TECHNICAL REPORT

ISO/TR 14047

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Environmental management — Life cycle assessment — Illustrative examples on how to apply ISO 14044 to impact assessment situations

Management environnemental — Analyse du cycle de vie — Exemples illustrant l'application de l'ISO 14044 à des situations d'évaluation de l'impact du cycle de vie

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Foreword

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ISO/TR 14047 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/TR 14047:2003), which has been technically revised.

Introduction

The heightened awareness of the importance of environmental protection and the possible environmental significance of a product system[1)], have increased the interest in development of methods to better understand this significance. One of the techniques being developed for this purpose is Life Cycle Assessment (LCA).

The life cycle impact assessment (LCIA) is the third phase of life cycle assessment and its purpose is to assess a product system's life cycle inventory analysis (LCI) results to better understand their environmental significance. LCIA models selected environmental issues called impact categories. Through the use of category indicators which help condense and explain the LCI results, LCIA provides a picture of the aggregate emissions or of resource use to reflect their potential environment impacts.

This Technical Report provides examples to support ISO 14044:2006. It uses several examples on key areas of ISO 14044 in order to enhance the understanding of the requirements of the standard.

1) In this Technical Report, the term "product system" also includes service systems.

Environmental management — Life cycle assessment — Illustrative examples on how to apply ISO 14044 to impact assessment situations

1 Scope

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 ISO 14044. They offer "a way" or "ways" rather than the "unique way" of applying ISO 14044. They reflect the key elements of the life cycle impact assessment (LCIA) phase of the LCA. The examples presented in this Technical Report are not exclusive and other examples exist to illustrate the methodological issues described.

2 Organization of examples in this Technical Report

2.1 Mandatory and optional elements

The general framework of the LCIA phase is composed of several mandatory elements that convert Life Cycle Inventory (LCI) results to indicator results. In addition, there are optional elements for normalization, grouping or weighting of the indicator results and data quality analysis techniques for assisting the interpretation of the results.

2.2 Scope of examples

The examples provided within this Technical Report illustrate and support the methodology specified in ISO 14044:2006, 4.4. The coverage is indicated in Table 1.

Table 1 — Elements or clauses of ISO 14044:2006 illustrated with examples

ISO 14044:2006 reference	IS0 14044:2006 Clause	Example coverage in this Technical Report
1 to 3	**Scope, Normative references, Terms and definitions**	**Examples of impact categories**
4.4.2 4.4.2.1 4.4.2.2 4.4.2.3 4.4.2.4	**Mandatory elements of LCIA** General Selection of impact categories, category indicators and characterization models Assignment of LCI results to the selected impact categories (Classification) Calculation of category indicator results (characterization)	**Example 1, Example 2, Example 3, Example 4, Example 5**
4.4.3 4.4.3.1 4.4.3.2 4.4.3.3 4.4.3.4	**Optional elements** General Normalization, Grouping Weighting	**Example 1, Example 2, Example 6, Example 7** *(Calculating the magnitude of the category indicator results relative to reference value(s))* **Example 1** **Stem example, Example 5, Example 8**
4.4.4	**Additional LCIA Data Quality analysis**	**Stem example, Example 5**
4.4.5 5 6	LCIA intended to be used in comparative assertions to be disclosed to the public Public Reporting Critical review	Not covered in this Technical Report

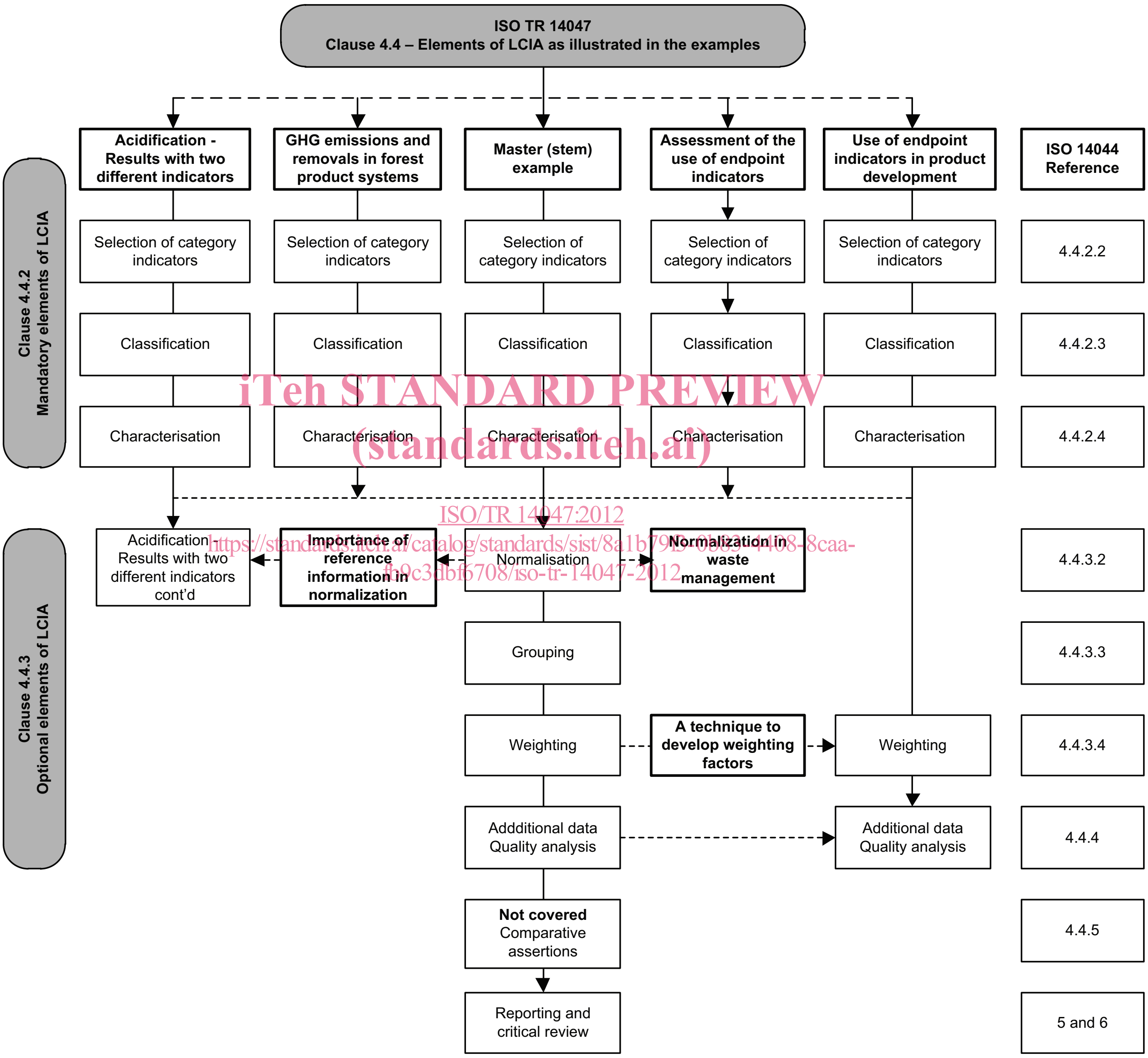
In some key areas more than one example is provided to illustrate the different ways that may be possible in applying ISO 14044:2006. It is important to stress this point. In many LCIA studies more than one approach or practice may be used which still allow conformance with the methodology prescribed in ISO 14044:2006. There is currently no unique approach. This Technical Report may be thought of as illustrating a number of ways that may be used in the LCIA phase as prescribed in ISO 14044:2006. Table 2 gives the title of the example and the purpose of the illustration.

Table 2 — Example titles and the purpose of the illustrations

Example No.	Title	Purpose of illustration	ISO 14044:2006 clause reference
1	Use of two different materials for gas pipelines	Full procedure of LCIA	4.4.2 and 4.4.3
2	Two acidification impact category indicators	Consequences of using general or site dependant models	4.4.2
3	Impacts of Greenhouse Gas (GHG) emissions and carbon sinks on forestry activities	GHG emissions and carbon sinks	4.4.2
4	Endpoint category indicators assessment	Transforming of ionising radiation inventory results to impact category indicator (YLL)	4.4.2
5	Choice of material for a wind spoiler in car design study	Impact modelling at endpoint level and weighting	4.4.2, 4.4.3.4
6	Normalization of LCIA indicator results for the use of different refrigerator gases	Normalization using different types of reference information	4.4.3.2
7	Normalization in a waste management study	Use of normalization in the communication processes	4.4.3.2 (reference to example 6)
8	A technique for the determination of weighting factors	The use of a panel of experts in such a study	4.4.3.3

2.3 Organization of document and route map

The structure of this Technical Report departs from a more recognized approach used in ISO standards since it provides examples about applications of ISO 14044:2006. It would help visualize better the structure of this Technical Report considering Example 1 as the trunk of a tree which runs through clauses pertaining LCIA both for its mandatory and optional elements. It of course uses its own set of LCI data. Examples 2 to 5 could be considered « branches » addressing specific different applications of the mandatory elements of LCIA. Example 2 extends into the optional element of normalization. Each of these examples is based on its own set of LCI data. Examples 6 to 8 are also « branches » addressing specific applications of the optional elements of the LCIA. Figure 1 lays the structure out in a flow diagram.



Key

Direct route through an example

Indirect routes through example

Figure 1 — Organization and route map for this Technical Report

NOTE Following Clause 3 the examples are organized thus:

— Examples in Clause 4, Mandatory elements running consecutively, i.e. Example 1, Illustration of ISO 14044:2006, 4.2.2, followed by Example 2, followed by Example 3, etc.

— Examples in Clause 5 are organized on a "topic" basis, e.g. with all examples on Illustration of ISO 14044:2006, 4.4.3.2, on normalization followed by examples on Illustration of ISO 14044:2006, 4.4.3.3, on grouping, etc.

The reader may adopt a number of alternative ways of using this Technical Report. These are broadly as follows:

— Follow Example 1 from start to finish;

— Select an alternative example and follow the process flow;

— Select a topic and read all the alternative approaches on that particular topic.

Each example is preceded by an overview that is intended to state the key area of ISO 14044:2006 that is illustrated. The body of the example follows the overview. Where an example continues through this Technical Report, it generally has not been necessary to precede each clause/subclause with an overview.

3 Elements of LCIA as illustrated in the examples

3.1 Overview

This clause gives a general description of LCIA explaining key elements of the procedure and it places the examples in the context of ISO 14044. The LCIA process elements are shown in Figure 2.

3.2 Mandatory elements

According to ISO 14044:2006, 4.4.2, the mandatory elements of LCIA are:

— Selection of impact categories, category indicators and characterization models;

— Assignment of LCI results (classification) to the impact categories;

— Calculation of category indicator results (characterization).

3.2.1 Selection of impacts categories, category indicators and characterization models

For each impact category a distinction can be made between LCI results, including resources (inputs), and emissions (outputs), category endpoints and intermediate variables in the environmental mechanism between these two groups (sometimes called "midpoints"). This is illustrated in Figure 3.

When defining the impact categories, an indicator is chosen somewhere in the environmental mechanism. Often indicators are chosen at an intermediate level somewhere along that mechanism, sometimes they are chosen at endpoint level. Table 3 shows examples of relevant intermediate variables and relevant category endpoints, for a number of impact categories.

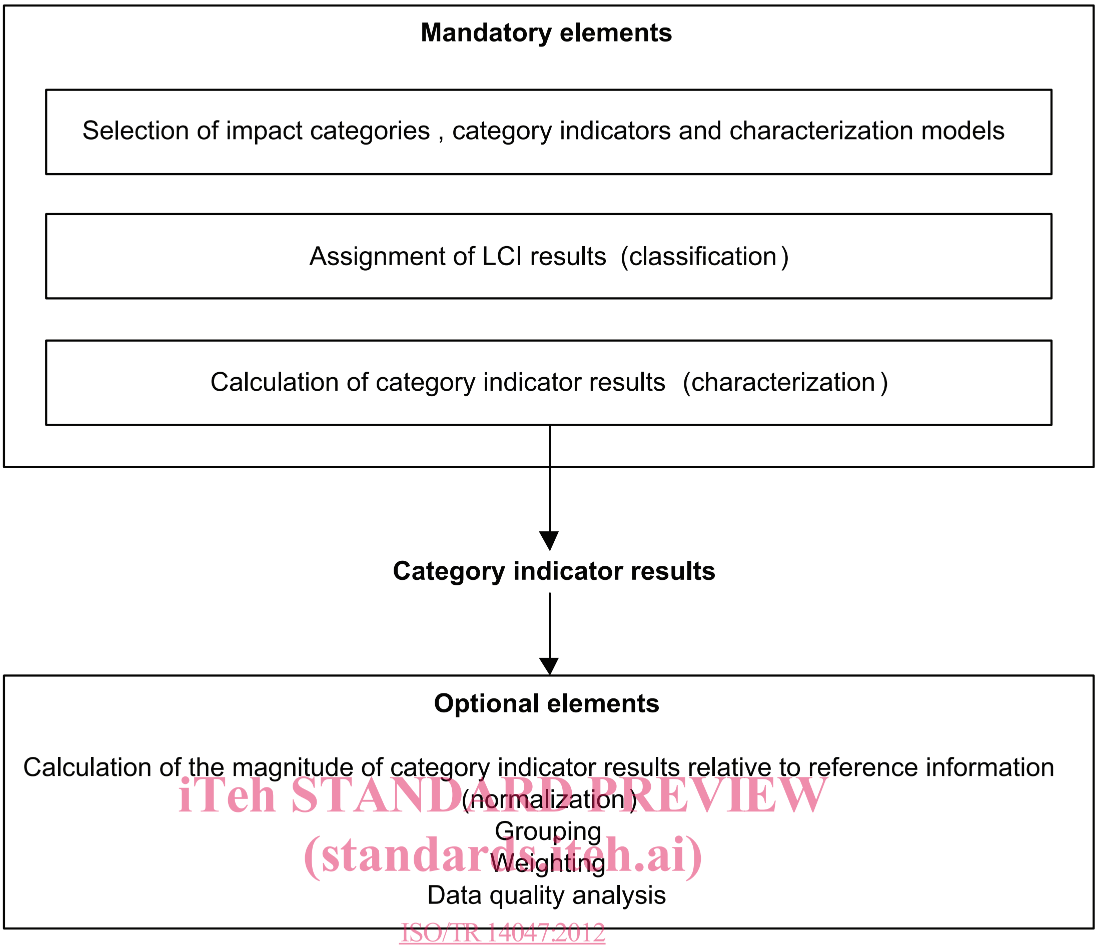


Figure 2 — Element of the LCIA phase (ISO 14044:2006)

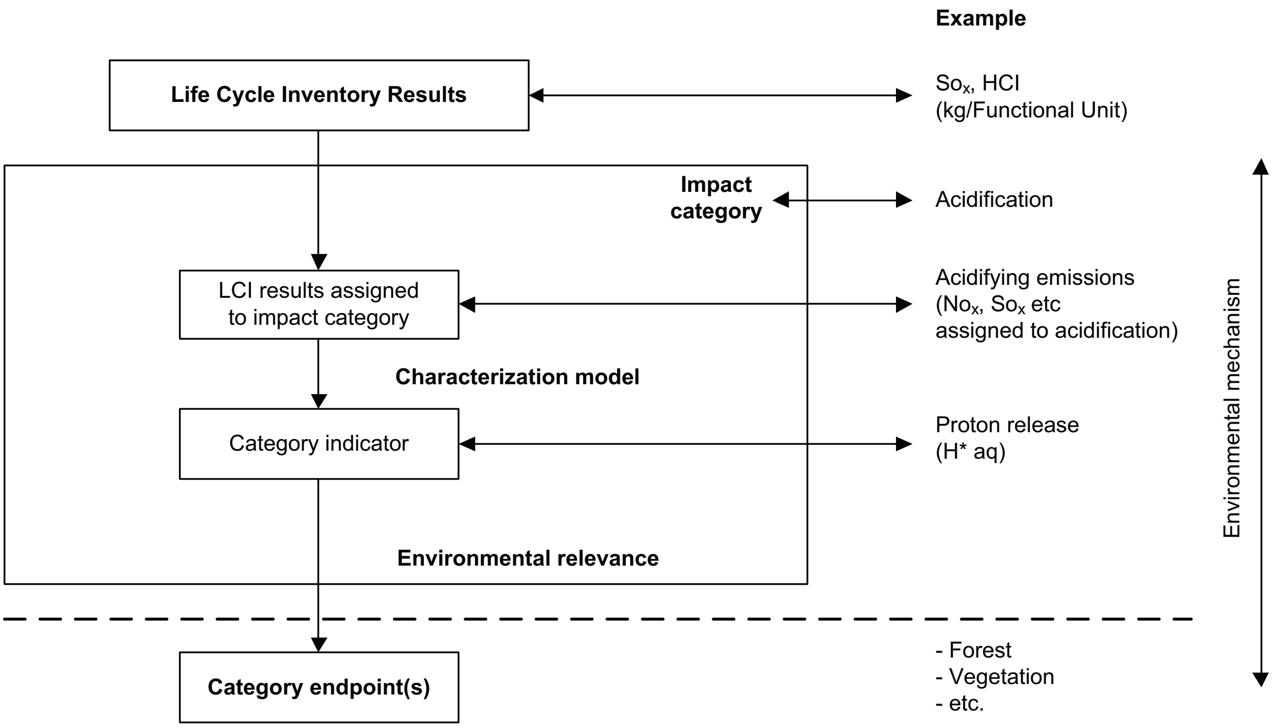


Figure 3 — Concept of category indicators (Figure 3 from ISO 14044:2006)

Table 3 — Examples of intermediate variables and category endpoints for a number of impact categories

Impact category	Choices of indicator level	
	Examples of intermediate variables	**Examples of category endpoints**
Climate change	Infrared radiation, temperature, sea-level	Human life expectancy, coral reefs, natural vegetation, forests, crops, buildings
Stratospheric ozone Depletion	UV-B radiation	Human skin, ocean biodiversity, crops
Acidification	Proton release, pH, base cation level, Al/Ca ratio	Biodiversity of forests, wood production, fish populations, materials
Nutrification	Concentration of macro-nutrients (N, P)	Biodiversity of terrestrial and aquatic ecosystems
Human toxicity	Concentration of toxic substances in environment, human exposure	Aspects of human health (organ functioning, human life expectancy, number of illness days)
Eco-toxicity	Concentration or bio-availability of toxic substances in environment	Plant and animal species populations

In Tables 4, 5 and 6, LCI results and indicator results are expressed per the same functional unit (the one selected in definition of the scope of the LCI phase).

In Table 4, the terms used for defining an impact category and describing the chosen characterization model are exemplified for six different impact categories to further illustrate the principles of table from ISO 14044:2006. Impact categories 1 and 2 are input related, impact categories 3 to 6 are output related.

In Table 4 all six examples chose the category indicator at the level of intermediate parameters in the environmental mechanism. In order to illustrate the number of possible options when defining an impact category and choosing a characterization model, Table 5 gives examples of different category models and category indicators within the environmental mechanism of one impact category – photochemical ozone formation. The given examples are not the only alternative. A similar table could be prepared for each of the impact categories in Table 4. Five of the alternatives presented in Table 5 focus on the same category indicator chosen early in the environmental mechanism, but compares five different characterizations models. For the sixth alternative, the indicator is chosen close to the endpoint. The main distinguishing features are presented in bold.

Table 4 — Examples of definitions and descriptions of impact categories

Term	Impact Category 1	Impact Category 2	Impact Category 3	Impact Category 4	Impact Category 5	Impact Category 6
Impact category	Depletion of fossil energy resources	Depletion of mineral resources, (excluding energy resources)	Climate change	Stratospheric ozone depletion	Nutrification	Ecotoxicity
LCI results	Extraction of resources of different fossil fuels	Extraction of resources, expressed as useful material	Emissions of Greenhouse gases	Emissions of ozone depleting gases	Emissions of nutrients	Emissions of organic substances to air, water and soil
Characterization model	Cumulated energy demands	Static scarcity model	The model as developed by the Intergovernmental Panel on Climate Change (IPCC [a]) defining the global warming potential of different greenhouse gases [6], [7]	The model as developed by the World Meteorological Organization (WMO [b] defining the ozone depletion potential for different ozone depleting gases [8], [9]	The stoichiometric procedure as described by [10], which identifies the equivalence between N and P for both terrestrial and aquatic systems.	USES 2.0 [c] model developed at RIVM, describing fate, exposure and effects of toxic substances, adapted to LCA by [11]
Category indicator	Energy content of energy resources	Extraction of material in the ore per estimated supply horizon of the reserve base	Increase of infrared radiative forcing (W/M^2)	Increase of stratospheric ozone breakdown	Deposition increase ÷ N/P equivalents in biomass	Predicted Environmental Concentration increase ÷ Predicted No-Effect Concentration
Characterization factor	Low calorific value per mass unit	Present extraction of the material in the ore divided by estimated supply horizon of the reserve base	Global Warming Potential for time horizon of 100 years (GWP100) for each greenhouse gas emission (kg CO_2 eq. / kg emission)	Ozone Depletion Potential in the steady state ($ODP_{steady\ state}$) for each emission (kg CFC - 11 eq. / kg emission)	Nutrification Potential (NP) for each eutrophicating emission to air, water and soil (kg PO_4^{3-}- eq. / kg emission)	Eco-toxicity Potential (ETP) for each emission of a toxic substance to air, water and soil (kg 1,4 -dichlorobenzene eq. / kg emission)
Indicator result	Total low calorific value (Mega Joules)	Total mass of used material in the ore divided by estimated supply horizon of the reserve base	Kg of CO_2-equivalents	Kg CFC -11 equivalents	kg PO_4^{3-} -equivalents	kg 1,4 -dichlorobenzene equivalents
Category endpoint	Heating, mobility	Availability of resources	Years of life lost, coral reefs, crops, buildings	Illness days, marine productivity, crops	Biodiversity, natural vegetation, algal bloom	Biodiversity
Environmental relevance	Diverse problems known from energy crises	Diverse problems from mineral resources	Infrared radiative forcing is a proxy for eventual effects on the climate depending on the integrated atmospheric heat absorption caused by emissions and the distribution over time of the heat absorption	Empirical and experimental linkage between UV-B radiation levels and damage	The nutrification indicator represents a clear causal factor in the mechanism of nitrification for different types of ecosystems; it is defined at a global level	The PNEC represents a threshold for a possible effect of the substance on the species composition of an ecosystem; no spatial differentiation is considered

[a] Intergovernmental Panel on Climate Change
[b] Word Meteorological Organization
[c] Uniform System for the Evaluation of Substances

Table 5 — Example of terms and different characterization models for the impact category photo-oxidant formation

Term	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Impact category	Photo -oxidant formation	Photo -oxidant formation	Photo -oxidant formation	Photo -oxidant formation	Photo -oxidant formation	Photo -oxidant formation, impacts on vegetation
LCI results	Emissions of substances (VOC, CO) to air	Emissions of substances (VOC, CO) to air	Emissions of substances (VOC, CO) to air	Emissions of substances (VOC, CO) to air	Emissions of substances (VOC, CO) to air	Emissions of substances (NO_x, VOC, CO) to air
Characterization model	UNECE Trajectory model [12], [13]	Trajectory model [14]	Maximum Incremental Reactivity (MIR) scenario; Single cell model [15], [16]	Maximum Ozone Incremental Reactivity (MOIR) scenario; Single cell model [15], [16]	Equal Benefit Incremental Reactivity (EBIR) scenario; Single cell model [15], [16]	RAINS adapted to LCA Option for spatial differentiation within Europe [17]
Category indicator	Quantity of tropospheric ozone formed	Quantity of tropospheric ozone formed	Quantity of tropospheric ozone formed	Quantity of tropospheric ozone formed	Quantity of tropospheric ozone formed	Area of ecosystem times duration and extent of exposure above critical level for plants
Characterization factor	Photochemical Ozone Creation Potentia (POCP) for each emission of VOC or CO to air (kg ethylene eq. / kg emission)	Photochemical Ozone Creation Potential (POCP) for each emission of VOC or CO to air (kg ethylene eq. / kg emission)	Kg formed ozone for each emission of VOC or CO to air (kg ozone / kg emission)	Kg formed ozone for each emission of VOC or CO to air (kg ozone / kg emission)	Kg formed ozone for each emission of VOC or CO to air (kg ozone / kg emission)	Extent of exposure above critical level for each emission of NO_x, VOC or CO to air (m^2*ppm*hours / kg emission)
Indicator result	Kg ethylene equivalents	Kg ethylene equivalents	Kg ozone	Kg ozone	Kg ozone	m^2*ppm*hours
Category endpoint	Illness days, crops	Illness days, crops	Illness days, crops	Illness days, crops	Illness days, crops	Crops, natural vegetation
Environmental relevance	Ozone formation estimated with relative high background NO_x	Ozone formation estimated with low background NO_x	Highest rise in ozone levels per added amount of standard VOC mixture, very high NO_x concentration, high concentration is inhibiting ozone creation	Highest ozone concentration per added amount of standard VOC mixture, relative high NO_x concentration, realistic for peak situations	NO_x and VOC contribute equally to ozone production, relative low NO_x concentration, lower concentrations of NO_x and VOC both reduce ozone creation	Includes the contribution from NO_x together with VOCs and CO, permits spatial differentiation to take regional differences in reactivity and ecosystem sensitivity into account. Models close to endpoint

3.2.1.1 Identification of possible indicators

The task of LCIA is to establish a relation between the inputs, e.g. fossil fuels or minerals and outputs of the Life Cycle Inventory phase with the impacts on the environment. For this reason, for every impact category an indicator is chosen in the environmental mechanism, which as much as possible represents the totality of all impacts in the impact category. This indicator can in principle be located at any position in the mechanism, from the LCI results down to the category indicators. In Table 6 this aspect is illustrated for an impact category dealing with acidification. Here three different characterization models are compared; each of them focuses at a distinct category indicator. The three models, and connected indicators, differ in their degree of sophistication. The first category indicator is the simplest one and is defined at the level closest to the emissions. The second category indicator is defined at the level of an intermediate variable close to the endpoint; the third indicator is defined at endpoint level, also known as damage approach. Again, the major distinguishing cells are presented in bold.

Table 6 — Indicators and underlying models chosen at different places in the environmental mechanism

Term	**Alternative examples for the category indicator for acidification**		
Impact category	**Acidification**	**Acidification**	**Acidification**
LCI results	Emissions of acidifying substances to air and water	Emissions of acidifying substances to air	Emissions of acidifying substances to air
Characterization model	CML-method [10]; EDIP-model [17]	RAINS, adapted to LCA [11] and (Example 2 [6])	Ecoindicator-99 [18], using the model Nature Planner [19]; Fate modelling by SMART [20]; damage modelling by MOVE [21]
Category indicator	Maximum release of protons (H+)	Deposition / Acidification Critical Load	Increase in $PDF_{vegetation}$ (Potentially Disappeared Fraction) of plants species in natural areas
Characterization factor	Acidification Potential (AP) for each acidifying emission to air and water (kg SO_2 eq. / kg emission)	Acidification Potential (AP) for each acidifying emission to air (kg SO_2 eq. / kg emission)	Potentially Disappeared Fraction (PDF) for each acidifying emission to air (PDF.m^2.yr/kg emission)
Indicator result	Kg SO_2 equivalents	Kg SO_2 equivalents	PDF.m^2.yr
Category endpoint	Biodiversity, natural vegetation, wood, fish, monuments	Biodiversity, natural vegetation, wood, fish, monuments	Biodiversity, natural vegetation, wood, fish, monuments
Environmental relevance	Maximum potential effect; fate is not included; no spatial differentiation	Fate is included; risk of effects are spatially differentiated	Fate and effects on natural vegetation are included; effects in the Netherlands are a proxy for effects in Europe