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Sustainability Consulting

GAP ANALYSIS

for the Life Cycle Assessment of Container Packaging

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for

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GAP ANALYSIS for the Life Cycle Assessment of Container Packaging

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Executive Summary

According to the EU-Commission „LCAs provide the best framework for assessing the potential environmental impacts of products currently available.“ FEVE completed a comprehensive LCA study on packaging glass in Europe which was externally reviewed to comply with ISO 14040/44. However, there are still methodological limitations and certain environmental impacts which are not covered by LCA yet. Because stakeholders and policy makers use LCA results more and more for their decision making, they have to be aware of the inherent limitations of LCA – especially if they use LCA to compare different packaging materials. While FEVE generally supports LCA, it is acknowledged that LCA does not provide the “full environmental truth” and has its limitations. FEVE identified a need to inform stakeholders on relevant aspects for interpreting and understanding LCA results in a proper and robust manner – reflecting its shortcomings and gaps. This report presents the findings of a comprehensive gap analysis of LCA. Next to an overview of the limitations addressed in the relevant ISO standards itself, 7 inherent methodological limitations, 22 gaps in impact assessment and 7 practical limitations were identified.

Overview methodological gaps and limitations of LCA	
Inherent methodological gaps and limitations	
• Definition of system boundaries/ cut-off	• Relative approach
• Definition of functional unit	• Allocation of multi-functional processes
• Value choices	• Allocation of recycling or reuse processes
• Epistemological limitations	
Gaps and limitations of impact assessment	
• Water consumption	• Direct/indirect land use
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• Biogenic resource depletion	• Noise
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Decision-makers in both private and public organisations need to appreciate the benefits of LCA. However, for a robust, sustainable and credible use of LCA the over-interpretation of LCA results without proper consideration of its gaps and limitations should be avoided.

1. Introduction

1.1. Background

LCA is currently the most accepted tool to assess the environmental performance of products in Europe, around the globe and by all stakeholders, i.e. government, companies, NGOs, academia, etc. The underlying standards ISO 14040/44[1] are by far the most broadly accepted standards in the field and can be regarded as the „mother“ of almost all other standardization activities, such as ILCD-Handbook[2], UNEP Life Cycle Initiative[3], ISO 14067[4], GHG Protocoll[5], PAS 2050[6], etc. They all take ISO 14040/44 as basis and specify some general requirements – even though some do not go much beyond the original.

FEVE completed a comprehensive LCA study on packaging glass in Europe which was externally reviewed to comply with ISO 14040/44. However, there are still methodological limitations and certain environmental impacts which are not covered by LCA yet. Because stakeholders and policy makers use LCA results more and more for their decision making, they have to be aware of the inherent limitations of LCA – especially if they use LCA to compare different packaging materials. While FEVE generally supports LCA, it is acknowledged that LCA does not provide the "full environmental truth" and has its limitations. Therefore, FEVE identified a need to inform stakeholders on relevant aspects for interpreting

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[1] ISO 14040, Environmental management - Life cycle assessment - Principles and framework (ISO 14040:2006), International Organisation for Standardisation. 2006: Geneva, Switzerland.

ISO 14044, Environmental management - Life cycle assessment - Requirements and guidelines (ISO 14044:2006), International Organisation for Standardisation, 2006: Geneva, Switzerland.

[2] European Commission, International Reference Life Cycle Data System (ILCD) Handbook - General guide for Life Cycle Assessment - Detailed guidance. EUR 24709 EN, Joint Researc Centre - Institute for Environment and Sustainability. 2010, Luxembourg: Publication Office of the European Union.

[3] UNEP-SETAC Life Cycle Initiative, http://lcinitiative.unep.fr/ (04. October 2012)

[4] ISO/DIS 14067, Carbon footprint of products -- Requirements and guidelines for quantification and communication, International Organisation for Standardisation, 2012: Geneva, Switzerland.

[5] Greenhouse Gas Protocol, Product Life Cycle Accounting and Reporting Standard, World Businesscoucil on Sustainable Development and World Ressource Institute

[6] British Standards Institution et al. PAS 2050:2008:Specification for the assessment of life cycle greenhouse gas emissions of goods and services.

and understanding LCA results in a proper and robust manner – reflecting its shortcomings and gaps.

1.2. Project description

The target of the project is to perform a gap analysis to identify methodological and practical gaps in LCA, in general and with a particular focus on container packaging. The study is performed as desk research addressing the gaps on a high level, providing a qualitative estimation of the influence for the comparison of packaging materials, including an assessment of the potential solutions and providing an estimate of the efforts needed to overcome the limitations.

2. Gaps according to international standards ISO 14040/44

ISO 14040/44 acknowledge clearly, that any LCA study has its limitations. Therefore, the limitations of every study have to be documented in the Goal & Scope Definition (ISO 14040, 5.2.1.2). Moreover, there is a specific chapter on limitations of the Life Cycle Impact Assessment (LCIA), i.e. ISO 14040, 5.4.3 Limitations of LCIA:

"The LCIA addresses only the environmental issues that are specified in the goal and scope. Therefore, LCIA is not a complete assessment of all environmental issues of the product system under study.

LCIA cannot always demonstrate significant differences between impact categories and the related indicator results of alternative product systems. This may be due to

- *limited development of the characterization models, sensitivity analysis and uncertainty analysis for the LCIA phase,*
- *limitations of the LCI phase, such as setting the system boundary, that do not encompass all possible unit processes for a product system or do not include all inputs and outputs of every unit process, since there are cut-offs and data gaps,*
- *limitations of the LCI phase, such as inadequate LCI data quality which may, for instance, be caused by uncertainties or differences in allocation and aggregation procedures, and*
- *limitations in the collection of inventory data appropriate and representative for each impact category.*

The lack of spatial and temporal dimensions in the LCI results introduces uncertainty in the LCIA results. The uncertainty varies with the spatial and temporal characteristics of each impact category.

There are no generally accepted methodologies for consistently and accurately associating inventory data with specific potential environmental impacts. Models for impact categories are in different stages of development."

Furthermore, ISO 14044, 4.4.5 adds to that:

"An LCIA shall not provide the sole basis of comparative assertion intended to be disclosed to the public of overall environmental superiority or equivalence, as additional information will be necessary to overcome some of the inherent limitations in the LCIA.

Value-choices, exclusion of spatial and temporal, threshold and dose-response information, relative approach, and the variation in precision among impact categories are examples of such limitations. LCIA results do not predict impacts on category endpoints, exceeding thresholds, safety margins or risks."

ISO 14044, 4.1 addresses weighting:

"It should be recognized that there is no scientific basis for reducing LCA results to a single overall score or number."

All the limitations have to be addressed by making them transparent in the Reporting (ISO 14040, 6.), when the conclusions are drawn:

"Report the results and conclusions of the LCA in an adequate form to the intended audience, addressing the data, methods and assumptions applied in the study, and the limitations thereof."

In summary, the international standards of LCA are very explicit with regard to the limitations of the method. They explain the potential benefits and uses of LCA, but at the same time they are also particularly cautious on the need to draw robust conclusions that consider explicitly the limitations of each study.

3. Inherent methodological limitations and gaps

The following inherent methodological limitations and gaps were identified and are specified in the following:

- Definition of system boundaries and cut-off criteria
- Relative approach
- Definition of functional unit
- Allocation of multi-input or multi-output processes
- Allocation of recycling or reuse processes
- Value choices
- Epistemological limitations

3.1. Gap: Definition of system boundaries and cut-off criteria

Description:

The system boundary determines which unit processes shall be included within the LCA. Due to the life cycle and systems approach, a “complete” LCA would basically lead to a system boundary that contains the whole world. To make the LCA manageable, cut-off-criteria are applied. In addition, infrastructure and capital goods are often excluded as well.

Consequences:

LCAs suffer from a “truncation error”, which can be significant (Lenzen 2001, Frischknecht 2007). Several cut-off criteria are used in LCA practice to decide which inputs are to be included in the assessment, such as mass, energy and environmental significance. Making the initial identification of inputs based on mass contribution alone may result in important inputs being omitted from the study. The use of different cut-off criteria leads to different results. Inconsistent cut-off criteria distort comparisons.

Examples:

Truncation errors according to IOA data can reach 50% or more. The share of capital goods in the total environmental burdens can reach close to 100% for particular impact categories (e.g. mineral resources) and for particular products (e.g. wind or water power)

Key references, describing the gap:

Lenzen, M. 2001. Errors in Conventional and Input-Output-based Life-Cycle Inventories. Journal of Industrial Ecology. Vol. 4. No 4

Frischknecht R, Althaus H-J, Bauer C, Doka G, Heck T, Jungbluth N, Kellenberger D, Nemecek T (2007): The Environmental Relevance of Capital Goods in Life Cycle Assessments of Products and Services. Int J LCA, DOI: http://dx.doi.org/10.1065/lca2007.02.308

Relevance for comparing container packaging:

The definition of system boundaries can have a significant effect. Based on the information available, all packaging systems are affected and no particular advantage or disadvantage of any system can be determined.

Solution approach:

There is no generic, methodological solution. The particular truncation error risk for packaging systems could be estimated based on IO-data (1). Capital goods and infrastructure could be included in the LCA data (2).

Efforts needed:

(1): low (<50 k€), (2): medium (50-200 k€)

Key references, describing solution approaches:

-

3.2. Gap: Relative approach

Description:

LCA follows a relative approach, which is structured around a functional unit. This functional unit defines what is being studied. All subsequent analyses are then relative to that functional unit, as all inputs and outputs in the LCI and consequently the LCIA profile are related to the functional unit.

Consequences:

Due to the relative approach LCAs can only determine potential environmental impacts and no real environmental impacts, because the information about time and space is lost. In addition, the functional unit is typically determined on the microeconomic level (e.g. one piece, 1 kg or 1l, 1 MJ), but the real impact on the macroeconomic or societal level is determined by the total volume or population of a particular product.

Examples:

An LCI result of 1 kg of NOx per functional unit does not indicate whether they were released at once or over hundreds of years in the past and future (e.g. mining activity for recycled steel a long time ago or future emissions from a landfill). This result also does not indicate whether the emissions were released in one place or in thousands of places all over the word.

For the relevance of micro- and macro-level, the Lithium for electric cars can be used as example: for a small number of products, the current Lithium sources from lakes with a relatively low burden are sufficient; if there are higher volumes of electric cars, Lithium has to be produced from minerals with a higher burden.

Key references, describing the gap:

-

Relevance for comparing container packaging:

Based on the information available, all packaging systems are affected and no particular advantage or disadvantage of any system can be determined.

Solution approach:

There is no generic, methodological solution, because the relative approach is a key feature of LCA. There are concepts for macroeconomic scale-up of LCA results based on hybrid approaches with MFA- or IO-IO-data (1). Also, certain applications of consequential LCA could serve as solution as well (2).

Efforts needed:

(1): high (>200 k€), (2): medium (50 – 200 k€)

Key references, describing solution approaches:

L. Schneider, K. Reimann, M. Finkbeiner: A Comprehensive Approach Towards MFA and LCA, 5th International Conference on Industrial Ecology, 21.6 - 24.6.2009 Lisbon, Portugal

T. Ekvall, B. Weidema: System Boundaries and Input Data in Consequential Life Cycle Inventory Analysis, Int J LCA 9 (3) 161 – 171 (2004)

3.3. Gap: Definition of functional unit

Description:

The functional unit serves as the key reference for comparisons. Comparisons between systems shall be made on the basis of the same function(s), quantified by the same functional unit(s) in the form of their reference flows. However, many products and materials are multi-functional and usually only the primary function(s) are used for comparison.

Consequences:

Comparisons based on LCAs may suffer from neglecting secondary or qualitative functions of products and materials.

Examples:

In a comparison of car and train by the functional unit “transporting a person from A to B” additional functions of the car, such as flexibility of time, no extra walk from station etc., as well as additional functions of the train, like no need to drive, i.e. option to read or work etc., are neglected.

Key references, describing the gap:

-

Relevance for comparing container packaging:

The definition of functional unit can have a significant effect. Based on product performance like e.g. shelf life, hygienic quality and premium value perception. The exclusion of secondary functions could be a disadvantage for packaging glass.

Solution approach:

There is no generic, methodological solution. For particular case studies, the functions to compare the products should be as inclusive as possible and secondary functions could be considered (1).

Efforts needed:

(1): case specific, but low (<50 k€) to medium (50-200 k€)

Key references, describing solution approaches:

-

3.4. Gap: Allocation of multi-input or multi-output processes

Description

Few industrial processes yield a single output or are based on a linearity of raw material inputs and outputs. In fact, most industrial processes yield more than one product and waste treatment processes typically treat the waste of many different product systems.

Consequences:

For LCAs of one particular product, the burdens of such processes have to be partitioned or the system has to be expanded. Several allocation procedures are used in LCA practice, such as mass, energy and economic parameters. The use of different allocation factors leads to different results. Inconsistent allocation criteria distort comparisons.

Key references, describing the gap:

T. Ekvall, G. Finnveden: Allocation in ISO 14041—a critical review, Journal of Cleaner Production 9 (2001) 197–208

Relevance for comparing container packaging:

The allocation procedures can have a significant effect. Based on the information available, all packaging systems are affected and no particular advantage or disadvantage of any system can be determined unless inconsistent or biased allocation procedures are applied.

Solution approach:

There is no generic, methodological solution. The proper choice of system expansion or allocation has to be done case by case. For comparing packaging systems different ways to deal with multifunctional processes could be analysed (1).

Efforts needed:

(1): low (<50 k€)

Key references, describing solution approaches:

-

3.5. Gap: Allocation of recycling or reuse processes

Description:

The LCA calculation rules for recycling need to address whether and how the environmental burden of the primary production of a material is shared between the first user and the subsequent users of that material.

Consequences:

Several allocation procedures are used in LCA practice, such as the recycled content approach (also known as the cutoff approach) based on the principle of the first responsibility or the end of life recycling approach (also known as the avoided burden approach) based on the principle of the last responsibility. The use of different allocation factors leads to different results. Inconsistent allocation criteria distort comparisons.

Key references, describing the gap:

J. Vogtländer, H. Brezet, C.Hendriks: Allocation in recycling systems, The International Journal of Life Cycle Assessment, 2001, 6 (6), 344-355

Relevance for comparing container packaging:

The allocation procedures for recycling can have a significant effect. They are particularly tricky for biogenic products (which are part of some container packaging). Glass packaging has very good recycling properties, so an avoided burden approach is a proper choice. If the avoided burden approach is used for other container packaging systems like PETs or beverage cartons, it is a best case assumption for them. If the number of life cycles is known for returnable PET and glass bottles, it is reasonable to share the burden of the primary production equally among the life cycles.

Solution approach:

There is no generic, methodological solution. The proper choice of system expansion or allocation has to be done case by case. For comparing packaging systems different ways to deal with recycling processes including multi-recycling-approaches could be analysed (1).

Efforts needed:

(1): low (<50 k€) to medium (50-200 k€)

Key references, describing solution approaches:

M. Finkbeiner, S. Neugebauer, M. Berger (2012): Carbon footprint of recycled biogenic products: the challenge of modeling CO2 removal credits, International Journal of Sustainable Engineering, DOI:10.1080/19397038.2012.663414

3.6. Gap: Value choices

Description:

While LCA has the principle to prioritize a scientific approach, there are still always several types of value choices: from the reasons to carrying out an LCA at all, via goal, system borders in LCI, elementary flows to investigate in LCI, allocation principle in LCI, safeguards subjects, impact categories and category indicators, characterisation methods, normalisation methods, grouping methods to weighting methods.

Consequences:

LCAs do not lead to “purely” scientific results, because the result of a particular LCA study is also influenced by the value choices made.

Key references, describing the gap:

B. Steen: Describing Values in Relation to Choices in LCA, International Journal of Life Cycle assessment, 11 (4) 277 – 283 (2006)

Relevance for comparing container packaging:

The value choices can have a significant effect. Based on the information available, all packaging systems are affected and no particular advantage or disadvantage of any system can be determined unless value choices are made in a biased way.

Solution approach:

There is no generic, methodological solution. The effect of different value choices could be assessed (1).

Efforts needed:

(1): medium (50-200 k€)

Key references, describing solution approaches:

-

3.7. Gap: Epistemological limitations

Description:

It is empirically impossible to study the environmental impacts of a single product throughout its life cycle. Since impacts that are observed in the world cannot be connected to products by an experimental method, one must rely on models that are only valid within a certain context.

Consequences:

From the theory of science it follows that statements based on LCA are impossible to prove. It is even very difficult to falsify them, but this is at least theoretically possible.

Key references, describing the gap:

G. Finnveden: On the Limitations of Life Cycle Assessment and Environmental Systems Analysis Tools in General, Int. J. LCA 5 (4) 229 - 238 (2000)

Relevance for comparing container packaging:

Based on the information available, all packaging systems are affected and no particular advantage or disadvantage of any system can be determined.

Solution approach:

There is no generic, methodological solution.

Key references, describing solution approaches:

-

4. Limitations and gaps in Life Cycle Impact Assessment

The following limitations and gaps in life cycle impact assessment were identified and are specified in the following:

- Water consumption
- Direct/indirect land use
- Desertification
- Erosion
- Salination
- Microbiological pollution
- Biological invasion
- Risks/accidents
- Littering
- Waste
- Physical killing of animals
- Biogenic resource depletion
- Noise
- Odor
- Indoor emissions
- Particulate matter
- Ionizing radiation
- Electric smog
- Uncertainties in human-/eco-toxicity characterization models
- Substances neglected in human-/ eco-toxicity categories (USEtox)
- Biodiversity
- General gaps in other impact categories

4.1. Gap: Water consumption

Description:

If at all, water consumption is considered on the inventory level [m³]. Impact assessment models are in development but hardly applied. Currently, inventory requirements (regional, temporal) are hard to satisfy.

Consequences:

Water consumption and associated impacts on human health, ecosystems and resources are not accounted for in most of today's LCAs.

Examples:

Neglecting impacts of water consumption causes incomplete environmental profiles of agricultural products, biofuels, renewable raw materials, or energy production.

Key references, describing the environmental problem / the gap in LCIA:

A. Köhler (2008), Water use in LCA: managing the planet's freshwater resources, Int J Life Cycle Assess, 13:451–455

Relevance for comparing container packaging:

Water consumption is especially relevant for water intense production, and energy production. Hence, paper production in beverage cartons can be relevant as well as energy intense aluminum can production. Water consumption in washing of reused glass bottles should be checked, too.

Solution approach:

Required regionalized water inventories can be created in a top-down approach developed by TU Berlin. Based on geographically differentiated inventory, many of recently developed impact assessment methods can be applied and compared (1).

Efforts needed:

(1) low (< 50 k€)

Key references, describing solution approaches:

M. Berger & M. Finkbeiner (2010): Water Footprinting: How to Address Water Use in Life Cycle Assessment? Sustainability, Vol. 2, 919-944

S. Pfister, A. Koehler, and S. Hellweg, Assessing the environmental impacts of freshwater consumption in LCA. Environ. Sci. Technol., 2009. 43(11): p. 4098-4104.

M. Berger, J. Warsen, S. Krinke, V. Bach, M. Finkbeiner (2012): Water footprint of European cars: potential impacts of water consumption along automobile life cycles. Environ. Sci. Technol., 46 (7), 4091–4099

4.2. Gap: Direct/indirect land use

Description:

If at all, direct occupation/transformation of land is considered on the inventory level [m^2a]. Impact assessment models are in development but hardly applied. Indirect land use effects are not considered at all.

Consequences:

Consumption of land resources, resulting GHG emissions, and effects on biodiversity are usually not considered,

Examples:

Similar to water consumption, land use effects are particularly relevant for agricultural products, renewable raw materials, and biofuels.

Key references, describing the environmental problem / the gap in LCIA:

U. Bos and B. Wittstock (2007). Land use methodology. Report to summarize the current situation of the methodology to quantify the environmental effects of Land Use. Report, Lehrstuhl für Bauphysics, University of Stuttgart.

Relevance for comparing container packaging:

Since land use effects are mainly relevant for renewable raw materials, such as wood, beverage cartons are expected to cause higher impacts in this category than other container packaging materials.

Solution approach:

At least direct land use should be considered on the inventory level [m²a]. GHG emissions from land use have to be determined and assessed. Recently developed impact assessment methods for land use can be tested. (1)

Efforts needed:

(1) Low (<50 k€) to medium (50 - 200 k€)

Key references, describing solution approaches:

Milà i Canals, L., et al. (2007), Key elements in a framework for land use impact assessment within LCA. Int J LCA 12:5-15

4.3. Gap: Desertification

Description:

Desertification is usually not directly considered in LCA, only indirectly via land and water use. A recently developed characterization method is available – but has hardly been applied in praxis.

Consequences:

Impacts of desertification on human health, ecosystems, and resources are usually not considered in LCA.

Examples:

Desertification is a field of concern for cotton production and products leading to deforestation.

Key references, describing the environmental problem / the gap in LCIA:

FAO (2012), http://www.fao.org/desertification/default.asp?lang=en

Relevance for comparing container packaging:

Unless, wood production for beverage carton would lead to deforestation in extreme cases, this impact category seems to be not relevant for packaging materials.

Solution approach:

Data collection and application of recent impact assessment method (1)

Efforts needed:

(1) low (< 50 k€)

Key references, describing solution approaches:

M. Nunez, et al. (2010), Assessing potential desertification environmental impact in life cycle assessment, International Journal of Life Cycle Assessment, 15: 67–78.

4.4. Gap: Erosion

Description:

Erosion is usually not directly considered in LCA, only indirectly via land and water use.

Consequences;

Accounting and environmental impacts of loss of topsoil is neglected in current LCAs.

Examples:

Erosion of topsoil is a field of concern for cotton production and products leading to deforestation.

Key references, describing the environmental problem / the gap in LCIA:

UNEP (2012), http://www.unep.org/geo/gdoutlook/087.asp

Relevance for comparing container packaging:

Unless, wood production for beverage carton would lead to deforestation in extreme cases, this impact category seems to be not relevant for packaging materials.

Solution approach:

Data collection and application of recent impact assessment method. (1)

Efforts needed:

(1) low (< 50 k€).

Key references, describing solution approaches:

Muys, B., Garcia Quijano, J. (2002). A new method for Land Use Impact Assessment in LCA based on ecosystem exergy concept. Internal report. Laboratory for Forest, Nature and Landscape Research, KU. Leuven.

4.5. Gap: Salination

Description:

Similar to desertification and erosion, salination is usually not directly considered in LCA, only indirectly via land and water use.

Consequences:

Effects of salination, resulting from loss of water and deposition of ions (as a consequence of irrigation), are not considered in LCA.

Examples:

Salination can occur in strongly irrigated agriculture.

Key references, describing the environmental problem / the gap in LCIA:

Feitz, A., Lundie, S. (2002). Soil Salinisation: A Local Life Cycle Assessment Impact Category. International Journal of Life Cycle Assessment, 7 (4): 244-249.

Relevance for comparing container packaging:

Not relevant.

Solution approach:

First, existing impact assessment methods from Australia and South Africa need to be transferred to a global context. Then, data collection and application of developed impact assessment method can be accomplished. (1)

Efforts needed:

(1) medium (50 - 200 k€)

Key references, describing solution approaches:

Leske, T., Buckley, C. (2003). Towards the development of a salinity impact category for South African environmental life-cycle assessments: Part 1 - A new impact category. Water SA, 29, 3, 289-296.

Leske, T., Buckley, C. (2004a). Towards the development of a salinity impact category for South African life cycle assessments: Part 2 - A conceptual multimedia environmental fate and effect model. Water SA, 30, 2, 241-251.

Leske, T., Buckley, C. (2004b). Towards the development of a salinity impact category for South African life cycle assessments: Part 3 – Salinity potentials. Water SA, 30, 2, 253-265.

4.6. Gap: Microbiological pollution

Description:

Microbiological pollution comprises the pollution of mainly freshwater by pathogenic microorganisms, which may cause damages to human health and ecosystems. Infectious microorganisms can be grouped into bacteria, viruses, protozoa, and helminthes (NRMMC 2006) and cause mainly gastro-related diseases like diarrhea and vomiting (Larsen et al. 2009). However, despite data availability problems, there are currently neither elementary flows defined on the inventory level nor impact categories available on the impact assessment level.

Consequences:

Human health effects of microbiological pollution are neglected, which can be dominant in some cases.

Examples:

Microbiological pollution is relevant for product systems characterized by wet conditions, stagnant water, temperature changes, and availability of organic matter. Hence, microbiological pollution should be considered in LCAs of waste water treatment plants, hot air hand dryers in restrooms, water dispensers, use of manure for fertilization and biogas plants, etc.

Key references, describing the environmental problem / the gap in LCIA:

NRMMC (2006). Australian guideline for water recycling: Managing health and environmental risks (phase 1). Natural Resource Management Ministerial Council, Environment Protection and Heritage Council, Australian Health Ministers Conference. Chapter 3.

Larsen et al. (2009) NEPTUNE - New sustainable concepts and processes for optimization and upgrading municipal waster water and sludge treatment / Deliverable 4.2 Methodology for including specific biological effects and pathogen, Technical University of Denmark (DTU)

Relevance for comparing container packaging:

PET bottles are expected to have disadvantages due to surface properties, in which bacteria can develop.

Solution approach:

As a first step Larsen et al. (2009) propose a framework to assess health damages measured in DALY resulting from emission of pathogens into recreational water bodies and unintended swallowing of water during bathing. In order to address impact of microbiological pollution on human health, the various impact pathways need to be identified ranging from unintended swallowing of water during recreational activities, drinking of germ polluted water, ingestion of pathogens via food, etc. Second, adequate elementary flows need to be defined on the inventory level providing information on the number and kind of pathogens emitted. Finally, characterization models need to be developed which assess damages resulting from microbiological emissions. Such models should consider the fate of infectious microorganisms comprising distribution through environmental media and survival of pathogens. After that the uptake of microorganisms into the human body (via different uptake routes) should be modeled and health effects should be predicted by means of clinical dose-response relations. (1)

Efforts needed:

(1) medium (50 - 200 k€)

Key references, describing solution approaches:

Larsen et al. (2009) NEPTUNE - New sustainable concepts and processes for optimization and upgrading municipal waste water and sludge treatment / Deliverable 4.2 Methodology for including specific biological effects and pathogen, Technical University of Denmark (DTU)

4.7. Gap: Biological invasion

Description:

The invasion of foreign species into ecosystems can cause damages in local ecosystems if indigenous species are displaced by invaders. With regard to the environmental assessment of product systems, biological invasion is relevant for transports, especially for shipping. First, channels used by ships connect ecosystems and allow for a spreading of species. Second, ballast water, used to stabilize container ships during empty running, is a potential source for biological invasion as alien species, like jellyfish of mussels, can be transported over long distances where they are released into non-indigenous ecosystems. However, this effect is not taken into account in LCIA so far.

Consequences:

Effects of biological invasion of foreign species on local species in ecosystems are neglected (Biodiversity).

Examples:

Prominent examples are the Victoria Perch, a fish originating from the Nile which was brought into Lake Victoria and changed the entire ecosystem, or the Pacific Oyster which was brought into the North Sea and displaces the indigenous blue mussel.

Key references, describing the environmental problem / the gap in LCIA:

International Journal on Bioinvasion Management:

http://www.managementofbiologicalinvasions.net/

Relevance for comparing container packaging:

Container packaging alternatives are only affected via transport. Hence, biological invasion is equally (ir)relevant for all alternatives.

Solution approach:

In a LCA context, biological invasion is proposed as an indicator describing impacts on biodiversity, by means of e.g. “percent coverage of invasive species within protected areas” (Schenk 2001). However, no cause effect chains are modeled so far (Curran et al. 2011). Recently Narščius et al. (2012) published a method which allows for the assessment of biological invasion impacts and biopollution which might be transferred into a characterization model for LCIA (1). The model determines a biopollution level by relating a classified abundance and spreading range of alien species to the magnitude of their consequences on communities, habitats and ecosystem functioning. However, it should be noted that any impact assessment method for biological invasion requires regional inventory data as biological invasion in itself as well as potential impacts are strongly site-dependent.

Key references, describing potential solution approaches:

Rita Schenk: Land Use and Biodiversity Indicators for Life Cycle Impact Assessment, Int. J. LCA 6 (2) (2001) 114 – 117

Michael Curran, Laura de Baan, An M. De Schryver, Rosalie van Zelm, Stefanie Hellweg, Thomas Koellner, Guido Sonnemann, and Mark A. J. Huijbregts: Toward Meaningful End Points of Biodiversity in Life Cycle Assessment, *Environ. Sci. Technol.*, 2011, 45 (1), pp 70–79

Aleksas Narščius, Sergej Olenin, Anastasija Zaiko, Dan Minchin: Biological invasion impact assessment system: From idea to implementation, Ecological Informatics 7 (2012) 46–51

Efforts needed:

(1) medium (50 - 200 k€)

Key references, describing solution approaches: -

4.8. Gap: Risks/accidents

Description:

LCA accounts for the normal operation mode only. Hence, accidents are beyond the scope of LCA.

Consequences:

Impacts of accidents are neglected. LCA ignores different risk potentials of different alternatives.

Examples:

Nuclear power is only considered in the normal operation mode and therefore environmentally favorable in many impact categories. Emissions of machines are considered only in normal operation mode.

Key references, describing the environmental problem / the gap in LCIA:

K. Flemström, R. Carlson, M. Erixon (2004): Relationships between Life Cycle Assessment and Risk Assessment, Industrial Environmental Informatics (IMI), Chalmers University of Technology, Sweden

Relevance for comparing container packaging:

During the use phase, glass bottles will break when they fall down and there is a higher injury potential due to clippings than in other beverage containers. In contrast to PET bottles, cans, or beverage cartons, glass bottles can be misused as “weapon” leading to injuries and even death. For this reason they are forbidden at events like concerts or festivals. Besides risks in the foreground system mentioned above there are many risks in the background data (nuclear power, industrial processes).

Solution approach:

First, risks along the life cycles of beverage containers need to be identified. Second, probability of occurrence and scale of damage need to be quantified to determine the risk. (1)

Efforts needed:

(1) medium (50 - 200 k€)

Key references, describing solution approaches:

-

4.9. Gap: Littering

Description:

Littering describes the inappropriate disposal of products directly into the environment without any waste treatment. On the one hand littering occurs in countries with poorly developed waste collection and treatment systems. However, it is also observed in developed countries due to lack of environmental awareness. As LCA considers the intended way of disposal only, littering is neither addressed on the LCI nor on the LCIA level. Hence, LCA neglects the fact that some products are more likely to be littered than others and that consequences of littering might differ between products, too.

Consequences:

Since littering is not considered in LCA, resulting environmental consequences are neglected such as:

- Killing of animals when littered waste is ingested (plastics) (Wong et al. 1974)
- Cause of forest fires (glass)
- Leaching of chemicals (plastics)
- Esthetical disturbance of landscape

Examples:

Beverage packaging in landscape, PET bottles in oceans

Key references, describing the environmental problem / the gap in LCIA:

C.S. Wong, D.R. Green, W.J. Cretney (1974): Quantitative Tar and Plastic Waste Distributions in the Pacific Ocean, Nature 247, 30-32.

UNEP (2009): Marine Litter: A Global Challenge

Barnes et al. (2009): Accumulation and fragmentation of plastic debris in global environments, Phil. Trans. R. Soc. B 364, 1985–1998, doi:10.1098/rstb.2008.0205

BIO Intelligence Service (2011), Plastic Waste in the Environment, Final report prepared for the European Commission (DG Environment)

Relevance for comparing container packaging:

Beverage packaging with refund-systems are advantageous. On the one hand, glass is favorable as it is an inert material and no toxic emissions have to be feared when littered. On the other hand, glass littering can cause physical injuries via cullet or forest fires.

Solution approach:

In order to address this gap, littering could be assessed by determining the percentage of a product being disposed of irregularly. Additionally, the consequences of littering could be evaluated by means of existing or new impact categories (1):

- Killing of animals when eating waste -> Physical killing of animals
- Cause of forest fires (glass) -> land use, global warming
- Leaching of chemicals (plastics) -> Human- and eco-toxicity
- Esthetical disturbance of landscape -> Social LCA

Efforts needed:

(1) medium (50-200 k€)

Key references, describing solution approaches:

-

4.10. Gap: Waste

Description:

In theory waste treatment is within the system boundaries of a product system and associated environmental effects, e.g. emissions from waste incineration plants and landfills, are considered in other impact categories. In practice, especially in LCA databases, waste flows are often cut-off and not considered further.

Consequences:

Environmental effects of waste treatment or disposal are neglected, e.g. land use or methane emissions and leaching of chemicals from landfills.

Examples:

In electricity mix datasets radioactive wastes are cut-off, ignoring impacts of treating radioactive waste.

Key references, describing the environmental problem / the gap in LCIA:

Journal Waste Management & Research

http://wmr.sagepub.com/

Relevance for comparing container packaging:

Since this gap is caused by incomplete LCI data sets, it is expected to be equally important for all types of container packaging.

Solution approach:

Inclusion of cut-off waste flows into the system boundaries and assessment of environmental effects of waste treatment in other impact categories would be the preferred solution (system expansion) (1). If this is not feasible, waste can be considered on the inventory level [kg], classified in hazardous and non-hazardous waste. On impact assessment level, waste can be assessed via “land fill space” (2).

Efforts needed:

(1) medium (50 – 200 k€), (2) low (<50 k€)

Key references, describing solution approaches:

-

4.11. Gap: Physical killing of animals

Description:

As mentioned above, LCA considers the normal operation mode only. Thus, unintended mechanical or electrical killing of animals is not considered in LCA.

Consequences:

Deaths of individual animals and even extinction of animal populations in certain areas are neglected.

Examples:

Examples for physical killing of animals includes:

- Birds killed by wind mills or at transmission lines
- Animals killed in road traffic
- Fish killed in hydropower turbines
- Animals killed by swallowing (plastic) waste

Key references, describing the environmental problem / the gap in LCIA:

R.G. Powlesland (2009) Impacts of wind farms on birds: a review, Department of Conservation, Wellington, New Zealand

Relevance for comparing container packaging:

As physical killing of animals results mainly from energy production, energy intense aluminum can production might cause higher impacts. Also PET models might by disadvantageous in this category, as they can be swallowed by animal and fish when littered.

Solution approach:

Collection of statistical data concerning animal killing in relevant industries (1):

- Electricity production (wind- and hydropower on a national level)
- Electricity transport (transmission lines)
- Littering (waste eaten by animals/fish)

- Animals killed in transport

Efforts needed:

(1) Low (<50 k€)

Key references, describing solution approaches:

-

4.12. Gap: Biogenic resource depletion

Description:

The use of renewable raw materials is only assessed indirectly via land and water use, emission during production, etc. Consumption of biogenic resources itself is usually neglected or accounted for on the inventory level only.

Consequences:

Even though biogenic resources are renewable, it is neglected that renewable raw materials can also be depleted if production exceeds renewability rate on the macroeconomic level.

Examples:

Unsustainable use of wood.

Key references, describing the environmental problem / the gap in LCIA:

-

Relevance for comparing container packaging:

This so far neglected impact category can be relevant for paper production in beverage cartons, if paper is made from unsustainably produced wood.

Solution approach:

First, origin of paper used for beverage cartons needs to be identified and local harvest and regeneration rate need to be analysed. A potential depletion of renewable resources can assessed via availability horizon as described in reference below. (1)

Efforts needed:

(1) low (< 50 k€)

Key references, describing solution approaches:

Guinee, J.B., et al. (2002), Life cycle assessment - An operational guide to the ISO standards, in Eco-Efficiency in Industry and Science, Vol. 7, J.B. Guinee, Editor. Kluwer Academic Publishers: Dordrecht, The Netherlands.

4.13. Gap: Noise

Description:

Noise is usually not considered in LCA. Elementary flows on the inventory level and impact categories on the impact assessment level are still in development and focus on traffic only.

Consequences:

Impacts of noise pollution on human health and the environment are neglected in LCA.

Examples:

Noise is especially relevant for transport systems of for health and safety in working environments.

Key references, describing the environmental problem / the gap in LCIA:

Hans-Jörg Althaus & Peter de Haan & Roland W. Scholz, Traffic noise in LCA Part 1: state-of-science and requirement profile for consistent context-sensitive integration of traffic noise in LCA, International Journal of Life Cycle Assessment, 14, S. 560-570

John Reap & Felipe Roman & Scott Duncan & Bert Bras, A survey of unresolved problems in life cycle assessment Part 2: impact assessment and interpretation, International Journal of Life Cycle Assessment

EU (2011) Environmental Noise Directive http://ec.europa.eu/environment/noise/home.htm

Relevance for comparing container packaging:

Noise and resulting nuisance is mainly relevant in the upstream chain, where no information is available. However, glass collection containers can cause significant nuisance in residential areas.

Solution approach:

First, noise needs to be measured. Impact assessment methods developed for traffic need to be adjusted and applied. (1)

Efforts needed:

(1) medium (50 – 200 k€)

Key references, describing solution approaches:

Vicente Franco V, Garrain, Vidal R (2010) Methodological proposals for improved assessments of the impact of traffic noise upon human health. The International Journal of Life Cycle Assessment Volume 15, Number 8 869-882

Müller-Wenk, R. (2004). A Method to Include in LCA Road Traffic Noise and its Health Effects. International Journal of Life Cycle Assessment, 9 (2): 76-85.

Meijer, A., Huijbregts, M.A.J., Hertwich, E.G., Reijnders, L. (2006). Including Human Health Damages due to Road Traffic in Life Cycle Assessment of Dwellings. International Journal of Life Cycle Assessment, 11 (Special Issue 1): 64-71.

4.14. Gap: Odor

Description:

Apart from one framework, providing a potential solution approach, odor is not considered in LCA. There are neither elementary flows on the inventory level nor characterization models on the impact assessment level.

Consequences:

Impacts of odor on human wellbeing are neglected in LCA.

Examples:

Product systems in which odor plays a relevant role include, e.g.:

- Sewage treatment plants
- Biogas plants
- Animal farming

Key references, describing the environmental problem / the gap in LCIA:

Heijungs, R., et al., *Environmental life cycle assessment of products: guide and backgrounds* 1992, Institute of Environmental Sciences: Leiden.

Rebitzer, G., B. Weidema, and D.W. Pennington, *Life cycle assessment Part 1: Framework, goal and scope definition, inventory analysis and applications*
2003.

Guinée, J.B., et al., *Handbook on life cycle assessment. Operational guide to the ISO standards IIb: Operational annex*. 2001, Kluwer Academic Publishers: Dordrecht.

Relevance for comparing container packaging:

There is no detailed information available, but impacts resulting from odor are assumed to be low for all beverage containers.

Solution approach:

Elementary flows need to be developed, date needs to be collected, impact assessment methods need to be developed and applied. (1)

Efforts needed:

(1) high (> 200 k€)

Key references, describing solution approaches:

Marchand, M. and L. Aissani, *Odour and Life Cycle Assessment (LCA): a proposal of local assessment. Ecotech & Tools*, in *Environmental 6 Integrated assessment of complex systems Conference*. 2011, Cemagref: France.

4.15. Gap: Ionizing radiation

Description:

Few impact assessment models for ionizing radiation are available but hardly applied. Ionizing radiation is difficult to measure and there is hardly data in LCI databases.

Consequences:

Impacts of ionizing radiation on human health and ecosystems are neglected in current LCAs.

Examples:

Product systems in which ionizing radiation is relevant include e.g. nuclear waste (connected to risk/accidents) or radon emissions from clay used as a building material.

Key references, describing the environmental problem / the gap in LCIA:

WHO (2012) http://www.who.int/ionizing_radiation/about/what_is_ir/en/index.html

Relevance for comparing container packaging:

Ionizing radiation can occur only from nuclear energy production in the background system. Hence, it is assumed to be of low relevance for all types of container packaging.

Solution approach:

As nuclear waste is usually cut-off in LCI databases, waste treatment needs to be modeled and exposure of humans to ionizing radiation needs to be estimated in the normal operation mode (otherwise risk/accidents). Recently developed impact assessment methods can be applied. (1)

Efforts needed:

(1) medium (50-200 k€)

Key references, describing solution approaches:

Frischknecht, R., Braunschweig, A., Hofstetter P., Suter P. (2000), Modelling human health effects of radioactive releases in Life Cycle Impact Assessment. Environmental Impact Assessment Review, 20 (2) pp. 159-189.

Garnier-Laplace J. C., Beaugelin-Seiller K, Gilbin R, Della-Vedova C, Jolliet O, Payet J, (2009).A Screening Level Ecological Risk Assessment and ranking method for iquid radioactive and chemical mixtures released by nuclear facilities under normal operating conditions Radioprotection 44 (5) 903-908. DOI: 10.1051/radiopro/20095161

4.16. Gap: Electric smog

Description:

Electric smog is not considered in LCA. There are neither elementary flows on the inventory level nor impact categories on the impact assessment level.

Consequences:

Potential human health effects of electric smog are neglected in current LCA studies.

Examples:

Electric smog can be relevant for mobile phones, devices containing transmitters and receivers, transmission lines, etc.

Key references, describing the environmental problem / the gap in LCIA:

International Association for Elektrosmog-Research IGEF Ltd. (2012) http://www.elektrosmog.com/de/_br__img_src__http_www_elektrosmog_com_gb_gif_english_site/ (04 October 2012)

Relevance for comparing container packaging:

Electric smog is expected to be an irrelevant impact category for all types of container packaging.

Solution approach:

First, an inventory accounting scheme needs to be developed. After data collection, an impact assessment methods needs to be developed an applied. (1)

Efforts needed:

(1) high (> 200 k€)

Key references, describing solution approaches:

-

4.17. Gap: Uncertainties in human-/eco-toxicity characterization models

Description:

There are many assumptions and generic fate and effect models in the characterization models, leading to high uncertainties of characterization factors.

Consequences:

Uncertainties of results obtained in toxicology impact categories are high. Precision of characterization factors varies between a factor of 10-100 for ecotoxicity and 100-1,000 for human toxicity.

Key references, describing the environmental problem / the gap in LCIA:

R.K. Rosenbaum, et al. (2008): USEtox - The UNEPSETAC toxicity model: recommended characterisation factors for human toxicity and freshwater ecotoxicity in Life Cycle Impact Assessment. Int. J. Life Cycle Assess., 13(7):532-546.

Relevance for comparing container packaging:

Relevant uncertainties occur in all alternatives. Consequently, advantages of glass bottles identified in the AIGMF LCA study[7] are numerical but not significant.

Solution approach:

The LCI data in FEVE's LCAs can be validated and human- and eco-toxicity categories can be evaluated using the USEtox characterization model. (1) Solving uncertainties from the USEtox model is not possible for TU Berlin.

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[7] AIGMF (2012), Life Cycle Assessment of "Container Glass and Comparison with Alternate Packaging Mediums (PET, Beverage Carton, Aluminum Can and Pouch)"

Efforts needed:

(1) low (<50 k€)

Key references, describing solution approaches:

R.K. Rosenbaum, et al. (2008): USEtox - The UNEPSETAC toxicity model: recommended characterisation factors for human toxicity and freshwater ecotoxicity in Life Cycle Impact Assessment. Int. J. Life Cycle Assess., 13(7):532-546.

4.18. Gap: Substances neglected in human-/eco-toxicity categories (USEtox)

Description:

Characterization factors for human and eco-toxicity cover a relatively small range of organic and inorganic chemical substances only. There are many substances, causing unconventional human- and/or ecotoxic effects, which are not considered currently:

- Endocrine disruptors, which interfere with hormone systems in humans and animals and can cause cancerous tumors, birth defects, and other developmental disorders
- Nanomaterials, with up to now unknown toxic effects resulting from their carrier function of other pollutants and high reactivity due to the relatively large surface area
- Microscopic plastics, which can enter cells and bioaccumulate leading to toxic effects due to intrinsic toxicity and their characteristic to concentrate other environmental pollutants such as PAH, DDT, etc.

Consequences:

Toxic effects are underestimated in product systems, in which the abovementioned emissions occur.

Key references, describing the environmental problem / the gap in LCIA:

For endocrine disruptors: United States Environmental Protection Agency (2012), Endocrine Disrupter Screening Programme (EDSP), http://www.epa.gov/endo/index.htm

For nanomaterials: BIO Intelligence Service (2011), Study on coherence of waste legislation, Final report prepared for the European Commission (DG Environment)

For microscopic plastics: Eartheasy (2012), Microscopic Plastic Particles May be Entering Food Chain, http://eartheasy.com/blog/2012/02/study-microscopic-plastic-particles-may-be-entering-food-chain/

Relevance for comparing container packaging:

Unconsidered substances in human- and eco-toxicity impact categories tend to be advantageous for PET bottles, which:

- Leach endocrine disruptors, such as bisphenol A, used in the PET bottles
- Potentially cause emissions of nanomaterials, which can be used in PET bottles to improve the protection of bottles against oxidative agents or to modulate the strength or rigidity of materials
- May cause microscopic plastic emissions when littered (However, microscopic plastic emissions mainly originate from textiles).

Solution approach:

Toxic effects of endocrine disruptors, nanomaterials, and microscopic plastics can be described by means of a literature study and emissions due to PET bottles can be investigated (1). Providing characterization factors for endocrine disruptors, nanomaterials, and microscopic plastics requires intensive toxicological research (2) and is not possible for TU Berlin.

Efforts needed:

(1) low (<50 k€), (2) high (>200 k€)

Key references, describing solution approaches:

\-

4.19. Gap: Indoor emissions

Description:

Emissions of toxic substances are assessed in human- and ecotoxicity impact categories, which comprise fate models simulating the spreading of substances throughout different environmental compartments. For that reason, current characterization models for toxicity are not able to assess health effects of toxic substances emitted indoor. Moreover, no inventory data concerning indoor emissions and required spatial information is available.

Consequences:

Health effects of indoor emissions are neglected in current LCA studies.

Examples:

Indoor emissions mainly comprise VOC emissions resulting from plastics, paints, wood used in flats and houses.

Key references, describing the environmental problem / the gap in LCIA:

United States Environmental Protection Agency (1996): Characterizing Air Emissions From Indoor Sources. Indoor Air Research, Washington, D.C.

Meijer, A., The significance of indoor air emissions in life cycle assessment of dwellings, in International Conference Sustainable Urban Areas. 2007: Netherlands.

Relevance for comparing container packaging:

Indoor emissions are mainly relevant in the production phase considering the workplace. It should be checked if fumigating of chemicals from PET bottles in houses or cars is relevant.

Solution approach:

First, data on indoor emissions need to be collected or measured. Then concentrations need to be compared to legal thresholds. (1)

Efforts needed:

(1) medium (50 – 200 k€)

Key references, describing solution approaches:

Ik Kim and Tak Hur (2009): Integration of working environment into life cycle assessment framework, Int J Life Cycle Assess (2009) 14:290–301

Hellweg et al. (2009), Integrating human indoor air pollutant exposure within Life Cycle Impact Assessment, Environ Sci Technol., 43(6):1670-9.

German Environmental Protection Agency, http://www.umweltbundesamt.de/gesundheit-e/innenraumhygiene/richtwerte-irluft.htm (04 October 2012)

4.20. Gap: Particulate matter

Description:

There are few impact assessment models for particulate matter available. However, they are hardly applied in practice as particulate matter is very hard to measure and data availability and quality in LCI databases is expected to be rather poor.

Consequences:

Impacts of particulate matter on human health are neglected in most LCAs.

Examples:

Particulate matter is relevant for road transport (soot from diesel engines, wire abrasion particles, etc.).

Key references, describing the environmental problem / the gap in LCIA:

United States Environmental Protection Agency http://www.epa.gov/pm/

Relevance for comparing container packaging:

Relevant emissions are expected only from the production, end-of-life phase, and transports. They are assumed to be equal among alternatives.

Solution approach:

After data is collected or measured, recently developed impact assessment methods can be tested. (1) As an alternative, particulate matter data in LCI databases can be evaluated by means of recently developed impact assessment methods. (2)

Efforts needed:

(1) medium (50 – 200 k€), (2) low (< 50 k€)

Key references, describing solution approaches:

Greco, S.L., et al., *Spatial patterns of mobile source particulate matter emissions-to-exposure relationships across the United States.* Atmospheric Environment, 2007. **41**(5): p. 1011-1025.

Spadaro, J.V., *RiskPoll: A model for estimating public health and environmental impacts of air pollution*. 2004.

van Zelm, R., et al., *European characterization factors for human health damage of PM10 and ozone in life cycle impact assessment.* Atmospheric Environment, 2008. **42**(3): p. 441-453.

Humbert, S., et al., *Intake Fraction for Particulate Matter: Recommendations for Life Cycle Impact Assessment.* Environ. Sci. Technol., 2011. **45**(11): p. 4808-4816.

4.21. Gap: Biodiversity

Description:

Apart from few existing approaches to assess explicit impacts on biodiversity, consequences on biodiversity are usually assessed by means of land use indicators and by endpoint models for water consumption, eutrophication, acidification, and global warming. However, there are a lot of uncertainties in underlying characterization models. For instance, impacts are assessed on the level of vascular plant species loss only.

Consequences:

Endpoint results of ecosystem damage are currently incomplete and uncertain.

Examples:

Impacts on biodiversity are relevant in most product systems.

Key references, describing the environmental problem / the gap in LCIA:

UNEP (2012): http://www.unep.org/themes/biodiversity/

Relevance for comparing container packaging:

There are relevant uncertainties in all alternatives. It is unclear, which packaging system may have advantages.

Solution approach:

Several indicators and approaches for the assessment of biodiversity exist, such as species richness, variety or number of species, species vulnerability, net primary production, and scarcity or existence of one class of the ecosystem (Curran et al. 2011). But these approaches are not equally suitable and not valid to all kinds of ecosystems. Therefore, most authors suggest using indicator sets for a more overall perspective (Curran et al. 2011). Based on FEVE's LCIs, current land use indicators and endpoint methods assessing biodiversity damage can be tested. (1)

Efforts needed:

(1) low (< 50 k€)

Key references, describing solution approaches:

Curran, M., et al., Toward Meaningful End Points of Biodiversity in Life Cycle Assessment. Environmental Science and Technology. 2011.

4.22. General gaps in existing impact categories

Despite explicit gaps in life cycle impact assessment mentioned above, there are also shortcomings in existing and generally accepted impact categories concerning:

- Methodological uncertainties and assumptions
- Completeness of considered substances

- Completeness of impact pathways described
- Availability of characterization factors
- Interregional application of regional methods
- Requirements on inventory data

However, evaluating "default" impact categories commonly used in LCIA is beyond the scope of this project but can be reviewed in the ILCD-Handbook[8]

[8] European Commission-Joint Research Centre - Institute for Environment and Sustainability (2011): International Reference Life Cycle Data System (ILCD) Handbook- Recommendations for Life Cycle Impact Assessment in the European context. First edition November 2011. EUR 24571 EN. Luxemburg. Publications Office of the European Union.

5. Practical limitations and gaps

The following practical limitations and gaps were identified and are specified in the following:

- Non-standard operation and use of products
- Direct health effects from products
- Cut-off of delayed emissions
- Data availability
- Data quality
- Uncertainty analysis
- Robustness vs. sensitivity of results

5.1. Gap: Non-standard operation and use of products

Description:

LCAs account typically for the standard use and operation of products under average, steady-state operating conditions. Some events like unforeseen changes or maintenance activities or non-standard uses of products like e.g. the use of bottles as vases or the use of a used tire as a wave-breaker are excluded from the assessment.

Consequences:

Potential benefits on the one hand, but also potential negative environmental effects or risks are excluded from the assessment.

Examples:

In modern industrial solvent cleaning processes, there is no need to completely exchange the solvent due to integrated cleaning by distillation. However, due to some unforeseen contamination the complete solvent may have to be exchanged.

Key references, describing the practical gap:

-

Relevance for comparing container packaging:

On the process level non-standard events can happen in all packaging systems. On the product level, bottles are often re-used for non-intended applications like as refill water bottle, to store technical liquids or even oils etc. While these uses may represent an additional benefit, they come with risks. Due to hygienic properties, there might be an advantage for glass in certain cases.

Solution approach:

Non-standard operation cases (1) and non-standard use scenarios (2) could be assessed by a case study.

Efforts needed:

(1): medium (50 – 200 k€), (2): low (<50 k€)

Key references, describing solution approaches:

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5.2. Gap: Direct health effects from products

Description:

LCAs typically consider the elementary flows as flows to the environment, even though in some cases the flow enters directly into the human body. LCA impact assessment models use characterisation factors that assume that the fate and exposure of elementary flows go “through” the environment and do not assume direct exposure.

Consequences:

Direct health effects due to direct exposure to substances are typically both neglected in the inventory and underestimated by typical characterisation factors.

Examples:

Leaching of endocrine disruptors, like bisphenole A, or antimony from plastic bottles.

Key references, describing the practical gap:

M. Wagner, J. Oehlmann: Endocrine disruptors in bottled mineral water: total estrogenic burden and migration from plastic bottles, Environ Sci Pollut Res DOI 10.100

S. Keresztes, E. Tatár, V. Mihucz, I. Virág, C. Majdik, G. Záray: Leaching of antimony from polyethylene terephthalate (PET) bottles into mineral water, Sci Total Environ. 2009 Aug 1;407(16):4731-5

Relevance for comparing container packaging:

The direct health effects of leaching of chemicals, but also microbiological contamination can be significant. Due to chemical and hygienic properties, there is a high probability that there is an advantage for glass compared to other packaging systems (especially PET and beverage carton) which is not accounted for in typical LCAs.

Solution approach:

This gap could be closed by modelling such direct flows in the inventory based on available literature data (1) or based on measurements (2). Subsequently, characterisation factors for the relevant chemical substances for direct exposure to humans need to be calculated (3). For the microbiological aspect, see also the section in impact assessment (4).

Efforts needed:

(1): low (<50k€), (2): medium (50–200k€), (3): low (<50 k€), (4): at least medium (50–200k€)

Key references, describing solution approaches:

-

5.3. Gap: Cut-off of delayed emissions

Description:

In both LCA and Carbon Footprint standards there is no time cut-off for delayed emissions. While PAS 2050 allows reporting delayed emissions separately, it does not allow subtracting them from the total emissions. However, in some studies emissions occurring after 100 years are not considered at all.

Consequences:

Neglecting delayed emissions violates all current LCA and Carbon Footprint standards.

Examples:

A prominent example for delayed emission is GHG emissions from landfills.

Key references, describing the practical gap:

M. Finkbeiner, S. Neugebauer, M. Berger (2012): Carbon footprint of recycled biogenic products: the challenge of modeling CO2 removal credits, Int J of Sustainable Engineering

Relevance for comparing container packaging:

Embedded carbon in PET bottles can cause substantial CO2 or CH4 emissions after 100 years, when they are landfilled. If such delayed emissions are cut-off, PET bottles have an unjustified advantage compared to glass bottles.

Solution approach:

Delayed emissions should not be cut-off in future studies. The effect of cut-off delayed emissions in existing packaging LCAs can be analyzed and quantified (1).

Efforts needed:

(1): low (<50 k€)

Key references, describing solution approaches:

M. Finkbeiner, S. Neugebauer, M. Berger (2012): Carbon footprint of recycled biogenic products: the challenge of modeling CO2 removal credits, International Journal of Sustainable Engineering

5.4. Gap: Data availability

Description:

Due to the comprehensive scope and regionally different production processes and energy mixes, LCAs typically suffer from incomplete data availability – both on the inventory level and for impact assessment.

Consequences:

On the inventory level, this can result in data gaps or the use of inconsistent or proxy data with negative consequences on data quality (see next gap). On the impact assessment level, data availability limits the calculation and completeness of characterisation factors.

Examples:

Direct emission data for processes is often limited to regulated substances and diffuse emissions are not accounted for. Process data are not available for certain regions (e.g. a product contains a plastic material from China, but there are no Chinese data available for it). Most impact assessment methods for toxicity contain just a few hundred or thousand characterisation factors which represents a rather small share of the at least 200.000 potentially toxic substances.

Key references, describing the practical gap:

-

Relevance for comparing container packaging:

Data gaps can be significant for all packaging systems. For glass, there is already comprehensive LCI data available for Europe, USA and India. This could introduce bias in comparisons with other materials as more complete inventory data lead to a disadvantage in the results. For impact assessment, the data gaps could introduce bias if particular effects of one packaging system are neglected as e.g. the effect of endocrine disruption is typically excluded from the characterisation models (see chapter 4.18).

Solution approach:

Establish complete LCI data (1) and LCIA data (2).

Efforts needed:

(1): high (> 200 k€), (2): high (> 200 k€)

Key references, describing solution approaches:

-

5.5. Gap: Data quality

Description:

Data quality is defined as characteristics of data that relate to their ability to satisfy stated requirements. Due to the comprehensive scope and regionally different production processes and energy mixes and due to the goal dependency of LCA, data quality is a practical challenge. This applies to primary, foreground data, but particularly to background data taken from LCI databases. There is no accepted data quality assessment method.

Consequences:

On the inventory level, the data quality of the results obviously depends on the data quality of the input data. It is practically often impossible due to resource constraints to achieve a really good and fully consistent data quality with regard to the different aspects of time-related coverage, geographical coverage, technology coverage, precision, completeness, representativeness, consistency, reproducibility, sources of the data and uncertainty.

Examples:

Examples for inadequate data quality include:

- Use of European data for production in Asia
- Use of production data for Mg based on the electrolysis while currently by far most Mg is produced via the Pidgeon process
- Use of Ecoindicator 99 for a study in South America

Key references, describing the practical gap:

G. Sonnemann, B. Vigon, C. Broadbent, M. Curran, M. Finkbeiner, R. Frischknecht, A. Inaba, A. Schanssema, M. Stevenson, C. Ugaya, H. Wang, M. Wolf, S. Valdivia (2011): Process on "global guidance for LCA databases", The International Journal of Life Cycle Assessment, 2011, (DOI) 10.1007/s11367-010-0243-9

B. Weidema, M. Wesnæs: Data quality management for life cycle inventories—an example of using data quality indicators, Journal of Cleaner Production Volume 4, Issues 3–4, 1996, Pages 167–174

Relevance for comparing container packaging:

Data quality issues can be significant for all packaging systems. There is no significant difference between packaging materials on the general level. However, it is of utmost importance for the comparison of materials that they are based on unbiased and consistent data quality.

Solution approach:

In order to overcome this gap, data quality assessment approaches can be developed and tested (1). Moreover, the quality of underlying data of comparative studies can be checked (2).

Efforts needed:

(1): medium (50 – 200 k€), (2): low (<50 k€)

Key references, describing solution approaches:

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5.6. Gap: Uncertainty analysis

Description:

To address the relevance of all the gaps and limitations presented for a particular study, quantitative uncertainty analysis or the determination of a confidence interval of the results would be a practical solution. Methods proposed include qualitative or semi-quantitative methods, Monte-Carlo–simulation methods or fuzzy – sets. None of these proposed methods really solved the issue, yet. Maybe, there is no real solution possible due to the actual error types that are dominant in LCA, i.e. systematic „errors“ rather than statistical errors (-> then it would be an inherent limitation of LCA). On a practical level, there is no uniform or agreed approach.

Consequences:

The uncertainty of LCA results cannot be quantified in a robust and practicable way. It is not straightforward to determine significant differences in LCA results.

Examples:

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Key references, describing the practical gap:

S.M. Lloyd et al. (2007): Characterizing, Propagating and Analysing uncertainty in Life-Cycle Assessment, Journal of Industrial Ecology 11 (1) 161-179

S.C. Lo, H.W. Ma, S.L. Lo (2005): Quantifying and reducing uncertainty in life cycle assessment using the Bayesian Monte Carlo method, Science of the Total Environment 340 (1-3) 23-33

Relevance for comparing container packaging:

Uncertainty issues can be significant for all packaging systems. There seems to be no significant difference between packaging materials on the general level.

Solution approach:

In order to address this gap, uncertainty analysis approaches can be developed and tested (1).

Efforts needed:

(1): high (> 200 k€)

Key references, describing solution approaches:

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5.7. Gap: Robustness vs. sensitivity of results

Description:

To address the relevance of all the gaps and limitations presented for a particular study and because of the absence of robust and practicable quantitative uncertainty analysis, it is a challenge to determine the robustness respectively the sensitivity of the results. Sensitivity analysis is defined as systematic procedures for estimating the effects of the choices made regarding methods and data on the outcome of a study. It can be applied to both systematic and random errors.

Consequences:

If the LCA results are not robust, the sensitivity analyses lead to significant changes or different conclusions. The lack of any significant differences may be the end result of the study. The inability of a sensitivity check to find significant differences between different studied alternatives does still not automatically lead to the conclusion that such differences do not exist.

Examples:

Sensitivity analyses are often applied to test the influence of e.g. the following choices made:

- Economic instead of mass allocation
- Different impact assessment methods
- Average, import-mix data for materials vs. supplier specific or best available technology data

Key references, describing the practical gap:

A. Björklund: Survey of approaches to improve reliability in lca, The International Journal of Life Cycle Assessment Volume 7, Number 2 (2002), 64-72, DOI: 10.1007/BF02978849

A. Ansems, T. Lightart : LCA sensitivity and eco-efficiency analysis of beverage packaging systems, TNO Report 2002/179

Relevance for comparing container packaging:

Robustness vs. sensitivity issues can be significant for all packaging systems. There is no significant difference between packaging materials on the general level.

Solution approach:

In order to tackle this shortcoming, sensitivity assessment approaches can be tested and developed (1). Moreover, sensitivity checks of comparative studies can be accomplished (2).

Efforts needed:

(1): medium (50 – 200 k€), (2): low (<50 k€)

Key references, describing solution approaches:

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6. Conclusions and outlook

LCA can assist in identifying opportunities to improve the environmental performance of products at various points in their life cycle. Moreover, it enables informing decision-makers in industry, government or non-government organizations (e.g. for the purpose of strategic planning, priority setting, product or process design or redesign). LCA further supports the selection of relevant indicators of environmental performance, including measurement techniques, and marketing (e.g. implementing an ecolabelling scheme, making an environmental claim, or producing an environmental product declaration).

Despite the fact, that LCAs are probably the best method to identify the environmental performance of products currently available, this study identified a still significant number of methodological gaps and challenges:

- according to ISO 14040/44,
- inherent methodological gaps and limitations,
- limitations of impact assessment,
- practical limitations.

These methodological gaps and choices have an obvious influence on the results of LCA studies in general and as a consequence, also for container packaging. Several gaps are inherent in the LCA method as such, others can be addressed by future scientific work and progress. However, significant resources are needed for some of the issues identified.

Value choices can be scientifically informed, but they remain value choices. On a scientific level, it can only be checked, if these value choices are made consistently throughout a study and particularly between alternatives.

Decision-makers in both private and public organisations need to appreciate the benefits of LCA. However, for a robust, sustainable and credible use of LCA the over-interpretation of LCA results without proper consideration of its gaps and limitations should be avoided. LCAs should be seen as one relevant element of environmentally motivated decision making, but as ISO 14040 puts it *„An LCIA shall not provide the sole basis of…overall environmental* *superiority or equivalence, as additional information will be necessary to overcome some of the inherent limitations in the LCIA."*

It is basically a value choice and decision of FEVE, which of these gaps might be worth tackling with priority in future work. From the perspective of TU Berlin, the following topics appear relevant and promising:

- Assessment of existing FEVE LCI with European Product Environmental Footprint methods (this includes e.g. USEtox)
- Recycling allocation and multi-recycling approaches for glass
- Assessment of „non-standard“ impacts, e.g. microbiological pollution.
- Direct health effects of products
- Relevance of temporal cut-off
- Water Footprint