Ökobilanz für

PET-Einwegsysteme unter Berücksichtigung der Sekundärprodukte

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Ökobilanz für PET-Einwegsysteme unter Berücksichtigung der Sekundärprodukte

<u>Autoren</u>

Andreas Detzel

Jürgen Giegrich

Martina Krüger

Sandra Möhler

Axel Ostermayer

IFEU GmbH, Heidelberg, August 2004

Wilckensstr. 3, 69120 Heidelberg,
Tel. 06221-47670, Fax: 06221-476719
e-mail: andreas.detzel@ifeu.de

SUMMARY

Background and Goals

The current German Packaging Directive from 1998 imposes a mandatory deposit on one-way packaging systems if a certain refillable beverage container quota is not met. Mandatory deposits came into force in January 2003. Meanwhile, the Ministry of Environment issued a proposed draft for a revision of the Packaging Ordinance. A main aspect of this draft was to substitute the quota for refillable beverage systems by a concept that involves so-called environmentally friendly packaging systems. Decisions as to which beverage containers are to be included in this category would be taken by the Ministry with, amongst other criteria, reference to the results of Life Cycle Assessments.

In this context the IFEU-Institute was commissioned to conduct an LCA study on one-way PET bottles (PET-OW) for water and carbonated soft drinks in comparison to refillable glass bottles (Ref-Glass). The study, which included a comprehensive stakeholder participation in form of a project panel, was commissioned by PETCORE (Brussels) with the participation of Forum PET (Bad Homburg) as well as individual beverage companies (Aqua Montana, Beckers Bester, Brandenburger Urstromquelle, Eckes-Granini, Gehring-Bunte, Hansa-Heemann, Hochwald-Sprudel, Holsten Brauerei, SDI, Stute) and was completed in August 2004. It was peer reviewed by internationally acknowledged LCA and PET experts and is in accordance with the international standard ISO 14040 ff.

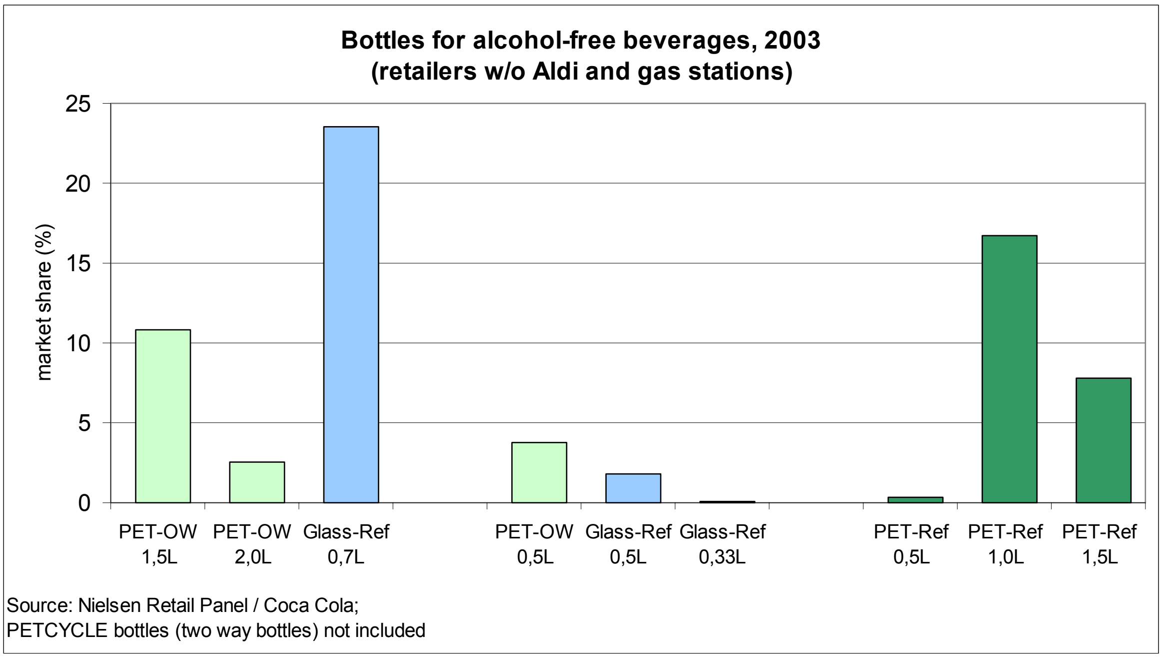
The project panel agreed upon the following goal of the study:

The use of PET one-way-bottles for carbonated mineral water, non-carbonated mineral water and soft drinks should be compared to the most reasonable refillable glass bottle system for the same beverage, for a situation close to present practices. Focus is on the German market for mineral water and soft drinks. Any relevant parameter should be evaluated against the corresponding ecoprofile of refillable glass systems. The variation of the systems should be examined.

The study was designed to provide fact-based environmental information to political decision makers in Germany. In addition, the stakeholders in the PET supply chain should learn about important aspects which influence the environmental performance of the one way PET systems including improvement options for the producers and fillers. Furthermore, consumer and environmental organisations should obtain support for product information on environmental grounds.

The choice of refillable glass bottle systems as an environmental benchmark for the one-way PET bottle systems was made for two reasons. On the one hand, if looking at individual bottle types, the refillable glass bottles still are the dominant bottle systems within the refillables (see picture 1). On the other hand refillable glass has been used as the packaging of reference by the German Environment Agency in the German beverage LCA II [UBA 2000, UBA 2002].

Refillable PET bottles which represent an alternative to refillable glass bottles have not been included within the scope of the study as the LCA exercise did not aim at a comparison between one-way and refillable bottles in general terms.



Picture 1: Market share of selected bottle sizes by beverage volume sold

The LCA study has a reference period around 2002/2003 and was designed to reflect the German market conditions as close as possible. Here a difficulty arose due to the fact that since January 2003 the one-way PET bottles were charged with a mandatory deposit. This caused a shift of the collection of used PET bottles from the DSD system to the retailers. For this reason the study comprises scenarios for both routes.

Packaging Systems Examined

For the purpose of this LCA the packaging systems have been assigned to two application groups:

a) bottles for “home consumption” having a volume of > 0.5 L

b) bottles for “away from home” consumption having a volume of ≤ 0.5 L

Within these groups individual bottles are assumed to be functionally equivalent. This differentiation refers to a consumer behavior where the consumer tends to buy larger bottle sizes for beverage consumption at home and smaller sizes for “away from home” consumption [UBA 2000].

The individual packaging systems examined are shown in table 1 (home consumption) and table 2 (outside home consumption) giving selected data for packaging system description. Data on composition and mass of primary and secondary packaging materials have been communicated by and agreed upon with panel members respectively. They are meant to represent an average German market situation.

As can be seen in table 1 and 2 quotas had to be fixed regarding the collection and recovery rates of used one-way PET bottles. Within the DSD (German Green Dot), which is a kerbside collection system, a collection rate of 79.7 % was achieved in 2002. This resulted in an overall recovery rate of 66.1% of the one-way PET bottles consumed in that year. While material flows within the DSD system are well documented, information on the exact material flows within the deposit system handled by the retailers were scarce. The respective data for modeling of the deposit based material flow have been based on information related to the deposit system in Sweden as well as information from press releases and experts in the field. The model applied in this LCA also takes into account that about 80% of the one-way PET bottles collected via deposits are exported to the Far East.

The recovery rate of 76.8 % calculated for the deposit system is significantly higher than the DSD quota. The underlying assumption is that losses through e.g. sorting are smaller in a deposit system. Due to this fact also the overall outlet of R-PET flakes increased to 66.8% in the deposit system in comparison to 39.1 % in the DSD system. In the latter case the main reason for the smaller R-PET outlet is that about 20 % of PET ends up in the mixed plastics fraction. In other “Green Dot countries”, with a longer history of PET collection, this additional loss does not occur.

	PET-OW CD 1.5 L	PET-OW Non CD 1.5 L	PET-OW CD 2.0 L	Ref-Glass CD 0.7 L
Primary Packaging				
Bottle	36.5 g (PET)	33 g (PET)	49 g (PET)	590 g (Glass)
Closure	3.2 g (HDPE)	2.7 g (HDPE)	3.2 g (HDPE)	3.2 g (20% HDPE) 1.5 g (80% Alu)
Label	0.6 g (95% PP) 1.0 g (5% Paper)	0.6 g (95% PP) 1.0 g (5% Paper)	0.5 g (PP)	1.0 g (Paper)
Secondary Packaging				
Shrink Foil	26 g (LDPE)	26 g (LDPE)	27 g (LDPE)	--
Reusable Crate	--	--	--	1,400 g (HDPE)
Collection and Recycling (PET-OW-Systems)				
Collection Quota DSD	79.7 %	79.7 %	79.7 %	--
Recovery Quota DSD	66.1 %	66.1 %	66.1 %	--
Collection Quota Deposit	80 %	80 %	80 %	--
Recovery Quota Deposit	76.8 %	76.8 %	76.8 %	--
Reuse (Ref-Glass-Systems)				
No of bottle reuses	--	--	--	50
CD = carbonated drink; non CD = non carbonated drink, OW = one-way				

Table 1: Bottles examined in the “home consumption” group including selective parameters for system specification

It must be emphasized that the deposit system model setup in the present study is not as reliable as the model based on the well-documented DSD data. This is due to lacking data particularly in the area of sorting of collected PET bottle fractions and reclaiming in the Far East. For this reason, material losses related to entry sorting and moisture content in baled bottle bulk in the present study probably have been underestimated in the deposit based PET recovery chain.

	PET-OW CD 0.5 L	Ref-Glass CD 0.33 L	Ref-Glass CD 0.5 L
Primary Packaging			
Botte	20.5 g (PET)	434 g (Glass)	360 g (Glass)
Closure	3.2 g (HDPE)	2.3 g (Crown Cap)	1.5 g (Alu)
Label	0.4 g (80% PP) 1.0 g (20% Paper)	0.5 g (Paper)	1.10 g (Paper)
Secondary Packaging			
Shrink Foil	8.4 g (LDPE)	--	--
Reusable Crate	--	1,741 g (HDPE)	1,350 g (HDPE)
Collection and Recycling (PET-OW-Systems)			
Collection Quota DSD	79.7 %	--	--
Recovery Quota DSD	66.1 %	--	--
Collection Quota Deposit	80 %	--	--
Recovery Quota Deposit	76.8 %	--	--
Reuse (Ref-Glass-Systems)			
No of bottle reuses	--	25	21
CD = carbonated drink; non CD = non carbonated drink; OW = one-way			

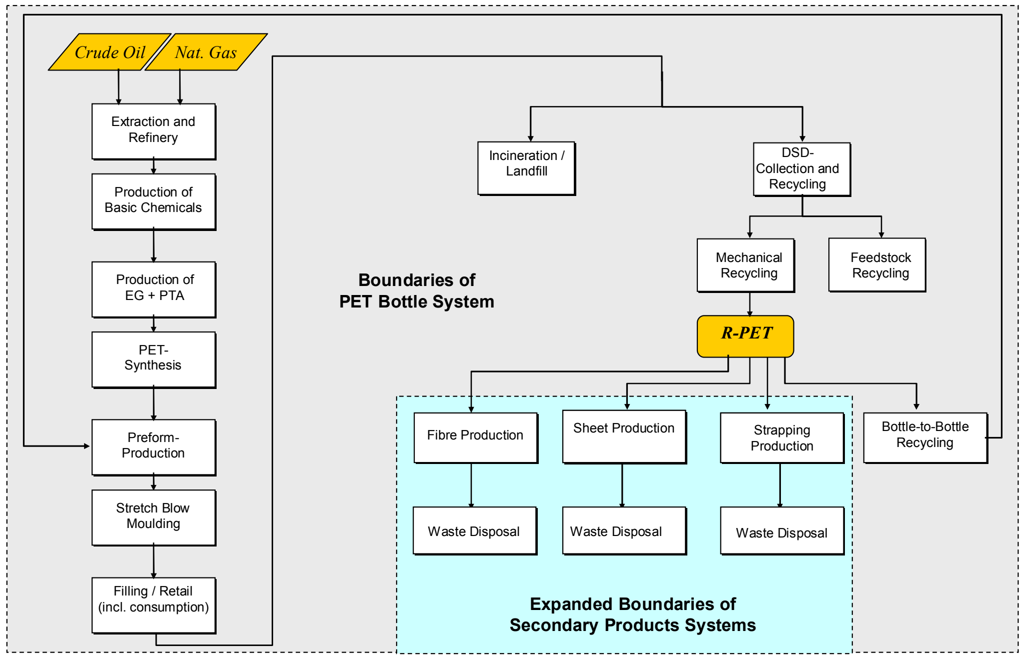
Table 2: Bottles examined in the "outside home consumption" group including selective parameters for system specification

System Boundaries and Functional Unit

In general terms, the environmental burden of all life-cycle steps from raw material extraction to final waste treatment or waste recovery and recycling respectively has been accounted for in each packaging system examined. The focus was on the packaging systems. The production of the beverage itself was not included in this study.

Beverage container LCAs traditionally consider the beverage packaging only. System boundaries in such a case include e.g. the one way PET bottle (picture 2, grey shaded area) or the refillable glass bottle (picture 3, grey shaded area). They also include recycled product obtained through closed-loop-recycling. E.g. in picture 2 and 3 the grey shaded areas cover the use of R-PET for new PET bottles (rectangle: "Bottle-to-Bottle Recycling") and the remelting of used glass respectively.

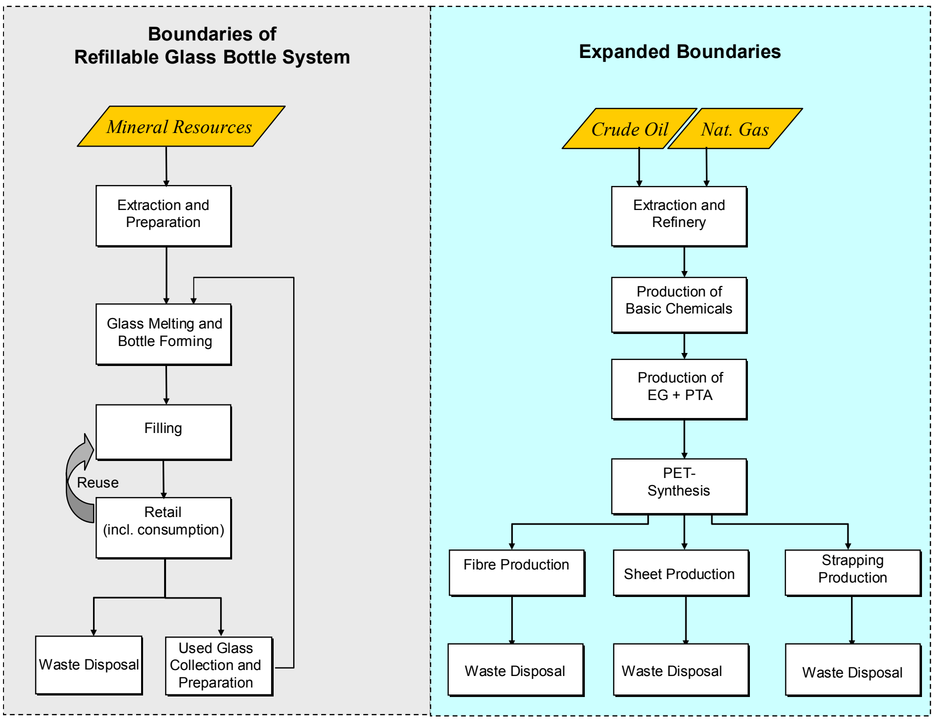
However, system boundaries in that traditional product LCA approach **do not** include recycled products which are not fed back into the same system. In the one way PET bottle system this kind of recycling product mainly are *staple fibres*, *sheets* and *strapping* made from recycled PET. **In contrast** to the traditional approach, in the present LCA the system **boundaries of the PET bottle system have been expanded** in order to include these additional products (picture 2, light blue shaded area).



EG: Ethylenglycol
PTA: Purified Terephtalic Acid

Picture 2: Simplified model of boundaries in the PET-OW-System

The expanded system therefore also has a multiple benefit related to the consumption of one way PET bottles. On the other hand, if the secondary PET products form part of the overall benefit of an individual system under examination then it has to be made sure that the system to be compared with provides the same overall benefit. Only then both systems can be compared. For this reason also the glass bottle systems had to be expanded for the production of fibres, sheets and strapping (picture 3, light blue shaded area).



Picture 3: Simplified model of boundaries in the Ref-Glass-System

As can be seen in picture 3 the expanded glass bottle system not only contains materials typically used for glass bottle production but also virgin PET and PET products flows. At first sight, this seems odd. It does of course not mean that PET products are in any way directly derived from the glass bottle. The expansion of the glass bottle system is just a logical adaptation in order to obtain the same products as in the expanded PET bottle system.

This aspect of multiple benefits also has to be covered in the definition of the functional unit (FU) which is the core element for all comparisons made between the packaging systems. Still, the initial benefit in both the one way PET and the refillable glass bottle consists in the application for packaging and distribution of the beverage. It thus serves as a starting point for the FU:

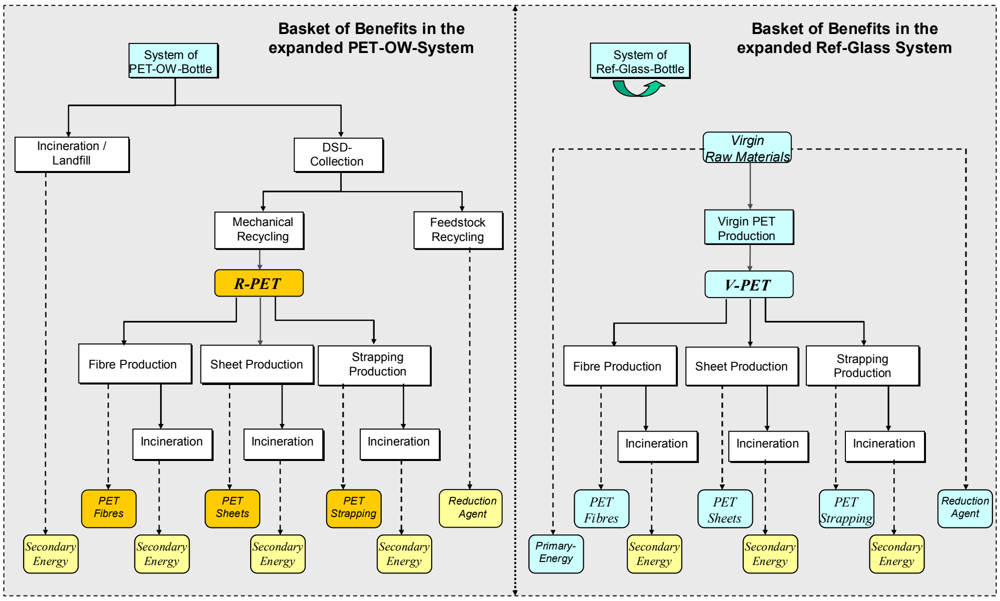
The initial function examined in this LCA is the delivery of beverage to the consumer at the point-of-sale. The functional unit, to which all data in the first place refer to, is the packaging system required to deliver 1000 litres of beverage to the consumer.

In the second step the additional benefit related to recycling and final treatment of the PET bottles has to be accounted for. This benefit also includes the material and energy recovery of used PET. The total of all benefit related to recycling and final disposal of PET can be described as a basket of benefits (see picture 4, left side). As explained before, the compared system, i.e. the refillable glass bottle system, has to be adjusted to the same basket of benefits (picture 4, right side).

Picture 4 shows a simplified illustration. The initial production and use of beverage bottles here is represented by a single rectangle at the top of the flow charts. The fact that the refillable glass bottle is reused several times is indicated by an arched arrow.

The symmetry of the benefits between the one way PET bottle system and the refillable glass bottle system has been visualized by the arrangement of the processes and products forming the basket of benefit. The difference between both systems can be found in the fact that the adjustment of the benefit from R-PET in the one way PET bottle system requires the application of virgin PET and primary energy sources in the refillable glass bottle system.

Consequently, the reference flow of a one way PET bottle system and the related scenarios respectively consists of the initial type and amount of packaging material required for 1000 L of beverage packed in PET bottles and the type and amount of secondary products. The reference flow of a refillabe glass bottle system and the related scenarios respectively consists of the initial type and amount of packaging material required for 1000 L of beverage packed in glass bottles and the virgin materials required to produce the same type and amount of additional products as in the PET bottle system.



Picture 4: Simplified model showing the basket of benefit in both the PET-OW-System and the Ref-Glass-System

By the way, the quantified basket of benefit also differs from one PET bottle system to another. E.g. for the same bottle size different amounts of R-PET flakes are obtained in the DSD route as compared to the deposit route. The result is a different amount in e.g. secondary fibres and thus a different basket of benefits.

As a consequence of the system expansion as described above, allocation between the bottle systems and the secondary product systems was not necessary.

The complete and much more complex reference flows are documented in the main report (in German).

Data Used

Most of the data used in the study refer to a period between 1998 and 2003 and represent the average technological standard implemented in operational practice. Packaging material datasets have been derived mainly from literature or were collected by IFEU in previous studies. Data on virgin PET production, PET preform and bottle production as well as PET bottle recycling have been collected and updated for the purpose of this LCA study.

The datasets for transportation, energy generation and disposal operations have been taken from the IFEU database and are representative for the reference period 2002/2003 of this study.

Particular emphasis has been on data collection and validation related to the virgin PET production data and the beverage distribution model.

The data structure of virgin PET production has been divided into the steps:

a) petroleum and gas extraction and refinery with naphta and xylene as products

b) production of ethylene and ethyleneglycol

c) production of purified terephtalic acid (PTA)

d) PET polycondensation.

The data for a) were calculated on basis of a refinery model developed at IFEU representing the technology of current European process operation. The data for b) were derived from information on cracker facilities obtained in several IFEU studies and supplemented by literature data. The datasets for steps c) and d) are based on plant data provided directly by companies and collected by Prof. Rieckmann (FH Köln) and transferred into LCI format by IFEU. The data can be classified as representative for the current European PET production.

Based on former experience the beverage distribution was likely to be a result-sensitive life-cycle step especially for the refillable glass packaging systems. This proved to be true when the first draft results were available. These results were based on the so-called “UBA-distribution” which is the distribution model set-up in the beverage LCA of UBA [UBA 2000] on the grounds of a comprehensive survey among retailers in 1996. In this model, transport distances between filling plants and point-of-sales (POS) are about 190 km for refillable glass bottles and about 250 km for one-way bottles.

The distribution situation in Germany has in the meantime changed. Several fillers and logistic companies were asked to provide more current and representative distribution data. The information obtained represents about 38 % of the German market and indicates that transport distances between filling plants and point-of-sales (POS) nowadays could be about 120 km for refillable glass bottles and about 320 km for one-way PET bottles as an average.

However, due to the relatively poor representativity it was decided to give preference to the “officially” accepted UBA-distribution data being the best available approximation. This is a shortcoming for the otherwise excellent symmetry of the time reference of this study. The “new” data have still been used for sensitivity analysis.

Impact Assessment

The environmental impact categories listed below have been selected in order to assess the environmental performance of the packaging systems examined. These impact categories stand for environmental problems generally perceived to be relevant. They are also widely used in LCA practice.

A) Categories related to resource depletion

- Fossil Resource Consumption (weighted with scarcity of fossil fuel equivalents)
- Use of Nature[1]

B) Categories related to emissions

- Global Warming (Climate Change)
- Acidification
- Terrestrial Eutrification (i.e. eutrification of soils by atmospheric emissions)
- Aquatic Eutrification (i.e. eutrification of water bodies by effluent releases)
- Summersmog (Photo-Oxidant Formation)

Additional indicators for information purposes at the inventory level used in this study are

- Cumulative Primary Energy Demand (CED)
- Transport Intensity

The CED here comprises all primary energy independent of the type of energy source. It is different from the fossil resource consumption which is restricted to fossil fuels. The transport intensity indicates the amount of kilometres driven by lorries. Both indicators can not directly be linked to impacts and have been excluded from the final interpretation. They serve as information only.

[1] Regarding the assessment of Use of Nature (often referred to as "land use") several methodological approaches have emerged in recent years. The method developed by IFEU is based on an ordinal scale of 7 area classes of proximity-to-nature (e.g. area 1: nature without direct anthropogenic influences; area 2: forest managed in a very natural way; area 7: sealed areas (like production sites and roads and landfill sites). For the purpose of this exercise it is applied in a simplified way by focussing on *area class* 7).

Results

The LCA results are discussed with the help of the impact categories mentioned here. In a first step the dominance of individual life cycle steps is analysed (picture 5 ff). In a second step the results are normalised (picture 6) and impact categories are ranked for further interpretation.

The discussion of the results as well as the interpretation focused on the 1,5 L PET bottle for carbonated drinks as it is by far the most important PET bottle size on the German market in the reference period of this study. In the pictures pairs of bar charts are shown giving the indicator results of the PET bottle system and the reference glass bottle system. There is always one pair for the DSD scenarios and one pair for the deposit scenarios respectively.

Dominance Analysis

For the purpose of dominance analysis the bar charts in picture 5 ff have been broken down to individual life cycle sectors or steps, which are listed in the following:

Life Cycle Sector with Legend Symbol	Comment
Glass Bottle	includes melting process and bottle forming
Virgin PET	
PET Preform and Bottle	
Closures and Labels	
Secondary and Tertiary Packaging	
Filling	Includes washing of crates and bottles
Distribution	
Final Disposal LC1 (Life Cycle 1)	Refers to non source separated packaging wastes
Mechanical Recycling	In PET deposit scenarios also contains transport of baled bottles for recycling in Far East
Feedstock Recycling / Complementary Processes	
PET Strapping / Complementary Processes	Complementary processes can be seen especially in the results bars of the glass bottle scenarios. E.g. in case of PET fibres it means the production of PET fibres from V-PET as complementary to the R-PET fiber in the PET bottle system
PET Fibres / Complementary Processes	
PET Sheets/ Complementary Processes	
Other Complementary Processes	
Final Disposal LC2 (Life Cycle 2)	Refers to wastes resulting from the additional products in the expanded system boundaries

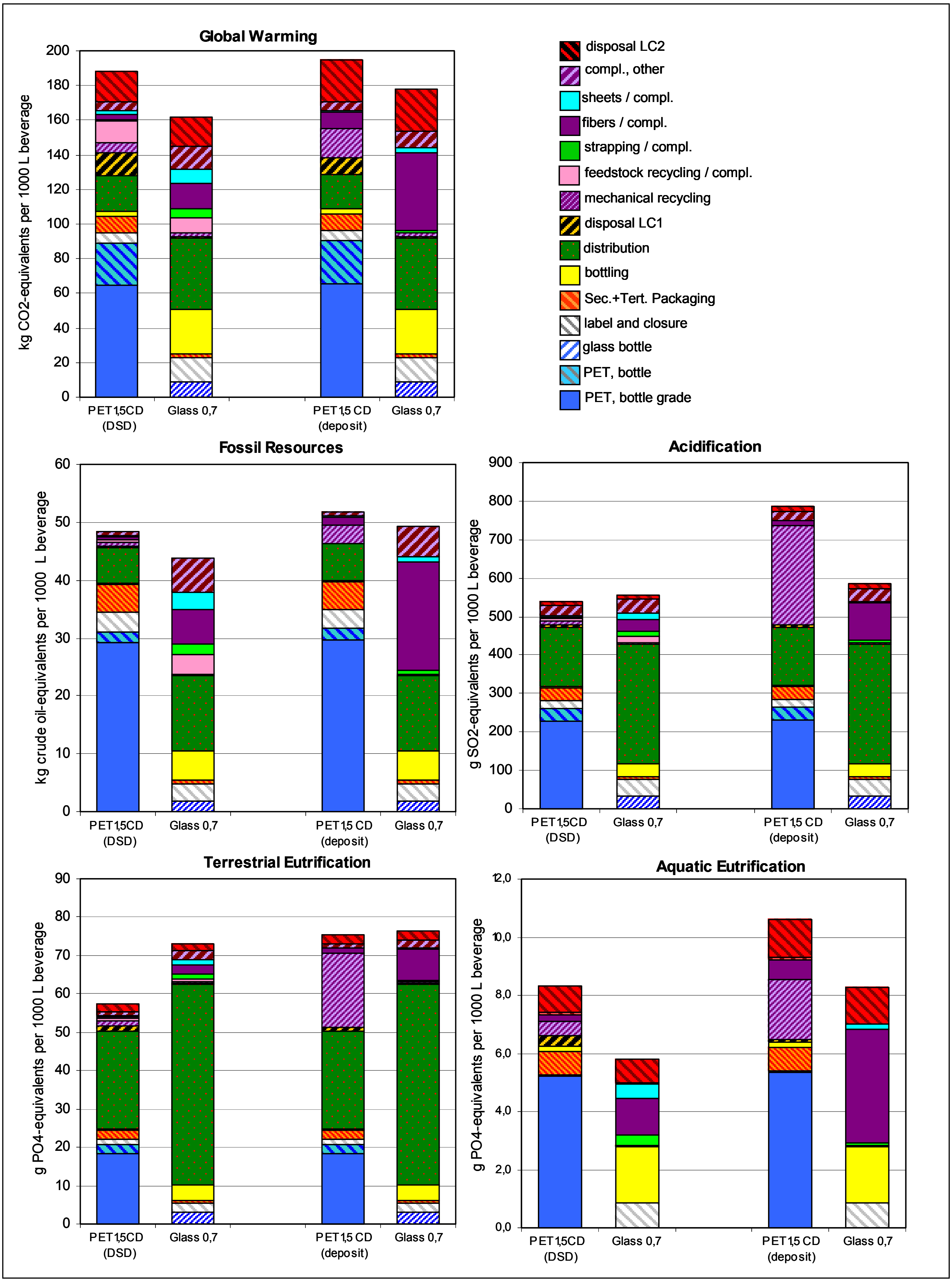
Table 3: life cycle sectors of the investigated systems

Dominance analysis for PET one-way systems: From picture 5 ff it can be seen that primary PET production in the PET-OW-System with DSD recovery has a major contribution to the results for most indicators. Only for terrestrial eutrification and use of nature the share of beverage distribution is larger. Furthermore, relevant contributions to global warming are associated with the PET bottle production and its final disposal. Environmental impacts from the production of secondary and tertiary packaging and the products from recycled PET are of minor scale.

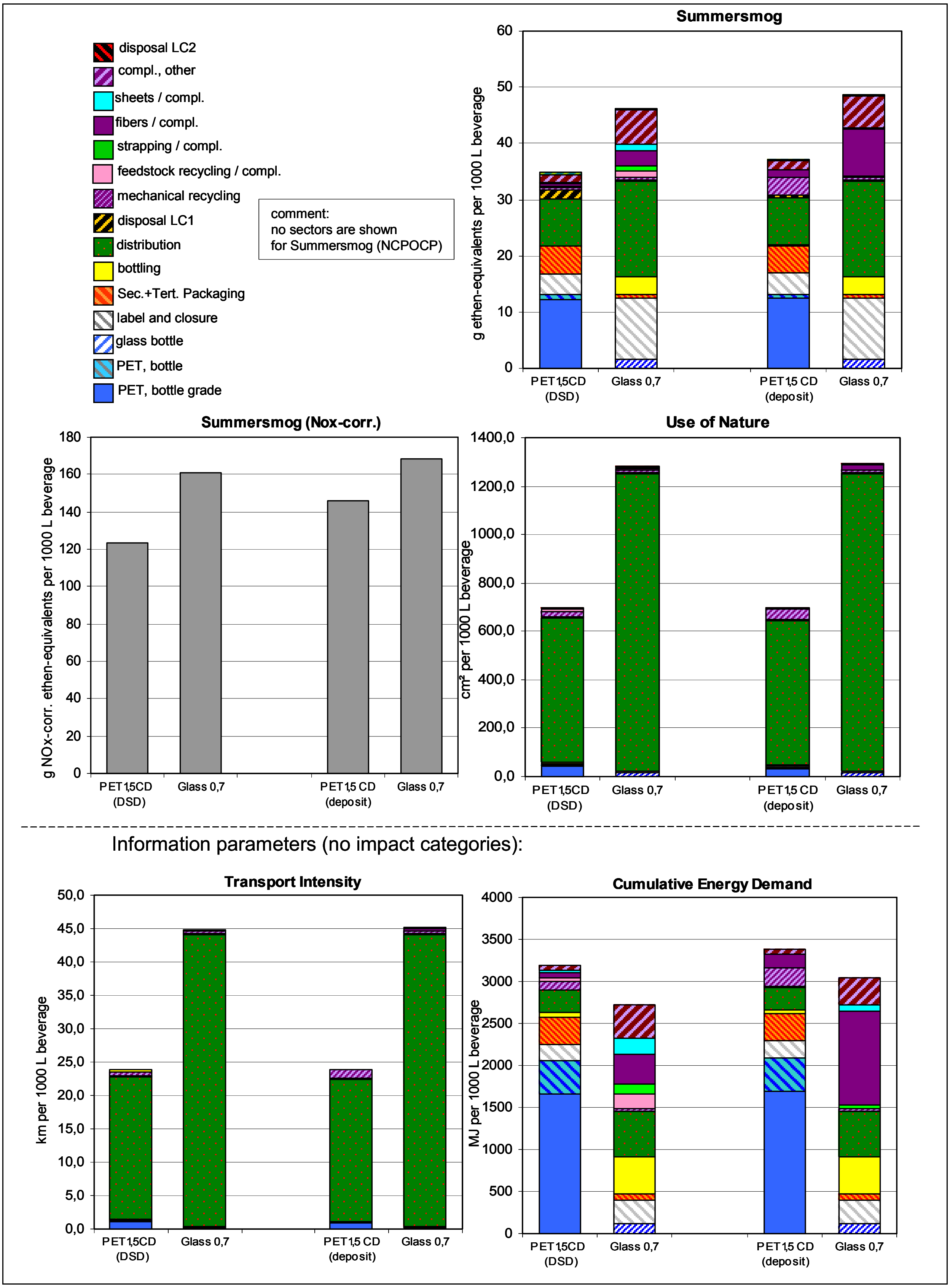
Basically the same is true for the results of the one-way PET bottle system with deposit. The only difference is the relatively large contribution from the mechanical recycling sector which again is dominated by the oversea transport for recycling of baled PET bottles which has been assigned to this sector.

Dominance analysis for refillable glass bottle systems: In the case of the glass bottle systems the most relevant sectors are distribution and filling. Distribution is explicitly dominant for terrestrial eutrification, use of nature and transport intensity. On top of that there is a remarkable influence of the complementary processes on the indicator results of the Ref-Glass-System.

These findings are not restricted to the 1.5-L-PET bottle and the 0.7-L refillable glass bottle as shown in picture 5 but in principal also apply to the other bottle volumes examined.



Picture 5: Dominance analysis for basic scenarios of the 1.5-L PET-OW-System and 0.7-L Ref-Glass-System by DSD route and deposit route each



Picture 5 ff: Dominance analysis for basic scenarios of the 1.5-L PET-OW-System and 0.7-L Ref-Glass-System by DSD route and deposit route each

Normalisation

Normalisation is used to analyse the relative importance of the indicator results in relation to the overall environmental impacts caused in Germany. Normalised results in the present are expressed as so-called person equivalents. One person equivalent represents the statistical impact caused by a single German inhabitant in a reference year comprising all relevant industrial, public and private activities causing the regarded impact.

The normalisation here is a two-step procedure:

1. Indicator results for the functional unit of 1000 litres of beverage are scaled to the overall volume of mineral water and carbonated softdrinks consumed in Germany. This is done individually for each packaging scenario.
2. Results obtained in step 1 are divided by the person equivalent. Again, the result of this operation is the number of person equivalents related to an individual packaging system if all beverage considered was packed in this individual packaging system

Ranking

In order to facilitate the interpretation of results the impact categories applied in this study have been ranked into priority groups (table 4, column 4) having a decreasing environmental priority with increasing numbers. The ranking is based on [UBA 1999] where the impact categories had been classified according to the criteria “environmental vulnerability” and “distance to target”. The ranks are summarized in table 4.

Impact Category	Environmental Vulnerability	Distance to Target	Priority Groups (in this study)
Global Warming	A	A	1
Terrestrial Eutrification	B	B	2
Acidification	B	B	
Aquatic Eutrification	B	C	3
Fossil Resource Consumption	C	B	
Summersmog	D	B	4
Use of Nature (nature proximity class 7)	no rank	no rank	
A: very high > **B**: high > **C**: medium > **D**: small > **E**: very small			

Table 4: Ranking of impact categories applied in this study. Ranks are based on [UBA 1999]

According to the UBA method results can be weighed against each other within the same priority group but not across them. This approach has also been applied in the interpretation step of this study.

Comparison of 1.5-L PET-OW CD and 0.7-L Ref-Glass

Normalised comparative results are shown in picture 6 and 7 separately for the DSD and the deposit route. Picture 6 shows the total person equivalents results. Picture 6 shows the person equivalent results of the one-way PET bottles in relation to the refillable glass bottle. The latter is the zero line. Positive bars indicate an advantage, negative bars indicate a disadvantage of the one-way PET system.

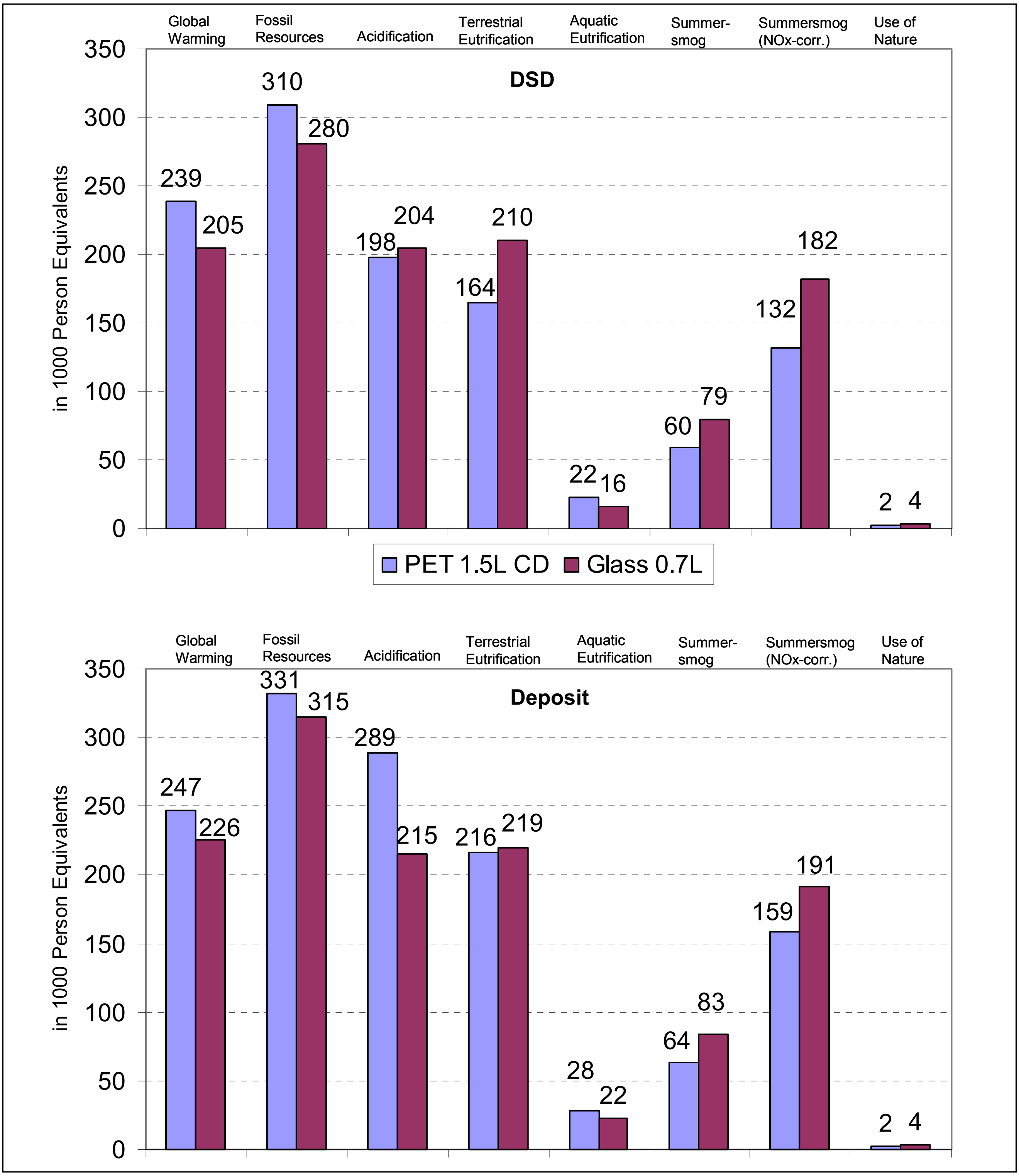
1.5-L PET bottle system with DSD collection route

The results of one-way PET bottle system with DSD collection are structured and described with the help of the previously named priority groups (also see picture 6 and 7):

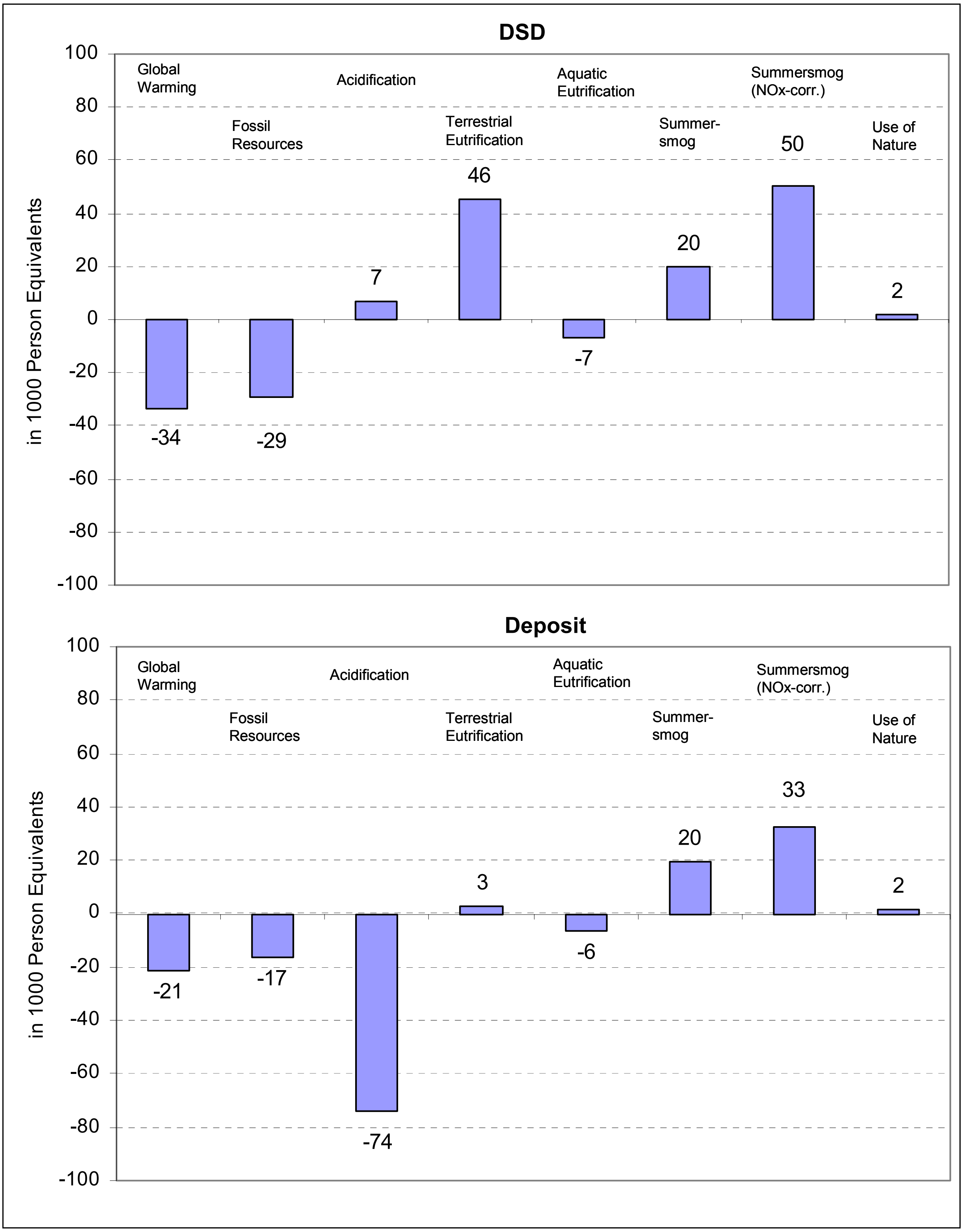
1. For global warming there is a difference of 34,000 person equivalents in favour of the refillable glass bottle system which corresponds to an advantage of 14 % over the one-way PET bottle system in this category
2. For acidification and terrestrial eutrification there is a difference of 7,000 person equivalents and 46,000 person equivalents respectively in favour of the one-way PET bottle system which corresponds to an advantage of 3 % and 22 % respectively over the refillable glass bottle system in these categories
3. For aquatic eutrification and fossil resource consumption there is a difference of 7,000 person equivalents and 29,000 person equivalents respectively in favour of the refillable glass bottle system which corresponds to an advantage of 32 % and 9 % respectively over the one-way PET bottle system in these categories
4. For summersmog there is a difference of 50,000 person equivalents in favour of the one-way PET bottle system which corresponds to an advantage of 27 % over the refillable glass bottle system in this category

- For use of nature (class 7) there is a difference of 2,000 person equivalents in favour of the one-way PET bottle system which corresponds to an advantage of 50 % over the refillable glass bottle system in this category

Priority groups 1 and 3 speak in favour of the refillable glass bottle system whereas priority groups 2 and 4 speak in favour of the one-way PET bottle system. Based on this an overall environmental advantage of one of both systems cannot be derived.



Picture 6: Normalised results (expressed as person equivalents) of the 1.5-L PET-OW-System and 0.7-L Ref-Glass-System by DSD route and deposit route each.



Picture 7: Normalised relative results (expressed as person equivalents) with the 0.7-L refillable glass bottle system being the baseline (zero line).

1.5-L PET bottle system with deposit based collection

The results of one-way PET bottle system with deposit based collection are structured and described with the help of the previously named priority groups (also see picture 6 and 7):

1. For global warming there is a difference of 21,000 person equivalents in favour of the refillable glass bottle system which corresponds to an advantage of 9 % over the one-way PET bottle system in this category
2. For acidification - **in contrast** to the results for the DSD route - now there is a difference of 74,000 person equivalents in favour of the refillable glass bottle system which corresponds to an advantage of 26 % over the one-way PET bottle system in this category. For terrestrial eutrification the difference is only 3,000 person equivalents in favour of the one-way PET bottle system 22 % which corresponds to an advantage of 1 % over the refillable glass bottle system in this category
3. For aquatic eutrification and fossil resource consumption there is a difference of 6,000 person equivalents and 17,000 person equivalents respectively in favour of the refillable glass bottle system which corresponds to an advantage of 21 % and 5 % respectively over the one-way PET bottle system in these categories
4. For summersmog there is a difference of 33,000 person equivalents in favour of the one-way PET bottle system which corresponds to an advantage of 18 % over the refillable glass bottle system in this category

- For use of nature (class 7) there is still the same difference of 2,000 person equivalents in favour of the one-way PET bottle system which corresponds to an advantage of 50 % over the refillable glass bottle system in this category

Here we find a decisive change in the results of priority group 2. By combining the results of acidification and terrestrial eutrification within this group the refillable glass bottle system gains advantage. Thus priority groups 1, 2 and 3 now speak in favour of the refillable glass bottle system, with only priority group 4 in favour of one-way PET. Based on this an overall environmental advantage of the refillable glass bottle systems can be stated.

In order to test the reliability of these findings a series of sensitivity analyses were performed. In the following only the sensitivity of distribution data will be described in more detail. Sensitivity analysis also will be addressed in the conclusions and recommendations chapter.

Sensitivity analyses on distribution data: 1.5-L PET bottle system with DSD collection

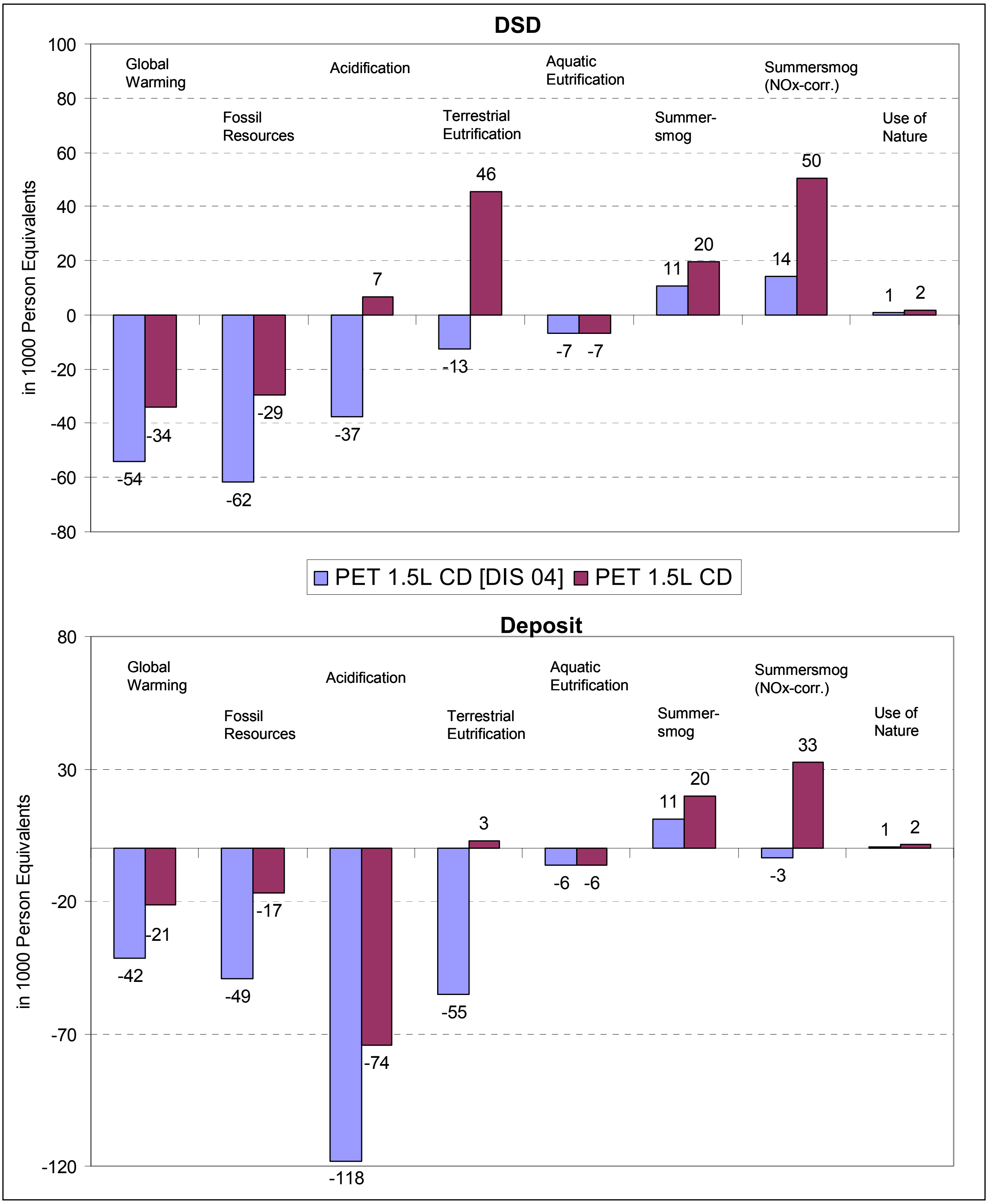
The results of one-way PET bottle system with DSD collection are structured and described with the help of the previously named priority groups (also see picture 8):

1. For global warming there is an increased difference of 54,000 person equivalents in favour of the refillable glass bottle system
2. For acidification and terrestrial eutrification results now are reversed. There is now a difference of 37,000 person equivalents and 13,000 person equivalents respectively in favour of the refillable glass bottle system
3. For aquatic eutrification and fossil resource consumption there is a difference of 7,000 person equivalents and 64,000 person equivalents respectively in favour of the refillable glass bottle system
4. For summersmog there is still a difference of 14,000 person equivalents in favour of the one-way PET bottle system

- For use of nature (class 7) there is still a difference of 1,000 person equivalents in favour of the one-way PET bottle system

With the distribution situation examined here there is a clear advantage of the refillable glass bottle system in priority group 2. Thus priority groups 1, 2 and 3 now speak in favour of the refillable glass bottle system. This situation in the scenarios with deposit based collection applies even to priority group 4.

The influence of the implementation of assumed current distribution logistics is considerable as it would result in an overall environmental advantage of the refillable glass bottle systems.



Picture 8: Sensitivity analysis with respect to distribution data. Normalised relative results (expressed as person equivalents) with the 0.7-L refillable glass bottle system being the baseline (zero line).

Conclusions

The present LCA study with its defined boundaries showed that the environmental impact profiles of both the expanded one-way PET and the refillable glass bottle systems are strongly influenced by the assumptions related to collection and recovery of used packaging materials as well as the distribution logistics. The implications of these aspects and some relevant additional findings of the study can be structured and summarized in the following statements which particularly apply to the packaging systems for “home consumption”:

- Under the conditions of a source separated kerbside collection of PET-OW bottles there is no clear environmental advantage for either of both packaging systems
- Under the conditions of a deposit based collection system and a shipping of baled bottles to the Far East for recycling there is a clear environmental advantage for the refillable glass bottle system. This is mainly due to the transport efforts involved and partly also to the less strict emission standards in the Far East.
- The environmental advantage of the refillable glass bottle systems over the deposit based one-way PET bottle systems would disappear if recycling of one-way PET was to happen in (EU) Europe.
- A distribution situation with relative shorter distances for refillable glass bottle systems and relative larger distances for the one-way PET bottle systems – as assumed to be the case in the current distribution practice in Germany – shows environmental advantages of the refillable glass bottle systems independently from the collection and recycling routes chosen in the one-way PET bottle systems.
- Sensitivity analyses concerning minimum and maximum values for bottle size, bottle weight as well as energy consumption in PET preform and bottle production showed that bottle weight in particular is a parameter with relevant influence on the results of the one-way PET bottle systems. However, the overall findings listed under the preceding headings proved to be robust even when minimum and maximum values were applied.
- Regarding the packaging systems related to the “away from home” consumption clear environmental advantages of the 0.5 L refillable glass bottle and slight advantages of the 0.33 L refillable glass bottle over the 0.5 L one-way PET bottle can be found.

If the comparative LCA results are traced back to the level of inventory data the importance of NO_x and partly SO_2 must be highlighted. Here one should take into consideration that NO_x emission factors of transport had been systematically underestimated in the past. On the other hand, the new virgin PET dataset developed in the context of this study is associated with significantly smaller NO_x and SO_2 emissions than the datasets publicly available. Both points imply advantages for the one-way PET bottle systems.

The NO_x issue is also the reason why beverage distribution logistics and transport of collected PET bottles are so sensitive for the LCA results obtained here. Consequently, for more straightforward conclusions a reliable and representative picture of the current distribution situation would be required.

Recommendations

The following recommendations are directed to the three target groups of the study.

Recommendations to political decision makers

The LCA study showed that an understanding of the surrounding conditions is relevant in order to avoid misinterpretation in view of the complex picture of results obtained in this particular study. When interpreting the results of the present study political decision makers should take into consideration that

- due to technological innovations in the PET production, reduced PET bottle weights and increased mechanical recycling of used PET bottles the overall ecological differences between refillable glass bottle systems and one-way PET bottle systems have become smaller
- the assumptions related to the logistics of beverage distribution is currently the most relevant aspect in the decision as to whether refillable glass bottle systems score environmentally better or not than one-way PET bottle systems
- a mandatory deposit as such not necessarily leads to ecological advantages if the recovery chain is not included in the political control mechanism. The current PET recovery in the Far East causes even clear disadvantages
- NO_x emissions must still be regarded as a political action point given the importance of this individual parameter for the overall LCA results

Recommendations to consumer and environmental organisations

Basically all points made above also apply for this target group as it is involved in political decision processes in a way. However, there is an important additional aspect: for this target group the consumption of refillable beverage container systems has traditionally been symbolic for environmentally friendly consumer behaviour.

Nevertheless, while consumer and environmental organisations have to communicate clear and simple messages to the public on the one hand they should not disregard the complex information obtained by LCA on the other hand. Aspects to be focused upon here are:

- Relevance of transports

  The environmental relevance of transports is clearly indicated in the context of this study and highlights the potential improvements achievable through minimisation of transports. Especially refillable glass bottle systems loose their environmental benefits when distributed over large distances

- Relevance of high value mechanical recycling

  A high value mechanical recycling of all packaging materials is an important environmental feature. Particularly for one-way packaging systems it is a precondition for being environmentally comparable to refillable packaging systems

- Relevance of surrounding conditions and assumptions

  Communication strategies should include sufficient details on the surrounding conditions of the LCA study like e.g. the assumptions on distribution or the different recovery routes examined. This helps interested consumers and environmentalists to judge the environmental position of refillable glass bottle systems and one-way PET bottle systems from the more holistic LCA point of view.

Recommendations to stakeholders in the PET supply chain

It is the task of the stakeholders in the PET supply chain to further optimize the overall system from an ecological point of view. The assessment of potential options for optimization has not been a priority goal of the study but related information can be deducted from the sensitivity analyses performed.

- Reduction of PET bottle weight

  The baseline of the LCA was the respective average bottle weight, e.g. in case of the one-way 1.5-L PET bottle 36.5 g (carbonated drinks) and 33.5 g (non carbonated drinks) have been assumed. The assessment of minimum and maximum weight figures showed that bottle weight is a relevant parameter for LCA results of the overall one-way PET bottle system.

  The one-way 1.5-L PET bottle has its minimum weights with 34.5 g (carbonated drinks) and 28 g (non carbonated drinks). It is recommended to use reduced bottle weights throughout the market for waters and soft drinks to further improve the environmental profile. This measure would also directly reduce the PET raw material demand and thus improve the economic balance as well. The existence of rather high bottle weights of 47.0 g (carbonated drinks) and 36.0 g (non carbonated drinks) indicates that some fillers and retailers have homework to do. In these cases a further reduction of bottle weights is indispensable.

- Optimised recovery of PET bottles

  The study showed that short transport distances within the PET recovery chain are an important component of environmentally sound PET recycling. In this aspect the shipping of baled PET bottles to the Far East has an obvious adverse effect. It counteracts the potential environmental improvement of increased mechanical recycling of PET bottles which has been achieved by collection of used bottles through a mandatory deposit system.

  An increase of recycled content in PET bottles does not change the overall environmental profile when under an expanded system boundary regime the benefits of all recycling outlets are taken into account. If however PET bottles are seen as a stand-alone segment, then Bottle-to-Bottle recycling is an interesting option for improvement of the whole PET bottle system from an environmental point of view. Effort should be put in maintaining the success which has been achieved in B-t-B in Germany.