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Bio-based products — Life Cycle Assessment

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National foreword

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European foreword

This document (EN 16760:2015) has been prepared by Technical Committee CEN/TC 411 “Bio-based products”, the secretariat of which is held by NEN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2016, and conflicting national standards shall be withdrawn at the latest by May 2016.

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

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Introduction

Bio-based products from forestry and agriculture have a long history of application, such as paper, board and various chemicals and materials. The last decades have seen the emergence of new bio-based products in the market. Some of the reasons for the increased interest lie in the bio-based products' benefits in relation to the depletion of fossil resources and climate change. Bio-based products may also provide additional product functionalities. This has triggered a wave of innovation with the development of knowledge and technologies allowing new transformation processes and product development.

Acknowledging the need for common standards for bio-based products, the European Commission issued mandate M/492[1], resulting in a series of standards developed by CEN/TC 411, with a focus on bio-based products other than food, feed and biomass for energy applications.

The standards of CEN/TC 411 "Bio-based products" provide a common basis on the following aspects:

— Common terminology;

— Bio-based content determination;

— Life Cycle Assessment (LCA);

— Sustainability aspects;

— Declaration tools.

It is important to understand what the term bio-based product covers and how it is being used. The term 'bio-based' means 'derived from biomass'. Bio-based products (bottles, insulation materials, wood and wood products, paper, solvents, chemical intermediates, composite materials, et cetera) are products which are wholly or partly derived from biomass. It is essential to characterize the amount of biomass contained in the product by for instance its bio-based content or bio-based carbon content.

The bio-based content of a product does not provide information on its environmental impact or sustainability, which may be assessed through LCA and sustainability criteria. In addition, transparent and unambiguous communication within bio-based value chains is facilitated by a harmonized framework for certification and declaration.

This European Standard aims to provide specific life cycle assessment requirements and guidance for bio-based products, based on EN ISO 14040 *Environmental management — Life cycle assessment — Principles and framework* and EN ISO 14044 *Environmental management — Life cycle assessment — Requirements and guidelines*.

Though the scope of CEN/TC 411 excludes food, feed and energy, life cycle assessment of biomass and bio-based products should follow the same principles irrespective of their use.

This European Standard informs and guides life cycle assessment and applications including for example Product Category Rules (PCR). An LCA assessment carried out according to this standard can be used as a basis to assess certain criteria as laid down in prEN 16751.

[1] A Mandate is a standardization task embedded in European trade laws. M/492 Mandate is addressed to the European Standardization bodies, CEN, CENELEC and ETSI, for the development of horizontal European Standards for bio-based products.

1 Scope

This European Standard provides specific life cycle assessment (LCA) requirements and guidance for bio-based products, excluding food, feed and energy, based on EN ISO 14040 and EN ISO 14044.

This European Standard covers bio-based products, derived wholly or partly from biomass.

This European Standard provides guidance and requirements to assess impact over the life cycle of bio-based products with the focus on how to handle the specificities of the bio-based part of the product.

The applications of LCA as such are outside the scope of this European Standard. Clarifications, considerations, practices, simplifications and options for the different applications, are also beyond the scope of this European Standard. In addition, this European Standard may be applied in studies that do not cover the whole life cycle, with justification e.g. in the case of business-to-business information, such as cradle-to-gate studies, gate-to-gate studies, and specific parts of the life cycle (e.g. waste management, components of a product).

2 Normative references

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

EN 16575, *Bio-based products - Vocabulary*

EN ISO 14025, *Environmental labels and declarations - Type III environmental declarations - Principles and procedures (ISO 14025)*

EN ISO 14040:2006, *Environmental management - Life cycle assessment - Principles and framework (ISO 14040:2006)*

EN ISO 14044:2006, *Environmental management - Life cycle assessment - Requirements and guidelines (ISO 14044:2006)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 16575, EN ISO 14040 and EN ISO 14044 apply.

4 Methodology for LCA of bio-based products

4.1 General description of an LCA

The general description of life cycle assessment is defined in EN ISO 14040:2006, Clause 4, with 4.1 *Principles of LCA*, 4.2 *Phases of an LCA*, 4.3 *Key features of an LCA*, 4.4 *Product system*.

4.2 General aspects of LCA for bio-based products

The LCA of a bio-based product shall cover the whole product, not only its bio-based part, see Figure 1. However, the focus of this European Standard is on how to handle the specificities of the bio-based part of the product.

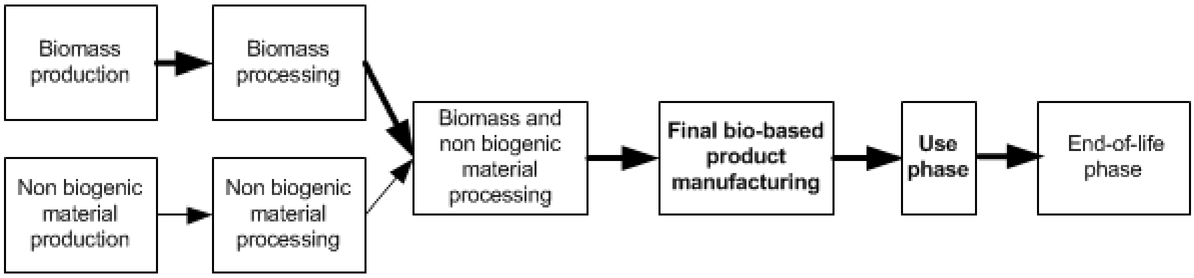

Figure 1 — Example of a product system of a bio-based product which includes biomass as well as non-biogenic material feedstocks

NOTE 1 The boxes linked with bold arrows in Figure 1 represent the flows of bio-based products (partly or fully derived from biomass) that can be raw materials, intermediary products and final product.

NOTE 2 For simplification purposes, transportation steps have not been reported in Figure 1, but transportation can occur between any of the unit processes.

This European Standard provides additional requirements and guidelines for bio-based products on: Goal and scope (see 4.3), Life Cycle Inventory - LCI (see Clause 5), Life Cycle Impact Assessment - LCIA (see Clause 6) and Interpretation and reporting (see Clause 7).

An LCA for a bio-based product shall include the four phases of LCA. LCA requirements and guidelines are provided in EN ISO 14044:2006, 4.2, 4.3, 4.4 and 4.5.

This European Standard provides further guidance on the following, which can be important for bio-based products, due to their biomass origin:

— geographical (see 5.2.2) and temporal scope (see 5.2.3) to be representative for the biomass acquisition phase considering agricultural, forest and aquaculture specificities;

— allocation procedures (see 5.3) as the production stages typically generates co-products;

— consideration for resource elementary flows (see 5.4.1);

— data collection and modelling for land use (see 5.4.2), water use (see 5.4.3), and fossil and biogenic carbon flows (see 5.5);

— modelling of agriculture, forestry and aquaculture systems (see 5.6); and

— inventory and modelling requirements for bio-based products end-of-life (see 5.6.4).

This series of European Standards focuses on bio-based products for industrial applications; food, feed and energy are excluded from the scope. However the guidelines and requirements for LCA provided in this standard can be applied to any product derived from biomass, irrespective of the application.

4.3 Goal and Scope of the LCA study

4.3.1 Goal of the LCA study

When defining the goal and scope of the LCA study, the requirements of EN ISO 14040:2006, 5.2.1 and EN ISO 14044:2006, 4.2.2 and 4.2.3 shall apply.

There is no single solution as to how LCA can best be applied, it will depend on the goal of the LCA and on each organization's size, its products, the strategy, the internal systems, tools and procedures and the external drivers.

In defining the goal of an LCA, the following items shall be unambiguously stated:

— the intended application of the study;

— 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.

4.3.2 Scope of the LCA study

4.3.2.1 General

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. In addition to the definition of the scope of the LCA study in EN ISO 14044:2006, 4.2.3, the limitations, assumptions and methods to assess issues specific to bio-based products should be explained (e.g. assumptions for use stage, for end-of–life stage, carbon storage)

In some cases, the goal and scope of the study may be revised due to unforeseen limitations, constraints or as a result of additional information. Such modifications, together with their justification, should be documented. It shall be determined which impact categories, category indicators and characterization models are included within the LCA study. The selection of impact categories, category indicators and characterization models used in the LCIA methodology shall be consistent with the goal of the study and considered as described in EN ISO 14044:2006, 4.4.2.2.

Any technical input to establish and manage the system producing the biomass is considered within the system boundary and thus part of the LCA of the bio-based material.

4.3.2.2 Function, functional unit and reference flows

In defining the functional unit, the requirements of EN ISO 14040:2006, 5.2.2 and EN ISO 14044:2006, 4.2.3.2 shall apply.

The scope of an LCA shall clearly specify the functions (performance characteristics) of the product system being studied. The functional unit shall be consistent with the goal and scope of the study. One of the primary purposes of a functional unit is to provide a reference to which the input and output data are related. This reference is necessary to ensure a common basis for comparability of LCA results, in particular when different systems are being assessed. Therefore the functional unit shall be clearly defined and measurable. An appropriate reference flow shall be determined in relation to the functional unit. The quantitative input and output data collected in support of the analysis shall be calculated in relation to this flow. For bio-based products which are intermediates or which can serve several functions or service, it is recommended to use a reference flow such as weight or volume (e.g. 1kg of product), and to provide information whether it refers to dry matter weight, gross weight, etc.

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 the case of the air-dryer, this would be related to the mass of hot air needed to dry the hands (copied from EN ISO 14040:2006, 5.2.2).

4.3.2.3 System boundary

In defining the system boundary, the requirements of EN ISO 14040:2006, 5.2.3 and EN ISO 14044:2006, 4.2.3.3 shall apply.

The system boundary shall be explained clearly and in an unambiguous way, preferably in a flow chart figure. The exclusion of any life cycle stages shall be documented and explained.

LCA technique with proper justification may be applied in studies that are not LCA or LCI studies. Examples are:

— cradle-to-gate studies;

— gate-to-gate studies; and

— specific parts of the life cycle (e.g. waste management, components of a product).

4.3.2.4 Cut-off criteria

When using cut-off criteria to decide on inclusion of inputs and outputs, the requirements of EN ISO 14044:2006, 4.2.3.3.3 shall apply.

The choice of elements of the physical system to be modelled depends on the goal and scope definition 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 defined within the goal and scope definition phase. The effect on the outcome of the study of the cut-off criteria selected shall also be assessed and described in the final report.

In principle, all elementary and technosphere flows should be accounted for. If not, mass, energy and environmental significance should be used to determine cut-off criteria. The final report shall include an estimation of completeness, based on:

— Mass (in % of total product mass): best estimation of the mass all non-accounted components of the product.

— Energy (in % of total energy consumption): best estimation of all energy consumption of non-accounted mass inputs.

— Environmental significance: decisions on cut-off criteria should be based on relevant information about the environmental impacts. Such information may e.g. be sought on Safety Data Sheets for toxicological and ecotoxicological effects of a product where substance classification can guide on possible cut-offs regarding such categories. For the assessment of other relevant environmental impacts also other sources of information should be looked for, e.g. emission declarations, approval documentation, etc. Inputs such as transport of staff, or consumer transport may be excluded where it is established that they are insignificant.

Such simplifications shall be explicitly stated in the study report along with any supporting documentation showing these calculations, specifying the names of any flows which have not been taken into consideration.

4.3.2.5 LCIA methodology and types of impacts

It shall be determined which impact categories, category indicators and characterization models are included within the LCA study. The selection of impact categories, category indicators and characterization models used in the LCIA methodology shall be consistent with the goal of the study and considered as described in EN ISO 14044:2006, 4.4.2.2.

NOTE This text is copied from EN ISO 14044:2006, 4.2.3.4.

4.3.2.6 Data quality

Data quality requirements shall be specified to enable the goal and scope of the LCA to be met and should address what is listed in EN ISO 14044:2006, 4.2.3.6.2 and 4.2.3.6.3.

Site-specific, primary and secondary data should be used as appropriate and in line with the goal and scope of the study. The selection of level of geographical detail should be consistent with the goal and intended use of the LCA and be justified in view of the availability and quality of data.

4.3.2.7 Comparisons between systems

As this European Standard provides additional guidance and requirements for bio-based products, the equivalence of the systems being compared shall be evaluated before interpreting the results. Consequently, the scope of the study shall be defined in such a way that the systems can be compared. Systems shall be compared using the same functional unit and equivalent methodological considerations, such as 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. If the study is intended to be used for a comparative assertion intended to be disclosed to the public, interested parties shall conduct this evaluation as a critical review.

A life cycle impact assessment shall be performed for studies intended to be used in comparative assertions intended to be disclosed to the public.

If comparative assertions are intended to be disclosed to the public, additional requirements as set in EN ISO 14044:2006 apply.

5 LCI – Life Cycle Inventory

5.1 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.

The qualitative and quantitative data for inclusion in the inventory shall be collected for each unit process that is included within the system boundary. The collected data, whether measured, calculated or estimated, are utilized to quantify the inputs and outputs of a unit process.

When data have been collected from public sources, the source shall be referenced. For those data that can be significant for the conclusions of the study, details about the relevant data collection process, the time when data have been collected, and further information about data quality indicators shall be referenced.

If such data do not meet the data quality requirements, this shall be stated.

To decrease the risk of misunderstandings (e.g. resulting in double counting when validating or reusing the data collected), a description of each unit process shall be recorded.

Since data collection may span several reporting locations and published references, measures should be taken to reach uniform and consistent understanding of the product systems to be modelled.

5.2 Sources of data

5.2.1 General

Sources of inventory data should be specified and transparent.

Responsible sourcing and sustainable management practices can be found in the production of bio-based raw materials. Certification schemes usually address a broad array of management and performance aspects that can be used directly in determining elementary flows and in informing impact assessment and interpretation.

EXAMPLE Managing production in conformity with standards covering fertilizer application may be linked directly to levels of fertilizer run-off and therefore elementary flow determination.

If biomass has been produced in conformance with a relevant standard this shall be taken into account in determining elementary flows and in impact assessment and interpretation.

The most representative data should be used and the quality of data shall always be examined in order to guarantee that they are adequate for the purpose of the study and that they comply with the data quality requirements of the study.

5.2.2 Geographical data

Data should be assessed across an appropriate and representative geographical area for there to be a mean effect. The data and scales used should be clearly specified in the study in order to ensure optimal transparency. Mean values by region are available only for some data (e.g. use of fertilizers, yields, etc.), as other data cannot yet be regionalised due to the lack of a recognized model (e.g. N_2O emissions).

Where there are significant differences within a geographical area, e.g. yield differences, this should also be taken into account.

5.2.3 Temporal data

Time period is an important issue in LCA, as emissions to air, water and soil are subject to variation over the management cycle of the system. The LCI should cover the relevant period in the life cycle of the product.

For industrials processes and systems, the inventory may cover the cycle of productions, e.g. seasonal production, start-up, maintenance, and temporary process shutdown.

For biomass production the collection of data and modelling should consider the management regime and cropping, harvesting and crop rotation (including the positioning of the crop in the rotation), e.g. the effect of inter- and intra-annual variation and when possible use values representing the selected period.

5.3 Allocation procedure

The inputs and outputs shall be allocated to the different products according to clearly stated procedures that shall be documented and explained together with the allocation procedure.

The sum of the allocated inputs and outputs of a unit process shall be equal to the inputs and outputs of the unit process before allocation.

In line with EN ISO 14044, the study shall identify the processes shared with other product systems (i.e. multifunctional processes for instance in agricultural and forestry systems) and deal with them according to the stepwise procedure[2] presented below.

Step 1: Wherever possible, allocation should be avoided by:

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[2] Formally, Step 1 is not part of the allocation procedure.

1) dividing the unit process to be allocated into two or more sub-processes and collecting the input and output data related to these sub-processes; or

2) expanding the product system to include the additional functions related to the co-products, taking into account the requirements of EN ISO 14044:2006, 4.2.3.3.

NOTE System expansion means: “expanding the product system to include additional functions”. So all additional functions are modelled and calculated and there are multiple benefits; nothing is subtracted.

Step 2: Where allocation cannot be avoided, the inputs and outputs of the system should be partitioned between its different products or functions in a way that reflects the underlying physical relationships between them; i.e. they should reflect the way in which the inputs and outputs are changed by quantitative changes in the products or functions delivered by the system.

NOTE Physical relationships are for example: mass, energy content.

Step 3: Where physical relationship alone cannot be established or used as the basis for allocation, the inputs should be allocated between the products and functions in a way that reflects other relationships between them. For example, input and output data might be allocated between co-products in proportion to the economic value of the products.

For economic allocation, an average economic value on a relevant time period should be used and the geographical scope of the study should be considered in order to limit high variation of results.

For bio-based products, the biogenic carbon content can be of key importance to determine greenhouse gas emissions. To track biogenic carbon in a value chain allocation based on carbon content can be used. When allocating based on other relationships the modelled biogenic carbon flows might not reflect the actual physical content and flows.

Whenever several alternative allocation procedures seem applicable, a sensitivity analysis shall be conducted to illustrate the consequences of the departure from the selected approach.

Annex A provides an example of allocation and a sensitivity analysis.

5.4 LCI – Collecting data and modelling

5.4.1 Considerations for resource use

The inventory of resources in an LCA is of primary importance because when moving from a LCI to LCIA environmental, resource depletion impacts will be associated to the use of these natural resources.

The distinction between resource and raw material is decisive for biomass. Resources enter the system as elementary flows, while raw materials are intermediate flows within the system. Biomass that has been drawn from the environment without previous human transformation shall be inventoried as an elementary flow.

In LCI modelling for bio-based products it is necessary to further distinguish material use from the use of energy.

Resources can be consumed to provide the energy needed to produce the product under consideration.

Resources can also be used as a constituent of the product itself (feedstock or reactant) or as material inputs of the production process.

5.4.2 Land use

5.4.2.1 General

Agriculture and forestry, like other human activities, use land and at the same time these activities influence the land they use through for example good management practices. Land use is an important aspect of the life cycle of bio-based products.

Land use has two aspects: land occupation and land transformation; these can both have positive or negative effects on for example biotic production potential, biodiversity, ecological soil quality, soil carbon content, soil erosion and fresh water availability. Land use is associated with physical as well as often chemical impacts on the soil and therefore on its fertility or production potential.

Potential impacts due to land use are captured in impact categories such as freshwater eutrophication, acidification or climate change.

5.4.2.2 Considerations for modelling land use in LCI

5.4.2.2.1 General

In order to determine the environmental impact of a given land use it is necessary to know for what activity the land is used and the time during which it is used for that particular purpose.

5.4.2.2.2 Area as physical unit

The area used to source the product or raw material is usually defined as land use for agricultural and forest ecosystems. For other ecosystems such as aquaculture the volume may be a relevant measure.

5.4.2.2.3 Distinction of transformation and occupation

Land use includes both land transformation and land occupation per reference flow and the quantification of land use should consider the following:

— Land occupation is measured in m^2 times time [m^2 x a];

— Land transformation is measured in area [m^2] changed.

Land use transformation addresses the quality change which is induced by changing land use type. This quality change can be directly determined if the land use before transformation is known. The same holds true for the transformation after the occupation period ends.

5.4.2.2.4 Identification of land use type

The determination of the classification system is decisive for the characterization of transformation and occupation as correlations reveal:

— physical-chemical properties of ecosystems (e.g. buffer capacities);

— ecosystem services (e.g. for human use);

— land cover characteristics (e.g. different use intensities).

For inventory modelling the initial land use and the resulting land use/land cover after occupation should be documented.

Land use types relate to the given activity and are usually classified in schemes. These schemes can comprehensively reveal all different land use types on a global scale or can be adapted to the spectrum of land use types in a given region.

Land use types are specifically related to the human use (agricultural crops, forestry) and can be scaled by the intensity of use.

In order to determine the characteristics of the transformed/occupied entity of land ecosystem and biome, classifications are used. These differ widely in the underlying typology (examples are Holdridge life zones, IPCC classification).

Land use and land cover are also sometimes combined e.g. in Corine land cover classes used to monitor land use and land cover consistently in Europe.

5.4.2.2.5 Land use change in GHG accounting

While in LCI modelling typically land transformation and occupation is considered, there are LCA applications for GHG accounting which use the source category of Land Use, Land Use Change and Forestry (LULUCF) of the IPCC or the concept of direct land use change and indirect land use change (dLUC and iLUC) which is used in the context of the European Renewable Energy Directive.

Indirect land use change considers potential land transformations which are not caused directly by the operator but may be seen as response of other operators. There is currently no agreed scientific method to characterize indirect land use change in coherence with the modelling principles of LCA. The consideration of potential effects from indirect land use change in the context of addressing GHG emissions may only be addressed during the interpretation phase.

5.4.3 Water inventory

5.4.3.1 General

Water is of vital importance for the production of biomass and impacts on water quality and availability is of crucial importance for bio-based products.

5.4.3.2 Elementary flows

Data related to water which represent elementary flows may be directly collected from unit processes or derived from data which represent material flows, e.g. ancillary material or waste for further processing.

The water inventory should include inputs and outputs from each unit process being part of the system to be studied. Any discrepancies in the inventory balance shall be explained.

Generally, information on each elementary flow should include, where relevant:

a) quantities of water used:

— mass or volume (e.g. water inputs and water outputs);

b) resource types of water used, e.g.:

— surface water;

— seawater;

— brackish water;

— groundwater (excluding fossil water);

— fossil water;

NOTE 1 Tap water or treated water are not elementary water flows but intermediate flows from a process within the technosphere (e.g. from a water treatment plant).

NOTE 2 Precipitation is not accounted as water input for agriculture and forestry, as it is largely emitted by evaporation and transpiration by the plant and the ground, and which contributes to the natural water cycle, or is incorporated into the output product flow of the system.

c) water quality parameters and/or characteristics, e.g.:

— physical (e.g. thermal), chemical, and biological characteristics, or functional water quality descriptors;

d) forms of water use, e.g.:

— evaporation;

— product integration;

— release into different drainage basins or the sea;

— displacement of water from one water resource type to another water resource type within a drainage basin (e.g. from groundwater to surface water);

— other forms of water use (e.g. in-stream use);

e) geographical location of water used or affected (including withdrawal and/or release);

— information on the physical location of water used or affected, including withdrawal and release (as site-specific as needed) or assignment of the physical locations to a category derived from an appropriate classification of drainage basins or regions;

NOTE 3 Environmental condition indicator (e.g. water scarcity, local level of social development, etc.) may require information on the location where the water use takes place.

f) temporal aspects of water use, e.g.:

— time of use and release if relevant residence time occurs within the system boundaries;

g) emissions to air, water and soil with impact on water quality.

NOTE 4 There may be other emissions to air and soil in the product system that do not impact water quality.

Water inputs or water outputs of different resource types, different quality, different form, different location with different environmental condition indicators, or different timing should not be aggregated in the inventory phase. This requirement does not apply when the use of generic databases is permitted. Aggregation may be performed at the impact assessment phase.

Where input and output data for each unit process for the biomass acquisition phase are not available, water used for irrigation, water used for spraying (e.g. fertilizers, pesticides), and water used for the production of those inputs should at least be considered.

5.5 Inventory of fossil and biogenic carbon flows

GHG emissions and removals arising from fossil carbon sources and biogenic carbon sources and sinks shall be included and listed separately in the inventory.

NOTE Further guidance can be found in Annex B.

5.6 Guidance for modelling agriculture, forestry and aquaculture systems

5.6.1 Modelling agricultural systems

5.6.1.1 General

Agriculture can have positive and negative impacts on the environment. Agricultural produce can be used as raw materials in bio-based products. It is commonly recognized that the following have environmental impacts e.g.:

— use of fertilizers on the field;

— irrigation;

— land occupation and transformation;

— soil management; and

— activities for the production of agricultural inputs such as mineral fertilizers and fuels.

It is noted that agricultural field work is complex, and practices vary significantly across farms and regions. Many parameters influence LCA impacts of agriculture, including intensification and optimization of production practices.

At the same time (resource-, energy-, emission-) efficiency and thus the resulting environmental interventions mirrored in LCA of agricultural production, vary significantly amongst the (a) type of crop cultivated (b) management regime (fertilizer, pesticide, mechanization, irrigation, tillage practices) (c) soil and climate characteristics (hence location and time), (d) farm practices for (potential) conservation and drying steps of harvest etc.

The following guidance is intended for practitioners that have to create a new unit process for an agricultural product; in other cases such data sets, however, can be extracted from existing databases (life cycle inventories). The choice will depend on the goal and scope definition of a given study and the corresponding data quality requirements. Where data sets from existing databases are extracted, the following guidance can help to assess the data and documentation quality of the respective data set/life cycle inventory.

5.6.1.2 Key characteristics

5.6.1.2.1 Reference flow

Regarding the reference flow of a given unit process, it is recommended to use a physical unit of mass or volume, together with a parameter of product quality: dry matter content, density, energy content (e.g. gross calorific value, net energy of lactation, metabolizable energy), oil content, raw protein content or other meaningful and unambiguous characteristics.

EXAMPLE 1 1 kg of rapeseed, dry matter: xx mass-%, oil content: xx-mass%

As agricultural raw products go through various steps of primary production, transport, and conservation, it should be mentioned already in the title /description of the reference flow to which stage of the production or life cycle the system refers, that is, which processes are included.

EXAMPLE 2 Product x, quality y, at the field border / at the farm gate / at the feed mill

The inputs and emissions of the process are related to the reference flow by calculating the ratio of inputs and emissions per produced unit; to this end, it is usually necessary to have information about the yield of the agricultural production. The yield should be documented in units of mass per area. As yields typically significantly vary by year, for annual crops, an average yield on a time-span of at least three years should be derived.

EXAMPLE 3 The following fresh matter yield for grain corn in Germany is reported in the statistical yearbook of agriculture:

— 2007: 9,49 ton/hectare

— 2008: 9,91 ton/hectare

— 2009: 9,20 ton/hectare

— Hence, an average yield of 9,53 ton/hectare is obtained for this region and time period.

5.6.1.2.2 Process-specific background information

To support transparency of the documentation, process and site specific parameters (depending on the level of detail in the modelling of specific activities) should be documented, for example:

— Distances for all transports involved in the field work, mostly the field-to-farm distance (km by ton dry matter or equivalent unit);

— Climate information: climatic zone and meteorological information, as they can influence plant perspiration (water loss);

— Times of application and condition of spraying: phenomenological growth stage of the plant, soil characteristics, organic remains of previous crops;

— Climatic conditions when spraying, as they influence the mineralisation kinetics, uptake by plants of elements, and emissions into the ecosphere.

5.6.1.2.3 Inventory net interventions

Only the net interventions related to human land management activities should be inventoried, e.g. not the basic Nitrate leaching resulting from N input via rain. Of the applied fertilizers and agrochemicals (e.g. fungicides) the amounts that leave the site (i.e. the field) should be inventoried as emissions to air or water.

5.6.1.3 Exchanges with technosphere

The use of inputs in agricultural production typically (not necessarily) includes seed, fertilizers, lime, pesticides, fuel for agricultural machinery, other fuel use e.g. for post-harvesting drying of produce or burning weeds, water, agricultural foils, etc. When deriving a new data set (unit process), the quantity and type of the respective input and how it was derived should be described, for example from an agricultural field work protocol. This is helpful for quality assessment, review and potential updates of the input data. The type (name and quality) and quantity of each input should be documented in units of mass or volume per reference flow quantity of the process. In building a product system / life cycle model, all this information is required to derive/identify the corresponding appropriate input data sets / life cycle inventories. Specifically for fertilizers (mineral and organic), the nutrient content should be specified, in mass percent of N, P_2O_5, K_2O, S, Mg, etc. Specifically for organic fertilizer the mineralization potential (quantity of fertilizer that can be mineralized or absorbed by the plant produced) should be specified.

Waste flows to waste treatment processes and infrastructure processes are handled analogously. Examples for waste include packaging, agricultural foils after use etc. The type, treatment and amount of waste should be documented in units of mass per reference flow quantity. Examples for infrastructure include agricultural machinery and buildings.

In the modelling of transport processes distances for all transports involved in the field work should be documented, in particular the field-to-farm distance (ton x km or equivalent unit). Explanatory note (adopted from ILCD handbook): Pesticide and fertilizer applications (to the field) are no emission, but part of the product flows within the (man-managed) technosphere. The emissions are the flows from the field to the ecosphere via leaching and run-off of e.g. nitrates and phosphate, off-drift of pesticides during application and their volatilisation from plant and soil surface etc.

5.6.1.4 Land occupation and transformation flows

For the modelling of land occupation and land transformation flows, the provisions detailed in 5.4.2 apply. The following additional guidance is provided for land occupation flows of agricultural activities:

To quantify land occupation the use of agricultural/arable land per reference flow quantity (related to yield, see 5.6.1.2.1) and production time has to be known. The production time is the time of the campaign/season, for field crops typically from soil preparation before drilling/seeding to harvest and potential subsequent soil/stubble treatment. The corresponding definition of production time should be documented.

5.6.1.5 Water use flows

The inventory may include the fraction of water withdrawn (e.g. for irrigation) which is not released back to the source of origin, e.g. because of evaporation, evapotranspiration, product integration or release into a different drainage basin or the sea (see 5.4.3). The transpiration rates from irrigated arable land should be derived by appropriate modelling, e.g. applying the Penman-Monteith relation. Alternatively, a default consumptive fraction of 100 % as a worst case estimate may be assumed.

5.6.1.6 Gaseous emission from agricultural soils

N-based emissions consist primarily of direct and indirect emission of nitrous oxide (N_2O), ammonia (NH_3), and nitrogen oxides (NO_x). CO_2 emissions arise from e.g. application of urea, lime, and from mineralization of organic matter in soil, or burning of crop residues. Correspondingly, CO_2 sequestration in the soil (build-up of soil organic matter), where it occurs as a consequence of agricultural management or land use change, can be considered flow of CO_2 from the atmosphere into the system.

The following greenhouse gas emission terms are related to land use and biomass production:

— CO_2 emissions and CO_2 removals resulting from carbon stock change, related to land use change and improved agricultural management;

— CO_2 emissions resulting from burning of vegetation or dead organic matter as part of land use change process or pre- and post-harvest burning; and

— field emissions, including CH_4 and N_2O, occurring during cultivation as a result of land management.

NOTE Useful guidance can be found in EN 16214–4:2013, 5.2.1, 5.2.2, 5.2.3, 5.3.4 and 5.3.6.

Field emissions of N_2O and CH_4 may be calculated in accordance with the IPCC Guidelines or any further update. In the absence of more specific data the Tier 1 approach as defined in Chapter 11 of the IPCC Guidelines should be used, but the Tier 2 and Tier 3 approach may be used if appropriate data are available.

Furthermore, emission of acidifying gases ammonia (NH_3) and nitrogen monoxide (NO) should be included based on a suitable emission model. In the absence of more specific data, literature emission factors may be applied, e.g. the default factor for ammonia in IPCC 2006.

5.6.1.7 Emissions to water

Emissions to water in agricultural activities occur as a consequence of leaching and run-off from agricultural soils. The relevant emissions flows include nitrate, phosphate, organic pollutants and heavy metals stemming from application of fertilizers (mineral as well as organic). A specific methodology or emission model for emissions to water cannot be recommended at present because various approaches exist and can be preferable depending on the goal and scope of a given study and the expertise of the practitioner. The methodology and assumptions applied in the specific case should be documented.

Heavy metal emissions to water bodies should be modelled and inventoried; that means, define heavy metal emission flows as crossing the system boundary to the ecosphere when they leave the agricultural field.

5.6.1.8 Guidance on allocation for agricultural processes

In general terms, the principles for dealing with allocation for processes of EN ISO 14040:2006 and EN ISO 14044:2006 apply.

Special attention should be paid in modelling of agricultural processes to the following aspects:

A part of the nutrients from fertilisation may remain in the field after harvest and serves as input to the next crop, hence crosses the system boundary within the technosphere over time. In this case the substance is a co-function of the preceding crop, making that process multi-functional. The general provisions for solving allocation apply. The same provision can be applied to green fertilizers crops and nitrogen-fixing crops.

Intercropping is the practice of growing two or more crops in proximity. The most common goal of intercropping is to produce a greater yield on a given piece of land by making use of resources that would otherwise not be utilized by a single crop.

For those cropping elements from such an intercropping system which are harvested, the production process should be handled according to the general provision for the allocation. For intercrop elements that are not harvested, but remain on the field to improve soil quality or for other beneficial reasons, these are included within the system boundaries of another, primary system/product and should not be treated as a separate process.

5.6.2 Modelling forestry systems

5.6.2.1 Inventory net interventions

Only the net interventions related to human land management activities should be inventoried, e.g. not the basic Nitrate leaching resulting from N input via rain. Of the applied substances (e.g. fertilizers) the amounts that leave the site should be inventoried as emissions to air or water.

5.6.2.2 Spatial and temporal boundaries

The spatial and temporal boundaries and approach used for modelling of forest systems is very important for determining all inventory flows and outcome of the study. The spatial and temporal system boundaries should be transparently defined and justified with relation to the goal and scope of the study.

Forests are in principle managed in a region or landscape which is essential to estimate elementary flows appropriately. LCA studies should consider with care the appropriate production unit or scale to include, in relation to the goal and scope of the study.

5.6.2.3 Addressing biogenic carbon

Sustainable Forest Management ensures that carbon stocks in forests stay stable or even improve over time. When modelling forestry systems on landscape level, the biogenic carbon content of harvested wood shall be considered a material inherent property, resulting from the uptake and storage of CO_2 from the atmosphere. A forest management unit managed on a sustained yield basis should be modelled as a unit process in a steady-state with carbon emissions equalling uptake. If modelled on stand level delays between biogenic carbon emissions and sequestration should be integrated over time.

The spatial and temporal boundaries and assumptions are important to model carbon sequestration and should be set and documented transparently.

5.6.2.4 Land occupation and transformation flows

To address impacts other than GHG emissions from land transformation and land occupation (e.g. biodiversity impacts) the area needs to be determined as important parameter to scale impacts from transformation and occupation as detailed in 5.4.2.

Relevant environmental aspects can be identified by identifying ecosystems services.

A valuable source of information to address transformation and occupation are certification schemes and management plans which detail forest management practices and which may e.g. exclude certain types of transformations (like deforestation) while also requesting a less exclusive/fully reversible occupation.

Multi-functionality of production systems of biomass, e.g. sustainably managed forests, shall be considered according to the rules of co-product allocation in 5.3 when attributing land occupation and land transformation to the functional unit under study.

5.6.3 Modelling aquaculture systems

Aquaculture, algae, marine or fresh water biomass can be used as a basis for bio-based products. There are few specific methods existing to assess aquaculture systems.

To establish the Life Cycle Inventory for those systems, the guidelines for agriculture may be considered.

5.6.4 Modelling end-of-life processes in LCAs of bio-based products

5.6.4.1 General

In this European Standard focus will be on end-of-life processes of bio-based products, even though the relevance of these processes is not restricted to bio-based products.

5.6.4.2 End-of-life processes of bio-based products

Special care should be applied when modelling carbon flows and balances in end-of-life process for bio-based materials. Options for end-of-life and guidance on inventory are provided in CEN/TR 16957, *Bio-based products - End-of-life options*.[3]

The model on which the inventory data are derived from along with any hypothesis and assumptions made shall be clearly documented and reported in the study (e.g. as an appendix). Also product characteristics such as mineralization rate, composition etc. shall be reported. Experimental models and/or data may be used as long as scientifically robust.

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[3] In preparation.

6 LCIA – Life Cycle Impacts Assessment

6.1 Impact categories and impact indicators

6.1.1 General

Life cycle impact assessment is covered by EN ISO 14040:2006, 5.4 and EN ISO 14044:2006, 4.4. Provisions of these standards shall apply to life cycle impact assessment of bio-based products.

6.1.2 Selection of impact categories

A key strength of LCA is the ability to look not just along the length of the life cycle but also across a breadth of different impact categories. Restricting an assessment to one impact category, as is done in carbon footprint or water footprint, provides only partial information and thus should not be considered as an environmental assessment of a product.

A well conducted study can help prevent burden shifting, not only between life cycle stages but also between impact categories. EN ISO 14044 states that the selection of impact categories shall reflect a comprehensive set of environmental issues related to the product system being studied, taking goal and scope into consideration.

Annex C includes a list of examples of impact categories and impact indicators.

6.1.3 Applicability of methods and data

According to EN ISO 14044, impact categories should be internationally accepted, characterization models and factors scientifically and technically valid and category indicators environmentally relevant. For biomass production systems issues such as scale, geographical or spatial specificity, nonlinearity of effects, reversibility of effects, temporal issues, multi-functionality and appropriate reference situation are particularly relevant to consider in relation to satisfying the given criteria for impact assessment approaches. EN ISO 14044 also requires that it be taken into account whether the quality of the LCI data and results is sufficient to conduct the LCIA in accordance with the study goal and scope definition.

The impact assessment methodologies for a number of impact categories often considered as particularly relevant for biomaterial systems, e.g. land use, water use, soil degradation and biodiversity are not sufficiently developed to satisfy some or all of the given criteria. This applies to midpoint and end point approaches which include or build on these same categories. It can also be that inventory data are insufficient to support meaningful application of an otherwise acceptable assessment method. Where either of these situations prevails and inventory data indicate potential significance in relation to the goal and scope of the study other information relevant to the system of study and the impact category or categories of concern should be sought and shall be considered in assessment and interpretation e.g. evidence of accepted good practice and/or conformance with accepted sustainability criteria (see Clause 7 Interpretation).

The evaluation of the robustness of indicators is not simple, and choices of indicators should refer to science-based experts recommendations, such as the Recommendations for Life Cycle Impact Assessment in the European context provided by the ILCD, or in scientific publications (the ProSuite project gives recommendations for bio-based products).

6.1.4 Weighting and comparative assertions disclosed to the public

Special attention shall be paid to the LCIA dispositions related to reporting and critical review, as well as to those applicable to comparative assertions intended to be disclosed to the public. EN ISO 14044, (4.4.5) states that weighting shall not be used in comparative assertions intended to be disclosed to the public; that category indicators used in this context shall be scientifically and technically valid, and environmentally relevant; and that comparisons shall be conducted category indicator by category indicator.

6.2 Guidelines for specific impact indicators

6.2.1 Treatment of biogenic and non-biogenic carbon in assessing climate change

To calculate life cycle impact assessments, all biogenic and non-biogenic carbon emissions and removals should be considered. Two main approaches may be applied for modelling CO_2 emissions and removals related to biomass:

1) the CO_2 sequestered in biomass during the growth phase is included in the model with negative values in the growth phase and positive values as it is emitted at end-of-life; or

2) the CO_2 sequestered in biomass during the growth phase is included in the model with a characterization factor of zero and emission of biogenic CO_2 correspondingly have a characterization factor of zero.

The biogenic carbon embedded in the bio-based products should also be equal to biogenic carbon released in case of end-of-life treatment of the product with complete oxidation. For this specific case, the net result, summing up the results over the whole life cycle of a product, of both approaches is identical, however contributions of different life cycle steps (e.g. biomass production) to global warming potential will be different.

Where temporal accounting of GHG emissions is relevant, it should be taken into account but reported separately. Assessment may be carried out according to CEN ISO/TS 14067. Examples for calculation can be found in B.3.

6.2.2 Land use impact on areas of protection

6.2.2.1 General

For the characterization of the inventoried land use several methods with different sets of characterization factors are available. Specific impact assessment methods for land use are recent and there is no scientific consensus on those methods. Any may be used in practice, with a careful review of the validity and limitations of the method used.

Evidence for responsible sourcing and sustainable management practices can deliver information to address impacts resulting from land use.

Two areas of protection on which land use can have an impact are:

— natural environment/ecosystem quality; and

— ecosystem services/natural resources.

NOTE In LCA three areas of protection are usually distinguished – human health, natural resources and ecosystem quality.

6.2.2.2 Land use related to Natural Environment / Ecosystem Quality

Specific methods for impact on natural environment and ecosystem quality are recent and there is no scientific consensus on those methods. Such methods may be used in practice, with a careful review of the validity and limitations of the method used. Examples for such methods are Potentially Disappeared Fraction (PDF) (ReCiPe) and Biodiversity Damage Potential (BDP) (UNEP/SETAC).

6.2.2.3 Land use related to Ecosystem Services / Natural Resources

Specific methods for impact on ecosystem services and natural resources are recent and there is no scientific consensus on those methods. Such methods may be used in practice, with a careful review of the validity and limitations of the method used. Examples for such methods are SOM: Soil organic matter (ILCD handbook) and ecosystem services (guidance is provided by UNEP/SETAC)

6.2.3 Impact of water use

There is no current international acceptance for any single model assessing the impact of water use. The choice of model shall be documented and justified, with a careful review of the validity and limitations of the method used.

In addition to input and output flows in the inventory, ISO 14046 [14] describes procedures and requirements to carry out a water impact assessment for e.g. water scarcity.

7 Interpretation and reporting of LCA

7.1 Interpretation

Guidance and requirements for interpretation are provided in EN ISO 14040:2006, 5.5 and EN ISO 14044:2006, 4.5.

The interpretation phase of an LCA serves to draw conclusions out of the inventory and impact assessment phase in view of the goal and scope definition.

Decisions in view of the iterative nature of an LCA study are taken in view of further data collection activities or the reduction of scope due to the limitations in data availability.

The interpretation phase encompasses techniques (e.g. contribution and sensitivity analysis) to understand the significance of LCIA results and relevance of modelling choices. Optional elements which further aggregate results are weighting, sorting and ranking.

Also data quality and representativeness are evaluated and are assessed in view of their relevance.

In particular for bio-based products the interpretation phase allows also to consider qualitative information e.g. regarding management practices in the production of bio-based products.

In LCA studies where a comparative assertion is intended to be disclosed to the public special care shall be taken to ensure that the comparison is in line with the requirements in EN ISO 14044.

In comparison to traditional, existing products such as glass, paper and fossil-based materials, the new generation of bio-based products are often in a relatively early stage of development, and assumptions are needed to portray the life cycle. LCA studies revealing bio-based products the differences in maturity of products or production systems should be addressed during the Interpretation phase.

A thorough check of possible inconsistencies and/or different level of detail of inventories should always be performed in comparative studies between bio-based products and their alternatives.

Inconsistency can occur when different databases, based on different level of detail and modelling choices, are used. For instance human toxicity and ecotoxicity impact categories can be affected by this issue due to gaps in the inventory.

7.2 Reporting of LCA

Also for bio-based products the reporting guidelines provided in EN ISO 14040:2006, Clause 6 and EN ISO 14044:2006, Clause 5 shall be followed.

The content of the third party report – which is mandatory for any type of LCA communication – depends on the intended application; in particular if a comparative assertion is intended to be disclosed to the public.

If a comparative assertion is intended to be disclosed to the public the following information shall apply as additional reporting requirements, otherwise they should be considered:

— sourcing aspects;

— treatment of biogenic carbon in the LCA; and

— treatment of technological maturity.

The only standardized approach to simplify the results out of an LCA is the Type III environmental declaration according to EN ISO 14025. In LCA itself the standardized reporting tool is the third party report. However, the outcome of both options is still often too complex in Business to Business and especially Business to Consumer communication.

7.3 Critical review

Guidance and requirements on critical review are given in EN ISO 14040:2006, Clause 7 and EN ISO 14044:2006, Clause 6.

Annex A
(informative)
Example of allocation on glycerol

A.1 Example for the based approach

Glycerol: The last step of glycerol production is the transesterification of vegetable oils or animal fats into the main product, the biofuel, and a co-product, the glycerol.

1) Is it possible to subdivide the process in several and distinct processes to avoid allocation?

No as a single reaction (transesterification) is delivering two products.

2) Is it possible to apply system expansion?

No, the glycerol available on the market is produced through various routes where glycerol is also always a co-product (e.g. soap production and fatty acid/alcohol production from various vegetable and animal feedstocks or synthetic glycerol production from propylene).

Conclusion: Allocation is required. As specific physical relationship between products could not be determined, common physical properties can be applied: mass and energy based on energy content.

Results (with illustrative values for allocation method parameters, and also other existing relationships: economic is added):

Table A.1 — Allocation methods and result

Allocation method	**Biodiesel**	**Glycerol**	**Allocation for biodiesel**	**Allocation for glycerol**
Energy (NCV)	37 000 MJ/t	17 000 MJ/t	37 000/(37 000+17 000*0,05) = 98 %	2 %
Mass	1 t	0,05 t	1/1,05 = 95 %	5 %
Economic (sales price)	1 480 €/t	300 €/t	1 480/(1 480+300*0,05) = 99 %	1 %

In this example, there is no issue on the allocation as the results are similar (all methods reveal an influence of < 5 % impact for glycerol).

Annex B
(informative)
Examples of fossil and biogenic carbon flows accounting and communication

B.1 Example of fossil and biogenic carbon flows accounting

Carbon flows can have two origins: fossil or biogenic. Carbon flows can both come from material resources (fossil and biomass) used as a feedstock of the bio-based product and from energy resources (fossil and biomass) used in the production of the product.

Fossil and biogenic carbon emissions both need to be accounted for. In the creation of LCIs for bio-based or partially bio-based products, sequestration of atmospheric carbon by the plant should be considered. As required under 5.5: “GHG emissions and removals arising from fossil and biogenic carbon sources and sinks shall be included and listed separately in the inventory”.

NOTE 1 The amount of CO_2 taken up in biomass and the equivalent amount of CO_2 emissions from the biomass at the point of complete oxidation results in zero net CO_2 emissions when biomass carbon is not converted into methane, non-methane volatile organic compounds (NMVOC) or other precursor gases.

NOTE 2 This example describes LCI generation for biogenic and fossil carbon accounting. Emissions from land use change and of non-carbon emissions (e.g. N_2O emissions from farming) need to be considered and included in the inventory. However, the specific guidance for calculations of land use change and farming emissions is addressed in 5.4.2.

In this example, fossil carbon flows emitted to the environment, are accounted for as positive flows. The nature of the emissions is identified (e.g. CO_2, CH_4, and other fossil carbon emitted to air, water, soil).

The considered carbon flows in this example are shown in Table B.1.

Table B.1 — Inventory of fossil and biogenic carbon flows

	Inventory flows (quantity)	**Nature of emissions**
Biogenic carbon		
Atmospheric Carbon fixation during biomass growth	- BC1	
Carbon emitted to air/water and soil during production phase	+BC2	
Carbon permanently sequestered in e.g. co-products or landfilled production wastes.[a]	+ BC3	
Biogenic carbon embedded	**BC = -BC1 + BC2 + BC3**	
Biogenic carbon emissions to air, water and soil at end-of-life	+C4	
Net biogenic carbon emissions	**E = BC+ C4**	
Fossil carbon		
Fossil Carbon emitted to air/water and soil during production phase	+FC1	
Fossil Carbon emissions to air, water and soil during end-of-life	+FC2	
Total fossil carbon emissions	E’ = FC1 + FC2	

[a] If landfilling of production wastes and partial degradation generates greenhouse gas emissions (e.g. methane, CO_2), those need to be taken into account as well).

A simplified approach may be used to determine the net quantity of atmospheric carbon dioxide fixed in a product using stoichiometry or the biogenic carbon content.

EXAMPLE According to the chemical structure the carbon content in polylactic acid is 50 %. According to ^{14}C analysis the origin of the carbon is for 100 % biogenic. Using these data the net quantity of atmospheric carbon dioxide harnesses becomes: 0,5 × 1 / 12 × 44 = 1,83 kg CO_2/kg PLA.

B.2 Example of a representation of cradle-to-gate / cradle-to-grave emissions

Figure B.1 presents the cradle-to-gate perspective and Figure B.2 the cradle-to-grave inventory for a bio-based/fossil-based product.

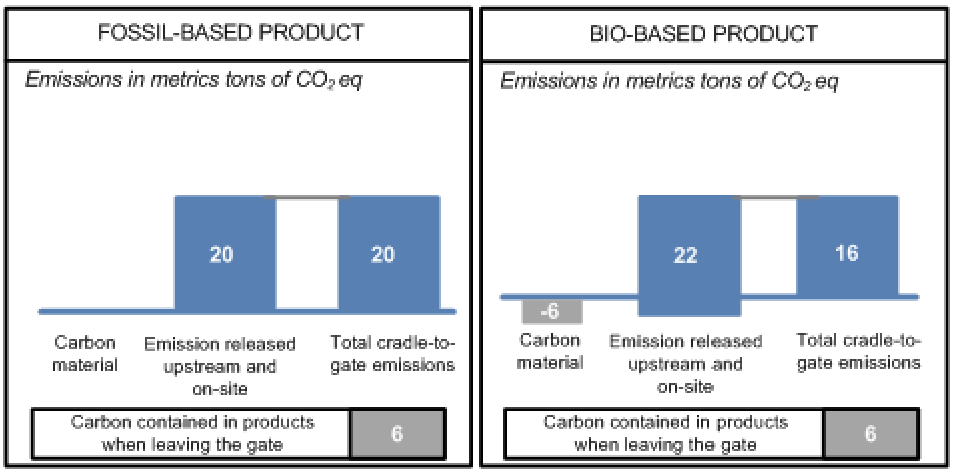

Figure B.1 — Cradle-to-gate inventory for a bio-based/fossil-based product

Figure B.2 represents the end-of-life emissions via incineration without temporal accounting. Temporal accounting for carbon storage can be included based on guidance from ILCD as in B.3.

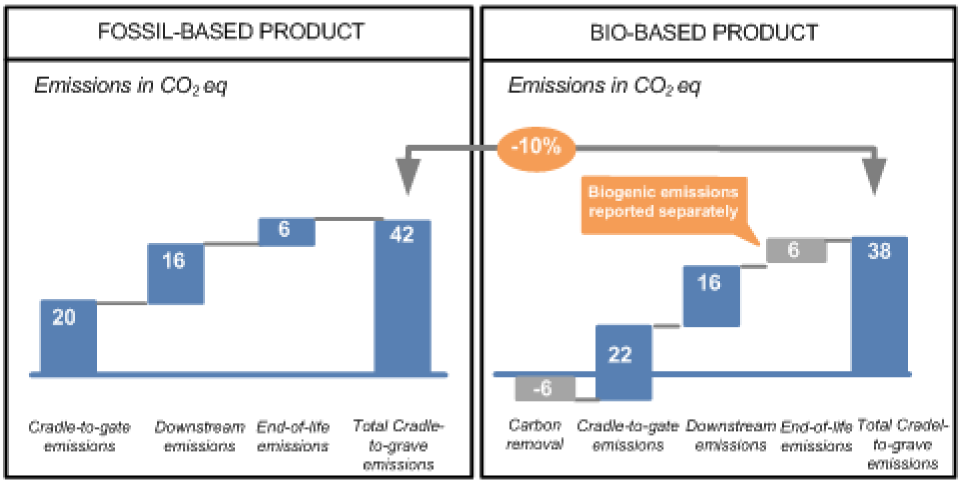

Figure B.2 — Cradle-to-grave inventory for a bio-based/fossil-based product

B.3 Temporal accounting

B.3.1 ILCD guidance for calculating temporal accounting (CFP = Carbon Footprint)

$$CFP_{temp,Storage} = - \sum m_i * t_S * GWP_{IPCC,i} / 100$$

$CFP_{\text{temp.Storage}}$: Carbon footprint of temporarily stored GHG species i

m_i: Mass of greenhouse gas i removed:

For CO_2: $m_{CO2} = m_c * M_{CO2} / M_C$

with m_c being the mass of carbon stored in a product and released as carbon dioxide within a 100 yr timeframe;

M_{CO2}, M_C being the molecular weights of CO_2 and carbon, respectively.

For CH_4: $m_{CH4} = m_c * M_{CH4} / M_C$

with m_c being the mass of carbon that is temporarily stored in e.g. a landfill and released as methane within a 100 yr timeframe;

M_{CH4}, M_C being the molecular weights of methane and carbon, respectively.

t_S: Time of temporal removal/storage in years

$GWP_{IPCC,i}$: IPCC GWP for 100-year time horizon for greenhouse gas *i* (Table A.1)

According to the ILCD Handbook the time period of the removals t_S, relative to the year of production of the product, shall be documented separately in the report.

According to the ILCD Handbook, when greenhouse gases are removed over more than 100 years, these removals shall be calculated as if they were stored indefinitely.

B.3.2 Example of calculation temporal accounting

Determination of temporal accounting of the bio-based product (embedded carbon: 6 kg CO_2 eq. / kg) illustrated in Figures B.1 and B.2. The bio-based product sequesters carbon for 80 years in the use phase.

$CFP_{\text{temp,Storage}} = - \sum m_{CO2} * t_S * GWP_{IPCC,i} / 100 = -6$ kg eq. CO_2 * 80 *1 / 100 = - 4,8 kg eq. CO_2

The bio-based product illustrated in Figures B.1 and B.2 has a total cradle-to-grave carbon footprint of 38 kg eq. CO_2/kg and realizes an additional benefit due to temporal storage of bio-based carbon of - 4,8 kg eq. CO_2. The total net cradle-to-grave carbon footprint including temporal storage is 33,2 kg eq. CO_2.

Annex C
(informative)
Examples of impact categories and impact indicators

C.1 Indicator of impacts which contribute to Climate change

— Global warming

This indicator characterizes the anthropogenic increase in mean atmospheric concentration of substances such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). These emissions disrupt the balance of the atmosphere and contribute to global warming. The unit used is the kg CO_2 equivalent.

C.2 Indicators of impacts which contribute to the exhaustion of non-renewable resources

— Non-renewable energy consumption

This covers all sources of energy which are extracted from natural reserves (coal, natural gas, oil and uranium). The unit is the MJ.

— Natural resource exhaustion

This indicator quantifies the extraction of natural resources which are considered as non-renewable, i.e. consumed faster than they can be formed naturally. The unit used is the kg Sb equivalent (antimony).

C.3 Indicators of impacts affecting human health

— Ozone layer depletion

This potential impact is caused by complex reactions between stratospheric ozone and compounds such as CFCs. Thinning of the ozone layer has effects including less effective natural filtering of ultraviolet radiation. The unit used is the kg CFC-11 equivalent.

— Photochemical oxidation

This indicator characterizes impacts due to organic substances. It is expressed in kg ethylene (C_2H_4) equivalent. It expresses a number of complex reactions between volatile organic compounds and nitrous oxides which contribute to the formation of low-atmosphere ozone. Tropospheric ozone has harmful effects on human health and plants.

This impact category takes into account the formation in the troposphere of certain reactive chemical compounds known as photo-oxidants, specifically including ozone (O_3), through the action of the sun on certain primary pollutants. In particular, photo-oxidants may appear in the troposphere due to the influence of ultraviolet radiation, photochemical oxidation of volatile organic compounds (VOCs) and carbon monoxide (CO), in the presence of nitrous oxides (NO_x). Ozone (O_3) and, to a lesser degree, peroxyacyl nitrates or PANs, are considered to be the principal photo-oxidant compounds. The full range of effects that this type of pollutant may potentially have is relatively poorly understood. For instance, ozone (O_3) has effects on human health including irritation of the eyes, respiratory tracts and mucous membranes. These problems may become much more serious for individuals suffering from respiratory problems. This category of impact is also known as “smog formation” or “summer smog”.

Volatile Organic Compounds (VOCs) are the principal causes of this effect. However, NO_x acts as a catalyst.

This question is often apprehended by means of a synthetic indicator known as Photochemical Ozone Creation Potential (POCP). This value, measured experimentally for each molecule, is expressed as the effect that x kg of ethylene (C_2H_4) would have, which is why it is expressed in kg ethylene equivalent.

Table C.1 — Indicative list of highly-reactive volatile organic compounds

Isoprene	1.3-Butadiene	All alkanes	Toluene
m-Xylene	Propene	Acetaldehyde	Methyl-Cyclopentane
Ethene	Formaldehyde	Xylene	Ethanol

— Human toxicity

This impact category relates to the effects of substances which are toxic for human health. These substances may be present both in the environment and in the workplace. The range of molecules, their modes of action and the damage caused depending on exposure, the effects of indirect exposure and cocktail effects represent such a degree of complexity that this impact category is one of the most difficult to model. Consequently, in general, the results supplied should be seen as orders of magnitude, and differences should be observed for a number of factors before a real difference in terms of impact may be inferred.

Table C.2 — Principal families of toxic molecules

Family	Examples
Metals, metal ions and other metallic compounds	Arsenic, mercury, chromium, antimony, etc.
VOCs	Aldehydes, benzene, dichlorobenzenes, 1.3-butadiene, etc.
Other atmospheric pollutants	NO_x, SO_x, etc.
PAHs	Pyrene, naphthalene, tephenyl, etc.
Particulate Matter (PM)	< 2,5 microns, < 10 microns, etc.
Other toxic molecules (particularly carcinogens)	Pesticides, naphthalene, toluene, chlordane, etc.

— Aquatic and terrestrial ecotoxicity

This indicator makes it possible to assess eco-toxicity. It characterizes the potential risks arising from the presence of chemical compounds within a specific ecological system. The unit used is the kg 1,4 DB (DichloroBenzene) equivalent.

— Terrestrial acidification

This indicator characterizes the increase in the quantity of acidic substances in the lower atmosphere. These emissions are responsible for acid rain, leading to the deterioration of certain forests. The compounds which contribute to this phenomenon include the following: SO_2, NO_x, NH_3, HCl, HF. Acid precipitation affects materials, forest ecosystems and freshwater ecosystems. This indicator is expressed in kg SO_2 equivalent.

— Aquatic eutrophication

The introduction of nutrients in the form of phosphate or nitrogen compounds disrupts ecosystems by favouring the proliferation of certain species (microalgae, plankton, etc.). This effect may lead to a drop in the oxygen content of the aquatic medium, with significant repercussions on aquatic fauna and flora. The unit used is often kg PO_4 (phosphate) equivalent.

Bibliography

[1] prEN 16751:2014, *Bio-based products — Sustainability criteria*

[2] S. Humbert et al., *IMPACT 2002+: User Guide Draft for version 2.1* (land occupation expressed as m^2 Organic arable land eq × year PDF.m^2.yr).

[3] *ReCiPe (land occupation & land conversion)* [online] [viewed 2015-04-07] http://www.lcia-recipe.net

[4] *IPCC Guidelines for National Greenhouse Gas Inventories*; Volume 4, Agriculture, Forestry and Other Land Use (2006), [online] [viewed 2015-04-07] http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

[5] *Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC*

[6] *Crop evapotranspiration — Guidelines for computing crop water requirements*, FAO Irrigation and drainage paper 56, FAO — Food and Agriculture Organization of the United Nations Rome, 1998

[7] EN 16214-4:2013, *Sustainability criteria for the production of biofuels and bioliquids for energy applications - Principles, criteria, indicators and verifiers - Part 4: Calculation methods of the greenhouse gas emission balance using a life cycle analysis approach*

[8] European Commission - Joint Research Centre - *Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook - General guide for Life Cycle Assessment - Detailed guidance*. First edition March 2010. EUR 24708 EN. Luxembourg. Publications Office of the European Union; 2010

[9] *PROSUITE, PROspective SUstaInability Assessment of Technologies*, www.prosuite.org

[10] CEN ISO/TS 14067, *Greenhouse gases - Carbon footprint of products - Requirements and guidelines for quantification and communication (ISO/TS 14067)*

[11] The UNEP/SETAC working group 'Operational Characterization Factors for Land use Impacts on Biodiversity and Ecosystem Services http://lcinitiative.unep.fr/

[12] Köllner T., de Baan L., Beck T., Brandão M., Civit B., Margni M. i Canals, L.M., Saad, R., de Souza, D.M., Müller-Wenk, R. 2013, *UNEP-SETAC guideline on global land use impact assessment on biodiversity and ecosystem services in LCAInternational Journal of Life Cycle Assessment*. 2013, **15** p. 1

[13] WBCSD. *Guidance for Accounting & Reporting Corporate GHG Emissions in the Chemical Sector Value Chain*, [online, viewed 2015-04-07] http://www.wbcsd.org/Pages/EDocument/EDocumentDetails.aspx?ID=15375

[14] ISO 14046, *Environmental management — Water footprint — Principles, requirements and guidelines*

[15] 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*

[16] European Commission - Joint Research Centre - *Assessing temporary carbon storage in life cycle assessment and carbon footprint - Outcomes of an expert workshop, 7th-8th October 2010, Ispra (Italy).*

[17] LIME2 [online] [viewed 2015-04-07] http://lca-forum.org/english/

[18] MILÀ I CANALS L., BAUER C., DEPESTELE J., DUBREUIL A., KNUCHEL R.F., GAILLARD G. et al. Key elements in a framework for land use impact assessment within LCA. *International Journal of Life Cycle Assessment*. 2007a, **12** (1) pp. 5–15

[19] KÖLLNER & SCHOLZ. 2007a Köllner T. and Scholz R. (2007a), *Assessment of land use impact on the natural environment: Part 1: An Analytical Framework for Pure Land Occupation and Land Use Change*, In: Int J LCA, 12(1), pp. 16-23.

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