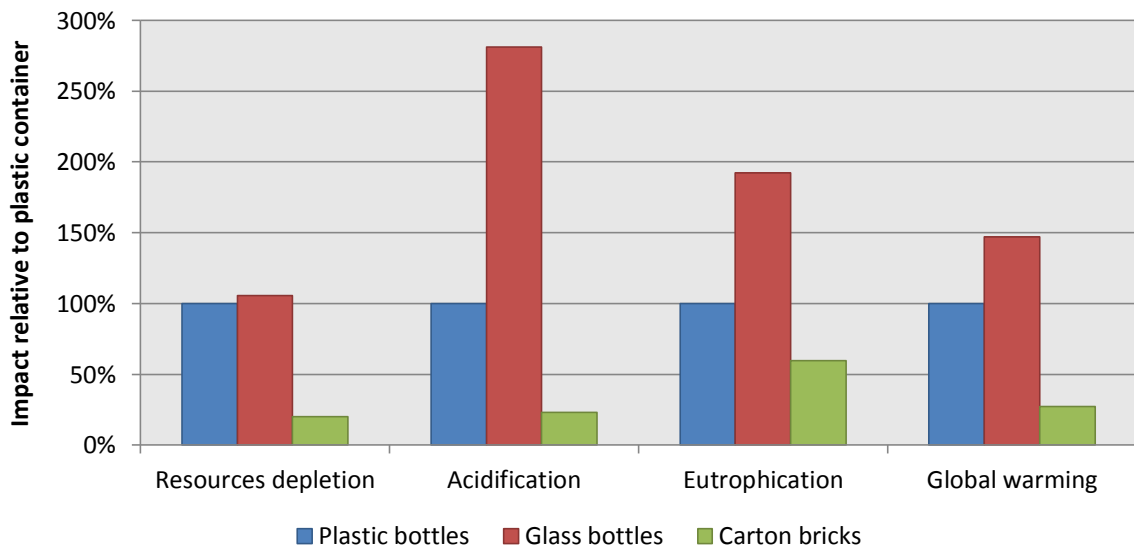
- Table 2: Container types of group A, 1000 ml containers for beverage products

In group A, the 1000 ml carton containers were found to have the lowest compared to the plastic and glass containers, in all impact categories. Depending on the category, the other containers were 1 up till 12 times more environmental harming. The plastic container has the highest impact in the category fresh water aquatic eco-toxicity. For glass, the relative biggest impact compared to the other containers is in acidification and terrestrial eco-toxicity. For the plastic container this is resource depletion and fresh water aquatic eco-toxicity. Even though carton containers score lower on each point, relatively seen their highest impact is caused in terrestrial eco-toxicity.

Impact category	Unity	Carton	Plastic	Glass
Abiotic depletion	kg Sb eq	0,60	2,99	3,15
Acidification	kg SO2 eq	0,29	1,27	3,57
Eutrophication	kg PO4 eq	0,19	0,31	0,60
Global warming	kg CO2 eq	77,68	286,03	420,70
Human toxicity	kg 1,4-DB eq	72,31	280,75	342,96
Fresh water aquatic eco-toxicity	kg 1,4-DB eq	69,47	138,39	106,94
Marine aquatic eco-toxicity	kg 1,4-DB eq	93198,65	174702,12	251090,34
Terrestrial eco-toxicity	kg 1,4-DB eq	0,39	0,46	1,36
Photochemical oxidation	kg C2H4 eq	0,02	0,07	0,14

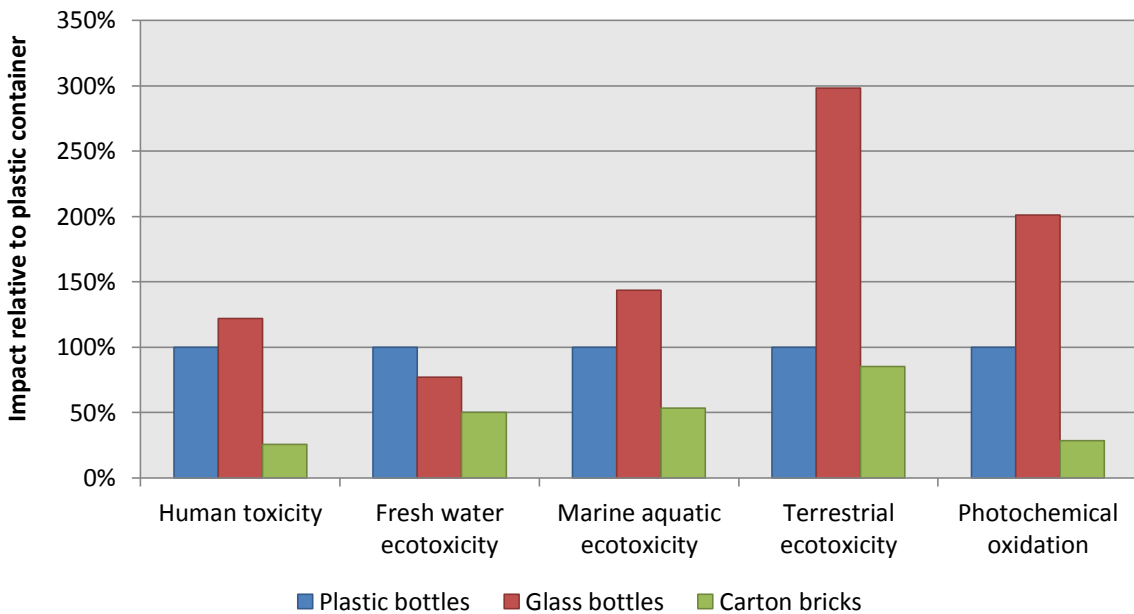
- Table 3: Overall LCA results per container type, for 1000 litres of beverage (kg)

Environmental impact - 1000 ml beverage containers (part 1)



- Figure 2.A: Overall LCA results per container type, for 1000 litres of beverage (kg)

Environmental impact - 1000 ml beverage containers (part 2)



- Figure 2.B: Overall LCA results per container type, for 1000 litres of beverage (kg)

The glass containers have a substantial higher impact compared to the impact of other container types. Looking at the glass bottle's life cycle into the phases raw material, container manufacturing and waste management, it becomes clear that the cause of the impact mainly comes from the manufacturing process. The global warming potential (CO₂ emissions) of the glass bottle manufacturing mainly result from direct process emissions as well as from fossil fuel combustion. The manufacturing of glass requires a high level of energy consumption, which causes greenhouse gas emissions from the use of oil, electricity, and natural gas. Process emissions occur due to the decarbonisation of the carbonate raw material in the process input,

mainly sodium carbonate (soda), limestone and dolomite. Also for the abiotic resources depletion, the main impact does not come from the abundant raw materials like silica sand, soda, or limestone, but from the use of the non-renewable fossil fuels in the manufacturing process. This all gets extra emphasized by the fact that a glass bottle needs a much larger quantity (in weight) of material, in order to serve the same function as other container types (plastic and carton). These results do not mean that glass per definition is a worse packaging container from an environmental perspective. However, it can be concluded that in order for glass packaging containers to be a more sustainable choice than other packaging types, reuse of the container will be required. Depending on the impact category, the amount of reusing times vary between 1 till 2 times compared to plastic containers, and between 1 and 12 times compared to carton containers.

The plastic container scored highest in the category fresh water eco-toxicity, and 2nd highest in the other impact categories. The impact of the plastic containers is diverse and caused by the raw material extraction, container manufacturing, as well as the waste management, however each process effecting different impact categories. The raw material extraction and the manufacturing process mainly cause impacts due to the extraction of minerals and fossil fuels used for the manufacturing process, the emissions released during this process, and the effects they have for the human health and ecosystems. This helps explaining why plastic containers have a high score on abiotic depletion (almost equalling the impact of the glass containers), as the raw material of plastic is oil-based and the production process uses non-renewable energy sources like oil.

Looking at the results of the three container types, the waste management has the most significant impact in the impact categories fresh water aquatic eco-toxicity and marine aquatic eco-toxicity. As seen in figure 12, the one category in which the highest impact comes from plastic containers is fresh water aquatic eco-toxicity, caused for 80% by the waste management process. Looking within the waste management process of these plastic containers, it becomes clear that this impact is mainly caused by the landfill (90% landfill and 10% incineration). Due to this landfill impact, the total fresh water eco-toxicity value of plastic containers surpasses that of glass containers. Also within marine aquatic eco-toxicity, 70% of the plastic container impact is caused by waste management. Remembering that waste management impact was mostly applicable for these two categories, it can be concluded that that from a waste prevention perspective, the waste management of the plastic containers should have priorities over other types of containers, as their impacts related to waste are more harmful. In other words, plastic container waste causes higher environmental impacts than glass or carton container waste.

The carton containers or so-called liquid packaging boards, are the least environmental harming packaging container in Group A. The different impacts of the carton brick are versatile and hard to be assigned to one specific process or material. Roughly said, the raw material process contributes the biggest part in the overall impact of the carton containers, in which paperboard contributes the most. The deviating categories are fresh water aquatic eco-toxicity, marine aquatic eco-toxicity and eutrophication, which are mainly caused by the waste management of the elements HDPE and LDPE. However, here it also contributes a big part to the categories eutrophication and human toxicity. In the depletion of resources, the raw

materials account for 80% of all the products impact, which is due to the variety of materials used (plastics, aluminium and paperboard). An even though aluminium only represents a small part of the carton containers composition, its impact compared to the other materials goes from 4 till 20% of the total impact, depending on the category. This fact would make an further investigation between shelf stable carton (with layers of aluminium) or refrigerated carton (without aluminium) quite interesting. Also, further research can be done on the impact of paperboard, and whether this impact comes from the bleaching of the pulp.

Group B: 330 ml containers for beverage products (sodas and beer)

Group B, exists out of the two different containers for gaseous beverages like beer and soft drinks. Both containers are used for the containment of gaseous drinks and therefore need to be corrosion resistance. Both containers serve the same function and are placed into a separate group for comparison.

Type of packaging	Product	Size	Weight	Material
Aluminium can	Beer	330 ml	13,35 g	Aluminium
Steel can	Soft drinks	330 ml	20,79 g	Chromium steel

- Table 4: Container types of group B, 330 ml containers for beverage products

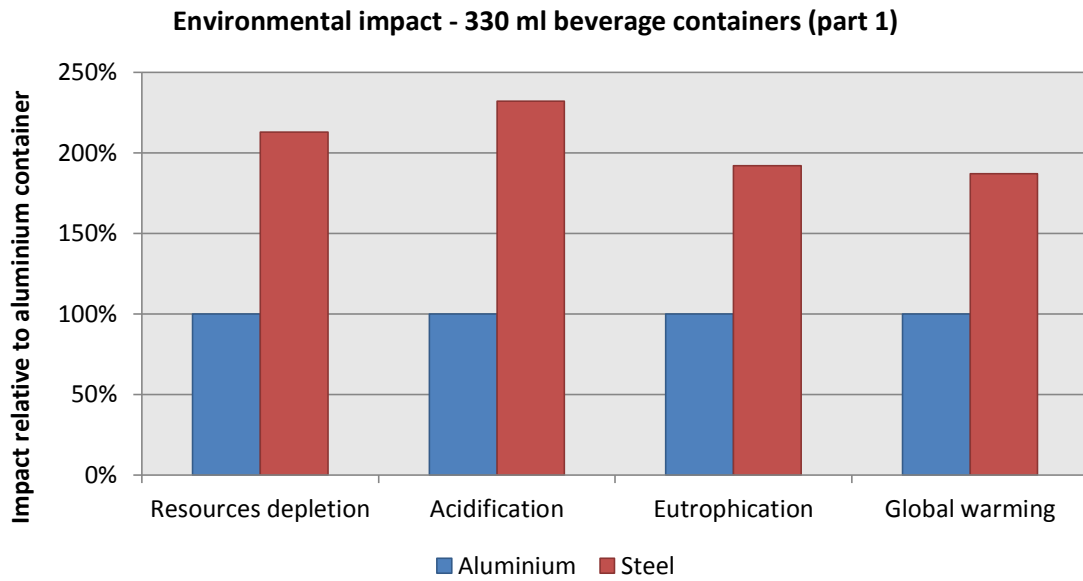
In all the impact categories, steel containers scores higher than aluminium cans, with ratios varying from 60% till 90%. In appendix D, the product specific impacts of the aluminium and steel cans, show that the impact in practical all categories mainly comes from the raw material extraction.

Impact category	Unity	Aluminium	Steel
Abiotic depletion	kg Sb eq	0,862	1,836
Acidification	kg SO ₂ eq	0,612	1,421
Eutrophication	kg PO ₄ eq	0,266	0,511
Global warming	kg CO ₂ eq	133,375	249,556
Human toxicity	kg 1,4-DB eq	487,151	4613,535
Fresh water aquatic eco-toxicity	kg 1,4-DB eq	86,359	1039,061
Marine aquatic eco-toxicity	kg 1,4-DB eq	150417,114	859344,432
Terrestrial eco-toxicity	kg 1,4-DB eq	1,408	8,771
Photochemical oxidation	kg C ₂ H ₄ eq	0,045	0,065

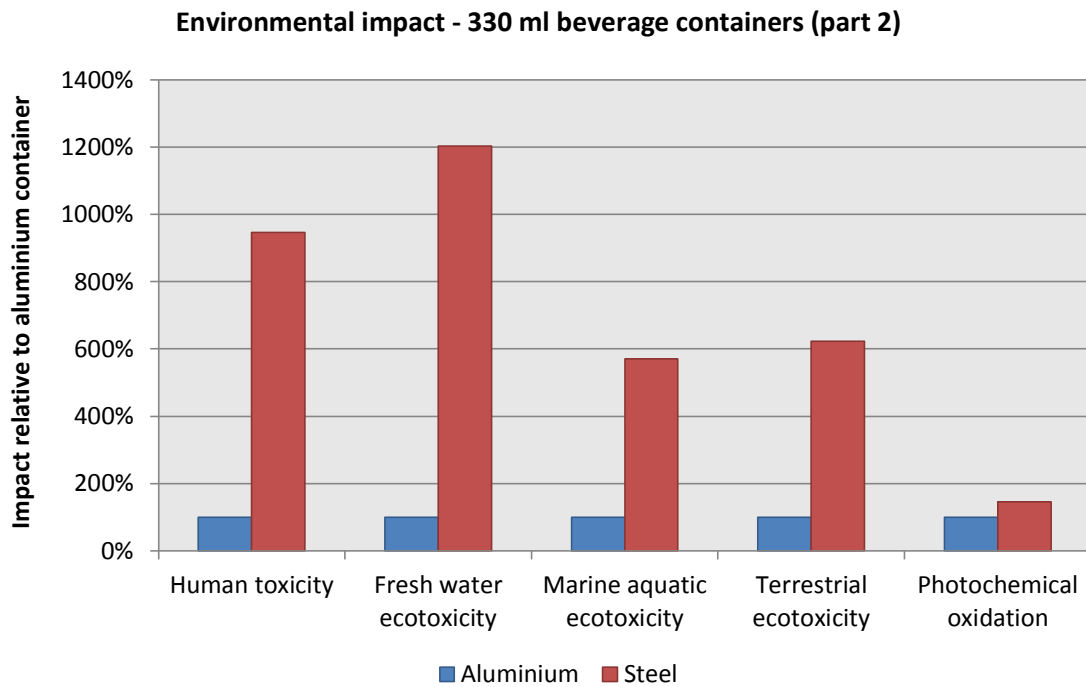
- Table 5: Overall LCA results per container type, for 1000 litres of beverage (kg)

Even though aluminium is the most abundant metallic element, the highest impact still occurs within the raw material extraction phase. The aluminium containers main impact comes from the cast aluminium ingot production, which is where the alumina solution is heated past its melting point (electrolysis) and cast into a shape suitable for further processing. The heating of the aluminium is a very energy intensive process. As electric power represents a high share of the total energy use in the production of aluminium, which makes the countries energy mix is a very determining factor in the level of environmental impact. The processing of the aluminium ingot in the container manufacturing accounts for 10% till 20% of the total impact. As aluminium has a very low acute toxicity, the landfill and incineration processes in the waste

management scenario have almost no impact compared to the other two processes. Recycling avoids the production of primary aluminium, yet the impact caused by the recycling is not included in this assessment.



- Figure 3.A: Overall LCA results per container type, for 1000 litres of beverage (kg)



- Figure 3.B: Overall LCA results per container type, for 1000 litres of beverage (kg)

Within packaging steels, several types of coating are used to provide the containers with good storage properties and strong resistance to corrosion. Many internal coatings, such as tinplate, are used to protect the contents of steel cans (20). This study includes the impacts of electrolytic chrome coated steels, which is an alternative to tin coatings for packaging products frequently used for cans. The process impact proportions of steel containers are very similar to that of aluminium, however the absolute values are much higher. This is mainly due to the high melting point of chromium, by which the production of ferrochrome in electric arc furnaces requires even more energy. In larger amounts and in different forms, chromium can be toxic. Especially chromium release from waste incineration has a high impact on fresh water aquatic eco-toxicity, accounting for 20% of the total impact on fresh water eco-toxicity.

Group C: 125/135 ml containers for food products (yogurts)

The final group C, compares two different containers for yogurts. For these results it should first be made clear that for the production of PS containers, no actual data could be used. Therefore an average impact of other plastic container productions has been used (HDPE, LDPE, and PET bottles). So potential particular PS characteristic of the PS container production are not included, however for the raw material and waste management the right processes where available. The two types of containers different not only in material, but the weight of the glass container is almost 20 times more than the plastic container.

Type of packaging	Product	Size	Weight	Material
Glass cup	Yogurt	135 ML	89,61 g	White glass
Plastic cup	Yogurt	125 ML	4,71 g	PS

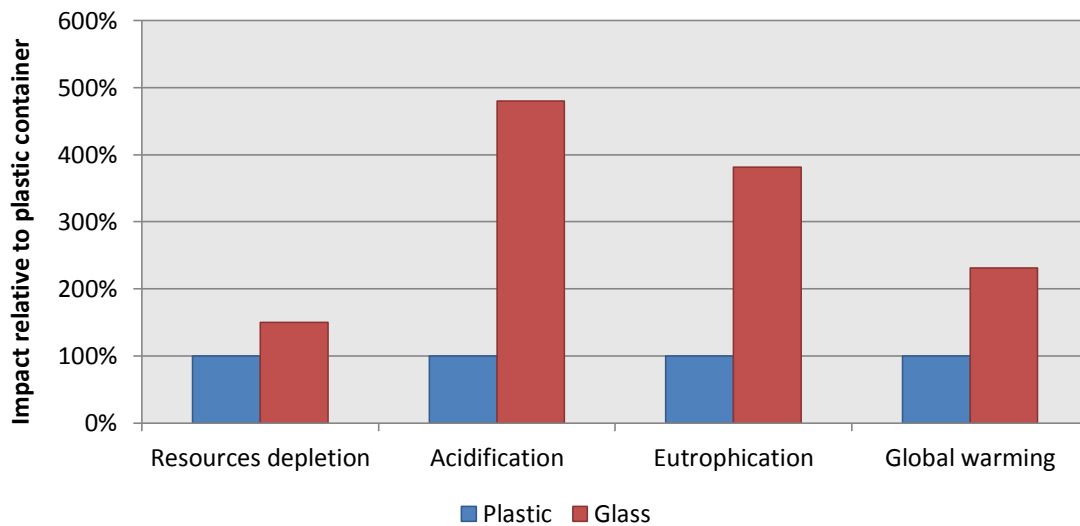
- Table 6: Container types of group C, 125/135 ml containers for yogurt products

Also here, the glass container has a much higher impact in almost all categories. A very interesting occurrence is that when comparing the containers per KG, glass would have less impact. However to be able to serve for the same function as a plastic yogurt container much more material is needed.

Impact category	Unity	Glass	PS
Abiotic depletion	kg Sb eq	4,709	3,138
Acidification	kg SO2 eq	5,407	1,126
Eutrophication	kg PO4 eq	0,892	0,234
Global warming	kg CO2 eq	631,563	273,338
Ozone layer depletion	kg CFC-11 eq	0,000	0,000
Human toxicity	kg 1,4-DB eq	483,325	107,122
Fresh water aquatic ecotox.	kg 1,4-DB eq	121,270	43,928
Marine aquatic ecotox.	kg 1,4-DB eq	359597,363	50165,985
Terrestrial ecotox.	kg 1,4-DB eq	1,855	0,117
Photochemical oxidation	kg C2H4 eq	0,202	0,066

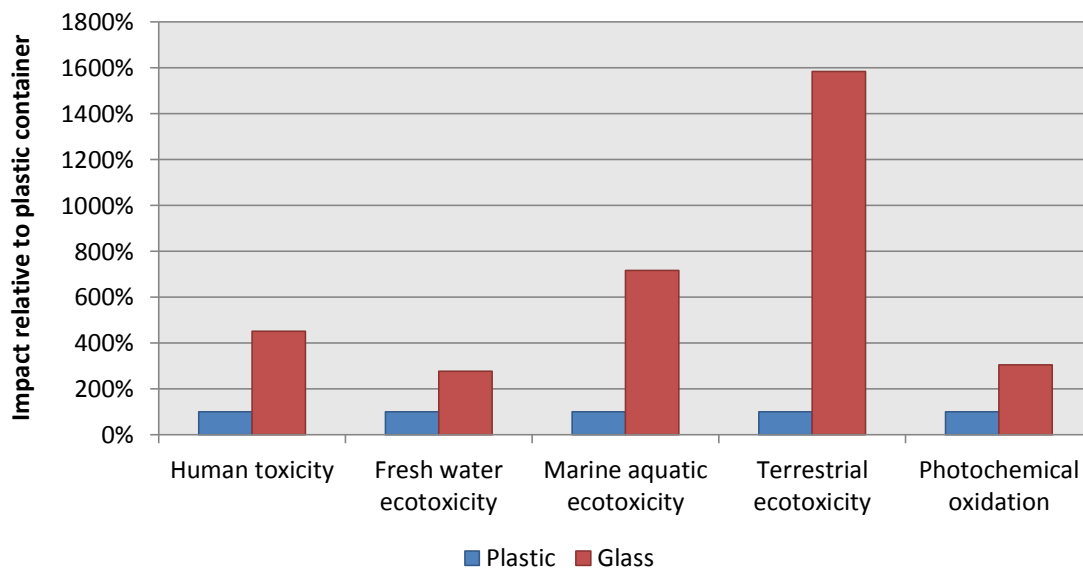
- Table 7: Overall LCA results per container, for plastic and glass yogurt containers (kg)

Environmental impact - 125 ml food containers (part 1)



- Figure 4.A: Overall LCA results per container type, for 1000 litres of yogurt (kg)

Environmental impact - 125 ml food containers (part 2)



- Figure 4.B: Overall LCA results per container type, for 1000 litres of yogurt (kg)

As with the plastic containers used for the conservation of beverages, the plastic PS container's impact is also much less than that of the glass container. The raw material extraction process causes the main impact in the category terrestrial eco-toxicity. The container manufacturing process has the overhand in causing resource depletion, acidification, human toxicity and photochemical oxidation. And the waste management process for water eco-toxicities and eutrophication. Again, the glass containers manufacturing process is what makes the packaging type more environmental damaging than other types. Compared to the plastic container the glass container causes 1.5 times more impact in the case of resource depletion, and up till 16 times within the terrestrial eco-toxicity category.

CONCLUSIONS

This research has identified carton containers, made out liquid packaging board, as the most sustainable packaging option for the preservation of 1000 ml, non-gaseous beverages. In all impact categories carton containers scored a lower impact. For the containment of 1000 litres of beverage, the carbon footprint of the carton containers (78 kg of CO₂), was calculated to be around 3.5 times lower than the plastic container (284 kg CO₂), and compared to glass container even almost 4.5 times less (420 kg CO₂). In other categories this difference varied from 1 up till 12 times the difference.

For gaseous drinks of 330 ml, the best container for home consumption is made out of aluminium. Mainly due to the extra coating, steel cans have a higher environmental impact than aluminium. Even though less harming than steel cans, the aluminium extraction is energy and also causes high impacts (e.g. for the carbon footprint 250 kg CO₂, compared to 133 kg CO₂ for 1000 litre of beverage).

Small plastic and glass containers are commonly used for the preservation of yogurts. For the containment of 1000 litres of yogurt, the 125 ml plastic containers have less than 2 times the carbon footprint (273 kg CO₂), than the 135 ml glass container (632 kg CO₂). Also in the other categories the glass container causes 1.5 times and up till 16 times more impact.

Further research

This study made the basis in comparing the potential environmental impacts associated to different packaging alternatives. However extended research will help to complement the present outcomes. This study is only applicable to the processes included within the research boundaries, yet the container life cycle includes other phases like the user and transport phase. Therefore, it could be very interesting to complete the present research with the stages excluded in the study. Issues, like the impact of secondary packaging and transit packaging, or the weight/size of packaging containers influencing the transportation phase, are all factors that can influence the results. However for the completeness of this research the following topics should be added.