ISSN 1831-9424

Developing life cycle inventory datasets for the hydrogen value chain

A step-by-step guidance towards the publication in the Life Cycle Data Network. v1.0

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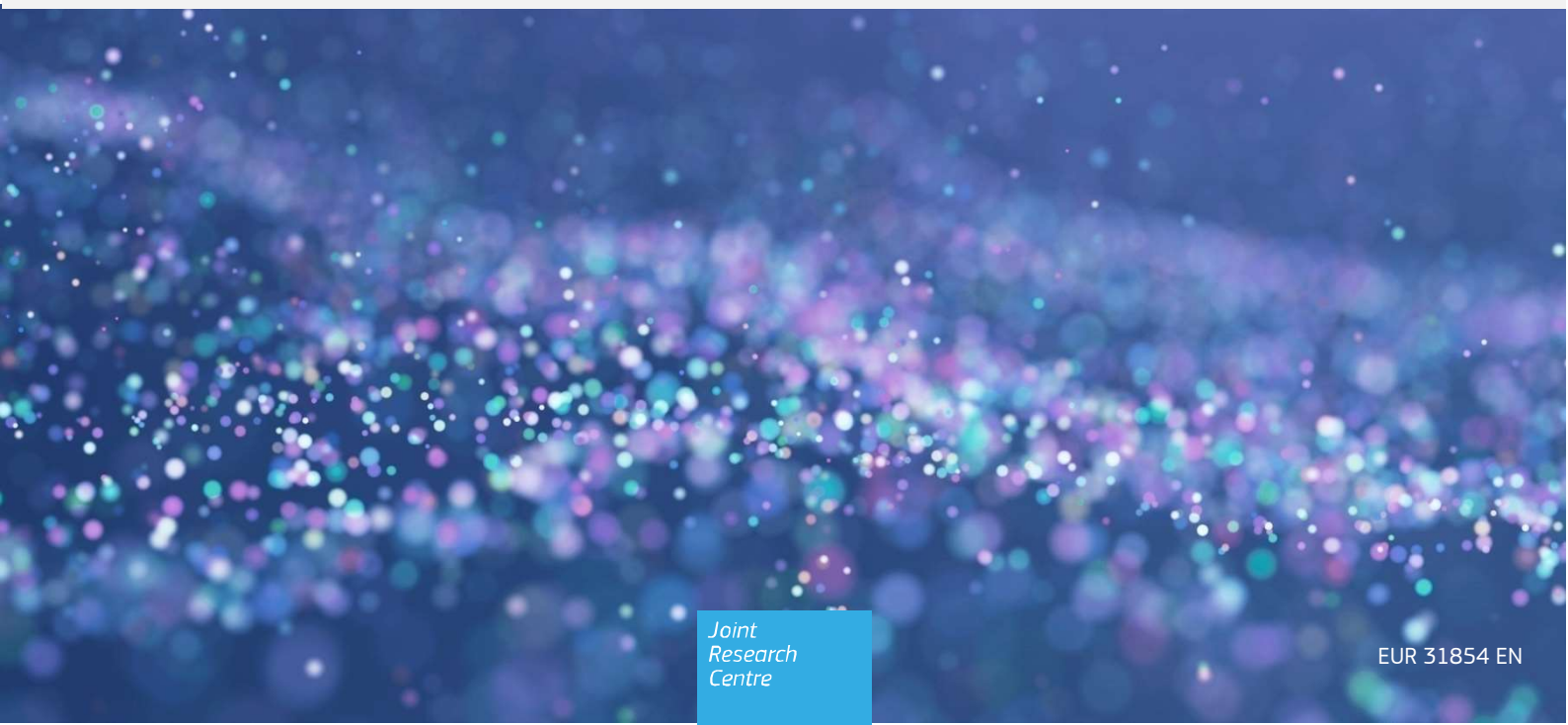
2024



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JRC136553

EUR 31854 EN

PDF ISBN 978-92-68-12869-5 ISSN 1831-9424 doi:10.2760/426933 KJ-NA-31-854-EN-N

Luxembourg: Publications Office of the European Union, 2024

How to cite this report: European Commission, Joint Research Centre, Santucci, V., Eynard, U., Valente, A. and Mathieux, F., *Developing life cycle inventory datasets for the hydrogen value chain*, Publications Office of the European Union, Luxembourg, 2024, https://data.europa.eu/doi/10.2760/426933, JRC136553.

Contents

Abstract

The development of a quality-assured life cycle data inventory has to fulfil several requirements, as established by existing compliance systems. As Fuel Cell and Hydrogen (FCH) systems are a recently growing technology sector with high opportunities for green energy production and decarbonisation in the near future, the development of reliable data to perform Life Cycle Assessment (LCA) of different products is fundamental to monitor progress on the sustainability objectives and ensure that environmental impacts along the life cycle are minimized.

This document defines the main steps that data developers are required to follow to share compliant datasets, acting as a reference procedure for a broad range of users, not necessarily with a specific background on data development.

Datasets in the Life Cycle Data Network (LCDN) can be validated and accepted based on the different compliance levels, namely the International Reference Life Cycle Data System – Entry Level (ILCD Entry level) and the Environmental Footprint (EF) compliance (in line with the more recent Environmental Footprint scheme, launched by the European Commission in 2013). When developing a dataset, it is important to understand how different compliance levels imply differences in documentation, review and methodology. Thus, these aspects are addressed and clarified in this procedure. Moreover, the working principles of the nodes, which allow users to share and retrieve datasets from LCDN, are explained. References to official tools and manuals users should follow are provided, with the final aim to create a node in the LCDN dedicated to FCH systems and populate it with Life Cycle Inventory (LCI) data.

Foreword

The Commission's Joint Research Centre (JRC) undertakes high quality research in the field of fuel cells and hydrogen that is of considerable relevance to the implementation of the Clean Hydrogen Joint Undertaking (JU) activities. During the Horizon 2020 period, a Framework Contract between the Clean Hydrogen JU and JRC was approved by the Governing Board on 23/12/2015 and signed by both parties on 18/02/2016. Under Horizon Europe, a new Framework Agreement between Clean Hydrogen JU and JRC was signed in the spirit and as continuation of the previous Framework Contract on 29/11/2022.

The scope of the Framework Agreement covers the activities that JRC provides to the Clean Hydrogen JU, against payment from the Clean Hydrogen JU operational budget. In line with the JRC mission, these support activities will primarily support the formulation and implementation of the Clean Hydrogen JU strategy and activities in the areas of standardisation, technology monitoring and assessment and sustainability.

Since 2018, JRC has provided an inventory and gap analysis of the work performed in the various projects to the FCH 2 JU, focusing on LCA methodology. Since 2014, JRC manages the Life Cycle Data Network and supports Environmental Footprint activities and European Commission Life-Cycle based projects, including the data development. Therefore, JRC has a central role in supporting the Clean Hydrogen JU projects in the steps towards the creation of a database on FCH.

This report is an annual deliverable of the Framework Contract between JRC and the Clean Hydrogen JU, for the JU Work Programme 2023.

1 Introduction

With the purpose of addressing the sustainable development of new technologies and industries, it is crucial to support collaboration and exchange of information among stakeholders of various industrial sectors. Recent policies and measures adopted in the EU are aimed at supporting Life Cycle Assessment (LCA) of products and services, with the production of useful databases. Particular emphasis is put on the availability and transparency of data. In this context, the Life Cycle Data Network (LCDN) could play an important role to support the scientific community and decision-making, as an international tool available for all users online.

In the sector of Fuel Cell and Hydrogen (FCH) products the market is still establishing and it is often challenging to make a comparison of environmental performances of products or systems, due to the rapid changes occurring in the technology and the supply chain.

The aim of this document is to illustrate the steps that data developers are required to take for preparing and sharing datasets in the Life Cycle Data Network (LCDN) infrastructure. This document is based on: the international standards on LCA ISO 14040 (ISO 2006a), ISO 14044 (ISO 2006b), the reference document ILCD handbook (Joint Research Centre 2010), and the Environmental Footprint (EF) method (European Commission 2021). This document provides specific recommendations for applying these methodologies to FCH systems, where appropriate.

The goal is to promote the production of compliant datasets of the life-cycle environmental impacts of FCH products ensuring the respect of minimum levels of documentation, methodological consistency among datasets and coherence in terms of format and nomenclature. Hence, this document will be used by the projects implemented by the Clean Hydrogen Joint Undertaking (JU) for the collection of data and the population of a dedicate Life Cycle Inventory (LCI) database.

The creation and publication of data in accordance with the International Reference Life Cycle Data (ILCD) System is a process that often involves many actors, having different backgrounds.

Therefore, this procedure aims at guiding different users throughout the data development, considering the requirements that applies in different aspects of the data development process (format, documentation, review, etc.). The intended users of this guide are:

- unexperienced LCA practitioners, regarding the indication of reference standard methodologies to follow;
- experienced LCA practitioners, regarding specific principles and approaches to follow for FCH technologies, or for ensuring the respect of a target compliance;
- data providers, regarding the indication of the main tools and steps for sharing and publishing data for LCA;
- IT operators, regarding the indication of file formats, software, and requirements related with the LCDN.

. Furthermore, one of the secondary outcomes of this document is encouraging data developers from industry, environmental services, academia and institutions to produce interoperable and well-documented data for LCA practitioners. This will contribute to the development of the LCDN and the inclusion of data related with the FCH sector.

2 Scope and application of this document

The scope of this document is the activity of support to the LCA projects in the sector of FCH systems, with the provision of a reference procedure for developing datasets compliant with the most up to date European guidelines on life cycle-based analyses (i.e., EF methodology). Furthermore, this document contains in section 4 recommendations for other stakeholders involved in the dataset development, such as data owners or data providers, to manage the data throughout the publication process online. In particular, the topics addressed in this guide are:

- Development of compliant datasets from life cycle inventories
- Datasets compliance requirements
- Upload and management of datasets in the LCDN

Box 1. Technical specifications for data generator/ modeller

Advanced technical recommendations about data format, Life Cycle Assessment software and IT tools are reported in grey boxes throughout the document.

2.1 The Life Cycle Data Network

The LCDN is a web-based infrastructure for better availability of quality-assured data for LCA. It favours the exchange of data in different technological or industrial sectors. For the hydrogen sector, the LCDN is an opportunity to share data about the life-cycle of technologies across the hydrogen value chain. The datasets accessible on the LCDN are built on the International Reference Life Cycle Data System (ILCD) format which is one of the main formats allowed in the "Global LCA Data Access" network (GLAD)[1], which is an international directory of Life Cycle Assessment (LCA) datasets, from independent LCA database providers.

A complete overview of the LCDN purpose and functionality is available on the web site of European platform for LCA (EPLCA), at https://eplca.jrc.ec.europa.eu/LCDN/index.xhtml.

The LCDN is composed of nodes. Each node allows data providers to publish life cycle assessment datasets, but also allows LCA practitioners to search for and gather datasets to be used in LCA studies.

Figure 1 summarises the main operations required for users willing to develop datasets for the LCDN. The entire procedure is briefly explained as follows:

(a) preparation of data (via either MS Excel spreadsheet or LCA software) and export in XML ILCD format (see Box 3);

(b) technical validation of the data;

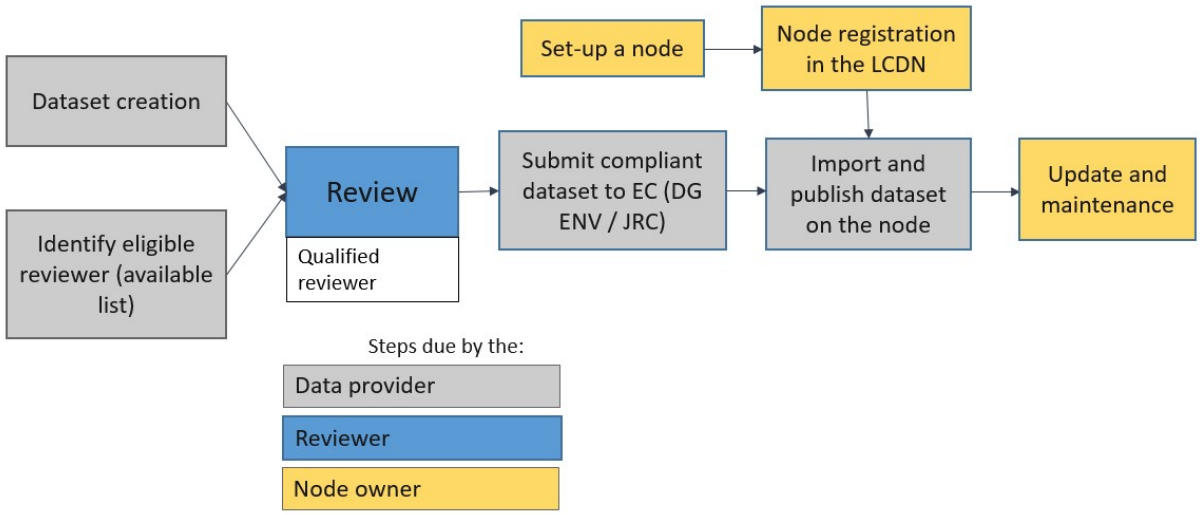
(c) setting up of a node for participation in the LCDN;

(d) uploading of the data into the node;

(e) publication of the data on the LCDN.

[1] https://eplca.jrc.ec.europa.eu/globalLCA.html

Figure 1. Operations and subjects involved in the data development for LCDN.



Source: JRC elaboration.

In the following sections each of the steps of figure 1 is explained and links to related guidance documents or tools are provided. For general information on the steps for publishing on the LCDN and related aspects it is recommended to read the chapter 1 of "Life Cycle Data Network Handbook for Users and Data Developers" (Fazio et al. 2016).

Box 2. Registries of Life Cycle Data Network

A single node to be part of the network is connected to other nodes in the same *registry*. Two registries have been established in the LCDN depending on the level of compliance of dataset registered: ILCD-EL and EF. Further details about the network registries are available in section 4.1 of this document.

When developing and sharing new datasets it is important to define the targeted level of compliance (see section 3).

3 Developing compliant datasets

3.1 Compliance

Datasets in LCDN can have different levels of compliance. These levels are defined in order to ensure minimum standards of overall reliability of the data. A dataset, to be declared compliant, shall fulfil specific requirements regarding aspects of:

- Documentation
- Nomenclature
- Data quality
- Methodology
- Review

The two levels of compliance allowed in LCDN and the reference documents that report their requirements are:

- ILCD-entry level (EL): https://eplca.jrc.ec.europa.eu/LCDN/developerILCD.xhtml-
    - Reference guidance: "ILCD: Compliance rules and entry-level requirements" (JRC and European Commission 2012)[2]
- Environmental Footprint (EF) scheme: https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml
    - Reference guidance: "Guide for EF-compliant datasets" (Fazio et al. 2020)[3]

While these two compliance levels are both valid for sharing datasets in the LCDN, EF compliance is preferable in terms of reliability of the data. Advantages of EF-compliant datasets are, among others:

- improved transparency and traceability of data since more detailed documentation is required;
- they are in line with the most recent reference nomenclature (Environmental Footprint reference package);

  their quality is assessed according to the overall data quality rating (DQR), which is not required for ILCD EL datasets;. Only datasets with a minimum score of quality are allowed in the registry (quality score ≤ 3.0 = "Good")[4];
- they are in line with the official EU reference methodology (European Commission 2021);
- improved methodological consistency and correctness of results, due to a higher number of reviewers involved in the review process.

Box 3. ILCD format datasets

ILCD format datasets are developed in extensible mark-up language (XML) files. Datasets in XML files are based on a set of "tags", which are defined in the first rows of the document (see Figure 2).

(2) https://eplca.jrc.ec.europa.eu/uploads/ILCD-Data-Network-Compliance-Entry-level-Version1.1-Jan2012.pdf
(3) https://eplca.jrc.ec.europa.eu/permalink/Guide_EF_DATA.pdf
(4) Definitions of the data quality criteria in accordance with the document "Commission Recommendation (EU) 2021/2279 on the Use of the Environmental Footprint Methods to Measure and Communicate the Life Cycle Environmental Performance of Products and Organisations."
1="Excellet", 2="Very Good", 3="Good", 4="Fair", 5="Poor". Please note that as the quality improves, the score of the rating decreases.

Figure 2. Example of a dataset (source dataset of the ILCD format),

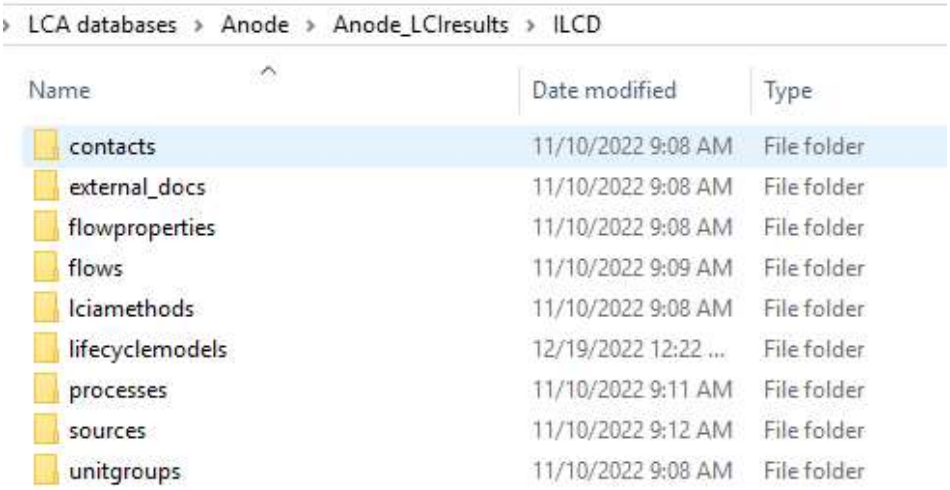
```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<?xml-stylesheet type='text/xsl' href='../../stylesheets/source2html.xsl'?>
<sourceDataSet xmlns="http://lca.jrc.it/ILCD/Source" xmlns:common="http://lca.jrc.it/ILCD/Common" xmlns:xsi=
"http://www.w3.org/2001/XMLSchema-instance" version="1.1" xsi:schemaLocation="http://lca.jrc.it/ILCD/Source
../../schemas/ILCD_SourceDataSet.xsd">
 <sourceInformation>
  <dataSetInformation>
   <common:UUID>a97a0155-0234-4b87-b4ce-a45da52f2a40</common:UUID>
   <common:shortName xml:lang="en">ILCD format</common:shortName>
   <classificationInformation>
    <common:classification>
     <common:class level="0">Data set formats</common:class>
</common:classification>
</classificationInformation>
```

Source: EF reference package 3.0 (https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml).

Each element linked to a process dataset (namely flows, sources, external documents, impact assessment methods, units and flow properties) shall be documented in its own dataset (XML). In order to apply the correct format to such datasets, the tables of the "ILCD data format" available at https://eplca.jrc.ec.europa.eu/LCDN/developerILCDDataFormat.xhtml shall be followed,

Compressed folders .zip shall be used for sharing multiple datasets of different interlinked elements (processes, flows, sources, etc.). The compressed folder shall contain the ILCD directories, which are the same directories of the EF reference package (Fazio et al. 2020)(see Figure 3).

Figure 3. Main folder's structure according to the ILCD format



Source: JRC Elaboration

3.2 Type of datasets

All the datasets are characterized by a Life cycle Inventory (LCI) which contains a list of exchanges (input and output flows) and their amount. The LCI can be referred to the complete or partial life cycle of a product system depending on the considered system boundaries, and it can aggregate the resources/emissions of several processes in it. Moreover, LCIs can contain elementary flows, product flows or waste flows next to a reference flow that should always be present to express the functional unit. Depending on these features datasets are classified into different types. The different types of datasets of the ILCD system are defined in the documents:

— ILCD Format 1.1 Documentation - Enumerated Lists[5]

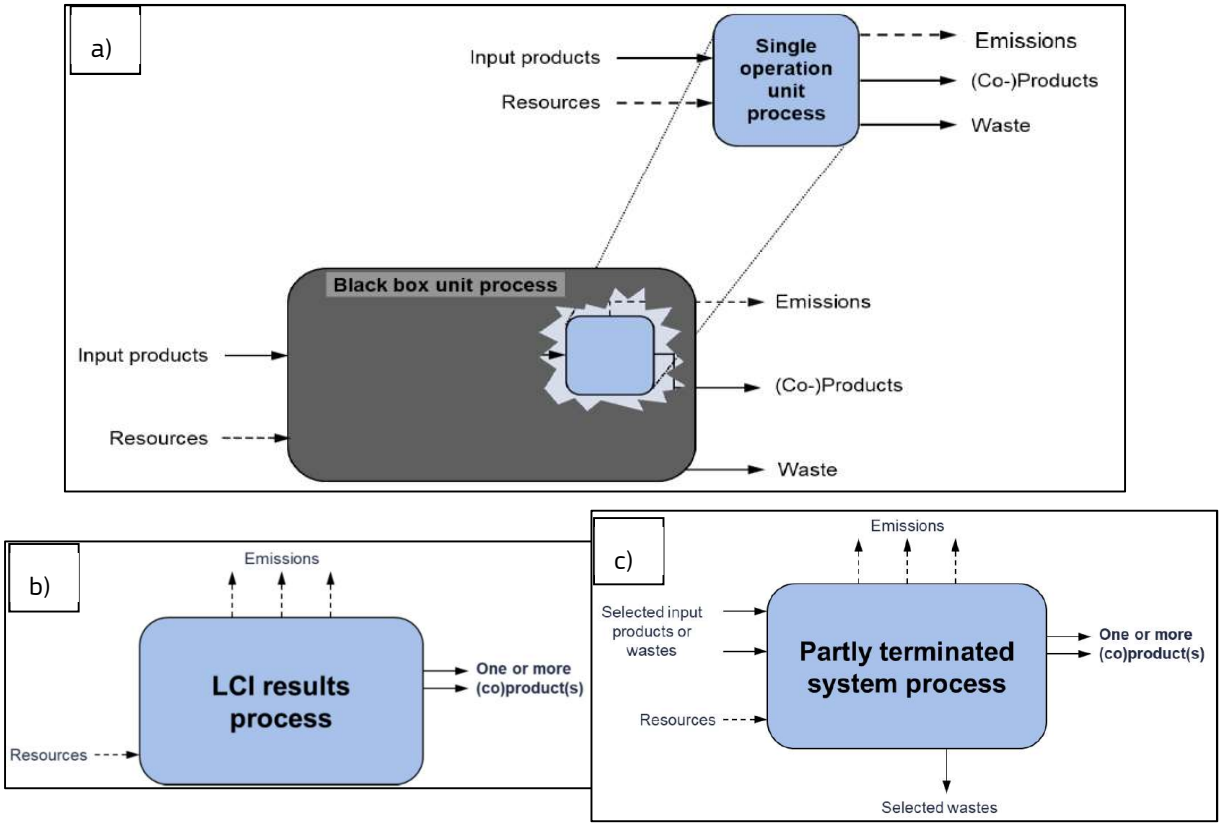
[5] https://eplca.jrc.ec.europa.eu/LCDN/downloads/ILCD_Format_1.1_Documentation/ILCD_Common_EnumerationValues.html

— "ILCD handbook – General guide for LCA detailed guidance"[6]

— "Guide for EF-compliant datasets" (Fazio et al. 2020)[7]

When modelling the life cycle it is recommended to clearly identify the type of dataset to be developed, among the four alternative types allowed (based on the reference documents mentioned above): *Unit process, single operation (Figure 4a)*, *Unit process, black box (Figure 4a)*, *LCI Result (Figure 4b)*, *Partly terminated system (Figure 4c)*.

Figure 4. Flow diagram of different types of dataset. a) Unit process, single operation dataset and Black box unit process dataset; b) LCI results process dataset, c) partly terminated system process dataset.



Source: *"Guide for EF-compliant datasets" (Fazio et al. 2020)*

3.3 Documentation

In the development of a process dataset, the related documentation shall be provided together (in a compressed folder) with the other aspects of the dataset before its submission to the review process (reviewer/reviewing team).

Box 4. ILCD format documentation

For each dataset, a compressed folder (.zip) shall contain the sub-folders and their content as reported in Table 1. The compressed folder shall be prepared in order to allow the traceability of full documentation related to the developed data.

[6] https://eplca.jrc.ec.europa.eu/uploads/ILCD-Handbook-General-guide-for-LCA-DETAILED-GUIDANCE-12March2010-ISBN-fin-v1.0-EN.pdf
[7] ttps://eplca.jrc.ec.europa.eu/permalink/Guide_EF_DATA.pdf

Table 1. Documentation of ILCD format datasets

Folder path (ILCD/)	**content**
Flows	All the *elementary flows*, *waste flows* and *product flows* listed in the LCI exchanges of the process dataset. For datasets of the type "LCI results" *other flows* are not allowed. Only radioactive waste flows and quantitatively irrelevant others waste flows may remain in the inventory (Fazio et al. 2020).
Unitgroups	Unit groups datasets of the reference package (EF or ILCD Software Developer Kit (SDK) depending on the compliance level), plus any new unit groups to be added when necessary.
Flowproperties	Flow property datasets of the reference package (EF or ILCD SDK depending on the compliance level), plus any new unit groups to be added when necessary.
lciamethods	Life Cycle Impact Assessment (LCIA) methods datasets corresponding to the methods applied for the LCIA results of the process dataset. For EF-compliant datasets all the LCIA methods datasets contained in the reference package
External docs	Digital files of Review report(s), flow diagrams, pictures, charts, tables, technical reports, publications (.pdf, .jpg, etc.)
Contacts	Contact datasets linked to the process dataset: reviewers, owner, generator, commissioner of the dataset
Sources	Source datasets of all the references used for developing the process dataset (literature, data sources, LCA methodology reports, source data stocks). Source dataset of the reference ILCD format shall always be present (UUID:a97a0155-0234-4b87-b4ce-a45da52f2a40)
Processes	Datasets developed for the process in scope, complete of metadata and results. Allowed type of process datasets are: • LCI results • Partly terminated system • Unit process, single operation • Unit process, black box according to the definitions provided In the document *"Guide for EF-compliant datasets"* (Fazio et al. 2020).
Lifecyclemodels	Only when developing Lifecyclemodels (check the eILCD-Software Developer Kit available at https://eplca.jrc.ec.europa.eu/LCDN/developerILCDDataFormat.xhtml

Source: JRC Elaboration

Further details on the ILCD format documentation are available on the reference webpage of EPLCA:

https://eplca.jrc.ec.europa.eu/LCDN/developerILCDDataFormat.xhtml

3.4 Nomenclature

The developed datasets shall be named following the nomenclature rules which apply to:

- elementary flows,
- product or waste flows,
- processes,

- flow properties,
- units and unit groups.

For scientific- and technology-specific terms to be used in datasets related to water electrolysis it is recommended to follow the guidelines provided in the document "EU Harmonised Terminology for Low-Temperature Water Electrolysis for Energy Storage Applications". (Tsotridis and Pilenga 2018).

3.4.1 Elementary flows

Elementary flows used in process datasets shall always be part of the proper "reference system" (list of the allowed elementary flows and their universally unique identifier (UUID) which depends on the target compliance level and the specific version of its reference package. The nomenclature of elementary flows shall be in line with the rules reported in the documents:

— *ILCD Handbook – "Nomenclature and Other Conventions*" (Joint Research Centre 2010), section 3.3 – Naming of elementary flows.

— For EF-compliant datasets: only the elementary flows included in the most recent version of the EF reference package (available at https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml) are allowed.

3.4.2 Product/waste flows and processes

Nomenclature of product flows is defined in the reference document *ILCD Handbook – "Nomenclature and Other Conventions*" (Joint Research Centre 2010) for both ILCD EL and EF-compliant datasets. Sections 3.1, 3.2. of this document provide details and the "mandatory" rules to be followed for structuring flow names and avoiding shortcomings.

3.4.3 Flow properties, units and unit groups

Nomenclature of flow properties, units and unit groups is defined in the reference document ILCD Handbook – "Nomenclature and Other Conventions" (Joint Research Centre 2010) for both ILCD EL and EF-compliant datasets.

Box 5. Available flow properties, units and unit groups

Please note that naming flow properties, units or unit groups is a step required only when the flow property or unit that is needed to characterize any flow in the process dataset under development is not already defined. For ILCD EL and EF compliance, already-defined flow properties are available in the EF reference package (https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml).

3.4.4 Classification

The ILCD data format provides a list of classes to categorise developed datasets according to the specific sector of application (e.g. "Energy carriers and technologies/Lignite based fuels" or "Emissions/ Emissions to air/ Emissions to urban air close to ground"). In order to categorise datasets into ILCD classes, the ILCD rules for nomenclature shall be followed. In particular:

Box 6. Classification of datasets

- for elementary flows, sections 1.4 and 2.1 of "ILCD Handbook Nomenclature and other conventions" shall be followed;

- for product flows and processes, section 2.2 of "ILCD Handbook Nomenclature and other conventions" shall be followed;

Nevertheless, the classes of the file ILCDClassificationXML shall be used. This file is available in the eILCD-SDK_v2.1.1 developer kit package[8] and the EF reference package[9].

Datasets representing hydrogen technologies can fall into different categories of the ILCD classification system. Datasets that cover the industrial production of specific systems, devices or components related to hydrogen, containing cradle-to-gate inventories, fall into the class "ILCD/systems". For example, the class for a dataset representing the cradle-to-gate production of a full water electrolysis system is class 3.2 of the ILCD classification (ILCD/systems/electrics and electronics). Datasets that represent the processes for producing compressed hydrogen, either gate-to-gate or cradle-to-gate, with hydrogen as reference flow among outputs, should fall into the class "ILCD/Materials Production/Inorganic chemicals".

3.5 Data quality

The quality of datasets registered in the LCDN shall be evaluated and declared. Several quality criteria are defined for datasets and, for each data quality criterion, a rating shall be provided. The recommendations to calculate and rate data quality are available in the following documents:

- For ILCD EL datasets the quality rating shall be carried out using the ISO criteria (ISO 14040 and ISO 14044)
- For EF-compliant datasets the quality rating shall be carried out according to (Fazio et al. 2020) (section 5.2.17). To calculate the overall data quality rating of secondary datasets a contribution analysis of the total environmental impact (single score) based on the EF normalisation and weighing factor is necessary[10].

The reviewer takes responsibility for the correctness of the data quality ratings. However, the DQRs can be either calculated directly by the reviewer or by the dataset developer. In any case, the reviewer shall check and validate the correctness of the assigned values.

One of the requirements of EF-compliant datasets is that each single quality criterion shall not be higher[11] than 3.0 (Fazio et al. 2020). No minimum data quality criteria are required for ILCD-EL datasets.

3.6 Methodology / LCA modelling

For compliant datasets registered in LCDN, the methodology shall always be in line with the two standard methodologies for LCA:

- ISO 14040:2006 - Environmental management — Life cycle assessment — Principles and framework (ISO 2006a)
- ISO 14044:2006 - Environmental management — Life cycle assessment — Requirements and guidelines (ISO 2006b)

The methodological consistency for both ILCD-EL and EF-compliant datasets shall be checked by the reviewer and declared in the metadata of the dataset in the field *Validation/Compliance Declarations* under the *Modelling and validation* section.

The recommendations for modelling EF-compliant datasets are available in the document: "Guide for EF-compliant datasets" (Fazio et al. 2020). In particular, the related parts are:

- Section 4: Harmonization of EF-compliant datasets partly disaggregated at level-1;
- Section 6: modelling requirements

([8]) Available at https://eplca.jrc.ec.europa.eu/LCDN/developerILCDDataFormat.xhtml

([9]) Available at https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml

[10] For further details please consult the EF method, available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32021H2279

[11] Definitions of the data quality criteria in accordance with the document "Commission Recommendation (EU) 2021/2279 on the Use of the Environmental Footprint Methods to Measure and Communicate the Life Cycle Environmental Performance of Products and Organisations."

1="Excellet", 2="Very Good", 3="Good", 4="Fair", 5="Poor". Please note that as the quality improves, the score of the rating decreases.

In addition to the base requirements from the ISO 14040 and ISO 14044 standards mentioned above, compliance with the documents reported in the following applies as extra requirements. In particular:

- For modelling ILCD EL datasets there are no additional specific requirements beyond the two ISO standards mentioned above, as defined in the document "ILCD: Compliance rules and entry-level requirements" (JRC and European Commission 2012).
- EF complaint datasets shall be modelled in accordance with the European Commission Recommendation 2021/2279[12]. The Recommendation for PEF studies applies analogously to EF-compliant datasets. The EC Recommendation provides complete and detailed guidance about the compliant methodology, such as the modelling of transportation, application of the Circular Footprint Formula, use of secondary data, etc.

(JRC and European Commission 2012)(JRC and European Commission 2012)(JRC and European Commission 2012)(JRC and European Commission 2012)(JRC and European Commission 2012)(JRC and European Commission 2012)All the references followed for modelling a dataset shall be included in the "source datasets" and reported in the metadata field "LCA methodology Report".

Modelling recommendations for Hydrogen-specific technologies are available in the following documents:

- "Guidance Document for Performing LCA on Hydrogen Production Systems." (Lozanovski, Schuller, and Faltenbacher 2011)
- "Guidance Document for Performing LCAs on Fuel Cells and Hydrogen Technologies (Hyguide)." (Masoni and Zamagni 2011)
- *"IEA Hydrogen Task 36 - Life Cycle Sustainability Assessment of Hydrogen Energy Systems"* (Iribarren, Valente, and Dufour 2018)

Upcoming recommendations and updates on LCA of hydrogen technologies will be released at https://sh2e.eu/.

The implementation of the Circular Footprint Formula (CFF) is a mandatory requirement when modelling EF datasets (Fazio et al. 2020). The CFF allows keeping into account the environmental burdens and credits deriving from material recycling, energy recovery and waste disposal processes, related to the products in scope. It shall be applied to each material that constitutes the products in the scope of the dataset (and packaging, if any). The methodology for implementing the CFF is available in the "Commission Recommendation (EU) 2021/2279" (European Commission 2021), in section 4.4.8. The implementation of CFF suggested for PEF studies applies analogously to EF-compliant datasets.

The list of default application-specific and material-specific values for the parameters to be used in the application of the CFF is available for download at https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml.

3.6.1 Source datasets

3.6.1.1 EF compliance

As established by the EF guidance for dataset development, the source datasets used to model sub-processes of an EF-compliant dataset shall be EF-compliant datasets in the latest available version. The use of non EF-compliant datasets is allowed only when an EF dataset for the sub-process to model is not available. In particular:

- Sub-processes for Energy, Transport, Packaging and End Of Life activities used to model EF-compliant data sets shall be those (in aggregated form) available on the Thinkstep LCDN node (currently "Sphera") "http://lcdn.thinkstep.com/Node/" in the proper data stock (in line with the version of the EF reference package used).
- For all other sub-processes used to model EF-compliant data sets, the following hierarchy shall be applied:
    1. If the EF-compliant dataset is available, it shall be used (either from a commercial or free database);

[12] Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32021H2279

2. If there is no EF-compliant dataset representing the specific sub-process searched, a proxy EF-compliant dataset shall be used (see the "Commission Recommendation (EU) 2021/2279", (European Commission 2021)).
3. If there is no EF-compliant dataset available, an ILCD-EL compliant data set shall be used (Fazio et al., 2020).

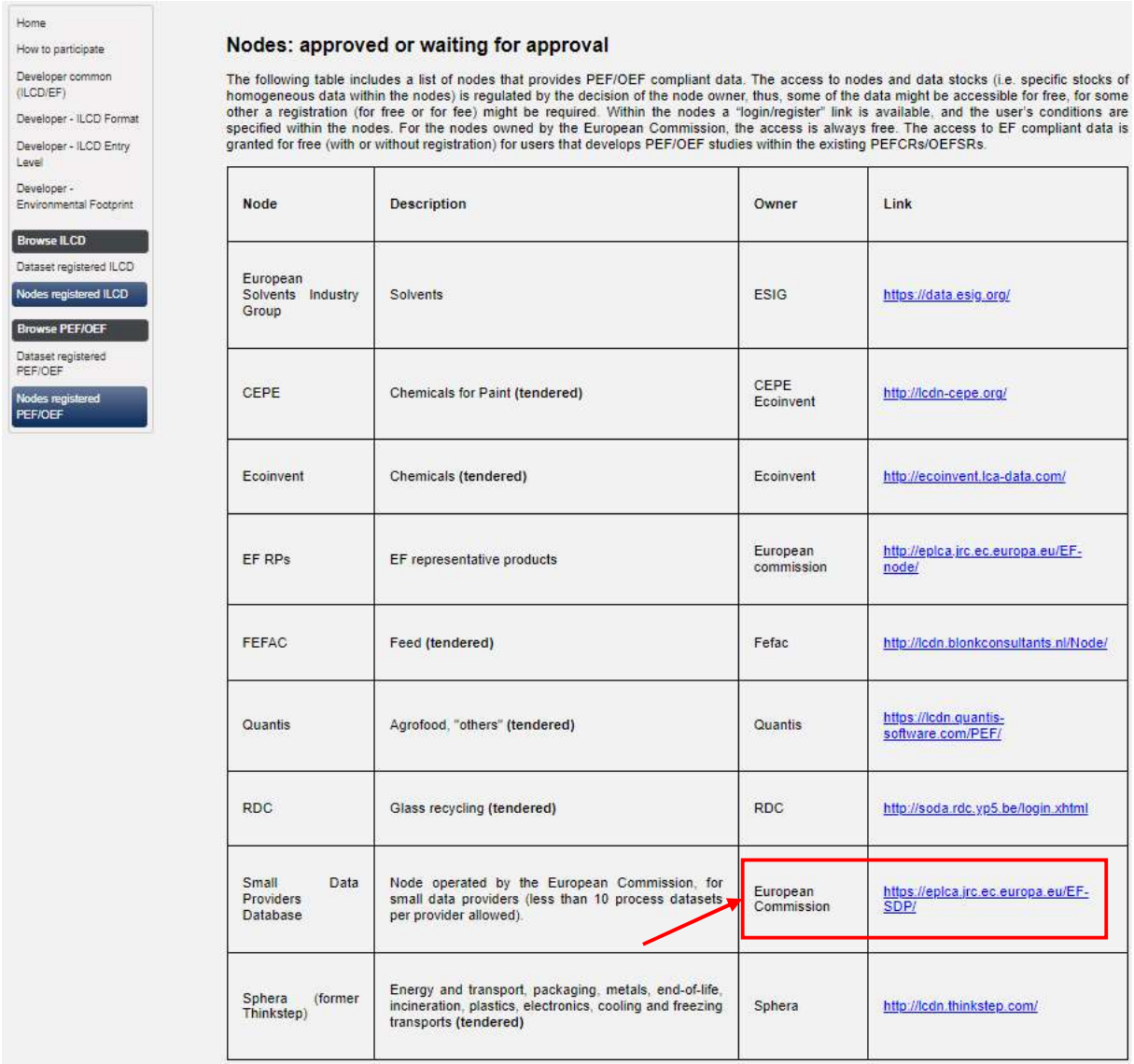
The list of nodes to download EF datasets from LCDN is available at: https://eplca.jrc.ec.europa.eu/LCDN/contactListEF.xhtml.

Box 7. Retrieving datasets from LCDN nodes

Note that the steps reported in this box illustrate how to download datasets in ILCD format. If LCA software is used for developing datasets, it is important to check whether the LCA software provides the functionality to import ILCD-format datasets.

The table reported on the webpage contains a list of nodes registered EF in the LCDN (see figure 1). In some cases it is possible to download datasets for free and without the need for registration, some others can require to subscribe and register with a user account.

Figure 5. Nodes in the LCDN.



Nodes: approved or waiting for approval

The following table includes a list of nodes that provides PEF/OEF compliant data. The access to nodes and data stocks (i.e. specific stocks of homogeneous data within the nodes) is regulated by the decision of the node owner, thus, some of the data might be accessible for free, for some other a registration (for free or for fee) might be required. Within the nodes a "login/register" link is available, and the user's conditions are specified within the nodes. For the nodes owned by the European Commission, the access is always free. The access to EF compliant data is granted for free (with or without registration) for users that develops PEF/OEF studies within the existing PEFCRs/OEFSRs.

Node	Description	Owner	Link
European Solvents Industry Group	Solvents	ESIG	https://data.esig.org/
CEPE	Chemicals for Paint **(tendered)**	CEPE Ecoinvent	http://lcdn-cepe.org/
Ecoinvent	Chemicals **(tendered)**	Ecoinvent	http://ecoinvent.lca-data.com/
EF RPs	EF representative products	European commission	http://eplca.jrc.ec.europa.eu/EF-node/
FEFAC	Feed **(tendered)**	Fefac	http://lcdn.blonkconsultants.nl/Node/
Quantis	Agrofood, "others" **(tendered)**	Quantis	https://lcdn.quantis-software.com/PEF/
RDC	Glass recycling **(tendered)**	RDC	http://soda.rdc.yp5.be/login.xhtml
Small Data Providers Database	Node operated by the European Commission, for small data providers (less than 10 process datasets per provider allowed).	European Commission	https://eplca.jrc.ec.europa.eu/EF-SDP/
Sphera (former Thinkstep)	Energy and transport, packaging, metals, end-of-life, incineration, plastics, electronics, cooling and freezing transports **(tendered)**	Sphera	http://lcdn.thinkstep.com/

Source: https://eplca.jrc.ec.europa.eu/LCDN/contactListEF.xhtml.

Once registered to the node, personal credentials (if necessary) are needed to log in. Then a drop-down menu in the upper right corner of the page allows selecting the data stock containing the dataset needed for the LCA model. A data stock is a folder containing a list of datasets.

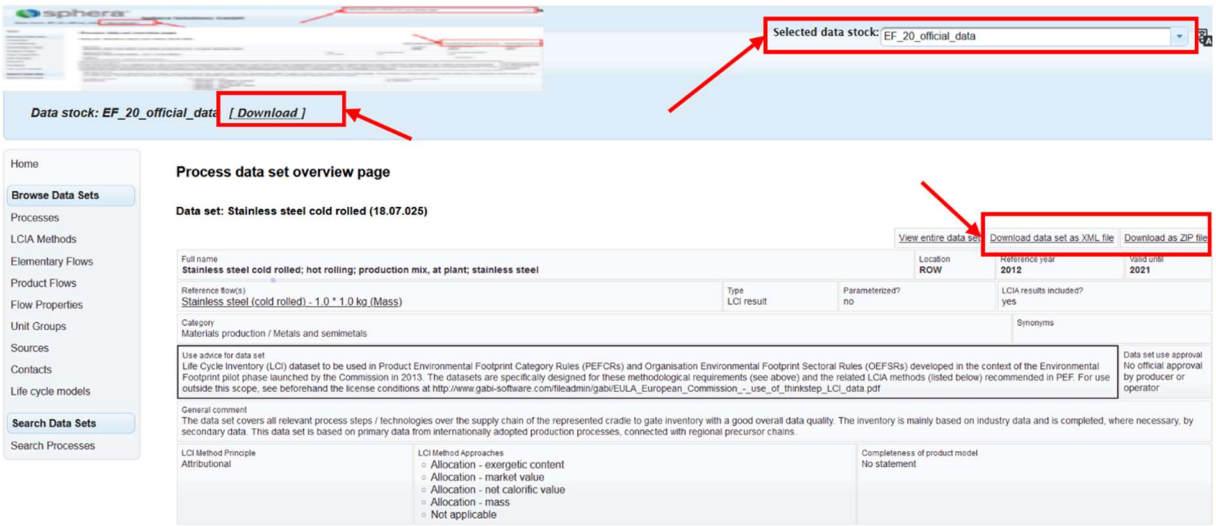
As shown in Figure 3, once the data stock is selected it is possible either to:

- use the left-side browser to search for and download one specific process from the selected data stock. The overview of the dataset page will be opened by clicking on the selected dataset. It is possible to download either the dataset as XML (only the file representing the process) or as .zip (an ILCD formatted folder containing the selected process file (XML), plus all the referenced flows and documentation linked to the dataset).

or

- download the entire data stock, containing all the datasets registered under the selected data stock. A .zip folder will be downloaded.

Figure 6. Downloading datasets in LCDN



Source: https://eplca.jrc.ec.europa.eu/LCDN/contactListEF.html . .

3.6.1.2 ILCD EL compliance

For developing an ILCD EL-compliant dataset, the datasets used to model sub-processes in the LCI of a dataset under development are not subjected to any restriction (provided that they follow the ILCD nomenclature and format). However, it is recommended to use datasets according to the same hierarchy reported in section 3.6.1.1, as EF-compliant datasets are characterised by higher data quality and traceability.

3.6.2 Importing and exporting datasets

In order to ease the use and development of datasets in compliance with the ILCD format, common LCA software provide integrated options for import and export. Commonly, the import function is used to include existing datasets of sub-processes in the model under development. The export function is used to convert the created datasets into the desired format, to be used in other software.

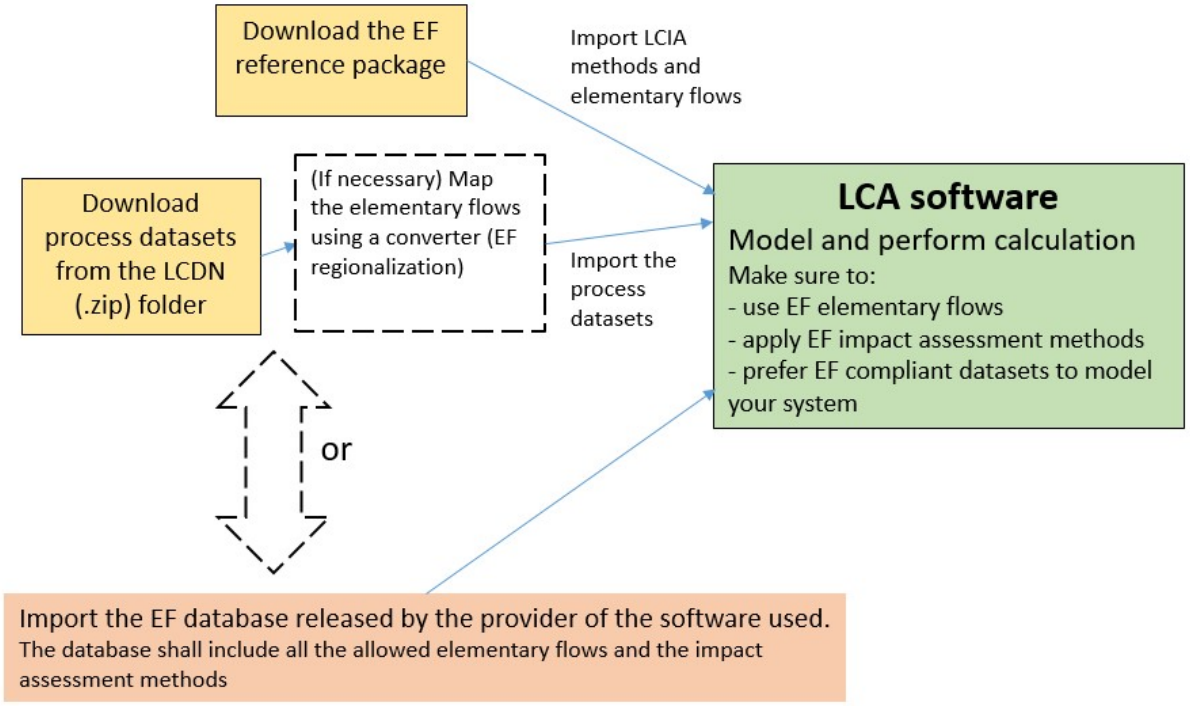
Box 8. Recommendations regarding LCA software for modelling

There are two options (depending on the software and availability of datasets) to import the datasets of sub-processes needed for modelling in the software (see Figure 9). For EF datasets, in order of preference:

- If an LCA database is available for the software used with a specific file extension, this can be directly imported and used in the software.

- If the LCA software provides functionality for importing ILCD datasets, the datasets needed for modelling can be imported in the ILCD format. The full EF reference package containing the LCIA methods has to be downloaded[13]. The complete package of the datasets with their dependencies shall be imported as a compressed folder (.zip file). When importing the packages, please make sure that the datasets are of the same compliance version as the reference package.

Figure 7. Import of datasets in LCA software

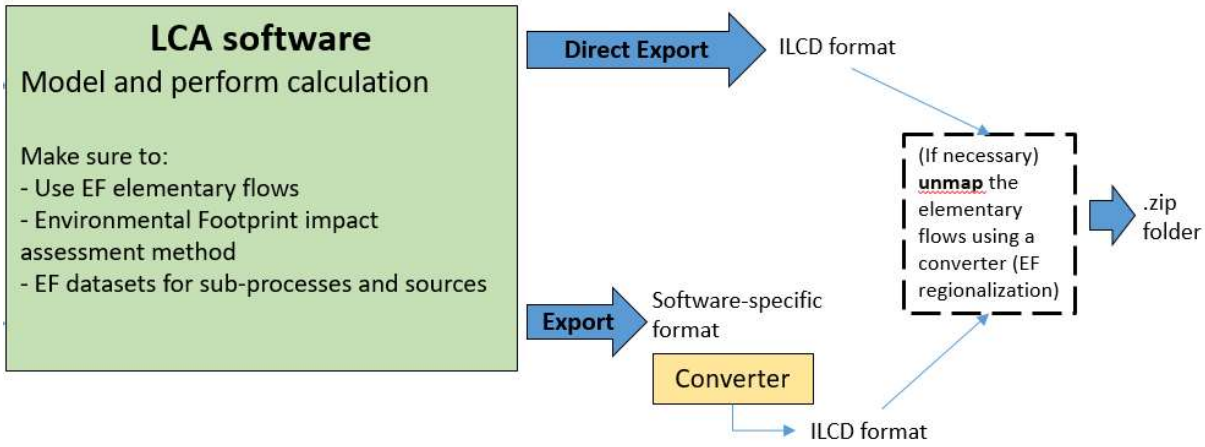


Source: JRC elaboration.

Recommendations about software-specific export options are available in the "Life Cycle Data Network Handbook for Users and Data Developers (Fazio et al. 2016). The functionality for exporting datasets developed in the software in the ILCD format folder (.zip) has been implemented in several LCA software. In case the used software does not support the export of datasets into ILCD format, a conversion from the software-specific format to the ILCD format shall be done using the conversion tool OpenLCA Converter (Fazio et al. 2016) (see Figure 4).

([13]) https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml

Figure 8. Export of datasets from LCA software



Source: JRC elaboration.

Box 9. Regionalization in dataset elements

The exchanges of a process dataset within the LCDN include the element "location". This element allows to apply region-specific characterization factors in the LCIA.

Since regionalization of elementary flows is a mandatory requirement for EF-compliant datasets, attention shall be paid to keeping the information related to regionalization of exchange flows in the datasets while importing and exporting the datasets to a software. Location codes are allowed for flows related to water use and land use (any country code) and for ammonia, nitrogen oxides and sulphur oxides (only for a limited group of countries, see Annex 1 of Fazio et al., 2020). Only two-letters country codes are valid for the location of exchanges. Therefore, datasets can contain several times the same elementary flows among the exchanges, but with different location codes (Figure 6).

Figure 9. Location element in exchanges and characterization factors

```
<exchange dataSetInternalID="1">
  <referenceToFlowDataSet
    type="flow data set"
    refObjectId="e3abf13f-3bb9-4e52-b72b-9bd276625c55"
    version="01.00.000"
    uri="../flows/e3abf13f-3bb9-4e52-b72b-9bd276625c55">
    <common:shortDescription xml:lang="en">1,1,1,2-Tetrachloroethane</common:shortDescription>
  </referenceToFlowDataSet>
        <location>PL</location>
  <exchangeDirection>Output</exchangeDirection>
  <meanAmount>1.0</meanAmount>
  <resultingAmount>1.0</resultingAmount>
</exchange>
```

```
<factor>
  <referenceToFlowDataSet
    refObjectId="03b56eb6-cc68-4251-9317-06878cb27dff"
    type="flow data set"
    uri="../flows/03b56eb6-cc68-4251-9317-06878cb27dff.xml"
    version="03.00.000">
    <common:shortDescription xml:lang="en">from arable, irrigated,</common:shortDescription>
  </referenceToFlowDataSet>
  <location>AD</location>
  <exchangeDirection>Input</exchangeDirection>
  <meanValue>-128</meanValue>
</factor>
```

Source: https://github.com/msrocka/peflocus .

Some LCA software does not support a "location" element for exchanges. For such software, some "mapped" databases have been developed that contain one different flow for each different location. This requires for the data provider to apply a further conversion of elementary flows after the dataset in ILCD format has been exported, and before importing as well. See Figures 4 and 5. In this case, datasets can be converted using the tool PEFlocus (https://github.com/msrocka/peflocus).

3.7 Review

The review is a mandatory requirement for datasets that have to be registered in LCDN as compliant (both ILCD EL and EF). To fulfil this requirement, the data provider shall submit a review report, completed in all its parts and signed by an eligible reviewer, before registering any dataset in the LCDN.

It is recommended to follow these steps in the review process:

1. To define the type of reviewer to fulfill the eligibility requirements based on the compliance level of the dataset:
    (a) ILCD EL: according to "Review Schemes and Reviewers' Selection Criteria in the Life Cycle Data Network Framework, and at Global Level" (Fazio and European Commission. Joint Research Centre. 2016 - Table 6)
    (b) EF: according to Guide for "EF-compliant Data Sets" (Fazio et al. 2020 - Section 8 "Reviewer requirements for Environmental Footprint process data sets and review report template")
2. To identify the eligible reviewers:

in line with the specifications referenced in step 1 (eligibility requirements), the reviewers (or reviewing teams) with the required expertise shall be identified. The selected reviewers self-declare to be qualified for the dataset review and shall be able to provide proof of their expertise.

3. To check and correct the dataset based on the compliance requirements (done by the reviewer):
    (a) Aspects related to completeness and methodological consistency in the modelling of datasets are assessed by one or more reviewing teams. The same goes for the assessment of data quality.
    (b) Compliance aspects related to ILCD format syntax, categories, links, references to elementary flows and nomenclature and other specific requirements depending on the compliance level can be validated using the software "ILCD Validation tool"[14] (please see "Life Cycle Data Network Handbook for Users and Data Developers", (Fazio et al. 2016).,
4. To fill in and sign the review report (done by the reviewer).
    (a) Use ILCD EL review report template (JRC and European Commission 2012). Available for download at: https://eplca.jrc.ec.europa.eu/LCDN/developerILCD.xhtml
    (b) Use EF review report template (Fazio et al. 2020). Available for download at: https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml
5. To attach the review report in the ILCD package folder ILCD/ external_docs and add the link to the review report in the process dataset under "*modelling and validation*" section.

3.8 Metadata entry

The term "metadata" refers to all those elements of a process dataset that are neither LCIA results nor LCI inventory. Metadata contain key information and important description regarding the modelling, use and validity of a given dataset.

Box 10. Metadata in ILCD format

The list of the metadata sections and fields is available in the ILCD format documentation (for different types of dataset). The information fields are contained in the dataset as an XML file which is structured in a predefined scheme and syntax (use of XML tags). According to the ILCD format, each piece of relevant information shall be reported in the appropriate field, as defined on the webpage on the ILCD format documentation[15]. Among metadata the entries which, in the ILCD format, are labelled as "r" in the column "Requ." shall be always filled in to fulfil the ILCD EL requirements. Entries labelled as "o" can be omitted.

For EF-compliant datasets please refer to Section 5 of the document "Guide for EF-compliant Datasets" Fazio et al., 2020 (Requirements for meta-data information in EF-compliant data sets), which contains a comprehensive list of recommendations for reporting metadata. This document provides relevant information on how data should be structured and how to fill in fields of the metadata (all EF requirements are in addition to the ILCD-Entry Level requirements, as mentioned above, in line with the ILCD format). In the picture of the Flow diagram(s) to attach under "process information > technological representativeness" (Fazio et al. 2020), all the relevant processes and flow of the model within the system boundaries shall be included, reporting the numeric flow amounts whenever feasible.

When the LCA software includes the specific option, part of the metadata might be entered through the LCA software used for model and calculation. For further information please check: the "Life Cycle Data Network handbook for users and data developers", (Fazio et al. 2016)

For datasets of hydrogen-related technologies, further supporting information on the content of metadata in line with the ILCD format[16] are available:

— Annex II of "Guidance Document for Performing LCAs on Fuel Cells and Hydrogen Technologies (Hyguide)." (Masoni and Zamagni 2011)

[14] ILCD format validation tool available at: https://bitbucket.org/okusche/ilcdvalidationtool/downloads
[15] https://eplca.jrc.ec.europa.eu/LCDN/downloads/ILCD_Format_1.1_Documentation/ILCD_ProcessDataSet.html
([16]) https://eplca.jrc.ec.europa.eu/LCDN/downloads/ILCD_Format_1.1_Documentation/ILCD_ProcessDataSet.html

— Annex II of "Guidance Document for Performing LCA on Hydrogen Production Systems." (Lozanovski et al. 2011)

These two guidance documents have both been prepared as part of the FC-HyGuide project – the former is related to fuel cell systems and the latter addresses hydrogen production systems. Annex II of both documents shows the meta documentation fields for the ILCD format to be filled out within the data sets.

In metadata fields containing technological descriptions, assumptions, parameters and modelling constants related to water electrolysis it is recommended to follow the guidelines provided in the document "EU Harmonised Terminology for Low-Temperature Water Electrolysis for Energy Storage Applications" (Tsotridis and Pilenga 2018).

3.9 LCIA Results

The results of the Life Cycle Impact Assessment (LCIA) shall be reported in the dedicated section of the ILCD dataset folder (in the XML files these are entered under the `<LCIAResults>` element). This section is mandatory for "LCI results" and "Partly terminated system" datasets[17].,

Box 11. LCIA Calculation

The tool developed by JRC Look@LCI allows the users to calculate the LCIA results based on the EF characterization factors. This tool can be used to check the correctness of the results of EF-compliant datasets. The calculation is to be done using the latest available EF reference package and with the latest version of Look@LCI, which is periodically updated (https://eplca.jrc.ec.europa.eu/LCDN/developer.xhtml). Please make sure that LCIA results are checked through the latest version of the software released.

Figure 10. Example of LCIA results section.

```
<LCIAResults>
    <LCIAResult>
        <referenceToLCIAMethodDataSet type="LCIA method data set" refObjectId=
        "b5c611c6-def3-11e6-bf01-fe55135034f3" version="01.03.001" uri=
        "../lciamethods/b5c611c6-def3-11e6-bf01-fe55135034f3.xml">
            <common:shortDescription xml:lang="en">EF-Acidification terrestrial and freshwater
            </common:shortDescription>
        </referenceToLCIAMethodDataSet>
        <meanAmount>0.0588934051501131</meanAmount>
    </LCIAResult>
    <LCIAResult>
        <referenceToLCIAMethodDataSet type="LCIA method data set" refObjectId=
        "b2ad6d9a-c78d-11e6-9d9d-cec0c932ce01" version="02.00.001" uri=
        "../lciamethods/b2ad6d9a-c78d-11e6-9d9d-cec0c932ce01.xml">
            <common:shortDescription xml:lang="en">EF-Climate Change</common:shortDescription>
        </referenceToLCIAMethodDataSet>
        <meanAmount>7.65071266294837</meanAmount>
    </LCIAResult>
```

Source: JRC Elaboration

In the review process, the LCIA results reported in the dataset are compared with those calculated with Look@LCI, using as input the LCI results (input and output lists of elementary flows and their amounts). To pass the review checks according to EF compliance, the LCIA results reported in the dataset can deviate less than 1% from the LCIA results calculated by Look@LCI. Check the document "Guide for EF-compliant datasets" (Fazio et al. 2020) section 6 and Table 5.

([17]) The LCIA results reported in "Partly terminated systems" datasets shall refer to their "LCI result" variant

LCIA results can be either calculated with the tool released by the EC Look@LCI or with the LCA software used for modelling, as long as EF LCIA methods are adopted. It is recommended to carry out the LCIA calculation with both the mentioned tools, thus performing a crossed-check of results. The guide for the use of Look@LCI is available online with the tool (European Commission 2021).

3.10 General recommendations

Considering the two compliance levels (EF and ILCD-EL) of LCDN, Table 2 provides an overall summary of the datasets requirements for both alternatives.

Table 2. Summary of the main requirements in EF and ILCD-EL compliance.

Compliance level	**ILCD-Entry Level**	**Environmental Footprint (EF) level**
Modelling and methodological consistency	ISO 14040 and ISO 14044 compliant process-based LCA	ISO 14040 and ISO 14044 compliant process-based LCA
		+ compliance with modelling requirements of EF data (European Commission 2021; Fazio et al. 2020)
Format	ILCD	ILCD
Documentation	minimum documentation extent specified as in ILCD Handbook - Specific guide for LCI datasets	minimum documentation extent specified as in ILCD Handbook - Specific guide for LCI datasets
		+ required metadata information according to Guide to EF-compliant datasets (Fazio et al, 2020)
Data Quality	following ISO quality criteria	following Guide to EF-compliant datasets (Fazio et al, 2020)
		+ define overall data quality rating (to be validated by the reviewer)
		+ quality requirement to respect (≤ 3.0 = "Good")
Review	at least 1 reviewer, independent, internal or external (in line with ISO 14025 (chapter 6.1)	Review: at least 2 reviewers, independent, with at least 1 external

Source: JRC Elaboration

4 Nodes and datasets in LCDN

Datasets are shared in the LCDN through "nodes". For a node to work in the LCDN it is required the availability of an IT-infrastructure and an internet web domain. The node runs with the software soda4LCA, a web-based centralized architecture that is placed on a remote server. The owner of the node owns the web domain where the Soda4LCA is installed and can manage data and visibility of data contained in it.

Soda4LCA is an application intended merely for storing datasets. Only datasets in the ILCD format are accepted. An overview of the node and its integration is reported in the "Life Cycle Data Network Handbook for Users and Data Developers" (Fazio et al. 2016) (section 5).

In the case a dedicated Node of LCDN is not available for sharing datasets, a node managed by European Commission can be used to host data of the hydrogen sector. To this end, a request should be sent to eplca@jrc.ec.europa.eu and the developed datasets shall be sent as well. Datasets hosted on EC nodes, once published, are free of charge for all users and uses. In the EC node "EU Funded research projects" (EUFRP), a data stock for data related to the hydrogen value chain is available.

Box 12. Node Installation - for node owners

It is strongly recommended to run the node on a GNU/Linux (11)- or *nix (12)-based operating system.

The latest soda4LCA release and its documentation is available for download at: https://bitbucket.org/okusche/soda4LCA/downloads/. It is recommended to always use the latest available stable release.

To install the software soda4LCA closely follow the "installation guide" in the *doc* folder of the software package or online. Following the instructions of the guide set the URL of the MySQL database and the server port based on the IT infrastructure where your Node will run.

Specifications on how to change any setting for the node are available in the "Configuration_Options_Guide" in the *doc/Installation* guide folder of the software package (set administrative contact of the node and emails, node title, logo, theme, registration and account-activation for users, etc.).

Instructions regarding the management of data and options available in the node are available in the "Administration guide" in the "doc" folder of the software package.

4.1 Node and datasets registration

After the node has been installed and it is running, it needs to be registered in order to be connected to the LCDN. Beyond the default registry of LCDN which hosts ILCD EL datasets, a new registry was established by the European Commission, the EF registry, to host and share data packages in line with the Environmental Footprint framework.

Box 13. Network registries

The reference document that contains general instructions about the registration of nodes in the network is "Life Cycle Data Network Handbook for Users and Data Developers" (Fazio et al. 2016), in section 5.4. Further details are available in the "Administration guide" of sSoda4LCA. For this task a request shall be sent to the JRC (which operates the network registry), by email at eplca@jrc.ec.europa.eu.

Please note that the registration procedure is necessary for datasets too. Once the node has been registered in the desired network registry(s), every dataset imported on the node needs to be registered with the registry and approved by the registry administrator. The detailed procedure is described in the "Node user guide" available in the soda4LCA zip package[18] and explanatory examples are provided in "Life Cycle Data Network Handbook for Users and Data Developers" (Fazio et al. 2016), section 6.4.

[18] https://bitbucket.org/okusche/soda4LCA/

4.2 Managing datasets

A single dataset, as XMLan XML file, can be uploaded in the node, using the software soda4LCA. Alternatively, multiple datasets can be uploaded as zip packages, containing XML files located in the folders of the ILCD format.

Anyone retrieving datasets from the Node is considered a “user” of the node. Users can be “registered” (they can log in with a registered account) or “regular” (they can retrieve data anonymously, without the need for registration).

Nodes are managed by one or more “admin” profiles. By default, only the administrator(s) of a Node can import and export the datasets. However, administrator(s) can set privileges for each specific user, including, among others, the possibility of importing and exporting datasets.

Datasets are assigned to one or more data stocks available on the Node. Moreover, the visibility of data stocks can change according to the user of the node. In fact, for every single data stock the node administrator has the possibility to select only specific groups of users allowed to view the data stock in the node (e.g.: in the case, a data stock is only intended for internal use, the node administrator can provide access to users of his organization only).

Instructions regarding:

— importing and exporting datasets on the node;

— setting the visibility of datasets;

— organizing datasets and data stocks;

— setting user access rights

are reported in “Life Cycle Data Network Handbook for Users and Data Developers” (Fazio et al. 2016).

Box 14. Update and maintenance

Datasets can require updates in the following situations:

- Change in the contents of the dataset (due to change in the reference time validity, errors in previously uploaded versions, additional review performed, etc.)

- Change the compliance level or the reference package (nomenclature, allowed elementary flows, etc.).

- Whenever a new version of a dataset is released (replacing an older version), it is important to follow the recommendations of the document “Management of UUID and version number of data sets” (Joint Research Centre 2012). Depending on the specific type of change it should be assessed whether it is the case of updating the version number (and how) or providing the dataset with a new identifier (UUID).

- For EF-compliant datasets, the steps that the data provider shall take when updating a dataset are explained in the “Guide for EF-compliant Data Sets“ (Fazio et al. 2020). Please notice that each time a dataset is being updated the EC and the EF helpdesk shall be notified (Fazio et al. 2020, section 3.4, 3.5).

- Regarding the software updates, the procedure for upgrading Soda4LCAsoda4LCA to a newer version are available in the “installation guide” in the doc folder of the software package.

5 Conclusions

This document is addressed to data developers in the sector of FCH systems. It reports and explains all the steps, and provides recommendations to follow for the production of LCI datasets in ILCD format.

Regarding LCI data, five different aspects shall be considered when developing compliant datasets: nomenclature, documentation, data quality, methodological consistency, and review. Knowing and mastering the functionalities of software used for LCA modelling is crucial to properly carry out the dataset creation in ILCD format.

Datasets can be stored and shared in the LCDN through nodes. It is important to properly follow the correct instructions for the use of nodes in LCDN. Useful recommendations and reference guides are provided in this document concerning the phase of installation, administration and management of data in the node, update and maintenance.

Considering the emerging demand from policy makers for data regarding the environmental impacts and the life cycle of products and services, this document supports developers in the procedure for the creation of quality-assured datasets.

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List of abbreviations and definitions

CF characterization factor

CFF Circular Footprint Formula

DQR Data Quality Rating

EC European Commission

EF Environmental Footprint

EU European Union

EoL End of life

EPLCA European Platform for Life Cycle Assessment

FCH Fuel Cell and Hydrogen

FU functional unit

GHG greenhouse gas

GLAD Global LCA Data Access

GWP global warming potential

IEA International Energy Agency

ILCD International Reference Life Cycle Data System

ILCD-EL International Reference Life Cycle Data System – Entry Level

IPHE International Partnership for Hydrogen and Fuel Cells in the Economy

ISO International Organisation for Standardisation

IT Information Technology

JRC Joint Research Centre

JU Joint Undertaking**LCA** Life Cycle Assessment

LCDN Life Cycle Data Network

LCI life cycle inventory

LCIA life cycle impact assessment

P precision

PEF Product Environmental Footprint

RED Renewable Energy Directive

SDK Software Developer Kit

TeR technological representativeness

TiR time representativeness

UUID Universally Unique Identifier

Definitions

Allocation - an approach to solving multi-functionality problems. It refers to 'partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems.

Aggregated Dataset - Complete or partial life cycle of a product system that next to the elementary flows (and possibly not relevant amounts of waste flows and radioactive wastes) lists in the input/output list exclusively the product(s) of the process as reference flow(s), but no other goods or services. Aggregated datasets are also called "LCI results" datasets. The aggregated dataset may have been aggregated horizontally and/or vertically.

Characterisation Factor – factor derived from a characterisation model which is applied to convert an assigned life cycle inventory result to the common unit of the Environmental Footprint impact category indicator.

Classification – Assigning the material/energy inputs and outputs tabulated in the life cycle inventory to Environmental Footprint impact categories according to each substance's potential to contribute to each of the EF impact categories considered.

Cradle to gate – A partial product supply chain, from the extraction of raw materials (cradle) up to the manufacturer's "gate". The distribution, storage, use stage and end of life stages of the supply chain are omitted.

Data provider – Subject (individual or organization) that makes data available to Life Cycle Assessment practitioners.

Data Quality - Characteristics of data that relate to their ability to satisfy stated requirements (ISO 14040:2006). Data quality covers various aspects, such as technological, geographical and time-related representativeness, as well as completeness and precision of the inventory data.

Data Quality Rating - Semi-quantitative assessment of the quality criteria of a dataset based on Technological representativeness, Geographical representativeness, Time-related representativeness, and Precision. The data quality shall be considered as the quality of the dataset as documented.

EF-compliant dataset – Dataset developed in compliance with the Environmental Footprint requirements provided at http://eplca.jrc.ec.europa.eu/LCDN/developer.xhtml.

Elementary Flows – In the life cycle inventory, elementary flows include "material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation" (ISO 14040, 3.12). Elementary flows include, for example, resources taken from nature or emissions into air, water, soil that are directly linked to the characterisation factors of the Environmental Footprint impact categories.

Environmental Impact – Element of an organisation's activities or products or services that interacts or can interact with the environment (ISO 14001:2015).

Flow diagram – Schematic representation of the flows occurring during one or more process stages within the life cycle of the product being assessed.

Functional unit – The functional unit defines the qualitative and quantitative aspects of the function(s) and/or service(s) provided by the product being evaluated. The functional unit definition answers the questions "what?", "how much?", "how well?", and "for how long?".

Gate to Gate – A partial product supply chain that includes only the processes carried out on a product within a specific organisation or site.

Input flows – Product, material or energy flow that enters a unit process. Products and materials include raw materials, intermediate products and co-products (ISO 14040:2006).

Land use – Environmental Footprint impact category related to use (occupation) and conversion (transformation) of land area by activities such as agriculture, forestry, roads, housing, mining, etc. Land occupation considers the effects of the land use, the amount of area involved and the duration of its occupation (changes in quality multiplied by area and duration). Land transformation considers the extent of changes in land properties and the area affected (changes in quality multiplied by the area).

Life cycle – Consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal (ISO 14040:2006).

Life cycle Assessment (LCA) – Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle (ISO 14040:2006).

Life cycle Impact assessment (LCIA) – Phase of life cycle assessment that aims at understanding and evaluating the magnitude and significance of the potential environmental impacts for a system throughout the life cycle (ISO 14040:2006). The Life Cycle Impact Assessment methods used provide impact characterisation factors for elementary flows to in order to aggregate the impact to obtain a limited number of midpoint and/or damage indicators.

Life cycle Inventory - The combined set of exchanges of elementary, waste and product flows in a Life Cycle Inventory dataset.

Life cycle inventory (LCI) dataset - A document or file with life cycle information of a specified product or other reference (e.g., site, process), covering descriptive metadata and quantitative life cycle inventory. A Life Cycle Inventory dataset could be a unit process dataset, partially aggregated or an aggregated dataset.

Multi-functionality – If a process or facility provides more than one function, i.e. it delivers several goods and/or services ("co-products"), then it is "multifunctional". In these situations, all inputs and emissions linked to the process will be partitioned between the product of interest and the other co-products according to clearly stated procedures.

Node - The repository of a developer/owner of dataset(s). Individual nodes compose a network.

Node Owner – Individual or organization owning the Information Technology (IT) infrastructure which allows the node to run.

Normalisation – After the characterisation step, normalisation is the step in which the life cycle impact assessment results are multiplied by normalisation factors that represent the overall inventory of a reference unit (e.g. a whole country or an average citizen). Normalised life cycle impact assessment results express the relative shares of the impacts of the analysed system in terms of the total contributions to each impact category per reference unit. When displaying the normalised life cycle impact assessment results of the different impact topics next to each other, it becomes evident which impact categories are affected most and least by the analysed system. Normalised life cycle impact assessment results reflect only the contribution of the analysed system to the total impact potential, not the severity/relevance of the respective total impact. Normalised results are dimensionless, but not additive.

Output flows – Product, material or energy flow that leaves a unit process. Products and materials include raw materials, intermediate products, co-products and releases (ISO 14040:2006).

Partially disaggregated dataset at level-1 - A partially disaggregated dataset at level-1 contains elementary flows and activity data of one level down in the supply chain, while all complementing underlying datasets are in their aggregated form.

PEF study – Term used to identify the totality of actions needed to calculate the Product Environmental Footprint results. It includes the modelling, the data collection, and the analysis of the results. It excludes the PEF report and the verification of the Product Environmental Footprint study and report.

Primary data - This term refers to data from specific processes within the supply chain of the user of the Product Environmental Footprint method or user of the Product Environmental Footprint Category Rules (PEFCR). Such data may take the form of activity data, or foreground elementary flows (life cycle inventory). Primary data are site-specific, company-specific (if multiple sites for the same product) or supply chain specific. Primary data may be obtained through meter readings, purchase records, utility bills, engineering models, direct monitoring, material/product balances, stoichiometry, or other methods for obtaining data from specific processes in the value chain of the user of the Product Environmental Footprint method or user of the Product Environmental Footprint Category Rules. In this method, primary data is synonym of "company-specific data" or "supply-chain specific data".

Process dataset - Data set for unit processes, partly terminated systems, and Life Cycle Inventory results. May contain Life Cycle Impact Assessment results as well.

Product – Any goods or services (ISO 14040:2006).

Product flow – Products entering from or leaving to another product system (ISO 14040:2006).

Raw material – Primary or secondary material that is used to produce a product (ISO 14040:2006).

Reference flow – Measure of the outputs from processes in a given product system required to fulfil the function expressed by the functional unit (based on ISO 14040:2006).

Review - process intended to ensure consistency between a life cycle assessment and the principles and requirements of the International Standards on life cycle assessment (ISO 14040:2006).

Reviewer – Expert performing the review and declaring whether the reviewed Life Cycle Assessment data are compliant with specific compliancy rules.

Secondary data - It refers to data not from a specific process within the supply-chain of the company performing a Product Environmental Footprint study. This refers to data that is not directly collected, measured, or estimated by the company, but sourced from a third party Life Cycle Inventory database or other sources. Secondary data includes industry average data (e.g., from published production data, government statistics, and industry associations), literature studies, engineering studies and patents, and may also be based on financial data, and contain proxy data, and other generic data. Primary data that go through a horizontal aggregation step are considered as secondary data.

Sub-processes - Those processes used to represent the activities of the level 1 processes (=building blocks). Sub-processes may be presented in their (partially) aggregated form (see Figure 1).

Supply chain – It refers to all of the upstream and downstream activities associated with the operations of the user of the Product Environmental Footprint method, including the use of sold products by consumers and the end of life treatment of sold products after consumer use.

System boundary – Definition of aspects included or excluded from the study. For example, for a "cradle-to-grave" Environmental Footprint analysis, the system boundary includes all activities from the extraction of raw materials through the processing, distribution, storage, use, and disposal or recycling stages.

Waste – Substances or objects which the holder intends or is required to dispose of (ISO 14040:2006).

Water use – It represents the relative available water remaining per area in a watershed, after the demand of humans and aquatic ecosystems has been met. It assesses the potential of water deprivation, to either humans or ecosystems, building on the assumption that the less water remaining available per area, the more likely another user will be deprived (see also http://www.wulca-waterlca.org/aware.html).

Weighting – Weighting is a step that supports the interpretation and communication of the results of the analysis. Product Environmental Footprint results are multiplied by a set of weighting factors, which reflect the perceived relative importance of the impact categories considered. Weighted Environmental Footprint results may be directly compared across impact categories, and also summed across impact categories to obtain a single overall score.

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