ENVIRONMENTAL EFFECTS OF DIFFERENT PACKAGE SYSTEMS FOR FRESH MILK

O.C.L. Mekel
G. Huppes

Computer Assistance and Data Check:

R. Huele
J.B. Guinée

Centre for Environmental Studies
Leiden University
P.O. Box 9518
2300 RA Leiden
The Netherlands
../(0)71/277461

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PREFACE

This study has been commissioned to the Centre for Environmental Studies by General Electric Plastics Netherlands B.V. Three months of working time were planned. In the process of executing the study we, the researchers, revised our initial objective which was to specify the environmental effects of the polycarbonate milk bottle and compare the results to existing studies on other milk package systems. When executing the study we ran into so many problems that no significance could be attached to such a comparison.

Therefore we revised our objective and developed a compatible analysis for a polycarbonate bottle with 50 and 75 trips, for a glass bottle with 20 and 30 trips, and for the gable top one trip carton package, all for fresh milk. Data were gathered in a similar manner for all types of packages, including those for transport systems, washing, waste handling and recycling and energy re-use at waste burning.

We, the authors, are confident that the results now are quite robust, based on the method used. Only major changes in main processes may change the outcomes significantly. However, due to the little time available the documentation of the data is not yet up to the standards we would like to adhere to. But all basic data are given in full detail however and checks against other sources, the ones used and other ones, can be made. We hope that in projects to come improvements in this respect will be made possible.

Reasons for caution in using the results remain. The method used is not fully specified. It is incomplete in some important environmental respects like climate change, ozone layer depletion, eutrophication, risk of accidents, noise, and resource depletion. Its foundations are disputed by some because all effects depending on specific locations have been omitted. And, finally, what we estimate to be minor empirical flaws might by others be seen as essential data that is missed.

Special thanks go to Ruben Huele, who further improved on the software developed at the CML for making ecoprofiles, and to Jeroen B. Guinée, for his assistance in finding and especially checking and interpreting data on processes in the literature. Also several people at GEP Bergen op Zoom gave their assistance in getting together relevant facts. Remaining lapses and omissions of course are our own responsibility.

CML, Leiden, september 1990, Odile C.L. Mekel
Gjalt Huppes

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SUMMARY AND CONCLUSIONS

Aim

In this study the environmental impacts of different milk package systems for pasteurized milk are analysed. In the future new package systems will be introduced such as lighter refillable glass bottles and refillable polycarbonate bottles. This study is focused on these new package systems and extra attention is given to the polycarbonate bottle. One litre fresh milk packages are treated, based as far as possible on production and distribution conditions in the Netherlands. The specifications of the packages that are studied are listed in table 1. For the refillable milk bottle systems different trip rates are assumed: the trip rate of polycarbonate bottles is assumed to be 50 or 75; for 480-gramm glass bottles it is 20 or 30 trips.

For each package system some elements in the total system are variable, like cap- and labelling systems and transit packs (crates etc.).

Table 1 Specification of elements of fresh milk package systems

	PACKAGE		
Specification	coated carton	glass bottle	polycarbonate bottle
PACKAGE			
board (g)	25.3	-	-
coating (g)	3.2	-	-
glass (g)	-	480	-
polycarbonate (g)	-	-	70
Total weight (g)	28.5	480	70
Number of trips	1	20/30	50/75
CAP (one-way)			
aluminium (g)	-	0.25-0.3	0.25-0.3
polyethylene (g)	-	4.0	4.0
Twist-off (g)	-	4.35	4.35
LABEL (one-way)			
paper (g)	-	1.72	1.72
polyethylene (g)	-	1.5-2.0	1.5-2.0
TRANSIT PACKAGING			
roll-in container (kg) (160-litres; 750 trips)	20	-	20
polyethylene box (kg) (20-litres; 500 trips)	2	-	2
polyethylene crate (kg) (12-litres; 500 trips)	-	1.98	-

As closing and labelling systems of refillable bottles can vary, several existing cap-systems and labelling-systems are analysed. For final comparison between package systems the environmentally optimal one is chosen, one for both bottle types.

Polycarbonate bottles and carton packages can use the same transit packs. For distribution to supermarkets roll-in containers are used mainly; for smaller shops the milk is delivered in polyethylene boxes. Glass bottles are assumed to be distributed in polyethylene 12-litre crates.

Method

In the integral analysis of the milk package systems the entire life cycle of the products is considered: the extraction of raw materials, manufacturing of the product, product usage, processing of discarded products and processing of waste from all stages. The environmental effects of these phases are ascribed to the functional unit of the packaging of a thousand litres of milk.

The environmental impact of the milk package systems is evaluated based on three main aspects:

1) the use of raw materials, especially fossil fuels;
2) pollution of the environment by the emission of potentially hazardous substances (including emissions due to energy consumption);
3) the generation of final waste.

With respect to the raw materials only the fossil fuels are evaluated in this study and expressed in megajoules (MJ). The emissions of environmentally hazardous substances are related to their toxicity and acidifying effects; thus the emissions have been divided by media-related and substance-oriented standards, totalled and expressed in UPA (Units Polluted Air) and Acidification Equivalents (AE) and UPW (Units Polluted Water). For air the media-related standards of Dutch MAC-values (Maximum Acceptable Concentration on the shop floor) are used; the Acid Equivalents are derived from the Program for the Prevention of Acidification. For water emissions the SWD-standards (Surface Water intended for Drinking, EG-Standards) are used as media-related norms. Final waste is expressed in the model in units of mass, without specifying the space required for landfill.

Effects of emissions on the ozone layer on climate and on eutrophication have not been specified yet. Neither are purely local effects, safety and health aspects at the working place or risk of accidents included in the ecoprofiles.

The main environmental categories quantified (fossil fuels, air and water pollution, acidification and final waste) are not weighted into one final overall score. This means that for example the consumption of fossil fuels is not compared to emissions to the air. Only when a package system scores positive or negative in all categories an overall comparative assessment can be given.

One main methodological question is how to treat the recycling of waste. First, if waste is recycled then no final waste will be generated by the process itself. This recycled material still has an economic value as a secondary raw material. Considering the production of the material as a whole, the overall production of the primary material will be reduced by recycling. Depending on the economic value of the recycled waste the input of the primary production for the milk package or parts thereof could be reduced proportionally. A rough measure on relative economic value has been used in classes of 75%, 50% or 25%. The negative environmental effects due to processing for recycling are assumed to be included in the deduction percentages implied. One special case of re-use is the burning of waste in incinerators. The electricity produced there is delivered to the general grid. The environmental effects of not producing this electricity for the grid in the usual dutch installations is deducted for 100% from the environmental account of the product investigated.

Another methodological question is how to treat capital goods. We now specify only the roll-in container and the crate. In principle depreciation and maintenance should be fully attributed to each package system. When improving on the current results priority should be given to specify the truck for milk transport and all non-durable parts in fixed installations like conveyor belts.

Data

The environmental data of the production of polycarbonate have been supplied by the Dutch polycarbonate industry and have been checked by the independent agency B&G, see appendix 1. The data of the production processes of substances which are not manufactured by the polycarbonate industry itself, could not be traced adequately. Only for the production of acetone and phenol the raw material consumption and process energy could be estimated.

The environmental data for the production of glass have been supplied by the Dutch glass industry. These data are not checked by the agency B&G, but are compared to a Swiss study which is also given. The environmental data for the production and manufacture of milk cartons are derived from a Swedish study by a carton manufacturer. These data incorporate the production, manufacture and transport. The data for other production processes of materials are derived mainly from Swiss studies and previous CML-studies.

The data of the cleaning of the refillable bottles are derived from a German study and information from dairies. Filling of the packages is not considered for lack of accurate data. This does not seem to be an important factor, nor does it discriminate between package systems.
With all numbers of trips occurring, ranging from 20 to 75, it is assumed that equal amounts are discarded at households and dairies respectively.

The distribution of the milk and transport of empty refillable bottles is analysed using our own model developed for the Netherlands. No storing by retailers and handling by consumers is taken into account. Glass bottles would have relatively large effects here due to their weight on transport and the increased cooling space required for them.

The processing of household waste is assumed to be 40% incineration and 60% landfill. The incineration percentage is increasing. The emissions that occur on incineration of substances are not yet considered. No deduction has been made for evaporation of water when burning water soaked cartons.

For many basic processes data are lacking on the waste produced at mining. The lacunae in the data are described further in the main text and in appendix 3 and 4.

Findings

The findings will first be described in seperate parts with results for the elements of :

- life cycle of the main materials of the bottles and cartons (without caps and labels, but including transport) (table 2);
- life cycle of cap systems (table 3)
- life cycle of labelling systems (table 4)
- life cycle of transit packages (table 5).

The overall results, the ecoprofiles, of five different functional units of milk package systems are given in table 6.

Table 2 Environmental effects of different life cycles of milk package materials per 1000 litres packed milk, including manufacture, distribution of milk, washing of the bottles and waste processing. For glass in brackets the Swiss data are given.

		polycarbonate		*glass 480 g*			*milk*
		50 trips	*75 trips*	*20 trips*	*30 trips*		*carton*
Fossil energy resources	*MJ*	*282*	*256*	*431*	*373*	*(370)*	*530*
UPW	*dm^3*	*2.54*	*2.09*	*2.04*	*1.78*	*(5.79)*	*32.6*
UPA	*m^3*	*11.7*	*11.4*	*24.6*	*20.9*	*(32.3)*	*61.5*
AE	*ha*	*0.351*	*0.341*	*0.983*	*0.786*	*(0.693)*	*3.78*
Waste	*kg*	*0.752*	*0.587*	*6.41*	*4.37*	*(7.90)*	*18.1*

UPW= Units Polluted Water; UPA= Units Polluted Air; AE= Acidification Equivalents

In table 2 the environmental effects of the life cycle of different milk packages are given, taking into account only the main material of the package considered. However data on milk transport and washing are included. For polycarbonate and glass two more pessimistic trip-rates are also given for comparison. For glass bottles the environmental effects at 30 trips according to a Swiss study are listed in brackets.
Both bottles score better than the carton because of recycling possibilities for discarded bottles. In this study it is assumed that at the end of the life cycle 50% of the glass bottles will be discarded at the dairies and return to the glass industry where new bottles are manufactured. Twentyfive percent is subtracted for the recycling process. Another 25% of all bottles discarded by consumers is put into glass containers. These give a net lower value glass which is valued at 25%. Polycarbonate bottles which are discarded at the dairies cannot be recycled into new milk bottles, but in other high quality non-food products. A reduction of

75% on primary production of polycarbonate is assumed per kilogram recycled material. Recycling of polycarbonate from households is not assumed.

Caps

In table 3 the environmental effects of several cap systems are listed.

Table 3 Environmental effects of different life cycles of cap systems for milk package systems per 1000 litres packed milk.

		aluminium	*polyethylene*	*Twist-off*
Fossil energy resources	*MJ*	*52.9*	*64.2*	*92.3*
UPW	dm^3	*0.0525*	*1.04*	*17.0*
UPA	m^3	*9.96*	*0.156*	*15.2*
AE	*ha*	*0.56*	*0.00094*	*0.147*
Waste	*kg*	*3.94*	*0.238*	*14.5*

UPW= Units Polluted Water; UPA= Units Polluted Air; AE= Acidification Equivalents

The twist-off cap scores the worst of all considered cap systems on the pollution of water, air and generated waste. Only on Acidification Equivalents (AE) can the Twist-off cap compete with the aluminium cap. The aluminium cap scores lower than the polyethylene cap on consumption of fossil energy resources and emissions to water. This means that it cannnot be stated that either the aluminium cap or the polyethylene cap has a better environmental impact. The choice is not made on environmental grounds but on transport and consumer grounds. The polyethylene cap is strong enough to put several bottles directly on one another and it can be reclosed after partial consumption.

Labels

It is likely that in the future the refillable milk bottles will be labelled. In table 4 the environmental effects of two types of labelling systems are listed.

Table 4 Environmental effects of different life cycles of labelling systems for milk package systems per 1000 litres packed milk.

		paper label	*polyethylene label**	
Fossil energy resources	*MJ*	*72.7*	*51.5*	
UPW	dm^3	*11.5*	*0.808*	
UPA	m^3	*2.65*	*0.176*	
AE	*ha*	*0.0667*	*0.00998*	*0.01*
Waste	*kg*	*1.04*	*0.0157*	

UPW= Units Polluted Water; UPA= Units Polluted Air; AE= Acidification Equivalents

* 50 trips assumed

The polyethylene label scores better than the paper label on all evaluation aspects. Therefore the polyethylene label is chosen for further computations. Another reason for this choice of label on the polycarbonate bottle is that the glue on the polycarbonate makes high quality recycling expensive or impossible.

Transport packages

In table 5 the environmental effects of the life-cycle of the transit packages are listed.

Table 5 Environmental effects of the life cycles of milk package transit systems per 1000 litres packed milk.

		roll-in container	*polyethylene box/crate 2 kg 20 liters*	*polyethylene crate 1.98 kg 12 liters*
Fossil energy resources	*MJ*	*3.57*	*2.55*	*4.30*
UPW	*dm^3*	*0.510*	*0.040*	*0.0673*
UPA	*m^3*	*0.546*	*0.0089*	*0.0149*
AE	*ha*	*0.006*	*0.0005*	*0.000847*
Waste	*kg*	*0.505*	*0.0002*	*0.000339*

UPW= Units Polluted Water; UPA= Units Polluted Air; AE= Acidification Equivalents

For glass bottles there is no choice; only the 12 bottle crate is applicable. For transport reasons (a factor not included in this analysis but in that of the main material of the bottle, see table 2) the choice is made for the roll-in container for polycarbonate bottles and cartons although its environmental effects are worse in all quantified respects.

Package systems defined

All the values listed in the tables 2-5 can be linked at various ways for the package systems. Three combinations have been chosen. Other combinations can easily be made and analysed.

The environmental impact of following combinations are listed in table 5.
1) refillable polycarbonate bottle (70 gram) at 50 and 75 trips, polyethylene cap (4 gram) and label (2 gram) and roll-in container as transit package;
2) refillable glass bottle (480 gram) at 20 and 30 trips, polyethylene cap (4 gram) and label (2 gram) and polyethylene crate (1.98 kg) as transit package;
3) *milk carton (28.5 gram) with roll-in container as transit package.*

Ecoprofiles

The environmental impacts of the functional units as defined give the ecoprofile. These are the main result of the study. They should be interpreted with all the precautions stated.

Table 6 Ecoprofiles of the functional units (1000 litres packed milk) of five different milk package systems. In brackets the glass production data of Switzerland (at 30 trips) are given.

		polycarbonate		glass 480 g			milk carton
		50 trips	75 trips	20 trips	30 trips		
Fossil energy resources	*MJ*	366	353	552	494	(663.9)	534
UPW	dm^3	4.90	4.46	3.97	3.70	(9.61)	33.1
UPA	m^3	11.2	11.3	24.9	21.3	(28.61)	62.0
AE	*ha*	0.304	0.319	1.0	0.806	(0.69)	3.78
Waste	*kg*	1.37	1.26	6.68	4.63	(6.95)	18.6

UPW= Units Polluted Water; UPA= Units Polluted Air; AE= Acidification Equivalents

Evaluation

The overall assessment shows the polycarbonate package system to be superior to the carton gable top system in all quantified environmental respects. However, the data on emissions by production of board and paper as supplied by the producer seem somewhat outdated.
The glass bottle system is superior to the carton pack in nearly all respects. It scores worse only in the amounts of fossil energy resources extracted, only at the lower trip rate of 20.
The comparison of the glass bottle system to the polycarbonate system shows the latter to be more attractive in four environmental respects, with only water pollution slightly higher than that of the glass system.

There seems to be a slight bias in missing data against the glass bottle alternative.

One important factor in the lower energy use of the gable top is an asymmetry between production and waste processing. Production of first wood and then board and paper takes place in Sweden with little energy consumption, which, moreover, is supplied mainly by water turbines and nuclear power (together 97%) which do not require fossil energy. Waste processing in incinerators, at the other end of the life cycle, is assumed to replace electricity generation in the Netherlands based mainly on fossil fuels. This amount of fossil fuels is subtracted from primary energy extraction.
Similarly the polycarbonate system is improved in pollution respects by burning polycarbonate in household waste and subtracting emissions there, while at production many emissions from the refining industry and the chemical industry are, not yet, included.

The number of trips does not seem to influence the environmental effects substantially. This is due to the increased recycling of waste when the trip number goes down and to the preponderance of trip independent elements as a sources for environmental effects. Peculiar is the very slight increase in air pollution from the polycarbonate system if the number of trips goes up. This effect is due to the decrease in incineration of polycarbonate with higher trip numbers.

Missing data seem to have a slight bias against the glass system.

Conclusions

Based on the data and method used the main conclusion is that the polycarbonate package system for fresh milk is to be preferred to the carton gable top in all quantified environmental respects. This conclusion holds for a broad range of trip numbers assumed.

Further, also the refillable glass bottle systems seem to have a considerable lower environmental impact than the one-way milk carton. Only the amount of fossil energy required is similar.

Finally, if more household waste is going to be burned, as planned, and the efficiency of electricity production at incinerators is improved, a systematic difference in effects on package system may be expected. The scores of the carton system will improve substantially, the scores of the polycarbonate system moderately and those of the glass system not at all.

- INTRODUCTION
- METHOD OF INTEGRAL ANALYSIS OF ENVIRONMENTAL EFFECTS OF PRODUCTS
- DESCRIPTION OF THE LIFE CYCLE OF DIFFERENT MILK PACKAGE SYSTEMS
- FINDINGS AND CONCLUSIONS

1 INTRODUCTION

1.1 Aim of the study

In this report an integral analysis and evaluation is made of the environmental effects of alternative packages for fresh milk, with special attention to a possible alternative made of polycarbonate.

In the Netherlands several milk package systems are on the market and some new ones will be introduced in the near future.
Currently (1990) most of the fresh milk is packed in polyethylene (PE)-coated cartons. A smaller part of the total fresh milk is sold in an old model refillable glass bottle (weight ± *600* gram). In table 1.1 the market shares over the years of milk packaging systems in the Netherlands is given.

Table 1.1: Packaging of milk and liquid milk products in the Netherlands in percentages.

	glass	carton	one-way plastic	loose
1970	71	14	12	4
1975	46	39	14.3	0.7
1980	32.4	54.3	12.9	0.4
1985	21.2	69.5	9.1	0.2
1987	17.4	73.3	8.8	0.5
1988	15.7	76.6	7.4	0.3

(Source: Produktschap Zuivel (1989) after Jansen e.a., 1989)

New package systems may be introduced in the near future such as lighter refillable glass bottles and refillable polycarbonate bottles. This report focusses on these new package systems with special attention given to the polycarbonate bottle.

The aim of this study is to analyse the environmental impacts of the refillable polycarbonate milk bottle and compare these with the environmental effects of milk cartons and refillable glass bottles. Only one litre packages are treated. Results are based as far as possible on production and distribution conditions in the Netherlands. The packages that are studied are given in Table 1.2.

In the Netherlands an old model glass bottle of 600 grams is mainly used. In the most thorough comparative studies by Lundholm and Sundström and by Franke this glass bottle is not included. This package system is therefore not included in this study. Lighter glass bottles are now being introduced. In this study the heavier version of these lighter bottles will be considered (480 grams) as the lighter bottle might not be suitable for a high number of return trips. Estimates for current heavy bottles *range* from 25 to 40 trips per bottle *(average 32.5 trips)*. It is assumed that the lighter bottles will reach 30 trips. A lower estimate of 20 trips is also considered.
Current coated carton milk packages weigh about 31 grammes (Rijsdorp e.a., *1989*). *In this study a lighter type carton package of 28.5 grammes* is assumed (corresponding to the study by Lundholm and Sundström (1986)).

The distribution of the milk in polycarbonate bottles can be identical to the distribution of milk in gable top carton packages using roll-in containers or polyethylene boxes.

Table 1 Specification of elements of fresh milk package systems

	PACKAGE		
Specification	coated carton	glass bottle	polycarbonate bottle
PACKAGE			
board (g)	25.3	-	-
coating (g)	3.2	-	-
glass (g)	-	480	-
polycarbonate (g)	-	-	70
Total weight (g)	28.5	480	70
Number of trips	1	20/30	50/75
CAP (one-way)			
aluminium (g)	-	0.25-0.3	0.25-0.3
polyethylene (g)	-	4.0	4.0
Twist-off (g)	-	4.35	4.35
LABEL (one-way)			
paper (g)	-	1.72	1.72
polyethylene (g)	-	1.5-2.0	1.5-2.0
TRANSIT PACKAGING			
roll-in container (kg) (160-litres; 750 trips)	20	-	20
polyethylene box (kg) (20-litres; 500 trips)	2	-	2
polyethylene crate (kg) (12-litres; 500 trips)	-	1.98	-

1.2 Design of the report

In chapter 2 the method for the integral analysis of the environmental impact of products is described. In chapter 3 the product life cycle of the considered package systems is described. In this chapter the most important assumptions of this study will be explained. Chapter 4 describes the results of the calculations. The summary and the conclusions are placed at the head of the report.

2 METHOD OF INTEGRAL ANALYSIS OF ENVIRONMENTAL EFFECTS OF PRODUCTS

2.1 *Introduction*

The integral environmental analysis of a product takes into consideration the environmental effects of the entire life-cycle of that product: the extraction of the raw materials, manufacturing of the product, use of the product, processing of discarded products and processing of waste from all stages. Figure 2.1, the Life Cycle of Products for one-litre milk containers shows that environmental effects can occur in all phases of this life cycle. This figure shows both refillable package systems and one-way package systems. The lines to and from bottle cleaning are *irrelevant for one-way milk package systems.*

In this study the considered environmental effects include the following three main aspects:

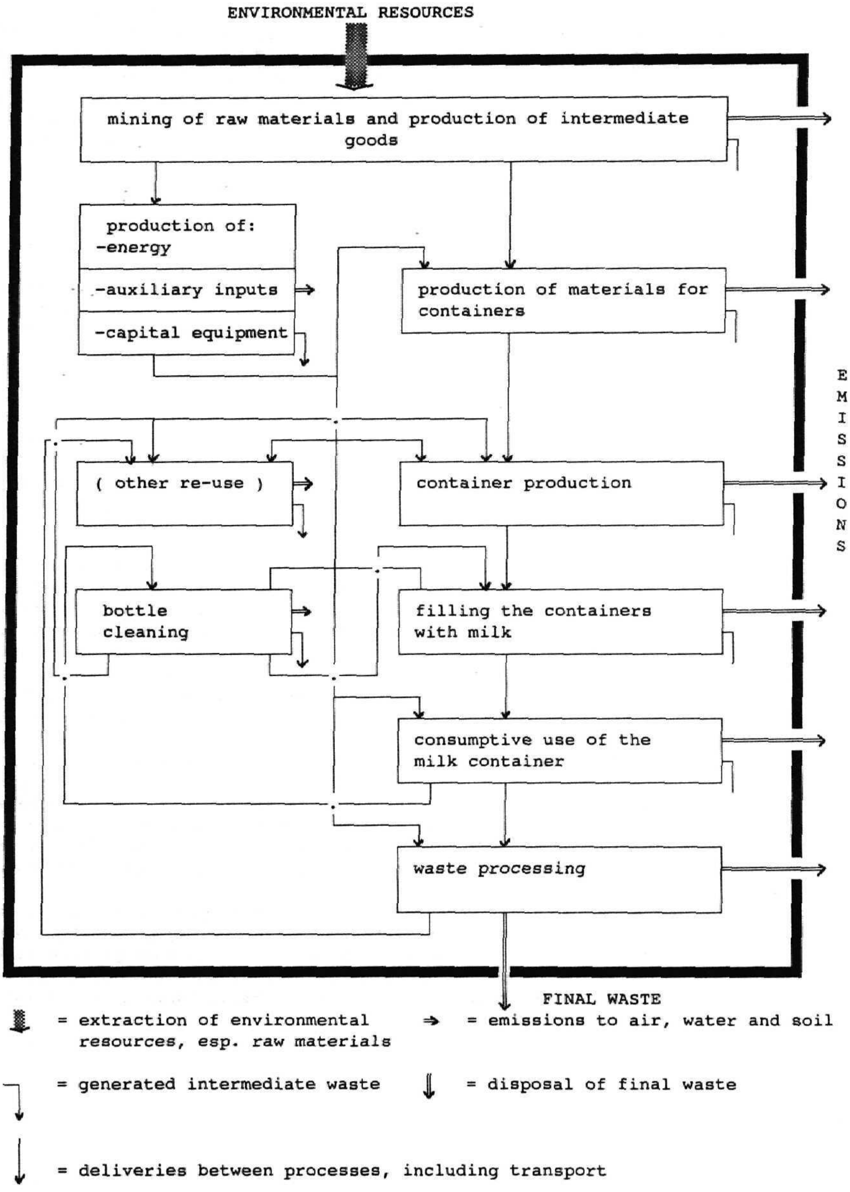
1) the extraction of raw materials (including fuel resources for electricity generation) contributing to their depletion;
2) pollution of the environment by the emission of potentially hazardous substances (including emissions due to electricity generation), leading to several types of environmental problems. The emissions considered are only the emissions to air and to water;
3) *the creation of final waste.*

More location-bound environmental effects such as any direct affects on nature, factory space etc. have not been brought into the analysis, because they are extremely difficult to ascribe to specific products. Another reason for their exclusion is that an overlap with process oriented policies would result. The environmental effects are quantified as far as possible.

One main methodological question is how to treat the recycling of waste. *First, if waste is recycled then no final waste will be generated by the* process itself. This recycled material still has an economic value as a secondary raw material. Considering the production of the material as a whole, the overall production of the primary material will be reduced by recycling. Depending on the economic value of the recycled waste the input of the primary production for the milk package or parts thereof could be reduced proportionally. A rough measure on relative economic value has been used in classes of 75%, 50% or 25%. The negative environmental effects due to processing for recycling are assumed to be included in the deduction percentages implied. One special case of re-use is the burning of waste in incinerators. The electricity produced there is delivered to the general grid. The environmental effects of not producing this electricity for the grid in the usual dutch installations is deducted for 100% from the environmental account of the product investigated.

Another methodological question is how to treat capital goods. We now specify only the role-in container and the crate. In principle depreciation and maintenance should be fully attributed to each package system. When improving on the current results priority should be given to specify the truck for milk transport and all non-durable parts in fixed installations like conveyor belts.

Figure 2.1 Life cycle of one-litre milk containers (refillable- and one-way containers).



The main lines of the method of the integral analysis of the environmental effects of products has been described earlier by Guinée et al (1988) and Rijsdorp et al (1989).

2.2 Data

In order to compare functionally equivalent products in terms of environmental aspects, a large amount of data on processes must first be gathered. This requires that the data about the environmental effects of these processes be known, preferably systematically compiled and processed.
After the process data has been compiled, it must be assigned to the products concerned. The process data is always assigned to "functional units of product" as opposed to "physical units of product". "Functional units of product" refer to the amount of the product necessary to fulfil its specific function. In the case of milk packages the functional unit of product is 1000 litres packed and distributed milk.

Until now information on the environmental impact of milk packages has been available for carton and refillable glass bottles in studies by Lundholm and Sundström (Lundholm and Sundström, 1986) and in a study of Franke (Franke, 1984). The study by Lundholm and Sundström which has been carried out for Tetra Pak has been revised for the Dutch situation by the Dutch institute TNO-CPM. The main text was still in print when closing off this study. Partly our work will overlap with that carried out by TNO.
In this study the following references have served as the most important sources of information.

The process data of the polycarbonate production have been supplied by the Dutch polycarbonate industry (GE Plastics Europe). These data are checked by the independent B&G agency. The comment on these data is seperately given in Appendix 1.

For production and manufacture of the milk carton the study of Lundholm and Sundström (1986) has served as basic data source. Additionally the study of Franke (Franke, 1984) and Golding (Golding, 1989) has been used. The process data for the manufacture of glass have been supplied by the Dutch glass industry and have been compared with data from a study by Thalmann and Humbel (1985). Data on the cleaning of returnable bottles with modern washing machines come from the study of Golding (Golding, 1989) with additional information from a dairy.

2.3 Energy and transport

Different studies pay much attention to the energy demand for the production of materials. Sometimes in the literature the energy content of a product is given, meaning the total embodied energy (combustion energy of the raw material added to the required process energy and transport energy). Energy consumption itself is not an environmental effect, but this consumption requires resources and leads to emissions into the air and water; all relevant environmental important aspects. The input of resources (i.e. oil or coal) is listed separately and also aggregated in MJ. The process energy is the energy required by some processes for the manufacture of a product (like steel, fertilizer etc.). The way the process energy and electricity is generated differs much per country and industry branch.

In the Netherlands the basic chemical industry uses mostly gas as a raw material input for the electricity and steam generation. The communal electricity generators in the Netherlands use 31% coal, 61% gas, 2% oil and 6% uranium as input (Lindeijer et al, in press).

In other studies different mixtures of raw material are used as inputs for the generation of electricity. The Swiss environmental impact studies use the so called "Western World" energy model. In this model, that originated from the American situation, the input of raw materials is 48,2% coal, 23,5% gas, 17% oil and 11,3% other (i.c. water- and nuclear energy) (Thalmann, 1985; Thalmann & Humbel, 1985; Fecker, 1989). In West-Germany the chemical industry uses raw materials for the generation of electricity and steam in following percentages: 60% coal, 25% gas, 8% oil and 7% other energy (Kindler and Mosthaf, 1989). Finally the Swedish environmental impact study of milk cartons uses the Swedish energy model that consists of 41% nuclear power, 56% water power and 3% oil (Lundholm and Sundström, 1986).

The different input mixtures for the generation of electricity and/or steam lead to different emissions to air, water and generated waste. Therefore a choice must be made which energy model to use. In this report the environmental impact of the Dutch milk package systems will be described. Therefore the processes for which it is sure that they take place in the Netherlands, the Dutch energy model will be used. A differentiation is made between electricity generation in the basic chemical industry and in communal power stations. In case of the energy generation for the polycarbonate production, the data of the Dutch polycarbonate industry are used. For the production of raw materials for glass manufacture only Swiss data is available (including the Swiss energy model). The energy consumption for the manufacture of glass is derived from the Dutch glass industry. For the carton production, the energy data of Lundholm and Sundström are used (mixed Swedish and West German model). In Appendix 5 the various energy models and emission factors are listed.

2.4 Evaluation of the environmental effects

Once the environmental effects have been quantitatively ascribed, first to processes and then to products, a quantitative evaluation of the separate environmental effects is made. In this chapter the method of evaluation of environmental effects is briefly described. In Appendix 6 the method is more extensively described in Dutch.

Raw materials

The evaluation model categorizes raw materials according to their energy-content, here only for the raw materials gas, oil and coal. The energy content is defined as the lowest combustion value according to the IFIAS-conventions for attributing energy. In table 2.1 the combustion values of some energy resources and materials are listed.

Table 2.1 Energy content of several materials (Kindler & Nikles, 1980; Blok e.a., 1989).

Fossil fuel	Energy content
natural gas	31.65 MJ/m^3
coal	29.3 MJ/kg
oil	42.3 MJ/kg
diesel	36 MJ/dm^3

Emissions to air and water

Emissions are evaluated as to the potential effects they might have. These effects maybe related to health hazards, acidification, ecotoxicity, eutrophication, ozone layer depletion and global warming. Only the former two have been quantified in this study. Purely local effects, safety and health aspects at the working place and risk of accidents are not included in the ecoprofiles either.

For assessing potential health effects and acidifying effects the emissions have been divided by media-related and substance-oriented standards, and totalled per volume of medium potentially polluted up to the norm. The emissions into the air are expressed in UPA (Units Polluted Air) and Acid Equivalents (AE); the emissions into the water are expressed in UPW (Units Polluted Water). In this way different emissions to air and water for each product alternative can be evaluated because the hazardousness of the substances are related to the norms and therefore to the UPW, UPA and AE.

For air the media-related norms of Dutch MAC-values (Maximum Acceptable Concentration on the shop floor) are used (Nationale MAC-lijst, 1989); the Acid Equivalents are derived from the Progam for Prevention of Acidification (Bestrijdingsplan Verzuring, 1989). For water emissions the SWD-norms (Surface Water intended for Drinking, EG-Standards) are used as media-related norms.

Not all emissions can be aggregated into UPA, AE or UPW for lack of sufficient compartment-related norms of substances. Those emissions will be mentioned separately as so called 'missing' values. Eutrophication, climatical and ozone effects are not considered for the time being.

The norms used have their limitations. Not all MAC-values have been evaluated on carcinogenic properties. In addition these values are drawn up for the maximum acceptable concentration on the shop floor and not for the total environment (ecosystems, etc.). The quantity of air quality guidelines for the total environment is too small to use these values for aggregation of different emissions to air.

Although not all surface water has the destination of drinking water, the guidelines for such surface water is taken into account.

Finally the evaluation method at this time doesn't consider the period of *time in which the potential damage to the environment might occur.*

Waste

Final waste is expressed in the current model in units of mass, without specifying the space required for landfill.

Quantitative evaluation of environmental impacts

Each product alternative can now be evaluated on these five categories. Between these categories (use of fossil energy resources, UPW, UPA, AE *and final waste) no weighting factors have been used. This means that for* example the use of fossil fuels is not compared to acidifying emissions to air. Only when a package system scores positive or negative in all categories, an overall comparative assessment can be given.

In addition to the evaluation, recommendations are given to improve details in the package systems for an improved environmental profile. *The* lacunae in the data used will also be described.

3 DESCRIPTION OF THE LIFE CYCLE OF DIFFERENT MILK PACKAGE SYSTEMS

3.1 Introduction

In this chapter the life cycle of the different milk package systems will be described. The life cycle of the polycarbonate milk bottle will be described more extensively than the other milk package systems. Several capping and labeling systems are possible for refillable bottles. The life-cycles of these elements are described seperately in § 3.5.

The transit packaging (roll-on containers, crates/boxes) can vary too. Milk in polycarbonate or carton is mostly distributed in roll-in containers to supermarkets. For smaller shops the packaged milk is distributed in polyethylene boxes. Glass bottles are always distributed in (12 litre) crates.

3.2 Life Cycle of the refillable polycarbonate milk bottle

3.2.1 Production process of polycarbonate

In figure 3.1 the production process of polycarbonate is shown. The processes between the double lines are carried out by the polycarbonate industry. The polycarbonate resin can be delivered as a powder or as granules. In this report only the granule form is considered. This means that the extrusion process for granules is taken into account.

In the Netherlands polycarbonate is produced under very strict safety conditions, especially for the production of chlorine and phosgene. These processes take place in gas-tightened factories at the site of the polycarbonate production. Thus no transport risks are involved.
In the process specifications in Appendix 2 the input of materials is listed, excluding capital equipment.

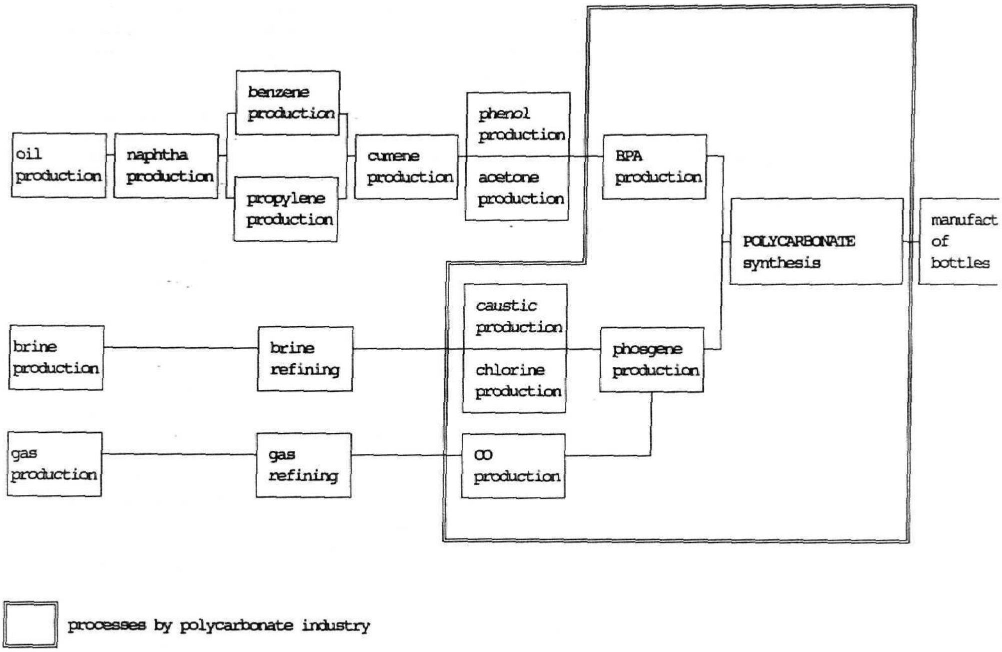
The process energy, steam and electricity, is mostly generated by the polycarbonate industry itself using natural gas as an energy source. Waste from wornout capital equipment is not included.

The substances acetone, phenol and dichloromethane are not manufactured at the polycarbonate industry plant. No specific environmental data on their production processes is available. The use of raw materials for acetone and phenol, however, is estimated by subtracting the input of naphtha from their energy equivalents as given by Kindler and Nikles (1980). Similarly the process energy for manufacture of acetone and phenol is estimated. No further process data on acetone and phenol is available.

3.2.2 Manufacturing of the bottles

The polycarbonate granules are transported to the plastic converter industry where the bottles are manufactured. The environmental effects of the manufacturing of the bottles are determined by the transport distance and the process energy for extrusion blow moulding or injection blow

Figure 3.1 The production process of polycarbonate bottles



moulding the bottles. The electricity for this process is assumed to be delivered by communal electricity generators. Capital goods are not considered. The transport of granulate to the bottle manufacturer is not considered.

3.2.3 Filling and distribution at the dairies

The bottles will be transported to the dairies where they will be filled with milk and sealed with a one-way cap and labelled. The transport of bottles from the bottle manufacturer to the dairies is not considered. The milk is transported to the supermarket in roll-in containers (160 bottles/container; trips 750). The median distance between the dairy and the retailers is assumed to be 40 kilometres. In Appendix 2 the distribution model is described extensively. The transport of the milk is assumed to be in roll-in containers similar to the transport and distribution system of milk cartons. Almost the same number of empty bottles returned as are delivered. No accurate data is available for filling the bottles with milk. The filling is considered to be the same for all package types.

3.2.4 Consumer use and washing of the bottles

At home the consumer will wash the bottle when it is empty. Franke (1984) gives an amount of 2-3 ml milk that is left in the bottle when the bottle is empty. These 2-3 ml will be diluted with the washing water and will be purified by the communal sewer installation. The environmental effects of this does not seem to be a major aspect.
The consumer will return the empty bottle to the shop or supermarket. The empty bottles are then returned to the dairy (see § 3.2.3.). No consumer effects have been included.

At the dairy the bottles are unpacked from the containers and before washing, the remaining caps and possibly labels are removed.
The washing lines for polycarbonate bottles are the same as for glass bottles. This means that the bottles are washed with soda and other detergents. The consumption of soda differs per washing machine. The energy consumption of the washing machines may differ widely too. In this study the technical data of modern washing machines are considered. This means a soda consumption of 0.65 litres 30% NaOH and a energy consumption of 85 $MJ_{th.eq.}$/1000 litres (Golding, 1989). In the final rinsing section of the washing machine the bottles are disinfected with a chlorine solution. According to Jansen et al. (1990) this is 20-40 mg/litre washing water in the final bath section.
The technical data for the washing machines is given for washing moderatly contaminated milk bottles. Several factors can lead to increased soda consumption and electricity consumption like highly contaminated bottles, glued paper labels etc. For washing polycarbonate bottles, the energy consumption could probably be lower due to the lower weight of the bottles and the lower specific heat of polycarbonate. No quantitative data is available at the moment.
In Appendix 2 the technical details of washing milk bottles is described more extensively.

After washing, the bottles are refilled, capped and relabelled.

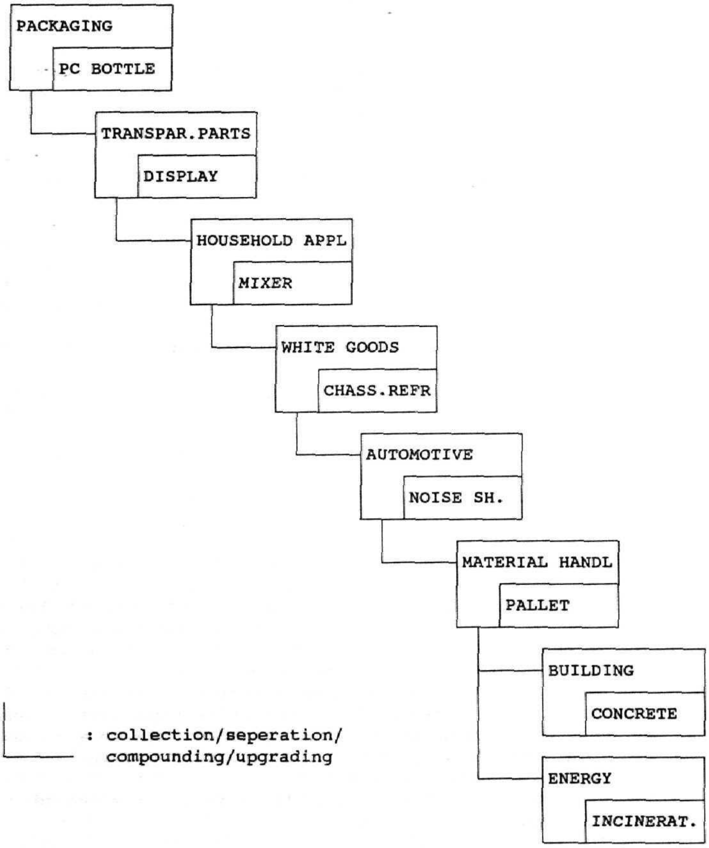
3.2.5 Number of trips

In the United States there is a long experience (15 years) in re-usable polycarbonate milk bottles; 100 trips seem to be common. In Switzerland where 3 litre milk bottles are used, they estimate 75 trips. The number of trips depends on: i) the number of locations where the empty bottles can be returned; ii) the deposit value; iii) the misuse of the bottle by consumers and iv) the strength of the material.
For this study it is assumed that these conditions are optimal. A deposit value of Dfl 1.- is assumed which will minimize negligence losses at households. The polycarbonate industry gives 75 trips as a reasonable estimate. For 1000 litres packed milk 13.3 new polycarbonate bottles are needed and the same number is discarded.
For comparison a lower estimate of 50 trips is also considered. Then 20 bottles are required for 1000 liter.

3.2.6 Disposal and waste processing of polycarbonate bottles

Before and after the washing, the bottles are inspected optically and with sniffers. The bottles with bad esthetics are sorted out and grinded into granules at the dairy. Fifty percent of the 13.3 bottles are assumed to be discarded this way at the end of their life-cycle. These granules are returned to the polycarbonate industry and used for high quality non-food products made from polycarbonate. In Figure 3.2 the so called polycarbonate cascade is shown. This study does not consider the environmental impact of this cascade; the environmental effects must be considered for the next product cycle itself. The environmental effects of the process energy for grinding the bottles into granules and the transport of the granules is of interest but not considered for lack of data. A

Figure 3.2 The polycarbonate cascade (source: GEP, revised)



deduction of 25% on the amount recycled this way is made, reflecting both the somewhat lower value of re-use and the environmental effects of the recycling processes required. The polycarbonate that is re-used in the cascade process generates no waste in the bottle cycle.
At the end of the life cycle the other 50% of the 13.3 bottles goes into the household waste. This waste is either dumped in landfills or incinerated. For this study 60% landfill and 40% incineration is assumed, so that 3.9 bottles are landfilled and 2.6 bottles are incinerated. At incineration electricity is produced with an assumed efficiency of 30%.

3.3 Life Cycle of the 480 gram refillable glass milk bottle

3.3.1 Production of glass and manufacture of the bottle

The glass bottle consists of more than 95% of siliciumoxide, sodiumoxide and calciumoxide. The melting process of glass requires a lot of energy. The source of energy for melting white glass in the Netherlands is mainly gas, according to the Dutch glass industry. The German glass industry gives a reduction of 3% of primary energy resources for each 10% external cullet used in the melting process. The use of the anorganic raw materials (siliciumoxide, feldspate, dolomite etc.) and fuels can be reduced by using recycling glass as secundary raw material input (BV Glas und Mineralfaser, 1990). This reduction should be attributed more to the original process producing a "secondary resource" than to the proces using partly remelted glass.

The environmental data for the melting of glass have been supplied by the Dutch glass industry. Compared to the environmental data of the Swiss glass study (Thalmann & Humbel,1985a), the environmental data of the Dutch glass industry are a factor 3-4 lower. These differences can be partly explained by the high use of gas as an energy resource in the Netherlands. Further explanations cannot be made for lack of information about the production processes in the Netherland and in Switserland.
The environmental data of the production of the raw materials for the glass production are derived from the same Swiss study (Thalmann & Humbel, 1985a).

The production of white glass does not need a high amount of external cullet. In the production of white and brown glass only external cullet with the same colour can be used. The collection of waste glass in glass collection containers is not differentiated to colours so that the amount of pure white external cullet is limited.

The manufacture of the bottles is on the same site as the production of glass. In the process data the energy consumption of this manufacture is included. Capital equipment is not considered.

3.3.2 Filling and washing at the dairies, distribution and consumptve use of the bottle

The bottles will be transported to the dairies where they will be filled with milk and sealed with a one-way cap (see § 3.5). The milk is transported to the supermarket in crates of polyethylene (12 bottles per crate; 500 trips) (Nusselder, 1984, adjusted to the situation of Dutch dairy using lighter-than-usual milk bottles). At delivery of the filled bottles nearly the same number of empty bottles are taken back. In Appendix 2 the distribution model is described.

The washing and filling of the bottles is as described under § 3.2.4.

3.3.3 Number of trips

In the Netherlands there is long experience with refillable glass bottles. The number of trips varies between 25 and 40 trips (Jansen et al., 1989), but is decreasing, especially in the larger cities. With a higher deposit, Dfl. 1.- instead of the current Dfl 0.25, the number of trips could be raised substantially. The high number of trips technically possible has been attributed to the heavy (and therefore strong) glass bottle. Glass bottles of less weight are not presumed to reach such high trip rates. A conservative estimate for the number of trips of lighter bottles seems to be 30, and analogue to the polycarbonate bottle a lower estimate of 20 trips has been considered as well. The number of new bottles needed and old bottles discarded is 33.3 and 50 respectively.

3.3.4 Waste processing of glass

The bottles that are picked out at the dairies will return to the glass producers. This high quality glass can be used for the production of new bottles. It is assumed that 50% of the bottles are discarded at the dairies and go back to the glass producers for the production of new milk bottles. For the recycling of white glass a deduction of 50% is made for energy use at re-melting. Households put another 25% in glass containers, with a re-use value of 25%. Only green glass can be made from the mized colours in containers. The last 25% goes into the household waste and is dumped as waste. The glass that is re-used, will not generate waste in the original bottle cycle.

The glass that is thrown away (25%) can be landfilled or incinerated. At incineration the volume will not be reduced. This means that all the bottles that are disposed of in this way, will generate the same amount of waste volume.

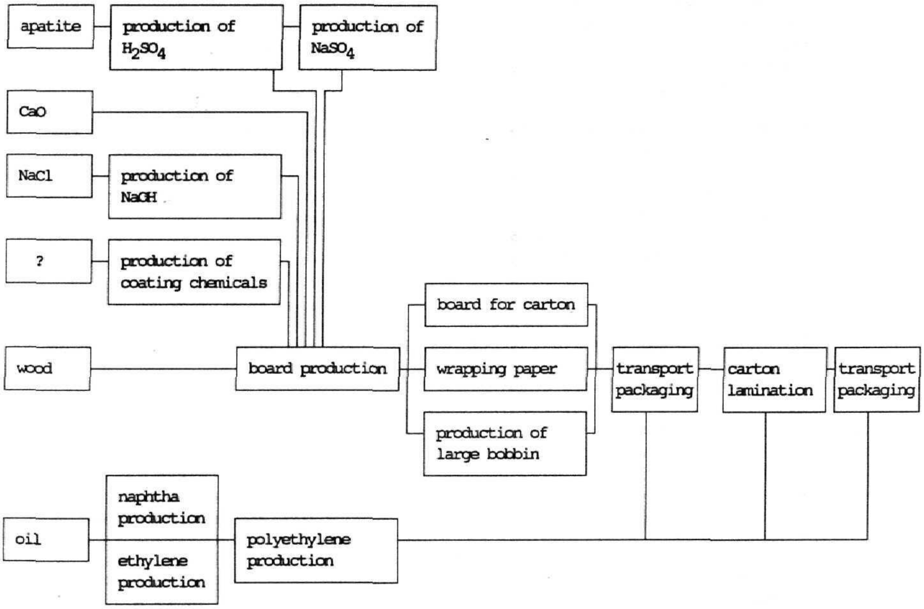
3.4 Life cycle of PE coated milk carton

3.4.1 Carton production

The board for the gable top is assumed to be manufactured in Sweden (Lundholm and Sundström, 1986). Wood is the main raw material input for board. For the production of pulp sulphuric chemicals are added. The board is coated with coating chemicals and transported on reels to the carton manufactures in the relevant countries by rail and boat.

At the carton manufacturing plant the board is printed and laminated with polyethylene and transported on large bobbins by road to the dairies. In figure 3.3 the production process of carton is shown schematically.
The data on carton manufacture and transport from Sweden are used. The transport from Sweden to the Netherlands is assumed to be the same as the transport from Sweden to West-Germany as given by Lundholm and Sundström.

Figure 3.3 The production process of carton (Lundholm & Sundström, 1986)



3.4.2 Filling at the dairies and distribution of the carton container

At the dairies the board is cut, manufactured into containers and filled with milk. The transport of milk to the retailers is assumed to be on roll-in containers. (160 litres/container; 750 trips). After delivering the milk the truck will return to the dairies with the empty roll-in containers (see also Appendix 2).

3.4.3 Waste processing

After consumption of the milk, the cartons are thrown away as household waste. The household waste is collected and 40% of the waste is incinerated and 60% is landfilled. At incineration the combustion energy of the milk pack is used for producing electricity for the national grid at an efficiency of 30%. No deduction is made for the evaporation of water soaked into the cartons.

3.5 Additional packaging elements

There are different options to seal and label refillable milk bottles. The caps can be made out of aluminium, polyethylene or steel. In table 3.1 these cap systems are listed. All the cap systems are one-way systems.
In the future milk bottle labeling is expected to be a marketing demand. Dairies and retailers than can provide more product information than is possible on the cap. Two types of labels are possible: a glued paper label or a polyethylene sleeve label. The specifications of these labels are given in table 3.2.

The transit packaging (crates and containers) can vary depending on the storage place and milk sold at the retailers. Carton packages and polycarbonate bottles can use the same distribution package systems. For supermarkets roll-in containers are at the moment widely used for carton packages. Delivery at smaller shops is carried out in smaller polyethylene boxes/crates. The distribution of 480 grams glass bottles is expected to be in 12-liter crates. In table 3.3 the several distribution packages are listed.

Table 3.1 Cap systems for refillable glass and polycarbonate bottles (Lundholm and Sundström, 1986; Jansen et al., 1989; Golding, 1989, pers comm. Maas, 1990).

material	aluminium cap	polyethylene cap	twist-off cap
aluminium	0.25-0.3 g	-	-
polyethylene	-	4.0 g	-
steel	-	-	3.47 g
PVC & paint	-	-	0.88 g *

* *The PVC amount is estimated (assumed) by the authors to be 0.88* gramme.

3.5.1 Caps

All the caps are one-way caps so that the manufacture and waste processes are important to look at. For 1000 litres milk 1000 caps are needed.

Aluminium caps
Aluminium caps will be thrown away as household waste after use. Household waste is 40% incinerated and 60% dumped into landfills.

Polyethylene caps
90% of the polyethylene caps will return to the dairy assuming that the consumer is asked to do this. Polyethylene can be recycled into polyethylene products of roughly the same quality. One of the possibilities is recycling into new polyethylene caps. In this study it is assumed that the polyethylene caps will be recycled into other products and therefore no waste will be generated for these caps. A deduction of 25% is made for lower value and for recycling processes.
The other 10% of the polyethylene caps are assumed to remain in the households (thus 100 caps) and thus thrown away as household waste. Household waste is 40 % incinerated and 60 % dumped into landfills.

Table 3.2 Labeling systems for refillable glass and polycarbonate bottles (Golding, 1989; pers. comm. Maas, 1990).

material	paper label	polyethylene label
paper	1.79 g	-
glue	.??. g	-
polyethylene	-	1.5-2.0

Table 3.3 Distribution package systems for milk packages (Franke, 1984; Nusselder, 1984; Lundholm and Sundström, 1986; pers. comm. Hogendorp, 1990; pers. comm. Kamps, 1990).

specification	roll-in container	polyethylene box/crate	polyethylene crate
zinked steel	20 kg	-	-
polyethylene	-	2 kg	1
number of trips	750	500	500
litres milk	160	20	6
suitable for package system	carton polycarbonate	carton polycarbonate	glass

Twist-off caps
The Twist-off caps consist of painted steel and at the inside of the cap a *PVC-film. The specification in table 3.5.1 is given for a Twist-off cap* with ϕ 44 mm (Golding, 1989). The amount of PVC is assumed (estimated) to be 0.88 grammes.

Similar to the polyethylene caps 90% of the Twist-off caps are assumed to return to the dairies where they are collected and returned to the iron industry and recycled into new iron. The other 10% of the Twist-off caps will remain as household waste. The waste management today may sort steel and iron magnetically. In this way 50% of the steel in household waste is assumed to be collected. The total number of caps that are finally dumped into landfills and incinerated will be 5% of the 1000 caps (50 caps). Of these 50 caps 40% is incinerated and 60% is dumped into landfills. The environmental effects of incineration is determined by the air emissions of incinerating PVC. The steel does not decrease in volume at incineration (van Duin & Kerkhoven, 1988). The environmental effects of landfilled Twist-off caps are determined by the emission of corrosive metals.
The environmental effects of the burning of PVC during the recycling of the caps in the iron industry is not considered for lack of information.

3.5.2 Labels

In the future the trend will be that refillable milk bottles will be labelled instead of printed product information on the caps. Two labeling systems are possible; glued paper and polyethylene sleeves. The paper labels must be glued to the bottles; no data is available about the amount of glue per bottle. The polyethylene stretch labels are pulled down over the bottle and released, producing a tight fit without the need of an adhesive. Each trip the bottle makes new paper- or polyethylene labels are applied, so that 1000 labels for 1000 litres of milk are required.

Paper labels
The paper labels are removed during the washing. The energy- and detergent consumption of the washing machines will increase with the increasing size of the paper label and the increasing amount of glue used (Golding, 1989). No quantitative data is available for this increasing energy consumption. The removed labels are discarded. The waste management is assumed to be similar to that of household waste (40% incineration, 60% landfilled).

Polyethylene labels
The printed polyethylene labels will return nearly all to the dairies. At 75 trips six labels will remain in the household together with the 6 polycarbonate bottles not returned. The quality of recycling depends on the way the labels are printed and attached to the milk bottle. The technical elaboration of the label must be suited for re-use, otherwise the polyethylene could only be recycled as low quality.

3.5.3 Transit packages

As mentioned before carton and polycarbonate milk package systems may use the same distribution systems. For supermarkets roll-in containers and for smaller shops polyethylene boxes are used. The distribution of glass bottles is carried out only in polyethylene crates.
In the next paragraph the life cycles of the several distribution packages are given. The environmental impact of the distribution itself is analysed elsewhere in this report.

Roll-in containers

The roll-in containers are made of zinked steel. All roll-in containers will return to the dairies each trip. At the end of the life cycle (after 750 trips) the roll-in containers are collected and returned to the iron industry for use as scrap iron so that no waste will be generated. Other parts on the container than those of steel and zinc, like weels and bearings, have not been considered. more or less compensatingly the recycling of the steel has been left out of the materials account.

Polyethylene crates

All polyethylene crates and boxes will return to the dairies each trip. The polyethylene crates and boxes will be recycled at the end of their life cycle (after 500 trips) so that no waste will be generated. For carton packages and polycarbonate bottles 1 polyethylene box is required for 20 litres. For glass bottles 1 polyethylene crate is required for 12 litres. This means that more crates are necessary for distributing glass bottles than for other milk package systems.

4 FINDINGS AND CONCLUSIONS

The data that is used in this study is listed in Appendix 3 (process definitions). Some remarks and assumptions concerning these data are given in Appendix 4.

4.1 Elements of packaging systems

One central element in the analysis conducted here is that packages are treated as systems with quite complex relations. If the weight of a PE cap on a bottle is changed, changes result in several types of energy conversion systems, in PE production volume with its related emissions, in waste volume and in the amount of energy to be produced at incinerating waste. These effects are dependent on the number of trips a bottle makes. So how may a good choice in system specification be made?

As a first step in our analysis we optimized the elements of the system by taking their overall contributions seperately. Those elements were chosen that seemed reasonable from a functional point of view and attractive from an enviromental point of view. The cap, the label, and the transport container are treated in that order and five systems are defined. For comparison first the life cycle of the main material of the milk containers is given.

Main materials

Next the ecoprofiles of the five systems investigated are given and evaluated (4.2). These ecoprofiles form the core of the results of the study. The ecoprofiles may be used for guiding the choice between these systems. However, the analysis executed may also be used to give clues as to further refinements in the system or the effects of external changes on the system. A number of such possible changes is treated (4.3).

Table 4.1 Environmental effects of different life cycles of milk package materials per 1000 litres packed milk, including manufacture, distribution of milk, washing of the bottles and waste processing. For glass in brackets the Swiss data are given.

		polycarbonate		*glass 480 g*			*milk*
		50 trips	*75 trips*	*20 trips*	*30 trips*		*carton*
Fossil energy resources	*MJ*	*282*	*256*	*431*	*373*	*(370)*	*530*
UPW	*dm^3*	*2.54*	*2.09*	*2.04*	*1.78*	*(5.79)*	*32.6*
UPA	*m^3*	*11.7*	*11.4*	*24.6*	*20.9*	*(32.3)*	*61.5*
AE	*ha*	*0.351*	*0.341*	*0.983*	*0.786*	*(0.693)*	*3.78*
Waste	*kg*	*0.752*	*0.587*	*6.41*	*4.37*	*(7.90)*	*18.1*

UPW= Units Polluted Water; UPA= Units Polluted Air; AE= Acidification Equivalents

In table 4.1 the environmental effects of the life cycle of different milk packages are given, taking into account only the main material of the package considered. However data on milk transport and washing are included. For polycarbonate and glass two more pessimistic trip-rates are also given for comparison. For glass bottles the environmental effects at 30 trips according to a Swiss study are listed in brackets.
The use of fossil energy for the polycarbonate and glass bottles is almost the same although the production of glass is a high energy consuming process. The reason for the relatively low fuel consumption of glass is the possibility of recycling the glass bottles that are discarded at the dairies into new bottles. In this study it is assumed that 50% of the bottles at the end of the life cycle will be discarded at the dairies and return to the glass industry where new bottles are manufactured. Twentyfive percent is subtracted for the recycling process. Another 25% of all bottles discarded by consumers is put into glass containers. These give a lower value glass which is valued netto at 25%. Polycarbonate bottles which are discarded at the dairies cannot be recycled into new milk bottles, but in other high quality non-food products. A reduction of 75% on primary production of polycarbonate is assumed.

Caps

In table 4.2 the environmental effects of several cap systems are listed. Effects of recycling have been worked into the results.

Table 4.2 Environmental effects of different life cycles of cap systems for milk package systems per 1000 litres packed milk.

		aluminium	*polyethylene*	*Twist-off*
Fossil energy resources	*MJ*	*52.9*	*64.2*	*92.3*
UPW	dm^3	*0.0525*	*1.04*	*17.0*
UPA	m^3	*9.96*	*0.156*	*15.2*
AE	*ha*	*0.56*	*0.009*	*0.147*
Waste	*kg*	*3.94*	*0.238*	*14.5*

UPW= Units Polluted Water; UPA= Units Polluted Air; AE= Acidification Equivalents

The twist-off cap scores worst of all considered cap systems on the pollution of water, air and generated waste. Only on Acidification Equivalents (AE) can the Twist-off cap compete with the aluminium cap. The aluminium cap scores lower than the polyethylene cap on consumption of fossil energy resources and emissions to water. This means that it cannnot be stated that either the aluminium cap or the polyethylene cap has a better environmental impact. The choice is not made here on environmental grounds but on transport and consumer grounds. The polyethylene cap is strong enough to put several bottles directly on one another when transporting them and the bottle can be reclosed after partial consumption.

Labels

It is likely that in the future the refillable milk bottles will be labelled. In table 4.3 the environmental effects of two types of labelling systems are listed.

Table 4.3 Environmental effects of different life cycles of labelling systems for milk package systems per 1000 litres packed milk.

		paper label	*polyethylene label**
Fossil energy resources	*MJ*	*72.7*	*51.5*
UPW	*dm^3*	*11.5*	*0.808*
UPA	*m^3*	*2.65*	*0.16*
AE	*ha*	*0.0667*	*0.010*
Waste	*kg*	*1.04*	*0.06*

UPW= Units Polluted Water; UPA= Units Polluted Air; AE= Acidification Equivalents
* 50 trips assumed

The polyethylene label scores better than the paper label on all evaluation aspects. Therefore the polyethylene label is chosen for further computations. Another reason for this choice for labels on the polycarbonate bottle is that the glue on the polycarbonate makes high quality recycling expensive or impossible.

Transport packages
In table 4.4 the environmental effects of the life-cycle of the transit packages are listed.

Table 4.4 Environmental effects of the life cycles of milk package transit systems per 1000 litres packed milk.

		roll-in container	*polyethylene box/crate 2 kg 20 liters*	*polyethylene crate 1.98 kg 12 liters*
Fossil energy resources	*MJ*	*3.57*	*2.55*	*4.30*
UPW	*dm^3*	*0.510*	*0.040*	*0.0673*
UPA	*m^3*	*0.546*	*0.0089*	*0.0149*
AE	*ha*	*0.006*	*0.0005*	*0.0008*
Waste	*kg*	*0.505*	*0.0002*	*0.0003*

UPW= Units Polluted Water; UPA= Units Polluted Air; AE= Acidification Equivalents

For glass bottles there is no choice; only the 12 bottle crate is applicable. For transport reasons a factor not included in this analysis but in that of the main material of the bottle, see table 2) the choice is on the roll-in container although its environmental effects are worde in all respects.

Package systems defined

All the values listed in the tables 2-5 can be linked at various ways for the package systems. Three combinations have been chosen. Other combinations can easily be made and analysed.

The environmental impacts of following combinations are listed in table 4.4.

1) refillable polycarbonate bottle (70 gram) at 50 and 75 trips, polyethylene cap (4 gram) and label (2 gram) and roll-in container as transit package;
2) refillable glass bottle (480 gram) at 20 and 30 trips, polyethylene cap (4 gram) and label (2 gram) and polyethylene crate (1.98 kg) as transit package;
3) milk carton (28.5 gram) with roll-in container as transit package.

4.2 Ecoprofiles

Results

The environmental impacts of the functional units as defined give the ecoprofile, see tabel 4.5 These are the main result of the study. They should be interpreted with all the precautions stated.

Table 4.5 Ecoprofiles of the functional units (1000 litres packed milk) of five different milk package systems. In brackets the glass production data of Switserland (at 30 trips) are given.

		polycarbonate		*glass 480 g*			*milk*
		50 trips	*75 trips*	*20 trips*	*30 trips*		*carton*
Fossil energy resources	*MJ*	*366*	*353*	*552*	*494*	*(663.9)*	*534*
UPW	dm^3	*4.90*	*4.6*	*3.97*	*3.70*	*(9.61)*	*33.1*
UPA	m^3	*11.2*	*11.3*	*24.9*	*21.3*	*(28.61)*	*62.0*
AE	*ha*	*0.304*	*0.319*	*1.0*	*0.806*	*(0.69)*	*3.78*
Waste	*kg*	*1.37*	*1.26*	*6.68*	*4.63*	*(6.95)*	*18.6*

UPW= Units Polluted Water; UPA= Units Polluted Air; AE= Acidification Equivalents

Evaluation

The overall assessment shows the polycarbonate package system to be superior to the carton gable top system in all quantified environmental respects. However, the data on emissions at production of board and paper as supplied by the producer seem somewhat outdated.
The glass bottle system is superior to the carton pack in nearly all respects. It scores worse only in the amounts of fossil energy resources extracted, only at the lower trip rate of 20.
The comparison of the glass bottle system to the polycarbonate system shows the latter to be more attractive in four environmental respects, with only water pollution slightly higher than that of the glass system.

One important factor in the lower energy use of the gable top is an asymmetry between production and waste processing. Production of first wood and then board and paper takes place in Sweden with little energy consumption, which, moreover, is supplied mainly by water turbines and nuclear power (together 97%) which do not require fossil energy. Waste processing in incinerators, at the other end of the life cycle, is

assumed to replace electricity generation in the Netherlands based mainly on fossil fuels. This amount of fossil fuels is subtracted from primary energy extraction.
Similarly the polycarbonate system is improved in pollution respects by burning polycarbonate in household waste and subtracting emissions there, while at production many emissions from the refining industry and the chemical industry are, not yet, included.

The number of trips does not seem to influence the environmental effects substantially. This is due to the increased recycling of waste when the trip number goes down and to the preponderance of trip independent elements as a sources for environmental effects. Peculiar is the very slight increase in air pollution from the polycarbonate system if the number of trips goes up. This effect is due to the decrease in incineration of polycarbonate with higher trip numbers.

How might the results be influenced by flaws in the data used? One systematic omission is that on the waste production of basic resource processing. Mainly Swiss data are available. More waste is probably attributed to the glass system relatively than to the carton and polycarbonate system. Especially coal and nuclear energy produce large amounts of waste. Nuclear energy, wich is used most in Swedisch board production, has no negative effects at all on the final ecoprofile.
Lack of data on the basic chemical industry makes the inputs to the polycarbonate process look cleaner than they are. Energy resource extraction has been taken into account there somewhat but emissions surely have been underestimated.
Conclusion is that there might be a slight bias against the glass system.

4.3 Effects of system changes

When interpreting results it is tempting to think in terms of processes that are 'responsible' predominantly. Is it 'production' of a bottle that causes emissions or 'washing' when using the bottle? Such questions become increasingly difficult to answer when systems become complexer. For example, in the software used recycling of PE is treated as a reduction in primary production. Which production level, with associated resource use, emissions and waste is now the relevant one to consider, the one with or without recycling? In the end such questions become irrelevant. What is relevant however is how system changes lead to changes in overall changes in environmental effects. Then it is not so much given systems that are compared to each other but it is the evaluation of system changes. Some examples are given below.

For the polycarbonate bottle:
Get all household waste burned

Another change might be realized through current goverment policy. Landfill activities may be reduced and all waste could be burned in incinerators with electricity generating facilities. This does not seem irrealistic. The emissions at incinerating would be very modest, while the electricity, delivered to the mains grid, would save on relatively dirty electricity generation. A substantial improvement in environmental scores would result, see table 4.6.

Figure 4.6 Changes in the polycarbonate packaging system, 75 trips

	energy MJ	water UPW	air UPA	acid UA	waste kg
system as specified:	327	4.46	10.4	0.28	1.18
change:					
-all waste burned	317	no	10.1	0.26	0.86
improvement	3%	changes	3%	7%	27%
-washing energy halved	312	no	9.89	0.25	1.13
improvement	5%	changes	5%	11%	4%

Halving bottle cleaning energy
Imagine that through heat exchangers and isolation the energy requirements of the washing process of the polycarbonate bottle could be halved. The effects are given in table 4.6. It seems one of the few possibilities for process changes in fields where bottle producers and dairies have a direct responsibily. The results show that overall improvements are sensible but limited.

For glass bottles:
Halving weight

The glass bottle has no energy savings at waste processing. The glass is recycled to a large extent already. One way to improve would be to reduce the amount of glass per bottle. The results are given in table 4.7

Table 4.7 Changes in the glass bottle packaging system, 30 trips

	energy MJ	water UPW	air UPA	acid UA	waste kg
system as specified:	467	3.7	20.4	0.76	4.55
change:					
-glass weight halved	436	3.43	17.7	0.61	4.59
improvement	7%	7%	13%	20%	-1%
-no labels at bottle	442	2.88	21.1	0.796	4.61
improvement	5%	22%	-3%*	-5%*	-1%*

*due to decreased positive effect of recycling

No sleeve

Another way to improve on the glass bottle is to get rid of the sleeve label; up till now bottles went without labels as well. The results show that the improvements are minor. Against a moderate reduction in energy resource use and a substantial improvement in emissions to water, see table 4.7. there is a minor deterioration the three other environmental aspects. If there are no strong marketing reasons for having one, leaving out the sleeve is, on balance, an only slightly environmentally attractive possibility.

For carton gable tops:
Halving energy in production

A main element in the carton production is the energy requirement for board production. Suppose this energy use could be halved, would that be attractive environmentally? Results, see table 4.8, show that improvements for such a rigorous technological change are relatively moderate as the Swedish use mainly water power and nuclear power with little effects on the ecoprofile.

Table 4.8 Changes in the gable top carton packaging system

	energy MJ	water UPW	air UPA	acid UA	waste kg
system as specified:	534	33.1	62	3.78	18.6
change:					
-energy for board half	445	no	53.2	3.1	18.6
improvement	17%	changes	14%	18%	0%
-all waste incinerated	469	no	59.8	3.67	4.72
improvement	5%	changes	4%	3%	75%

Get all household waste burned

As in the polycarbonate example, an change in the handling of household waste might be most attractive in changing the ecoprofile of the carton package. Using wood based carton as a fuel source is attractive environmentally as long as Swedish electricity production for processing is relatively clean as compared to the Dutch one. The main effect however is the decrease in final waste.

4.4. Conclusions

Based on the data and method used the main conclusion is that the polycarbonate package system for fresh milk is to be preferred to the carton gable top in all quantified environmental respects. This conclusion holds for a broad range of trip numbers assumed.

Further, also the refillable glass bottle systems seem to have a considerably lower environmental impact than the one-way milk carton. Only the amount of fossil energy required is similar.

Finally, if more household waste is going to be burned, as planned, and the efficiency of electricity production at incinerators is improved, a systematic difference in effects on package system may be expected. The scores of the carton system will improve substantially, the scores of the polycarbonate system moderately and those of the glass system not at all.

- APPENDICES

APPENDICES

CONTENT

Review CESL-analysis:

'Integral analysis of the environmental effects of different milk package systems for fresh milk'

Subject:	Integral product-comparison of milk package systems, report of Centre for Environmental Studies, State University Leiden, The Netherlands
Commmissioner of the audit:	General Electric Plastics, Bergen op Zoom, The Netherlands
Executed by:	H. de Goede, R. van Duin, Bureau B&G, Rotterdam, The Netherlands
Date:	september 1990

0. Scope of the review

Commissioned by General Electric Plastics, Bergen op Zoom, the Centre for Environmental Studies, State University Leiden, (CESL) analysed the environmental impact of three different milk package systems for pasteurized milk. Bureau B&G is commissioned to review the data supplied by General Electric Plastics and the CESL-analysis of the PC-milk package system.

The findings of Bureau B&G are stated below in a general review, in a review of the study as such and in an overall conclusion.

1. General review

Scope of the CESL-analysis and used methodology
The analysis is focused on a new developed milk packaging system, the refillable polycarbonate bottle with a polyethylene cap and label, for the Dutch situation. Comparisons are made with two other systems 1) using a new developed refillable glass bottle with a polyethylene cap and 2) using the present coated carton box. Recent and present data are used concerning the environmental impact of energy-use, transport and waste processing.

Note:
- * The possible environmental advantages resulting from the development of new (coated) carton boxes are not taken into account.
- * In the near future, a.o. because of Dutch and European environmental policy, changes can be expected concerning the environmental impact of:
  - energy use (other 'energy models');
  - transport (regulation of emissions); and
  - waste processing (more recycling).

The 'product-comparison' is based on an analysis-methodology which regards the complete life-cycle of the three milk packaging systems. This methodology is rather new and not yet fully developed. The present limitations of the methodology affect the comparison of packaging systems in different ways.

Note:
- * A relevant influence on the results of the study can be expected of further improvement of the methodology such as
  - development of standard methods for assessments and calculations;
  - extension of the number of chemicals taken into account;
  - not leaving aside the aspect 'risk calculation'.

Simplifications and assumptions
In productstudies usually there have to be made simplifications and assumptions because of missing data and lack of sufficient norms.
In the CESL-study too there were made simplifications to make the analysis feasible. To meet noticed gaps in necessary norms and data several assumptions had to be made.

Note: * Some of the simplifications and assumptions that have been made in the product analysis of the PC-bottle might have an important influence on the results of the environmental product-comparison. For example:

- Climatical and ozone layer effects are not specificly included in the analysis;
- Possible accidental emissions and other environmental risks are not taken into account [such as benzene emissions and -slight- risks of phosgene emissions in the productionphase].
- Environmental aspects of the transport of raw materials and products are only partially taken into account.
- Noticeable missing data concern all emissions during transport, transhipping and storage, materials/products like oil, naphta, benzene en propylene and all kinds of additives (in coated carton and Lexan).

Endnote The analysis is based on the present available methodology and the present available data completed with assumptions.
The result of the product analysis has a (time)restricted value.
The outcome of the product-comparison can change when
- more environmental aspects are discounted (risks, CO_2-emissions)
- more norms and data are available.

2. Review of the study

The new-developed polycarbonate bottle, a new-developed glass bottle and the present-day coated carton box have been subject of the CESL-study. The environmental aspects of these three milk package systems are compared through the entire life-cycle. An analysis was made of environmental aspects of the extraction of raw materials (phase A), manufacturing of the product (phase B), product usage (phase C) and waste processing (phase D).

Analysis of the polycarbonate bottle
With respect to phase A and B data were supplied by General Electric Plastics, vouching for the correctness. The determination of environmental data per kg PC produced is based on process data (flow of materials) and emission-figures mostly periodically checked by independent officials. Recent improvements in the production processes are taken into account. Data with respect to phase C and D are mainly based on desk-research.

Note: * Our review of data and figures give no apparent reason to doubt the correctness of the data used. The input-figures supplied by General Electric Plastics are sufficient for this study and correctly used by CESL.

* With reference to former remarks on simplifications and assumptions it is noticed that the following points are supposed to be neglectable:

- environmental effects of production and use of additives used for the production of Lexan are not taken into account because of missing data;
- risks of production and transport of raw materials (oil, chlorine), spills of benzene and accidental (phosgene-) emissions are not taken into account. [Noticeable is that General Electric Plastics is exempted from the duty to produce an 'external safety report' by the government seeing the extreme safety measurements];
- assumptions are made with respect to raw materials and production of materials in earlier phases, because of missing data.

Analysis of glass bottle and coated carton

An important part of the data was extracted from existing studies. Furthermore the analysis is based on actual data of Dutch and foreign industries.

Note: * Data concerning foreign industries (and from foreign studies) are not necessary valid for the Dutch situation in the nearby future.

* Several data - especially concerning the milk carton - had to be estimated because they were not available yet.

Endnote The data that are used are sufficient for a global product-comparison seeing similar deficiencies in the analyses of the different packaging systems. However, especially where small differences are involved, the results of the product-comparison should be used carefully.

Sensitivity of the analyses

In the CESL-study the life-cycle-approach is worked out as good as possible as a modus for the time being. New developments can influence the three packaging systems in a different way. In future product-comparisons adjustments should be made taking into account changed situations and new data.

Note: * With respect to phases A and B data have to be gathered especially on emissions of several processes.

It is expected that this new information will importantly affect the results of the product-comparison. Adjustments seem to have a major negative influence on the results of the coated carton package system in comparison with the two bottle systems. Adjustments seem to have a negative influence on the results of the polycarbonate bottle in comparison with the glass bottle.

* With respect to phase D it should be noticed that in the near future a important alteration of the overall waste processing is expected. In particular relevant is the intended decrease of landfill and the increase and improvement of recycling and incineration (with more severe regulation of

emissions). These adjustments seem to have a positive influence on the results of the coated carton package system in comparison with the two bottle systems. The adjustments seem to have a minor influence on the results of the polycarbonate bottle in comparison with the glass bottle.

3. General conclusions

The analysis of the PC-bottle packaging system is a careful and sound description of the present-day environmental profile, based on data delivered by General Electric Plastics, data derived from the available database and other data.

Available data were sufficient to give reliable indications concerning the environmental impact of the three milk package systems.
Nevertheless the results of the study have a restricted value due to further developments in the used methodology, expected developments in environmental policies and missing norms and data. So the results of the comparison of packaging systems should be looked at with some caution.

A comparison of the two bottle systems - polycarbonate and glass - shows differences in environmental impact of minor importance given the uncertainties in the CESL-study.
A comparison of the two bottle systems on the one hand and the coated carton on the other hand shows differences in environmental impact of major importance given the uncertainties in the CESL-study.

Given the mentioned restrictions Bureau B&G can agree with use of data and the results of the CESL-study.

Rotterdam, september 1990.

APPENDIX 2 Distribution, washing and filling of milk package systems.

1 Distribution and transport of milk package systems.

In the analysis of the environmental effects of refillable drink package systems, the transport of the empty bottles receives much attention.
In this appendix the major assumptions for transport and distribution of fresh milk in several milk package systems are explained.

Kilometres

The distribution system is considered to be a direct "point-goal" delivery system, to and from the retailer.
The washing and filling are at the same site so that no extra kilometres will be made.
For the Netherlands the average distance between dairy and retailer is assumed to be 40 kilometres.

Amount of milk transported

At delivering of the filled bottles the empty refillable bottles are taken back. This means that nearly the same amount of bottles are transported the whole traject.
In a all package systems the return transport is determined by the transport package (i.c. roll-in containers and/or bottles). The truck transports one type of package. Principally the truck could transport other goods at its way back. But the cooling trucks are not equipped to transport other goods as milk or milkproducts. Therefore such an option is not further considered.
The limiting factor for transport is the volume. Glass in 12-litre crates can be stacked 5 crates high and 4 piles on a pallet. On one pallet 240 litres milk can be stacked (Hogendorp, pers. comm. 21-6-1990). The stacking of 6-litre crates is assumed to be the same as 12-litre crates, thus 240 litres milk are stacked on one pallet.
For this audit the transport of cartons and polycarbonate bottles is considered to be only in roll-in containers. Two roll-in containers (160-litres) are stacked on one pallet thus 320 litres milk on one pallet are transported. In case of transporting carton packages or polycarbonate bottles in polyethylene boxes (in this study not further considered), 480 litres milk can be stacked on one pallet (20-litre polyethylene boxes, 24 boxes on one pallet).

The milk is transported in a 8-9 ton truck.
In a truck of 8-9 tons 21 pallets can be transported. This means 5040 glass bottles, 6720 carton packages or 6720 polycarbonate bottles. The weight of each trip is given in table A.2.

The calculations have been made for glass bottles with a Twist-off cap transported in 6-litre crates; carton packages transported in roll-in containers and polycarbonate bottles with polyethylene caps transported in roll-in containers. Each other combination of transit packagings, caps and labels is possible but no further elaborated.

In table A.1 the specifications of the studied package systems with their transit packages are listed.

Table A.1 *Weight of distributed milk per litre milk*

	PACKAGE		
Specification	coated carton	glass bottle	polycarbonate bottle
PACKAGE			
Total weight (g)	25	480	70
Weight of milk (kg)	1.028	1.028	1.028
CAP (one-way) (variable)			
aluminium (g)	-	0.25-0.3	0.25-0.3
polyethylene (g)	-	4.0	4.0
Twist-off (g)	-	4.35	4.35
LABEL (one-way) (variable)			
paper (g)	-	1.72	1.72
polyethylene (g)	-	1.5-2.0	1.5-2.0
TRANSIT PACKAGING per litre milk			
roll-in container (kg)	0.125	-	0.125
polyethylene box (kg)	0.1	-	0.1
polyethylene crate (kg)	-	0.166	-

Table I.2 Total weight of 1 litre milk transported to retailers and from retailers.

	coated carton	glass bottle	polycarbonate bottle
Total weight (kg) to	1.178	1.67835	1.227
Total weight (kg) from	0.125	0.65555	0.235

Diesel consumption

The diesel use is attributed to the transport of milk in different package systems, including the total truck itself and the milk.
Mean speed of the truck is set up to 45,4 km/hr (Franke, 1984; Golding, 1989).

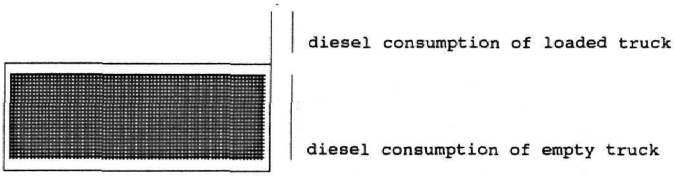
Emissions to air at this speed in grams per litre of diesel:

soot	1,8
CO	32,0
SO_2	4,1
NO_x	7,5
KWS	2,0

(Golding, 1989)

The diesel consumption of a truck is stated to be proportional with the load (Nusselder, 1984; TNO, 1985 in Jansen 1989; Golding, 1989). Mostly only the diesel (or energy) consumption of a full loaded truck is given. The dieselconsumption of an empty truck is assumed by Nusselder at 70% of a full loaded truck; TNO gives 65% and Golding 50%.

Given the diesel consumption of a loaded truck and the diesel consumption of an empty truck following relationship can be drawn:



Assuming the mean percentage of diesel consumption for empty truck 65%, this means for each delivery following equotation counts:

$$\{ (1-0.65) \frac{\text{actual load}}{\text{maximum load}} * D \} + \{ 0.65 * D \}$$

whereby

actual load = transport load (milk, packages)
maximum load = maximum load of the truck (here 8-9 tonnes)
D = specific diesel consumption / km

The diesel specific consumption for different kinds of trucks is given in table A.3

Table A.3 Energy consumption of different truck types (Nusselder, 1984) and calculated diesel consumption per ton kilometres (1 litre diesel is 36 MJ (BINAS, 1977).

truck load	energy (MJ/tkm)	l diesel/tkm
10-20 ton	1.2-1	0.033-0.027
10-20 ton	1.2-1.0	0.033-0.027
2-8 ton	3.3-1.3	0.092-0.036
2-8 ton	3.8-1.4	0.105-0.0389
common truck	1.6-1.7	0.044-0.0472

In this audit, the distribution of the fresh milk is assumed to be in a 8-9 ton lorry with a specific diesel consumption of 0,3375 l diesel per kilometer (full loaded).

Calculations

Diesel consumption for distribution **glass** bottles:

I to retailer:

$$(0.35 * \frac{5040 * 1.67835}{9000} * 40 * 0.3375) + (0.65 * 40 * 0.3375) = 13.215914 \text{ litres diesel/5040 litres milk}$$

= 2.6222052 *litres diesel/1000 litres milk*

II from retailer:

$$(0.35 * \frac{5040 * 0.6555}{9000} * 40 * 0.3375) + (0.65 * 40 * 0.3375) = 10.509453 \text{ litres diesel/5040 litres milk}$$

= 2.0852089 litres diesel/1000 litres milk

Total diesel *consumption for distribution of milk in* **glass** bottles (I and II) is 4.7074141 litres diesel/1000 litres milk.

Diesel consumption for distribution of 1000 litres milk in **carton** packages:

I to retailer:

$$(0.35 * \frac{6720 * 1.178}{9000} * 40 * 0.3375) + (0.65 * 40 * 0.3375) =$$

12.930984 litres diesel/6720 litres milk =
1.9242536 litres diesel 1000 litres milk

II from retailer:

$$(0.35 * \frac{6720 * 0.125}{9000} * 40 * 0.3375) + (0.65 * 40 * 0.3375) =$$

9.216 litres diesel/6720 litres milk =
1.3714286 litres diesel/1000 litres milk

Total diesel consumption for distribution of milk in **carton** packages is 3.2956822 litres diesel/1000 litres milk.

Diesel consumption for distribution of 1000 litres milk in **polycarbonate** bottles:

I to retailer:

$$(0.35 * \frac{6720 * 1.227}{9000} * 40 * 0.3375) + (0.05 * 40 * 0.3375) =$$

13.103856 litres diesel/6720 litres milk =
1.9499786 litres diesel/1000 litres milk

II to retailer:

$$(0.35 * \frac{6720 * 0.235}{9000} * 40 * 0.3375) + (0.65 * 40 * 0.3375) =$$

9.60408 litres diesel/6720 litres milk =
1.429178 litres diesel/1000 litres milk

Total diesel consumption for distribution of 1000 litres milk in **polycarbonate** bottles (I and II) is 3.3791572 litres diesel/1000 litres milk.

Table A.4 Diesel consumption to and from retailers for diffent milk package systems for distribution of 1000 litres milk.

	coated carton	glass bottle	polycarbonate bottle
Diesel consumption (l)	3.296	4.707	3.379

Conclusion

The diesel consumption for distribution of milk in carbon packages or polycarbonate bottles differ slightly from eachother.
The diesel consumption for distribution of milk in glass (480 gram bottles) is the highest of all. This high diesel consumption is not only due to the weight of the bottles but also due to the greater required loading volume. (In a truck 1720 litres milk in glass can be transported less than in carton or polycarbonate packages.)

The emissions to air are calculated with the emissionfactors mentioned above.

2 Bottle washing

Energy consumption
In refillable bottle systems the bottles will be washed at home and at the dairies. The bottle washing at home is not considered by lack of data. It does not seem to be a major aspect.
The bottlewashing at the dairies is the major aspect to consider.

Golding (1989) gives a list of technical data of several washing machines. In table A.5 these data are listed.

Table A.5 Technical data of several milk bottle washing machines (Golding, 1989) per 1000 bottles.

Manufacturer or reference	Energy demand steam and electr. energy ($MJ_{th.eq.}$)	Used water (in litres)	Soda used (30% NaOH)
Stork	74	330	0.6 litres
Silmo	90-109	250-1500	0.7 litres
after Num	153	1000	11.6 litres
Num in Sundström after Franke	97	500-1800 (1000)	7 litres

Golding calculates with the mean energy demand of 85 $MJ_{th.eq.}$/1000 litres (Golding, 1989).

Lundholm and Sundström (1986) give in their report an energy demand of 290 MJ. This amount is a combination of the following factors: washing of the crates 73.5 MJ/1000 litres; washing of the bottles 142.8 MJ/1000 bottles, production and transport of NaOH and treatment of water from bottle washer (incl. pumping) 74 MJ/1000 litres.

Jansen et al (1990) take the energy demand of Lundholm and Sundström and add 10 MJ.

The technical data mentioned in table A.3 are given for moderately contaminated milk bottles. Highly contaminated bottles and glued paper labels lead to increased consumption of energy and detergents (Golding, 1989; pers. comm. Broers, 1990).
On the other hand the energy consumption for washing polycarbonate bottles could be lower than for washing glass bottles as shown in table A.6.

Table A.6 Energy consumption for heating polycarbonate bottles and glass bottles from 20 °C up to 100 °C.

	specific heat (kJ/kg °C)	required energy/bottle	required energy/1000 bottles
polycarbonate	1.25	7 kJ	7 MJ
glass	*0.865 (mean)*	*33 kJ*	*33 MJ*

According to Golding modern washing machines will use 74-109 $MJ_{th.eq.}$ for 1000 bottles. Therefore the mean value that Golding recommends is taken (85 $MJ_{th.eq.}$/1000 litres). The energy is assumed to be purchased from the communal electricity generators.
According to information of polycarbonate industry the washing of polycarbonate bottles is similar to the glass milk bottles.

Detergents
All machines use soda as a detergent. The required amount of soda is mentioned in table A.5. Here too, the several different machine require different amounts. In this study the use of 0.65 litres of 30% soda is assumed, according to the modern washing machines (Golding, 1989).
The production data of soda in the study of Lundholm and Sundström (1986): for 1 litre (50% NaOH) 1.5268 kg NaOH is required; process energy for production of soda is 11'000 MJ/tonne 50% soda lye (Trier, 1982 in Lundholm and Sundström, 1986).
Franke (1984) gives another calculation of the NaOH. According to her study 30% soda is based on weight percentages. Therefore 300 gram NaOH is required for 30% caustic.
At this stage it is unclear which calculation method is the best. For *0.65 litres of 30% caustic this means either* 1.5268/50*30*0.65= 0.595452 kg NaOH/1000 bottles or 0.3*0.65= 0.195 kg NaOH/1000 bottles, a difference of a factor 3.
The process energy for manufacture of soda can only calculated for the data of Lundholm and Sundström. For 0.595452 kg NaOH 11*1.5268/50*30*0.65= 6.549972 MJ process energy is required. This value is taken in this report.
The soda containing waste water is neutralized drained into the sewer. The environmental effects of this neutralized water are of minor importance.

Besides soda some other detergents are used for washing the bottles. Jansen et al (1990) mention phosphates and phosphate-substitutes but give no quantitative data. Menken van Grieken dairy uses also foam reducing substances together with the caustic soda (0.1% in bathsection equal to 0.08 kg/1000 bottles). The composition of these foam reducing substances Unfortunally no estimation could be made of the amount. The bottles are in the bath disinfected with a chlorine solution (1.2% in last section equal to 0.25 kg/1000 bottles) (Menken van Grieken, 1990). This amount of chlorine is considered in this audit.

Conclusion

Modern washing machines have a energy consumption of 74-109 $MJ_{th.eq.}$per 1000 bottles. The mean value is set up to 85 $MJ_{th.eq.}$ in this report. Washing of crates requires 73.6 $MJ_{th.eq.}$ (1000 bottle equivalent) and the energy consumption for production of soda is 6.549972 MJ (for 0.65 litres of 30% caustic soda). washing of the crates is not further considered. The soda consumption of modern washing machines is set up to 0.65 litres of 30% caustic soda. Other detergents are phosphates and phosphate-substitutes. These amounts are not quantified. Chlorine solution is used in the disinfection bathsection and the end of the washing line. For 1000 bottles the waste water is maximum contaminated with 0.25 chlorous substances.

3 Filling of the package systems

Lundholm and Sundström give different energy requirements for the filling of glass bottles and cartons are given in the flow diagram in their *summary*.

Glass bottles:	200 MJ/1000 litres
Cartons:	150 MJ/1000 litres

The calculation in the appendix of the study of Lundholm and Sundström is as follows:

Glass:

950 kWh electricity/10^6 bottles== 0.000950 kWh/l.
Efficiency factor of electricity generator is set up to 0.35.
So that 0.002714 kWh th.eq./bottle is needed.
In addition 20 kg oil/10^6 bottles is required equal to 0.000265 kWh/bottle.

For 1000 bottles	1000*0.002714= 2.71428 kWh	= 9.7714 $MJ_{th.eq.}$
	1000*0.000265= 0.26500 kWh	= 0.9540 $MJ_{th.eq.}$
Total		10.7254 $MJ_{th.eq.}$

Cartons:

8 kWh/3'600 cartons == 0.002222 kWh/carton
Efficiency factor of electricity generator is set up to 0.35.
So that 0.006349 kWh th.eq./carton is needed.
For 1000 cartons 1000*0.006349 = 6.3490 kWh = 22.8564 $MJ_{th.eq.}$

These values does not correspond to the values mentioned by Lundholm and Sundström in their summary. In table A.7 these findings are summarized.

Table A.7 Energy consumption of filling milk packages with milk according to Lundholm and Sundström their summary and recalculated above.

Milk filled in:	energy consumption in summary Lundholm	energy consumption calculation in report
carton packages	150 MJ/1000 litres	22 MJ/1000 litres
glass bottles	200 MJ/1000 litres	10 MJ/1000 litres

Conclusion

The values of Lundholm and Sundström are therefore unreliable. By lack of other data, in this report the filling of the package systems is set up to be the same with no differences in environmental effects, so that the filling of the bottles or cartons are no further considered.

APPENDIX 3 PROCESS DEFINITIONS

In this appendix the considered data are listed. Each process is defined in use of raw materials (marked as G), emissions to air (marked as U), emissions to water (marked as L) and generated waste (marked as A) and inputs of other processes (marked as 01).
After each proces definition the output of what process is given (expressed in kg or pieces (in Dutch: st.). The extinction _fu means 'functional unit' and _lc means 'life cycle'. For example the total life cycle of the polycarbonate bottle can be found under PC_bot_lc. Note that this procesdefinition is completely defined by inputs of other processes. The underlying data of these processes are found under the respectively processdefinition.
The values e-3 and e3 mean 10^{-3} and 10^{3}.

Summarized:

Process	Process-definition	Value	Remarks; explanation
xx	01xx	kg or st	output of proces xx
	01yy		input of process yy
	G1xx		consumption of raw material 1 for proxess xx
	U1xx		emission 1 to air at process xx
	L1xx		emission 1 to water at process xx
	A1xx		generated waste 1 at process xx
En_Sw_elec Sweden	01en_Sw_elec	1 MJ	therm. energy of el. generator
	01ol_Sw_cent	0.03 MJ	therm. energy out of oil generator
	01ke_cent_NL	0.41 MJ	therm. energy from nuclear power
	01wa_Sw_cent	0.56 MJ	therm. energy from water power
Wa_Sw_cent	01wa_Sw_cent	1 MJ	assumed: no relevant environmental interventions
01_Sw_cent	01ol_Sw_cent	1 MJ	therm. energy out of oil generator
	G1ol_Sw_cent	23.8e-3 kg	oil
	A1ol_Sw_cent	kg	combustion waste
	U1ol_Sw_cent	240e-6 kg	stikstofoxyde
	U2ol_Sw_cent	920e-6 kg	zwaveldioxyde
	U3ol_Sw_cent	30e-6 kg	stof
	U4ol_Sw_cent	7e-6 kg	KWS
	U5ol_Sw_cent	4e-6 kg	koolmonoxyde
	U6ol_Sw_cent	kg	kooldioxyde
En_FRG_elec	01co_FRG_cent	0.33 MJ	
	01ga_FRG_cent	0.22 MJ	
	01ol_FRG_cent	0.11 MJ	
	01li_FRG_cent	0.16 MJ	
	01ot_FRG_cent	MJ	other energy (water and nuclear power)

	O1en_FRG_elec	1	MJ	therm. energy of el. generator (FRG)
Co_FRG_cent	O1co_FRG_cent	1	MJ	therm energy out of coal generator FRG
	G1co_FRG_cent	37.2e-3	kg	coal
	A1co_FRG_cent		kg	ashes of mining after re-use
	A2co_FRG_cent		kg	waste of coal mining
	U1co_FRG_cent	420e-6	kg	stikstofoxyde
	U2co_FRG_cent	755e-6	kg	zwaveldioxyde
	U3co_FRG_cent	75e-6	kg	stof
	U4co_FRG_cent	3.4e-6	kg	KWS
	U5co_FRG_cent	17e-6	kg	koolmonoxyde
	U6co_FRG_cent		kg	kooldioxyde
	U7co_FRG_cent		kg	PAK
	U8co_FRG_cent		kg	fluoride
	U9co_FRG_cent		kg	kwik
	U10co_FRG_cent		kg	cadmium
	U11co_FRG_cent	80e-6	kg	HCl
	U12co_FRG_cent	7e-6	kg	HF
Li_FRG_cent	O1li_FRG_cent	1	MJ	therm energy out of lignite generator FRG
	G1li_FRG_cent	37.2e-3	kg	lignite
	A1li_FRG_cent		kg	ashes of mining after re-use
	A2li_FRG_cent		kg	waste of lignite mining
	U1li_FRG_cent	180e-6	kg	stikstofoxyde
	U2li_FRG_cent	760e-6	kg	zwaveldioxyde
	U3li_FRG_cent	50e-6	kg	stof
	U4li_FRG_cent	3.4e-6	kg	KWS
	U5li_FRG_cent	11e-6	kg	koolmonoxyde
	U6li_FRG_cent		kg	kooldioxyde
	U7li_FRG_cent		kg	PAK
	U8li_FRG_cent		kg	fluoride
	U9li_FRG_cent		kg	kwik
	U10li_FRG_cent		kg	cadmium
	U11li_FRG_cent	20e-6	kg	HCl
	U12li_FRG_cent	0.5e-6	kg	HF
Ga_FRG_cent	G1ga_FRG_cent	31.6e-3	m3	gas
	O1ga_FRG_cent	1	MJ	therm. energy out of gas el. generator (FRG)
	U1ga_FRG_cent	190e-6	kg	stikstofoxyde
	U2ga_FRG_cent	10e-6	kg	zwaveldioxyde
	U3ga_FRG_cent	0.1e-6	kg	stof
	U4ga_FRG_cent	0.45e-6	kg	KWS
	U5ga_FRG_cent	1e-6	kg	koolmonoxyde
	U6ga_FRG_cent		kg	kooldioxyde
Ol_FRG_cent	O1ol_FRG_cent	1	MJ	therm. energy out of oil generator
	G1ol_FRG_cent	23.8e-3	kg	oil
	A1ol_FRG_cent		kg	combustion waste
	U1ol_FRG_cent	240e-6	kg	stikstofoxyde
	U2ol_FRG_cent	920e-6	kg	zwaveldioxyde
	U3ol_FRG_cent	30e-6	kg	stof
	U4ol_FRG_cent	7e-6	kg	KWS
	U5ol_FRG_cent	4e-6	kg	koolmonoxyde

	U6ol_FRG_cent		kg	kooldioxyde
El_cent_bus	O1el_cent_bus	1	MJ	therm. *energy of el. generator*
	G1el_cent_bus	17.05e-3	kg	coal
	G2el_cent_bus	3.86e-3	kg	oil
	G3el_cent_bus	4.49e-3	m3	gas
	U1el_cent_bus	0.44e-3	kg	stikstofoxyde
	U2el_cent_bus	1.11e-3	kg	zwaveldioxyde
	U3el_cent_bus	0.25e-3	kg	stof
	U4el_cent_bus	0.17e-3	kg	KWS
	U5el_cent_bus	0.05e-3	kg	koolmonoxyde
	U6el_cent_bus		kg	kooldioxyde
	U6el_cent_bus	2.7e-6	kg	others
	L1el_cent_bus	0.06e-3	kg	acids
	L2el_cent_bus	0.01e-3	kg	metalic ions (Fe)
	L1el_cent_bus	*0.05e-3*	kg	*other*
diesel_trns	O1diesel_trns	1	MJ	diesel transport
	O1diesel_prMJ	1	MJ	diesel production
	U1diesel_trns	1.1e-3	kg	stikstofoxyde
	U2diesel_trns	120e-6	kg	zwaveldioxyde
	U3diesel_trns	100e-6	kg	stof
	U4diesel_trns	260e-6	kg	KWS
	U5diesel_trns	350e-6	kg	koolmonoxyde
	U6diesel_trns	0	kg	kooldioxyde
Diesel_prMJ	O1diesel_prMJ	1	MJ	production of 1 MJ diesel
	O1oil_refMJ	1.14	MJ	refining of 1 MJ diesel from 1.14 MJ oil
Oil_refMJ	O1oil_refMJ	1	MJ	
	G1oil_refMJ	1	MJ	raw material; emission data unknown
Diesel_pr_l	O1diesel_pr_l	1	l	production of 1 l diesel
	O1oil_ref_l	1.14	l	refining of 1 l diesel from 1.14 l oil
Oil_ref_l	O1oil_ref_l	1	l	1 l crude oil
	G1oil_ref_l	48	MJ	raw material; expressed as energy
En_elec_NL	O1co_cent_NL	0.31	MJ	
	O1ga_cent_NL	0.61	MJ	
	O1ol_cent_NL	0.02	MJ	
	O1ke_cent_NL	0.06	MJ	
	O1en_elec_NL	1	MJ	therm. energy of el. generator (NL)
Ga_cent_NL	G1ga_cent_NL	31.6e-3	m3	gas
	O1ga_cent_NL	1	MJ	therm. energy out of gas el. generator
	U1ga_cent_NL	134e-6	kg	stikstofoxyde
	U2ga_cent_NL	1.8e-6	kg	zwaveldioxyde
	U3ga_cent_NL	0.3e-6	kg	stof
	U4ga_cent_NL	1.9e-6	kg	KWS
	U5ga_cent_NL	6.3e-6	kg	koolmonoxyde
	U6ga_cent_NL	56.1e-3	kg	kooldioxyde

Ga_cent_ch	G1ga_cent_ch	31.6e-3	m3	gas
	O1ga_cent_ch	1	MJ	therm. energy out of gas el. generator chemical industry
	U1ga_cent_ch	80e-6	kg	stikstofoxyde
	U2ga_cent_ch	5.0e-6	kg	zwaveldioxyde
	U3ga_cent_ch	0.03e-6	kg	stof
	U4ga_cent_ch	2.0e-6	kg	KWS
	U5ga_cent_ch	13e-6	kg	koolmonoxyde
	U6gal_cent_ch	56.1e-3	kg	kooldioxyde
Ga_cent_pc	G1ga_cent_pc	31.65e-3	m3	gas
	O1ga_cent_pc	1	MJ	therm. energy out of gas at polycarbonate industry
	U1ga_cent_pc	160.2e-6	kg	stikstofoxyde
	U2ga_cent_pc	81e-6	kg	KWS
	U3ga_cent_pc	31e-6	kg	koolmonoxyde
	U4ga_cent_pc	56.1e-3	kg	kooldioxyde
Ke_cent_NL	G1ke_cent_NL	9e-4	kg	uranium ore
	O1ke_cent_NL	1	MJ	nuclear power expressed as therm. energy
	A1ke_cent_NL	5.9e-9	m3	high reactive nuclear waste
	A2ke_cent_NL	14.5e-9	m3	low and medium reactive nuclear waste
Co_cent_NL	G1co_cent_NL	37.2e-3	kg	coal
	O1co_cent_NL	1	MJ	therm. energie out of coal el. generator
	A1co_cent_NL	3.2e-3	kg	ashes of mining after re-use
	A2co_cent_NL	6.7e-3	kg	waste of coal mining
	U1co_cent_NL	290e-6	kg	stikstofoxyde
	U2co_cent_NL	459e-6	kg	zwaveldioxyde
	U3co_cent_NL	13e-6	kg	stof
	U4co_cent_NL	4e-6	kg	KWS
	U5co_cent_NL	10e-6	kg	koolmonoxyde
	U6co_cent_NL	94.2e-3	kg	kooldioxyde
	U7co_cent_NL	15e-11	kg	PAK
	U8co_cent_NL	2.33e-6	kg	fluoride
	U9co_cent_NL	9e-9	kg	kwik
	U10co_cent_NL	85e-9	kg	cadmium
Ol_cent_NL	G1ol_cent_NL	23.8e-3	kg	oil
	O1ol_cent_NL	1	MJ	therm. energy out of oil in el. generator
	A1ol_cent_NL	70e-6	kg	combustion waste
	U1ol_cent_NL	160e-6	kg	stikstofoxyde
	U2ol_cent_NL	567e-6	kg	zwaveldioxyde
	U3ol_cent_NL	23e-6	kg	stof
	U4ol_cent_NL	6.3e-6	kg	KWS
	U5ol_cent_NL	19e-6	kg	koolmonoxyde
	U6ol_cent_NL	94.2e-3	kg	kooldioxyde
aceton_prod	O1ga_cent_ch	13	MJ	for manufacture out of naphtha
	O1aceton_prod	1	kg	aceton
	O1nafta_prod	1	kg	nafta

Al_prod	G1al_prod	4.788	kg	bauxite
	G2al_prod	0.3132	kg	brine
	G3al_prod	0.0874	kg	stone salt
	G4al_prod	1.365	kg	oil
	G5al_prod	1.11	m3	gas
	G6al_prod	3.06	kg	coal
	A1al_prod	11.4	kg	waste from bauxite mining
	A2al_prod	0.0342	kg	waste from brine mining
	A3al_prod	0.0214	kg	waste from kalk manufacture
	A4al_prod	2.14	kg	red mud Bayerprocess
	A5al_prod	0.186	kg	dust from Bayerprocess
	A6al_prod	0.283	kg	combustion waste
	A7al_prod	0.601	kg	waste of mining of fuels
	U1al_prod	66.36e-3	kg	stof
	U2al_prod	98e-3	kg	stikstofoxyde
	U3al_prod	249e-3	kg	zwaveldioxyde
	U4al_prod	22e-3	kg	koolmonoxyde
	U5al_prod	38.43e-3	kg	KWS
	U6al_prod	1.372	kg	kooldioxyde
	U7al_prod	0.49e-3	kg	fluoride
	U8al_prod	1.85e-3	kg	chloor
	U9al_prod	1e-4	kg	teer (PAK)
	L1al_prod	1.1e-7	kg	fluoride
	L2al_prod	1.3e-7	kg	teer (PAK)
	L3al_prod	1.5e-3	kg	BOD
Al_rolled	O1al_rolled	1	kg	aluminium foil
	O1al_prod	1	kg	
	O1en_elec_NL	30	MJ	
board_lam	O1board_lam	1	st	1 manufactured coated carton package
	O1board_prod	0.0253	kg	board
	O1PE_L_prod	0.0032	kg	PE per package
	O1en_FRG_elec	53.4e-3	MJ	lamination
	O1ga_FRG_cent	3.13e-3	MJ	lamination
	O1en_FRG_elec	7.82e-3	MJ	drying and printing ink
	O1ga_FRG_cent	2.57e-3	MJ	drying and printing ink
	O1en_FRG_elec	33.92e-3	MJ	slicing and cooling water
	O1ink_prod	0.000243	kg	ink
Board_prod	O1board_prod	1	kg	1 kg board
	O1ol_Sw_cent	0.155	MJ	transport of wood to factory
	O1en_Sw_elec	5.51	MJ	electric energy for board production
	O1ol_Sw_cent	6.8	MJ	therm energy for board production
	O1diesel_trns	0.456	MJ	transport to FRG (NL)
	O1en_Sw_elec	0.31	MJ	transport to FRG (NL)
	G1board_prod	2	kg	wood
	L1board_prod	3.0e-3	kg	suspended substances (solids)
	L2board_prod	1.93e-3	kg	BOD7
	L3board_prod	14.17e-3	kg	COD
	L4board_prod	8.59e-6	kg	sulphides expressed as H2S
	L5board_prod	0.08e-3	kg	aluminium
	L6board_prod	0.023e-3	kg	total phosphorus
	L7board_prod	0.208e-3	kg	Kjeld-N
	L8board_prod	1.72e-6	kg	NO3-N
	U1board_prod	6.255e-3	kg	zwaveldioxyde

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                U2board_prod   2.21e-3 kg  stof
                U3board_prod  0.021e-3 kg  organic S
                U4board_prod  0.565e-3 kg  koolmonoxyde
                U5board_prod  0.072e-3 kg  H2S
                O1coat_prod      0.121 kg  only H2SO4 for coating
                O1CaO_prod     5.24e-3 kg  calciumoxide
                O1H2SO4_prod   9.44e-3 kg  for paper production
                O1Na2SO4_prod   0.0157 kg  for paper production
                O1NaOH_prod     0.0105 kg

CaO_prod        O1CaO_prod           1 kg  CaO
                O1en_Sw_elec      0.39 MJ
                O1ol_Sw_cent         5 MJ

cap_al_fu       O1al_rolled       0.25 kg  aluminium foil for 1000 caps
                O1cap_al_fu          1 st  1000 aluminium caps
                A1cap_al_fu       0.25 kg  aluminium waste

cap_pe_fu       O1cap_pe_fu          1 st  1000 caps of 4 gram each
                O1cap_pe_prod     1000 st
                O1PE_waste      400e-3 kg  100 caps in household waste; assump-
tion: independent of number of trips

cap_pe_prod     O1cap_pe_prod        1 st  cap of 4 gram
                O1PE_prod         4e-3 kg
                O2PE_prod      -2.7e-3 kg  net effect recycling; 75% of 90% of
4 gram

Cap_twist       O1cap_twist          1 st  twist-off cap (44 mm diametre)
                O1pvcw_comp    0.88e-3 kg
                O1st_rolled    3.47e-3 kg

Cap_twist_fu    O1cap_twist_fu       1 st
                O1cap_twist       1000 st
                O1twist_waste       50 st

cart_pack       O1cart_pack          1 st
                O1board_lam          1 st

cart_pack_fu    O1cart_pack_fu       1 st  number of packs as specified in
functional unit: gable_totall
                O1cart_pack       1000 st

cart_pack_lc    O1cart_pack_lc       1 st  life cycle of 1000 milk cartons
                O1cart_pack_fu       1 st
                O1gable_waste     1000 st
                O1trnsp_carton       1 st  1 st contains 1000 packs including
milk

gable_totall    O1gable_totall       1 st  ecoprofile of gable top; 1 trip
                O1cart_pack_lc       1 st  lifecycle carton pack, including
milk transport
                O1cont_fu            1 st  0.833e-3 containers

gable_waste     O1gable_waste        1 st  1 gable top
                O1PE_waste       3.2e-3 kg  PE coating
```

	O1cart_waste	*25.3e-3*	*kg*	*board and paper*
cart_waste	O1cart_waste	1	kg	1 kg board and paper
	O1cart_landf	0.6	kg	board and paper on landfill
	O1cart_inci	0.4	kg	board and paper in incinerator
cart_landf	O1cart_land	1	kg	board and paper on landfill
	A1cart_landf	1	kg	board and paper waste
cart_inci	O1cart_inci	1	kg	board and paper incineration
	O1en_elec_NL	-4.41	MJ	recovery of energy: efficiency 30%
	U2cart_inci		kg	kooldioxyde
	U3cart_inci		kg	KWS
	A1cart_inci	0.1	kg	incinerator waste
Coat_prod	O1coat_prod	1	kg	coating chemicals
	O1H2SO4_prod	0.32	kg	H2SO4
	O1ol_Sw_cent	0.013	MJ	
	O1en_Sw_elec	8.53e-4	MJ	
	G1coat_prod	1.15	kg	
Cont_prod	O1cont_prod	1	st	roll-in container
	O1st_zinc	20	kg	
	O2st_zinc	*-5*	*kg*	*net effect recycling ; no other* parts specified
Cont_fu	O1cont_fu	1	st	functional unit container
	O1cont_prod	8.33e-3	st	at 750 trips for 1000 liter milk
ethanol_prod	O1ethanol_prod	1	kg	ethanol
	O1en_FRG_elec	6.99	MJ	
	O1ol_FRG_elec	11.46	MJ	
	O1diesel_trns	0.098	MJ	
	L1ethanol_prod	50e-3	kg	suspended substances
	L2ethanol_prod	340e-3	kg	BOD
	L3ethanol_prod	770e-3	kg	COD
	L4ethanol_prod	140e-3	kg	other pollutants
	Lethanol_prod	45e-3	kg	Kjeld-N
fenol_prod	*O1ga_cent_ch*	*20*	*MJ*	*for manufacture out of naphtha*
	O1fenol_prod	1	kg	fenol
	O1nafta_prod	1	kg	nafta ; including winning ?
Glas_prod Switzerland	O1glas_prod	1	kg	glass without external cullet
	G1glas_prod	0.204	kg	oil
	G2glas_prod	0.021	kg	gas
	G3glas_prod	0.031	kg	coal
	G4glas_prod	0.6218	kg	quarts sand
	G5glas_prod	0.1099	kg	dolomite
	G6glas_prod	0.1028	kg	kalk
	G7glas_prod	0.0569	kg	feldspate
	G8glas_prod	0.2821	kg	brine
	G9glas_prod	0.0340	kg	small substances
	G10glas_prod	0.0898	kg	cullet from glass production
	A1glas_prod	*0.324722*	*kg*	*waste of production process*

```
              A2glas_prod       0.004293 kg  combustion waste
              U1glas_prod      9.875e-3 kg  stof
              U2glas_prod      4.866e-3 kg  stikstofoxyde
              U3glas_prod      2.078e-3 kg  KWS
              U4glas_prod     11.407e-3 kg  zwaveldioxyde
              U5glas_prod      0.649e-3 kg  koolmonoxyde
              U6glas_prod      0.004e-3 kg  aldehydes
              U7glas_prod      0.051e-3 kg  other anorganic substances
              U8glas_prod      0.600e-3 kg  ammoniak
              L1glas_prod      0.324e-3 kg  dissolved substances
              L2glas_prod      0.001e-3 kg  fenol
              L3glas_prod      0.001e-3 kg  COD
              L4glas_prod      0.910e-3 kg  suspended substances
              L5glas_prod      0.350e-3 kg  acids
              L6glas_prod      0.094e-3 kg  metalic ions (Fe)
              L7glas_prod      1.054e-3 kg  other not defined substances

Glas_prod_nl  O1glas_prod_nl          1 kg  white glass with small amount
external cullet Netherlands
              O1el_cent_bus         2.4 MJ  for melting process
              O1en_elec_NL         0.18 MJ  for raw materials
              O1en_elec_NL         2.36 MJ  for production of raw materials
originally therm. eq.
              G1glas_prod_nl     0.1927 m3  gas
              G2glas_prod_nl      0.615 kg  quartz sand
              G3glas_prod_nl      0.185 kg  kalk
              G4glas_prod_nl      0.054 kg  nefiline
              G5glas_prod_nl     0.2877 kg  brine (calculated)
              G6glas_prod_nl      0.005 kg  Na2SO4
              G7glas_prod_nl     0.0002 kg  cokes
              G8glas_prod_nl      0.120 kg  cullet from glass production and
external (small)
              U1glas_prod_nl     170e-6 kg  stof
              U2glas_prod_nl     820e-6 kg  stikstofoxyde
              U3glas_prod_nl     780e-6 kg  zwaveldioxyde
              U4glas_prod_nl      50e-6 kg  chloor
              U5glas_prod_nl       5e-6 kg  fluoride
              L1glas_prod_nl          0 kg  metalic ions (Fe)

gl_nl_30_fu   O1gl_nl_30_fu           1 st  1 functional unit of 33.3 bottles of
480 g NL
              O1gl_nl_ru           33.3 st

gl_nl_30_lc   O1gl_nl_30_lc           1 st  total life cycle of 33.3 bottles
              O1gl_nl_30_fu           1 st  production of 33.3 bottles of 480
gram
              O1glas_waste            1 st  waste of 10 bottles in household
waste
              O1trnsp_glass           1 st  transport of 1000 litres milk in 480
gram glass bottle
              O1wash_func             1 st  washing of 1000 bottles in dairy

Gl_nl_ru      O1Gl_nl_ru              1 st  glass bottle with small external
cullet from NL; Dutch data
              O1glas_prod_nl      0.480 kg  glass
              O2glas_prod_nl     -0.120 kg  net effect recycling: high quality
```

	O3glas_prod_nl	-0.030	kg	net effect recycling: low quality
Glas_prod_ru	O1Glas_prod_ru	1	st	glass bottle with no external cullet
	O1glas_prod	0.480	kg	glass
	O2glas_prod	-0.120	kg	net effect recycling: high quality
	O3glas_prod	-0.030	kg	net effect recycling: low quality
Gl_nl_20_fu	O1gl_nl_20_fu	1	st	number of bottles as specified in functional unit: glass_total20
	O1gl_nl_ru	50	st	
Gl_nl_20_lc	O1gl_nl_20_lc	1	st	total life cycle of 50 bottles
	O1gl_nl_20_fu	1	st	production of 50 bottles of 480 gram
	O1glas_waste2	1	st	waste of 12.5 bottles in household waste
	O1trnsp_glass	1	st	transport of 1000 litres milk in 480 gram glass bottle
	O1wash_func	1	st	washing of 1000 bottles in dairy
Glas_bot_fu	O1glas_bot_fu	1	st	1 functional unit of 33.3 bottles of 480 g
	O1glas_prod_ru	33.3	st	
Glas_bot_lc	O1glas_bot_lc	1	st	total life cycle of 33.3 bottles
	O1glas_bot_fu	1	st	production of 33.3 bottles of 480 gram
	O1glas_waste	1	st	waste of 8.3 bottles in household waste
	O1trnsp_glass	1	st	transport of 1000 litres milk in 480 gram glass bottle
	O1wash_func	1	st	washing of 1000 bottles in dairy
Glas_waste	O1glas_waste	1	st	waste of 8.3 bottles in household waste
	A1glas_waste	4	kg	bottles landfilled and incinerated
Glas_waste2	O1glas_waste2	1	st	waste of 12.5 bottles in household waste
	A1glas_waste	6	kg	bottles landfilled and incinerated
Gl30_total	O1gl33_total	1	st	ecoprofile of glass bottle: 30 trips
	O1gl_nl_30_lc	1	st	glass lifecycle; Dutch data
	O1pegl_cra_fu	1	st	crate
	O1cap_pe_fu	1	st	cap
	O1lab_pe_fu30	1	st	label
Gl20_total	O1gl20_total	1	st	ecoprofile of glass bottle: 20 trips
	O1gl_nl_20_lc	1	st	glass lifecycle; Dutch data
	O1pegl_cra_fu	1	st	crate
	O1cap_pe_fu	1	st	cap
	O1lab_pe_fu20	1	st	label
H2SO4_prod	O1H2SO4_prod	1	kg	H2SO4
	O1en_Sw_elec	1.47	MJ	electric energy
	G1H2SO4_prod	0.65	kg	sulphur pyrite

	L1H2SO4_prod	140e-3	kg	suspended sulphate sludge (or 50% less)
	U1H2SO4_prod	5e-3	kg	zwaveldioxyde
	U2H2SO4_prod	0.5e-3	kg	H2SO4
ink_prod	O1ink_prod	1	kg	ink
	O1en_FRG_elec	30.85	MJ	
	O1pigment_prod	0.285	kg	
	O1ethanol_prod	0.325	kg	
	O1diesel_trns	0.05	MJ	
lab_pa_fu	O1lab_pa_fu	1	st	1000 paper labels of 1.72 gram each
	O1lab_pa_prod	1000	st	
	A1lab_pa_fu	1.032	kg	paper on landfill
lab_pa_prod	O1lab_pa_prod	1	st	paper label of 1.72 gram
	O1paper_prod	1.72e-3	kg	
lab_pe_fu75	O1lab_pe_fu75	1	st	1000 PE labels of 2 gram each
	O1lab_pe_prod	1000	st	
	O2lab_pe_prod	-497	st	recycled: 993.3 labels; loss of quality: 50 %
	O1PE_labwaste	6.7	st	6.7 PE labels with bottles in household waste
lab_pe_fu50	O1lab_pe_fu50	1	st	1000 PE labels of 2 gram each
	O1lab_pe_prod	1000	st	
	O2lab_pe_prod	-495	st	recycled: 990 labels; loss of quality: 50 %
	O1PE_labwaste	10	st	10 PE labels with bottles in household waste
lab_pe_fu30	O1lab_pe_fu30	1	st	1000 PE labels of 2 gram each
	O1lab_pe_prod	1000	st	
	O2lab_pe_prod	-492	st	recycled: 983 labels; quality loss 50 %
	O1PE_labwaste	16.6	st	16.6 PE labels with bottles in household waste
lab_pe_fu20	O1lab_pe_fu20	1	st	1000 PE labels of 2 gram each
	O1lab_pe_prod	1000	st	
	O2lab_pe_prod	-490	st	recycled: 980 labels; loss of quality: 50 %
	O1PE_labwaste	20	st	20 PE labels with bottles in household waste
PE_labwaste	O1PE_labwaste	1	st	label waste
	O1PE_waste	2e-3	kg	pe label waste
lab_pe_prod	O1lab_pe_prod	1	st	PE label of 2 gram
	O1PE_prod	2e-3	kg	
nafta_prod	O1nafta_prod	1	kg	nafta
	G1nafta_prod	1.045	kg	oil
	U1nafta_prod	0.175	EVL	raffinage en energieverbruik
Na2SO4_prod	O1Na2SO4_prod	1	kg	Na2SO4

	O1en_Sw_elec	2.54	MJ	
	O1ol_Sw_cent	2.28	MJ	
	O1H2SO4_prod	2.5	kg	
	G1Na2SO4_prod	2.5	kg	apatite
	U1Na2SO4_prod	1.39e-3	kg	Na2SO4
	U2Na2SO4_prod	1.22e-3	kg	HCl
NaOH_prod	O1NaOH_prod	1	kg	NaOH
	O1en_Sw_elec	13.11	MJ	
	U1NaOH_prod	0.94e-6	kg	chloor
	U2NaOH_prod	0.94e-4	kg	stof
paper_prod	O1paper_prod	1	kg	bleached sulfuric paper
	G1paper_prod	64e-3	kg	chlor
	G2paper_prod	12e-3	kg	soda lye
	G3paper_prod	2.14	kg	wood
	G4paper_prod	0.865	kg	oil
	G5paper_prod	0.040	kg	gas
	G6paper_prod	0.151	kg	coal
	U1paper_prod	3.908e-3	kg	stof
	U2paper_prod	1.319e-3	kg	koolmonoxyde
	U3paper_prod	18.189e-3	kg	stikstofoxyde
	U4paper_prod	92.302e-3	kg	zwaveldioxyde
	U5paper_prod	6.773e-3	kg	KWS
	U6paper_prod	235e-6	kg	organische verbindingen (als eth.imin)
	U7paper_prod	190e-9	kg	kwik
	L1paper_prod	8.6e-3	kg	dissolved substances
	L2paper_prod	1.185e-3	kg	acids
	L3paper_prod	0.096e-6	kg	kwik
	L4paper_prod	72.7e-3	kg	chloor
	L5paper_prod	154.5e-3	kg	COD
	L6paper_prod	0.034e-3	kg	organic chlorine substances
	L7paper_prod	0.341e-3	kg	metalic ions (Fe)
	A1paper_prod	63.876e-3	kg	waste
PC_man_bot	O1PC_man_bot	1	st	functional unit for 1000 litres milk
	O1PC_man	13.3	st	extruded bottles for 75 trips
PC_bot_lc75	O1PC_bot_lc75	1	st	total life cycle of PC bottle
	O1PC_man_bot	1	st	functional unit for 1000 litres milk
	O1PC_waste	6.7	st	total of 6.7 bottles that are household waste
	O1trnsp_pc	1	st	transport of 1000 litres milk in polycarbonate
	O1wash_func	1	st	washing of 1000 bottles in dairy
PC_man	O1ga_cent_pc	0.432	MJ	energy for manufacturing of 1 PC bottle
	O1PC_man	1	st	manufactured polycarbonate bottle
	O1PC_prod	70e-3	kg	polycarbonate
	O2PC_prod	-38e-3	kg	net effect of recycling
	O1trnsp_en	0	1	transport of PC to convertor manufacture; data unknown!

PC50_total	O1pc50_total	1	st	ecoprofile of functional unit pc; 50 trips
	O1pc_bot_lc50	1	st	20 bottle life cycles
	O1cap_pe_fu	1	st	1000 caps
	O1lab_pe_fu50	1	st	1000 labels
	O1cont_fu	1	st	8.33e-3 containers
PC75_total	O1pc75_total	1	st	ecoprofile of functional unit pc; 75 trips
	O1pc_bot_lc75	1	st	13.3 bottle life cycles
	O1cap_pe_fu	1	st	1000 caps
	O1lab_pe_fu75	1	st	1000 labels
	O1cont_fu	1	st	8.33e-3 containers
PC_50_bot	O1PC_50_bot	1	st	functional unit for 1000 litres milk
	O1PC_man	20	st	extruded bottles for 50 trips
PC_bot_lc50	O1PC_bot_lc50	1	st	total life cycle of PC bottle
	O1PC_50_bot	1	st	functional unit for 1000 litres milk
	O1PC_waste	10	st	total of 10 bottles that are household waste
	O1trnsp_pc	1	st	transport of 1000 litres milk in polycarbonate
	O1wash_func	1	st	washing of 1000 bottles in dairy
PC_waste	O1PC_waste	1	st	total of 1 bottle that is household waste
	O1PC_landf	0.6	st	0.6 bottles on landfill
	O1PC_inci	0.4	st	0.4 bottles incineration
PC_landf	O1PC_landf	1	st	bottle on landfill
	A1PC_landf	70e-3	kg	polycarbonate
PC_inci	O1PC_inci	1	st	bottle incineration
	O1en_elec_NL	-9.21	MJ	recovery of energy: efficiency 30%
	A1PC_inci	0	kg	incineration waste
	U1PC_inci		kg	koolmonoxyde
	U2PC_inci		kg	kooldioxyde
	U3PC_inci		kg	KWS
PC_prod	O1PC_prod	1	kg	polycarbonate
	O1aceton_prod	0.245	kg	aceton
	O1fenol_prod	0.775	kg	fenol
	O1en_elec_NL	2.18	MJ	
	O1ga_cent_pc	27.92	MJ	
	G1PC_prod	0.157	m3	gas
	G2PC_prod	0.638	kg	natriumchloride
	G3PC_prod	0.26	kg	natriumchloride
	G4PC_prod	0.2e-3	kg	tolueen
	G5PC_prod	2.0e-3	kg	dichloormethaan
	U1PC_prod	0.2e-3	kg	tolueen
	U2PC_prod	1.8e-3	kg	dichloormethaan
	U3PC_prod	4.27e-3	kg	koolmonoxyde
	L1PC_prod	0.01e-3	kg	fenol
	L2PC_prod	0.0003e-3	kg	dichloormethaan

	L3PC_prod	634e-3	kg	natriumchloride
	A1PC_prod	0.031	kg	afval
PE_prod	*G1PE_prod*	1.01572	*kg*	*oil*
	G2PE_prod	0.256	m3	gas
	O1PE_prod	1	kg	PE
	U1PE_prod	38e-6	kg	stof
	U2PE_prod	378e-6	kg	koolmonoxyde
	U3PE_prod	610e-6	kg	stikstofoxyde
	U4PE_prod	1.09e-3	kg	zwaveldioxyde
	U5PE_prod	4.623e-3	kg	KWS
	L1PE_prod	4e-6	kg	fenol
	L2PE_prod	*376e-3*	*kg*	*anorganic suspended substances*
	L3PE_prod	120e-3	kg	other organic suspended substances
	A1PE_prod	4.030e-3	kg	solid waste
PE_waste	O1PE_waste	1	kg	1 kg PE
	O1PE_landf	0.6	kg	0.6 PE on landfill
	O1PE_inci	0.4	kg	0.4 PE incineration
PE_landf	O1PE_landf	1	kg	PE on landfill
	A1PE_landf	1	kg	polyethene waste
PE_inci	*O1PE_inci*	1	*kg*	*bottle incineration*
	O1en_elec_NL	-13.83	MJ	recovery of energy: efficiency 30%
	U1PE_inci		kg	koolmonoxyde
	U2PE_inci		kg	kooldioxyde
	U3PE_inci		kg	KWS
	A1PE_inci	0	kg	incineration waste
PE_crate_fu	O1PE_crate_fu	1	st	crates for 1000 litres
	O1PE_cra_prod	0.1	st	crates with 500 trips for 1000
litres milk				
	O1PE_waste	0	kg	0 crates in household waste assumed
PEgl_cra_fu	O1PEgl_cra_fu	1	st	crates for 1000 glass bottles
	O1PEgcra_prod	0.17	st	crates with 500 trips for 1000
litres milk				
	O1PE_waste	0	kg	0 crates in household waste assumed
PE_cra_prod	O1PE_cra_prod	1	st	crate for 20 packages (PC or carton)
incl. recycling				
	O1PE_prod	2	kg	weight of crate
	O2PE_prod	*-1.50*	*kg*	*net effect of recycling; 75%*2 kg*
PEgcra_prod	O1PEgcra_prod	1	st	crate for 12 glass bottles incl.
recycling				
	O1PE_prod	1.98	kg	weight of crate
	O2PE_prod	-1.485	kg	net effect of recycling; 75%*1.98 kg
PE_L_prod	O1PE_L_prod	1	kg	PE production according to Lundholm
	G1PE_L_prod	1.08	kg	oil
	O1en_FRG_elec	29.3	MJ	
	O1diesel_trns	0.48	MJ	transport of granulate to plant
	L1PE_L_prod	*0.05e-3*	*kg*	*COD*
	U1PE_L_prod	3.54e-3	kg	stikstofoxyde
	U2PE_L_prod	1.56e-3	kg	zwaveldioxyde

	U3PE_L_prod	3.99e-3	kg	KWS
	APE_L_prod	0.05	kg	
pigment_prod	O1pigment_prod	1	kg	pigment
	O1en_FRG_elec	10.29	MJ	
	O1diesel_trns	0.104	MJ	
PVC_prod	G1pvc_prod	0.468	kg	oil
	G2pvc_prod	1.016	kg	brine
	G3pvc_prod	0.193	kg	gas
	O1pvc_prod	1	kg	PVC
	A1pvc_prod	0.010	kg	waste chlor production
	A2pvc_prod	0.063	kg	waste of brine mining
	A3pvc_prod	0.015	kg	mixed waste (hazardous composition)
	A4pvc_prod	0.015	kg	combustion waste
	U1pvc_prod	1.4e-3	kg	vinylchloride
	U2pvc_prod	1.7e-3	kg	1.2_dichloorethaan
	U3pvc_prod	3.9e-4	kg	koolmonoxyde
	U4pvc_prod	2.7e-3	kg	stikstofoxyde
	U5pvc_prod	3.9e-4	kg	stof
	U6pvc_prod	2.5e-3	kg	zwaveldioxyde
	U7pvc_prod	2.8e-7	kg	kwik
	U8pvc_prod	3e-7	kg	chloor
	U9pvc_prod	1.3e-4	kg	zoutzuur
	U10pvc_prod	14e-4	kg	KWS
	L1pvc_prod	3e-4	kg	2_chloorethanol
	L2pvc_prod	1.2e-3	kg	trichloorethanol
	L3pvc_prod	5.7e-6	kg	vinylchloride
	L4pvc_prod	19e-6	kg	fenol
	L5pvc_prod	4e-6	kg	lood
	L6pvc_prod	1.7e-8	kg	kwik
PVCw_comp	O1pvc_prod	0.70	kg	
	G1pvcw_comp	0.30	kg	weekner (di_2_eth.hex.phtal.)
	O1en_elec_NL	7	MJ	
	O1pvcw_comp	1	kg	week PVC
PVC_waste	G1pvc_waste	-0.002	kg	oil
	G2pvc_waste	-0.005	kg	brine
	G3pvc_waste	-0.001	kg	gas
	O1pvc_waste	1	kg	PVC
	A1pvc_waste	0.006	kg	combustion waste
	A2pvc_waste	0.621	kg	rest waste
	U1pvc_waste	3.76e-4	kg	koolmonoxyde
	U4pvc_waste	7.43e-3	kg	stikstofoxyde
	U5pvc_waste	1.8e-4	kg	stof
	U6pvc_waste	1.005e-3	kg	zwaveldioxyde
	U7pvc_waste	-0.02e-7	kg	kwik
	U8pvc_waste	-3e-7	kg	chloor
	U9pvc_waste	2.2e-4	kg	zoutzuur
	U10pvc_waste	0.056e-3	kg	KWS
St_zinc	O1st_rolled	0.97	kg	
	G1st_prod	0.03	kg	zink
	O1en_elec_NL	9.2	MJ	
	O1st_zinc	1	kg	zinkcoated steel

	U1st_zinc	0.077	evl	
	L1st_zinc	3.6e-3	evw	
St_rolled	O1st_prod	1	kg	
	O1en_elec_NL	2.14	MJ	
	O1st_rolled	1	kg	rolled steel
St_prod	O1st_prod	1	kg	steel
	G1st_prod	1.454	kg	iron ore
	G2st_prod	0.128	kg	limestone
	O1en_elec_NL	18.8	MJ	
	U1st_prod	3.4	evl	
	L1st_prod	4.2	evw	
	A1st_prod	4	kg	mining waste of iron ore
	A2st_prod	0.050	kg	non re-usable slags of melting-furnace
	A3st_prod	0.025	kg	oxylime mud (chemical waste)
trnsp_glass (480 g)	O1trnsp_glass	1	st	transport of 1000 litres in glass
	O1trnsp_en	4.707	l	diesel for truck of 5 ton
trnsp_carton	O1trnsp_carton	1	st	transport of 1000 litres in carton
	O1trnsp_en	3.296	l	diesel for truck of 5 ton
trnsp_pc	O1trnsp_pc	1	st	transport of 1000 litres in PC
	O1trnsp_en	3.379	l	diesel for truck of 5 ton
trnsp_en	O1trnsp_en	1	l	diesel consumption at 45.4 km/h
	G1trnsp_en	1	l	diesel
	U1trnsp_en	1.8e-3	kg	roet
	U2trnsp_en	32e-3	kg	koolmonoxyde
	U3trnsp_en	4.1e-3	kg	zwaveldioxyde
	U4trnsp_en	7.5e-3	kg	stikstofoxyde
	U5trnsp_en	2.0e-3	kg	KWS
Twist_waste	O1twist_waste	1	st	twist-off cap in household waste
	O1steel_waste	3.47e-3	kg	
	O1pvc_waste	0.7e-3	kg	
wash_bottle	O1en_elec_NL	0.085	MJ	energy for mediate modern washing machine
	O1wash_bottle	1	st	
	G1wash_bottle	0.595e-3	kg	NaOH
	O1en_elec_NL	6.55e-3	MJ	energy for soda production (G1)
	L1wash_bottle	0.25e-3	kg	chloor
	L2wash_bottle	0.595e-3	kg	geneutraliseerd NaOH
wash_func	O1wash_func	1	st	
	O1wash_bottle	1000	st	washing of 1000 bottles

APPENDIX 4 REMARKS TO THE PROCESDEFINITIONS.

label_paper	According to Golding (1989) the quality of paper labels is 75g/m^2. Size of the label is 85 mm x 270 mm. This means that each paper label weighs 1.72 gram. The environmental data are derived from the BUS-study (1984). Only the sum parametre of COD is taken into account for the water polution, while another sumparametre BOD is already attributed to COD (see page 7 of Thalmann & Humbel, 1985b).
Twist-off cap	The composition of the Twist-off cap is derived from the study by Golding. However he mentions that 0.88 gram consists of PVC and paint, he calculates with 0.88 gram PVC. This method is also followed in this audit.

APPENDIX 5 ENERGY MODELS

A. Energy model Federal Republic of Germany (Kindler and Mosthaf,1989)

Energy input	communal electricity generators	industrial electricity generators
coal	53.5%	60%
2oil	1.9%	8%
gas	6.7%	25%
other energy input	1.0%	7%
nuclear power	32.4%	
water, wind	4.5%	

The effenciency factor of the communal electricity generators is 0.378 so that 1kWh = 9,52 MJ. The efficiency factor at the industrial electricity generators is 0,827 so that 1 kWh is 4,35 MJ. As maintenance and depreciation of the capital goods is not accounted for energy from water and wind does not contribute to environmental effects.

Kindler and Mosthaf give mean emmision factors for the two ways of electricity generators:

Emission to air in mg/MJ$_{th}$		*waste in g/MJ*	
Soot	15	slags	1
SO_2	120		
NOx	130		
CO	10		
CH	10		

B: Energy model "FOSSILE BRENNSTOFFE" (Thalmann, 1985; Fecker, 1989)

Input and output factors for generating 3600 MJ_{el} (1000 KWH_{el}) electric energy (after Hunt and Welch, 1974)

		coal	oil	gas	other	total
Quantity		(186kg)	(46,11)	(66m^3)		
% of total energy input		48.2 %	17 %	23.5 %	11 %	100 %
Input:						
Energy	MJ_{th}	5'258.2	1'854.6	2'563.6	1'232.7	10'909.1
Output:						
- Solid wastes:						
"mining"	kg	35.27				35.27
fuel combustion	kg	12.82	0.13			12.95
- Atmospheric emissions:						
particulates	kg	2.41	0.08	0.25		2.74
nitrogen oxides	kg	1.78	0.68	2.33		4.79
hydrocarbons	kg	0.13	0.25	1.48		1.86
sulphuroxides	kg	10.51	1.56	0.04		12.11
carbon monoxide	kg	0.55	0.04			0.59
other	kg	0.01	0.01	0.01		0.03
- Waterborne wastes:						
acid	kg	0.41	0.03	0.24		0.68
metalion	kg	0.10	0.01	0.05		0.16
other	kg	0.08	0.25	0.25		0.58

The efficiency factor is 0.33

C: Energy model of the Netherlands (after Lindeijer, et al, in press)

Input and output for generating 1000 MJ^{th} electrical energy by communal electricity gener tors; situation Netherlands (CBS, 1987)

		coal	oil	gas	other	total
Quantity		11.5 (kg)	0.476 (kg)	19.3 ($^{m}3$)	0.054 (kg)	
% of total energy input		31 %	2 %	61 %	6 %	100 %
<u>Input</u>:						
Energy	MJ_{th}	310	20	610	60	1000
<u>Output:</u>						
- <u>Solid wastes</u>:						
"mining"	kg	2.08				2.08
mining waste after re-use	kg	0.992				0.992
fuel combustion	kg		0.0014			0.0014
nuclear waste:						
* high active	m^3				$3.54 \cdot 10^{-7}$	$3.54 \cdot 10^{-7}$
* middle and low active	m^3				$8.70 \cdot 10^{-7}$	$8.70 \cdot 10^{-7}$
- *<u>Atmospheric emissions</u>*:						
particulates	kg	0.00403	0.00046	0.000183		0.00467
nitrogen oxides	kg	0.0899	0.00320	0.08174		0.17484
hydrocarbons	kg	0.00124	0.0001256	0.00116		0.00252
sulfur oxides	kg	0.14200	0.0	0.00110		0.15500
carbon monoxide	kg	0.00310	0.00038	0.00384		0.00732
carbon dioxide*	kg	29.2	1.884	34.22		65.3
PAH	kg	$4.65 \cdot 10^{-8}$				$4.54 \cdot 10^{-8}$
F-	kg	$7.22 \cdot 10^{-4}$				$7.22 \cdot 10^{-4}$
Hg	kg	$2.79 \cdot 10^{-6}$				$2.79 \cdot 10^{-6}$
Cd	kg	$2.63 \cdot 10^{-5}$				$2.63 \cdot 10^{-5}$
- <u>Waterborne wastes</u>:						
BOD		$1.18 \cdot 10^{-3}$				$1.18 \cdot 10^{-3}$

* estimated with method of Blok e.a. (1989)

D: Energy model of chemical industry and polycarbonate industry in the Netherlands (CBS, 1987 and pers. comm. Vos, 1990)

		chemical industry	polycarbonate industry
Quantity gas input	m^3	31.65	31.65
<u>Input</u>:			
Energy	MJ_{th}	1000	1000
<u>Output</u>:			
- <u>Solid wastes</u>		--	--
- <u>Atmospheric emissions</u>:			
particulates	kg	0.00003	n.d.
nitrogen oxides	kg	0.080	0.1602
hydrocarbons	kg	0.002	0.081
sulfuroxides	kg	0.005	n.d.
carbon monoxide	kg	0.013	0.031
carbon dioxide*	kg	56.1	56.1
- <u>Waterborne wastes</u>:		--	--

* estimated with method Blok et al. (1989)

n.d. = not detectable

APPENDIX 6 Method of integral analysis of environmental effects of different products (in Dutch; reprint of Lindeijer, E., O. Mekel, G. Huppes and R. Huele (in press) Milieu-effecten van kozijnen; Interim-rapportage fase 1. CML-report no. 67)

1 Milieu-effecten per funktionele eenheid

Wanneer de milieu-effecten van een concrete funktionele eenheid produkt moeten worden berekend, worden eerst per materiaal waaruit het produkt is opgebouwd alle betrokken processen geanalyseerd op hun milieu-effecten. Het rekenwerk dat volgt wanneer de gegevens van de milieu-effecten zijn verzameld, is vrij eenvoudig:

> de gegevens worden vermenigvuldigd met het betreffende materiaalgewicht, dat zonodig gecorrigeerd is met het afvalverlies van het voorgaande proces. Gelijksoortige uitkomsten kunnen vervolgens nog opgeteld worden. Om ongelijksoortige milieu-effecten (verschillende grondstoffen, ijzererts en hout, en verschillende emissies, cadmium en zwaveldioxide bijvoorbeeld) voor een aantal milieu-aspecten bij elkaar op te kunnen tellen, is het nodig een aggregatiemethode te hanteren. Deze is in beginsel ontwikkeld en wordt nader belicht in de volgende paragraaf.

2 Methode van aggregatie van milieu-effecten

Voor de aggregatie van ongelijksoortige milieu-effecten vormt de methode zoals die in eerdere CML-studies is ontworpen de basis (Druijff, 1984; Van den Berg e.a., 1986; Rijsdorp e.a, 1989). Deze methode is in principe kwantitatief en grijpt aan op het niveau van het produkt. Hierbij gaat het erom, de verschillende effecten (zoals van kwik en fluoride) binnen elk milieu-aspect (bv. waterverontreiniging) onder één noemer te brengen om zo een optelling van die effecten mogelijk te maken. De geaggregeerde waarden worden milieu-kentallen genoemd.
Het beoordelingsresultaat op basis van onderstaande methode zal dikwijls een onderdeel zijn van de uiteindelijke afweging omtrent de keuze voor een produktalternatief. In deze afweging spelen ook funktionele en kostenaspecten van het produktalternatief mee.

In het milieubeleid worden diverse centrale milieuthema's onderscheiden. Daarnaast is er ook sprake van enkele gesignaleerde milieuvraagstukken (VROM, 1986). De milieu-effecten die optreden bij de diverse fasen in de produktlevensloop, worden op hun bijdrage aan deze thema's beoordeeld. Een stof kan aan meerdere milieuthema's een bijdrage leveren en daarop beoordeeld worden. Per milieu-aspect wordt hieronder de mogelijkheid tot aggregatie in milieukentallen kort besproken.

2.1 Uitputting van grondstoffen

Grondstoffenverbruik leidt tot uitputting van grondstoffen. Bij weging van de uitputting van verschillende grondstoffen dienen deze onderling vergeleken te worden. In het geval van kozijnen gaat het bijvoorbeeld om de vergelijking tussen ijzererts, bauxiet en verschillende soorten hout. De belangrijkste verschillen tussen grondstoffen zijn de omvang van de aanwezige voorraden, de mogelijkheid tot substitutie door andere grond-

stoffen en het al dan niet vernieuwbaar zijn van de grondstof. Onder het vernieuwbaar zijn van een grondstof wordt verstaan dat dezelfde gebruikte hoeveelheid grondstof binnen een periode van enkele generaties weer geregenereerd kan worden (Rijsdorp e.a., 1989). Het is nog niet mogelijk een aggregatie van uitputting voor de verschillende grondstoffen als totaal te geven. Wel wordt, gezien het belang dat binnen het milieubeleid wordt gehecht aan het energieverbruik, het verbruik van niet-vernieuwbare energiedragers eruit gelicht. Energie in de vorm van electriciteit (of warmte) is het produkt van de omzetting van een grondstof. De belangrijkste grondstoffen hiervoor zijn aardolie, aardgas, steenkool en uranium. Uiteindelijk wordt energieverbruik uitgedrukt in het verbruik van grondstoffen en wordt de energie-inhoud van de desbetreffende grondstoffen bij elkaar opgeteld. De energie-inhoud is hierbij gedefinieerd als de verbrandingswarmte van de desbetreffende grondstof, conform de IFIAS-conventies voor energietoekenning. De emissies die onstaan bij de energieopwekking worden eveneens in beschouwing genomen.
Hout uit tropische bossen wordt ook als een niet-vernieuwbare grondstof aangemerkt aangezien momenteel van tropisch produktiebos nog nauwelijks sprake is. De hoeveelheid hout wordt omgerekend naar hectare aangetast tropisch regenwoud.
Samenvattend wordt het grondstoffengebruik voor processen en energieopwekking aangegeven in kg gebruikte grondstof (m^3 bij gas of m^2 bij hout) per produkt. De energiedragers (gas, kolen en olie) worden opgeteld naar energie-inhoud.

2.2 Emissies van schadelijke stoffen

Verspreiding
Een thema dat centraal staat binnen het milieubeleid is de verspreiding van de prioritaire stoffen. In eerdere CML-studies is een methode gebruikt voor het beoordelen van emissies van schadelijke stoffen. De methode komt neer op het omrekenen van emissies naar 'eenheden verontreinigd milieucompartiment' met behulp van bestaande milieuhygiënische normen voor het desbetreffende compartiment. De norm voor bijvoorbeeld het kwik-gehalte in Oppervlaktewater bestemd voor Drinkwater (OvD-norm) bedraagt 0,3 $\mu g/l$. Een kwik-emissie naar het oppervlaktewater van 50 g is dus voldoende om $1,7 \cdot 10^5$ m^3 water tot aan de drinkwaternorm te verontreinigen, en kan daarmee worden omschreven als $1,7 \cdot 10^5$ EVW (Eenheden Verontreinigd Water). Eenzelfde berekeningswijze kan gelden voor emissies naar lucht (EVL) en bodem (EVB). Voor het compartiment water wordt gewogen met de norm voor de kwaliteit van het oppervlaktewater bestemd voor drinkwater (OvD-norm) en voor het compartiment lucht met de Maximaal Aanvaardbare Concentratie (MAC-waarde) voor de luchtkwaliteit op de werkplek[1].

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[1] Aan de gehanteerde normen kleeft een aantal beperkingen. Zo komen in MAC-waarden mogelijk kankerverwekkende of kankerbevorderende eigenschappen vaak nog niet tot uitdrukking (b.v. 1.2.-dichloorethaan). Tevens zijn deze waarden opgesteld voor de maximale aanvaardbare concentratie op de werkplek en niet als zodanig voor het milieu in ruime zin. Opvallend is dat de verhouding tussen stoffen van toelaatbare stoffen sterk kunnen verschillen. De verhouding tussen CO : dichloorethaan is bij de MAC-waarden 1 : 7; bij milieukwaliteitsnormen is deze verhouding 1 : 1000. De hoeveelheid milieugebonden luchtnormen (MIC-waarden) is te gering om te kunnen gebruiken voor de aggregatie van verschillende emissiewaarden voor lucht.

Voor het compartiment bodem kan gewogen worden met de streefwaarde bodemkwaliteit. In deze studie wordt geen weging voor het compartiment bodem uitgevoerd in verband met het ontbreken van de benodigde basisgegevens over de emissies naar de bodem. In een bijlage zijn de emissienormen voor lucht en water weergegeven.

Een andere mogelijkheid in dezelfde richting is de emissies niet te confronteren met milieucompartimentgebonden normen, maar met normen die direkt gericht zijn op de menselijke gezondheid. Meer specifiek kunnen hiervoor ADI-waarden (Aanvaardbare Dagelijkse Inname) gebruikt worden. De emissies worden dan als het ware uitgedrukt in 'eenheden verontreinigde mens' (EVM). Op zichzelf levert dit een mooiere beoordeling op omdat op deze wijze de normen die de basis vormen voor de vergelijking eenvormig zijn; milieucompartiment-normen zijn er van allerlei aard en met allerlei achterliggende beleidsdoelen, en zijn daarom niet altijd goed vergelijkbaar. Bovendien kunnen op deze manier emissies naar alle milieucompartimenten bij elkaar worden opgeteld, gewogen naar hun schadelijkheid voor de mens. Daarnaast blijft voorlopig het probleem staan in welke mate emissies tot blootstelling van de mens kunnen leiden. Deze mate van potentiële blootstelling verschilt sterk voor de verschillende stoffen: geëmitteerd kwik kan zeer lang voor opname beschikbaar blijven, terwijl benzeen in korte tijd wordt afgebroken.
De 'EVM-benadering' kan op dit moment nog niet toegepast worden, ook omdat voor vele geëmitteerde stoffen nog geen ADI-waarde bestaat. Daarom is het, om al te veel ongelijksoortige maten in de milieuvergelijking te voorkomen, voorlopig beter om de genoemde compartimentgerichte normen aan te houden.

Verzuring

Bij het thema verzuring worden de stoffen analoog aan de EVL/EVW-benadering geaggregeerd in milieukentallen. Een emissie wordt dan uitgedrukt zuurequivalenten (ZE). Deze zuurequivalenten zijn alleen een aggregatievorm en zeggen niets over de effecten van verzuring. De normen voor zuurdepositie zijn weergegeven in de bijlage.

Verstoring en vermesting

Voor het thema's verstoring en vermesting zijn nog geen bruikbare normen voor een aggregatiemethode ontwikkeld.

Klimaatverandering en aantasting ozonlaag

Voor het gesignaleerde vraagstuk van de klimaatverandering en als onderdeel daarvan de aantasting van de ozonlaag zijn vooral CO_2, sommige koolwaterstoffen (KWS) en chloorfluorkoolwaterstoffen (CFK's) van belang. In principe is een aggregatie mogelijk. Voor sommige ozonaantastende stoffen is een zogenaamde 'Ozon Depletion Potential' (ODP) vastgesteld en voor het broeikaseffect kan met het 'Global Warming Potential' gewerkt worden. Het zeer partiële karakter van de gegevens rechtvaardigt nu nog geen aggregatie naar deze aspecten.
Vanwege het belang van deze stoffen worden de emissies als ze bekend zijn, analoog aan de 'beoordeling' van uitputting van grondstoffen, in kg geëmitteerde verbinding aangegeven.

Beperkingen van de aggregatiemethode voor schadelijke emissies

Een deel van de basisgegevens voor lucht- en wateremissies die in deze studie gebruikt zijn, is alleen gewogen vorm beschikbaar, in termen van EVL en EVW. Vanwege de geaggregeerde vorm van deze gegevens is het niet

mogelijk om per stof de afzonderlijke emissie te vermelden. Dit is de belangrijkste reden dat het vooralsnog niet mogelijk is om een aantal deelprocessen te beoordelen op hun bijdrage aan het thema verzuring in de vorm van hectares potentieel verzuurde bodem en het thema klimaatverandering in de vorm van kg geëmitteerde CO_2, CFK's en koolwaterstoffen.
Aan de gehanteerde normen kleven een aantal beperkingen. Zo komen in MAC-waarden mogelijk kankerverwekkende of kankerbevorderende eigenschappen vaak nog niet tot uitdrukking (bijv. 1.2-dichloorethaan). Ook blijft in de nu gehanteerde beoordelingsmethode de tijdsduur waarin de potentiële milieuschade op kan treden buiten beschouwing.

2.3 Ontstaan van vast afval

Binnen het thema verwijdering is het beleid gericht op het verminderen van afvalstromen. Het milieu-effect van vast afval heeft vooral betrekking op het in beslag nemen van ruimte bij de stort van het vaste afval en de uitloging van schadelijke stoffen naar het grondwater. In dit rapport wordt een onderscheid gemaakt tussen schadelijk en niet-schadelijk afval op basis van eigen interpretatie. De potentiële giftigheid is hierbij globaal als criterium gebruikt. Het ontstane vaste afval wordt dan ook beoordeeld op basis van de hoeveelheid gegenereerd vast schadelijk en niet-schadelijk afval in kg en voor zover mogelijk op basis van emmissies naar water door uitloging.

3 De geïntegreerde milieubeoordeling

De in § 2 geschetste aggregatiemethode voegt alle relevante gegevens samen naar een beperkt aantal aspecten, zoals de uitputting van grondstoffen, de potentiële gezondheidsschade (EVL en EVW), de potentiële verzuring (ZE) en de hoeveelheid finaal vast afval. Deze aggregatiemethode dient uitsluitend voor de onderlinge vergelijking van emissies van de produktalternatieven in hetzelfde aspect van milieuaantasting. Aan deze geaggregeerde waarden kan geen absolute waarde worden toegekend in de zin dat voor een bepaald produktalternatief bijvoorbeeld de emissie naar water, uitgedrukt als 100 EVW, groter is dan de emissie naar lucht, uitgedrukt als 80 EVL.
Uit deze beoordeling op deelaspecten moet vervolgens een totaal-oordeel worden afgeleid. Dit totaal-oordeel is vergelijkend tussen produkten: het gaat om de bepaling van het relatief milieuvriendelijkste alternatief voor een gegeven produkttype, in dit geval een kozijn.
Voor dit totaal-oordeel voor een kozijnalternatief zullen de deelaspecten veelal onderling tegen elkaar afgewogen moeten worden. Gegeven de huidige methode, moeten zo grondstoffen- en energiegebruik, emissies en afvalgewicht tegen elkaar afgewogen worden. Het probleem hierbij is om bijvoorbeeld de relatief geringe bijdrage van een kozijn aan het ontstaan van vast afval tegen relatief hoge luchtemissies, en relatieve wateremissies tegen relatieve luchtemissies af te wegen. Een algemene methode om tot deze afweging te komen is vooralsnog niet beschikbaar.

In deze studie zal nu de volgende methode aangehouden worden om tot een totaal-oordeel te komen:

Eenvoudig is het totaal-oordeel wanneer het ene alternatief in alle opzichten beter is dan het andere. Moeilijker wordt een totaal-oordeel wanneer de beoordeling van twee alternatieven per deelaspect verschillend uitvalt. Voor een kwantitatieve beoordeling op deelaspecten, als basis voor een totaaloordeel, worden nu extra hoge eisen gesteld aan de onderliggende informatie. Op basis van een betrouwbare kwantificering van effecten is, via de tussenstap van de kwantitatieve beoordeling op deelaspecten, een totaaloordeel eerder mogelijk dan wanneer alleen inkomplete, semi-kwantitatieve of kwalitatieve informatie over de verschillende milieuaspecten beschikbaar is. Wanneer bijvoorbeeld van een produktalternatief bekend is dat het 90% minder -min of meer gelijkwaardig- grondstoffengebruik en afval veroorzaakt en slechts 5% meer emissies dan zal redelijk algemeen erkend worden dat dit produkt uit milieu-oogpunt te prefereren is. Zonder die kwantitatieve beoordeling op deelaspecten is vrijwel nooit een overkoepelend milieuoordeel mogelijk.

Een totaal-oordeel, zoals hierboven beschreven, is vooral mogelijk voor eenvoudig samengestelde produkten als verpakkingsmaterialen, aangezien voor die produkten de verwachting het grootst is dat één alternatief op alle milieuaspecten het best scoort. Het blijft echter wel vereist dat er per alternatief voldoende informatie aanwezig is als basis voor een milieubeoordeling. Wanneer deze informatie onvoldoende is kan aanvullend empirisch onderzoek de milieubeoordeling haalbaar maken (het zogenaamde fase 2 onderzoek).

Bij produkten die uit meerdere materialen zijn samengesteld, zoals kozijnen, is de kans minder groot dat één alternatief op alle aspecten het beste scoort.

4 Huidige kennis en kennislacunes

Een produkt kan pas op milieu-effecten geanalyseerd en beoordeeld worden als er voldoende kennis bestaat van de milieu-effecten van de betrokken processen.

De gehanteerde beoordelingsmethode op basis van MAC-waarden en OvD-normen zorgt voor enkele lacunes in de eindbeoordeling van de milieu-effecten van een produkt. Zo zijn niet voor alle stoffen dergelijke normen voorhanden. Eventueel kan een MAC-norm afgeleid worden van een andere norm zoals voor dioxinen op basis van de ADI-waarde voor dioxinen. Tevens is er geen methode voorhanden voor een onderlinge weging tussen EVL, EVW en verdwijnen van tropisch regenwoud.

Voor de milieu-effecten betreffende klimaatverandering is nog geen beoordelingsmethode voorhanden; dit betekent dat de milieu-effecten van CFK's en koolwaterstoffen niet in de beoordeling opgenomen zijn.

Bijlage 2 Overzicht van de normen voor prioritaire stoffen

	MAC-TGG[3]	OvD[2]	ref.waarde bodem[4]	zuur-depositie[5]
verzurende en vermestende stoffen				
- ammoniak (NH_3)	18 mg/m^3	1,2 mg N/l (≈1,5 mg NH_3/l)	-	857 ze/ha/j
- fosfaat (P)	-	0,2 mg P/l	-	-
- nitraat (NO_3)	-	50 mg NO_3/l	-	-
- NO_x	9 mg/m^3	-	-	857 ze/ha/j
- SO_2	13 mg/m^3	-	-	400 ze/ha/j
- organisch gebonden N	-	2,5 mg N/l	-	-
- zoutzuur	7 mg/m^3	-	-	-
metalen/metalloïden				
- arseen	0,05 mg/m^3	50 µg/l	29 mg/kg	-
- cadmium	0,02 mg/m^3	3 µg/l	0,8 mg/kg	-
- chroom (VI)	0,5 mg/m^3	50 µg/l	100 mg/kg	-
- koper	0,2 mg/m^3	50 µg/l	36 mg/kg	-
- kwik en -zouten	0,05 mg/m^3	0,3 µg/l	0,3 mg/kg	-
- kwikverbindingen (org.)	0,01 mg/m^3	-	-	-
- lood	0,15 mg/m^3	50 µg/l	85 mg/kg	-
- zink(oxide)	5,0 mg/m^3	1000 µg/l	140 mg/kg	-
- ijzer	-	500 µg/l	-	-
organische verbindingen				
niet gehalogeneerd				
- aardolie	-	200 µg/l	50 mg/kg	-
- acroleine	0,25 mg/m^3	-	-	-
- acrylonitril	9 mg/m^3	-	-	-
- benzeen	30 mg/m^3	-	-	-
- etheen	-	-	-	-
- fenol(en)	19 mg/m^3	5 µg/l	-	-
- formaldehyde (methanal)	1,5 mg/m^3	-	-	-
- ftaalzuuranhydride	6 mg/m^3	-	-	-
- methylbenzeen (tolueen)	375 mg/m^3	-	-	-
- propyleenoxide	240 mg/m^3	-	-	-
- ethyleenoxide	90 mg/m^3	-	-	-
- PAK	0,2 mg/m^3	0,2 µg/l	100-10000 µg/kg	-

---

[2] Waterleidingbesluit, 1984.

[3] Nationale MAC-lijst, 1989. MAC-TGG = maximale aanvaardbare concentratie - tijdgewogen gemiddelde.

[4] Milieuprogramma 1989-1992.

[5] 1 zuurequivalent (ze) ≈ 32 g SO_2 ≈ 46 g NO_x ≈ 17g NH_3; voor N-houdende stoffen is een hogere waarde ingevoerd, omdat 53 % van de emmissie niet verzurend werkt. De normen zijn uitgedrukt in potentieel verzurende eenheden (Bestrijdingsplan verzuring 2000, 1989)

vervolg

organische verbindingen

niet gehalogeneerd

- styreen	420 mg/m^3	-	-	-
- koolwaterstoffen (KWS)[6]	500 mg/m^3	-	-	-
- chem. zuurstofverbruik (CZV)	-	30 mg/l	-	-
- biol. zuurstofverbruik (BZV)	-	7 mg/l	-	-

gehalogeneerde aromaten

- chlooranilines	-	-	-	-
- chloorbenzenen	350 mg/m^3	-	-	-
- chloorfenolen	-	-	-	-
- dioxinen	-	-	-	-
- PCB en PCT	-	-	1-10 µg/kg	-

overige gehalogeneerde verbindingen

- CFK's	-	-	-	-
- 1,2-dichloorethaan	200 mg/m^3	-	-	-
- dichloormethaan	350 mg/m^3	-	-	-
- hexachloorcyclohexaan	-	-	-	-
- methylbromide	20 mg/m^3	-	-	-
- tetrachlooretheen	240 mg/m^3	-	-	-
- tetrachloormethaan	-	-	-	-
- 1,1,1-trichloorethaan	1080 mg/m^3	-	-	-
- trichlooretheen	190 mg/m^3	-	-	-
- trichloormethaan	50 mg/m^3	-	-	-
- mono-vinylchloride	2,8 mg/m^3 [7]	-	-	-

overige stoffen

- asbest	-	-	-	-
- fluor	2,0 mg/m^3	-	-	-
- fluoriden	2,5 mg/m^3	1,0 µg/l	-	-
- koolmonoxide	29 mg/m^3	-	-	-
- ozon	0,2 mg/m^3	-	-	-
- stof (fijn)	10 mg/m^3	50,0 µg/l	-	-
- stof (grof)	-	-	-	-
- zwavelwaterstof	15 mg/m^3	-	-	-
- chloor	3 mg/m^3	-	-	-

---

[6] fictieve MAC-waarde

[7] komt overeen met 3 ppm. 1ppm ≈ 26,9 deeltjes/m^3 lucht (p= 1,29 kg/m^3, Mr= 28,8 g/mol). 1 ppm ≈ 44,7·10^{-3}x Mr (mg/m^3)

APPENDIX 7 FINDINGS

Content

table 7.1a
environontal effects of life cycles
polycarbonate 50 trips

	pc_bot_lc50
RAW MATERIALS	
coal	6.47E-01
dichloormethaan	1.28E-03
diesel	3.38E+00
gas	2.40E+00
naoh	5.95E-01
natriumchloride	5.75E-01
oil	7.09E-01
tolueen	1.28E-04
uranium ore	3.03E-03
EMISSIONS TO AIR	
cadmium	1.48E-06
dichloormethaan	1.15E-03
fluoride	4.05E-05
kooldioxyde	5.82E+00
koolmonoxyde	1.12E-01
kwik	1.57E-07
kws	9.07E-03
pak	2.61E-09
raffinage en energyverbruik	1.14E-01
roet	6.08E-03
stikstofoxyde	4.04E-02
stof	2.63E-04
tolueen	1.28E-04
zwaveldioxyde	2.26E-02
EMISSIONS TO WATER	
chloor	2.50E-01
dichloormethaan	1.92E-07
fenol	6.40E-06
geneutraliseerd naoh	5.95E-01
natriumchloride	4.06E-01
WASTE	
afval	1.98E-02
ashes of mining after re-use	5.57E-02
combustion waste	7.85E-05
high reactive nuclear waste	1.99E-08
incineration waste	0
low and medium reactive nuclear waste	4.88E-08
polycarbonate	4.20E-01
waste of coal mining	1.17E-01

```
ENERGY                                           2.47E+02
UPW                                               2.54E+00
UPA                                               1.03E+01
AE                                                2.79E-01
WASTE                                             6.12E-01


         MISSING UPW
geneutraliseerd naoh                              5.95E-01
natriumchloride                                   4.06E-01


         MISSING UPA
kooldioxyde                                       5.82E+00
roet                                              6.08E-03
```

table 7.1b
environental effects of life cycles
polycarbonate 75 trips

	pc_bot_lc75
RAW MATERIALS	
coal	7.82E-01
dichloormethaan	8.51E-04
diesel	3.38E+00
gas	2.18E+00
naoh	5.95E-01
natriumchloride	3.82E-01
oil	4.86E-01
tolueen	8.51E-05
uranium ore	3.66E-03
EMISSIONS TO AIR	
cadmium	1.79E-06
dichloormethaan	7.66E-04
fluoride	4.90E-05
kooldioxyde	5.86E+00
koolmonoxyde	1.11E-01
kwik	1.89E-07
kws	8.37E-03
pak	3.15E-09
raffinage en energyverbruik	7.60E-02
roet	6.08E-03
stikstofoxyde	4.07E-02
stof	3.17E-04
tolueen	8.51E-05
zwaveldioxyde	2.44E-02
EMISSIONS TO WATER	
chloor	2.50E-01
dichloormethaan	1.28E-07
fenol	4.26E-06
geneutraliseerd naoh	5.95E-01
natriumchloride	2.70E-01
WASTE	
afval	1.32E-02
ashes of mining after re-use	6.73E-02
combustion waste	9.49E-05
high reactive nuclear waste	2.40E-08
incineration waste	0
low and medium reactive nuclear waste	5.90E-08
polycarbonate	2.81E-01
waste of coal mining	1.41E-01

```
ENERGY                                          2.34E+02
UPW                                              2.11E+00
UPA                                              1.05E+01
AE                                               2.94E-01
WASTE                                            5.03E-01


        MISSING UPW
geneutraliseerd naoh                             5.95E-01
natriumchloride                                  2.70E-01


        MISSING UPA
kooldioxyde                                      5.86E+00
roet                                             6.08E-03
```

table 7.1c
environental effects of life cycles
glass bottle 20 trip

	gl_nl_20_lc
RAW MATERIALS	
brine (calculated)	4.75E+00
coal	2.21E+00
cokes	3.30E-03
cullet glass production and external (small)	1.98E+00
diesel	4.71E+00
gas	5.93E+00
kalk	3.05E+00
na2so4	8.25E-02
naoh	5.95E-01
nefiline	8.91E-01
oil	2.16E-01
quartz sand	1.01E+01
uranium ore	7.21E-03
EMISSIONS TO AIR	
cadmium	3.52E-06
chloor	8.25E-04
fluoride	1.79E-04
kooldioxyde	8.72E+00
koolmonoxyde	1.54E-01
kwik	3.72E-07
kws	1.65E-02
others	1.07E-04
pak	6.21E-09
roet	8.47E-03
stikstofoxyde	8.96E-02
stof	1.33E-02
zwaveldioxyde	9.68E-02
EMISSIONS TO WATER	
acids	2.38E-03
chloor	2.50E-01
geneutraliseerd naoh	5.95E-01
metalic ions (fe)	3.96E-04
other	1.98E-03
WASTE	
ashes of mining after re-use	1.32E-01
bottles landfilled and incinerated	6.00E+00
combustion waste	1.87E-04
high reactive nuclear waste	4.72E-08
low and medium reactive nuclear waste	1.16E-07
waste of coal mining	2.77E-01

ENERGY	4.31E+02
UPW	2.04E+00
UPA	2.46E+01
AE	9.83E-01
WASTE	6.41E+00

MISSING UPW	
acids	2.38E-03
geneutraliseerd naoh	5.95E-01
other	1.98E-03

MISSING UPA	
kooldioxyde	8.72E+00
others	1.07E-04
roet	8.47E-03

table 7.1d
environental effects of life cycles
glass bottle 30 trips

	gl_nl_30_lc
RAW MATERIALS	
brine (calculated)	3.16E+00
coal	1.83E+00
cokes	2.20E-03
cullet glass production and external (small)	1.32E+00
diesel	4.71E+00
gas	4.54E+00
kalk	2.03E+00
na2so4	5.49E-02
naoh	5.95E-01
nefiline	*5.93E-01*
oil	1.59E-01
quartz sand	6.76E+00
uranium ore	6.45E-03
EMISSIONS TO AIR	
cadmium	3.15E-06
chloor	5.49E-04
fluoride	1.41E-04
kooldioxyde	7.80E+00
koolmonoxyde	1.53E-01
kwik	3.33E-07
kws	1.42E-02
others	7.12E-05
pak	5.55E-09
roet	8.47E-03
stikstofoxyde	7.68E-02
stof	9.02E-03
zwaveldioxyde	7.56E-02
EMISSIONS TO WATER	
acids	1.58E-03
chloor	2.50E-01
geneutraliseerd naoh	5.95E-01
metalic ions (fe)	2.64E-04
other	1.32E-03
WASTE	
ashes of mining after re-use	1.19E-01
bottles landfilled and incinerated	4.00E+00
combustion waste	1.67E-04
high reactive nuclear waste	4.23E-08
low and medium reactive nuclear waste	1.04E-07
waste of coal mining	2.48E-01

ENERGY	3.73E+02
UPW	1.78E+00
UPA	2.09E+01
AE	7.86E-01
WASTE	4.37E+00

MISSING UPW

acids	1.58E-03
geneutraliseerd naoh	5.95E-01
other	1.32E-03

MISSING UPA

kooldioxyde	7.80E+00
others	7.12E-05
roet	8.47E-03

table 7.1e
environental effects of life cycle
milk carton

	cart_pack_lc
RAW MATERIALS	
apatite	9.93E-01
coal	1.71E+00
diesel	3.30E+00
gas	3.53E-01
lignite	1.18E+00
missing	3.52E+00
oil	8.28E+00
raw material; emission data unknown	1.49E+01
sulphur pyrite	1.44E+00
uranium ore	5.52E-02
wood	5.06E+01
EMISSIONS TO AIR	
cadmium	-1.64E-06
chloor	2.50E-07
fluoride	-4.50E-05
h2s	1.82E-03
h2so4	1.11E-03
hcl	6.34E-03
hf	4.72E-04
kooldioxyde	-4.07E+00
koolmonoxyde	1.26E-01
kwik	-1.74E-07
kws	2.44E-02
na2so4	5.52E-04
organic s	5.31E-04
pak	-2.90E-09
roet	5.93E-03
stikstofoxyde	1.31E-01
stof	6.96E-02
zwaveldioxyde	4.41E-01
EMISSIONS TO WATER	
aluminium	2.02E-03
bod	2.69E-02
bod7	4.88E-02
cod	4.19E-01
kjeld-n	8.82E-03
no3-n	4.35E-05
other pollutants	1.11E-02
sulphides expressed as h2s	2.17E-04
suspended substances	3.95E-03
suspended substances (solids)	7.59E-02
suspended sulphate sludge (or 50% less)	3.10E-01
total phosphorus	5.82E-04

WASTE	
ashes of mining after re-use	-6.18E-02
board and paper waste	1.52E+01
combustion waste	-8.73E-05
high reactive nuclear waste	3.62E-07
incineration waste	0
incinerator waste	1.01E+00
low and medium reactive nuclear waste	8.90E-07
missing	1.60E-01
polyethene waste	1.92E+00
waste of coal mining	-1.29E-01
waste of lignite mining	0

ENERGY	5.30E+02
UPW	3.26E+01
UPA	6.15E+01
AE	3.78E+00
WASTE	1.81E+01

MISSING UPW	
aluminium	2.02E-03
other pollutants	1.11E-02
sulphides expressed as h2s	2.17E-04
suspended sulphate sludge (or 50% less)	3.10E-01

MISSING UPA	
h2so4	1.11E-03
kooldioxyde	-4.07E+00
na2so4	5.52E-04
roet	5.93E-03

table 7.2a: ecoprofile milk carton

	gable_totall
RAW MATERIALS	
apatite	9.93E-01
coal	1.75E+00
diesel	3.30E+00
gas	4.24E-01
iron ore	1.76E-01
lignite	1.18E+00
limestone	1.55E-02
missing	3.52E+00
oil	8.28E+00
raw material; emission data unknown	1.49E+01
sulphur pyrite	1.44E+00
uranium ore	5.54E-02
wood	5.06E+01
zink	3.75E-03
uitstoot	
cadmium	-1.55E-06
chloor	2.50E-07
fluoride	-4.24E-05
h2s	1.82E-03
h2so4	1.11E-03
hcl	6.34E-03
hf	4.72E-04
kooldioxyde	-3.83E+00
koolmonoxyde	1.26E-01
kwik	-1.64E-07
kws	2.44E-02
missing	4.22E-01
na2so4	5.52E-04
organic s	5.31E-04
pak	-2.73E-09
roet	5.93E-03
stikstofoxyde	1.32E-01
stof	6.96E-02
zwaveldioxyde	4.42E-01
lozing	
aluminium	2.02E-03
bod	2.69E-02
bod7	4.88E-02
cod	4.19E-01
kjeld-n	8.82E-03
missing	5.09E-01
no3-n	4.35E-05
other pollutants	1.11E-02
sulphides expressed as h2s	2.17E-04

suspended substances	3.95E-03
suspended substances (solids)	7.59E-02
suspended sulphate sludge (or 50% less)	3.10E-01
total phosphorus	5.82E-04

WASTE	
ashes of mining after re-use	-5.82E-02
board and paper waste	1.52E+01
combustion waste	-8.21E-05
high reactive nuclear waste	3.63E-07
incineration waste	0
incinerator waste	1.01E+00
low and medium reactive nuclear waste	8.93E-07
mining waste of iron ore	4.85E-01
missing	1.60E-01
non re-usable slags of melting-furnace	6.06E-03
oxylime mud (chemical waste)	3.03E-03
polyethene waste	1.92E+00
waste of coal mining	-1.22E-01
waste of lignite mining	0

ENERGY	5.34E+02
UPW	3.31E+01
UPA	6.20E+01
AE	3.78E+00
WASTE	1.86E+01

missing UPW	
aluminium	2.02E-03
other pollutants	1.11E-02
sulphides expressed as h2s	2.17E-04
suspended sulphate sludge (or 50% less)	3.10E-01

missing UPA	
h2so4	1.11E-03
kooldioxyde	-3.83E+00
na2so4	5.52E-04
roet	5.93E-03

table 7.2b: ecoprofiles of glass bottles at 20 and 30 trips

	glas_total20	glas_total30
RAW MATERIALS		
brine (calculated)	4.75E+00	3.16E+00
coal	2.19E+00	1.80E+00
cokes	3.30E-03	2.20E-03
cullet from glass production and external (small)	1.98E+00	1.32E+00
diesel	4.71E+00	4.71E+00
gas	6.50E+00	5.11E+00
kalk	3.05E+00	2.03E+00
na2so4	8.25E-02	5.49E-02
naoh	5.95E-01	5.95E-01
nefiline	8.91E-01	5.93E-01
oil	2.66E+00	2.60E+00
quartz sand	1.01E+01	6.76E+00
uranium ore	7.08E-03	6.32E-03
EMISSIONS TO AIR		
cadmium	3.45E-06	3.08E-06
chloor	8.25E-04	5.49E-04
fluoride	1.77E-04	1.40E-04
kooldioxyde	8.56E+00	7.65E+00
koolmonoxyde	1.54E-01	1.54E-01
kwik	3.66E-07	3.27E-07
kws	2.76E-02	2.53E-02
others	1.07E-04	7.12E-05
pak	6.09E-09	5.44E-09
roet	8.47E-03	8.47E-03
stikstofoxyde	9.06E-02	7.78E-02
stof	1.34E-02	9.10E-03
zwaveldioxyde	9.90E-02	7.79E-02
lozing		
acids	2.38E-03	1.58E-03
anorganic suspended substances	9.04E-01	9.02E-01
chloor	2.50E-01	2.50E-01
fenol	9.62E-06	9.60E-06
geneutraliseerd naoh	5.95E-01	5.95E-01
metalic ions (fe)	3.96E-04	2.64E-04
other	1.98E-03	1.32E-03
other organic suspended substances	2.88E-01	2.88E-01
WASTE		
ashes of mining after re-use	1.30E-01	1.16E-01
bottles landfilled and incinerated	6.00E+00	4.00E+00
combustion waste	1.83E-04	1.64E-04
high reactive nuclear waste	4.64E-08	4.14E-08
incineration waste	0	0

low and medium reactive nuclear waste	1.14E-07	1.02E-07
polyethene waste	2.64E-01	2.60E-01
solid waste	9.69E-03	9.67E-03
waste of coal mining	2.72E-01	2.43E-01

ENERGY	5.52E+02	4.94E+02
UPW	3.97E+00	3.70E+00
UPA	2.49E+01	2.13E+01
AE	1.00E+00	8.06E-01
WASTE	6.68E+00	4.63E+00

missing UPW

acids	2.38E-03	1.58E-03
anorganic suspended substances	9.04E-01	9.02E-01
geneutraliseerd naoh	5.95E-01	5.95E-01
other	1.98E-03	1.32E-03
other organic suspended substances	2.88E-01	2.88E-01

missing UPA

kooldioxyde	8.56E+00	7.65E+00
others	1.07E-04	7.12E-05
roet	8.47E-03	8.47E-03

table 7.2c: ecoprofile of polycarbonate bottle at 50 trips

	pc50_total
RAW MATERIALS	
coal	6.63E-01
dichloormethaan	1.28E-03
diesel	3.38E+00
gas	3.02E+00
iron ore	1.76E-01
limestone	1.55E-02
naoh	5.95E-01
natriumchloride	5.75E-01
oil	3.06E+00
tolueen	1.28E-04
uranium ore	3.10E-03
zink	3.75E-03
EMISSIONS TO AIR	
cadmium	1.51E-06
dichloormethaan	1.15E-03
fluoride	4.15E-05
kooldioxyde	5.91E+00
koolmonoxyde	1.13E-01
kwik	1.60E-07
kws	1.98E-02
missing	4.22E-01
pak	2.67E-09
raffinage en energieverbruik	1.14E-01
roet	6.08E-03
stikstofoxyde	4.20E-02
stof	3.57E-04
tolueen	1.28E-04
zwaveldioxyde	2.53E-02
EMISSIONS TO WATER	
anorganic suspended substances	8.69E-01
chloor	2.50E-01
dichloormethaan	1.92E-07
fenol	1.56E-05
geneutraliseerd naoh	5.95E-01
missing	5.09E-01
natriumchloride	4.06E-01
other organic suspended substances	2.77E-01
WASTE	
afval	1.98E-02
ashes of mining after re-use	5.70E-02
combustion waste	8.05E-05
high reactive nuclear waste	2.03E-08

incineration waste	0
low and medium reactive nuclear waste	5.00E-08
mining waste of iron ore	4.85E-01
non re-usable slags of melting-furnace	6.06E-03
oxylime mud (chemical waste)	3.03E-03
polycarbonate	4.20E-01
polyethene waste	2.52E-01
solid waste	9.31E-03
waste of coal mining	1.19E-01

ENERGY	3.66E+02
UPW	4.90E+00
UPA	1.12E+01
AE	3.04E-01
WASTE	1.37E+00

missing UPW

anorganic suspended substances	8.69E-01
geneutraliseerd naoh	5.95E-01
natriumchloride	4.06E-01
other organic suspended substances	2.77E-01

missing UPA

kooldioxyde	5.91E+00
roet	6.08E-03

table 7.2d: ecoprofile of polycarbonate bottle at 75 trips

	pc75_total
RAW MATERIALS	
coal	7.98E-01
dichloormethaan	8.51E-04
diesel	3.38E+00
gas	2.80E+00
iron ore	1.76E-01
limestone	1.55E-02
naoh	5.95E-01
natriumchloride	3.82E-01
oil	2.83E+00
tolueen	8.51E-05
uranium ore	3.74E-03
zink	3.75E-03
EMISSIONS TO AIR	
cadmium	1.82E-06
dichloormethaan	7.66E-04
fluoride	5.00E-05
kooldioxyde	5.95E+00
koolmonoxyde	1.12E-01
kwik	1.93E-07
kws	1.90E-02
missing	4.22E-01
pak	3.22E-09
raffinage en energieverbruik	7.60E-02
roet	6.08E-03
stikstofoxyde	4.23E-02
stof	4.11E-04
tolueen	8.51E-05
zwaveldioxyde	2.71E-02
EMISSIONS TO WATER	
anorganic suspended substances	8.67E-01
chloor	2.50E-01
dichloormethaan	1.28E-07
fenol	1.35E-05
geneutraliseerd naoh	5.95E-01
missing	5.09E-01
natriumchloride	2.70E-01
other organic suspended substances	2.77E-01
WASTE	
afval	1.32E-02
ashes of mining after re-use	6.86E-02
combustion waste	9.69E-05
high reactive nuclear waste	2.45E-08
incineration waste	0

low and medium reactive nuclear waste	6.02E-08
mining waste of iron ore	4.85E-01
non re-usable slags of melting-furnace	6.06E-03
oxylime mud (chemical waste)	3.03E-03
polycarbonate	2.81E-01
polyethene waste	2.48E-01
solid waste	9.29E-03
waste of coal mining	1.44E-01

ENERGY	3.53E+02
UPW	4.46E+00
UPA	1.13E+01
AE	3.19E-01
WASTE	1.26E+00

missing UPW

anorganic suspended substances	8.67E-01
geneutraliseerd naoh	5.95E-01
natriumchloride	2.70E-01
other organic suspended substances	2.77E-01

missing UPA

kooldioxyde	5.95E+00
roet	6.08E-03

Table 7.3 Environmental effects of the life-cycles of different cap-systems.

	aluminium cap	polyethylene cap	Twist-cap
RAW MATERIALS			
bauxite	1.20E+00	0	
brine	7.83E-02	0	6.26E
coal	8.51E-01	0	9.09E
gas	4.22E-01	1.03E+00	1.19E
iron ore	0	0	5.05E
limestone	0	0	4.44E
oil	3.45E-01	4.07E+00	3.26E
stone salt	2.18E-02	0	
uranium ore	4.05E-04	0	4.26E
weekner (di_2_eth.hex.phtal.)	0	0	2.64E
EMISSIONS TO AIR			
1.2_dichloorethaan	0	0	1.05E
cadmium	1.98E-07	0	2.08E
chloor	4.62E-04	0	1.74E
fluoride	1.28E-04	0	5.69E
hcl	0	2.02E-04	
kooldioxyde	8.33E-01	0	5.15E
koolmonoxyde	5.55E-03	1.96E-03	8.31E
kwik	2.09E-08	0	3.92E
kws	9.63E-03	1.86E-02	1.06E
missing	0	0	1.18E
other organic substances	0	8.12E-05	
pak	3.49E-10	0	3.67E
stikstofoxyde	2.58E-02	2.85E-03	1.57E
stof	1.66E-02	3.24E-04	6.15E
teer (pak)	2.50E-05	0	
vinylchloride	0	0	8.62E
zoutzuur	0	0	8.78E
zwaveldioxyde	6.34E-02	5.15E-03	1.38E
EMISSIONS TO WATER			
2_chloorethanol	0	0	1.85E
anorganic suspended substances	0	1.51E+00	
bod	3.75E-04	0	
fenol	0	1.60E-05	1.17E
fluoride	2.75E-08	0	
kwik	0	0	1.05E
lood	0	0	2.46E
missing	0	0	1.46E
other organic suspended substances	0	4.81E-01	
teer (pak)	3.25E-08	0	
trichloorethanol	0	0	7.39E
vinylchloride	0	0	3.51E

Table 7.3 Environmental effects of the life-cycles of different cap-systems.

	aluminium cap	polyethylene cap	Twist-cap
WASTE			
aluminium waste	2.50E-01	0	
ashes of mining after re-use	7.44E-03	0	7.82E
combustion waste	7.08E-02	0	9.56E
dust from bayerprocess	4.65E-02	0	
high reactive nuclear waste	2.66E-09	0	2.79E
low and medium reactive nuclear waste	6.52E-09	0	6.86E
mining waste of iron ore	0	0	1.39E
mixed waste (hazardous composition)	0	0	9.24E
non re-usable slags of melting-furnace	0	0	1.73E
oxylime mud (chemical waste)	0	0	8.67E
red mud bayerprocess	5.35E-01	0	
rest waste	0	0	2.17E
solid waste	0	1.61E-02	
waste	0	1.12E-02	
waste chlor production	0	0	6.16E
waste from bauxite mining	2.85E+00	0	
waste from brine mining	8.55E-03	0	
waste from kalk manufacture	5.35E-03	0	
waste of brine mining	0	0	3.88E
waste of coal mining	1.56E-02	0	1.64E
waste of mining of fuels	1.50E-01	0	

	aluminium cap	polyethylene cap	Twist-cap
ENVIRONMENTAL FACTORS			
Fossil energy resources	5.29E+01	2.05E+02	9.23E
UPW	5.25E-02	3.20E+00	1.70E
UPA	9.96E+00	8.78E-01	1.52E
AE	5.61E-01	4.75E-02	1.47E
Waste	3.94E+00	2.73E-02	1.45E
missing UPW			
2_chloorethanol	0	0	1.85E
anorganic suspended substances	0	1.51E+00	
other organic suspended substances	0	4.81E-01	
teer (pak)	3.25E-08	0	
trichloorethanol	0	0	7.39E
vinylchloride	0	0	3.51E
missing UPA			
kooldioxyde	8.33E-01	0	5.15E
other organic substances	0	8.12E-05	

Table 7.4 Environmental effects of the life cycles of milk bottle labeling systems.

	paper label	polyethylene label
RAW MATERIALS		
chlor	1.10E-01	0
coal	2.60E-01	0
gas	6.88E-02	5.12E-01
oil	1.49E+00	2.03E+00
soda lye	2.06E-02	0
wood	3.68E+00	0
EMISSIONS TO AIR		
hcl	0	6.06E-06
koolmonoxyde	2.27E-03	7.69E-04
kwik	3.27E-07	0
kws	1.16E-02	9.25E-03
organische verbindingen (als eth.imin)	4.04E-04	0
other organic substances	0	2.44E-06
stikstofoxyde	1.41E-02	1.23E-03
stof	6.72E-03	8.11E-05
zwaveldioxyde	3.96E-03	2.20E-03
EMISSIONS TO WATER		
acids	2.04E-03	0
anorganic suspended substances	0	7.52E-01
chloor	1.25E-01	0
cod	2.66E-01	0
dissolved substances	1.48E-02	0
fenol	0	8.00E-06
kwik	1.65E-07	0
metalic ions (fe)	5.87E-04	0
organic chlorine substances	5.85E-05	0
other organic suspended substances	0	2.40E-01
WASTE		
paper on landfill	1.03E+00	0
solid waste	0	8.06E-03
waste	6.67E-03	3.35E-04

Table 7.4 continued   Environmental effects of the life cycles of milk bottle labeling systems.

ENVIRONMENTAL FACTORS	paper label	polyethylene label
Fossil energy resources	7.27E+01	1.02E+02
UPW	1.15E+01	1.60E+00
UPA	2.65E+00	3.60E-01
AE	6.67E-02	2.03E-02
Waste	1.04E+00	8.39E-03
missing UPW		
acids	2.04E-03	0
anorganic suspended substances	0	7.52E-01
organic chlorine substances	5.85E-05	0
other organic suspended substances	0	2.40E-01
missing UPA		
organische verbindingen (als eth.imin)	4.04E-04	0
other organic substances	0	2.44E-06

Table 7.5 Environmental effects of the life cycles of transit packaging systems.

	roll-in container	polyethylene box/crate 2 kg	polye crate
RAW MATERIALS			
coal	5.67E-02	0	
gas	9.48E-02	5.13E-02	8.46E
iron ore	2.35E-01	0	
limestone	2.07E-02	0	
oil	2.34E-03	2.03E-01	3.36E
uranium ore	2.65E-04	0	
zink	5.00E-03	0	
EMISSIONS TO AIR			
cadmium	1.30E-07	0	
fluoride	3.55E-06	0	
hcl	0	1.01E-05	1.67E
kooldioxyde	3.21E-01	0	
koolmonoxyde	3.60E-05	9.81E-05	1.62E
kwik	1.37E-08	0	
kws	1.24E-05	9.30E-04	1.53E
missing	5.62E-01	0	
other organic substances	0	4.06E-06	6.70E
pak	2.29E-10	0	
stikstofoxyde	8.60E-04	1.42E-04	2.35E
stof	2.30E-05	1.62E-05	2.67E
zwaveldioxyde	7.61E-04	2.58E-04	4.25E
EMISSIONS TO WATER			
anorganic suspended substances	0	7.53E-02	1.24E
fenol	0	8.00E-07	1.32E
missing	6.79E-01	0	
other organic suspended substances	0	2.40E-02	3.97E
WASTE			
ashes of mining after re-use	4.88E-03	0	
combustion waste	6.88E-06	0	
high reactive nuclear waste	1.74E-09	0	
low and medium reactive nuclear waste	4.28E-09	0	
mining waste of iron ore	6.46E-01	0	
non re-usable slags of melting-furnace	8.08E-03	0	
oxylime mud (chemical waste)	4.04E-03	0	
solid waste	0	8.06E-04	1.33E
waste	0	5.58E-04	9.20E
waste of coal mining	1.02E-02	0	

Table 7.5 continued   Environmental effects of the life cycles of transit packaging systems.

	roll-in container	polyethylene box/crate 2 kg	polye crate
ENVIRONMENTAL FACTORS			
Fossil energy resources	4.76E+00	1.02E+01	1.69E
UPW	6.79E-01	1.60E-01	2.64E
UPA	7.28E-01	4.39E-02	7.25E
AE	8.12E-03	2.37E-03	3.92E
Waste	6.74E-01	1.36E-03	2.25E
missing UPW			
anorganic suspended substances	0	7.53E-02	1.24E
other organic suspended substances	0	2.40E-02	3.97E
missing UPA			
kooldioxyde	3.21E-01	0	
other organic substances	0	4.06E-06	6.70E

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