Clip-Lok SimPak International

Life Cycle Assessment of the Clip-Lok SimPak™ Reusable, Collapsible Packaging System

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Contents

Glossary of Terms

BOD	:	Biological oxygen demand
COD	:	Chemical oxygen demand
DTU	:	Danish Technical University
EDIP	:	Environmental Development of Industrial Products
EPA	:	Environmental Protection Agency
IPU	:	Institute of Product Design
ISO	:	International Organisation for Standardisation
LCA	:	Life Cycle Assessment
NOx	:	Nitrogen Oxide
RORO	:	Roll on – roll off
SETAC	:	Society of Environment, Toxicology and Chemistry
SOx	:	Sulphur Oxides
VOC	:	Volatile organic compound

1. Introduction

This report presents the results of a Life Cycle Assessment of the Clip-Lok SimPak™ packaging system. The Clip-Lok system basically consists of a reusable, collapsible plywood case, assembled using spring steel clips (see Figure 1 below).

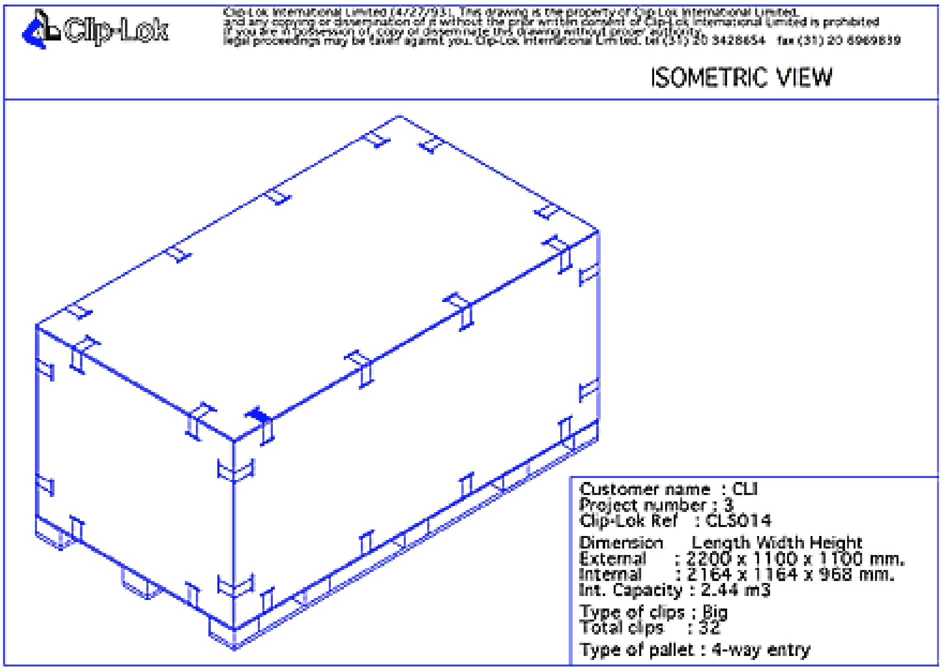
Clip-Lok SimPak International commissioned this Life Cycle Assessment to:

1. Describe the improvements that can be made to the case design to reduce the environmental impacts from its entire life cycle

2. Document the reference product's environmental performance, which may then be distributed to clients as a form of consumer service

3. Compare the lifecycle environmental impacts of the Clip-Lok SimPak™ reusable case, with the lifecycle environmental impacts of one way packaging.

Figure 1. The basic Clip-Lok SimPak™ packaging system



2. The Clip-Lok SimPak™ Reusable Packaging System

2.1 The Reference Product

Clip-Lok SimPak Scandinavia Ltd manufactures the Clip-Lok SimPak™ cases in Denmark, and distributes the cases worldwide. The cases are customised to suit the cargo being transported, and therefore come in a wide variety of sizes and models, all of which are collapsible and reusable. Due to their variety and worldwide distribution, this report has selected a Clip-Lok SimPak™ case used on the route between Düsseldorf, Germany and Chicago, USA, as the reference product in the Life Cycle Assessment.

The main materials used in the construction of the Clip-Lok SimPak™ case are spruce plywood, spring steel clips and a pallet block of recycled wood.

2.2 The Supply Chain

Clip-Lok SimPak Scandinavia Ltd markets and sells the Clip-Lok SimPak™ cases in Scandinavia, under license from Clip-Lok International. The cases are manufactured by AL Emballage A/S in Skibby, Denmark. The Clip-Lok clips are manufactured in Canada, the United Kingdom and South Africa.

The supply chain for the Clip-Lok SimPak™ transportation container system consists of companies supplying the following materials:

- Spruce plywood
- Recycled wood pallet blocks
- Nails
- Spring steel clips
- Paint for logos

3. Life Cycle Assessment (LCA)

3.1 What is Life Cycle Assessment?

A Life Cycle Assessment (LCA) is a comprehensive method for describing a product's environmental impact throughout the life cycle of that product.

The LCA in this report has been developed using the Danish Environmental Protection Agency's Environmental Development of Industrial Products (EDIP) tool. The Institute for Product Development at the Danish Technical University devised the EDIP[1] methodology, which is supported by a computation application and a LCA database.

According to SETAC[2], "Life-Cycle Assessment is a process to evaluate the environmental burdens associated with a product, process or activity by identifying and quantifying energy and materials used and wastes released to the environment; To assess the impact of those energy and material uses and releases to the environment; And to identify and evaluate opportunities to affect environmental improvements. The Assessment includes the entire life cycle of product, process, or activity, encompassing extracting and processing raw materials; manufacturing, transportation and distribution; use, reuse, maintenance; recycling, and final disposal." [Guidelines for Life - Cycle Assessment: A "Code of Practice". SETAC 1993]

ISO[3] state that "LCA is a technique for assessing the environmental aspects and potential impacts associated with a product, by compiling an inventory of relevant inputs and outputs of a product system, evaluating the potential environmental impacts associated with those inputs and outputs, interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study." [ISO/FDIS 14040: 1997]

In a LCA, an analysis and evaluation is made of the environmental impacts caused by a specific product during the entire life cycle of that product. The assessment assists the integration of environmental issues into a company's decision-making processes, by for example making changes in the production system.

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[1] LCA-System, Version 2.10 Beta, Danish EPA, Office for Cleaner Technology and Products.

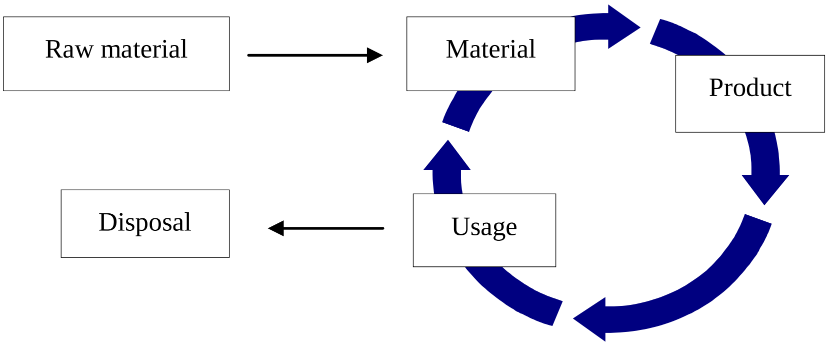
[2] Society of Environment, Toxicology and Chemistry

[3] International Organisation for Standardisation

3.2 The Life Cycle of a Product

The phases in a product's life cycle are relatively the same for the majority of products, as shown in Figure 2.

Figure 2: A product's life cycle

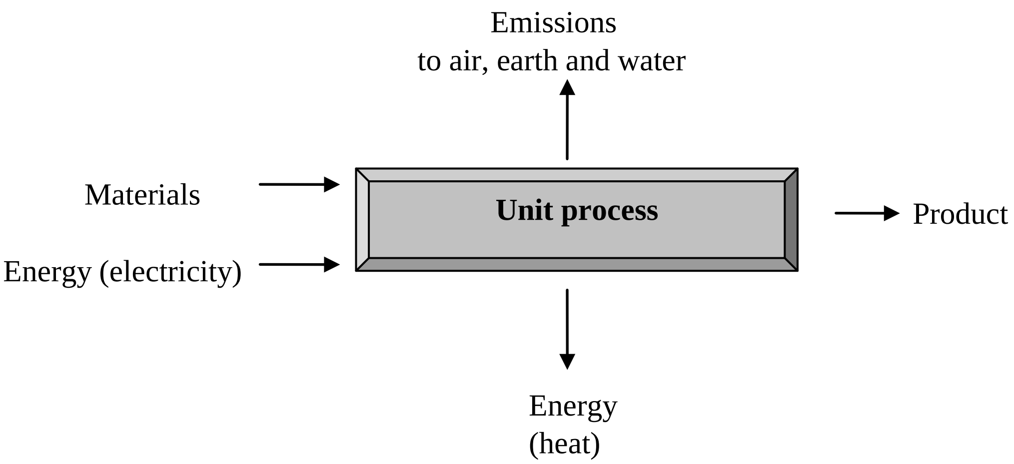


In the first phase of a product's life cycle, the necessary raw materials are extracted and processed into a range of different materials. In the second and third phases of a product's life cycle, these raw materials enter a variety of production processes, and are transformed into products. In the fourth phase of a product's lifecycle, the products are in use. In the fifth and final phase of the life cycle, the products are finally disposed of – either through reuse, recycling or by landfill.

During the product's life cycle, energy and a number of secondary materials are added to the product in a variety of different processes. Furthermore, transportation also takes place between the different processes in the life cycle phases, which also has to be accounted for.

In a LCA, the different processes within each phase of the product's lifecycle are systematically divided up into unit processes. In each unit process, the inputs and outputs are quantified (see Figure 3).

Figure 3: A unit process in the life cycle



3.2.1 Inputs

The term “inputs” is used to describe the materials and energy that the unit process requires.

3.2.2 Outputs

The term “outputs” is used to describe the products of the unit process, i.e. the final product, waste heat and emissions to land, air, and water.

3.3 The Life Cycle Assessment Framework

Although the methodology used for developing a LCA is yet to be standardised, there is general consensus that a LCA should be based on the following framework:

- Scope
- Inventory
- Environmental Impact Assessment
- Environmental Analysis
- Suggestions for improvement

3.3.1 Scope

The scope of the LCA has two functions. Firstly it defines the purpose of the LCA by identifying the functional unit. The functional unit is the product being assessed and the functions that it performs during its lifetime. Secondly, the scope of the LCA identifies the system boundaries. If the system boundaries are not identified the survey will become too extensive and data availability problems might occur. The system boundaries should therefore taken into consideration on a continual basis throughout the LCA.

3.3.2 Inventory

The inventory of the LCA describes the product’s unit process on a "cradle to grave" basis, and quantifies the inputs and outputs from each unit process.

3.3.3 Environmental impact assessment

A profile of the environmental impact of the product is produced by transferring the inputs and outputs quantified in the inventory, into measures of environmental impacts. In this report, the EDIP LCA tool has been used for the environmental impact assessment.

3.3.4 Environmental analysis

The environmental analysis identifies the most significant environmental impacts during the product life cycle. Simulations of different lifecycle possibilities form a central part of the environmental analysis (see section 7.4).

3.3.5 Suggestions for improvements

Alternative materials and production forms that the company can use to optimise its environmental efforts are identified on the basis of the environmental analysis.

4. Methodology and Aims of this LCA

4.1 Methodology

The methodology used in this LCA is derived from the EDIP LCA tool. EDIP complies with the international principles for LCA developed by SETAC and ISO.

The Clip-Lok SimPak™ reusable packaging system is mainly constructed of wood, which is considered to be a renewable resource, and steel, which can be recycled. Effects on the outer environment are traditionally separated into three sub-categories, depending on the geographical area affected. These are:

Global Effects
- Global warming
- Ozone depletion

Regional Effects
- Photochemical ozone formation (smog)
- Acidification
- Nutrient enrichment
- Some toxic effects

Local Effects
- Humane toxicity
- Eco-toxicity
- Waste

For a further description of these effects, see Enclosure 17.

4.2 Aims

The aims of this LCA are to:

- Assess the environmental impacts from "cradle to grave" of the Clip-Lok SimPak™ reusable packaging system

- Identify the materials and processes with the highest impact on the environment

- Provide environmental improvement options

- Make a comparative analysis of the Clip-Lok SimPak™ reusable packaging system with one way packaging

5. Scope

5.1 Functional Unit

Clip-Lok SimPak Scandinavia Ltd customises the cases to match customer specifications. A specific Clip-Lok SimPak™ case has therefore been selected for use as the reference product in this LCA, to insure consistency. The transportation route during the usage phase is defined as Düsseldorf to Chicago via New York, with a total of four roundtrips per year.

The functional unit for the reference case in this LCA is defined as:

50 round trips of each 0,9024m^3 goods during its expected lifetime of 12,5 years

The reference cases only carry goods one way, and are returned empty. In this assessment a waste factor of 2% is used per trip. If the waste factor is 2%, the lifetime is predicted to be 50 trips. After 50 trips, the whole case has theoretically been substituted.

The dimensions of the Clip-Lok SimPak™ reference case made in 18mm plywood, are 1200*800*940mm. The dimensions of the one way packaging made in 6,5mm plywood are 1200*800*940 mm.

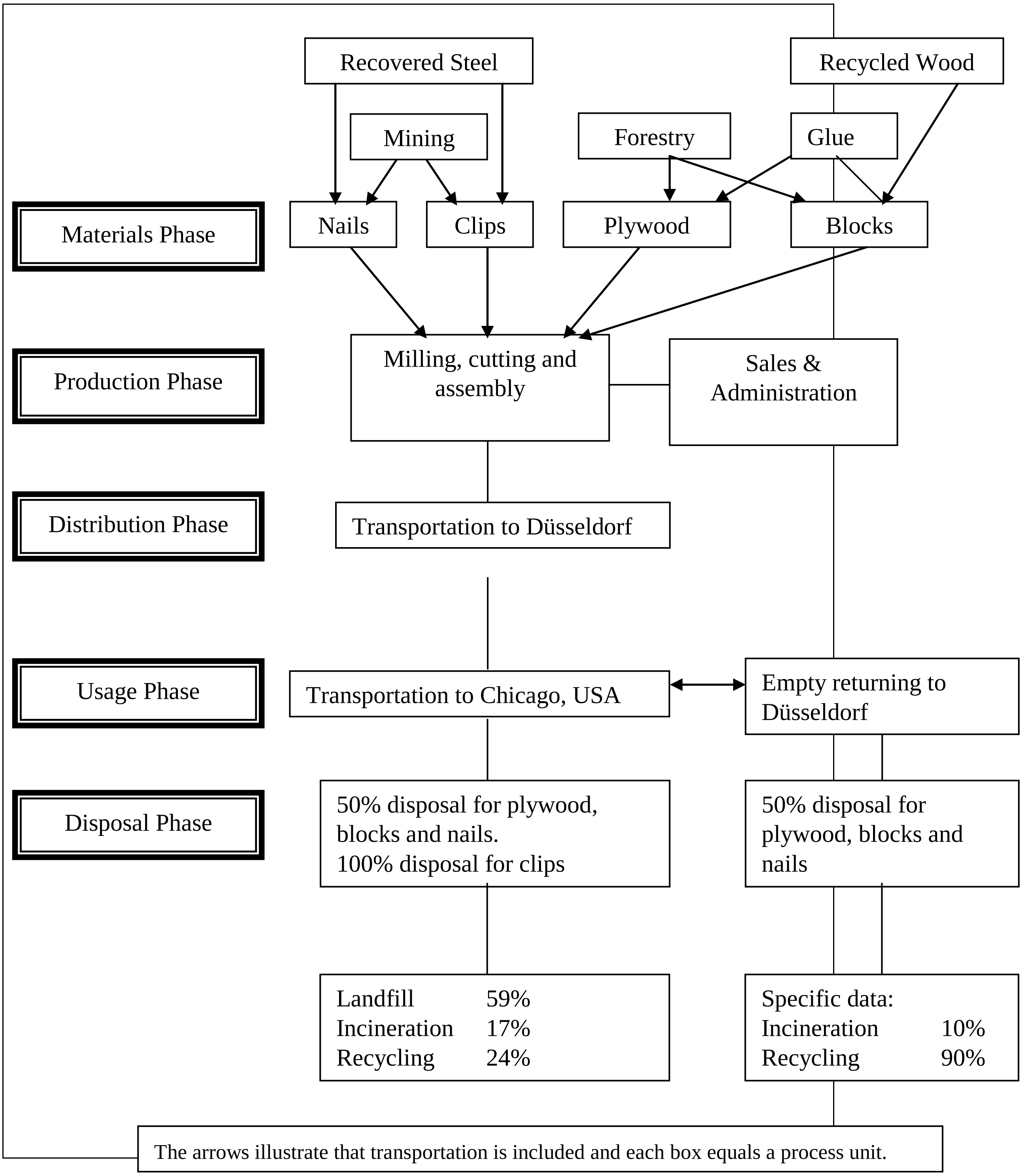
The material lists for the two containers are shown in table 1.

Table 1: Material lists

	Materials	Name	Weights [Kg]
Reference case (Clip-Lok SimPak™)	Plywood	Case	45.84
	Plywood	Runners	3.24
	Steel	Clips (18mm)	3.60
	Steel	Nails	0.27
	Recycled wood	Blocks	8.10
	Paint	Paint	0.01
	Total		61.06
One way packaging	Plywood	Case	16.56
	Plywood	Runners	3.24
	Steel	Band	1.85
	Recycled wood	Blocks	5.40
	Paint	Paint	0.01
	Total		27.06

Source: Clip-Lok SimPak Scandinavia Ltd., 1999

Figure 4: Life cycle of the reference case



5.2 System Boundaries

The lifecycle of the reference case can be divided into five phases (see Figure 4 above):

- Materials phase
- Production phase
- Distribution phase
- Usage phase
- Disposal phase

The five phases cover the product from "cradle to grave". Information on the raw materials used in the reference product has, as far as possible, been researched back to the stage where the original materials were extracted from the earth. This information was collected from the literature and from the EDIP database. 94% of the materials' weight was traced back to the mining stage.

For data concerning the production of the materials, site specific data from the production processes has been used, and the same applies for transportation from the suppliers. 80% of the reference weight was gathered.

On delivery from the sub-supplier, the production facility cuts the boards into sizes according to the customers' specifications. The inserts for the clips are milled, the units for the pallets mounted, and the clips are fitted. Logos are then painted on the plywood sides. The paint for the logo is not included in the data model – partly because the amount used per case is extremely small compared to the weight of the reference case, and partly because the logos differ from case to case. However, the paint has been reviewed in terms of its environmental impacts. Cut-offs from the plywood cutting process are either used for pallet boards or sent for incineration. The finished case is then sent as flat-packs to Düsseldorf where it is assembled and used in the shipment of goods for a client in Chicago, USA.

6. Inventory

The following sections contain short descriptions of the data collection process for each phase in the lifecycle of the Clip-Lok SimPak™ reference case, as well as the limitations associated with data collection for each phase.

6.1 Materials

A questionnaire was sent to the suppliers to enable data collection. In the questionnaire, suppliers were asked to inform about their production processes (inputs and outputs), use of secondary materials and the content of those materials. Data provided by the suppliers includes energy consumption, raw material use, auxiliary materials and waste. A limitation has been that it was not possible to obtain data for water consumption and waste water discharge in the material phase.

6.1.1 Materials used in the reference product

Plywood: Due to the lack of data availability for spruce in the EDIP database, it was decided to use beech instead, as it differs only slightly from spruce[4]. Production data are site-specific and obtained from the suppliers. The water content in dried wood is estimated at 20%. When producing plywood the producer uses phenol formaldehyde glue. It has not been possible to obtain data for this type of glue, and formaldehyde glue has been used instead in the model. The glue in the plywood and blocks comprises only 6% of the total weight of the Clip-Lok SimPak™ reference case.

Clips: Site specific data from the producer has been used in the model. Further more, data from the EDIP programme has been used in association with the bending, cutting, and surface treatment processes.

Nails: Site specific data from the producer has been used in the model. Further more, data from the EDIP programme has been used. The data from EDIP covers a variety of processes, for example bending.

Blocks: Formaldehyde glue has been used in the model instead of the actual urea melamine formaldehyde, due to lack of data for the urea melamine formaldehyde. It is also assumed in the study that the wood in the blocks has gone through the same forest management as the beech tree in the plywood.

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[4] Source: “Miljøvurdering og videreudvikling af et reolsystem”. Environmental report #376, Danish EPA, 1998.

Paint: Paint is examined in the study, but is only a minor constituent in the product – with a total of only 0,7 grammes per reference case. It is, however, important to notice that the paint contains phthalates, which pose a threat to occupational health and safety, and are listed as an “undesired material” by the Danish Environmental Protection Agency.

6.1.2 Secondary materials not included

- Detergent is not included in the model because the floors in the production area are mainly swept clean, and are seldomly washed. The amount of detergent used is therefore very small
- Water for sanitary purposes
- Packaging (the straps are recycled)
- Lubricating oil for machinery - the producer uses very little

6.1.3 Transportation processes in the materials phase

Delimitations have not been made in the transport processes. Due to a lack of data on raw materials from the producer through to the wholesaler, only virgin wood and glue have been included in this study. Together these account for 94% of the total weight of the case.

Another limitation is that it was not possible to get precise data for the means of transportation used. Information from RAMBØLL and the Danish Shipowners' Association have therefore been used, together with the standard means of transport in the EDIP programme, to simulate the transport of the reference cases. Nonetheless, some deviations do occur between the results achieved in the data model and the actual resource consumption. The most direct and thereby the shortest distances have been chosen here.

Table 2: Transport from suppliers to production facility

Supplier	Distances [km]	Transport means	Transport type
Virgin wood (80%)	70,0	Highway	Diesel truck (>16 t)
Glue	175,0	Highway	Diesel truck (3,5-16 t)
Plywood	160,0 945,0 86,0	Railway Ship Motorway	Train Containership (28000 dwt.) Diesel truck (>16 t)
Spring steel clips	188,0 593,0 318,0	Motorway Ship Motorway	Diesel truck (3,5-16 t) Containership (28000 dwt.) Diesel truck (3,5-16 t)
Wastewood to blocks	150,0	Motorway	Diesel truck (3,5-16 t)
Blocks	700,0	Motorway	Diesel truck (>16 t)
Nails	88,0	Highway	Diesel truck (<3,5 t)
	945,0	Ship	RO-RO ship (3.600 dwt.)
Paint	1000,0	Motorway	Diesel truck (3,5-16 t)

Source: Suppliers, 1998-1999

Table 3: Disposal at suppliers

Supplier Countries				
Country	Landfill	Incineration	Recycling	Source
UK	100 %	-	-	Solid Waste Recycling in Western Europe
Finland	-	99 %	1 %	Suppliers
Netherlands	-	100 %	-	Solid Waste Recycling in Western Europe

6.1.4 Production phase

The Clip-Lok SimPak™ production facility was visited in connection with the Life Cycle Assessment, and the following observations were made:

- There is a plywood waste rate of 4.24 % on the reference case
- The waste rate for the remaining parts during assembly is very small.
- Some customers order a special print on the case. This is not included on the reference case
- The energy consumption (electricity and heating) in production as well as administration has been calculated per reference case by dividing the energy consumption in 1997, with the number of cases produced in 1997

6.1.5 Distribution phase

The Clip-Lok SimPak™ reference case is transported from Skibby, Denmark to the customer in Düsseldorf.

Distribution: Skibby, Denmark- Düsseldorf

(Europe)Route	Distance [km]	Transport means	Transport type
Skibby- Rødby	175,0	Motorway	Diesel truck (>16 t)
Rødby- Puttgarden	25,0	Ship	Ferry
Puttgarden- Düsseldorf	552,0	Motorway	Diesel truck (>16 t)

Source: EuroShell Route Planner, 1999

6.1.6 Usage phase

The reference case travels between Düsseldorf and Chicago.

Düsseldorf- Chicago

Route	Distance [km]	Transport means	Transport type
Düsseldorf – Rotterdam	230,0	Motorway	Diesel truck (>16 t)
Rotterdam – New York	6.115,0	Ship	Containership (28000 dwt)
New York – Chicago	1.260,0	Motorway	Diesel truck (>16 t)

Source: Danish Shipowners' Assoc., EuroShell Route Planner and US Highwaymap

6.1.7 Disposal phase

Specific data from customers is used wherever possible, however, it was not possible to get specific data from Illinois. General data from the US EPA are used instead. Specific data was collected from a customer in Illinois with a waste recycling programme, but because the recycling methods were not specified, the data cannot be used. If, for example, the wood is shredded and used in gardens then this is considered disposal and not recycling. Generally, it is only considered recycling when the waste material is used in the production of a new product.

Information received from Clip-Lok SimPak Scandinavia Ltd indicates that the majority of those spring steel clips that are lost, are lost simply because the customers forget to return them.

See table 4 for landfill, incineration, and recycling percentages in Düsseldorf and Illinois.

The following assumptions are made regarding the disposal of wood:

- By disposal of wood it is assumed that it will decompose into carbon dioxide and methane, 90% by anaerobic decomposition and 10% by aerobic decomposition.
- The glue used in the plywood is considered to be highly volatile due to its content of phenol and formaldehyde.

Table 4: Disposal phase

Country, Region, State	Landfill %	Incineration %	Recycling %	Source of Information
Düsseldorf, Germany General data	59,0	17,0	24,0	Solid Waste Recycling in Western Europe
Düsseldorf, Germany Specific data	-	10,0	90,0	Customer in Düsseldorf
Illinois, USA General data	76,0	1,0	23,0	US EPA
Illinois, USA Specific data	10,0	-	90,0	Customer in Illinois

Table 5: Danish and German incineration

	Denmark	Germany
Electricity	20%	15%
Heat	60%	55%
Loss	20%	30%

Source: Dalager, Søren. RAMBØLL, September 1999

6.2 Allocation

Table 6: Allocation in disposal phase

	Düsseldorf	Illinois
Wood incl. nails	50 %	50 %
Clips	-	100 %

The text in the following boxes is important to insure comprehension of the simulation results.

> Heat and electricity are potential by-products of waste incineration, their production depending on the system used. This energy can then be used to substitute the use of fossil fuels, for example coal and oil, in Denmark and Germany. This results in more waste volume than would by conventional combustion.

According to the EDIP programme, 84% of the steel is recycled in Denmark and Germany post-incineration. When it comes to incinerators on the other hand, the US does not use heat recycling or magnets. In Denmark and Germany, magnets are used to collect metal for recycling purposes after combustion has taken place[5].

[5] Dalager, Søren. RAMBØLL, September 1999

7. Environmental Impact Assessment

7.1 Environmental Impacts of the Reference Product

The graph below shows the environmental impacts of the Clip-Lok SimPak™ reference case after normalisation. The environmental impacts of the reference product are classified into the following four phases of its life cycle:

- Usage
- Production
- Material
- Disposal

Figure 5: The environmental impacts of the reference product

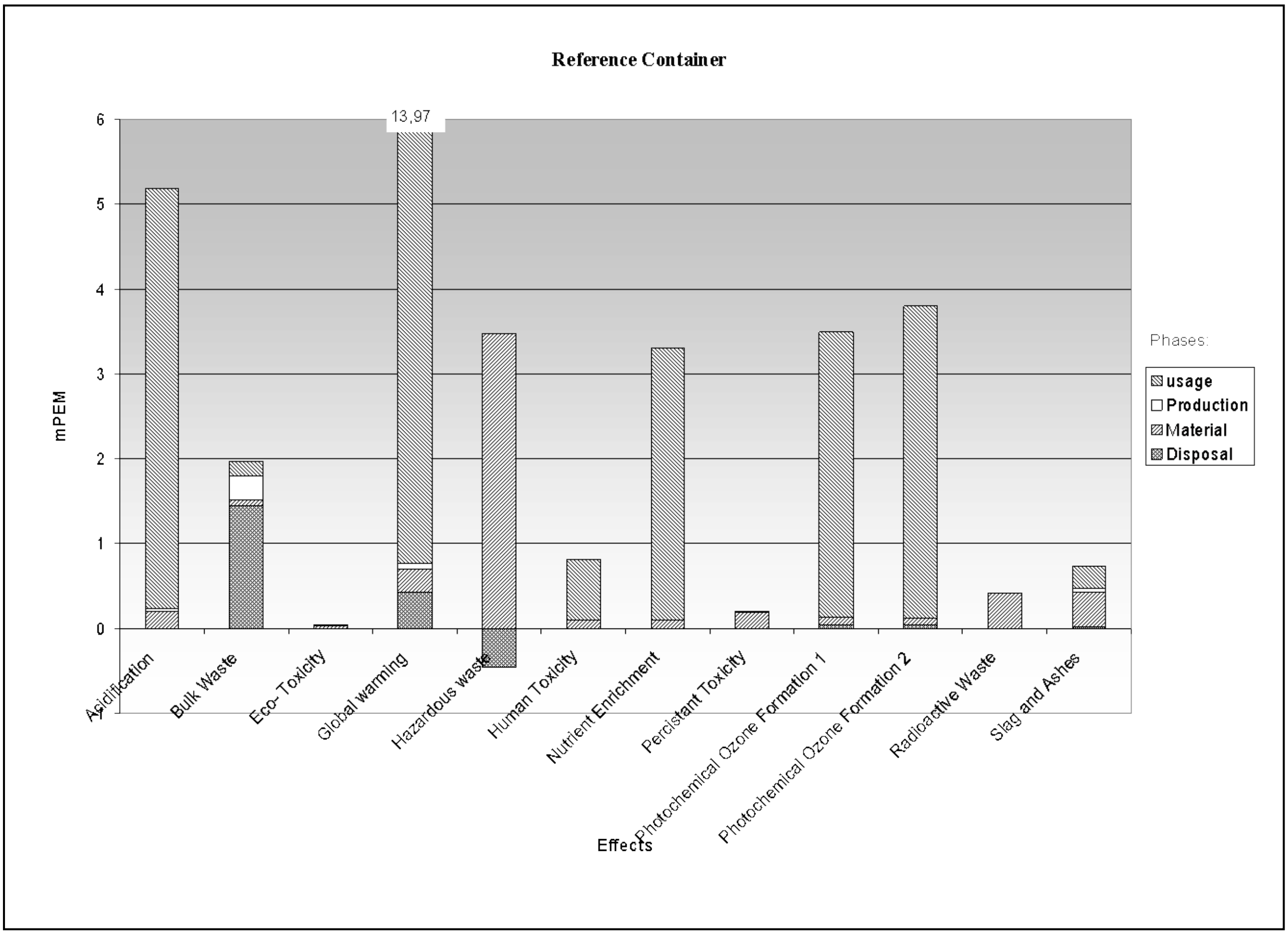

Figure 5 clearly shows that the most significant environmental impacts during the lifecycle of the Clip-Lok SimPak™ packaging system occur during the usage phase.

The main reason for these effects is that transportation is one of the main contributors to acidification, global warming, human toxicity, nutrient enrichment, photochemical ozone formation, and produces ashes as well as other deposits. Clip-Lok SimPak Scandinavia Ltd can only exert a small influence in this phase of the reference product's lifecycle.

In the material phase, environmental impacts are mostly derived from the hazardous waste, radioactive waste, slag and ashes, which result from metal production processes. The environmental effects mentioned above, as well as the remaining environmental effects in the graph, occur as a result of the energy consumption necessary for the treatment of resources, and the transportation of materials.

The production phase accounts for a minor part of the environmental effects produced from bulk waste. These include global warming, slag and ashes resulting from energy consumption. Finally, bulk waste occurs in the disposal phase. Global warming is primarily due to the combustion of fossil fuels. Due to the re-use of other materials in the production this substitutes the hazardous waste. Therefore this is negative. This graph is included in enclosure 1. Please see section 7.3 for more detailed comments and assessments.

Table 7: Major resource use and emissions per reference case in its full life cycle

	RESOURCE / EMISSION	WEIGHT (kg)
Materials	Natural gas	28,12
	Coal	10,32
	Oil	455,2
	Uranium	0,001
	Wood (Solid matter)	78,37
	Water	505,5
	Aluminium	0,035
	Iron	0,356
Waste	Volume	2,671
	Dangerous	0,245
	Radioactive	0,001
	Chemicals	0,075
	Slags and ashes	3,235
Air Emissions	Methane	1,772
	Carbon monoxide	5,396
	Carbon dioxide	1545,0
	Nitrogen oxides	9,03
	Sulphur dioxide	1,696
	VOC	0,008
	MNVOC	1,280
Water Emissions	COD	0,005
	BOD	0,002
	Nitrogen substances	0,001
	Metals	0,003

Most of the resources used in the lifecycle of the Clip-Lok SimPak™ case are utilised for energy consumption, especially during the usage phase.

7.2 The Reason for the Simulations

The Clip-Lok SimPak™ reference case has been the basis for developing the simulations based on the assumptions described above in chapters 3 – 5. All results are used in connection with the reference case. The simulations facilitate demonstrations of the resource usage and the potential environmental effects in different scenarios.

The results of the simulations are then normalised.

Normalisation has two purposes
- To provide an impression of the relative magnitudes of the potential impacts and resource consumption
- To present the results in a form suitable for the final decision making

In normalisation, the impact potentials and resource consumption which have been determined are compared with an impact which is common for all impact categories, and of which the consequences for the environment, resources and working environment are known. In this way an impression is gained of which potential impacts are large and which are small, seen in relation to the known reference impact.

As normalisation references the EDIP LCA tool used in the Clip-Lok SimPak LCA, uses the resource consumption and the potential impacts which society imposes on the environment and the working environment each year. When the impact potentials are normalised, they are expressed in person-equivalents (PE), i.e. fractions of the contribution to the impact deriving from the average person[6].

7.3 The Clip-Lok SimPak™ Reference Case and the Simulations

The following simulations are made for the reference case:
(If not mentioned all phases in the life cycle assessment are included)

1) Reference product

2) Simulation with 50 one way packages[7]

3) Simulation with 100 one way packages[8]

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[6] Wenzel, H., Hauschild, M., Alting, L., Environmental Assessment of Products, IPU, 1997

[7] To equalise the functional unit with the reference case, 50 one way packages are transported one way (from Düsseldorf to Chicago) after which they are disposed of (general data used). Specifically the following applies for the one way package: the distribution distance of the materials is the same as that applying for the reference case.

- ☎ The steelband used around the one way packaging is the equivalent of the clips used on the reference case. Furthermore the steelbands receive the same surface treatment as the reference case.
- ☎ The one way packaging is produced in Germany and the distribution is the same as that of the reference case.

[8] Simulation made to be compared with a reference case used both ways and therefore the disposal of the one way packaging is allocated 50% in Düsseldorf and 50% in Illinois (same disposal data used as for reference case).

4) Simulation with less weight but the same functional unit[9]

5) Simulation with a waste percentage of 1%

6) Simulation with a waste percentage of 4%

7) Simulation without glue in the plywood

8) Simulation of the production phase with a minimisation of 50% of the energy consumption

9) Simulation with a recycling program in Illinois equalling that of Düsseldorf

10) Simulation with general disposal in Illinois and Düsseldorf

11) Simulation with twice the transportation distance during use

12) Simulation of the materials phase where 89% primary steel is used instead of recovered steel

13) Simulation with train instead of truck.

Simulations especially for the sensitivity analysis:

1. Type of ship
2. Water percentage in the wood
3. Weight contra volume
4. Ocean transportation with regional effects

7.4 Results of the Simulations

It is recommended that the reader refers to the enclosures, starting on page 33, whilst reviewing the results of the simulations.

7.4.1 Enclosure 1: Clip-Lok SimPak™ reference case

This is the graph displayed in the beginning of this chapter (see Figure 5 above).

7.4.2 Enclosure 2: Reference case vs. 50 units of one way packaging

The enclosure demonstrates that the Clip-Lok SimPak™ reference case (empty return) is environmentally preferable to the one way packages, especially if one focuses on the following parameters: hazardous waste, humane toxicity, persistent toxicity, ecotoxicity, radioactive waste, and volume waste. The reason being that when 50 one way packages are compared to one reusable Clip-Lok SimPak™

[9] Simulation with 12mm plywood and a clip weight of 64g.

case, it is assumed that the reusable case delivers the same service as the 50 one way packages.

It can though be seen that the one way packages are environmentally preferable to the reference case in terms of contribution to nutrient enrichment. This is due to the fact that the reference case weighs more than the one way packaging during transportation. The difference, however, is considered to be relatively small, and the conclusion is that the Clip-Lok SimPak™ reference case is significantly preferable to one way packaging.

7.4.3 Enclosure 3: Reference case vs. 100 units of one way packaging

The enclosure shows that the Clip-Lok SimPak™ reference case (full return) in all effect categories is more preferable to the one way packages.

7.4.4 Enclosure 4: Reference case vs. case with 12 mm plywood and 64 g clips

Not surprisingly, enclosure 4 shows that a low weight case has a lower environmental impact than the reference case. This is because the lower the weight, the lower the amount of emissions during transportation.

7.4.5 Enclosure 5: Reference case vs. case with 1% wastage rate

The enclosure compares the reference case with its waste percentage of 2%, to a case with a waste percentage of 1%. This graph assesses a scenario where the wastage rate is lowered to 1%. All environmental effects are reduced at a wastage rate of 1. There are, however, two significant decreases by the smaller waste percentage. These are bulk waste, and hazardous waste. Logically it is environmentally preferable to take good care of the packaging box – thereby increasing its lifetime.

7.4.6 Enclosure 6: Reference case vs. case with 4% wastage rate

The significance of this graph, is that the volume of bulk waste and hazardous waste are double as high, when the wastage rate is increased in an equal amount. All other effects are higher as well at a higher wastage rate.

7.4.7 Enclosure 7: Reference case vs. case without glue

The diagram shows the difference in the material phase and the disposal phase between the Clip-Lok SimPak™ reference case and a case constructed of non-glued plywood. As mentioned in the report, the amount of glue used to produce plywood is not significant. Nonetheless, the case without glue has a better environmental profile for the following environmental effects: global warming, humane toxicity, persistent toxicity, and photo chemical ozone formation 2. This demonstrates that glue does have an influence on the overall toxicity levels in the lifecycle of the product.

7.4.8 Enclosure 8: Reference case vs. case using 50% less energy

Enclosure 8 displays the production phase of a scenario where the Clip-Lok SimPak™ reference case is compared to a case using 50% less energy during its lifecycle. All the environmental effects from the case with 50% less energy use are 50% lower, except for the quantity of oil used. This is due to the oil consumption used to produce the energy for heating the administration. It's only possible to reduce the energy use in administration by using low energy light bulbs, or by reducing the temperatures.

7.4.9 Enclosure 9: Reference case vs. case with more recycling in Illinois and vs. case with less recycling in Düsseldorf

As foreseen, it is environmentally preferable to optimise recycling. Low levels of recycling result in larger effects on the environment. The negative factors occur due to recycling and the substitution of fossil fuels with energy derived from incinerating the plywood. Somewhat surprisingly, the effects of the reference case are similar to those of the scenario with less recycling**.** This must be due to the fact that the recycling program in Chicago is so far limited. In this model, recycling is used when the disposed matters are recycled into new products.

7.4.10 Enclosure 10: Transportation length

This diagram shows the usage phase for the Clip-Lok SimPak™ reference case and a scenario with a case travelling double as long in the usage phase. The significance of this enclosure, is that the effect of global warming has doubled. Global warming is a consequence of transportation mainly by ship. Only those effects that are influenced by transportation are higher when the case travels double the distance, otherwise the effects stay the same

7.4.11 Enclosure 11: Recovered steel vs. primary steel

This graph shows the materials phase where 89% primary steel is used instead of recovered steel. Using primary steel generally increases the environmental effects during the lifecycle of the Clip-Lok SimPak™ reference case, especially the effects associated with iron consumption. The use of iron is significantly higher when using primary steel. This general observation does not apply for bulk waste though; the reason being that when recovered steel is used, a waste percentage is included. Another factor regarding the use of primary steel and recovered steel, is that when recovered steel is used, the effects on the landscape caused by mining are not encountered. Recovered steel is therefore preferable.

7.4.12 Enclosure 12: Transportation with train instead of truck in the usage phase

In this simulation, the reference case is transported by train from New York to Chicago, instead of by truck as per normal. The simulation results show that bulk waste, hazardous waste, and radioactive wastes especially are eliminated by train transport. All other effects show a likewise decrease, though of a lower magnitude.

The environmental improvements occur because it costs a train less energy to transport one kilo than it does for a truck to transport one kilo. This is partly due to the capability of the train to transport significantly more goods.

7.4.13 Enclosure 13: Containership vs. smaller ship (RORO ship)

This graph compares the containership that the Clip-Lok SimPak™ reference case uses, with a smaller ship of 3900 t, where 50 % of its capacity is utilised. The results of the simulation show that the effect of global warming is considerably higher for the smaller ship. This is due to the fact that a ship's propulsion consumes the main part of the energy used, compared to the transportation of goods itself. Generally it is preferable to use a containership as the reference case does.

7.4.14 Enclosure 14: Water percentage in plywood

This graph shows a simulation in which the Clip-Lok SimPak™ reference case is compared to a case in which the plywood has 40% water content. The simulation showed that using plywood with a water content of 40% has no significant effect on the environmental profile of the case.

7.4.15 Enclosure 15: Transportation calculated using volume instead of weight

There are two ways of calculating transportation. The first one is by using weight pr. kilometre and the other is by using volume pr. kilometre.

This graph shows the results of calculating the transport effects using volume instead of weight. As can be seen on the graph, the environmental impacts of the Clip-Lok SimPak™ reference case would have been reduced if volume had been chosen instead of weight. The explanation is that the environmental effects are much smaller because the cases are collapsible and therefore more cases can be transported when collapsed. In the study it was decided to use weight in the simulations of the Clip-Lok SimPak™ reference case, as the EDIP programme uses weight in the transport processes. Consequently the Clip-Lok SimPak™ may well have obtained a better environmental profile if volume was used instead.

7.4.16 Enclosure 16: Including regional effects under ocean transport

The graph shows the local, regional, and global effects that occur when the reference case is being transported on an ocean route. Outside the 12 nautical miles zone, it has been chosen to apply global effects only, thus giving a more reliable picture of the environmental effects.

7.5 General Results

7.5.1 Lifetime

The lifetime of the product is of major importance for the environmental profile of the product. The environmental impacts caused by the product will be consistently reduced for each year of its lifetime, due to the effects being spread over the years.

7.5.2 Materials

Enclosure 11 shows that spring steel clips made from recovered steel instead of primary steel are preferable but this is of not great importance for the overall environmental impact of the Clip-Lok SimPak™ reference case during its life cycle. The plywood used in the reference case is manufactured using glue, and this should be replaced by a non-glue plywood. Otherwise, the materials used in the reference case are good when seen from an environmental perspective.

7.5.3 Production

The environmental impacts during production are minimal if seen in connection with the whole life cycle of the Clip-Lok SimPak™ reference case. As can be seen from enclosure 8, a reduction of 50% in energy consumption does not mean a great deal for the environmental profile.

7.5.4 Usage

The environmental impacts by far arise in the usage phase meaning during transportation of the cases. Enclosure 1 shows that the emissions during transportation of the reference case are large compared to the other phases.
As seen from enclosure 12 it is environmentally preferable to transport the cases on cargo rail instead of truck.

7.5.5 Disposal

Enclosure 9 shows that recycling is universally preferable, followed thereafter by incineration.

7.5.6 One way packaging

Enclosures 3 and 4 show that the Clip-Lok SimPak™ reference case is environmentally preferable to both 50 and 100 units of one way packaging.

8. Data Quality and Sensitivity

8.1 Data Quality Table

The table below shows the quality of the data obtained for the Clip-Lok SimPak™ packaging system. Some of the data are considered below average quality, but have only a minor significance for the results of the entire LCA. Generally the quality of the data are good.

Table 8: Data quality table

PHASE	MATERIAL	DATA	DATA QUALITY	SOURCE
Material	Plywood	Specific data	AA	Supplier
	Blocks	Specific data	A	Supplier
	Nails	Specific data	BA	Supplier
	Paint	Specific data	AA	Supplier
	Clips	Specific data	BA	Supplier
	Transports	Specific and general data	AA	Supplier, Route planner + EDIP
Production	Energy	Specific data	A	Clip-Lok SimPak®
Usage	Transport	General data	A	Danish Shipowners' Ass + EDIP
	Lifetime	General data	A	Clip-Lok SimPak™
Disposal	Düsseldorf	Specific data	BA	Recycling company used by a main customer
	Düsseldorf	General data	A	Solid Waste Recycling in Western Europe
	Illinois	Specific data	BA	Recycling company used by a main customer
	Illinois	General data	A	EPA, Illinois

AA = Above Average data quality
A = Average data quality
BA = Below Average data quality

8.2 Sensitivity Evaluation

The purpose of the sensitivity evaluation is to compare what would happen if one factor in the reference product changes dramatically, for example if another kind of glue is used.

Table 9: Sensitivity evaluation

Phases	Estimated Data	Significance for the environmental impacts
Material Phase	Lower percentage of recycled steel	>
	Without glue in the plywood	0
	Water percentage in plywood	0
Usage Phase	RORO ship instead of containership	>>
	Volume instead of kg km	<<
	Choice of transportation length	>
	Lifetime of box -Wastage rate	<
	Ocean travel instead of normal EDIP data	<<
Disposal Phase	Specific data for disposal in Illinois instead of general data	<<
	Allocation	<<

< = Reduced environmental impact
> = Increased environmental impact
0 = Non important environmental effects
? = No knowledge

Table 10: Lack of Data

Phases	Data	Significance for the Environmental Impacts
Materials	Paint (is not included in simulations)	0
	Water emissions	0
	Water consumption	0
	Packaging material	0
Production	Sanitary, Water consumption	0
	Cleaning products	0
Disposal	Emissions glue, incineration	>

8.3 Comments to Sensitivity Evaluation and Lack of Data

The analysis of data sensitivity in Table 9 shows that there is some sensitivity for the data in the usage and disposal phases, while there is low data sensitivity in the material phase.

The lack of data is only of significance for the environmental impacts for incineration of glue.

9. Recommendations for Future Environmental Work

The recommendations are sorted into the following sections:

- General recommendations
- Materials phase
- Productions phase
- Usage phase
- Disposal phase

9.1 General Recommendations

The simulations give a clear result – the Clip-Lok SimPak™ reusable, collapsible packaging system is indeed environmentally preferable to one way packaging. There is, however, still room for improvement in the product design with the aim of further reducing environmental impacts during its entire lifecycle.

The simulations demonstrate that the largest emissions occur during the usage phase. This means that environmental benefits during production are of less importance, compared to the total life cycle impact of the product.

9.2 Materials Phase

On the basis of the simulations, it can be concluded that the weight of the Clip-Lok SimPak™ case has a significant influence on environmental effects during the usage phase. It is therefore recommended to seek materials with a lower weight in future design considerations for the product.

It is also recommended to substitute the present paint, which contains phthalates, with a more environmentally friendly paint. Phthalates are on the Danish EPA's list of unwanted substances. A law forbidding the use of this substance is predicted in the future.

The current use of recovered steel in the manufacture of the steel clips is environmentally beneficial, and it is recommended that this continue.

Clip-Lok should consider replacing the plywood that is used in the construction of the case, with plywood that contains a more environmentally friendly type of glue.

9.3 Production Phase

The simulations demonstrate that the actual production of the packaging system makes only a minor contribution to the product's overall environmental impact during its lifetime. The environmental impact created in the production phase is minor and consequently it can therefore not be recommended to focus on this issue.

9.4 Usage Phase

This study defines the usage phase of the product as being solely comprised of transport. The two most promising options for environmental improvements are firstly to decrease the waste rate, thus prolonging the product's lifetime and secondly to return the cases full, instead of empty. The means of transport used also plays a decisive factor, train or ship being the least polluting.

9.5 Disposal Phase

At first sight it would seem to be difficult for Clip-Lok SimPak Scandinavia Ltd to influence this phase of the Clip-Lok SimPak™ reference case's life cycle, for environmental improvement. However, the clear impression from this study is that the customers are in general quite capable of finding recycling arrangements for the product. This might be a result of the packaging design, which facilitates easy disassembly and therefore separation of the components for either storage or disposal or transportation as flat-packs.

It is, however, recommended that the customers, especially the new ones, are encouraged to send the case's components to recycling. This can be achieved by advising them to send the plywood to recycling (certain wooden products, for example pallet blocks, are constructed from wood waste), and the metal for recovery and recycling.

The wood is only considered to have been recycled if it is used as a raw material in a new product, simply shredding the wood and using it in gardens is not classified as recycling.

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11. Enclosures

Enclosure 17 – Environmental Effects

Global Effects

Substances that affect the global environment have some common characteristics. An example is long half-life periods, which means that they have long degradation times in the environments where they occur. Another typical attribute is a high mobility that enables quick diffusion to all areas in the global environment.

Global warming is probably the most well known global effect. Global warming literally means a heating of the Earth's atmosphere. The most well-known gasses that contribute to the global warming effect are carbon dioxide and methane – also known as greenhouse gasses. Carbon dioxide is discharged as the product of the combustion of a variety of fossil fuels. Carbon dioxide is considered to be the main contributor to global warming, due to the large amounts that are being discharged – mainly by the industrial world in their use of fossil fuels for transportation, energy, and heating. Methane gas is discharged in much smaller amounts than carbon dioxide but with a greenhouse gas potential 25 times as large as carbon dioxide over a period of a 100 years.

The global warming effect is manifested as a raise in the average global temperature. Increases in sea level in the world's oceans as a result of the melting of the polar icecaps, is one of the most serious consequences that are predicted as a result of climate change. The changes will in the worst cases occur too fast for both eco-systems and humans to adapt.

During the last decade, ozone depletion has also been in focus. The observed holes in the ozone layer over the poles are especially alarming. The ozone depletion reaction happens in the stratosphere 15-50 kilometres up in the atmosphere. The increased depletion is being caused by discharges of chlorine and bromine that contain organic substances such as halons and freons – both with such a long depletion period that they reach the stratosphere. Here they react with ozone causing this gas to deplete. The ozone layer filters the damaging UV-radiation. An exposure to stronger UV-radiation could increase the frequency of skin cancer and cause damage to the important part of algae and also higher plants that are responsible for photosynthesis.

Global warming and ozone depletion:

Source: carbon dioxide, methane etc. from e.g. combustion processes.
Problem: leaking of gasses into Earth's atmosphere.
Effects: rise in Earth's temperature and regional climate changes.

Regional Effects

Regional environmental effects occur in a region defined as being between 100 and 1000 kilometres in area. Here the environmental effects are caused by diffuse pollution, the source of which is difficult to track, either because it is located too far away, or because it is the result of a broad network of small sources contributing to the pollution. Regional effects can likewise reach across national borders.

Industrial discharges of acidifying substances such as sulphur dioxide, nitrogen oxides**,** and ammonia, will after a long period destroy the needles from a coniferous tree and acidify the ground, with dead lakes and trees the result. This is not an unknown phenomenon in Scandinavia. Besides interrupting ecosystems, it also destroys buildings. Nutrient enrichment mainly causes problems in aquatic ecosystems, and develops because of over fertilisation in agriculture, and from phosphor in household and industry discharges. The effects are most evident during the summer when algal blooms occur. The problem is that the algal blooms deplete the oxygen levels in the water body, suffocating aquatic life such as fish.

The last of the regional effects, photochemical ozone formation, is better known as smog. Whereas ozone is an important component in the stratosphere, it is not wanted in the lower layers of the atmosphere due to its oxidising effect. Smog is a problem in a lot of big cities and results in breathing problems for humans and animals.

Some substances have a poisoning effect in the form of chronical toxicity for humans and ecosystems on a regional level. Toxicity occurs because of small amounts of substances, which are hard for the environment to decompose and as a result are being concentrated in plants and animals to the extent that they become toxic later on in the food chain. The toxic effect in itself is not deadly. There has been a lot of attention, in the society, on pollution sources emitting heavy metals such as mercury and lead. Through the last decade it has become clear that several organic substances can contribute to this toxicity- called chronical or persistent toxicity. An example is a constant though small emission of substances such as phatalates and DDT with oestrogenic effect resulting in decreased ability to reproduction.

Photochemical ozone formation 1 and 2:
Source: combustion processes and the use of organic solvents.
Problem: smog on Earth.
Effects: irritation in eyes and respiratory organs and harm on crops.

Acidification:
Source: airborne pollution from combustion processes.
Problem: formation of SOx, NOx, and ammonia by rain showers.
Effects: harm to forests, lakes, and buildings.

Nutrient salt impact:
Source: carbon dioxide and phosphorous connections from e.g. wastewater and combustion processes.
Problem: an accumulation of nutrient salts in Eco-systems which result in the flourishing of algae and later on lacks of oxygen.
Effects: fish and plants will become extinct. Poisoning of fish from toxin producing algae.

Persistent toxicity:
Source: discharge of poor degradable poisonous substances by emissions of e.g. wastewater and combustion processes.
Problem: accumulation of poison in nature and in living organisms adding a concentration through the food chain.
Effects: chronically harm on the Eco-systems and on organisms.

Local effects
Local effects are limited to an area within 10 kilometres from the source of pollution.

The term local effects is mainly used to cover acute toxicity affecting eco-systems, airborne toxicity affecting humans, and waste which is considered problematic.

Humans have created many substances that in one way or another have effects on plants, micro-organisms, and animals. The list is long and comprehensive especially when it comes to substances contributing to ecotoxicity. Generally speaking there are two forms of ecotoxicity. The first one is acute toxicity, which occurs due to unusually large discharges of substances that are easily concentrated or degrade slowly in ecosystems. The other is chronical toxicity, which already have been described above under regional effects. An example of acute toxicity can be an accidental discharge which results in death of the micro-organisms in the biological water treatment plant – either due to direct deadly contact with the substances or because stronger micro-organisms take over.

With regard to humans, toxicity follows in principle the same pattern as for Eco toxicity. To a large extent it is the same substances which are causing the toxicity.

Volume waste as an effect on the outer environment has achieved increasing attention by society. The decrease of the waste is an important part of the product oriented environmental policy. There are three types of waste causing the main problems: slag and ashes, dangerous waste, and radioactive waste. The slag and ashes are typically coming from the burning of coal or production of raw materials, dangerous waste from product manufacturing and disposal, and finally radioactive waste from nuclear production of electricity and heat.

Human toxicity:
Source: chemicals, discharge of wastewater, combustion processes, and leaching from landfills.
Problem: release of poisonous substances from e.g. the air or by eating.
Effects: acute poisoning e.g. for asthmatics. Chronically poisoning and increased frequency of breast- and testicle cancer.

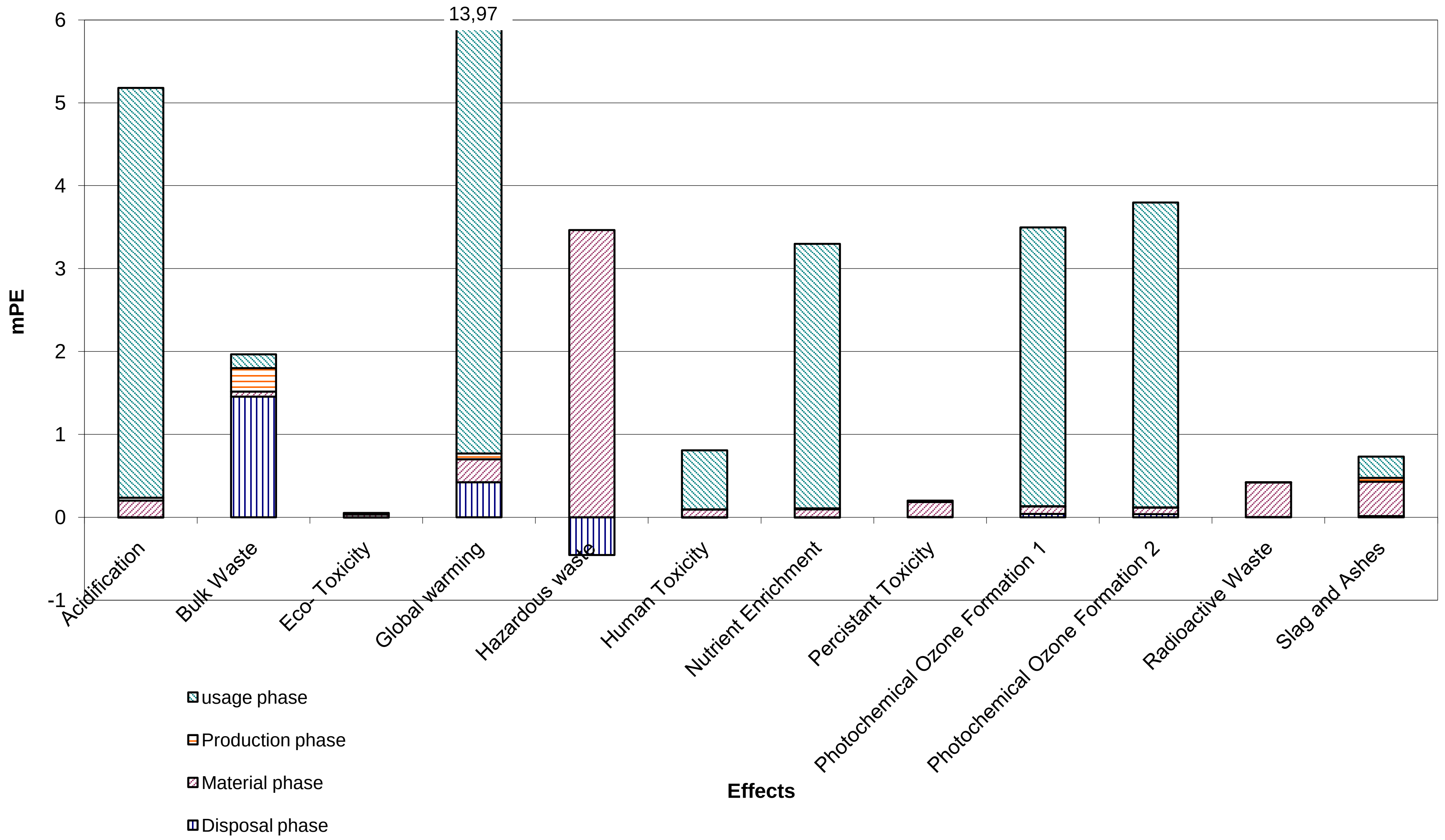
Eco toxicity:
Source: discharge of wastewater and combustion processes.
Problem: the organism are being exposed to poison both acute and chronically by prolonged action.
Effects: acute harm such as reduced photosynthesis by algae and death of the fishes. Chronically harm such as reduced growth.

Dangerous waste, radioactive waste, slag and ashes, and volume waste:
Source: industrial processes and household.
Problem: accumulation of waste.
Effects: discharge of environmentally damaging substances to land and groundwater leading to possible poisoning of plants and animals. Obnoxious smells and elimination of landscapes.

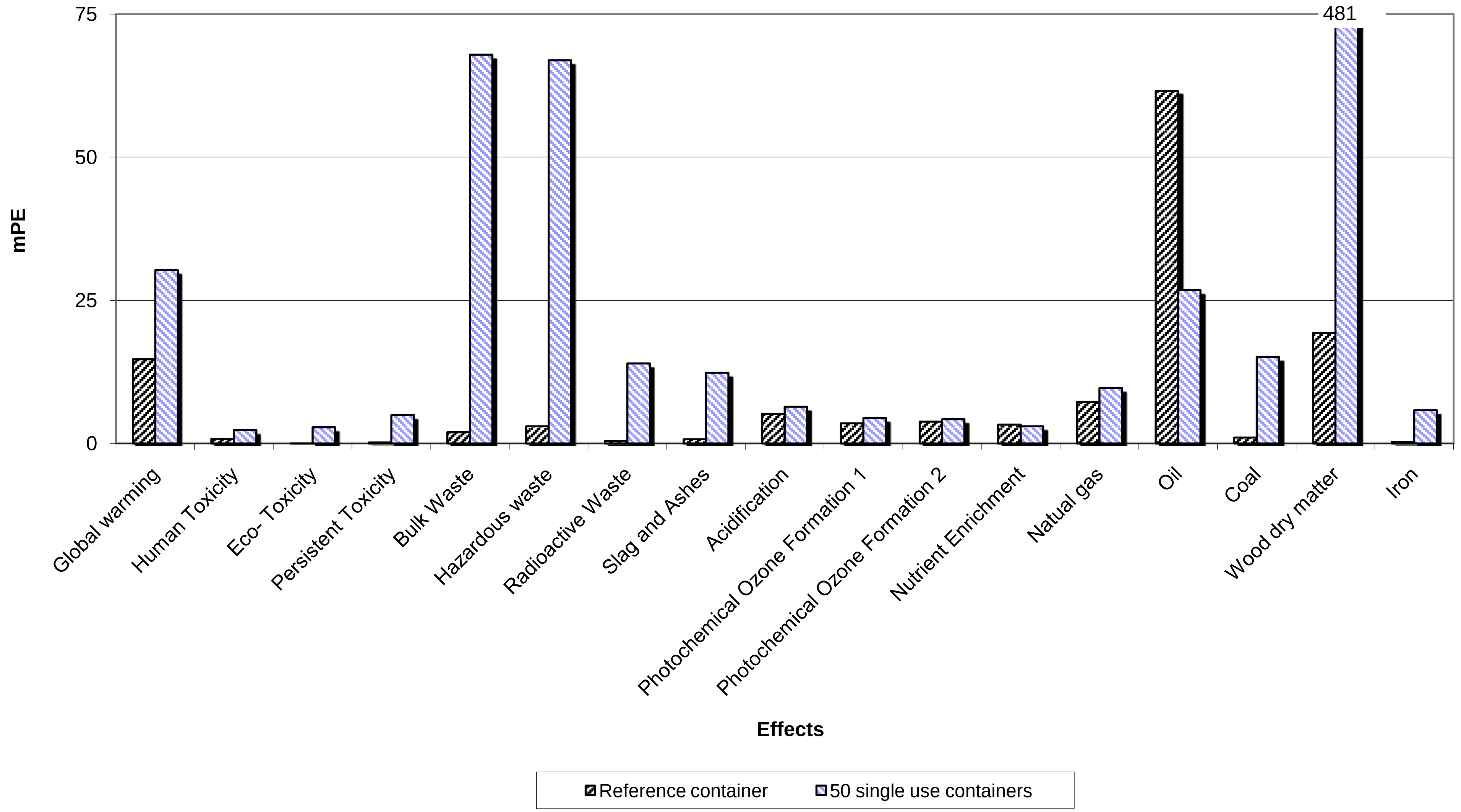
Resource Consumption

The term resource used here refers to primary raw materials, which in the life cycle means energy, construction materials, and additives**.** Materials can be both renewable and non-renewable resources. Renewable resources are those that can be re-established and will not disappear due to human consumption. Wood is an example of a renewable resource. Non renewable resources are those which can not be re-established. Oil is an example of a non-renewable resource. The use of resources is not directly connected with environmental effects but the material selection is an important part in product design and will have an influence on the environmental evaluation of a product’s life cycle.

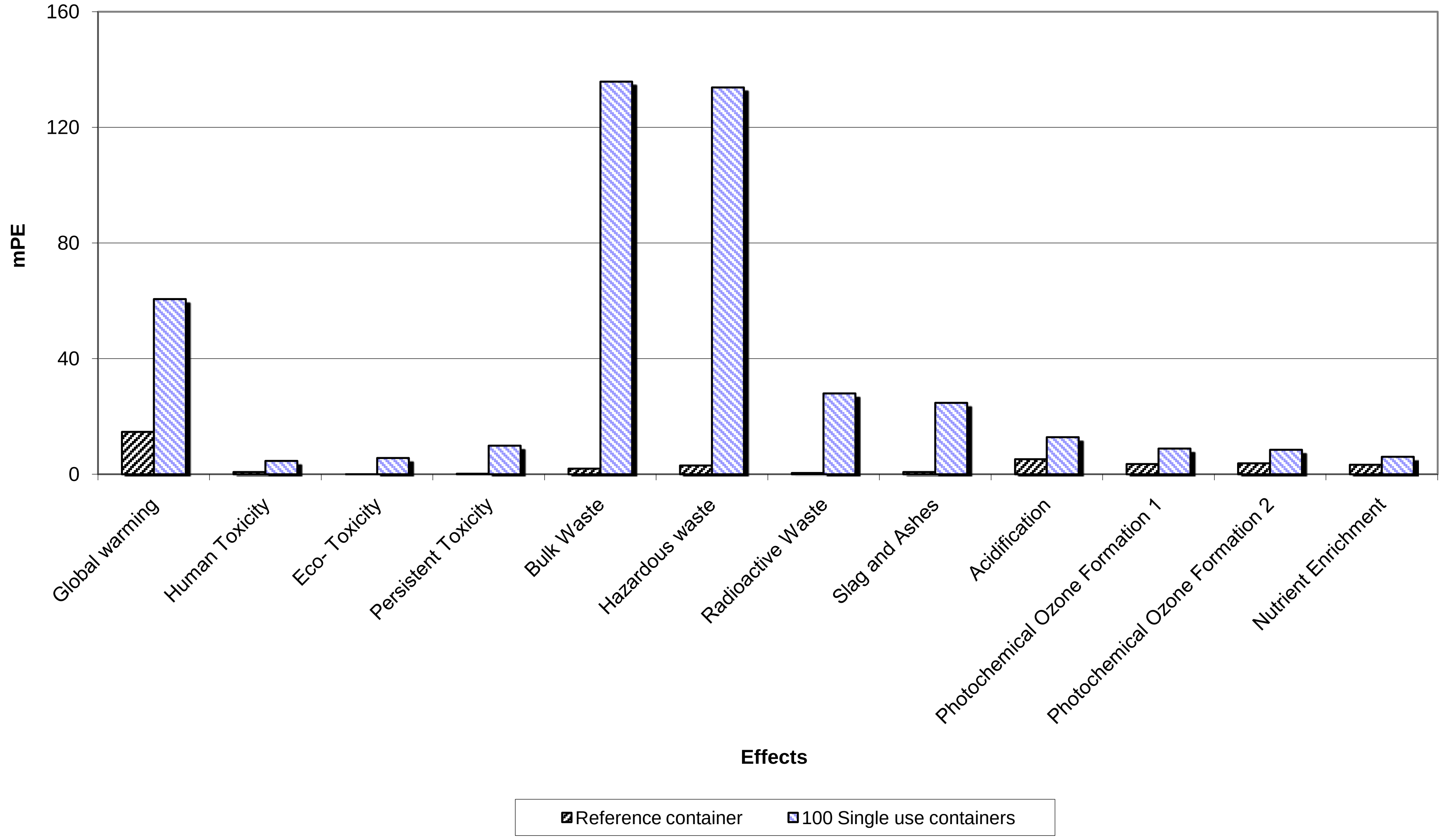
Enclosure 1
Reference container



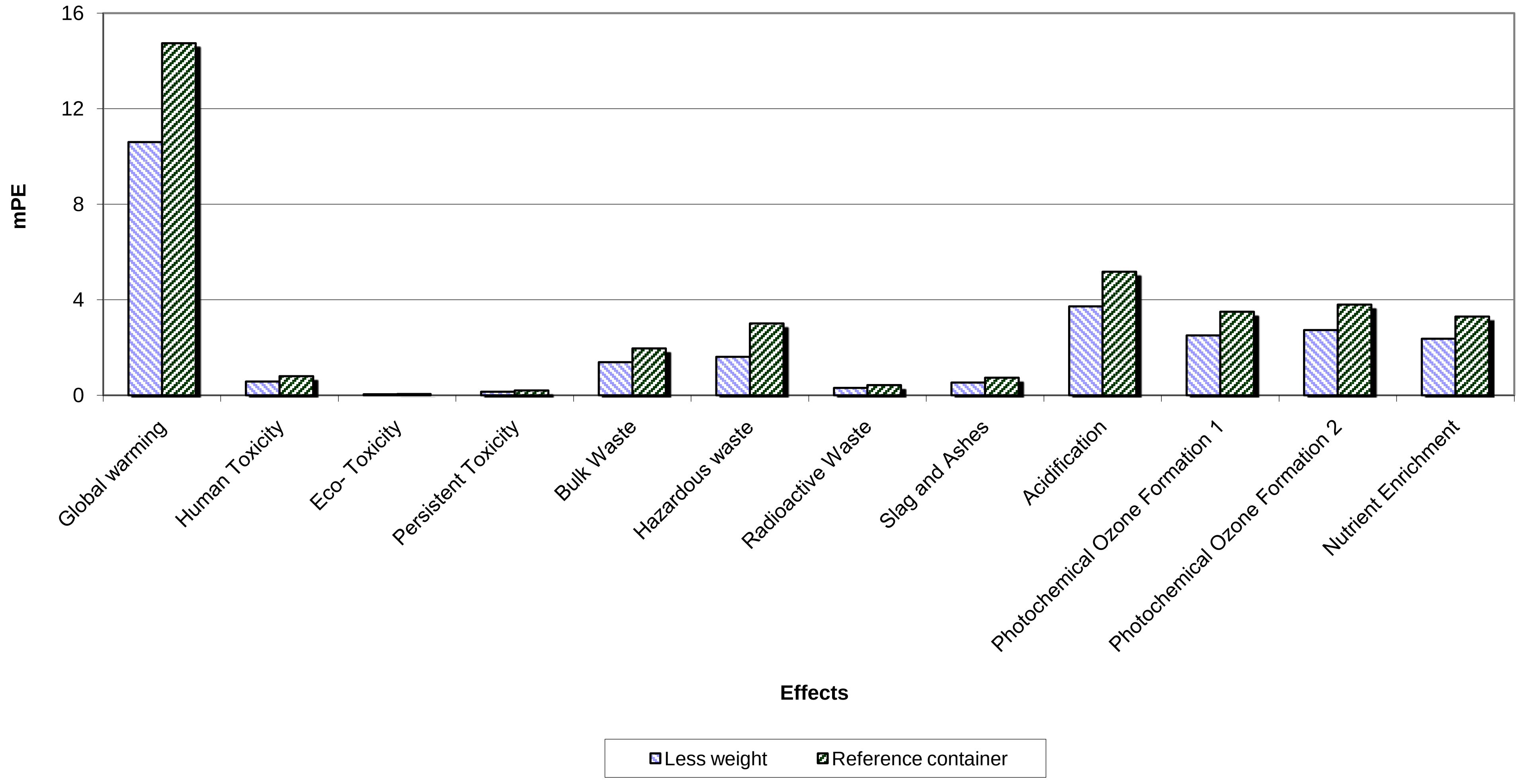
Enclosure 2
Reference container vs. single use containers
Empty return



Enclosure 3
Reference container vs. single use containers
Full return

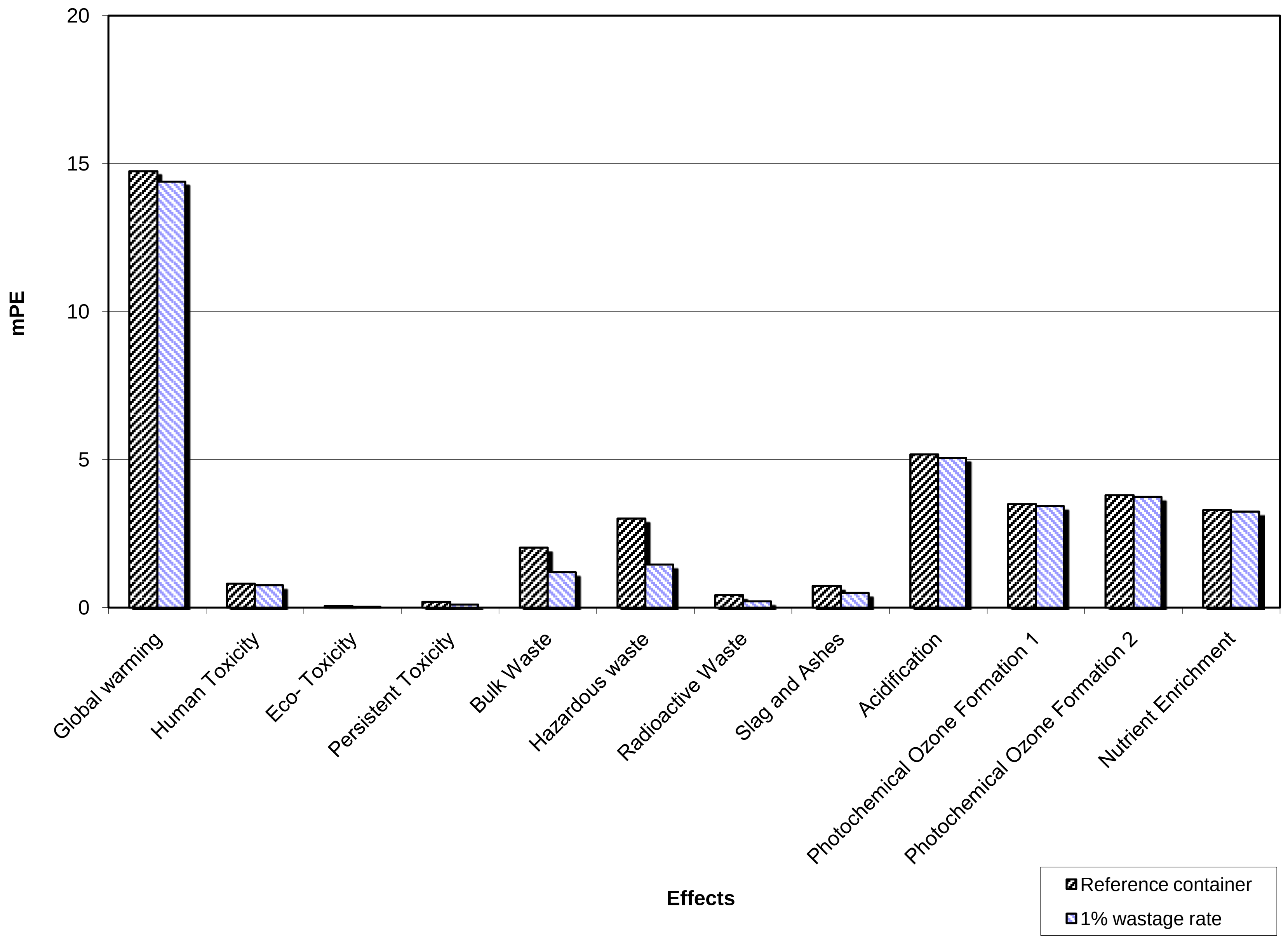


Enclosure 4
Reference container vs. less weight



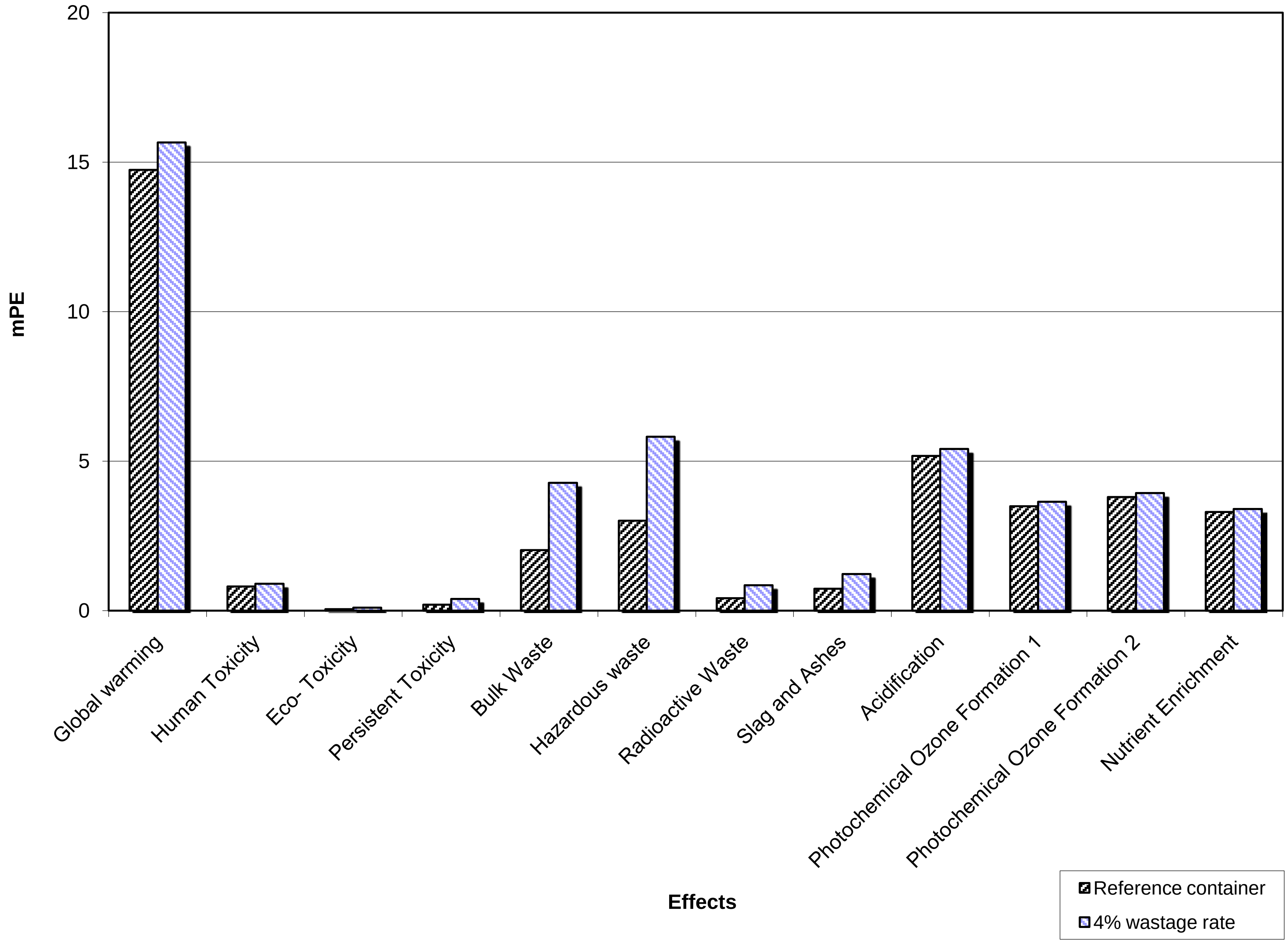
Enclosure 5

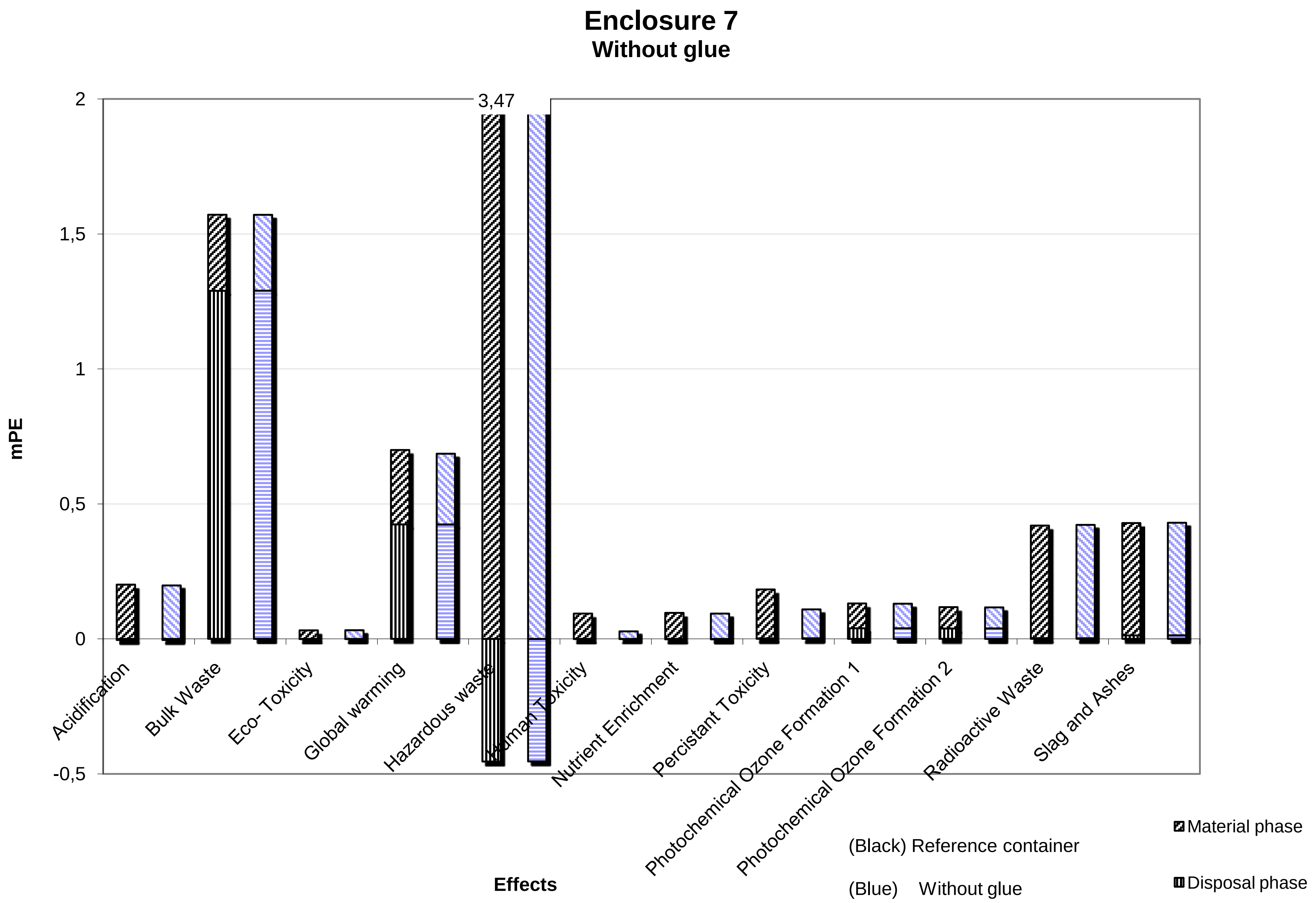
Reference container vs. 1% wastage rate



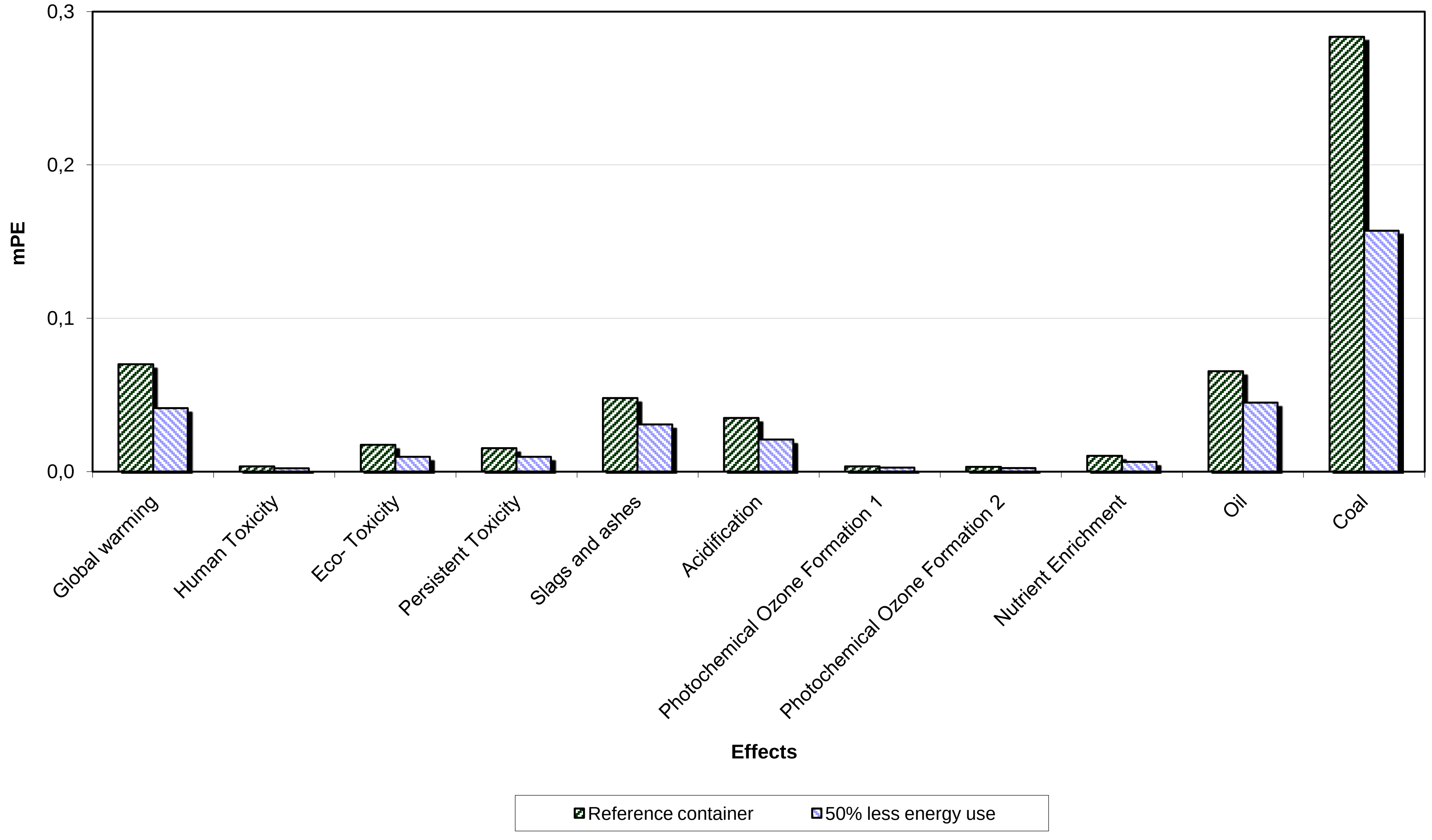
Enclosure 6

Reference container vs. 4% wastage rate



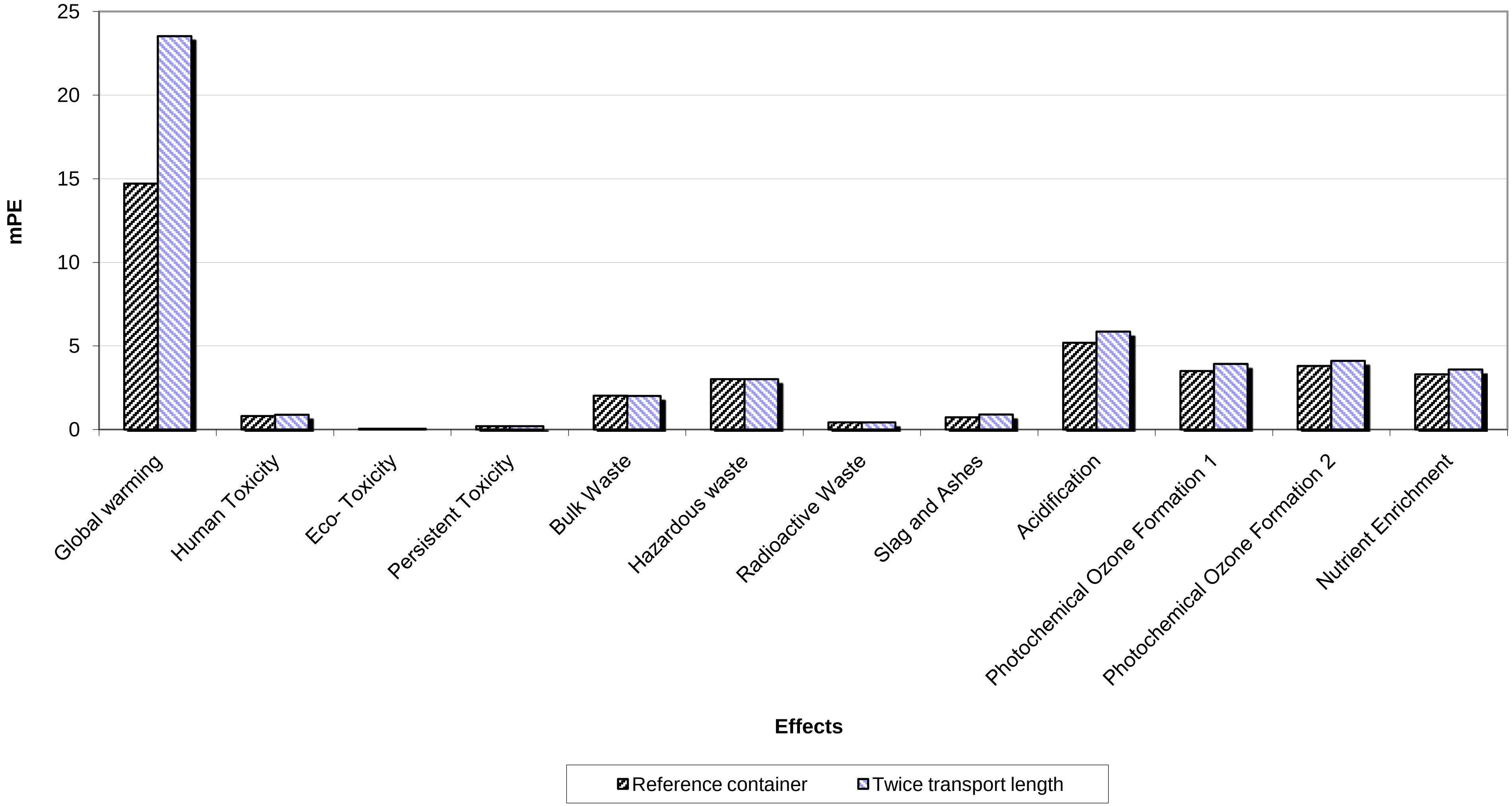

Enclosure 7
Without glue
mPE
2
1,5
1
0,5
0
-0,5
3,47
Acidification
Bulk Waste
Eco- Toxicity
Global warming
Hazardous waste
Human Toxicity
Nutrient Enrichment
Percistant Toxicity
Photochemical Ozone Formation 1
Photochemical Ozone Formation 2
Radioactive Waste
Slag and Ashes
Effects
(Black) Reference container
(Blue) Without glue
Material phase
Disposal phase

Enclosure 8
Production phase
Reference container vs. less energy use

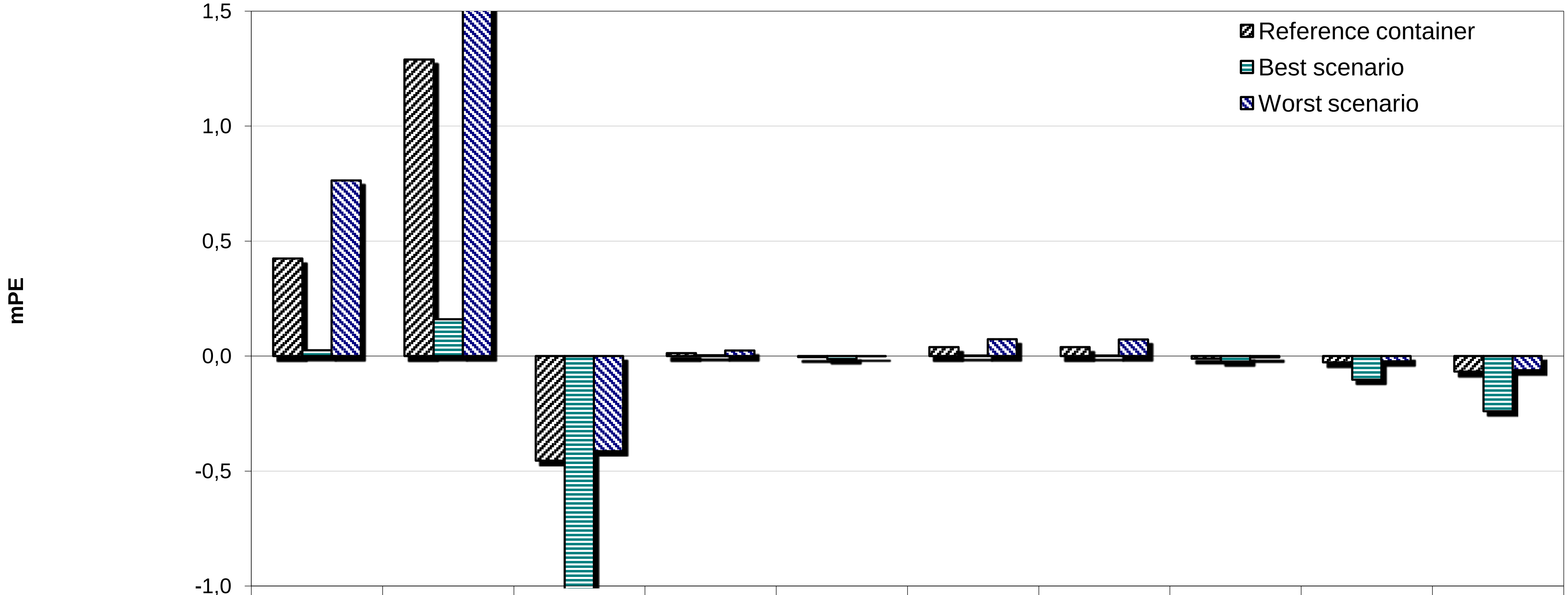


Enclosure 10

Reference container vs. twice Transport length



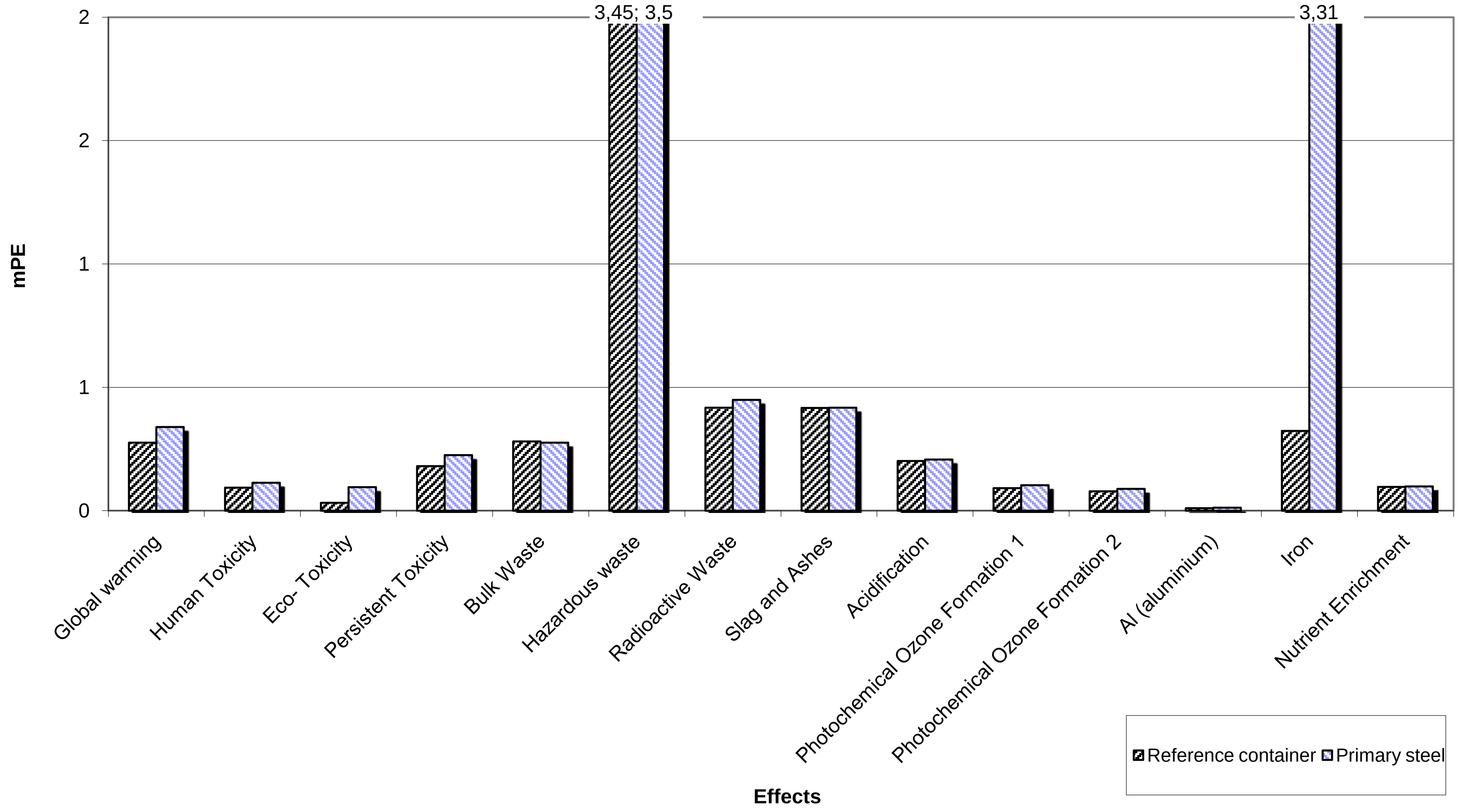
Enclosure 9
Disposal phase



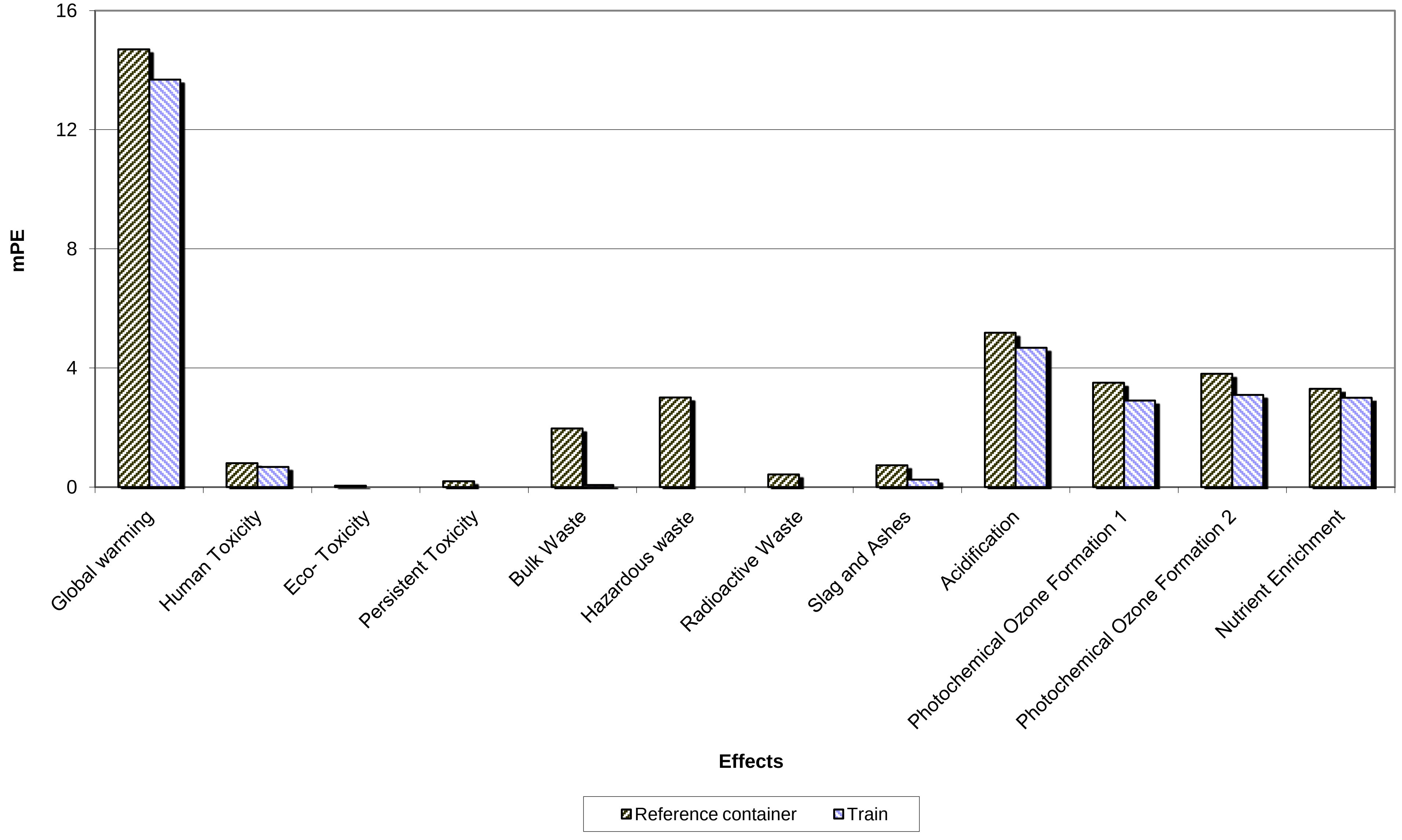
	Global warming	Bulk Waste	Hazardous waste	Slag and Ashes	Acidification	Photochemical Ozone Formation 1	Photochemical Ozone Formation 2	Oil	Coal	Iron
Reference container	0,424	1,290	-0,454	0,013	-0,004	0,039	0,039	-0,011	-0,027	-0,067
Best scenario	0,026	0,160	-1,610	0,004	-0,014	0,002	0,002	-0,023	-0,103	-0,240
Worst scenario	0,764	2,290	-0,413	0,024	0,000	0,073	0,072	-0,006	-0,022	-0,061

Effects

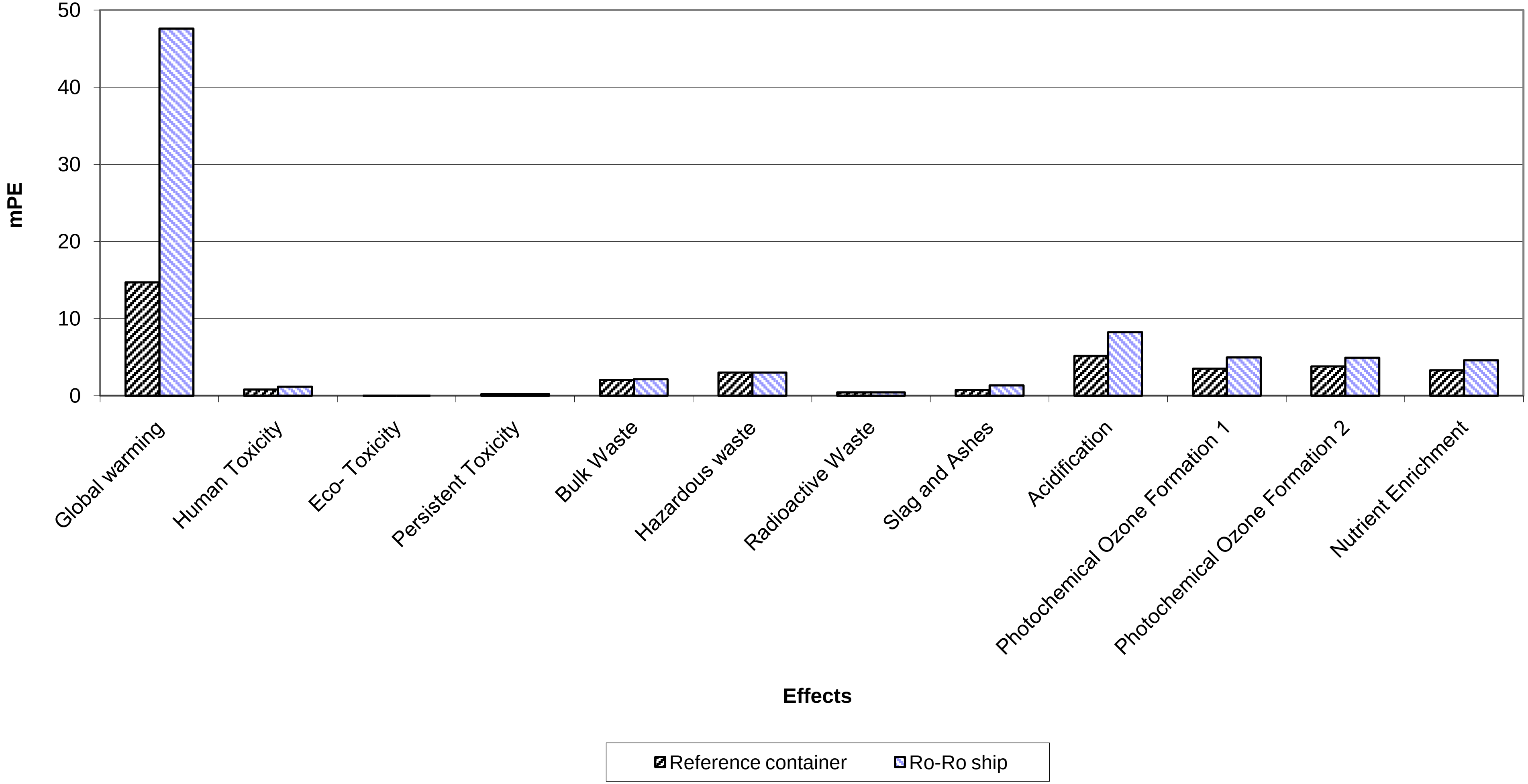
Enclosure 11
Material phase
Reference comtainer vs. 89% primary steel



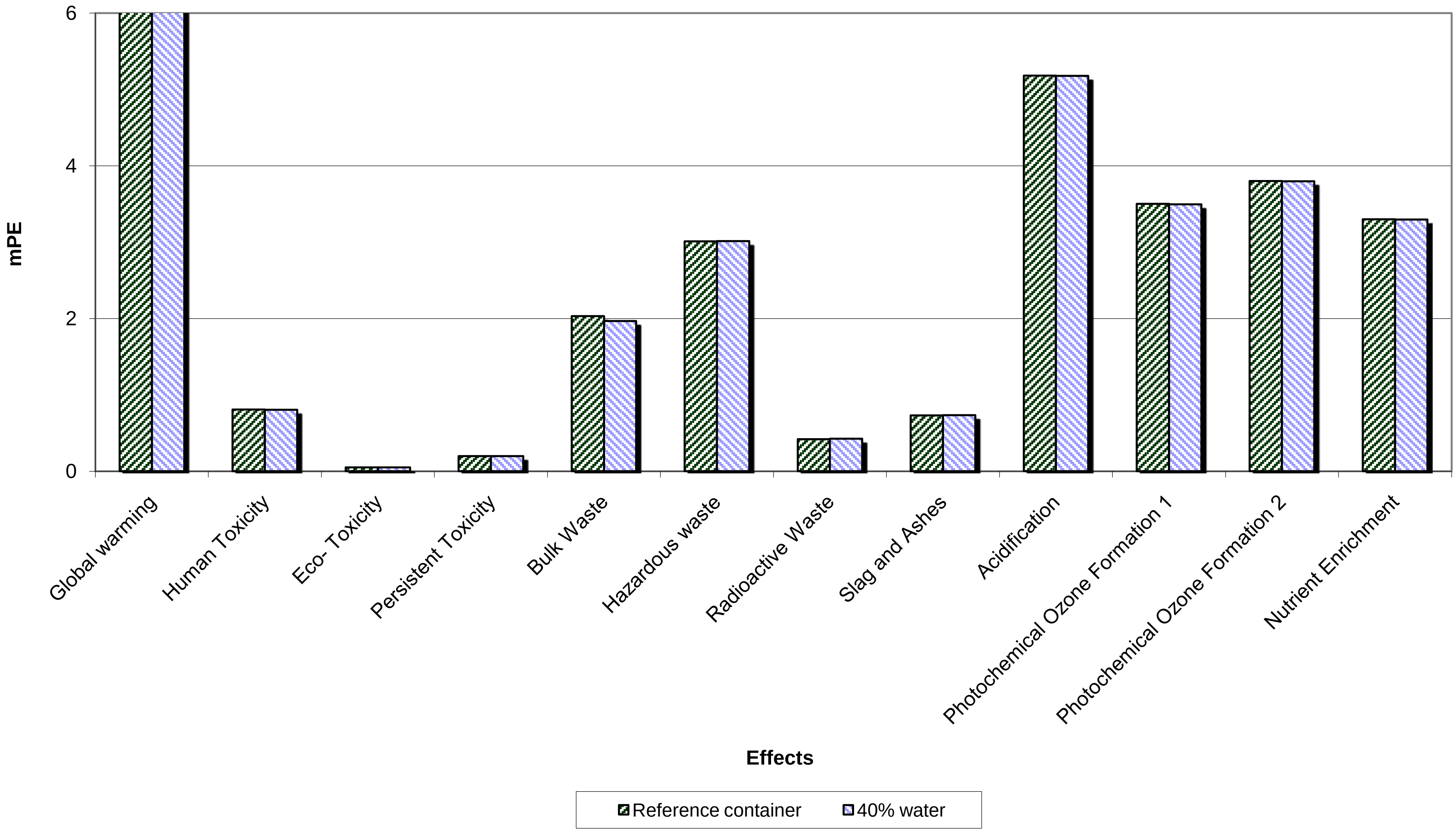
Enclosure 12
Reference container vs. train transport



Enclosure 13
Sensitivity simulation
Transportation with smaller ship

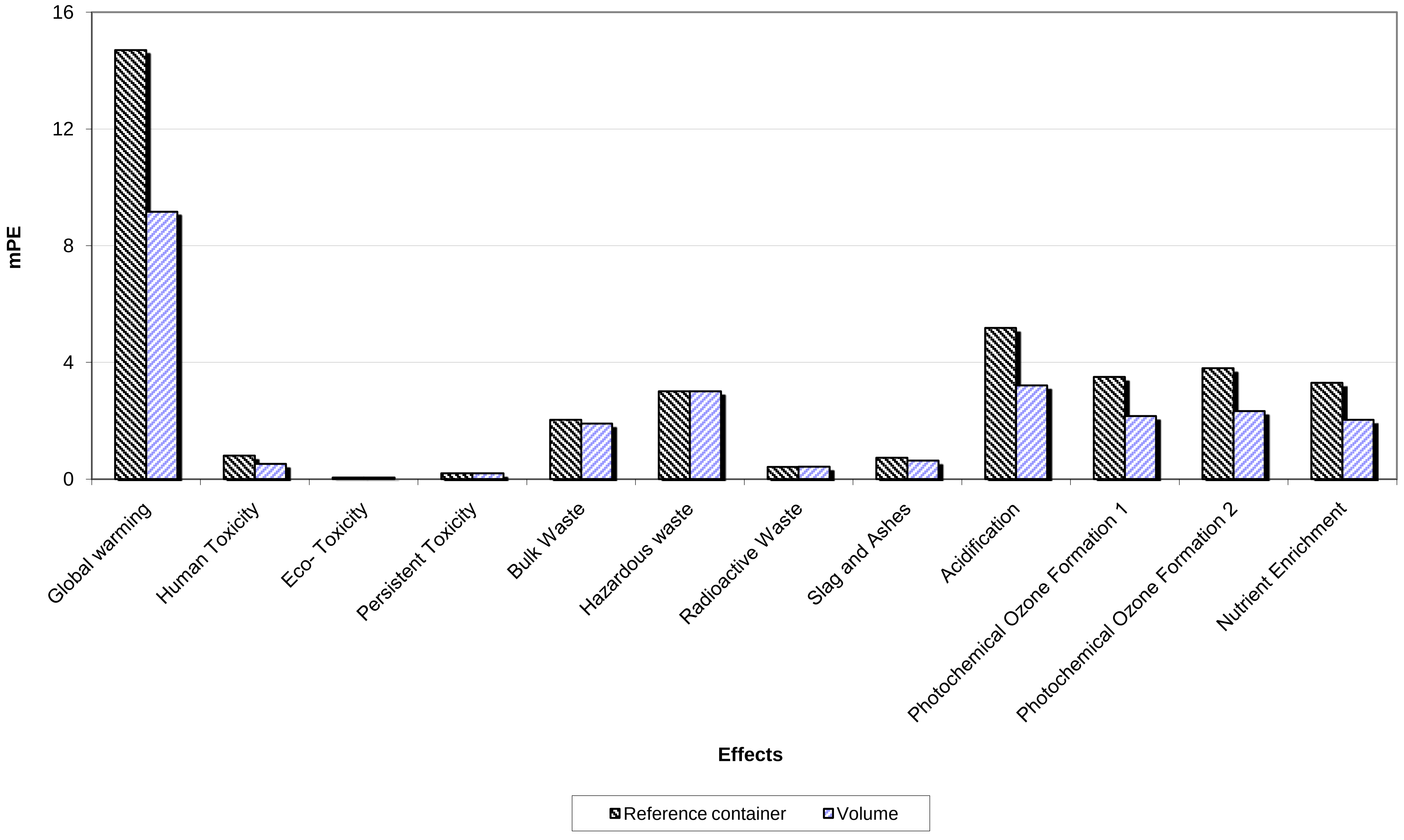


Enclosure 14
Sensitivity simulation
Waterprecentages in plywood



Enclosure 15

Sensitivity simulation
Transportation calculated using volume instead of weight



Enclosure 16

Sensitivity simulation
With and without regional and local effects