Chapter 3
The International Standards as the Constitution of Life Cycle Assessment: The ISO 14040 Series and its Offspring

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Abstract The establishment of the international standards of Life Cycle Assessment—LCA (ISO 14040 series) led to worldwide acceptance of LCA. The ISO standards of LCA (ISO 14040 and ISO 14044) are the only globally relevant international standard documents on LCA which are broadly referenced by users and other standardization processes. Thus, they represent the constitution of LCA.

This chapter opens with an outline of the historical development of the international LCA standardization process and ends with an outlook on the future. The main part deals with the core standards and the spin-off standards of LCA. The core standards are ISO 14040—Environmental Management—Life Cycle Assessment—Principles and Framework and ISO 14044—Environmental Management—Life Cycle Assessment—Requirements and Guidelines.

Based on these classical LCA standards, 'new' approaches have recently been developed which have led to several spin-off-standards. They cover issues such as:

- 'Single-issue-LCAs' like carbon footprinting (ISO 14067) or water footprinting (ISO 14046),
- 'Beyond environment-LCAs' like life cycle costing, social LCA and eco-efficiency assessments (ISO 14045) or even life cycle sustainability assessments,
- 'Beyond product-LCAs' like Organizational LCAs (ISO 14072) or sector-based IO-LCAs and
- 'Beyond quantification-LCAs' like type III environmental product declarations (ISO 14025) or other types of environmental labels and claims.

Keywords Carbon footprint · Eco-efficiency · History of life cycle assessment standards · International life cycle assessment standards · ISO 14040 series · Organizational LCA · Spin-off-standards · Standards of life cycle assessment · Water footprint

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1 Introduction

Standards play an important role in business and everyday life. They represent a consensus on good practice and state of the art. This applies to all kinds of technical topics—including life cycle assessment (LCA). International standards for LCA were developed since the nineties as part of the ISO 14000 family of environmental management standards. In 2010, the drivers for this development were summarized in a brochure of the responsible ISO technical committee (ISO 2010) due to the observation"…that organizations around the world, as well as their stakeholders, are becoming increasingly aware of the need for environmental management, socially responsible behaviour and sustainable development. Accordingly, as the proactive management of environmental aspects converges with enterprise risk management, corporate governance, sound operational practices and financial performance, international standards are becoming increasingly important for organizations to work towards common and comparable environmental management practices to support the sustainability of their organizations, products, and services. It is the role of such standards to be technically credible, to fulfill stakeholder needs, to facilitate the development of uniform requirements, to promote efficiencies, to support compliance, to enhance investor confidence and to lead to continual improvement".

ISO is the International Organization for Standardization. It has a membership of over 160 national standards institutes from countries large and small, industrialized, developing and in transition, in all regions of the world. ISO's portfolio of more than 18,000 standards provides practical tools for all three dimensions of sustainable development: economic, environmental and societal. ISO technical committee ISO/TC 207 'Environmental management' is responsible for developing and maintaining the ISO 14000 family of standards. The committee's current portfolio consists of more than 20 published international standards and other types of normative documents, with about another ten new or revised documents in preparation. ISO/TC 207 was established in 1993, as a result of ISO's commitment to respond to the complex challenge of 'sustainable development' articulated at the 1992 United Nations Conference on Environment and Development in Rio de Janeiro. Membership of ISO/TC 207 is among the highest of any ISO technical committee and is both broad and diverse in representation, which are two key indicators of the worldwide interest in its work. National delegations of environmental experts from over 100 countries participate in ISO/TC 207, including over 25 developing countries (ISO 2010).

That committee within ISO/TC207 dealing with LCA is called Subcommittee 5 or in short: ISO/TC207/SC5. It was established right from the beginning of TC207. So far, the leadership of SC5 has always been provided by Germany: 1993–2000, Manfred Marsmann, 2000–2007, Hans-Jürgen Klüppel, 2007–now, Matthias Finkbeiner. The Secretariat has always been regulated by the national French standardization body AFNOR. To implement ISO´s 'twinning' policy, Reginald Tan from Singapore has been serving as co-chair of SC5 since several years.

Within this introductory chapter, the history of LCA standards development (Sect. 1.1), the relevance of ISO standards on LCA (Sect. 1.2) and the standardization process (Sect. 1.3) itself will be introduced. This will be followed by a high-level description of the core standards of LCA: ISO 14040 and ISO 14044 (Sect. 2) and the the spin-off standards from ISO 14040 and 14044 (Sect. 3). Finally, the future standards based on ISO 14040 and ISO 14044 (Sect. 4) are introduced before this article concludes with an outlook (Sect. 5).

1.1 History of LCA Standards Development

This section will describe the history of the development of the international standards of LCA in three periods: the early days (see Sect. 1.1.1), the first revision (see Sect. 1.1.2) and the proliferation (see Sect. 1.1.3).

1.1.1 The Early Days

The standardization process of the early days was a real challenge, because in many methodological issues there was no real consensus when it started. Despite some important references serving as seed documents, especially the so-called 'Code of Practice' (SETAC 1993) from SETAC (Society of Environmental Toxicology and Chemistry), particularly the methodologies of impact assessment and interpretation had to be standardized in parallel to the ongoing scientific development. At that time SETAC was the most relevant platform for LCA discussions and methodology development (see this volume, Chap. 2).

Initially, the standardization process within ISO/TC207/SC5 was organized in five separate working groups (WGs) (Marsmann 1997, 2000; Marsmann et al 1997). WG 1 on principles and guidelines established in 1997 the first and basic document of the emerging ISO 14040-series, i.e. ISO 14040—Environmental Management—Life Cycle Assessment—Principles and Guidelines (ISO 14040 1997). WG 2 dealt with generic and WG 3 with specific aspects of the life cycle inventory. In 1998, both groups together established ISO 14041—Environmental Management—Life Cycle Assessment—Goal and Scope Definition and Inventory Analysis (ISO 14041 1998). WG 4 was working on the assessment of environmental impacts and their valuation and produced in 2000 ISO 14042—Environmental Management—Life Cycle Assessment—Life Cycle Impact Assessment (ISO 14042 2000). WG 5 was dealing with the interpretation phase and managed to publish in 2000 ISO 14043—Environmental Management—Life Cycle Assessment—Life Cycle Interpretation (ISO 14043 2000).

The publication of these first international standards of LCA was an important milestone for the application of LCA and an essential step to consolidate procedures and methods. However, the complex structure of the working groups, the partly parallel, partly serial development of the documents and the long time needed for

getting them published reveal the challenges to achieve international consensus. In addition, the parallel development of documents in different working groups has led to some inconsistencies between the first generation of standards that have been corrected in the first revision described in the following Sect. 1.1.2. However, despite such improvements, the key structure of the method, the four phases of LCA and the key requirements stood the test of time exceptionally well. The first revision reconfirmed, to a very large degree, the validity of the technical content of the first generation of standards. As a matter of fact, this clearly documents the outstanding work of the standardization pioneers in this first generation of LCA standards. They were ahead of the times in establishing these standards well before the years of the LCA boom. The relevance of this accomplishment gets even more obvious, if we take into account the standardization trials on carbon footprinting. Without proper LCA standards in place, the failure to deliver an international carbon footprint standard with sufficient speed to market (see Sect. 4.3) would be even more critical.

1.1.2 The First Revision

In the paper of Finkbeiner et al. (2006) about the new international standards for Life Cycle Assessment, ISO 14040 and ISO 14044 (Finkbeiner et al. 2006), the revision process and the main improvements achieved during the revision have been described in detail. This section is based on this paper and highlights some of the major changes made.

After the application experience of the first version of the standards, ISO/TC207/SC5 started a consultation on the need and the strategy of a revision of the first generation of standards. A consensus was achieved on the following four key objectives:

- Increase readability by compiling only two documents/ merging different documents/ reorganising the current standards, but
  - Keep the technical content (only improvements are acceptable),
  - Keep the consensus/ balance,
  - Keep the requirements.
- Address applications of LCA (life cycle thinking; relation to ecolabels, design for environment (DfE), life cycle management, etc.).
- Inclusion of economic and social aspects are beyond the scope of TC207, but links should be addressed.
- Give guidance/ training for application in industry, government, etc., especially in developing countries.

Not all of these issues could be handled within an international standardization process. However, most of the issues could be solved by a revision of the standards. To explore this possibility and with a focus to improve the readability of the ISO 14040 series, a new ad-hoc group was created in June 2002 to review the ISO 14040/41/42/43 standards. The mandate of the ad-hoc group was to seek consensus on a possible way for a revision of these standards (boundaries of the revi-

sion, structure, contents, etc.). The mandate also demanded to explore if there is a consensus to develop the corresponding New Work Item Proposals (NWIPs) with accompanying working documents.

The ad-hoc group, consisting of 21 international experts and co-chaired by Atsushi Inaba and Matthias Finkbeiner, had one meeting and achieved a consensus on a possible way of revision of the standards; it also developed the necessary elements for the corresponding NWIPs which were presented to ISO/TC207/SC5 in July 2003.

The scope of the proposed work items was to begin immediately with the revision of the standards ISO 14040, 14041, 14042 and 14043, with the objective of improving readability, while leaving the requirements and technical content unaffected, except for errors and inconsistencies. It was the intention:

1. to gather all requirements ('shalls') in one new standard, keeping the structure of 'goal and scope', 'inventory', 'impact assessment' and 'interpretation' as separate chapters,
2. to maintain ISO 14040 as a framework document, but transferring all requirements ('shalls') to the new standard, adding to ISO 14040 a requirement ('shall') of compliance with the requirements ('shalls') of the new standard.

This proposal was justified with regard to applicability and readability due to the request of several member bodies for improvement, because the existing documents were partly not consistent, partly not clear or even ambiguous. In addition to language improvement, a merging of standards was requested by some member bodies to make them more readable.

As indicated in the scope of the NWIP, it was proposed, to fulfill this need by two new standards: a revised ISO 14040 standard ('Environmental Management—Life Cycle Assessment—Principles and Framework') (ISO 14040 2006) and a new standard 14044 containing all requirements ('Environmental Management—Life Cycle Assessment—Requirements and Guidelines') (ISO 14044 2006).

The voting of the international member bodies on this proposal in the autumn of 2003 revealed an unanimous result (no negative vote, two abstentions). Therefore, a new working group WG6 (with more than 50 international experts, co-chaired by Atsushi Inaba (Japan), Reginald Tan (Singapore) and Matthias Finkbeiner (Germany), Secretariat provided by Kim Christiansen (Denmark)) was created to accomplish the revision of the standards according to the scope of the NWIPs. WG6 was working very efficiently and in good team spirit. Despite the fact that it had to deal with in total 1,900 comments, the work was accomplished with basically complete consensus in the minimum number of WG meetings and a few months ahead of schedule. Even though the scope for the revision was rather restrictive, several changes were made compared to the first generation of standards.

An obvious formal change due to the revision is the reduced number of standards, the reduced number of annexes and the reduced number of pages that contain requirements. All these changes were intended to increase the readability and accessibility of the standards. For the practitioners of LCA, this means that the technical

requirements can be found in one document (instead of previously four) and that they are condensed on 26 pages (instead of 44 previously).

Next to the more formal changes, some technical modifications were made as well. Generally, the main technical content of the previous standards was reconfirmed to be still valid. Many important issues of fundamental importance, e.g. allocation, requirements for comparative assertions or the phases of LCA were not changed. This was both not the intention of the revision and not found to be justified during the revision process. However, still some technical changes were made. The modified technical content is in line with the previous requirements and serves mainly as a clarification of the technical content, and as a correction of errors and inconsistencies. It includes, e.g., the addition of several definitions (e.g. product, process, etc.), the addition of principles for LCA, clarifications concerning

- LCA intended to be used in comparative assertions intended to be disclosed to the public,
- system boundaries,
- the critical review panel, and
- the addition of an annex about applications.

As an example, both the previous and the new ISO 14040 have in the title 'principles and framework', but the previous version did not include any principles. To remove this inconsistency, the following principles were added to the new ISO 14040:

- Life cycle perspective.
- Environmental focus.
- Relative approach and functional unit.
- Iterative approach.
- Transparency.
- Comprehensiveness.
- Priority of scientific approach.

It is explained that these principles are fundamental and should be used as guidance for decisions relating to both the planning and the conducting of an LCA.

The revised standards were approved by unanimous vote which means that they represent a complete consensus of all countries and stakeholders. The versions of ISO 14040 and 14044 developed in 2006 are still valid today. As part of the systematic review procedure of ISO standards, there was an inquiry on the need for revision to all member bodies in 2009. The result of the inquiry was an almost unanimous confirmation of the existing standards.

While the standards are sometimes criticized by some stakeholders (especially from academia) for not being specific enough on certain issues, they do represent the global consensus on those methodological features for which such a consensus exists. More specific stipulations on, e.g., allocation procedures or a default set of impact categories, let alone a particular impact assessment method might be desired by some stakeholders, but there is no global stakeholder consensus on that. It makes no sense to blame the standards for this, as it is the natural result of the

very democratic procedure to develop an ISO standard. The fact, that ISO 14040 and 14044 represent such a strong consensus among both private and public users of LCA and that they are the only globally relevant international standards of LCA, makes them so relevant. This was particularly demonstrated by their important role in the proliferation of standards based on LCA, which is addressed in the next Sect. 1.1.3.

1.1.3 The Proliferation

Soon after the publication of the revised standards, LCA started to boom. While part of this growth came from increased application and implementation of LCA itself in both private and public decision-making, an additional momentum was generated by the development of 'new' approaches built on the basis of classical LCA:

- 'Single-issue-LCAs' like carbon footprinting or water footprinting,
- 'beyond environment-LCAs' like life cycle costing, social LCA and eco-efficiency assessments or even life cycle sustainability assessments,
- 'beyond product-LCAs' like scope 3 type LCAs of organizations or sector-based IO-LCAs and
- 'beyond quantification-LCAs' like type III environmental product declarations or other types of environmental labels and claims.

While some of these additional standards are part of the ISO/TC207 family, additional public and private standardization bodies tried to penetrate the market with their products. Especially, the carbon footprint discussions led to a huge proliferation of different guidelines and standards. In the editorial 'Carbon footprinting—opportunities and threats' (Finkbeiner et al. 2006) which was published to announce a particular carbon footprint section in the International Journal of Life Cycle Assessment, the following non-exclusive list of initiatives was given:

- ISO 14067 on Carbon Footprint of Products.
- The World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI) developed two standards under their Greenhouse Gas Protocol Product/Supply Chain Initiative: A Product Life Cycle Accounting and Reporting Standard and a Corporate Accounting and Reporting Standard: Guidelines for Value Chain (Scope 3) Accounting and Reporting.
- The UNEP/SETAC Life Cycle Initiative launched a project group on carbon footprinting.
- The British Standards Institution published a Publicly Available Specification (PAS) to specify requirements for assessing the life cycle greenhouse gas emissions (GHG) of goods and services. The development of this PAS was co-sponsored by the Carbon Trust and the Department for Environment, Food and Rural Affairs (PAS 2050 2011).

- The Japanese Ministry of Economy, Trade and Industry (METI) launched a carbon footprint trial project, and a Technical Specification 'General principles for the assessment and labelling of Carbon Footprint of Products' was issued.
- Many more initiatives were launched, in Korea, the European Union, France, Germany, New Zealand, etc.

In Sect. 4, the future standards within the ISO 14000 series are introduced which are built on the LCA standards.

1.2 Relevance of ISO Standards on LCA

In the early days of LCA, the results of the studies were often apparently biased by vested interests of the study commissioners. While the general idea and concept of LCA was appealing to many stakeholders right from the start, the credibility of the method was severely damaged by such misuse. These 'wild-west' times of LCA had been overcome when the international standards of LCA were published to improve the quality of LCAs and to hinder wrong claims about the environmental superiority of products.

Before the establishment of the ISO standards of LCA, governments were reluctant to apply LCA for their policy development due to a lack of commonly accepted procedures and methods. Companies often had a risk-aversive strategy towards LCA because they were either afraid of market distortions of unjustified claims by competitors or barriers of trade, or of mandatory reporting requirements by public policy. These fears were partly amplified by the tendency of some LCA practitioners to oversell the tool. For some of them LCA was not any longer a tool, it was more a religion to determine what is good and what is evil. During that period in the nineties, LCA practitioners from academia and consultancy were typically belonging to different schools fighting about the right way to do LCA, the right impact assessment approach, the best LCA software, and so on.

The international standardization of LCA achieved a much clearer perspective and a much more sober view what LCA can do, but—at least likewise important—also what it can*not* do. It established a common language of terms and key methodological requirements, but it did not fix 'a one size fits all-LCA'. By giving the users of LCA an equally important voice as the providers of LCA, the consensus achieved in the standards did not make everybody happy, but it reached a fairly strong global consensus on the basic rules and framework of LCA. In addition, the standards made the limitations of LCA transparent and provided fairly strict requirements for the most contentious application of LCA, the so-called comparative assertions intended to be disclosed to the public. As such, the establishment of the international standards was of utmost importance for the broad acceptance of LCA all around the world and by all stakeholders. The ISO standards of LCA are until today the one and only globally relevant international

standard documents which are broadly referenced by users and other standardization processes.

1.3 ISO's Standardization Process

According to ISO, "an ISO Standard is a normative document, developed according to consensus procedures, which has been approved by the ISO membership and P-members of the responsible committee in accordance with the ISO/IEC Directives. ISO standards are developed by groups of experts, within technical committees (TCs). TCs are made up of representatives of industry, NGOs, governments and other stakeholders, who are put forward by ISO's members. Each TC deals with a different subject, for example there are TCs focusing on screw threads, shipping technology, food products and many, many more.

ISO's full members (member bodies, i.e. national standardization organizations) can decide if they would like to be a participating member (P-member) of a particular TC or an observing member (O-member). P-members participate actively in the work and have an obligation to vote on all questions submitted to vote within the technical committee. O-members follow the work as an observer but cannot make any comments about the development process or vote.

An ISO standard is developed by a panel of experts, within a technical committee. Once the need for a standard has been established, these experts meet in a working group established for this purpose to discuss and negotiate a draft standard. As soon as a draft has been developed, it is shared with ISO members who are asked to comment and vote on it. If a consensus is reached, the draft becomes an ISO standard, if not it goes back to the technical committee for further edits" (ISO 2012a).

According to ISO, the standardization process is built on four key principles (ISO 2012b):

- **"ISO standards respond to a need in the market**
  ISO does not decide when to develop a new standard. Instead, ISO responds to a request from industry or other stakeholders such as consumer groups. Typically, an industry sector or group communicates the need for a standard to its national member who then contacts ISO.
- **ISO standards are based on global expert opinion.**
  ISO standards are developed by groups of experts from all over the world that are part of larger groups called technical committees. These experts negotiate all aspects of the standard, including its scope, key definitions and content.
- **ISO standards are developed through a multi-stakeholder process**
  The technical committees are made up of experts from the relevant industry, but also from consumer associations, academia, NGOs and government.
- **ISO standards are based on a consensus**
  Developing ISO standards is a consensus-based approach and comments from stakeholders are taken into account."

2 The Core Standards of LCA: ISO 14040 and ISO 14044

As described in Sect. 1.1.2, ISO 14040 2006 and ISO 14044 2006 are the core standards of LCA that are still valid today. The current ISO 14040 is a framework and guidance standard, while ISO 14044 contains all technical requirements and guidelines on these. Therefore, ISO 14040 provides a more general, introductory reading of the concept and outline of LCA including its principles. For the LCA practitioner, ISO 14044 is the operational document including all requirements for ISO compliant LCA studies. This section is by no means able to replace reading the actual standard documents. It is rather intended to give a flavor of the key features of the standards and supposed to proselytize those who so far resisted the core standards of LCA.

According to Sect. 4.3 of ISO 14040 (ISO 14040 2006), the following aspects are defined as key features of the LCA methodology:

- "LCA assesses, in a systematic way, the environmental aspects and impacts of product systems, from raw material acquisition to final disposal, in accordance with the stated goal and scope;
- The relative nature of LCA is due to the functional unit feature of the methodology;
- The depth of detail and time frame of an LCA may vary to a large extent, depending on the goal and scope definition;
- Provisions are made, depending on the intended application of the LCA, to respect confidentiality and proprietary matters;
- LCA methodology is open to the inclusion of new scientific findings and improvements in the state-of-the-art of the technique;
- Specific requirements are applied to LCA that are intended to be used in comparative assertions intended to be disclosed to the public;
- There is no single method for conducting LCA. Organizations have the flexibility to implement LCA,…, in accordance with the intended application and the requirements of the organization;
- LCA is different from many other techniques (such as environmental performance evaluation, environmental impact assessment and risk assessment) as it is a relative approach based on a functional unit; LCA may, however, use information gathered by these other techniques;
- LCA addresses potential environmental impacts; LCA does not predict absolute or precise environmental impacts due to
  - the relative expression of potential environmental impacts to a reference unit,
  - the integration of environmental data over space and time,
  - the inherent uncertainty in modelling of environmental impacts, and
  - the fact that some possible environmental impacts are clearly future impacts;
- The LCIA phase, in conjunction with other LCA phases, provides a system-wide perspective of environmental and resource issues for one or more product system(s);

- LCIA assigns LCI results to impact categories; for each impact category, a life cycle impact category indicator is selected and the category indicator result (indicator result) is calculated; the collection of indicator results (LCIA results) or the LCIA profile provides information on the environmental issues associated with the inputs and outputs of the product system;
- There is no scientific basis for reducing LCA results to a single overall score or number, since weighting requires value choices;
- Life cycle interpretation uses a systematic procedure to identify, qualify, check, evaluate and present the conclusions based on the findings of an LCA, in order to meet the requirements of the application as described in the goal and scope of the study;
- Life cycle interpretation uses an iterative procedure both within the interpretation phase and with the other phases of an LCA;
- Life cycle interpretation makes provisions for links between LCA and other techniques for environmental management by emphasizing the strengths and limits of an LCA in relation to its goal and scope definition."

These key features describe the main aspects of LCA according to the ISO-standards. A particular feature mentioned there are the additional requirements for LCAs that are intended to support comparative assertions intended to be disclosed to the public. This application has potentially strong implications on third parties. As a consequence, ISO 14044 provides a set of particular requirements for these types of studies:

- The equivalence of the systems being compared shall be evaluated before interpreting the results. Systems shall be compared using the same functional unit and equivalent methodological considerations such as performance, system boundary, data quality, allocation procedures, decision rules on evaluating inputs, and outputs and impact assessment. Any differences between systems regarding these parameters shall be identified and reported.
- While an LCI study without impact assessment is a feasible choice for any other application, an LCIA is required for comparisons intended to be used in comparative assertions to be disclosed to the public.
- The LCIA shall employ a sufficiently comprehensive set of category indicators. The comparison shall be conducted by category indicator.
- Weighting shall not be used in LCA studies intended to be used in comparative assertions intended to be disclosed to the public.
- Several data quality requirements and sensitivity analyses are required and not only recommended.
- In order to decrease the likelihood of misunderstandings or negative effects on external interested parties, a critical review of a panel of interested parties is mandatory, whereas critical reviews are just recommended for all the other applications.
- Finally, specific reporting requirements apply as described in paragraph 5.3 of ISO 14044.

As any reputable LCA practitioner is supposed to get acquainted with the core standards of LCA rather sooner than later, we need not go into further details including all principles, requirements, guidelines, annexes on applications, examples of data collection sheets and examples of interpretation. However, the lesser known spin-off standards (see Sect. 3) of ISO 14040 and ISO 14044 as well as the currently developed future standards (see Sect. 4) justify a brief introduction.

3 The Spin-off Standards

The core standards of LCA quickly generated offspring, i.e. standards resulting from application of or as additional guidance to the ISO 14040 series of standards. One spin-off standard was developed outside ISO TC 207/SC5, because it is part of the ISO 14020 series of ecolabelling standards. However, as ISO 14025 on type III environmental declarations (ISO 14025 2006) provides basically a standardized reporting format for LCAs; it is briefly described in Sect. 3.1. Already in parallel to the development of the first generation of core standards of LCA, i.e. ISO 14040–43, the discussion started to supplement these requirement standards with non-normative documents (Technical Reports) that provide examples for their application. The resulting documents ISO/TR 14047 (ISO/TR 14047 2012) and ISO/TR 14049 (ISO/TR 14049 2012) are introduced in Sects. 3.2 and 3.4, respectively. The third spin-off document ISO/TS 14048 (ISO/TS 14048 2002), which is described in Sect. 3.3 deals with the issue of data documentation format.

3.1 ISO 14025—Type III Environmental Product Declarations

The ISO 14020 series differentiates between three types of environmental labels and declarations. Type I labels are the classical ecolabels like the German Blue Angel for providing a clear indication of environmental superiority to the consumer. Type II labels and claims are rather flexible and particularly focus on self-declared claims without third party verification. ISO type III environmental declarations provide quantified environmental data using predetermined parameters and, where relevant, additional environmental information. Most importantly, the predetermined parameters are based on the ISO 14040 series of standards, i.e. LCA. In a nutshell, such environmental product declarations (EPDs) are small environmental reports of a product reporting its LCA.

The latter is covered by the standard ISO 14025—Environmental Labels and Declarations—Type III Environmental Declarations—Principles and Procedures (ISO 14025 2006). This standards was published 2006 and was built on a Technical Report ISO/TR 14025 which was first issued in 2000. This standard establishes the principles and specifies the procedures for developing Type III environmental declaration programs and Type III environmental declarations. It specifically estab-

lishes the use of the ISO 14040 series of standards in the development of Type III environmental declaration programs and Type III environmental declarations.

Type III environmental declarations are primarily intended for use in business-to-business communication, but their use in business-to-consumer communication is not precluded.

On a technical level, ISO 14025 developed the concept of the so-called product category rules (PCRs). PCRs represent basically a predetermined goal and scope definition for a particular product group and are intended to achieve comparability within a set of products. The concept of PCRs gained significant importance in the current discussions on carbon footprint labels and are nowadays recognized as a relevant and feasible option to further specify the generic, cross-sectorial requirements of the LCA or footprinting standards for particular product groups.

3.2 ISO 14047—Examples of Impact Assessement

This document is officially called 'ISO/TR 14047: 2012 Environmental Management—Life Cycle Assessment—Illustrative examples on how to apply ISO 14044 to impact assessment' (ISO/TR 14047 2012). The current version is an editorially improved version of the original document from 2003.

"The purpose of this Technical Report is to provide examples to illustrate current practice of life cycle impact assessment according to ISO 14044 2006. These examples are only a sample of all possible examples that could satisfy the provisions of the standard. They offer 'a way' or 'ways' rather than the 'unique way' of applying the ISO 14044 2006. They reflect the key elements of the life cycle impact assessment (LCIA) phase of the LCA. The examples presented in this TR are not exclusive and other examples exist to illustrate the methodological issues described" (ISO/TR 14047 2012).

As there was no technical update during the revision, several of the examples given do not necessarily represent the latest state-of-the-art in impact assessment. In general, the document was definitely beneficial for some users, but has probably not really achieved a strong impact on the LCA community.

3.3 ISO 14048—Data Documentation Format

This Technical Specification 'Environmental Management—Life Cycle Assessment—Data Documentation Format' (ISO/TS 14048 2002) provides the requirements and a structure for a data documentation format to be used for transparent and unambiguous documentation and exchange of Life Cycle Assessment (LCA) and Life Cycle Inventory (LCI) data, thus permitting consistent documentation of data, reporting of data collection, data calculation and data quality, by specifying and structuring relevant information.

"The data documentation format specifies requirements on division of data documentation into data fields, each with an explanatory description. The description of each data field is further specified by the structure of the data documentation format.

The document intends to support LCA use and development, and is aimed primarily for data suppliers, LCA practitioners and LCA information system developers. The data documentation format is also intended to facilitate the exchange of LCI data without loss of transparency, even though the specification does not provide specific requirements for implementation of data exchange. The specification, explanation and implementation of the data documentation format are described in different parts of the document as follows:

- Clause 5 covers the specification and structure of the data documentation format and the names of all of the data fields;
- Clause 6 covers the specification of the data types used in the data documentation format;
- Clause 7 covers the specification of nomenclatures used in the data documentation format;
- Annex A contains formatting requirements and explanatory descriptions of each data field to help the user understand which information to place in each data field;
- Annex B contains a detailed example of the use of the data documentation format" (ISO/TS 14048 2002).

Due to the technical nature of the document, the relevance for the average LCA practitioner and user is somewhat limited. However, for database providers and software developers, ISO/TS 14048 serves as a useful reference.

3.4 ISO 14049—Examples of Inventory Analysis

The full title of this document is 'ISO/TR 14049: 2012 Environmental Management—Life Cycle Assessment—Illustrative examples on how to apply ISO 14044 to goal and scope definition and inventory analysis' (ISO/TR 14049 2012).

"This Technical Report provides examples about practices in carrying out a Life Cycle Inventory Analysis (LCI) as a means of satisfying certain provisions of ISO 14044. These examples are only a sample of the possible cases satisfying the provisions of ISO 14044. They offer 'a way' or 'ways' rather than the 'unique way' for the application of ISO 14044. These examples reflect only portions of a complete LCI study.

- Apart from some general content, the TR focuses on
- Examples of developing functions, functional units and reference flows
- Examples of distinguishing functions of comparative systems
- Examples of establishing inputs and outputs of unit processes and system boundaries

- Examples of avoiding allocation
- Examples of allocation
- Example of applying allocation procedures for recycling
- Examples of conducting data quality assessment
- Examples of performing sensitivity analysis (ISO/TR 14049 2012)."

Compared to ISO/TR 14047, the examples presented here stood the test of time fairly well and the document is still quite relevant today. From the author's non-representative experience, ISO/TR 14049 is the most popular and most used of the three spin-off-standards described in this section.

4 The Future Standards Based on ISO 14040/44

In this section, the future standards based on ISO 14040/44 are introduced. First, the just published ISO 14045 on eco-efficiency assessment is described in Sect. 4.1. This standard goes beyond the purely environmental perspective of LCA and adds the economic perspective into the assessment. In contrast to such broadening of the scope of LCA, the single-issue or footprinting standards have become popular recently. The upcoming ISO 14046 on water footprint is addressed in Sect. 4.2 while carbon footprinting according to ISO/TS 14067 is covered in Sect. 4.3. The final two documents ISO 14071 on critical review (Sect. 4.4) and ISO 14072 on the use of LCA for organizations (Sect. 4.5) provide additional specifications for one element of LCA, respectively guidance for the use of LCA not only on the product level, but also organization level. Because all numbers of the ISO 14040 series were already used, the two latter documents are developed within the new, additional number set for LCA, i.e. the ISO 14070 series (Finkbeiner 2013).

4.1 ISO 14045—Eco-Efficiency Assessment

The standard 'ISO 14045: 2012 Environmental Management—Eco Efficiency Assessment of Product Systems—Principles, Requirements and Guidelines' represents an important step due to a broader focus beyond environmental issues only (ISO 14045 2012). "Eco-efficiency assessment is a quantitative management tool which enables the consideration of life cycle environmental impacts of a product system alongside its product system value to a stakeholder.

Within eco-efficiency assessment, environmental impacts are evaluated using Life Cycle Assessment (LCA) as prescribed by other International Standards (ISO 14040, 14044). Consequently, eco-efficiency assessment shares with LCA many important principles such as life cycle perspective, comprehensiveness, functional unit approach, iterative nature, transparency and priority of scientific approach.

The value of the product system may be chosen to reflect, for example, its resource, production, delivery or use efficiency, or a combination of these. The value may be expressed in monetary terms or other value aspects.

The key objectives of this International Standard are to:

- establish clear terminology and a common methodological framework for eco-efficiency assessment;
- enable the practical use of eco-efficiency assessment for a wide range of product (including service) systems;
- provide clear guidance on the interpretation of eco-efficiency assessment results;
- encourage the transparent, accurate and informative reporting of eco-efficiency assessment results" (ISO 14045 2012).

4.2 ISO 14046—Water Footprint

As mentioned by Berger and Finkbeiner (2012), water footprinting is now a priority in current sustainability discussions after having been neglected for many years due to a lack of both awareness and appropriate methods for accounting and assessing water use and consumption. There is currently not the one and only water footprint method but different approaches to analyze the water use and consumption of organizations or along product life cycles. Next to stand-alone methods, such as virtual water, the method of the Water Footprint Network, the global water tool, or the corporate water gauge, many methods were developed in an LCA context (Berger and Finkbeiner 2012). A review of these methods is provided by Berger and Finkbeiner (2010), even though it is already slightly outdated due to the dynamic developments in the field.

Both the increasing relevance of water footprinting and the diverse methods were the drivers to work on an international standard. The market need for such a standard is confirmed by the large participation in the working group dealing with it. The working group includes more than 100 experts from a diverse mix of countries from the developing and developed world, and both countries which are lucky to have a lot of water resources and countries that suffer from water scarcity. Due to the state of the art in water footprinting, it is premature to expect a standard that will fix THE method to do it. The first version of the standard is about agreeing on the relevant terminology and some key methodological issues and concepts. One of these issues is the discussion of volumetric versus impact-oriented water footprint methods. While the method of the Water Footprint Network, which deserves credit for bringing the issue on the agenda, uses an inventory of water volumes, it is nowadays broadly accepted that this is scientifically not sufficient to address the issue of water scarcity. This is acknowledged by ISO 14046 which currently defines a water footprint clearly on the impact level as "parameter(s) that quantify(ies) the potential environmental impacts related to water" (ISO 14046.CD.1 2012)).

According to the current committee draft document (ISO 14046.CD.1 2012), the scope is defined as "specifying principles, requirements and guidelines to assess

and report the water footprints of products, processes and organizations based on life cycle assessment (LCA). The standard provides requirements and guidance for calculating and reporting a water footprint as a stand-alone assessment or as part of a more comprehensive environmental assessment. The water footprint is calculated as one impact indicator result or multiple impact indicator results."

Due to the large participation in the work and its relevance, the prediction of the publication date involves uncertainties. However, based on the current project plan, the publication of the document is expected for late 2014.

4.3 ISO/TS 14067—Carbon Footprint

As mentioned in Sect. 1.1.3, the topic of carbon footprinting contributed significantly to the growing use of life cycle based assessment tools on the one hand and to a proliferation of guides and 'standards' on the other. On the ISO level, the work on this topic is done by ISO/TC207/SC7 on Greenhouse Gas Management and has led to ISO/TS 14067 'Carbon footprint of products—Requirements and Guidelines for Quantification and Communication' (ISO/TS 14067 2013). According to the introduction of the document, "this International Technical Specification is based on existing ISO standards, e.g. ISO 14020, ISO 14025, ISO 14040 and ISO 14044 and aims to set more specific requirements for the quantification and communication of carbon footprints of products (CFP). Specific requirements apply where the CFP information is intended to be publicly available. This document is expected to benefit organizations, governments, communities and other interested parties by providing clarity and consistency for quantifying, communicating and verifying CFPs. Specifically, using life cycle assessment according to this International Standard with climate change as the single impact category may offer benefits through:

- providing requirements for the methods to be adopted in assessing the CFP;
- facilitating the tracking of performance in reducing GHG emissions;
- assisting in the creation of efficient and consistent procedures to provide CFP information to interested parties;
- providing a better understanding of the CFP such that opportunities for GHG reductions may be identified;
- providing CFP information to encourage changes in consumer behaviour which could contribute to reductions in GHG emissions through improved purchasing, use and disposal decisions;
- providing correct and consistent communication of CFPs which supports comparability of products in a free and open market;
- enhancing the credibility, consistency and transparency of the quantification, reporting and communication of the CFP;
- facilitating the evaluation of alternative product design and sourcing options, production and manufacturing methods, raw material choices, recycling and other end-of-life stages;

- facilitating the development and implementation of GHG management strategies and plans across product life cycles as well as the detection of additional efficiencies in the supply chain."

While the specification has grown to a lengthy document of over 50 pages, most of its content is just a repetition of content of previous standards. For the quantification part, a lot of content of ISO 14044 is copied into ISO/TS 14067. As a matter of fact, the additional CFP specific requirements for quantification are rather few and would easily fit on a handful of pages. While such a 'delta'-standard would have been more efficient, the working group wanted to develop a 'stand-alone' document. This was—amongst others (e.g. merging of the originally separate quantification and communication parts, lack of team spirit and knowledge on underlying standards, lack of process quality and leadership)—one of the reasons why the overall standardization process took much longer than it was supposed to be.

Originally, the publication of the standard was due in March 2011. The final publication of the document in 2013 was on the level of a Technical Specification and not on the level of an International standard, because the different committee drafts and draft international standards have been several times rejected in the voting of the national standardization bodies.

4.4 ISO 14071—Critical Review

The proposal to develop a Technical Specification ISO 14071 'Environmental Management—Life Cycle Assessment—Requirements and Guidelines for Critical Review Processes and Reviewer Competencies' was motivated from the discussion on conformity assessment of e.g. the carbon footprint standards or upcoming labelling initiatives. As part of these processes, different interested parties proposed different conformity assessment schemes including critical review according to ISO 14040 and ISO 14044, verification according to ISO 14025, but also the bureaucratic accountant approach according to greenhouse gas verification. The critical review approach was very successful within the LCA community. Despite the concise content in the standards, a common practice emerged in the market place that satisfied all stakeholders. For the mandatory case of comparative assertions disclosed to the public, but also in many cases for which a critical review is not mandatory, study commissioners decided to perform a critical review to improve their studies and to support credibility. One of the key success factors is that the system does not operate an accreditation scheme which tries to ensure quality by bureaucracy and in which verification bodies that can afford the overhead cost then send some inexperienced individuals actually doing the job. The critical review system ensured quality by making the individual reviewer accountable for the work and spending the resources on content rather than paper work.

While, this is generally accepted in the LCA world, the critical review system had a challenge to be argued 'against' the bloated verification documents of other schemes (sometimes even three—one for the verification process, one for veri-

fication bodies, one for the competence of verifiers). In order to document the well established critical review practice in a more formal way, the intention of this coming international technical specification is to provide requirements and guidelines for conducting a critical review and the competencies required. It will describe:

- details of a Critical Review process including clarification with regard to ISO 14044;
- guidelines to deliver the required Critical Review process linked to the goal of the LCA and its intended use;
- content and deliverables of the Critical Review process;
- guidelines to improve the consistency, transparency, efficiency and credibility of the Critical Review process;
- the required competencies for the reviewer(s) (internal, external and panel member);
- the required competencies to be represented by the panel as a whole.

The target is to provide a crisp and lean specification that documents the established best practice for performing critical reviews. The publication of the document is expected in 2014.

4.5 ISO 14072—Organizational LCA (OLCA)

The benefits and the potential of the life cycle approach are not limited to an application on products. While the LCA methodology was originally developed for products, its application on the organizational level is getting more and more relevant (Finkbeiner and König 2013). The discussions on carbon footprinting of companies including their upstream and downstream supply chains (the so-called ‘scope 3’ according to the GHG-Protocol) (Finkbeiner 2009) revealed that these ‘life cycle’ emissions can contribute significantly to the organizational footprint. The currently applied assessments mostly concentrate on a single aspect like carbon or water footprints. The purpose of this new standard is to present a general and comprehensive approach by adapting LCA methodology on organizations.

The document ISO 14072 is supposed to be a Technical Specification (TS) called Environmental management—Life cycle assessment—Requirements and guidelines for Organizational Life Cycle Assessment. The main goal is to provide additional guidance to organizations for an easier and more effective application of ISO 14040 and ISO 14044 on the organizational level including the advantages that LCA may bring to organizations, the system boundaries and the limitations regarding reporting, environmental declarations and comparative assertions. It is intended for any organization that has interest in applying LCA. It is not intended for ISO 14001 interpretation and covers the goals of ISO 14040 and 14044. The publication of the document is expected in 2014.

5 Summary and Outlook

The establishment of the international standards of LCA (ISO 14040 series) was crucial for the broad acceptance of LCA all around the world and by all stakeholders. The ISO standards of LCA (ISO 14040 and ISO 14044) are until today the one and only globally relevant international standard documents on LCA which are broadly referenced by users and other standardization processes. The standards contributed significantly to the transition of LCA from an academic toy or misused greenwashing machine towards a serious, robust and professional tool to support decision-making in public and private organizations.

They represent the constitution of LCA and should therefore be respected and protected by everyone. It is fair to ask for more specific stipulations in future versions, if global consensus evolves on such issues. If such a consensus does not exist, we have to be aware that asking for more sometimes leads to getting less than we already have—half a loaf is better than no bread.

Some future activities have already been highlighted in Sect. 4. They represent fairly well the future direction that the author anticipates at this point in time. We will have some additional standards that specify particular parts of LCA methodology (e.g. critical review, Organizational LCA), we will have some further standards on simplified LCA versions (e.g. carbon or water footprinting) and we will expand the environmental focus towards all three sustainability dimensions (resource efficiency, life cycle costing, social LCA, life cycle sustainability assessment). All these developments shall support the credible and robust use of LCA for real world decision-making in the sense of life cycle management and life cycle sustainability management (Finkbeiner 2011). “If we want to make sustainability happen as concrete reality in both public policy making and corporate strategies, sustainability cannot please everybody. This requires that we are able to address the question, how sustainability performance can be measured, especially for companies, products and processes. We have to be smart enough to be able to measure it or the real and substantial implementation of the sustainability concept will remain just wishful thinking. In order to achieve reliable and robust sustainability assessment results it is inevitable that the principles of comprehensiveness and life cycle perspective are applied” (Finkbeiner 2011). In systems that support participation of citizens and democracy, this requires commonly accepted rules. ISO 14040 and ISO 14044 achieved to be that for LCA in the last decade. The author sincerely hopes and expects that there are more global citizens and good reasons out there that ensure keeping such a basic law of LCA. It is by no means a guarantee for sustainable development, but it makes it more probable.

Appendix-Glossary

Core standards of LCA	ISO 14040 2006 and ISO 14044 2006
International standards of LCA	ISO 14040 series
ISO	International Organization for Standardization
ISO 14040	Environmental Management—Life Cycle Assessment—Principles and Framework (1997 and 2006)
ISO 14041	Environmental Management—Life Cycle Assessment—Goal and Scope Definition and Inventory Analysis (1998)
ISO 14042	Environmental Management—Life Cycle Assessment—Life Cycle Impact Assessment (2000)
ISO 14043	Environmental Management—Life Cycle Assessment—Life Cycle Interpretation (2000)
ISO 14044	Environmental Management—Life Cycle Assessment—Requirements and Guidelines (2006)
ISO/DIS	Draft International Standard
ISO/TC207/SC5	ISO/Technical Committee 207 (Environmental management)/Subcommittee 5 (LCA)
ISO/TR	Technical report
ISO/TS	Technical specification
NWIPs	New Work Item Proposals
Spin-off standards	ISO 14025—Environmental Labels and Declarations, Type III: Environmental Declarations—Principles and Procedures (2006) ISO 14045—Environmental Management—Eco-efficiency Assessment of Product Systems—Principles, Requirements and Guidelines (2012) ISO/CD.1 14046—Water Footprint—Requirements and Guidelines (publication is expected in late 2014) ISO/TR 14047—Environmental Management—Life Cycle Assessment—Illustrative examples on how to apply ISO 14044 to impact assessment situations (2012) ISO/TS 14048—Environmental Management—Life Cycle Assessment—Data Documentation Format (2002) ISO/TR 14049—Environmental Management—Life Cycle Assessment—Illustrative examples on how to apply ISO 14044 to goal and scope definition and inventory analysis (2012) ISO/TS 14067—Carbon Footprint of Products—Requirements and Guidelines for Quantification and Communication (2013) ISO/TS 14071—Environmental Management—Life Cycle Assessment—Requirements and Guidelines for Critical Review Processes and Reviewer Competencies (publication is expected in 2014) ISO 14072 is supposed to be a Technical Specification called Environmental management—Life cycle assessment—Requirements and guidelines for Organizational Life Cycle Assessment (publication is expected in 2014)
WBCSD	World Business Council for Sustainable Development (WBCSD)

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