

Description of life cycle assessment methodology

Supplementary information for tenders

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About us	ESU-services Ltd. was founded in 1998. Its core objectives are research, consulting, review, and training in the fields of life cycle assessment (LCA), carbon footprints, water footprint in all sectors including e.g. energy, civil engineering, basic minerals, chemicals, packaging, telecommunication, food and lifestyles. Fairness, independence, and transparency are substantial characteristics of our consulting philosophy. We work in an issue-related manner and carry out our analyses without prejudice. We document our studies and work transparently and comprehensibly. We offer fair and competent consultation, which makes it possible for the clients to monitor and continuously improve their environmental performance. The company has worked for various national and international companies, associations, and authorities. In some areas, team members of ESU-services performed pioneering work such as development and operation of web based LCA databases or quantifying environmental impacts of food and lifestyles.
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1 Life Cycle Assessment (LCA) Methodology

1.1 ISO 14040 and ISO 14044

The life cycle assessment (LCA) – sometimes also called ecobalance – is a method to assess the environmental impacts of a product¹. The LCA is based on a perspective encompassing the whole life cycle. Hence, the environmental impacts of a product are evaluated from cradle to grave, which means from resource extraction up to the disposal of the product and also the production wastes.

The International Organization for Standardization (ISO) has standardised the general procedure for conducting an LCA in ISO 14040 (International Organization for Standardization (ISO) 2006a) and ISO 14044 (International Organization for Standardization (ISO) 2006b).

An LCA consists of four phases (Figure 1):

- Goal and Scope Definition
- Inventory Analysis
- Impact Assessment
- Interpretation

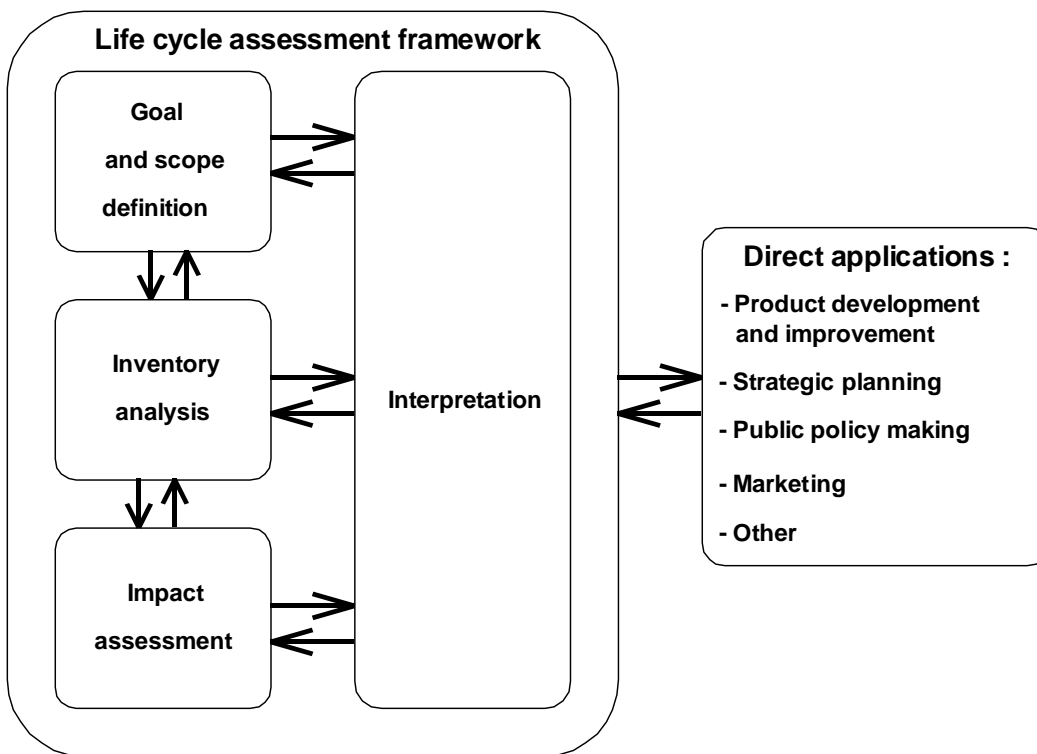


Fig. 1.1 Components of a life cycle assessment (LCA) according to the International Organization for Standardization

Goal Definition (phase 1) includes describing the object of investigation. The environmental aspects to be considered in the interpretation are also defined here. *Scope Definition* includes describing modelling approaches, the identification as well as the description of the key processes involved in

¹ The term product also encompasses services

the production of the object of investigation. The functional unit, which determines the basis for comparison, is defined here.

The direct environmental impacts², the quantity of semi-finished products, auxiliary materials and energy required for the processes involved in the life cycle are determined and inventoried in the *Inventory Analysis* (phase 2). This data is set in relation to the object of investigation, i.e. the functional unit. The outcome consists of the cumulative resource demands and emissions of pollutants.

The Inventory Analysis provides the basis for the *Impact Assessment*. Applying current evaluation methods to the inventory results in indicator values that are used for and referred to in the interpretation. ISO 14044 does not specify any specific methodology or support the underlying value choices used to group, normalize and weight the impact categories. The value-choices and judgements within these procedures are the sole responsibility of the authors and commissioner of the study.

Normalization and weighting are introduced into ISO 14044 as optional elements of LCIA after classification and characterization. Weighting shall not be used in LCA studies intended to be used in comparative assertions³ intended to be disclosed to the public. The draft ISO/TS 14074⁴ shall provide further guidance for normalization, weighting, and interpretation. It states e.g. that weighting is based on value value-choices and is not scientifically based. Furthermore, all indicator results of the study, before weighting, shall be included in the LCA report.

In fully aggregating methods, different environmental influences are weighted, based e.g. on political interests. The authors of the ISO standards see this as an increased risk of misinterpretation. In our view, however, this is also possible when using non-aggregated results, as readers could possibly weight the different environmental impacts of e.g. 1 kg phosphate equivalent and 1 kg CO₂ equivalent equally.

Since most studies do not pursue this goal, a disclaimer can be used: "A comparative statement in the sense of the ISO standard, i.e. an environmental statement on the superiority or equivalence of a product compared to a competing product with the same intended use, is not intended here. This eliminates the need for a review or a restriction regarding the use of fully aggregating indicators."⁵The results of the inventory analysis and the impact assessment are analysed and discussed in the *Interpretation* (phase 4) according to the initially defined goal and scope of the LCA. Final conclusions are drawn and recommendations stated.

If the results of a comparative study are not intended to be used in comparative assertions intended to be disclosed to the public, the ISO requirements regarding weighting are less strict.

1.2 Review and verification

A study can be carried out according to the ISO standard 14040. An external critical review by a review panel of at least three experts is (only) required to comply with to the ISO standard if the results of the study are intended to be used to support a comparative assertion to be disclosed to the public.

Furthermore, such a review or validation is also required for the publication of an EPD.

² Resource extraction and emission of pollutants

³ An environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function.

⁴ <https://www.iso.org/standard/61117.html>

⁵ <https://video.ethz.ch/events/lca/2019/autumn/72nd/e54eee95-f0dd-4915-84e7-18b7a8a47b7f.html>
https://www.lcaforum.ch/portals/0/df72/DF72-02_Buxmann.pdf

There is a fundamental difference between reviewing and verification. In a review, the consistency of procedures can be checked. Verification comes from the financial sector and it also covers the accuracy of the data, with options depending on whether the data is perfect or not. Verification of the ecoinvent database is not possible, as emissions fluctuate and we often do not know how products are made and who made them. Ecoinvent uses data from generic models and statistics. A review is possible. This has also been an important issue for PEF. The Commission commissioned a company to verify some of the primary activity data, such as the mass of the product, the material used and the transport distance. These can be verified, as there is full control over these parameters. The PEF does not verify any specific process data records.

1.3 Procedure of the critical review

Life cycle assessment at ESU-services is prepared in accordance with the ISO standards 14040/44 as far as possible. At minimum, each study at ESU-services is validated by an experienced practitioner within the company.

In the case of publication of comparative studies, the requirements of ISO standards 14040/44 for life cycle assessments or ISO-14067 for carbon footprints are only fully met if an external critical review of the overall study is carried out (International Organization for Standardization (ISO) 2006b, 2018). One to three reviewers need to be commissioned separately by the client.

The sole use of a single-score method (e.g. eco-points) is not ISO-compliant and a more detailed assessment of environmental impacts must therefore be provided.

A critical review of the study offers the following advantages:

- The review ensures the commissioner that the study was conducted in a professional manner. This is particularly helpful if the client has little previous experience with LCA.
- The review protects the contractor from being overly influenced by the client. It can support the authors in carrying out the study independently and with an open mind.
- The review increases the credibility of the study when it is published.

The following variants are possible:

- Review during the study (several review steps, support from the beginning) or review of the draft of the entire study (fewer possibilities to influence and improve the study).
- Review by individual experts, review panel (usually three LCA and technical experts), or with the involvement of interested parties (stakeholders from diverse options under consideration).

As part of the review, feedback is also provided by the client and an advisory group.

The contractor and the client mutually agree on the choice of reviewer. A specialist with experience in LCA is sought. A SimaPro licence is required to assess the database used. Potential reviewers are asked for a quotation based on the definition of objectives for the study. The final choice is made together with the client based on the offers.

A review leads to additional effort, time, and costs for conducting the study for detailed documentation, discussion with reviewers and revision of the report. In addition, the costs for the reviewers are borne directly by the client of the study.

2 Environmental product declaration (EPD) and Product Environmental Profile (PEP)

2.1 Environmental product declaration (EPD)

The aim of an Environmental Product Declaration (EPD) is to provide relevant, verifiable, and comparable information for consumers and business partners on the environmental impacts of products. The [International EPD®system](#) aims to support this goal and to assist organisations in providing information. It enables them to show the environmental performance of their products and services in a simple way.

For the preparation of environmental product declarations (EPDs), there are Product Category Rules (PCR) in which various specifications for carrying out the life cycle assessment are specified for products such as electricity. An important basis for construction products is EN 15804 (European Committee for Standardisation (CEN) 2022). Validation is necessary if the environmental declaration is to be published on an official website, e.g. EPD International AB⁶ (EPD 2019).

2.2 Product Environmental Profile (PEP)

The Product Environmental Profile (PEP) delivers accurate details regarding a product's environmental impact. This information is derived from quantified and diverse environmental data obtained through Life Cycle Assessment.

The PEP ecopassport Program⁷ offers a standardized procedures for companies seeking to register PEP declarations. These procedures ensure that companies provide data in accordance with the international standards. Compliance with the program requires adherence to the Product Category Rules (PCR) set forth by the PEP ecopassport Program.

3 Environmental Footprint (EF) for products (PEF) and organisations (OEF)

3.1 Introduction

There are many methods available to companies wishing to market their products as environmentally friendly in more than one EU Member State. They may have to use more than one method for different markets. This is costly for companies and confusing for consumers.

The Product Environmental Footprint (PEF) and Organisation Environmental Footprint (EF) methods were proposed by the European Commission as a common method to assess environmental performance ([Commission Recommendations 2013/179/EU](#)). The PEF and the OEF are the Life Cycle Assessment (LCA) based methods recommended by the EU for the quantification of the environmental impacts of products (goods or services) and organisations.

^{6 6} <https://www.environdec.com/>

⁷ <https://www.pep-ecopassport.org/>

The main purpose of the PEF and OEF is to enable the reduction in environmental impacts of goods, services, and organisations by taking supply chain activities along the whole life cycle into account (from the extraction of raw materials to disposal at the end of life).

To achieve this, detailed requirements for modelling the environmental impacts of the material and energy inputs as well as the emissions and wastes associated with a product or an organisation throughout the whole life cycle are provided (Zampori & Pant 2019).

3.2 Circular Footprint Formula (CFF)

The Circular Footprint Formula (CFF) is a specialized allocation criterion that is used for product recycling and provides a standardized approach for sharing environmental benefits and burdens between the supplier and user of recycled materials. The detailed description on the application of the CFF can be found in the JRC technical report on the PEF method (Zampori & Pant 2019). Fig. 3.1 describes the CFF as a combination of LCI's for material, energy, and disposal.

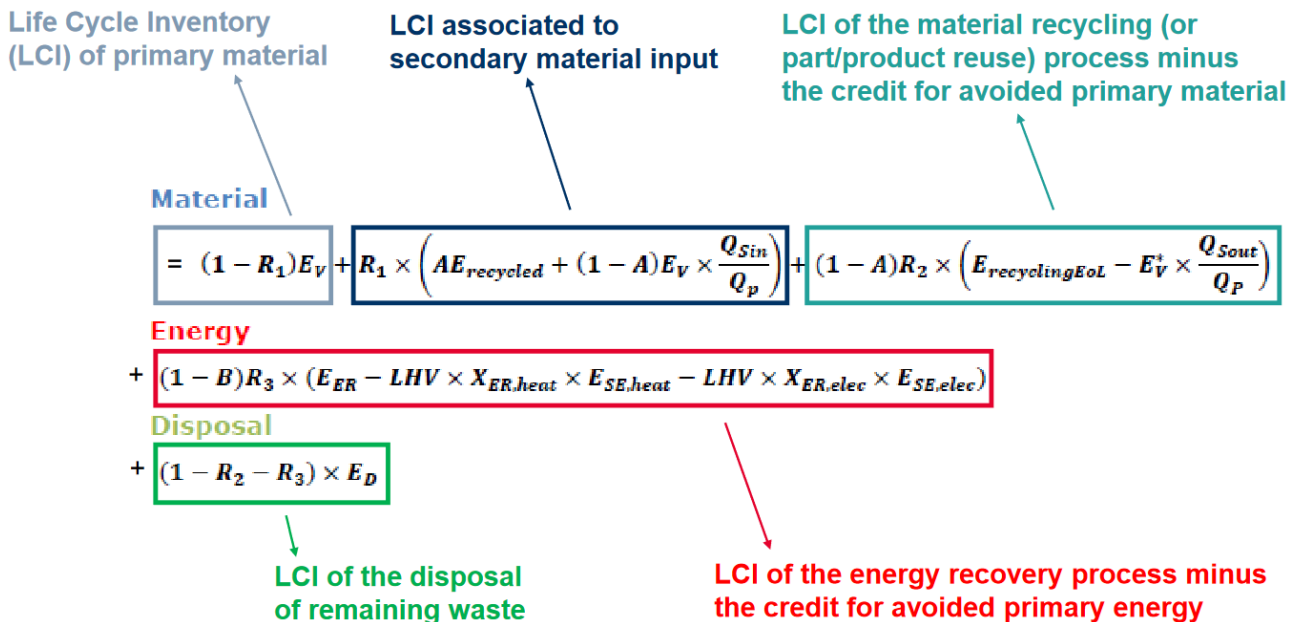


Fig. 3.1 Description of the CFF according to (Zampori & Pant 2019).

The following list contains a description of the different parameters of the CFF:

- A:** allocation factor of burdens and credits between supplier and user of recycled materials.
- B:** allocation factor of energy recovery processes: it applies both to burdens and credits.
- Q_{sin}:** quality of the ingoing secondary material, i.e. the quality of the recycled material at the point of substitution.
- Q_{sout}:** quality of the outgoing secondary material, i.e. the quality of the recyclable material at the point of substitution.
- Q_p:** quality of the primary material, i.e. quality of the virgin material.
- R₁:** it is the proportion of material in the input to the production that has been recycled from a previous system.

R₂: it is the proportion of the material in the product that will be recycled (or reused) in a subsequent system. R2 shall therefore take into account the inefficiencies in the collection and recycling (or reuse) processes. R2 shall be measured at the output of the recycling plant.

R₃: it is the proportion of the material in the product that is used for energy recovery at EOL.

E_{recycled} (E_{rec}): specific emissions and resources consumed (per unit of analysis) arising from the recycling process of the recycled (reused) material, including collection, sorting and transportation process.

E_{recyclingEoL} (E_{recEoL}): specific emissions and resources consumed (per unit of analysis) arising from the recycling process at EOL, including collection, sorting and transportation process.

E_v: specific emissions and resources consumed (per unit of analysis) arising from the acquisition and pre-processing of virgin material.

E*_v: specific emissions and resources consumed (per unit of analysis) arising from the acquisition and pre-processing of virgin material assumed to be substituted by recyclable materials.

EER: specific emissions and resources consumed (per unit of analysis) arising from the energy recovery process (e.g. incineration with energy recovery, landfill with energy recovery, ...).

E_{SE,heat} and E_{SE,elec}: specific emissions and resources consumed (per unit of analysis) that would have arisen from the specific substituted energy source, heat and electricity respectively.

ED: specific emissions and resources consumed (per unit of analysis) arising from disposal of waste material at the EOL of the analysed product, without energy recovery.

X_{ER,heat} and X_{ER,elec}: the efficiency of the energy recovery process for both heat and electricity.

LHV: Lower Heating Value of the material in the product that is used for energy recovery.

Further descriptions and examples can be found in the slides of a webinar from the European Commission on the CFF that can be retrieved online⁸. Also, there is an illustrated case study on the application of the CFF on intermediate paper products, that helps understanding the formula⁹.

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A.Data collection: Life Cycle Inventory Analysis (LCI)

A.1 Introduction

The life cycle inventory data is collected and compiled with information provided by the commissioner. If such data is not available, literature data or own assumptions are used to complete the life cycle inventory.

A.2 Stages of investigation

In the initial step, the life cycle stages to be investigated are determined together with the commissioner.

A.3 Inputs and outputs

For each life cycle stage, information on the quantity and type of energy and materials used must be provided by the customer per reference unit (e.g. kg of product) as far as possible for:

- Definition of equivalent product options (weight, size, area, etc.)
- Chemo-physical description of materials and products (balance of elements, heating value, density, etc.)
- Agricultural inputs (fertiliser, pesticides, fuels, fodder, etc.)
- Product properties of foods (content of calories, fat, protein, sugar, calcium, etc.)
- Amount and type of raw materials and material losses to produce the products
- Electricity use from grid (classified by country)
- Heating energy (specified by energy carrier e.g. heating oil, natural gas, wood, charcoal, biogas, etc.)
- Water use (classified by country)
- Use of chemicals, metals, plastics, or other auxiliary materials e.g. detergents, solvents, minerals, rare earths, packages, metals, plastics, etc.
- Transport of materials from previous stage to production location
- Losses of materials as waste or for recycling during processing
- Direct emissions to air, water, and soil
- Effluents / wastewater (classified by type of treatment and concentration of pollutants)
- Disposal of wastes (classified by type of material and treatment)
- Size of the factory infrastructure in relation to the total quantity of products per year

A.4 Inventory modelling

For each of the process stages outlined before, the commissioner must provide detailed information.

The offer is based on a basic price per unit process analysed. The analysis of a unit process includes the production of questionnaires where necessary and electronic documentation in the EcoSpold v1 format.

The best available version of ecoinvent data is used to complete the product systems with background processes (ESU-services 2024). Further information about the databases ESU-services uses in its projects can be found on the webpage.¹⁰

The modelling of the LCI and the calculation of results is done with the professional LCA software SimaPro 2023.

B. Description of the electronic data format according to ISO 14048

In accordance with the goal and scope definition, the inventory analysis will be conducted as far as possible in an electronic format in compliance with the technical specification ISO/TS 14048. The EcoSpold format will be used for this purpose. The format was developed in the ecoinvent project (Frischknecht et al. 2004). It is based on the Spold format for LCA. All unit process data will be available in electronic format as XML files. These files can be directly imported and used with all major LCA software products, e.g. SimaPro, GaBi or Umberto. The format also complies with the technical specification ISO/TS 14048.

Data will often be presented in the form of tables, which are a direct printout of the electronic format. Some reading guidance is given in this section. The so-called EcoSpold data format is briefly

¹⁰ Download on <https://esu-services.ch/address/tender/>

described in this chapter. For a more extensive description, we refer to Hedemann & König 2003 and to the three dataset schemas available on the Internet.¹¹

A process, its products and its life cycle inventory data are documented using the ecoinvent data format (EcoSpold) with the basic structure shown in Tab. 1.

Tab. 1 Structure of the EcoSpold data format

Meta information		
Process		
	ReferenceFunction	defines the product or service output to which all emissions and requirements are referred to
	TimePeriod	defines the temporal validity of the dataset
	Geography	defines the geographical validity of the dataset
	Technology	describes the technology(ies) of the process
	DataSetInformation	defines the kind of process or product system, and the version number of the dataset
Modelling and validation		
	Representativeness	defines the representativeness of the data used
	Sources	describes the literature and publications used
	Validations	lists the reviewers and their comments
Administrative information		
	DataEntryBy	documents the person in charge of implementing the dataset in the database
	DataGenerator AndPublication	documents the originator and the published source of the dataset
	Persons	lists complete addresses of all persons mentioned in a dataset
Flow data		
	Exchanges	quantifies all flows from technical systems and nature to the process and from the process to nature and to other technical systems
	Allocations	describes allocation procedures and quantifies allocation factors, required for multi-function processes

B.1 Unit process inventory (Flow Data)

The unit process inventory is an inventory of energy and material flows (in- and outputs), which are used or emitted by the unit process under study. It is also referred to as unit process raw data. There are two classes of inputs and outputs: elementary flows and technosphere flows. Elementary flows in this context are all direct resource uses (inputs, e.g. of fresh water or land) and all emissions of substances to the natural environment (output). An emission is a single output from a technical process to the environment, e.g. the emission of a certain amount of SO₂. Technosphere flows take place between different processes that are directly controlled by humans, e.g. the delivery of water from a pumping station to a private household. They can be physical or service inputs (e.g. electricity, fertilizer, waste management services or seeds) or outputs (e.g. the product).

Fig. 2 shows the unit process flow chart of potato cultivation with some inputs and outputs as an example. Potato seeds are the direct input; potatoes are the major output (product or reference flow) of this unit process. Additionally, further inputs, e.g. fertilizer, machinery hours or pesticides are necessary. Potato cultivation also produces some emissions, e.g. pesticides to water or N₂O to air.

¹¹ <https://www.ecoinvent.ch/> → Publications → ecoinvent Documents and Technical Specifications → Data exchange format (EcoSpold)

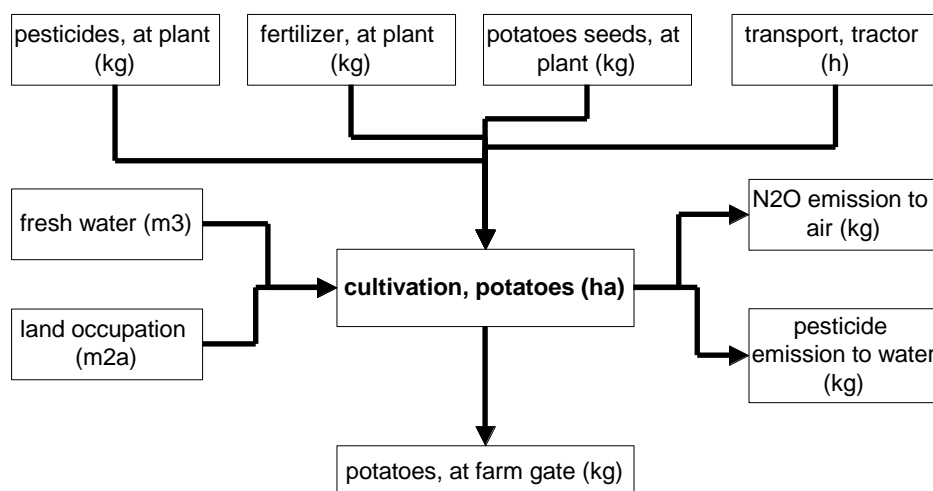


Fig. 2 Unit process flow chart of potato cultivation including some examples of inputs and outputs

Tab. 2 shows an example with some unit process raw data for potatoes at the farm gate. In the first four rows of column L, there is a description of the reference flow for this unit process. The description represents the structure of the process information shown in Fig. 2. This example refers to the production of 1 kg potatoes in Switzerland (CH) with integrated production (IP) technology (excerpt from Nemecek et al. 2007). For this example, only a part of the 67 inputs and outputs recorded is shown in this table.

Column B is not part of the EcoSpold-format, but it helps structure the information about different inputs and outputs in the spreadsheet. In columns F, G, J and K, the different inputs and outputs to and from the unit process are named and described in detail.

Typically, the reference flow describes an output to technosphere. Therefore, it should share a similar nomenclature as used for inputs from technosphere. Line 7, for instance, defines the input of a fertilizer (ammonium nitrate, as N, at regional storage). The fertilizer was produced in Europe (RER). It is not an infrastructure process and the quantity used per kg potatoes in column L is provided with the unit “kg”. Or in other words, line 7 can be read as follows: to produce 1 kg potatoes one needs 0.44 grams of nitrogen in the form of ammonium nitrate fertilizer.

Tab. 2 shows some further examples for the input of fertilizers, pesticides and transport services. These technosphere inputs are linked to other unit processes that are described in similar tables.

In rows 49-53, resource uses of carbon dioxide, energy from biomass and land are recorded (input flows from nature). The description of flows to and from nature differs slightly from technosphere flows. Often, there is no necessity to define the location or the “infrastructure” field. Emissions are distinguished according to the compartments (air, water, soil) and sub-compartments (e.g. river, groundwater). This information could be found in the hidden columns H and I.

Finally, the technosphere output or reference flow of the process is defined as 1 kg potatoes from integrated production in Switzerland. This row (highlighted in green) is typically hidden as it is equal to 1 in most datasets and therefore provides no additional information.

The inventory table also provides information on the uncertainty of the flows. In this case, the uncertainty type 1 (column M) stands for a lognormal distribution. The standard deviation in column N shows the square value for the 95% geometric standard deviation. The mean value multiplied or divided by the 95% squared geometric standard deviation gives the 97% maximum or the 2.5% minimum value, respectively.

The general comment in column R provides information about the estimation or calculation of each flow. In this example, the quantities of fertilizer are based on statistical data while different air emissions have been calculated with models.

Quite often, a simplified approach is used to estimate uncertainties. The pedigree matrix in the field “general comment” provides background information about this approach. Here different sources of uncertainty (Reliability, Completeness, Temporal correlation, Geographical correlation, Further technological correlation, Sample size) are estimated with scores between 1 and 5. The higher the scores, the higher the estimated uncertainty. A pedigree matrix of e.g. (4,4,1,1,1, na) means, that reliability and completeness are rather poor while temporal, geographical and technological correlations of the data source used are good. The sample size is not assessed anymore and therefore marked with “na” for “not available”. This pedigree assessment of the sources of information is used to calculate the standard deviation in column N. For detailed information, please refer to Frischknecht et al. 2004.

Tab. 2 Example of unit process raw data of the production of 1kg potatoes in Switzerland with integrated production technology (excerpt from Nemecek et al. 2007). Abbreviations: RER = Europe; CH = Switzerland; IP = Integrated Production

	B	F	G	J	K	L	M	N	R
	Explanations	Name	Location	Infrastructure-Process	Unit	potatoes IP, at farm	uncertaintyType	StandardDeviation85%	GeneralComment
3						CH	0		
4		Location							
5		InfrastructureProcess							
6		Unit				kg			
7	Technosphere	ammonium nitrate, as N, at regional storehouse	RER	0	kg	4.35E-4	1	1.07	(2,1,1,1,1,na) statistical data
17		[sulfonyl]urea-compounds, at regional storehouse	CH	0	kg	2.69E-7	1	1.13	(2,2,3,1,1,na) statistical data
23		potato seed IP, at regional storehouse	CH	0	kg	6.78E-2	1	1.07	(2,1,1,1,1,na) statistical data
25		fertilising, by broadcaster	CH	0	ha	8.08E-5	1	1.07	(2,1,1,1,1,na) statistical data
26		harvesting, by complete harvester, potatoes	CH	0	ha	2.69E-5	1	1.07	(2,1,1,1,1,na) statistical data
40		transport, lorry 28t	CH	0	tkm	1.57E-3	1	2.71	(4,5,na,na,na,na) standard assumption
49	resource, in air	Carbon dioxide, in air			kg	3.42E-1	1	1.07	(2,2,1,1,1,na) calculation
50	resource, biotic	Energy, gross calorific value, in biomass			MJ	3.87E+0	1	1.07	(2,2,1,1,1,na) measurement
51	resource, land	Occupation, arable, non-irrigated			m2a	1.27E-1	1	1.77	(2,1,1,1,1,na) statistical data
52		Transformation, from arable, non-irrigated			m2	2.69E-1	1	2.67	(2,1,1,1,1,na) statistical data
53		Transformation, to arable, non-irrigated			m2	2.69E-1	1	2.67	(2,1,1,1,1,na) statistical data
54	air, low population density	Ammonia			kg	4.36E-4	1	1.30	(2,2,1,1,1,na) modell calculation
55		Dinitrogen monoxide			kg	1.29E-4	1	1.61	(2,2,1,1,1,na) modell calculation
57	soil, agricultural	Cadmium			kg	2.62E-8	1	1.77	(2,2,1,1,1,na) modell calculation
58		Chlorothalonil			kg	8.83E-5	1	1.32	(2,2,1,1,1,na) modell calculation
71	water, ground-	Nitrate			kg	9.36E-3	1	1.77	(2,2,1,1,1,na) modell calculation
72		Phosphate			kg	3.06E-6	1	1.77	(2,2,1,1,1,na) modell calculation
73	water, river	Phosphate			kg	1.06E-5	1	1.77	(2,2,1,1,1,na) modell calculation
75	Outputs	potatoes IP, at farm	CH	0	kg	1.00E+0			

B.2 Unit process description (Meta Information)

The following Tab. 3 shows an example of data documentation. Column A provides some additional description for structuring the different rows. It is not part of the XML-files. In column C, the data field names can be seen. The following columns provide information for each unit process. In a report, several such columns for similar processes might be shown together.

In this example, the information refers to the unit process “diesel, used by tractor”. The process was investigated for the location “RER”. This stands for the continent Europe. Two-character location codes like DE, PL, etc. are used for individual countries and they are the same as the country abbreviations used for internet addresses. Location codes with four letters separated by “-” stand for specific regions of countries, e.g. CN-BJ stands for the Chinese region of Beijing. Three-character

References

abbreviations stand for regions like Europe (RER), Global (GLO), Oceans (OCE), etc. A full list of abbreviations can be found on the ecoinvent website.¹²

Row 4 (*InfrastructureProcess*) defines whether the unit process is an infrastructure process (1) or not (0). Some LCA software generally neglect infrastructure processes and thus this information is necessary for clear identification.

Row 5 (*Unit*) defines the reference unit of the process. In this case the process refers to one kg of diesel used in a European tractor. Other units are for example MJ, m², kWh, etc. The unit “unit” refers to the inventory of one item, e.g. one “unit”/piece of a tractor stands for one tractor according to the specifications described in the rows below.

For the remaining rows, please consult the explanations provided in column G of Tab. 3 (These explanations are not part of the electronic format).

As can be recognised from the row numbering, several rows, which are not of interest to the average user but are of interest to software developers, have been hidden in this simplified description. Detailed and complete information is available by Hedemann & König 2003.

¹²

https://www.ecoinvent.org/files/eiv3.6_geographies_names_coordinates_shortcuts_overlaps20190912.xlsx

Tab. 3 Example for the documentation of a unit process (Meta Information)

1	A	C	D	G
1	Type	Field name		Explanations for the single rows
2	ReferenceFunction	Name	diesel, used by tractor	Definition for the output of the unit process
3	Geography	Location	RER	Definition for the location of the investigated process.
4	ReferenceFunction	InfrastructureProcess	0	Line 4 (<i>InfrastructureProcess</i>) defines whether the unit process is an infrastructure process (1) or not (0). Some LCA software generally neglect infrastructure processes and thus this information is necessary for a clear identification.
5	ReferenceFunction	Unit	kg	Line 5 (<i>Unit</i>) defines the reference unit of the process. In this case the process refers to one kg of diesel used in an European tractor. Other units are for example MJ, m2, kWh, etc. The unit "unit" refers to the inventory of a full item, e.g. one "unit" of tractor stands for one tractor with the specifications described in the meta information.
14		IncludedProcesses	The inventory takes into account the diesel fuel consumption and the amount of agricultural machinery and of the shed, which has to be attributed to the use of agricultural machinery. Also taken into consideration is the amount of emissions to the air from combustion and the emission to the soil from tyre abrasion during the work process. The following activities where considered part of the work process: preliminary work at the farm, like attaching the adequate machine to the tractor; transfer to field (with an assumed distance of 1 km); field work (for a parcel of land of 1 ha surface); transfer to farm and concluding work, like uncoupling the machine. The overlapping during the field work is considered. Not included are dust other than from combustion and noise.	Line 14 (<i>IncludedProcesses</i>) shows the system boundaries of the unit process with a description of included and excluded parts of the life cycle.
17		Synonyms		In this line 17, synonyms to the process name might be shown. They can be used for an easy search in the different software products.
18		GeneralComment	Average data for use of diesel in agricultural machinery.	The general comment in line 18 (<i>GeneralComment</i>) gives an introducing description about this process.
20		Category	agricultural means of production	The "category" and "subcategory" can be used by different software programmes for structuring of a database.
21		SubCategory	work processes	
24		Formula		Additional information for chemical or technical products can be given in the following fields "formula", "CAS number" etc.
25		StatisticalClassification		
26		CASNumber		
27	TimePeriod	StartDate	1991	
28		EndDate	2002	
30		OtherPeriodText	Measurements were made in the last few years (1999-2001).	The fields for the time period describe in more detail the reference time frame for the investigation of the process, e.g. the time of publication, reference year for technical standards or statistical data, etc.
31	Geography	Text	The inventories are based on measurements made by agricultural research institute in Switzerland.	Line 31 with the field "Geography" describes more detailed the reference region for the dataset.
32	Technology	Text	Emissions and fuel consumption by the newest models of tractors set into operation during the period from 1999 to 2001.	The field on technology provides background about the status of technology, e.g. average, state of the art, etc.
34		ProductionVolume		
35		SamplingProcedure	The inventoried HC, NOx, CO values are measurements made following two test cycles (ISO 8178 C1 test and a specific 6-level-test created by the FAT) and on measurements made during the field work. The other emissions were calculated basing on literature data and the measured fuel consumption.	Lines 34 to 36 give more information about the sampling procedure for the data. It describes the actual production volume and the share considered for the inventory, the sampling procedure and the necessary extrapolations.
36		Extrapolations	Values given in the reference are representative for the average work processes. Processes are typical procedures for Switzerland around the year 2000, they are not statistical average processes.	
37		UncertaintyAdjustments	none	
45		PageNumbers	biomass production	Finally, "page numbers" gives information where more details can be found in the background report. The reference to a report is also part of the electronic format.

C. Monte-Carlo uncertainty analysis

Monte Carlo analysis is a technique used in the SimaPro software to quantify the uncertainty of LCA results. A Monte-Carlo-Simulation with 1000 runs is used to perform the uncertainty analysis for the product. The overall uncertainty of the results is calculated based on the uncertainty for the collected foreground data and the reported uncertainties in the background database.

Monte Carlo analysis is typically performed in SimaPro in the following steps:

- **Background and foreground data uncertainty:** SimaPro has a feature that allows to define the uncertainty parameters for each elementary flow (each input or emission) in the background databases. This uncertainty can be expressed as probability distributions for the input parameters (e.g., energy consumption, emissions) in the database.
- **Monte Carlo sampling:** SimaPro uses Monte Carlo sampling to generate many different scenarios by randomly sampling the input parameter values from the defined probability distributions

within the specified ranges. The software performs simulations by running a given number of iterations (in this case, 1000 runs) of the LCA calculations with different sets of input parameters.

- LCA calculations: SimaPro calculates the LCA results for each set of sampled input parameters. These LCA results help determine the range of possible outcomes and the probability distribution of the overall environmental impact of the assessed system or product.
- Analyzing results: Once the Monte Carlo analysis is complete, SimaPro provides statistical summaries and visualizations of the results. The Monte-Carlo- Simulation calculates the following indicators:
 - Mean = The average value
 - Median = The value in the middle of all values
 - SD = Standard deviation, how dispersed the data is from the mean
 - CV = Coefficient of variation, the ratio between standard deviation and the mean. i.e how “far” the data is spread in percentages (given as absolute value)
 - 2.50% = The value at the lower boundary of the values in the 95% confidence interval
 - 97.50% = The value at the upper boundary of the values in the 95% confidence interval
 - SEM = Standard error of the mean, the standard deviation divided by the square root of the sample size

This Monte Carlo analysis in the SimaPro LCA software helps quantify the uncertainty in LCA results due to variations in the background database. By running multiple iterations and sampling different input parameter values, it provides insights into the variation in environmental impact and helps assess the overall uncertainty of an LCA study.

D. Key parameter model

ESU-services offers a range of different tools which allow the calculation and analysis of the environmental impacts of products or services.¹³ The idea of a key parameter model (KPM)¹⁴ is to allow simplified calculation of environmental impacts for a specific type of product or service. They are based on the knowledge obtained from a detailed LCA case study. An Excel spreadsheet or a web-based solution (share&collect) can be offered. This helps to minimize the project costs if several equivalent products or services are to be analysed or compared.

The KPM are easy to handle for SME operators, designers, or manufacturers. The users can enter some key data. With the help of the key parameter models for companies, the user can, for example, carry out a simplified LCA of the annual environmental impacts within a few hours. The users do not have to deal with complicated questions such as choosing the correct data, different impact assessment methods or details of the LCA such as allocation. Several key parameter models have been developed by ESU-services e.g. for

- the naturemade certification for energy systems (biogas, photovoltaics, solar collector systems, wind, and hydro power plants)¹⁵
- environmental impacts of Christmas trees¹⁶

¹³ <https://www.esu-services.ch/software/>

¹⁴ <https://esu-services.ch/software/kwm/>

¹⁵ <https://esu-services.ch/projects/naturemade/>

¹⁶ <https://esu-services.ch/software/christmastrees/>

References

- environmental product declaration (EPD) for run-off-river hydro power plants¹⁷
- comparing transport chains
- analysing electricity mixes
- calculating the impacts of meals in canteens
- manufacturing of pipes with varied materials and diameters
- investigating the annual impacts and timeline of an organization's greenhouse gas emissions
- cooperative data collection for food production chains¹⁸
- comparing different beverage cups, packages, fertilizer substrates, vacation trips, etc.¹⁹
- personal environmental footprint calculators for Switzerland²⁰ and Germany²¹

For providing an offer we need the following information

- Have you already prepared a detailed LCA and do you know the main influencing parameters from an environmental point of view?
- How many key parameters shall be entered (e.g. energy use, materials, transports, etc.)?
- Which languages should be available for the end user?
- Which environmental indicators should be shown? Details for various LCIA methods available for such an assessment are described in a document provided on our webpage.²²
- Should there be an environmental product declaration for one product, or should it be possible to directly enter data for several options?
- Which type of results shall be shown (tables, figures, analysis)?

¹⁷ <https://esu-services.ch/ourservices/epd/>

¹⁸ <https://esu-services.ch/projects/lcafood/sense/>

¹⁹ <https://esu-services.ch/software/christmastrees/>

²⁰ <https://www.footprint.ch/>

²¹ <https://www.wwf.de/themen-projekte/klima-energie/wwf-klimarechner/>

²² Download on <https://esu-services.ch/address/tender/>