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To cite this article: T Brockmann 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **323** 012108

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Digitalization of building LCA and international activities – in the context of German assessment system for sustainable building

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Abstract. In this paper it is shown how digitalization and the establishment of an online infrastructure for life cycle assessment (LCA) in the context of the assessment system for sustainable building (BNB) by the German government forms starting point for an open international data network, as brought forward by the activities of InData (“International Open Data Network for Sustainable Building”). The establishment of the ILCD+EPD data format for EPD, the provision of interfaces, the development of workflow structures, guidelines and rules, which are openly published, internationally allow to access data from several databases. All these aspects are subject of the InData activities, and are decisive for a harmonization of LCA for sustainable building. With this concept of digitalization the propagation of the use of environmental product declarations (EPD) in building LCA was enhanced, and also new applications for using EPD data are offered, e.g. in BIM or other context.

1. Introduction

Nowadays the climate change is widely recognized. It is the motivation for manifold international, European, and national policy strategies regarding CO₂-reduction, energy and resource efficiency, all of these are aspects of sustainability. As a consequence, building certification systems for sustainable building have been established worldwide (Figure 1).



Figure 1: Building certification schemes for sustainable building worldwide.

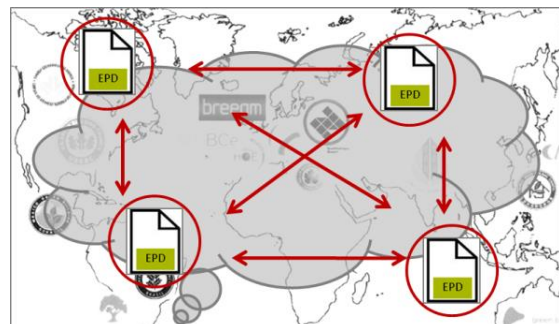


Figure 2. Integrated communication of EPD data via digitalization.

In Germany, Sustainable Building is part of the National Sustainability Strategy with the Guideline for Sustainable Building and the Assessment System for Sustainable Building (BNB) being most



essential for the construction sector. The government takes the responsibility and brings forward sustainability by establishing BNB as a binding instrument for federal buildings. All information and tools are offered with a high transparency in order to diminish barriers. Political programs and support is considered as very helpful, also for the definition of responsibilities. Experience in Germany has shown that the centrally bundled provision of data and tools by the government is a valuable instrument for a wide application of LCA at building level and the realization of sustainable buildings.

2. BNB

The sustainability of a building under the BNB principles takes into account Ecological, Economic, and Socio-Cultural aspects in equal parts, additionally regarding Technical and Process Quality for buildings. Particularly with respect to ecological quality, that is, when considering the impact on the global environment, LCA forms an essential part of the overall assessment (Figure 3). The primary energy demand and effects of the building on the global warming, ozone depletion, photochemical ozone creation, acidification and eutrophication potential are determined, taking into account the life cycle over the chosen time period of 50 years.

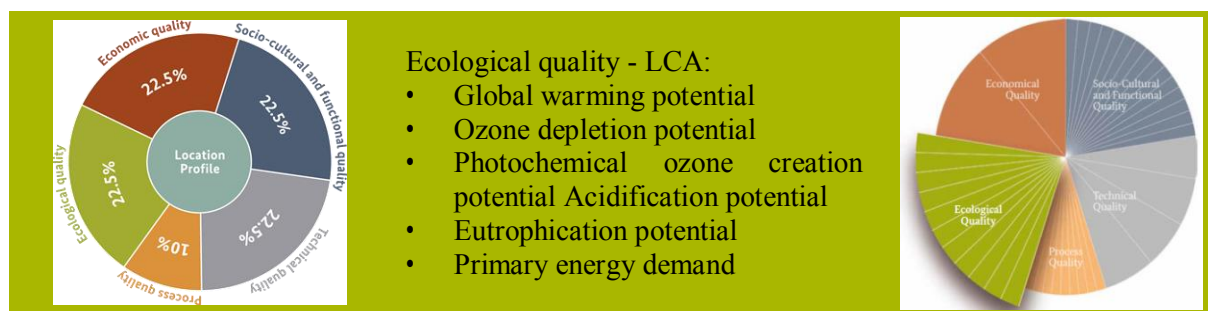


Figure 3. Considered dimensions of sustainability within BNB.

2.1. BNB tools

For choosing suitable building products and constructions BNB provides ÖKOBAUDAT with basic data for life cycle analysis at building level with the online tool eLCA. All provided tools are web-based, cost-free, open-source based, and publicly available; for all of them an English version (or other information) is given. The tools are initiated and maintained by the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR), a research Institution under the portfolio of the Federal Ministry of the Interior, Building and Community (BMI) [1, 2].

2.1.1. The ÖKOBAUDAT platform. It is a platform with data, information, and links related to the LCA of construction works. At the platform's core is the online database with LCA datasets on building materials, construction, transport, energy and disposal processes. ÖKOBAUDAT is provided already since 2009, and it is available for everybody interested in an ecological evaluation of buildings with a consistent database. Search- and filter-functionalities allow browsing relevant data for chosen materials or products directly in the online database.

Currently, ÖKOBAUDAT provides more than 1,200 datasets (about half of them are generic data) on all important construction product groups. Since 2013, it comprehensively meets the demands of European Standard EN 15804.

ÖKOBAUDAT data are used nationally and internationally by other certification schemes, LCA tools, BIM applications, or other. All ÖKOBAUDAT data are quality checked. The *ÖKOBAUDAT Manual* [6] contains technical and formal information on the ÖKOBAUDAT database.

2.1.2. eLCA software for building life cycle assessment. With the online tool eLCA the environmental effects of buildings can be easily determined taking into consideration the entire life cycle [7]. The basis is the calculation rules of BNB which are linked with the ÖKOBAUDAT data.

The core of eLCA is the component editor ("Bauteileditor"). The users can model their building

components in a very user friendly way. The dynamic graphic displays the building components with its material layers and enables the user to visually inspect the input data (Figure 4). The results can be directly compared with the benchmarks of BNB. eLCA presents the calculations transparently, and thereby enables detailed analysis of the results (Figure 5).

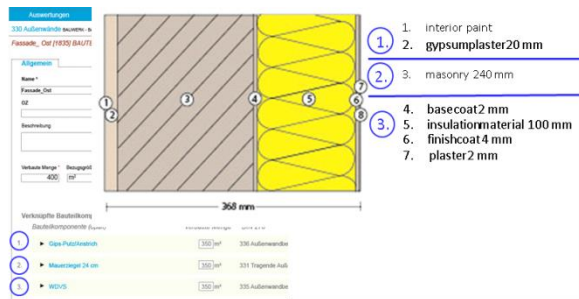


Figure 4. Dynamic graph – visual check input parameters.

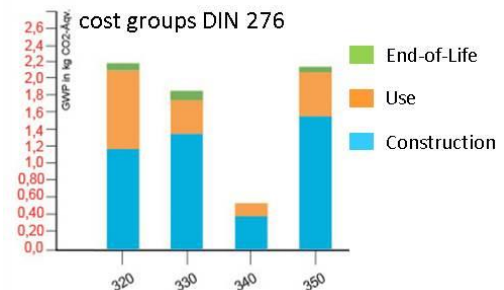


Figure 5. Analysis of eLCA results.

eLCA is a central instrument in the digitalization process as there is internal and external data transfer to and from the tool. Besides LCA, the instrument is used for other BNB criteria, like life cycle costing (LCC), transport calculations, and waste/recycling with digital data exchange.

It also imports building components from external software applications e.g. used for German (bindingly required) energy performance certificate for buildings (“Energieausweis”), and exports data/results to subsequently used applications.

Data transfer to/from BIM applications also is possible, and will be further developed in ongoing (research) projects.

3. Digital LCA infrastructure within German BNB

Reasons to digitalize the LCA infrastructure within the context of BNB were to improve all data related workflows, assure independency, and reduce cost for the production of building LCA.

In earlier stages ÖKOBAUDAT consisted of zip.files, and LCA sometimes was based on excel calculation routines. With a growing amount of data and data providers suitable workflows had to be developed. Also, the BMI/BBSR decided not only to offer online data transfer via ÖKOBAUDAT, but also to publish an independent building LCA calculation tool, eLCA.

Also, there already was the vision of an open international data network and to establish an integrated communication of EPD data and information. Standardized EPD were produced internationally, but due to the format (often pdf.file) they could not be used directly e.g. for LCA calculations.

A digital data format and interfaces were the precondition for these online structures. Within the digitalization process, most decisive was the development of a machine readable data format for EPD, i.e. the ILCD+EPD data format. This forms the basis for most other related activities.

3.1. LCA tool chain

BNB established a complete digitalized LCA ‘tool chain’. It starts with the basic material data from EPD, which are imported in the online database ÖKOBAUDAT, exported from there to eLCA, which results are used for the final evaluation with bronze, silver, or gold sustainability certificate (Figure 6).

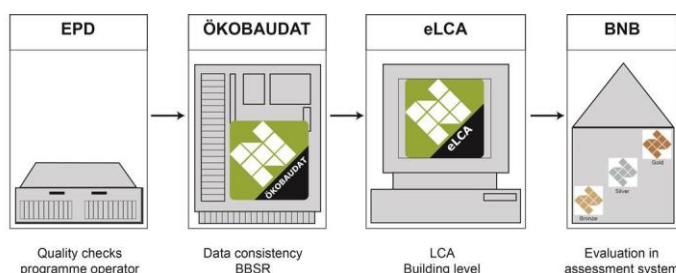


Figure 6. Digitalized tool chain LCA German BNB.

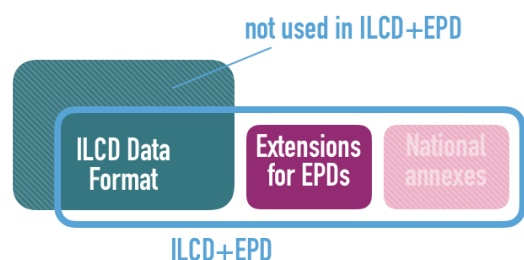


Figure 7. ILCD+EPD data format.

3.2. Technical Aspects

For a better understanding of the digitalized LCA structures the technical aspects are described.

3.2.1. Data format

The ILCD+EPD data format (short for ‘ILCD data format with EPD extensions’) is a technical means for transporting information associated with an EPD in a structured way. It is based on the established ILCD data format created by the European Commission [8]. It does not use the entire extent of the original ILCD format, but only those parts which are necessary and suitable for describing EPD data, complemented by additional EPD specific information that was not foreseen in the original ILCD format (Figure 7). The information is published in the *Table of Definitions ILD+EPD data format, CPEN2018* and corresponding *FAQ-document* [6]. The format structure allows for national annexes, where e.g. metadata can be integrated. Data format as in ÖKOBAUDAT is fully compatible with InData (Table 1).

3.2.2. *Databases.* In technical terms, the ÖKOBAUDAT database is based on the software soda4LCA [9].

3.2.3. *Interfaces.* The ÖKOBAUDAT is equipped with a standardized interface (API – application programming interface) for data exchange with other applications and software tools with the corresponding authorisations. The API documentation is provided in HTML and PDF formats in the zip.file *Developer documentation* [6].

3.2.4. *Data supply for ÖKOBAUDAT.* One of the decisive advantages of the digitalization is that now for all data providers an online data transfer into ÖKOBAUDAT is possible. There are essentially several ways of data import.

Import via EPD Editor

The currently published open source software, the EPD Editor [10], was developed on behalf of and financed substantially by BMI/BBSR. On the basis of existing EPD (e.g. pdf.format) with this software EPD datasets can be transformed/modelled in the ILCD+EPD data format with manual input, and then imported into ÖKOBAUDAT. A special feature of the tool is that datasets can be created in several languages and then offered in bi- or multilingual version. Currently the EPD programs ift Rosenheim, Bau EPD, kiwa, and Thünen Institut with representative average datasets, use the EPD Editor for data creation and transfer. For the *EPD-Editor manual* [6] and other support see website ÖKOBAUDAT/downloads.

Direct import via an interface

Data supplier can import their EPD/LCA datasets directly into ÖKOBAUDAT online from their database systems via the interface. Currently, the EPD program IBU and thinkstep with generic data use this option.

Validation tool

Before datasets are imported, which way ever, data providers must check their data with the validation tool [11]. Data are validated regarding data format, completeness, and product category allocation. The tool was developed for BNB and is regarded as highly user friendly and intuitive. It runs on a standalone, cross-platform basis. Instructions are given in *Technical Validation of datasets* [6].

3.3. Data quality management - ÖKOBAUDAT

While EPD programs publish several EPD types, e.g. differing in referenced standards (EN 15804, ISO 21930) [3, 4], background database (Gabi, ecoinvent), and depth of information (core EPD, program EPD), addressed location etc., the specific aim of ÖKOBAUDAT is the provision of data for building LCA. The results are related to benchmarks and are used for evaluation and comparison within certification schemes. For this application a high level of data quality and consistency is decisive. Therefore, the data quality management is an essential part of the LCA infrastructure. It comprises requirements regarding data format **and** data quality, in terms of EPD programs, processes and workflows.

3.3.1. Process of data acceptance. The process of data acceptance is as follows:

1. Send *Application form* [6] including self-declaration about compliance with requirements
2. Check of data provider (program and provided documents) by BMI/BBSR
3. Approval of data provider
4. Data supply to inbox of ÖKOBAUDAT
5. Plausibility checks (e. g. sample testing of data)
6. Full approval (data provider + data)
7. Publication of data in ÖKOBAUDAT

3.3.2. Requirements data provider. To ensure data quality in ÖKOBAUDAT, the data providers are checked in terms of meeting the requirements. Hence, they are asked to provide the following information / documents:

- Self-declaration stating conformity with relevant standards (e.g. EN 15804) and *Principles for acceptance of LCA data in ÖKOBAUDAT* [6]
- Access to program rules and PCR documents
- List of the members of the PCR review panel
- List of verifiers, description of the requirements for the verifiers and verification process
- Consent of the owner of the datasets for use in ÖKOBAUDAT

3.3.3. Requirements data format. To ensure compliance with the data format the following criteria need to be regarded:

- Delivery of data in ILCD+EPD data format
- Use of validation tool before data delivery
- Delivery of data for plausibility checks (sample testing)
- Validity of data

3.3.4. Quality aspects eLCA

The eLCA calculations are in line with quality assurance as the application of eLCA offers high transparency and consistency of calculations. Pre-configurations of data (e. g. if EPD datasets only offer production phase information, i.e. modules A1-A3, datasets for use phase and end-of-life scenarios need to be assigned), construction element templates, frontend for data input, and graphic presentation of results contribute to quality. Also, interfaces allow using synergies by importing building components from other (energy) calculation software, which also minimizes sources of errors by avoiding manual data input. Another aspect is ongoing optimisation by users' feedback.

3.4. BIM

As already mentioned data format and digitalized LCA structures allow to connect with BIM applications. BMI/BBSR currently is analysing suitable workflows, and further developments in ongoing (research) projects. As BNB has to be applied for federal buildings in general, relevant developments need to be aligned. As a public institution usually predominantly open source and regulations applicable for all stakeholders will be supported. BBSR is involved in national and international standardization works regarding BIM. As being part of InData which co-operates with

ECO platform, which both aim at digitalization and use of EPD for BIM, BBSR will support international harmonization of these processes.

4. International activities

International activities of BMI/BBSR aim at supporting sustainable building. For this reason, it is involved in national and international standardization works. It organizes sessions during (SBE and WSBE) conferences. In respect to building LCA, from beginning on, there was the vision of digitalization for an integrated international communication of data and information to enhance application of building LCA (Figure 2). This is an important motivation for the engagement in InData.

4.1. InData

InData was initiated after important talks/sessions at WSBE 2014 in Barcelona, and is chaired by the BBSR. The mission of InData is to establish an open web based international data network structure for EPD/LCA data using a common data format and open source software, as formulated in the *Decalogue* [6]. Within this network, data for specific purposes shall be identified by filters and easily implemented in applications. InData is an informal, non-profit working group of interested stakeholders who support the stipulated mission. It aims at establishing best practice for providing digitalized EPD as a quality source of verified EPD/LCA data for BIM, as for building LCA and other relevant applications.

With the participating members it represents important EPD programs and covers a significant amount of EPD (Figure 9). From 2014 with about 1,000 globally registered EN 15804 conform EPD it grew to about 6,000 in January 2019 [12]. With this, the interest in using digitalized structures is growing. Another reason for interest in InData is the growing amount of BIM applications in the construction sector which implies a strong demand to connect EPD data with BIM based building models. As InData is offering a platform for developing digitalization and harmonized structures, more stakeholders get involved. Starting with 6, now 12 nations are involved.

4.1.1. Open Network. InData bases its activities on the already existing ILCD+EPD data format, as this offers a high flexibility for possible adaptations, and allows open access to data, while maintaining individual ownership. Anyhow, the use and development of the format as such is to be seen independent.

The idea of InData is to represent defined data quality and consistency. Thus, it decided to define a InData compliance. Within the open data network only InData compliant data will be published. This means that most participants probably will only share certain parts of their databases within the InData network, (e.g. only English is compliant). Only those members who commit (by self-declaration) to meet InData compliance will be allowed to share data within the InData network.

4.1.2. InData compliance. InData compliance comprises common commitment about the data format **and** rules. Currently, it refers to construction products and European Standard EN 15804 (CPEN2018), but it is flexible for development and definitions of compliance for other products and standards. Actually, InData already is defining a compliance level for the amendment EN15804:A2. [5].

a) *Technical*

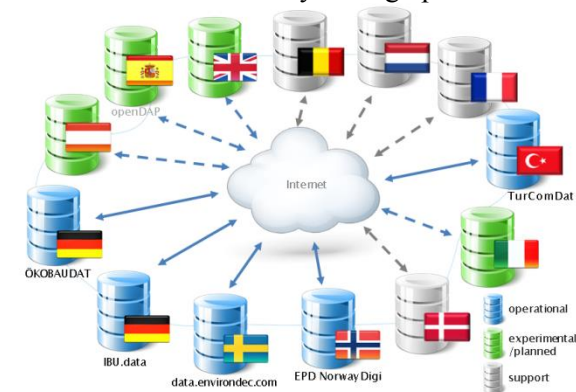
In Data defined a common core of information, i.e. the list of addressed elements of the data format, the definition and explanations of these, and stating mandatory data fields (Table 1). These commitments of harmonization between the international stakeholders are published in the *Table of Definitions ILD+EPD data format, CPEN2018* and corresponding *FAQ-document* [6].

b) *Compliance Rules*

The compliance rules *InData compliance – core rules and requirements* [6] address the data quality, which is mainly used in the sense “fitness for purpose”. With a high transparency and

given information about the delivered data the users will be enabled to filter the adequate data for their specific purposes. Anyhow, common basic rules are described, for EPD data (data format, standard EN 15804, verification, language, validity of data, product category structure, background databases, life cycle modules, and scenarios), data providers (responsibility on datasets, acceptance criteria, validation of data), and EPD programme operators (e. g. verification aspects).

4.1.3. *Currently in use.* Following BMI/BBSR with ÖKOBAUDAT, InData participants brought ideas to practice and now, are ready to contribute to the data network: IBU Germany with IBU.data, EPD International Europe with data.environdec.com, Metsims Turkey with TurComDat, and EPD Norge Norway with EPD-Norge Digi (Figure 8). It is a great success that these stakeholders were able to set up these databases structures on basis of the openly published information and the given open source structures, with only very little additional support from experienced experts. Further stakeholders are currently setting up further databases and corresponding structures.



InData = member, permanent guest, interested stakeholder.

Figure 8. InData Network - participating stakeholders.

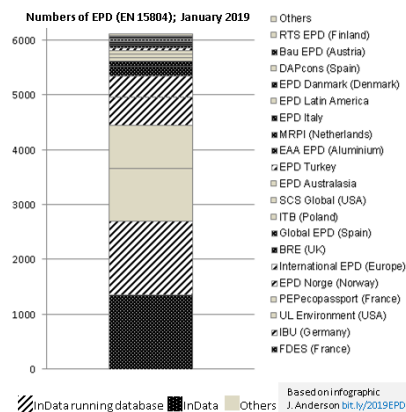


Figure 9. Represented EPD by InData.

4.1.4. *Website.* The InData website offers general information about InData, but the core element will be the browsing of InData compliant data, offered by the participating international stakeholders. Data and technical structure are ready for the publication of the data. As compliance rules are still on the way, the data will be published in a next step, after approval of these rules. Then, the data will be accessible in a table with user friendly search and filter functionalities (Figure 10).

Search results

License conditions of the individual data providers apply. Data resale prohibited

List datasets (Total number of entries: 38 of 1) (Page 1 of 2)

Name	Owner	Language	Locations	Reference year	Valid Until	Export	Node
UK Average Portland Cement	MPA - Mineral Products Association UK	en	GB	2017	2022	View Download as XML	IBU.data
Rendering mortar - Reinforcement Fibre Plaster	Sto SE & Co. KGaA	en	DE	2017	2019	View Download as XML	IBU.data
Fibre Cement Corrugated Sheets	Cembrit Holding A/S	en	DK	2016	2021	View Download as XML	IBU.data
Portland-composite cement CEM III/A-M(S-LL) 52,5 N	CEMEX Ltd	en	LV	2016	2021	View Download as XML	IBU.data
Fibre Cement Slates	Cembrit Holding A/S	en	DK	2016	2021	View Download as XML	IBU.data
Cement mortar	thinkstep	en	DE	2016	2019	View Download as XML	ÖKOBAUDAT
Cement (CEM IV 42,5); CEM IV 42,5	thinkstep	en	DE	2016	2019	View Download as XML	ÖKOBAUDAT

Figure 10. Screenshot browsing in InData network with search and filter functionalities (preview)

4.1.5. *International co-operations.* As InData committed to base its activities on already existing methods and standards it co-operates with ECO platform, the umbrella organization for EPD program operators. ECO platform offers a coherent framework, and it harmonizes activities on EPD, like e. g.

verification procedures and other processes. Harmonized rules will be regarded within InData. Also, ECO platform support InData with digitalization and thus, use of EPD for BIM and other applications. Exchange of both initiatives is given by joint international meetings.

5. Summary and Outlook

With establishing the digital infrastructure for building LCA the German government offered the basis and starting point for international activities which support the propagation of sustainability in the construction sector. The open access to quality-checked data and tools diminishes barriers and enhances harmonization. Decisive was the digitalized EPD format ILCD+EPD. Workflows, tools, user friendly features, and rules are further developed and enhanced continuously within multi-lateral co-operations, nationally and internationally. Digitalization not only improves quality, but also it allows for manifold further developments in future, especially as being open source based. Further developments for the optimization and use for BIM will be the issues in the coming working process, at national and international level. Anyhow, the participation and provision of already running databases according to offered data format and open source structures is considered as a great access for both, German LCA infrastructure as a national forerunner, and InData initiative as an international platform, and distributor of the ideas.

Acknowledgements

The mentioned developments were carried out in research projects within the research program Zukunft Bau run by BMI, in which amongst others, thinkstep, IBO, KIT, greendelta, okworx, and Online Now!, were involved. Especially to acknowledge are the valuable contributions to this paper by Hildegund Figl (IBO), and Oliver Kusche (okworx).

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- [3] Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products; German version EN 15804:2012+A1:2013
- [4] Sustainability in buildings and civil engineering works -- Core rules for environmental product declarations of construction products and services ISO 21930:2017
- [5] Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products; German and English version EN 15804:2012+A1:2013/prA2:2018
- [6] Referenced document/tool is published (directly or by links to other websites) at the website ÖKOBAUDAT (<https://www.oekobaudat.de/en.html>), or InData (www.indata.network).
- [7] eLCA: <https://www.bauteileeditor.de/>.
- [8] ILCD data format: <http://eplca.jrc.ec.europa.eu/LCDN/developerILCDDataFormat.xhtml>.
- [9] Soda4LCA: <https://bitbucket.org/okusche/soda4lca/>.
- [10] EPD-Editor: <https://github.com/GreenDelta/epd-editor/releases>.
- [11] Validation tool: <https://bitbucket.org/okusche/ilcdvalidationtool/>.
- [12] Construction LCA's 2019 Guide on Environmental Product Declarations. Infograph by Jane Anderson: bit.ly/2019EPD.

Table 1. ILCD+EPD data format (m = mandatory field InData compliance CPEN2018)

Field name (EN)	Administrative information
Process information	Data entry
Key data set information	Time stamp (last saved) ^m
UUID of data set ^m	Data set format(s) ^m
Name ^m	Data entry by
Classification ^m	Publication and ownership
General comment on data set	Date of last revision
Data set LCA report, background information	Data set version ^m
Generic data uncertainty loads	Issuer ^m
Description of generic data uncertainty loads	Registration number ^m
Scenarios	Owner of data set ^m
Scenario	Copyright ^m
Name	Exchanges
Default	LCIA results
Group	Indicator ^m
Description	Module/Phase ^m
Modules	Scenario
Module	Value ^m
Name	Unit ^m
Product system ID	Material properties ^m
Quantitative reference	Environmental indicators
Reference flow(s) ^m	Indicators of life cycle
Functional unit, production period, or other parameter	Use of renewable primary energy (PERE) ^m
Time representativeness	Use of renew. primary energy resources as raw materials (PERM) ^m
Reference year ^m	Total use of renewable primary energy (PERT) ^m
Data set valid until ^m	Use of non-renewable primary energy (PENRE) ^m
Time representativeness description	Use non-renewable primary energy as raw materials PENRM) ^m
Geographical representativeness	Total use of non-renewable primary energy resource (PENRT) ^m
Location ^m	Use of secondary material (SM) ^m
Geographical representativeness description	Use of renewable secondary fuels (RSF) ^m
Technological representativeness	Use of non-renewable secondary fuels (NRSF) ^m
Technology description including background system ^m	Use of net fresh water (FW) ^m
Technical purpose of product or process ^m	Hazardous waste disposed (HWD) ^m
Pictogram of technology	Non hazardous waste dispose (NHWD) ^m
Flow diagram(s) or picture(s)	Radioactive waste disposed (RWD) ^m
Modelling and validation	Components for re-use (CRU) ^m
LCA methodology report ^m	Materials for recycling (MFR) ^m
Subtype ^m	Materials for energy recovery (MER) ^m
Data sources, treatment, and representativeness	Exported electrical energy (EEE) ^m
Data sources used for this data set ^m	Exported thermal energy (EET) ^m
Use advice for data set ^m	Indicators of the impact assessment
Validation	Global warming potential (GWP) ^m
Type of review ^m	Depletion potential of the stratospheric layer (ODP) ^m
Review details	Formation potential of tropospheric ozone (POCP) ^m
Reviewer name and institution	Acidification potential of soil and water (AP) ^m
Complete review report	Eutrophication potential (EP) ^m
Compliance declarations	Abiotic depletion potential for fossil resources (ADP _{fossil}) ^m
Compliance system name ^m	Abiotic depletion potential non-fossil resources (ADP _{non-fossil}) ^m