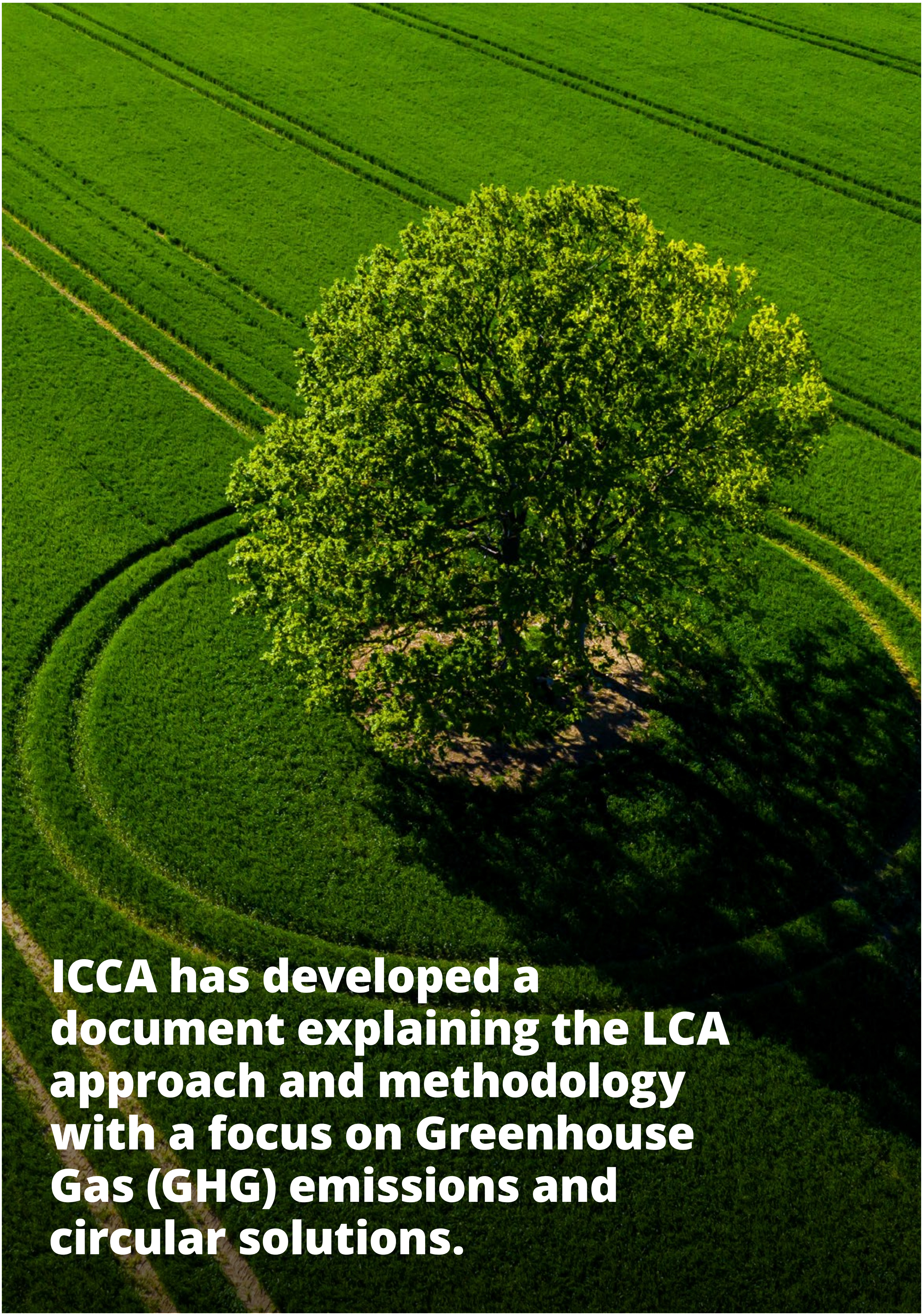
Avoiding greenhouse gas emissions

The essential role of chemicals

Life Cycle Assessment of circular systems

Approach and methodology

International Council of Chemical Associations



ICCA has developed a document explaining the LCA approach and methodology with a focus on Greenhouse Gas (GHG) emissions and circular solutions.

Introduction

The International Council of Chemical Associations (ICCA) is committed to ensure that Life Cycle Assessment (LCA) methodology provides a strong basis for environmental decision-making. The global chemical industry plays an important role in addressing sustainability challenges through the development of new, innovative products and technologies in the context of a growing circular economy. LCA is an essential step to check that these innovations are beneficial overall, regarding environmental impacts, and societal benefits.

To help decision-makers better understand life cycle assessment studies, ICCA has developed a series of studies on the quantification, with a life cycle perspective, of greenhouse gas (GHG) emissions savings enabled by products of the chemical industry.

This document follows the first edition ICCA LIFE CYCLE ASSESSMENTS TO CIRCULAR SYSTEMS (2021), which focuses on the LCA approach and methodology relevant for circular solutions,and was illustrated by case studies by ICCA and its member companies.

ICCA commissioned Quantis to apply these principles when reviewing through "Questions & Answers" an assessment by Imperial College London and Veolia of 73 publications on LCA of plastic packaging (referred to as Veolia's Report[1]).

The document provides a critical overview of the main elements to take into consideration when performing LCA methodology applied on existing circular model business cases.

The extensive assessment performed by Veolia and Imperial College provides an overview of how LCA methodology has been applied in a wide variety of situations. With this document, ICCA builds on Veolia's Report and aims to answer common questions that must be asked when reading through an LCA. The key to answering these questions is given by providing, for each question, a checklist of elements and questions that a decision-maker should keep in mind when reading an LCA. Through this document, ICCA hopes to give decision-makers the tools to make the most of LCA results to select technologies and projects, and/or to orient policies and strategies.

[1] **Voulvoulis, Nikolaos & Kirkman, Richard & Giakoumis, Theodoros & Metivier, Pauline & Kyle, Charlotte & Vicky, Midgley. (2020). Veolia Plastic White paper. 10.13140/RG.2.2.12793.70241.**

An in-depth review: assessing the environmental impacts of bottles made from plastic vs other materials

Veolia's Report compiles 73 publications on LCA of plastic packaging, aiming to draw general conclusions on its environmental performance relative to four other materials - liquid fiberboard, steel cans, aluminum cans, and glass bottles. After consideration of the specific context of each LCA, the authors are able to build on these studies to generate an average comparison between 500 ml containers made from the five materials.

To illustrate the results of this comparison, the authors calculate the carbon emissions that would have occurred in 2016 if all 500 ml PET bottles had been made from an alternative material [Table 1]. The results indicate that bottles made from plastic would have a lower carbon footprint in comparison to other virgin materials considered[2]. In 2016*, it is estimated that 500 ml PET bottles generated 25 million tons of CO_2 eq for their production, which is less than the alternatives that are liquid fiberboard packaging (25.5 millions t CO_2 eq), steel cans (43.7 millions t CO_2 eq), aluminum cans (105.9 millions t CO_2 eq), and glass bottles (112.4 millions t CO_2 eq).

The study also displays the importance of plastic recycling. Although container end-of-life is not included in the average comparison between the five materials, Veolia's Report cites several individual LCA that demonstrate the strongly positive effects of recycling. The authors conclude that "removing, reducing, reusing or recycling the plastic packaging placed on the market is the way forward", rather than switching to alternative materials or waiting for solutions that are not developed yet.

In order to draw such general conclusions from 73 different LCA, each corresponding to a specific context, the authors had to carefully examine the particularities of each study, identifying contextual elements that could have an impact on the results. The nine questions that follow provide a framework for such an assessment.

PDF **https://cdn.ca.emap.com/wp-content/uploads/sites/6/2020/07/Veolia-Plastic-Whitepaper.pdf**

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[2] It should be noted that these results presented by Veolia's paper do not include the end-of-life impacts of the packaging. Adding this life cycle stage to the results could lead to different conclusions.
*** Emissions have been calculated assuming average compositions and weights for each material type.**

Their results indicate that bottles made from plastic would have a lower carbon footprint in comparison to other virgin materials considered.

[Table 1] Calculating greenhouse gases emissions for producing all 500ml containers in 2016 from alternative materials

Container type (500ml bottle or can)	Composition	Weight per bottle (grams)	Tonnes in 2016 (485 billion bottles)	Tonnes CO_2-e per tonne of 500ml bottles/cans produced*	Million tonnes of CO_2 in 2016 from production if all plastic bottles were replaced by this format and material*
Plastic bottle (baseline)	Plastic (PET)	12.7	6,159,500	4.053	25.0
Liquid fiberboard packaging	Plastics (50% PET closure and 50% PE layer)	8	3,880,000	3.585	25.5 (+0.5)
	Aluminium	1	485,000	12.874	
	Carton	13	6,305,000	0.844	
Steel can	Steel	30	14,550,000	3.004	43.7 (+18.7)
Aluminium can	Plastics (PE layer)	4	1,940,000	3.116	105.9 (+80.9)
	Aluminium	16	7,760,000	12.874	
Glass bottle	Glass	259	125,615,000	0.895	112.4 (+87.4)

* Emissions have been calculated using the 2019 Conversion Factors from Defra that covers the extraction, primary processing, manufacturing and transporting materials to the point of sale.

Q1. How can this LCA be applied to reality and what can be learned from it?

LCA is a powerful tool to evaluate and compare the environmental impacts of products or services, providing guidance for decision-making. When making a decision based on an LCA, it is important to ensure that this LCA can be applied to the context of this specific decision.

One element to check is whether the assumptions taken in the LCA apply to the specific context of this decision from a temporal, geographic and technological context. Often, LCA must make assumptions on elements such as the type of energy consumed, the efficiency of industrial processes or the end-of-life scenario for the product assessed. These assumptions must be realistic for the specific context if the LCA is to be used as guidance for decision-making. In the case of plastic packaging, for example, Veolia's Report mentions that "some LCA maintain the assumption that all products are collected, recycled, and reused in the end-of-life phase. The reality, however, is not that simple; and often depends on recycling rate in a particular study/country/city". Indeed, an LCA of a plastic bottle in Germany, where recycling rates are high, cannot be easily applied to countries where the recycling rates are much lower since the impacts and benefits of the life-cycle stage would be significantly different, potentially altering the conclusions.

Furthermore, fair assessments should take product functionality into consideration. The notion of functionality applies, for example, to the comparison between two packaging materials. The function of a packaging material is to be a proper vehicle[3] for a given volume of product. An LCA should compare the impacts of the amount of each material that is necessary to package one unit of product (e.g. the mass amount of glass or plastic necessary to package 1 liter of milk), rather than comparing the materials on a weight basis (e.g. 1 kg of glass versus 1 kg of plastic). Therefore, decision-makers should base choices on a comparison that corresponds to the reality of product functionality.

Results of a comparative assessment are influenced by the choices made in the methodological assumptions, and by the way in which product functionality was taken into account. In order to base a decision on a comparative LCA, the questions to ask are the following:

- To **what extent** are the LCA assumptions coherent with the specific context of the decision?
- Does the **comparison make sense** in the specific context of this decision?

Q2. How is material quality taken into consideration?

When LCA is used to compare the environmental performance of two products or services, the basis of comparison of the assessment is defined based on functionality. This notion is dependent on material quality.

Some materials may not be suitable for specific applications. In the case of plastics, the degradation of polymer chains mean that some recycled plastics are deemed to be of insufficient quality for certain applications. In fact, not all recycling technologies lead to the same quality of recycled product. Chemical recycling is considered to produce virgin-quality outputs, whereas mechanical recycling may lead to quality degradation. For food-contact applications, where plastic quality is essential, chemically, and mechanically recycled plastic may not be functionally equivalent. Thus, when reviewing an LCA, it is important to ask whether material quality could be an issue in this specific situation.

However, the question of material quality is not always relevant. For example, Veolia's Report cites a study comparing virgin and recycled PET fibers for the production of bottles. The authors acknowledge that, in the case of mechanical recycling, recycled fibers are often inferior for some properties such as dyeability. However, they argue that, with a pure waste stream, mechanical recycling leads to recycled PET fibers that are of far sufficient quality for making plastic bottles. In this situation, potential quality differences are not an issue and virgin and recycled PET can be considered as equivalent. In another situation, however, such as producing brightly colored children's toys, the comparison may be less relevant given the limited dyeability of mechanically recycled PET. Thus, the final usage of the product determines whether the comparison makes sense or not from a quality standpoint.

When reviewing an LCA, it is important to check the following points:

- Is **material quality** taken into account in the assessment?
- Is it **necessary to take material** quality into account?
- If material quality is addressed, how does it **affect results**?

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[3] The notion of vehicle here includes holding, protecting, and ensuring transportability according to the needs of the product provider.

Q3. Are some assumptions made in the calculation likely to have a strong impact on results? If so, does the LCA include a sensitivity analysis?

LCA analyses are based on data coming from primary sources and databases used to provide secondary data, which are often completed with assumptions. Assumptions are a common part of LCA, as the complexity of value chains makes it so that no individual member could fully characterize each element in detail. Elements such as the type of energy consumed by an industrial process, its efficiency or the end-of-life scenario for a product often require the LCA practitioner to make assumptions based on knowledge of the context and the most common practices in the industry.

Such assumptions can have a large impact on results. When an assumption is presumed to have a large impact on LCA results, the best practice is to carry out a sensitivity analysis. In a sensitivity analysis, "best case" and "worst case" scenarios are defined to reflect the potential variations and uncertainty in the assumption. The definition of these scenarios is based on the LCA practitioner's knowledge of the studied process, thus it is easier to set credible scenarios when the potential variations are well-known.

For example, in an LCA of PET bottles in which the recycling rate is defined as the national average, the "worst case" could correspond to 0% recycling and the "best case" to 100% recycling. Such analyses provide insight on how LCA results may be different if the context evolves, because a process is carried out in a different location or because of changes over time.

When reading through an LCA, it is important to ask the following questions:

- What are the **main assumptions** made in the calculations?
- Are these **assumptions robust** or could they be questioned?
- How could these **assumptions affect results** and is there a sensitivity analysis?
- Is the scenario **analysis unbiased** (i.e. not focusing on the "best case scenario")?

Q4. Is the scope of the assessment in line with the objectives of the study?

By definition, Life Cycle Assessments take into account environmental impacts of a product or service across its full life cycle, from the extraction of the raw materials necessary for production ("cradle") all the way to end-of-life ("grave"). In practice, this "cradle-to-grave" approach is not always necessary, and life cycle steps might be omitted from the analysis if they are not relevant to the objectives of the study.

For example, "cradle-to-gate" studies are the assessment of a partial life cycle, from resource extraction to factory gate. Such studies omit the life cycle phases in which the product is transformed, transported, used and discarded. The cradle-to-gate approach may be relevant if the purpose is to provide information to the user of the specific raw material or product. For example, a cradle-to-gate LCA of a PVC resin generates results that can be reused by an electric cable manufacturer for an LCA of PVC-insulated cables.

For the sake of comparison, however, partial assessments do not always provide the full picture that is needed to make an informed decision between two products. Veolia's Report gives the example of LCA results comparing the impact of producing a 500-ml beverage container from plastic or from liquid fiberboard. When looking at CO_2 emissions, both containers generate a similar amount of emissions for their production. However, the LCA results do not reflect the end-of-life phase and, as stated in the Report, plastic bottles are much easier to recycle and thus, in regions where plastic recycling is common, plastic bottles could have a lower carbon footprint than non-recycled liquid fiberboard packaging. Thus, end of life for these materials should be taken into consideration in decision-making.

The scope of the assessment must be kept in mind when interpreting the results of an LCA. Depending on the study objective, a partial assessment may be the most appropriate choice as it provides results that are generic and widely applicable. If the aim is to compare two complex products, a full assessment is necessary to capture all environmental impacts at every life cycle stage. Thus, the following questions are important to consider regarding the scope of an LCA:

- Is the assessment being **used for material selection** or to choose between manufactures of the same product type?
- Are there any **life cycle stages** that are not accounted for in the assessment and why?
- If any life cycle **stages are omitted**, for example in a cradle-to-gate assessment, are they likely to have a strong impact on results?

Q5. Does the LCA make use of rigorous, representative data?

LCA methodology relies on a combination of modeled and process-specific data characterizing the product or service that is assessed. Whenever specific data is missing, surrogate data may be obtainable from LCA databases, from the literature or from simulations.

While process-specific data are always preferred, reliable surrogate data may be an option when specific data is not yet available for a new technology. Novel recycling technologies, for example, may not yet be operational or have generated enough data to quantify their energy consumption or their yield.

In such cases, it may be necessary to extrapolate from existing datasets, meaning that the results and the conclusions of the LCA might be less representative of the process under study. When reading through an LCA, and especially if it is an LCA of a new technology, it is important to ask the following questions:

- Does the LCA make use of **extrapolated data**?
- If so, is it **well-documented**, reliable, and justified?
- Could it introduce **a significant amount** of uncertainty in the results?
- Is this **gap acknowledged** and do the authors elaborate on it?

Q6. Does the LCA include an analysis of a future scenario?

LCA results are influenced by the context in which the assessment is taking place. For a product such as a PET bottle, many contextual elements can have an impact on LCA results, such as the availability of recycled input material, of green energy to power production, or of recycling options at end-of-life. Moreover these parameters can evolve over time, making LCA results time-bound.

In fact, several influential parameters are expected to change greatly in the coming years as countries invest in green energy, recycling, waste collection, energy efficiency and circularity. Veolia's Assessment mentions the example of evolving sources of electricity generation. As the electricity mix of countries is expected to become greener, the environmental footprint of electricity-consuming products and services is expected to change as well.

LCA practitioners sometimes investigate such potential evolutions by using a future scenario, which is an assumption on how several important parameters may evolve in the future. This approach provides an additional layer of information which can help guide decision-making and ensures the results of the LCA can be also useful for future users. It should however be considered carefully, as future scenarios are always uncertain. When reading through an LCA, it is thus important to ask the following questions:

- Is there **an analysis** of a future scenario?
- How are **results affected** by this different scenario?
- Is the **future scenario** plausible without being too optimistic?

LCA methodology relies on a combination of modeled and process-specific data characterizing the product or service that is assessed.

Q7. Are all relevant environmental impact categories taken into consideration?

LCA is useful to evaluate the impacts of products and services on several environmental criteria, including global warming, water consumption, resource depletion or acidification. Often, LCA results are presented with a focus on global warming expressed in kg of CO_2 equivalents emitted, a widely understood metric. Results for other environmental criteria are much less discussed and are often neglected, perhaps because they are less widely understood and because it facilitates the presentation of results.

It is nevertheless important to consider results for all relevant environmental criteria when looking at LCA results. Tradeoffs may occur between two criteria, where the reduction of one environmental impact leads to the increase of another. Biofuels are a common example, as they often are shown to lead to a reduction of greenhouse gas emissions, but may lead to increased toxicity, eutrophication, or land use due to the demand for more agricultural inputs.

Veolia's Report is an example of an LCA document centering chiefly on CO_2. This is made explicit from the title, "The Carbon Footprint". Focusing an assessment on one or a few environmental criteria is not an issue per se, as long as it is explicit that the assessment is partial. However, this focus should not lead to a selective presentation of results, showing only the most positive outcomes. Inclusion of other impact categories is recommended to help indicate if there are shifting of burdens.

When reading such an assessment, it is important to check whether all relevant environmental criteria are presented with equal importance, rather than in a "pick-and-choose" fashion. Incomplete assessments do not provide the full picture and may be hiding a potential trade-off.

Q8. Are some impacts and effects not captured by LCA?

LCA provides insight into key environmental challenges associated with a product or service. Several environmental criteria may be evaluated in the analysis, ranging from global warming to land use. While the methodology is strong on well-researched topics such as global warming, some complex topics may not be well captured in LCA.

When reviewing an LCA, it is thus important to check whether any adverse effects have been identified that are not captured in the assessment. LCA is a great tool as it is comprehensive and holistic, it would however be wise for decision-makers to complement LCA with other tools to ensure all aspects are covered.

Are there major differences in the methodological choices made in both studies?

Q9. How can these results be compared to other LCA studies?

The eight questions above demonstrate that each LCA differs in the scope of the assessment, the assumptions that are taken, and general methodological choices that are made in the assessment. Especially in the case of recycling, methodological decisions can lead to significant variations.

Despite these differences, some LCA studies may be comparable so long as their differences are identified and their impact on results is clear. For example, a cradle-to-gate study of PET bottles can be comparable to a cradle-to-grave assessment, so long as they are only compared on the life cycle phases they have in common.

Similarly, the results of two studies carried in two different contexts may be comparable in some cases, as long as the interpretation highlights how the context impacts the results. For example, assessments considering two different production countries would need to, among other things, consider how the electricity mix plays into the overall results, how the transportation distances might evolve between countries and how the end-of-life management can differ from one region to another.

When attempting to compare two different LCAs on a similar topic, some results may differ. In such cases, ask the following questions before relying on the analyses:

- Are there **major differences** in the methodological choices made in both studies?
- Are the data used in the analyses **reliable**, **credible**, and **well validated**?
- Is the context of the **assessment similar** in both studies?
- **What impact** could these differences have on results? Does it explain discrepancies?

Conclusion

LCA results can be difficult to interpret for those who do not work with LCA often. A better understanding of the methodology can help decision-makers appreciate when and how LCA results can be applied to a specific decision-making context.

LCAs can provide valuable information for a decision-making process, by providing a general, comprehensive document on LCA methodology followed by a checklist of elements to keep in mind when reviewing an LCA, ICCA hopes to support decision makers in their interpretation of LCA results.

About ICCA

The International Council of Chemical Associations (ICCA) is the worldwide voice of the chemical industry, representing chemical manufacturers and producers all over the world.

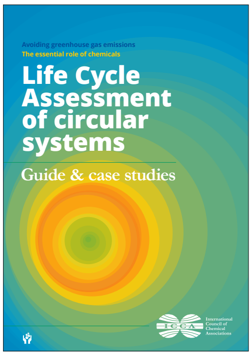
Responding to the need for a global presence, ICCA was created in 1989 to coordinate the work of chemical companies and associations on issues and programs of international interest. It comprises trade associations and companies involved in all aspects of the chemical industry.

ICCA is a chemical industry sector with a turnover of more than 3,600 billion euros. ICCA members (incl. observers & Responsible Care members) account for more than 90 percent of global chemical sales. ICCA promotes and co-ordinates Responsible Care® and other voluntary chemical industry initiatives.

ICCA has a central role in the exchange of information within the international industry, and in the development of position statements on matters of policy. It is also the main channel of communication between the industry and various international organizations that are concerned with health, environment and trade-related issues, including the United Nations Environment Programme (UNEP), the World Trade Organization (WTO) and the Organisation for Economic Co-operation & Development (OECD).

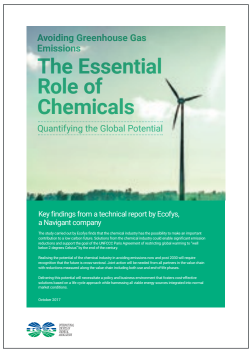
Related ICCA documents

This document on **LIFE CYCLE ASSESSMENTS APPLIED TO CIRCULAR SYSTEMS** is the latest of a series of studies on the quantification, with a life cycle perspective, of greenhouse gas (GHG) emissions savings enabled by products of the chemical industry:

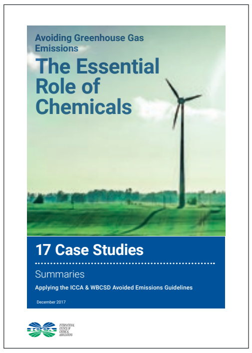


LIFE CYCLE ASSESSMENT OF CIRCULAR SYSTEMS: GUIDE & CASE STUDIES (2020): This document complements a series of studies by ICCA and its members companies, including a range of case studies and methodological documents, highlighting the importance of Life Cycle Assessments (LCA), especially when it comes to quantifying and reporting on the chemical industry's own footprint (scope 1 emissions), and the enabling role of its products in lowering CO_2 emissions in value chains.

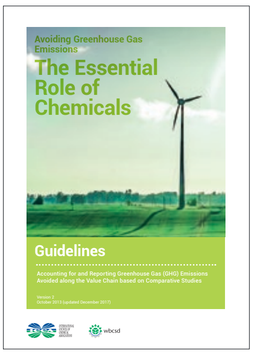
ENABLING THE FUTURE: CHEMISTRY INNOVATIONS FOR A LOW-CARBON SOCIETY (2019): Commissioned to KPMG and fors, the study reveals that 450 generic technologies are enablers of GHG savings, of which 137 are highly feasible. The 17 innovative solutions featured in the report could develop emission reductions of about 5-10 Gigaton by 2050 – which is about one quarter of the total world emissions today. These solutions will require robust transformation of entire sectors, such as power generation and storage, industry and production, mobility and transportation, nutrition and agriculture, and building and housing.



AVOIDING GREENHOUSE GAS EMISSIONS: THE ESSENTIAL ROLE OF CHEMICALS. QUANTIFYING THE GLOBAL POTENTIAL (2017): Commissioned to Ecofys, the report illustrates how efficient processes and chemical industry solutions can contribute to GHG savings. ICCA estimates that by 2030, light materials for transportation, efficient buildings and lighting, electric cars, wind and solar power and improved tires, at global scale, have the potential to avoid 2.5 Gigatons of GHG emissions globally every year.



AVOIDING GREENHOUSE GAS EMISSIONS: THE ESSENTIAL ROLE OF CHEMICALS - 17 CASE STUDIES (2017): Commissioned to Quantis, this report assembles 17 examples of Life Cycle Assessment case studies. The purpose is twofold: to motivate all stakeholders to discuss climate change using robust studies, taking the full life cycles into account, and to encourage all chemical companies to generate high quality assessments.



AVOIDING GREENHOUSE GAS EMISSIONS: THE ESSENTIAL ROLE OF CHEMICALS – GUIDELINES (UPDATED IN 2017): Prepared jointly with the World Business Council for Sustainable Development (WBCSD) the guidelines define how to measure avoided GHG emissions via LCA methodologies applied to entire value chains.

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