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Environmental management — Life cycle assessment — Principles and framework

Management environnemental — Analyse du cycle de vie — Principes et cadre

[Revision of first edition (ISO 14040:1997)]

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 14040 was prepared by Technical Committee ISO/TC 207, *Environmental Management*, Subcommittee SC 5, *Life cycle assessment*.

This second edition cancels and replaces the first edition (ISO 14040:1997, ISO 14041:1999, ISO 14042:2000, ISO 14043:2000), which have been technically revised.

Introduction

The increased awareness of the importance of environmental protection, and the possible impacts associated with products¹⁾, both manufactured and consumed, has increased the interest in the development of methods to better understand and address these impacts. One of the techniques being developed for this purpose is Life Cycle Assessment (LCA).

LCA can assist in

- identifying opportunities to improve the environmental performance of products at various points in their life cycle;
- informing decision-makers in industry, governmental or non-governmental organizations (e.g. strategic planning, priority setting, product or process design or redesign);
- selection of relevant indicators of environmental performance, including measurement techniques; and
- marketing (e.g. an environmental claim, ecolabelling scheme or environmental product declaration).

For practitioners of LCA, ISO 14044 details the requirements for the conduct of LCA studies and LCI studies.

LCA address the environmental aspects and potential environmental impacts²⁾ (e.g. resource use and environmental consequences of releases) throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment and disposal (i.e. cradle-to-grave).

There are four phases in an LCA study: The goal and scope definition phase, the inventory analysis phase, the impact assessment phase and the interpretation phase.

The scope, system boundary and level of detail of an LCA depend on the subject and intended use of the study. The depth and breadth of LCA may differ considerably depending on the goal of a particular LCA.

The life cycle inventory analysis phase (LCI phase) is the second phase of LCA. It is an inventory of input/output data with respect to the system being studied. It involves the collection of the data necessary to meet the goals of the defined study

The life cycle impact assessment phase (LCIA) is the third phase of the LCA. The purpose of LCIA is to provide additional information to help assess a product system's LCI results to better understand their environmental significance.

Life cycle interpretation is the final phase of the LCA procedure, in which the results of an LCI and/or of an LCIA, or both, are summarized and discussed as a basis for conclusions, recommendations and decision-making in accordance with the goal and scope definition.

There are cases where the goal and scope definition of an LCA may be satisfied by performing only an inventory analysis and an interpretation. This is usually referred to as an LCI study.

1) In this International Standard, the term "product" used alone not only includes product systems but also service systems.

2) The "potential environmental impacts" are relative expressions, as they are related to the functional unit of a product system.

This standard covers two types of studies: Life Cycle Assessment studies (LCA studies) and Life Cycle Inventory studies (LCI studies). LCI studies are similar to LCA studies but lack the LCIA phase. LCI studies should not be confused with the LCIA phase.

Generally, the information developed in an LCA or LCI study can be used as part of a much more comprehensive decision process. Comparing the results of different LCA or LCI studies is only possible if the assumptions and context of each study are equivalent. These assumptions are explicitly stated for reasons of transparency.

LCA is one of several environmental management techniques (e.g. risk assessment, environmental performance evaluation, environmental auditing, and environmental impact assessment) and may not be the most appropriate technique to use in all situations. LCA typically does not address the economic or social aspects of a product, but the life cycle approach and methodologies described in this International Standard can be applied on these other aspects.

Environmental management — Life cycle assessment — Principles and framework

1 Scope

This International Standard describes the principles and framework for life cycle assessment (LCA) including:

- a) The compilation and preparation of the definition of goal and scope of the LCA;
- b) The life cycle inventory analysis (LCI) phase;
- c) The life cycle impact assessment (LCIA) phase;
- d) The life cycle interpretation phase;
- e) The reporting and critical review of the LCA;
- f) The limitations of the LCA;
- g) The relationship between the LCA phases;
- h) The conditions for use of value choices and optional elements.

This International Standard covers life cycle assessment (LCA) studies and life cycle inventory (LCI) studies.

This International Standard does not describe the LCA technique in detail or specific methodologies for the individual phases of the LCA.

The intended application of LCA or LCI results is considered during the goal and scope definition, but the application is outside the scope of this International Standard.

This International Standard, like other International Standards, is not intended to be used to create non-tariff trade barriers or to increase or change an organization's legal obligations. Neither is the standard intended for contractual or regulatory purposes or registration and certification.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14044:200X, *Environmental management – Life cycle assessment – Requirements and guidelines*

3 Terms and definitions

For the purpose of this International Standard, the following terms and definitions apply.

3.1

allocation

partitioning the input or output flows of a process or other product system to the product system under study

3.2

ancillary input

material input that is used by the unit process producing the product, but not constituting a part of the product

3.3

category endpoint

attribute or aspect of natural environment, human health, or resources, identifying an environmental issue of concern

NOTE Figure 3 illustrates this term in further detail

3.4

characterization factor

factor derived from a characterization model that is applied to convert the assigned LCI results to the common unit of the category indicator

NOTE The common unit allows aggregation into category indicator result

3.5

comparative assertion

environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function

3.6

completeness check

process of verifying whether information from the phases of an LCA or an LCI study is sufficient for reaching conclusions in accordance with the goal and scope definition

3.7

consistency check

process of verifying that the assumptions, methods and data are consistently applied throughout the study and in accordance with the goal and scope definition

NOTE The consistency check should be performed before conclusions are reached

3.8

co-product

any of two or more products coming from the same unit process or product system

3.9

critical review

process ensuring consistency between an LCA and the principles and the requirements of the International Standards on life cycle assessment

NOTE 1 The principles are described in ISO 14040

NOTE 2 The requirements are described in ISO 14044

3.10

cut-off criteria

specification of amount of material or energy flow₁ or level of environmental significance associated with unit processes or product system to be excluded from a study

3.11**data quality**

characteristics of data that bear on their ability to satisfy stated requirements

3.12**elementary flow**

(1) material or energy entering the system being studied that has been drawn from the environment without previous human transformation

(2) material or energy leaving the system being studied that is released into the environment without subsequent human transformation

3.13**energy flow**

input to or output from a unit process or product system quantified in energy units

NOTE Energy flow that is input may be called energy input; energy flow that is output may be called energy output

3.14**environmental aspect**

element of an organization's activities, products or services that can interact with the environment

[ISO 14001 : 2004]

3.15**environmental mechanism**

system of physical, chemical, and biological processes for a given impact category, linking the LCI results to category indicators, and to category endpoints

3.16**evaluation**

step within the life cycle interpretation phase to establish confidence in the results of the LCA or LCI study

NOTE evaluation includes completeness check, sensitivity check, consistency check, and any other validation that may be required according to the goal and scope definition of the study.

3.17**feedstock energy**

combustion heat of raw material input that is not used as an energy source, to a product system, expressed in terms of higher heating value or lower heating value

NOTE Care should be taken to ensure that double counting of raw material energy content is not done.

3.18**functional unit**

quantified performance of a product system for use as a reference unit

3.19**impact category**

class representing environmental issues of concern to which LCI results may be assigned

3.20**impact category indicator**

quantifiable representation of an impact category

NOTE The shorter expression **3.19 category indicator** is used in the text of this International Standard for improved readability

3.21

input

material or energy, which enters a unit process

NOTE Materials may include raw materials and products

3.22

interested party

individual or group concerned with or affected by the environmental performance of a product system, or by the results of the life cycle assessment

3.23

intermediate flow

flow occurring between unit processes of the product system being studied

3.24

intermediate product

output from a unit process that is input to other unit processes requiring further transformation within the system

3.25

life cycle

consecutive and interlinked stages of a product system, from raw material acquisition or generation of natural resources to final disposal

3.26

life cycle assessment (LCA)

compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle

3.27

life cycle impact assessment (LCIA)

phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts of a product system

3.28

life cycle interpretation

phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are combined in line with the defined goal and scope in order to reach conclusions and recommendations

3.29

life cycle inventory analysis (LCI)

phase of life cycle assessment involving the compilation and quantification of inputs and outputs, for a given product system throughout its life cycle

3.30

life cycle inventory analysis result (LCI result)

outcome of a life cycle inventory analysis that catalogues the flows crossing the system boundary and provides the starting point for life cycle impact assessment

3.31

output

material or energy that leaves a unit process

NOTE Materials may include raw materials, intermediate products, co-products, products, and releases

3.32

process

set of interrelated or interacting activities that transforms inputs into outputs

[ISO 9000:2000, 3.4.1, without notes]

3.33

process energy

energy input required for operating the process or equipment within a unit process excluding energy inputs for production and delivery of the energy itself

energy input required for operating the process or equipment within a unit process

3.34

product

any goods or service

NOTE 1 The product can be categorized as follows:

- services (e.g. transport);
- software (e.g. computer program, dictionary);
- hardware (e.g. engine mechanical part);
- processed materials (e.g. lubricant);

NOTE 2 Services have tangible and intangible elements. Provision of a service can involve, for example, the following:

- an activity performed on a customer-supplied tangible product (e.g. automobile to be repaired)
- an activity performed on a customer-supplied intangible product (e.g. the income statement needed to prepare a tax return)
- the delivery of an intangible product (e.g. the delivery of information in the context of knowledge transmission)
- the creation of ambience for the customer (e.g. in hotels and restaurants)

Software consists of information and is generally intangible and can be in the form of approaches, transactions or procedures.

Hardware is generally tangible and its amount is a countable characteristic. Processed materials are generally tangible and their amount is a continuous characteristic

[Adapted from ISO 14021:1999 and ISO 9000:2000]

3.35

product flow

products entering from or leaving to another product system

3.36

product system

collection of unit processes with elementary and product flows, performing one or more defined functions, that models the life cycle of a product

3.37

raw material

primary or secondary material that is used to produce a product

NOTE Secondary material includes recycled material.

3.38

reference flow

measure of the outputs from processes in a given product system required to fulfill the function expressed by the functional unit

3.39

releases

emissions to air and discharges to water and soil

3.40

sensitivity analysis

systematic procedures for estimating the effects of the choices made regarding methods and data on the outcome of a study

3.41

sensitivity check

process of verifying that the information obtained from a sensitivity analysis is relevant for reaching the conclusions and giving recommendations

3.42

system boundary

a set of criteria specifying which unit processes are part of a product system

NOTE The term system boundary is not used in this standard in relation to LCIA.

3.43

transparency

open, comprehensive and understandable presentation of information

3.44

uncertainty analysis

systematic procedure to quantify the uncertainty introduced in the results of a life cycle inventory analysis due to the cumulative effects of model imprecision, input uncertainty, and data variability

NOTE Either ranges or probability distributions are used to determine uncertainty in the results.

3.45

unit process

smallest element of a product system for which data are collected when performing a life cycle assessment

3.46

waste

substances or objects which the holder intends or is required to dispose of

NOTE The definition is taken from the "Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal" (22. March 1989) but is not confined in this International Standard to hazardous waste

4 General description of life cycle assessment (LCA)

4.1 Principles of LCA

4.1.1 General

These principles are fundamental and should be used as guidance for decisions related to LCA.

4.1.2 Life cycle perspective

LCA considers the entire life cycle of a product, from raw material extraction and acquisition, through energy and material production and manufacturing, to use and end of life treatment and final disposal. Through such a systematic overview and perspective, burden shifting between life cycle stages or individual processes can be identified and possibly avoided.

4.1.3 Environmental focus

LCA addresses the environmental aspects and impacts of a product system. Economic and social aspects and impacts are, typically, outside the scope of the LCA. Other tools may be combined with LCA for more complete assessments.

4.1.4 Relative approach and functional unit

LCA is 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 the LCIA profile is related to the functional unit.

4.1.5 Iterative approach

LCA is an iterative technique. The individual phases of an LCA use results of the other phases. The iterative approach within and between the phases contributes to the comprehensiveness and consistency of the study and the reported results.

4.1.6 Transparency

Due to the inherent complexity in LCA, transparency is an important guiding principle in executing LCAs, in order to ensure a proper interpretation of the results.

4.1.7 Comprehensiveness

LCA considers all attributes or aspects of natural environment, human health and resources. By considering all attributes and aspects within one study in a cross-media perspective, potential trade-offs can be identified and assessed.

4.1.8 Priority of scientific approach

Decisions within an LCA are preferably based on natural science. If this is not possible, other scientific approaches (e.g. from social and economic sciences) can be used or international conventions can be referred to. If neither a scientific basis exists nor a justification based on other scientific approaches or international conventions is possible, then decisions may be based on appropriate value choices.

4.2 Phases of an LCA

LCA studies are comprised of four phases. The relationship between the phases is illustrated in figure 1. These are:

- definition of goal and scope;
- inventory analysis;
- impact assessment; and
- interpretation of results.

LCI studies are comprised of three phases:

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- definition of goal and scope;
- inventory analysis; and
- interpretation of results.

LCA results may be useful inputs to a variety of decision-making processes.

Direct applications of the results of LCA or LCI studies i.e. the applications intended in the goal and scope definition of the LCA or LCI study are depicted in figure 1. More information on application areas for LCA or LCI results can be found in Annex A.

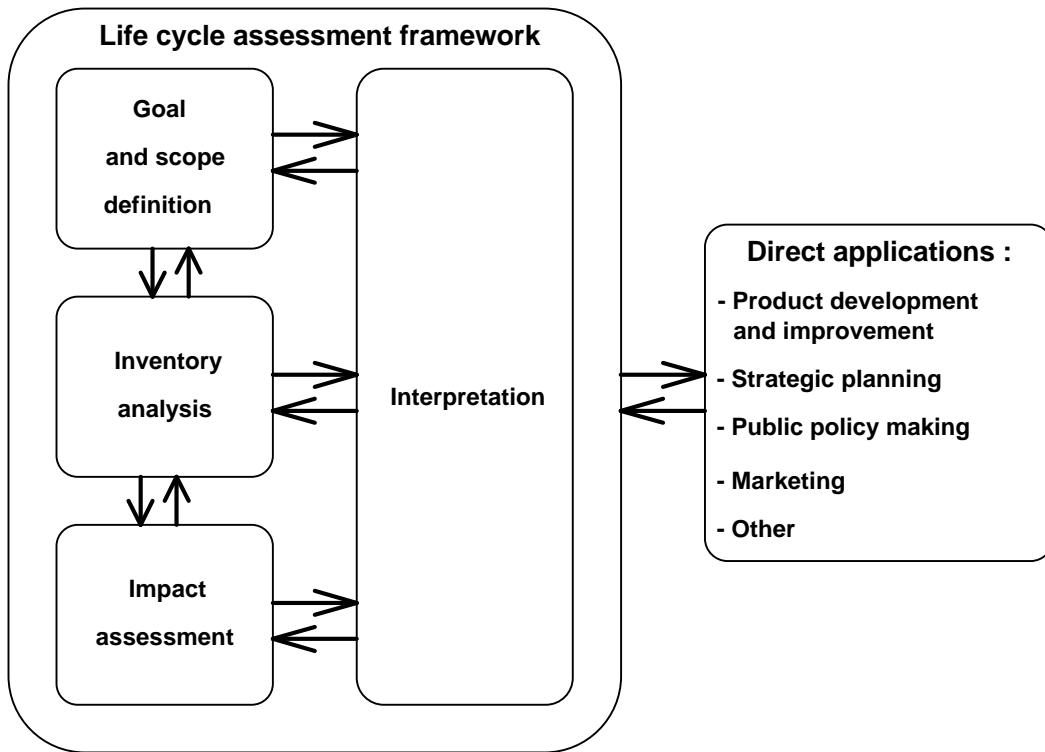


Figure 1 - Phases of an LCA

4.3 Key features of an LCA

The following list summarizes some of the key features of the LCA methodology:

- LCA studies address, systematically and adequately, the environmental aspects and impacts of product systems, from raw material acquisition to final disposal, according to its relative nature 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 definition of goal and scope;
- 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 technology;
- 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 as established in this International Standard, 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 in that 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 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, the life cycle impact category indicator is selected and the category indicator result, (hereafter referred to as the indicator result), is calculated. The collection of indicator results, hereafter referred to as 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 or LCI study, 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 or an LCI study;
- life cycle interpretation makes provisions for links between LCA and other techniques for environmental management by emphasizing the strengths and limits of an LCA or an LCI study in relation to its goal and scope definition.

4.4 General concepts of product systems

A product system is a collection of unit processes, which perform one or more defined functions.

The essential property of a product system is characterized by its function, and cannot be defined solely in terms of the final products. Figure 2 shows an example of a product system.

Product systems are subdivided into a set of unit processes (see Figure 3). Unit processes are linked to one another by flows of intermediate products and/or waste for treatment, to other product systems by product flows, and to the environment by elementary flows.

Dividing a product system into its component unit processes facilitates the identification of the inputs and outputs of the product system. In many cases, some of the inputs are used as a component of the output product, while others (ancillary inputs) are used within a unit process but are not part of the output product. A unit process also generates other outputs (elementary flows and/or products) as a

result of its activities. The level of modelling detail that is required to satisfy the goal of the study determines the boundary of a unit process.

The elementary flows may include the use of resources and releases to air, water and land associated with the system. Interpretations may be drawn from these data, depending on the goals and scope of the LCA. These data are the LCI results and constitute the input for LCIA.

Examples of elementary flows entering the unit process are crude oil from ground and solar radiation. Examples of elementary flows leaving the unit process are emissions to air, discharges to water or soil and radiation. Examples of intermediate product flows are basic materials and subassemblies. Examples of product flows entering or leaving the system are recycled materials and components for reuse.

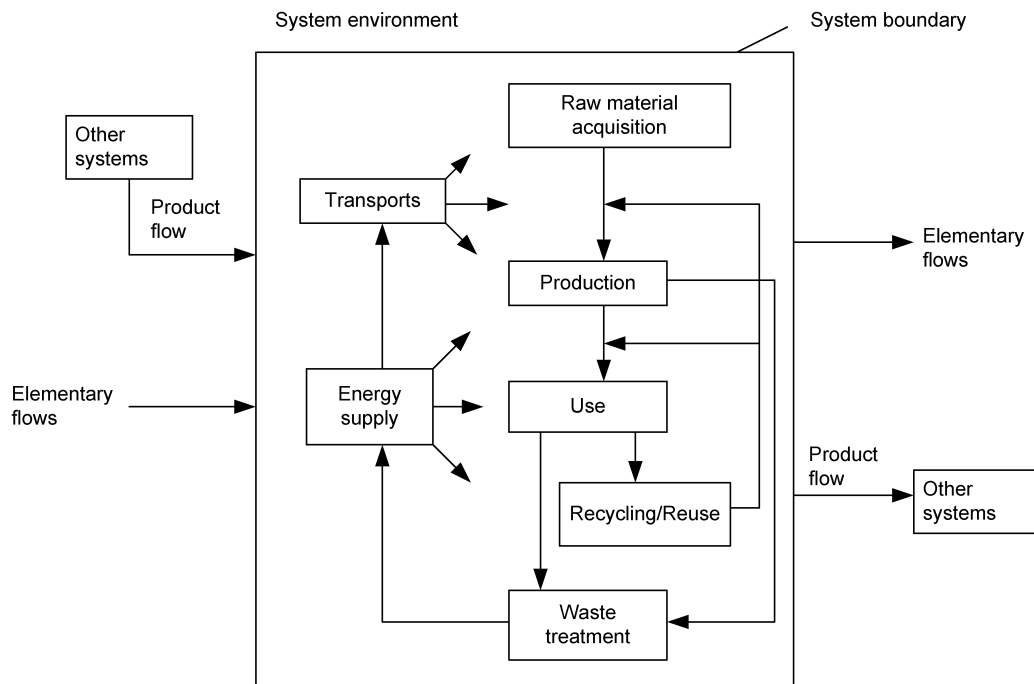


Figure 2 – An example of a product system for LCA

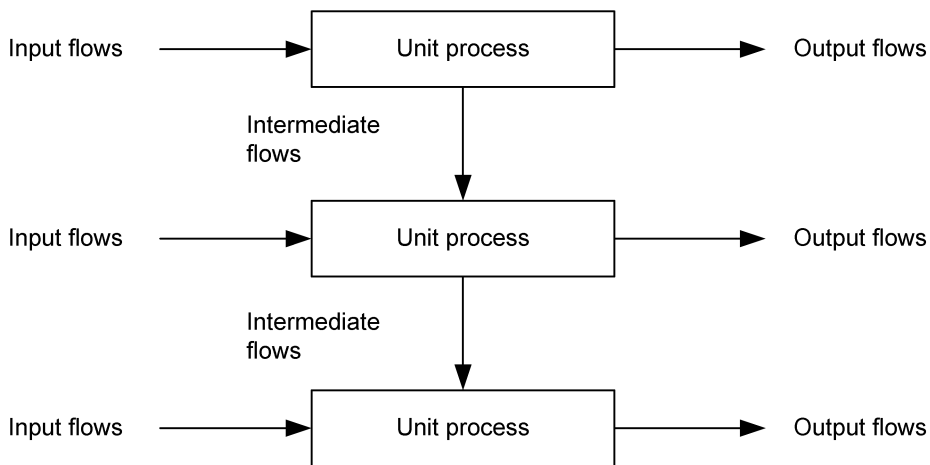


Figure 3 – An example of a set of unit processes within a product system e.g. for "Production"

5 Methodological framework

5.1 General requirement

When performing an LCA, the requirements of ISO 14044 shall apply.

5.2 Definition of goal and scope

5.2.1 General

The goal of an LCA states:

- the intended application;
- the reasons for carrying out the study;
- the intended audience, i.e. to whom the results of the study are intended to be communicated; and
- whether the results are intended to be used in comparative assertions intended to be disclosed to the public.

The scope should be sufficiently well defined to ensure that the breadth, depth and detail of the study are compatible and sufficient to address the stated goal.

The scope includes the following items:

- the functions of the product system, or, in the case of comparative studies, the systems;
- the functional unit;
- the product system to be studied;
- the system boundary;
- allocation procedures;
- impact categories selected and methodology of impact assessment, and subsequent interpretation to be used;
- data requirements;
- assumptions;
- limitations;
- initial data quality requirements;
- type of critical review, if any;
- type and format of the report required for the study.

LCA is an iterative technique, and as data and information are collected, various aspects of the scope may require modification in order to meet the original goal of the study.

5.2.2 Function, functional unit and reference flows

A system may have a number of possible functions and the one(s) selected for a study is (are) dependent on the goal and scope of the LCA.

The functional unit defines the quantification of the identified functions (performance characteristics) of the product. The primary purpose of a functional unit is to provide a reference to which the inputs and outputs are related. This reference is necessary to ensure comparability of LCA results. Comparability of LCA results is particularly critical when different systems are being assessed to ensure that such comparisons are made on a common basis.

It is important to determine the reference flow in each product system, in order to fulfil the intended function, i.e. the amount of products needed to fulfil the function.

EXAMPLE In the function of drying hands, both a paper towel and an air-dryer system are studied. The selected functional unit may be expressed in terms of the identical number of pairs of hands dried for both systems. For each system, it is possible to determine the reference flow, e.g. the average mass of paper or the average volume of hot air required for one pair of hand-dry, respectively. For both systems, it is possible to compile an inventory of inputs and outputs on the basis of the reference flows. At its simplest level, in the case of paper towel, this would be related to the paper consumed. In case of the air-dryer, this would be related to the mass of hot air needed to dry the hands.

5.2.3 System boundary

LCA studies are conducted by developing models that describe the key elements of physical systems. The system boundary defines the unit processes to be included in the system to be modelled. Ideally, the product system should be modelled in such a manner that inputs and outputs at its boundary are elementary flows and the environmental system should be modelled with respect to all impacts from those elementary flows. However, resources need not be expended on the quantification of such inputs and outputs that will not significantly change the overall conclusions of the study.

The choice of elements of the physical system to be modelled is dependent on the definition of the goal and scope of the study, its intended application and audience, the assumptions made, data and cost constraints, and cut-off criteria. The models used should be described and the assumptions underlying those choices should be identified. The cut-off criteria used within a study should be clearly understood and described.

The cut-off criteria used in setting the system boundary are important for the degree of confidence in the results of a study and the possibility of reaching its goal.

When setting the system boundary, several life cycle stages, unit processes and flows should be taken into consideration, e.g.:

- inputs and outputs in the main manufacturing/processing sequence;
- distribution/transportation;
- production and use of fuels, electricity and heat;
- use and maintenance of products;
- disposal of process wastes and products;
- recovery of used products (including reuse, recycling and energy recovery);
- manufacture of ancillary materials;
- manufacture, maintenance and decommissioning of capital equipment;

- additional operations, such as lighting and heating;
- other considerations related to impact assessment (if any) e.g. impact categories and category indicators, temporal and spatial extension, and position of category indicators in the cause-effect chain.

In many instances that system boundary defined initially will subsequently be refined.

5.2.4 Data quality requirements

Data quality requirements specify in general terms the characteristics of the data needed for the study.

Descriptions of data quality are important to understand the reliability of the study results and properly interpret the outcome of the study.

5.3 Life cycle inventory analysis (LCI)

5.3.1 General

Inventory analysis involves data collection and calculation procedures to quantify relevant inputs and outputs of a product system.

The process of conducting an inventory analysis is iterative. As data are collected and more is learned about the system, new data requirements or limitations may be identified that require a change in the data collection procedures so that the goals of the study will still be met. Sometimes, issues may be identified that require revisions to the goal or scope of the study.

5.3.2 Data collection

Data for each unit process within the systems boundary can be classified under major headings, including:

- energy inputs, raw material inputs, ancillary inputs, other physical inputs;
- products, co-products and waste;
- emissions to air, discharges to water and soil;
- other environmental aspects.

Data collection can be a resource-intensive process. Practical constraints on data collection should be considered in the scope and documented in the study report.

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.

5.3.3 Data calculation

Following the data collection, calculation procedures including validation of data collected and relating data to unit processes and to functional unit are needed to generate the results of the inventory of the defined system for each unit process and for the defined functional unit of the product system that is to be modelled.

The calculation of energy flows should take into account the different fuels and electricity sources used, the efficiency of conversion and distribution of energy flow as well as the inputs and outputs associated with the generation and use of that energy flow.

5.3.4 Allocation of flows and releases

In practice, few industrial processes yield a single output or are based on a linearity of raw materials inputs and outputs. In fact, most industrial processes yield more than one product, and they recycle intermediate or discarded products as raw materials.

Consideration should be given to the need for allocation procedures, when dealing with systems involving multiple products and recycling systems.

5.4 Life cycle impact assessment (LCIA)

5.4.1 General

The impact assessment phase of LCA is aimed at evaluating the significance of potential environmental impacts using the LCI results. In general, this process involves associating inventory data with specific environmental impact categories and category indicators, and thereby attempting to understand these impacts. The LCIA phase also provides information for the life cycle interpretation phase.

The impact assessment may include the iterative process of reviewing the goal and scope of the LCA study to determine if the objectives of the study have been met, or to modify the goal and scope if the assessment indicates that they cannot be achieved.

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.

Issues such as choice, modelling and evaluation of impact categories can introduce subjectivity in the LCIA phase. Therefore, transparency is critical to impact assessment to ensure that assumptions are clearly described and reported.

5.4.2 Elements of LCIA

The elements of the LCIA phase are illustrated in Figure 4.

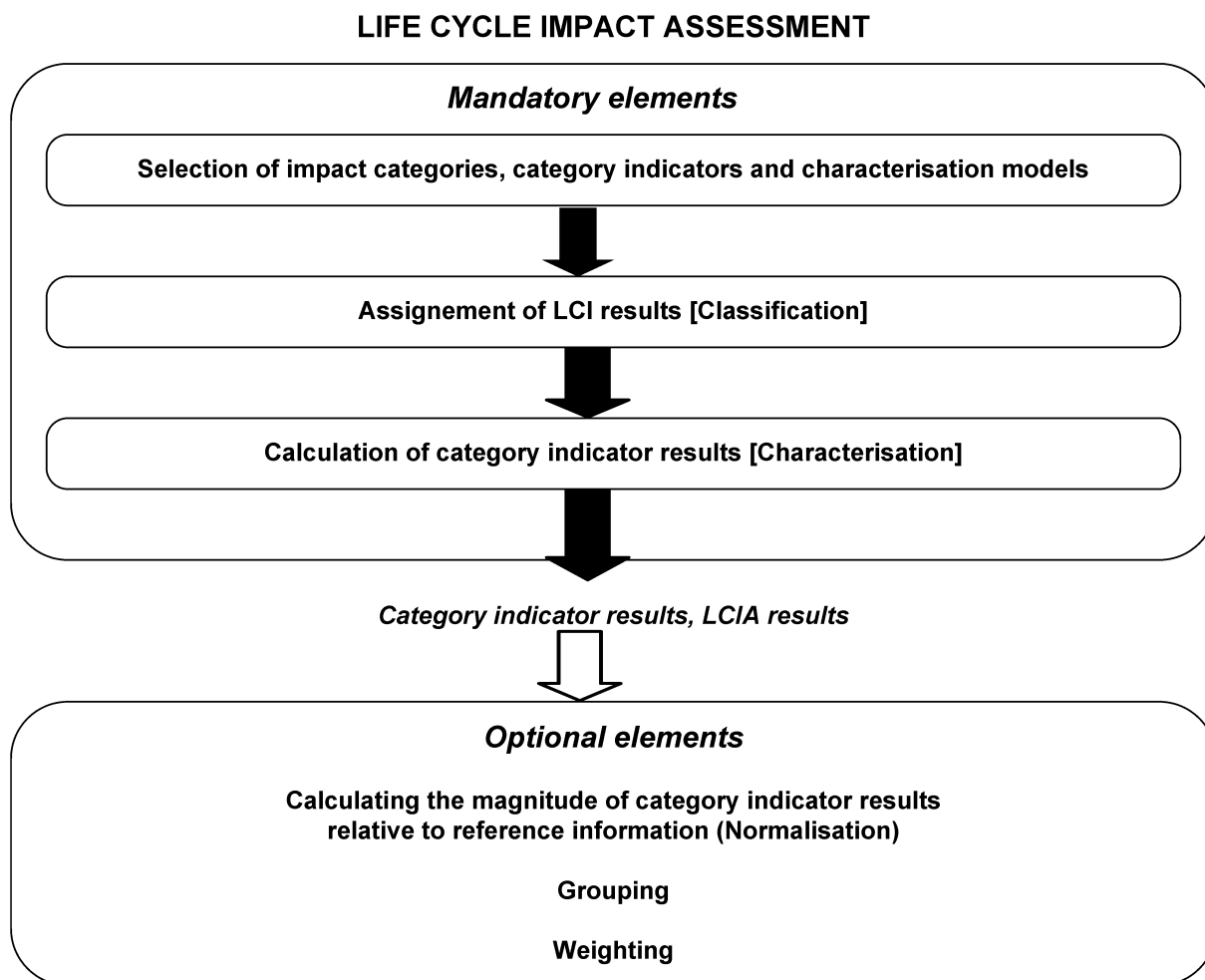


Figure 4 — Elements of the LCIA phase

Separation of the LCIA phase into different elements is helpful and necessary for several reasons.

- a) Each LCIA element is distinct and can be clearly defined;
- b) The goal and scope definition phase of an LCA can consider each LCIA element separately;
- c) A quality assessment of the LCIA methods, assumptions and other decisions can be conducted for each LCIA element;
- d) LCIA procedures, assumptions and other operations within each element can be made transparent for critical review and reporting;
- e) The use of values and subjectivity (hereafter referred to as value-choices), within each element, can be made transparent for critical review and reporting.

The level of detail, choice of impacts evaluated and methodologies used depend on the goal and scope of the study.

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 among 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 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.

5.5 Life cycle interpretation

Interpretation is the phase of LCA in which the findings from the inventory analysis and the impact assessment are considered together, or, in the case of LCI studies, the findings of the inventory analysis only. The interpretation phase should deliver results that are consistent with the defined goal and scope and which reach conclusions, explain limitations and provide recommendations.

The interpretation should reflect the fact that the LCIA results are based on a relative approach, that it indicates potential environmental effects and that it does not predict actual impacts on category endpoints, the exceedance of thresholds or safety margins or risks.

The findings of this interpretation may take the form of conclusions and recommendations to decision-makers, consistent with the goal and scope of the study.

Life cycle interpretation is also intended to provide a readily understandable, complete and consistent presentation of the results of an LCA or an LCI study, in accordance with the goal and scope definition of the study.

The interpretation phase may involve the iterative process of reviewing and revising the scope of the LCA, as well as the nature and quality of the data collected in a way, which is consistent with the defined goal.

The findings of the life cycle interpretation should reflect the results of the evaluation element.

6 Reporting

A reporting strategy is an integral part of an LCA. An effective report should address the different phases of the study under consideration.

The results and conclusions of the LCA or LCI study are reported in an adequate form to the intended audience. The data, methods, assumptions applied in the study and limitations thereof are addressed by the report.

If the study extends to the LCIA phase and is reported to a third-party, the following issues should be reported:

- relationship with the LCI results;
- category endpoints to be protected;
- selection of impact categories;

- characterization models;
- factors and mechanisms; and
- the indicator results profile.

The relative nature of the LCIA results and their inadequacy to predict impacts on category endpoints should also be addressed in the report. It also requires reference and description of value choices used in the LCIA phase of the study in relation to characterization models, normalization, weighting, etc.

Other requirements are included in ISO 14044 whenever the study results are intended to be used in comparative assertions intended to be disclosed to the public. Further, in reporting the interpretation phase, ISO 14044 requires full transparency in terms of value choices, rationales and expert judgements.

7 Critical review

7.1 General

Critical review is a process to verify whether an LCA or LCI study has met the requirements for methodology, data, interpretation and reporting.

In general, critical reviews of an LCA may utilize any of the review options outlined in 7.3. A critical review can neither verify nor validate the goals that are chosen for an LCA or LCI study by the study commissioner, or the uses to which LCA or LCI results are put.

7.2 Need for critical review

A critical review may facilitate understanding and enhance the credibility of LCA studies, for example by involving interested parties.

The use of LCA results to support comparative assertions raises special concerns and requires critical review, since this application is likely to affect interested parties that are external to the LCA. However, the fact that a critical review has been conducted should in no way imply an endorsement of any comparative assertion that is based on an LCA study.

7.3 Critical review processes

7.3.1 General

The scope and type of critical review desired is defined in the scope phase of an LCA. The scope should identify why the critical review is being undertaken, what will be covered and to what level of detail, and who needs to be involved in the process.

The review should ensure that the classification, characterization, normalization, grouping, and weighting elements are sufficient to support the life cycle interpretation phase of the LCA.

Confidentiality agreements regarding the content of the LCA should be entered into as needed.

7.3.2 Critical review by internal or external expert

The internal or external expert should be familiar with the requirements of LCA and have the appropriate scientific and technical expertise.

7.3.3 Critical review by panel of interested parties

An external independent expert is selected by the original study commissioner to act as chairperson of a review panel of at least 3 members. Based on the goal, scope and budget available for the review, the chairperson selects other independent qualified reviewers.

This panel may also include other interested parties affected by the conclusions drawn from the LCA, such as government agencies, non-governmental groups, or competitors.

Annex A (informative)

Application of results of LCA or LCI studies

A.1 Application areas

The intended applications of LCA are addressed in clause 4.2 (Figure 1) in a non-exclusive, exemplary manner. Further applications in the field of environmental management systems and tools include, among others:

- environmental management systems and environmental performance evaluation (ISO 14001, ISO 14004, ISO 14031 and ISO 14032) e.g. identification of significant environmental aspects of the products and services of an organization;
- environmental labels and declarations (ISO 14020, ISO 14021 and ISO 14025);
- integration of environmental aspects into product design and development (Design for environment) (ISO/TR 14062);
- inclusion of environmental aspects in product standards (ISO Guide 64);
- environmental communication (ISO 14063);
- quantification, monitoring and reporting of entity and project emissions and removals and validation, verification and certification of greenhouse gas emissions (ISO 14064);

There are a variety of potential further applications in private and public organizations. The list of techniques, methods and tools below does not indicate that they are based on the LCA technique as such, but that the life cycle approach, principles and framework can be beneficially applied. These are, amongst others:

- Environmental Impact Assessment – EIA;
- Environmental Management Accounting – EMA;
- Assessment of policies (models for recycling, etc);
- Sustainability assessment; economic and social aspects are not included in LCA, but the procedures and guidelines could be applied by appropriate competent parties;
- Substance and Material Flow Analysis - SFA and MFA;
- Hazard and risk assessment of chemicals;
- Risk analysis and risk management of facilities and plants;
- Product Stewardship, Supply Chain Management;
- Life Cycle Management - LCM;
- Design briefs, life cycle thinking;
- Life Cycle Costing – LCC.

ISO/DIS 14040

The applications of LCA as such are outside the scope of this International Standard.

Clarifications, considerations, practices, simplifications and options for the different applications are also beyond the scope of this International Standard.

There is no single solution as to how LCA can be best applied within the decision-making context. Each organization has to solve and decide that case by case, depending – amongst others - on the size and culture of the organization, its products, the strategy, the internal systems, tools and procedures and the external drivers.

LCA can be used for a broad spectrum of applications. The individual use, adaptation and practice of LCA for all potential applications are based on ISO 14040 and ISO 14044.

In addition the LCA technique with proper justification can be applied in studies, which are not LCA, or LCI studies. Examples are:

- cradle-to-gate studies;
- gate-to-gate studies;
- specific parts of the life cycle (e.g. waste management, components of a product).

For those studies most requirements of ISO 14040 and 14044 standards are applicable e.g. data quality, collection and calculation as well as allocation, but not all requirements for system boundary.

For specific applications, it can be appropriate, as part of the LCIA, to determine the indicator results of each unit process or of each stage of a life cycle individually and to calculate the indicator results of the whole product system by adding up the indicator results of the different unit processes or stages.

This procedure is within the framework of this standard, provided that

- it has been defined within the goal and scope definition phase;
- it is shown that the results of such an approach are identical with the results of an LCA which applies the sequence of steps according to the guidance of ISO 14040 and 14044 standards.

A.2 Application approach

It is necessary to consider the decision-making context when defining the scope of an LCA, i.e. the product systems studied should adequately address the products and processes affected by the intended application.

The examples of applications relate to decisions that aim for environmental improvements, which is also the overall focus of the ISO 14000-series. Therefore, the products and processes studied in an LCA are those affected by the decision that the LCA intends to support.

Some applications may not appear to immediately address improvements, such as LCA's to be used for education or information about the product life cycle. However, as soon as such information is applied in practice, it is used in an improvement context. Therefore, special care is necessary to ensure that the information is applicable to the context in which it is likely to be applied.

Two possible different approaches to LCA have developed during the recent years. These are:

- one which assigns elementary flows and potential environmental impacts to a specific product system typically as an account of the history of the product; and

- one which studies the environmental consequences of possible (future) changes between alternative product systems.

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