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LCA Checklist: a tool to improve the communication of the environmental sustainability of the Clean Hydrogen Joint Undertaking projects - v.1

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Contents

Abstract

In the context of research projects, the Life Cycle Assessment of the technologies under investigation is often required as a tool for considering their environmental performance. Regarding the emerging hydrogen sector, the Clean Hydrogen Joint Undertaking supervises several research projects whose partners are moving the first steps towards LCA, or that have a basic expertise in LCA. Hence, when producing the LCA deliverable, it is essential for the practitioners to understand what are the information that needs to be reported. This simple checklist is intended for ensuring a minimal level of completeness and documentation of LCA studies of hydrogen-related projects, with provision of examples referred to a hydrogen case study. It references the existing LCA standards that the practitioners are required to consult to fulfill the methodological recommendations. The definition of the basic LCA requirements in this document is based on the ISO 14040 and ISO 14044, which provide the generic guidance for conducting an LCA. Additional recommendations are taken from the ILCD Handbook and the SH2E guidelines which integrate the ISO standards with more detailed specifications on the methodological choices and the case studies of hydrogen systems, respectively. It also provides optional recommendations based on the Environmental Footprint methodology, which is the methodology currently recommended by the European Commission to measure and communicate the life cycle environmental performance of products and organisations.

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 Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 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.

According to the Clean Hydrogen JU SRIA, sustainability is one of the three focus areas of the Horizontal Activity 1: Cross-cutting Issues. To improve sustainability and circularity, the JU key focus areas for development and support are complete and integrated life cycle thinking tools, enhanced recovery of PGMs/CRMs including per- and polyfluoroalkyl substances (PFAS), development of recycling integrated processes, and development of eco-design guidelines and eco-efficient processes.

LCAs have already been part of the FCH 2 JU strategy: "it is expected that LCAs will be performed at both project and programme levels. The resulting Life Cycle Inventory (LCI) data sets will form a database, published as part of the ILCD Data Network, and maintained by the industry partners of the FCH 2 JU. The FCH 2 JU shall also establish an international exchange, thus providing for a globally consistent framework."

Since 2018 and as part of their Framework Agreement, JRC has been supporting the FCH 2 JU by providing an inventory and gap analysis of the work performed in the various projects to the FCH 2 JU, focusing on LCA methodology. Based on the outcome of this analysis, a workshop was held in 2019, and a number of recommendations were given by the experts, e.g. the need for a harmonisation effort in the approach to LCA. Meanwhile the JRC has continued to assess the LCA deliverables of all ongoing projects and reports to the Clean Hydrogen Joint Undertaking.

The present checklist was requested by the Clean Hydrogen JU with the intention to address the need of improving the quality of LCA deliverables produced by the Clean Hydrogen JU projects, among other entities, and its consistency with the most up to date European guidelines on life cycle-based analyses (i.e., EF methodology).

1 Introduction

More and more projects supported by the Clean Hydrogen Joint Undertaking[1] (formerly Fuel Cells and Hydrogen Joint Undertaking) are producing deliverables where the life-cycle environmental impact of their products/activities are assessed. These deliverables could serve three main purposes:

1. To assess the potential environmental impacts (positive and/or negative) caused by the project;
2. To identify potential environmental hot-spots;
3. To produce inventories for future life cycle assessments (LCAs).

These objectives are aligned with those of the Clean Hydrogen Joint Undertaking (JU) aiming to develop and deploy sustainable clean hydrogen technologies in the EU. The Joint Research Centre (JRC) has reviewed the LCA deliverables of the Clean Hydrogen JU projects since 2018. Unfortunately, in most cases the quality of the deliverables needs to be improved to meet the aforementioned objectives in terms of useful impact assessment and inventories. Regarding the assessments, a technical guidance was developed in 2011 by the HyGuide project to assist entities and practitioners when conducting a LCA on fuel cell and hydrogen (FCH) systems (Lozanovski et al., 2011; Masoni & Zamagni, 2011). While the guidance document is frequently referenced in the LCA deliverables, it is infrequently utilized in the assessments themselves. For instance, the projects fail to clearly define the goal of the study, or they do not provide crucial information regarding the scope of the analysis. We attribute this behaviour to several factors, including the complexity of the guidance, which may not be well suited to inexperienced LCA practitioners; the fact that adherence to the guidance is not mandatory; and the lack of a straightforward checklist or template to assist projects in carrying out their assessments. The HyGuide guidance was built on the International Reference Life Cycle Data System (ILCD)[2], which has been superseded now by the Environmental Footprint (EF) method[3]. The EF method is the method recommended by the European Commission to measure and communicate the life cycle environmental performance of products and organisations. The quality of the inventories developed by the Clean Hydrogen JU projects needs improvements to achieve either the level of ILCD-Entry Level or EF-compliant datasets. This complicates the work planned on the integration of hydrogen datasets in the Life Cycle Data Network[4] (LCDN), and potential development of specific Product Environmental Footprint Category Rules (PEFCRs) on FCH hydrogen related technologies.

To improve the quality of the LCA deliverables and inventories, the Clean Hydrogen JU requested from JRC to develop a checklist to be used by its projects. Overall, the two main objectives of the checklist are:

1. To improve the quality of the LCA deliverable produced by the Clean Hydrogen JU projects, and its consistency with the most up to date European guidelines on life cycle-based analyses (i.e., EF methodology);
2. To facilitate the integration of the inventories developed by the projects in an upcoming "Hydrogen node" of the LCDN, following the guidelines drafted by JRC (AWP 2022 - Deliverable B.4.3)

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1 https://www.clean-hydrogen.europa.eu/index_en
2 https://eplca.jrc.ec.europa.eu/ilcd.html
3 https://eplca.jrc.ec.europa.eu/EnvironmentalFootprint.html
4 https://eplca.jrc.ec.europa.eu/LCDN/index.xhtml

The shortcomings of the LCA deliverables encountered by the JRC reviews were found in all phases of the assessment. However, the most problematic phase appears to be the goal and scope definition because of:

— Lack of clear goal definition;

— Lack of details in the scope definition: e.g., description of the product system, system boundaries, flow chart, main assumptions;

— Inadequate selection or definition of the functional unit.

In our opinion, the execution of the goal and scope phase could be easily and greatly improved with a simple checklist. Nevertheless, the LCA deliverables can reach a higher quality regarding the inventory, impact assessment, and interpretation too. Although the execution of these phases is more difficult to be addressed compared to the goal and scope definition, we believe the checklist would improve the following aspects:

— Lack of information regarding the source and quality of data;

— Lack of information regarding the modelling approach (e.g., multi-functionality);

— Lack of information regarding the characterization model (e.g., global warming potential factors considered);

— Lack of interpretation of the results: e.g., what contributes to the impact and why.

A list of basic requirements for the LCA deliverable is provided in this checklist (light green boxes). The basic requirements are based on the International LCA standards ISO 14040, the ILCD Handbook, and the guidelines developed by the SH2E project([5]) (https://sh2e.eu/) for LCAs of harmonised hydrogen energy systems. The ISO 14040 and ISO 14044 standards are the reference documents that establish the basic LCA principles and provide the indispensable framework for LCAs. Since several recommendations of the ISO standards leave the LCA practitioner with a range of choices, in 2010 the JRC released the ILCD Handbook. The ILCD handbook addresses with a higher level of detail the provisions of the ISO standards, providing guidance for consistent and quality assured data and studies. The LCA methodological guidance with a specific focus on fuel cell and hydrogen systems is documented in the guidelines developed by the SH2E project, which build on the international documents mentioned above. Where applicable, a reference to specific sections of these documents have been included in the boxes.

While the list of basic requirements shall be completely checked by LCA practitioners, a list of optional provisions based on the EF method are also included (blue boxes) in this document, and they can be checked in addition to the basic requirements. The EF-oriented provisions are characterised by higher quality and more documentation than the basic requirements, but they allow to achieve a higher degree of robustness, consistency, reproducibility, and comparability of the results. Additionally, modelling life-cycle in line with EF-oriented provisions requires the LCA practitioner to use secondary datasets that are EF-compliant (which fulfil minimum criteria of data quality) when available. These specifications are oriented towards the development of LCAs in line with the European Commission Recommendation 2021/2279[6] on the use of the EF method to measure and communicate the life cycle environmental performance of products and organisations.

[5] SH2E will develop and demonstrate specific guidelines for the environmental (LCA), economic (LCC) and social (SLCA) life cycle assessment and benchmarking of fuel cell and hydrogen (FCH) systems, while addressing their consistent integration into robust FCH-LCSA guidelines, https://sh2e.eu/.

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

Addressing such requirements does not make the LCA study a compliant PEF/OEF study. The practitioner willing to develop a compliant PEF/OEF study shall use the methodologies provided by the Recommendation 2021/2279. However, conducting LCA studies that fulfil EF-oriented provisions will be strategic to develop product environmental footprint category rules (PEFCRs) on hydrogen-related technologies. Since there are aspects of the LCA in which the basic requirements and the EF-oriented provisions are aligned, several sections of this document report only one requirement that covers both.

Alongside the specifications to follow, this document provides some examples intended for guiding the LCA practitioners. The examples refer to a hydrogen production system via PEM electrolysis, when applicable. Due to the explanatory purposes of this document, the examples, number and figures reported shall not, in any way, be understood as representative of the existing technologies.

2 LCA checklist

Table 1 is intended to be followed when conducting an LCA study. Checking the box of each requirement means that the corresponding information has been reported in the deliverable of the LCA conducted.

The requirements of the checklist are differentiated into two levels: basic level requirements, which shall be intended as mandatory to achieve a basic, but complete LCA, and the EF requirements, to be fulfilled for improving the quality, reliability and documentation of the study.

Table 1. Checklist for the practitioner performing the LCA in a Clean Hydrogen Joint Undertaking project. Please check one option for each row.

Life cycle phase	Sections. Please click on titles below to be redirected to the corresponding section in the form	Basic requirement	EF-oriented provision
Goal of the LCA study	1. Intended applications of the LCA	☐	☐
	2. Application Situation	☐	
	3. Reasons for carrying out the study	☐	
	4. Modelling approach	☐	☐
	5. Target Audience	☐	
	6. Comparisons	☐	☐
	7. Influential actors	☐	☐
Scope of the LCA study	8. Functional unit	☐	
	9. Reference flow	☐	
	10. Considered stages	☐	☐
	11. Flow chart (system boundaries)	☐	☐
	12. Cut-off	☐	☐
	13. Impact assessment	☐	☐
	14. Multi-functionality aspects	☐	☐

	15. Assumptions and limitations of the study	☐	
	16. Calculation	☐	
Life cycle inventory	17. Life cycle stages (Life cycle Inventory)	☐	☐
	18. Input flows (Life cycle Inventory)	☐	☐
	19. Output flows (Life cycle Inventory)	☐	☐
	20. End of Life (EoL) modelling	☐	☐
	21. Data sources	☐	☐
	22. Data quality	☐	☐
	Datasets development. If life cycle inventory data are developed within the study, the following sections shall be filled in. If no inventory data are developed, please skip to section 27.		
	23. Administrative information (dataset development)	☐	☐
	24. Data review (dataset development)	☐	☐
	25. Documentation (dataset development)	☐	☐
	26. Data quality (for datasets)	☐	☐
Life Cycle Impact Assessment	27. Impact assessment method	☐	☐
	28. Characterisation model, weighting and normalization	☐	☐
Interpretation of the LCA and reporting	29. Hotspot analysis per impact categories (LC stages, processes, flows)	☐	☐

	30. Hotspot analysis based on single score (most relevant impact categories)	☐	☐
	31. Interpretation	☐	☐
Verification and Validation	32. Submission to the reviewer	☐	☐
	33. Review documentation	☐	☐

Source: JRC elaboration.

3 LCA form and example

3.1 Goal of the LCA study

3.1.1 Intended applications of the LCA

1 - Basic requirement	
Question	Are the intended applications of the LCA unambiguously stated?
Reference	Section 2 of the SH2E Guidelines.
Example	The intended application of the LCA study is the benchmarking of the technology required for water electrolysis by proton-exchange membrane (PEM) against other existing technologies.
Answer	☐Yes

1 - EF-oriented provision	
Question	Are the intended applications defined for LCA study in line with the EF methodology for products or for organisations, respectively? The methodologies provided in the European Commission Recommendation 2021/2279 can be applied to different purposes: - at product level, performing PEF studies, using existing Product Environmental Footprint Category Rules (PEFCRs) and developing new PEFCRs; - at organisation level, performing OEF study, using existing Organisation Environmental Footprint Category Sectoral Rules (OEFCSRs), developing new OEFSCRs.
Reference	Annex I and Annex III of 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
Example	Intended applications of the LCA: Provide information about the PEM electrolyser system to customers
Answer	☐Yes

3.1.2 Application Situation

2 - Basic requirement and EF-oriented provision	
Question	Has the application situation been indicated? This includes: - whether the LCA study would be employed for decision support - the scale of the induced changes in the considered system
Reference	Section 2 of the SH2E Guidelines.
Example	The results of this study will be used for policy support regarding the implementation of sustainable hydrogen production pathways from an environmental perspective. The related decisions are expected to bring effects at large scale in the considered system (macro level decision support).
Answer	☐Yes

3.1.3 Reasons for carrying out the study

3 - Basic requirement and EF-oriented provision	
Question	Is it explained why is the LCA study made?
Reference	Section 2 of the SH2E Guidelines.
Example	The reason for carrying out this study is to respond to a request from a customer.
Answer	☐Yes

3.1.4 Modelling approach

4 - Basic requirement	
Question	What modelling approach was used for the LCA study? Why?
Reference	Section 2 of the SH2E Guidelines.
Example	The technologies of PEM electrolysis are at an early stage of development and their market sector is still establishing. Therefore, decisions taken can induce significant changes in the considered system and a change-oriented LCA modelling principle has been adopted.
Answer	☐Yes

4 - EF-oriented provision		
Question	Is the EF modelling approach adopted?	
Reference	Section 4 of the EF method (Annex I and III of the European Commission Recommendation 2021/2279).	
Example	The life-cycle model to describe the production of PEM water electrolyser is in line with the EF method.	
Answer	☐Yes	☐No

3.1.5 Other relevant information

3.1.5.1 Target Audience

5 - Basic requirement and EF-oriented provision	
Question	Is it indicated within the defined goal who is the target audience (i.e., to whom the results of the study are intended to be communicated)?
Reference	Section 2 of the SH2E Guidelines.
Example	The target audience of this LCA study are the stakeholders of the hydrogen industry sector in European market.
Answer	☐Yes

3.1.5.2 Comparisons

6 - Basic requirement	
Question	Is it indicated within the defined goal whether the results are intended to be used in comparative assertions to be disclosed to the public?
Reference	Section 2 of the SH2E Guidelines
Example	The results of this LCA are intended to be used in comparative assertions to be disclosed with the public. The impacts of the PEM electrolyser systems are compared to competitor technologies, namely Alkaline and Solid Oxide systems.
Answer	☐Yes

6 - EF-oriented provision		
Question	Does the goal of the study fulfil the following criteria about the comparisons? • Comparisons([7]) and comparative assertions([8]) are allowed only for studies in compliance with an existing PEFCR or OEFSR. In this case, the conditions under which a comparison or comparative assertion may be made are specified in the PEFCR. • If there is no existing PEFCR for the product or organisation in scope, the study shall not provide any comparison or comparative assertion.	
Reference	Section 1 of the EF method (Annex I and III of European Commission Recommendation 2021/2279).	
Example	There is not an existing PEFCR for water electrolysers, which is the product in scope in this study. Therefore, comparisons between the product in scope and any other product are not allowed. If a PEFCR will be available for hydrogen systems/technologies, this shall be used and comparisons will be allowed only between studies compliant with the same PEFCR.	
Answer	☐Yes	☐No

3.1.5.3 Influential actors

7 - Basic requirement	
Question	Is it indicated within the defined goal who is the commissioner of the study and other influential actors?
Reference	Section 5.2 of the ILCD Handbook - General guide for Life Cycle Assessment (Joint Research Centre & European Commission, 2010)
Example	The commissioner of the study is the Joint Research Centre (European Commission)
Answer	☐Yes

7 A comparison, not including a comparative assertion, (graphic or otherwise) of two or more products based on the results of a PEF study and supporting PEFCRs

8 An environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function (including the benchmark of the product category).

7 - EF-oriented provision		
Question	Is the identity of the Verifier indicated in the defined goal of the study?	
Example	Verifier: Independent external verifier, Mr Y	
Answer	☐Yes	☐No

3.2 Scope of the LCA study

3.2.1 Functional unit

8 - Basic requirement and EF-oriented provision	
Question	Is the functional unit clearly specified? This shall be defined according to: "what": the function or service provided; "how much": the extent of the function "how long": the duration or the lifetime "how well": the expected level of quality? Different functional units are possible depending on the function that hydrogen fulfils in the considered system.
Reference	Section 3.2 of the SH2E Guidelines.
Example	Functional unit of an hydrogen production system by water electrolysis: What: "Hydrogen production from de-ionised water" How much: "1 kg" How long: "lifetime of the system is 10,000 hours of operation" How well: "purity grade > 99.999%w, at pressure of 30 bar and temperature of 20°C
Answer	☐Yes

3.2.2 Reference flow

9 - Basic requirement and EF-oriented provision	
Question	Is the defined reference flow a measure of the products needed to fulfil the function expressed by the functional unit? The reference flow of the system must be indicated and quantified.
Reference	Section 5.2.2 of the standard ISO 14040(ISO, 2006a)
Example	The reference flow is 1kg of hydrogen
Answer	☐Yes

3.2.3 System boundaries

3.2.3.1 Considered stages

10 - Basic requirement	
Question	What are the phases and processes considered in the LCA study? What are the system boundaries? Are the system boundaries consistent with the chosen goal of the LCA study (section 2.1)?
Example	System boundaries are cradle-to-gate including life cycle stages from raw material extraction to the delivery to final users (use phase are excluded). The processes included are: raw materials extraction (mining and preparation), production of hydrogen including treatments of purification, compression, transportation, storage and distribution to final user
Answer	☐Yes

10 - EF-oriented provision	
Question	Are the life cycle stages and processes defined in line with the classification of the Environmental Footprint method (European Commission, 2021) (i.e. raw material acquisition and pre-processing, manufacturing, distribution and storage, use stage and end of life treatment)?
Reference	Section 3.2.2 of the EF method (Annex I and III of European Commission Recommendation 2021/2279).
Example	System boundaries include raw materials extraction (mining and preparation), production of hydrogen including treatments of purification, compression,

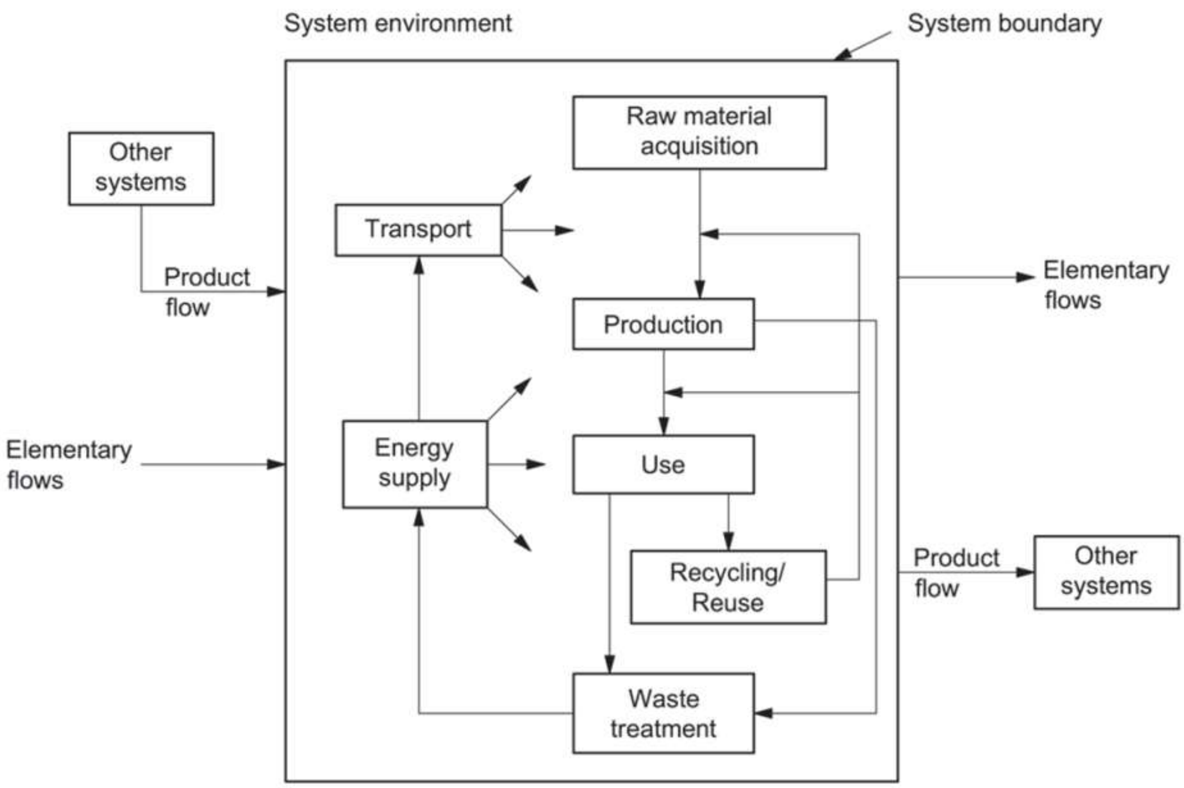
	transportation, storage and distribution to final user, excluding the use phase and EoL treatments.

Answer	☐Yes	☐No

3.2.3.2 Flow chart

11 - Basic requirement	
Question	Are the system boundaries shown in a flow chart?
Example	Yes. See Figure 1, taken from ISO 14040, as generic flowchart. This shall be adapted to the specific case study.
Answer	☐Yes

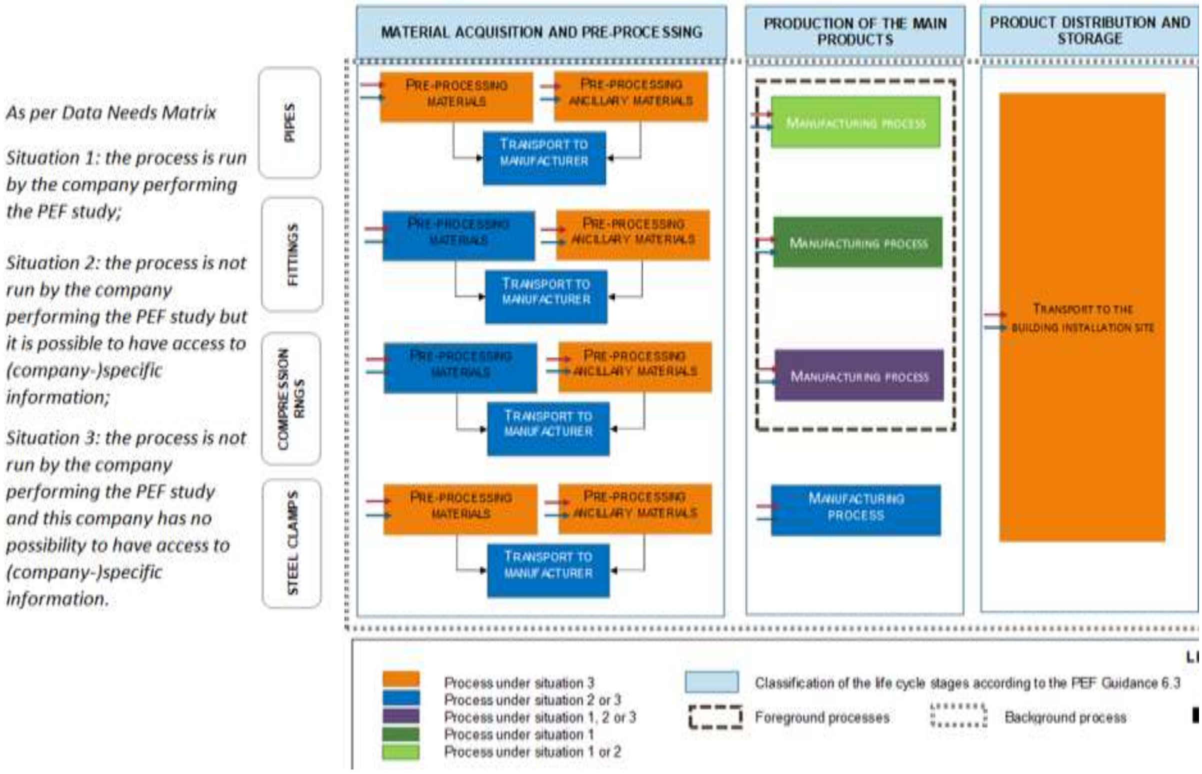
Figure 1. Example of flow chart for a generic product system for LCA.



Source: ISO 14040, 2006

11 - EF-oriented provision		
Question	Is the use of company-specific data indicated in the system boundary diagram? Activities modeled with the use of company-specific data shall be highlighted. The activity and/or process names in the system diagram shall be aligned with the names within the documentation of the same study.	
Reference	Section 3.2.2 of the Environmental Footprint Method (Annex I and III of the Recommendation).	
Example	Yes, see Figure 2	
Answer	☐Yes	☐No

Figure 2. Example of system boundary for hot and cold water supply piping system (for fitting producers) – partial view of the diagram.



Source: https://wayback.archive-it.org/org-1495/20221004164603mp_/https://ec.europa.eu/environment/eussd/smgp/PEFCR_OEFSR_en.htm

3.2.3.3 *Cut-off*

12 - Basic requirement	
Question	Is the applied cut-off clearly stated and justified (if any)?
Reference	Section 3.3 of the SHE Guidelines.
Example	Transportation processes are cut-off as the outcomes of a screening study (available in the documentation of the study) demonstrated that their environmental impacts within the considered system are negligible (based on normalized and weighted results). All elementary flows of environmental effect are included in the inventory.
Answer	☐Yes

12 - EF-oriented provision		
Question	Any cut-off shall be avoided, when applicable. Otherwise it can be applied only under the conditions recommended by the EF method. Is this requirement fulfilled?	
Reference	Section 4.6.4 of the EF method (Annex I and III of the Recommendation).	
Example	Cut-off was not applied.	
Answer	☐Yes	☐No

3.2.4 Impact assessment

13 - Basic requirement	
Question	Is the selected impact assessment method stated (including the impact categories selected and the methodology of impact assessment)? Are the indicators used to express the results clearly reported (including temporal differentiation of the indicators used e.g. GWP100a or GWP 20a)? Is the set of characterisation factors used for impact assessment clearly reported (and whether it includes regionalized factors)?
Example	The CML 2000 baseline midpoint method is used for the impact assessment. The impact categories considered are: climate change, ecotoxicity freshwater, eutrophication terrestrial, land use, acidification, human toxicity (non-cancer), human toxicity (cancer), and water use. For climate change the list of used characterization factors is available from IPCC 2013 (CH_4 fossil: 29.8; N_2O: 273, etc.) Indicator: kg CO_{2eq} For the category Water Use, the characterisation model Available WAter REmaining (AWARE) as recommended by UNEP, 2016 was used. Country-specific characterisation factors were used

	considering the country where each process of the system occurs, when available; if not available, global characterization factors were used. Indicator: m3 world$_{eq}$ [similarly for each other impact category…]
Answer	☐Yes

13 - EF-oriented provision		
Question	Are the default 16 EF impact categories considered? If not, is a justification specified? Is the latest release of the EF impact assessment method used? If not, is a justification specified? Is the version of the EF reference package (used for impact assessment) reported in the scope of the study?	
Example	The LCIA results are calculated based on the EF3.1 methods which provide updated characterisation factors in the following impact categories: Climate Change, Ecotoxicity freshwater, Photochemical Ozone Formation, Acidification, Human Toxicity non-cancer, and Human Toxicity cancer.	
Answer	☐Yes	☐No

3.2.5 Multi-functionality aspects

14 - Basic requirement	
Question	Are the following information included in the scope of the study? 1) What type of allocation was adopted in the background datasets used to model the life-cycle? 2) Does the foreground system include multifunctional processes? 3) What methodological choice was adopted to model multi-functionality? Why? 4) Is the adopted methodological choice in line with the functional unit?
Reference	Section 3.4 of the SH2E guidelines.
Example	Energy allocation is applied to partition the impacts among the co-products of the electrolysis process: hydrogen and oxygen. Energy content was deemed more suitable than mass allocation as allocation key, considering that the produced hydrogen is applied as fuel. Regarding processes of the background system the cut-off system model from ecoinvent is used. For combined heat and power production, allocation by exergetic content is applied. For co-productions of electricity and products with no energy value, allocation by market value is considered.
Answer	☐Yes

14 - EF-oriented provision		
Question	Is the decision hierarchy from EF method applied in the cases of multi-functionality (both in the foreground and background system)?	
Reference	Section 4.5 of the EF method (Annex I and III of European Commission Recommendation 2021/2279).	
Example	Yes. The co-production of oxygen by the electrolysis process was modelled with system expansion (i.e., first recommended option by the EF method). Since the function provided is the production of hydrogen from de-ionised water, hydrogen was identified as the main output product of the process. Oxygen is assumed to be recovered, avoiding the production of the same amount of oxygen by cryogenic distillation.	
Answer	☐Yes	☐No

3.2.6 Assumptions and limitations of the study

15 - Basic requirement	
Question	Are the limitations of the study clearly stated in terms of use and interpretation of the LCA results (due to assumptions and methodological choices)?
Reference	Section 2 of the SHE Guidelines.
Example	The LCA is limited to greenhouse gas emissions. Moreover, the results cannot be compared to other commercial electrolyser systems due to the very specific conditions in which the water electrolyser at lab scale was tested.
Answer	☐Yes

3.2.7 Calculation

16 - Basic requirement	
Question	Have the name and version of the LCA software used for calculating the results been reported? If calculation was implemented using excel spreadsheets, please provide those in the documentation.
Example	The version 9.2 of the software SimaPro was used for the assessment.
Answer	☐Yes

3.3 Life-cycle Inventory

3.3.1 Life cycle stages

17 - Basic requirement	
Question	Are all the life cycle stages modelled in accordance with the defined system boundaries? In case any life cycle stage is omitted, it must be clearly reported and should be justified by the fact that they do not contribute significantly to the LCI results in view of the intended application(s) of the outcome of the LCI/LCA study.
Reference	Section 4.2.3.3.1 of ISO14044 (ISO, 2006b).
Example	Dust and air emissions of the assembling process are not present in the model because according to the plant environmental integrated declaration of the year 2023 they were negligible in comparison with emissions of other treatments. The bill of measured values is reported in the appendix.
Answer	☐Yes

17 - EF-oriented provision		
Question	Are all the EF mandatory life cycle stages taken into account?	
Reference	Section 4.2 of the EF method (Annex I and III of European Commission Recommendation 2021/2279).	
Example	Yes. The processes required for raw material acquisition are mining at copper ore, transport to the refinery, refining, etc. [For each LC stage]	
Answer	☐Yes	☐No

3.3.2 Collection of primary and secondary inventory data on elementary and non-elementary flows

3.3.2.1 Input flows

18 - Basic requirement	
Question	Are all the relevant inputs to the foreground and background system modelled consistently with the defined system boundaries? (e.g. consumption of energy, water, transports, etc.)
Reference	Section 3.3 of the SH2E Guidelines.
Answer	☐Yes

18 - EF-oriented provision		
Question	Are all the following inputs considered (where needed) for developing the LCI? - Energy (from fuel, electricity) specifying the source of generation - Materials/components - Capital goods - Transport, different inputs for each different transportation mode and transported material - Elementary flows for consumed resources, land use, water use - One product or reference flow (for avoided products) They shall be modelled in line with the EF method.	
Reference	Section 4.4 of the European Commission Recommendation 2021/2279 (Annex I and III).	
Example	Yes. See table 2.	
Answer	☐Yes	☐No

Table 2. Inputs flows from the Life Cycle Inventory of the production process of a PEM water electrolyser

Flow	Amount	Unit	Provider (process)	Description
Anode, for water electrolyser	4.00E-05	m2	Anode, for water electrolyser - EU+EFTA+UK	
Balance_of_Plant	4.03E-06	Item(s)	Balance_of_Plant - EU+EFTA+UK	
Copper sheet	4.43E-06	kg	Copper sheet, single route, at plant, melting and mechanical treatment (fabrication), 8.92 g/cm3 - EU+EFTA+UK	current collector (5 mm thick) - copper processing (gate to gate) includes the rolling process and the production cathode copper as well. Input is copper concentrate
Electricity; < 1kV; consumption mix, at consumer; AC	0.177262	MJ	Electricity grid mix 1kV-60kV, consumption mix, to consumer, technology mix, 1kV - 60kV - EU+EFTA+UK	Assembling the BoP. The energy required for manufacturing is referred to the stack of 1 MW
Electricity; < 1kV; consumption mix, at consumer; AC	1.104956	MJ	Electricity grid mix 1kV-60kV, consumption mix, to consumer, technology mix, 1kV - 60kV - EU+EFTA+UK	assembling the stack
global mix copper concentrate	5.63E-06	kg	Copper Concentrate (Mining, mix technologies), single route, at plant, copper ore mining and processing, Copper - gold - silver - concentrate (28% Cu; 22.3 Au gpt; 37.3 Ag gpt) - GLO	current collector (5 mm thick) - copper raw material (cradle to gate)
Plastic part (unspecified)	4.83E-06	kg	Injection moulding, production mix, at plant, plastic injection moulding, for PP, HDPE and PE - EU+EFTA+UK	Moulding seals and gaskets

Platinum	1.06E-06	kg	Platinum, production mix, at plant, primary production, 21.45 g/cm3 , 195.08 g/mol - GLO	electrocatalyst cathode, plus platinum coating of PTL
Transport	2.58E-05	kgkm	Freight train, average, consumption mix, to consumer, mix of electricity driven and diesel driven, cargo, average train, gross tonne weight 1000t / 726t payload capacity - EU+EFTA+UK	BoP components, train
Transport	0.005622	kgkm	Barge, consumption mix, to consumer, technology mix, diesel driven, cargo, 1500 t payload capacity - EU+EFTA+UK	BoP components, ship
industrial area (land use/land occupation)	4.83E-05	m^2 *a		Land occupation normalized per year of operation

Source: JRC elaboration.

3.3.2.2 Output flows

19 - Basic requirement	
Question	Are the relevant output flows of products, co-products, waste, emissions modelled consistently with the defined system boundaries?
Reference	Section 3.3 of the SH2E Guidelines.
Answer	☐Yes

19 - EF-oriented provision	
Question	19.b Are all the following outputs considered (where needed) for developing the LCI? - One product flow as reference flow - Other product flows for co-products (if any) - Elementary flows for emissions and wastes They shall be modelled in line with the EF method.

Reference	Please refer to section 4.4 of the European Commission Recommendation 2021/2279 (Annex I and III).	
Example	Yes. See table 3.	
	☐Yes	☐No

Table 3. Output flows from the Life Cycle Inventory of the production of 1 m2 of proton exchange membrane.

Flow	Amount	Unit	Provider	Description
Polymer membrane, manufactured, proton-exchange, for water electrolysis	1	m2		reference flow
Incineration good (municipal solid waste)	0.0128	kg	Waste incineration of municipal solid waste, production mix, at consumer, waste-to-energy plant with dry flue gas treatment, including transport and pre-treatment, municipal solid waste - EU+EFTA+UK	waste - NaCl from the production of potassium amide
hydrogen	0.00022	kg		emissions - from the reaction of liquid ammonia with potassium chloride
waste heat	1.52	MJ		emissions - From electricity input
polychlorinated biphenyls	0.002	kg		direct emissions to air from the polymerisation process

Source: JRC elaboration

3.3.3 End of Life (EoL) modelling

20 - Basic requirement	
Question	Is the choice of the modelling approach to EoL documented and justified? Preparatory steps (collection, transport, pre-treatment (sorting, separation)) of EoL flows shall be considered, if not excluded by the method applied. Downstream activities of waste treatment, such as landfill operation and maintenance as well as ash disposal, shall be included.
Reference	Section 3.3.2 of the SH2E Guidelines
Example	End of Life was modelled using the “Recycled content approach” also known as cut-off or 100/0 method. Therefore, the recovery and upgrading of products at the end of life are “cut off” (no credits were given to the system for "secondary raw material” or energy recovery in the downstream), while the collection, transport and pre-treatment are included in the modelling. Recycled materials in input to the system were burdened with impacts from recovery and upgrading.
Answer	☐Yes

20 - EF-oriented provision		
Question	Is the Circular Footprint Formula (CFF) applied? Please document the parameters used(European Commission, 2021).	
Reference	Section 4.4.8.1 of the European Commission Recommendation 2021/2279 (Annex I and III).	
Example	Yes CFF was applied for different materials and applications using the default parameters from annex C of the PEF method, available online at https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml. [provide a table with the list of the values used for different materials and application].	
Answer	☐Yes	☐No

3.3.4 Data sources

21 - Basic requirement	
Question	Are the sources of each data used in the model reported and documented? Are secondary data used to develop the LCI or to integrate data gaps?
Reference	Section 4.1 of the SH2E Guidelines.
Example	Primary data for processes of the foreground system were retrieved from the bill of materials of the production plant. Secondary data (ecoinvent version 3.7) were used for background processes
Answer	☐Yes

21 - EF-oriented provision		
Question	Regarding secondary data sources, are EF compliant datasets used to model sub-processes (when available)?	
Reference	Section 4.6.3 of the European Commission Recommendation 2021/2279 (Annex I and III).	
Example	Energy and transport datasets from the PEF energy and transports tender are consistently used.	
Answer	☐Yes	☐No

3.3.5 Data quality

22 - Basic requirement		
Question	Is the quality of data used in the study assessed (e.g. providing a rating)?	
Reference	Section 4.2 of the SH2E Guidelines.	
Example	The quality assessment of the LCA was conducted using the ILCD data quality system.	
Answer	☐Yes	☐No

22 - EF-oriented provision		
Question	Is data quality assessed according to the EF method?	
Reference	Section 4.6.5 of the European Commission Recommendation 2021/2279 (Annex I and III).	
Example	The DQR formula was applied according to the PEF/OEF method. $DQR = \frac{TeR+GeR+TiR+P}{4}$ where TeR is the Technological-Representativeness, GeR is the Geographical-Representativeness, TiR is the Time-Representativeness, and P is Precision.	
Answer	☐Yes	☐No

3.3.6 Datasets development (only for practitioners producing LCI datasets)

The requirements reported in this section have to be checked only for practitioners producing LCI datasets for the Life Cycle Data Network (LCDN). In this case, it is highly recommended to follow the document "Procedure for developing datasets related with hydrogen value chain to be shared in the Life Cycle Data Network" - Deliverable D3, 2022.

3.3.6.1 Administrative information

23 - ILCD Entry-level requirement	
Question	Are the fields of the administrative section of the metadata filled out? The fields marked as "mandatory" according to the ILCD data format (European Commission, n.d.), as a minimum, shall be filled in.
Reference	https://eplca.jrc.ec.europa.eu/LCDN/downloads/ILCD_Format_1.1_Documentation/ILCD_ProcessDataSet.html
Example	Commissioner of dataset: JRC, Unit D3 Intended applications: This dataset provides a cradle-to-gate life-cycle inventory for the manufacturing process of a water electrolyser, to be used in LCA studies connected with hydrogen value chain and its technologies. Intended for the use in LCA studies of downstream products and PEF studies, where applicable. Time stamp (last saved): 2022-11-02T19:28:21.403+01:00 Data set format(s): ILCD format 1.1 UUID: a61747d7-ed89-441a-b313-26b1cbe691da Dataset version: 02.04.007

	Official approval of data set by producer/operator: No official approval by producer or operator Date of last revision: 2022-11-08T13:05:55.000 Owner of data set: JRC, Unit D3 Copyright?: No License type: Free of charge for some user types or use types
Answer	☐Yes

23 - EF compliance		
Question	Are administrative information (date of last revision, data provider, copyright, etc.) provided?	
Reference	Section 5.2 of the document Guide for EF compliant data sets (Fazio et al., 2020).	
Example	Yes. Similarly to 23 entry-level requirement.	
Answer	☐Yes	☐No

3.3.6.2 Data review

24 - ILCD Entry-level requirement	
Question	Is the signed review report available in the dataset documentation? Signed by a qualified independent reviewer, either internal or external, in line with ISO14044 requirements.
Reference	Please refer to “Review Schemes and Reviewers’ Selection Criteria in the Life Cycle Data Network Framework, and at Global Level”(Fazio, 2016).
Example	Yes
Answer	☐Yes

24 - EF compliance	
Question	Is the signed review report available in the dataset documentation? Signed by an eligible reviewer according to “EF-compliant Data Sets”.

Reference	Please refer to Fazio et al. 2020 - Section 8 "Reviewer requirements for Environmental Footprint process data sets and review report template"(Fazio et al., 2020).	
Example	Yes	
Answer	☐Yes	☐No

3.3.6.3 Documentation

25 - ILCD Entry-level requirement	
Question	Is documentation of the dataset in line with the ILCD Compliance Rules and Entry level requirements?
Reference	Please refer to the document "ILCD: Compliance rules and entry-level requirements" (JRC & European Commission, 2012).
Example	Yes – all the files are provided in .ZIP compressed folder and .XML files.
Answer	☐Yes

25 - EF compliance		
Question	Is documentation of the dataset in line with the Guide to EF-compliant datasets (Fazio et al, 2020)?	
Example	Yes – all the files are provided in .ZIP compressed folder and .XML files.	
Answer	☐Yes	☐No

3.3.6.4 Data quality (for datasets)

26 - ILCD Entry-level requirement	
Question	Are data quality ratings (following ISO quality criteria (ISO, 2006a, 2006b)) provided within the metadata of the dataset? Are they justified?
Reference	Section 4 of the document "ILCD: Compliance rules and entry-level requirements".
Example	Geographical reference: EU28

	The data set covers primary data for the gypsum and plasterboard production of the three most important production countries Germany, Spain and United Kingdom, covering more than 50% of the EU28 plasterboard production capacity. For the supply of the gypsum (hemihydrate), used for the plasterboard production, the average out of the situation in Germany, Spain and UK was used. For the plasterboard process, the energy supply was modelled according to the production capacity for plasterboards in Europe. Quality level: Good **...** [similarly for other ISO quality criteria].
Answer	☐Yes

26 - EF compliance		
Question	Are the following requirements respected? - calculate and document data quality ratings for the four criteria defined by Guide to EF-compliant datasets (Fazio et al, 2020) - all the four criteria have adequate data quality ratings (not higher than 3.0) as defined by Guide to EF-compliant datasets (Fazio et al, 2020) - Calculate the overall data quality rating.	
Reference	Section 5.2.17 of the document Guide for EF compliant data sets.	
Example	Technological representativeness: 2 = very good Technology aspects are very similar to what described in the title and metadata with need for limited improvements. For example: use of generic technologies' data instead of modelling all the single plants ….. [similarly for the other three quality criteria]. The overall rating calculated according to the EF method is 1.8 = "very good quality".	
Answer	☐Yes	☐No

3.4 Life Cycle Impact Assessment

3.4.1 Impact assessment method

27 - Basic requirement	
Question	Is the impact assessment method applied as specified in the scope of the study? Are the results without applying normalisation and weighting reported in the documentation of this study?
Reference	Section 5 of the SH2e Guidelines.
Example	The EF 3.1 method is used for impact assessment. Category: Ozone depletion Indicator: Ozone Depletion Potential (ODP) Unit: kg CFC-11 eq/functional unit Value: 6.77E-8 [similarly for every impact category]
Answer	☐Yes

27 - EF-oriented provision	
Question	Is the EF impact assessment method applied as specified in the scope of the study? Are the results reported as characterised? Are results reported as normalised? Are the results reported as normalised and weighted for each EF impact category and as a single overall score?
Reference	Section 5 of the European Commission Recommendation 2021/2279 (Annex I and III).

Example	Category: Ozone depletion Indicator: Ozone Depletion Potential (ODP) Unit: kg CFC-11 eq/functional unit Value: 6.77E-8 Normalised results (unitless): 1.295 E-6 Weighed (unitless): 8.17E-8 [similarly for every impact category] …………………………… The total single score impact is 3.91E-5 points/functional unit.	
Answer	☐Yes	☐No

3.4.2 Characterisation model, weighting and normalization

28 - Basic requirement	
Question	1)Characterisation: Is the amount of each elementary flow of the LC inventory multiplied by its corresponding characterisation factor (when available)? 2)Normalisation and weighting: No mandatory requirement
Reference	Section 4.4.2.4 of ISO 14044(ISO, 2006b) and section 8.2 of the ILCD Handbook(Joint Research Centre & European Commission, 2010).
Example	Output elementary flow: 2.3E-7 kg of benzene (in the class Emissions to water/Emissions to fresh water) Characterisation factor of benzene (Emissions to water/Emissions to fresh water) in the category Ecotoxicity, freshwater (according to the EF3.1 characterisation model): 1.97E-7 CTUe/kg Impact in the category Ecotoxicity freshwater: 2.3E-7 * 1.97E-7 = 4.67E-14 [similarly for each elementary flow and each impact category]
Answer	☐Yes

28 - EF-oriented provision	
Question	1)Characterization: What characterization factors were used for the main greenhouse gases? 2)Normalisation and weighting: Are normalisation and weighting factors from the EF method used to normalise the results?
Reference	The EF normalisation factors to be used are available at http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml (latest release of the EF reference package).
Example	1)Characterisation EF impact assessment method GWP based on 100 from IPPC (2013) is used, with the following main characterization factors: 36.8 kg CO2e/kg for fossil methane, 34 kg CO2e/kg for biogenic methane, and 298 kg CO2e/kg for nitrous oxide.

	2) Normalisation and weighing Impact category: Acidification Unit: mol H+ eq./person Normalisation factor: 5.56E+01 Weighing factor: 6.2 % Reference: Sala S, Cerutti AK, Pant R. (2018). [similarly for every impact category]	
Answer	☐Yes	☐No

3.5 Interpretation of the LCA and reporting

3.5.1 Hotspot analysis per impact categories (LC stages, processes, flows)

29 - Basic requirement	
Question	Is a contribution analysis provided (showing the contribution of each process to the total impact of each category)? Which are the most relevant impact life cycle stages, processes, wastes and flows? The most relevant life cycle stages, processes, wastes and flows of the LCA shall be identified.
Reference	Section 9 of the ILCD Handbook - General guide for Life Cycle Assessment.
Example	Contribution analysis to climate change in table. [similarly for every impact category]

Process	Required amount	Result [Kg CO2 Equivalents]	Contribution
Water Electrolyser, production mix - EU+EFTA+UK (TOTAL)	9.84874E-7 Item(s)	0.34122	100.00%
Electricity grid mix 1kV-60kV, consumption mix, to consumer, technology mix, 1kV - 60kV - EU+EFTA+UK	1.31007 MJ	0.15244	44.67%
Balance_of_Plant - EU+EFTA+UK	4.02901E-6 Item(s)	0.11068	32.44%
Anode, for water electrolyser - EU+EFTA+UK	4.00410E-5 m2	0.03362	9.85%
Platinum, production mix, at plant, primary production, 21.45 g/cm3 , 195.08 g/mol - GLO	1.05668E-6 kg	0.03229	9.46%
Titanium, production mix, at plant, technology mix, 4.50 g/cm3, 47.87 g/mol - GLO	0.00051 kg	0.00752	2.20%
Proton exchange membrane, for water electrolysis - EU+EFTA+UK	5.20532E-5 m2	0.00283	0.83%
stainless_steel_screws	9.84791E-5 kg	0.00067	0.20%
Barge, consumption mix, to consumer, technology mix, diesel driven, cargo, 1500 t payload capacity - EU+EFTA+UK	9.00718 kgkm	0.00029	0.09%
Articulated lorry transport, Euro 4, Total weight >32 t, consumption mix, to consumer, diesel driven, Euro 4, cargo, more than 32t gross weight / 24,7t payload capacity - EU+EFTA+UK	4.33679 kgkm	0.00029	0.08%
Hot rolled coil, production mix, at plant, hot rolling, carbon steel - EU+EFTA+UK	0.00011 kg	0.00027	0.08%
Freight train, average, consumption mix, to consumer, mix of electricity driven and diesel driven, cargo, average train, gross tonne weight 1000t / 726t payload capacity - EU+EFTA+UK	8.00638 kgkm	0.00016	0.05%
Transoceanic ship, containers, consumption mix, to consumer, heavy fuel oil driven, cargo, 27.500 dwt payload capacity, ocean going - GLO	9.14293 kgkm	7.92202E-05	0.02%
Articulated lorry transport, Total weight >32 t, mix Euro 0-5, consumption mix, to consumer, diesel driven, Euro 0 - 5 mix, cargo, more than 32t gross weight / 24,7t payload capacity - ROW w/o EU+EFTA	0.50794 kgkm	3.60938E-05	0.01%
Carbon black, general purposes production, production mix, at plant, technology mix, 100% active substance - EU+EFTA+UK	7.21458E-6 kg	1.88E-05	0.01%

In the system of production of PEM water electrolysers, the most contributing life-cycle stage is the production stage, due to the electricity consumption for manufacturing and assembling the components of the electrolyser system. "Electricity grid mix 1kV-60kV" is the process contributing the most to climate change, with a contribution to the total impact of 44.7%.

The contribution to climate change per elementary flow is reported in the table below. The elementary flow that contributes the most to climate change is emission to air, unspecified of "HFC-23 - EU+EFTA+UK" (0.217 kg CO_{2eq}).

Elementary flow	Required amount [kg]	Result [Kg CO2 Equivalents]	Contribution
Climate change - 2017 (TOTAL)	-	0.34122	100%
HFC-23 - EU+EFTA+UK	1.483E-05	0.216268	63%
CFC-12 - EU+EFTA+UK	3.645E-06	0.045777	13%
HCFC-22 - EU+EFTA+UK	1.653E-05	0.032438	10%
carbon dioxide (fossil) - EU+EFTA+UK	2.229E-02	0.022292	7%
CFC-10 - EU+EFTA+UK	6.787E-06	0.014909	4%
Other	3.947E-03	0.003947	1%

Answer

☐Yes

29 - EF-oriented provision		
Question	Are the most relevant life cycle stages, processes and flows identified according to the EF method (European Commission, 2021)?	
Reference	Section 6 of the European Commission Recommendation 2021/2279 (Annex I and III). A template is available in Annex E "PEF report template".	
Example	For processes: The most relevant processes of the considered system contributing to climate change (total impact of 0.34 kg CO_{2eq}) are : "Electricity grid mix 1kV-60kV" (45%), followed by "Balance of Plant, production mix" (32%), and "Anode for water electrolyser, production mix" (10%). The most relevant processes of the considered system contributing to ozone depletion are… [similarly for every impact category] For life cycle stages: The three life cycle stages "Raw material acquisition and pre-processing", "Production of the main product", "Product distribution and storage" are the ones identified as "most relevant" for climate change as they contribute to more than 80%, of the impact. [similarly for every impact category] For elementary flows: All the elementary flows contributing cumulatively at least to 80% of the impacts of climate change are: "HFC-23 (0.22 kg CO_{2eq}), "CFC-12" (0.05 kgCO_{2eq}) and "HCFC-22" (0.03 kg CO_{2eq}). [similarly for every impact category]	
Answer	☐Yes	☐No

3.5.2 Hotspot analysis based on single score (most relevant impact categories)

30 - Basic requirement	
Question	No mandatory requirement.

30 - EF-oriented provision	
Question	Are the most relevant impact categories identified according to the EF method?

Reference	Section 6 of the European Commission Recommendation 2021/2279 (Annex I and III). A template is available in Annex E "PEF report template".	
Example	For impact categories: Based on the normalised and weighted results, the most relevant impact categories are: climate change (21.5%), water use (18.6%), particulate matter (14.9%), land use (14.3%), and resource use (minerals and metals and fossils) for a cumulative contribution of 84.3% of the total impact.	
Answer	☐Yes	☐No

3.5.3 Interpretation

31 - Basic requirement	
Question	Are results consistent with the defined goal and scope? Do the interpretation of results reach conclusions, explain limitations and provide recommendations? Are results expressed taking into account the uncertainties of input activity data and assumptions (if any)? In the case of systems in which the results are provided both for the total life cycle and total life cycle excluding use stage, please specify.
Reference	Section 5.5 of ISO 14040 (ISO, 2006a).
Example	The analysis shows that: the climate change impact of the PEM water electrolyser is almost entirely caused by activities related to the production of components. In particular, the electricity consumption at the assembling plant and the production of the balance-of-plant are responsible for 77% of the total impacts. The LCIA showed similar results for the other categories addressed. Moreover, the components which contain materials mined and refined in non-EU countries (e.g. platinum, iridium, titanium) carry the higher impacts in most of the assessed categories. Decreasing the demand of such materials from non-EU suppliers could lead to significantly lower impacts. The data quality assessment proves a good level of reliability of both the model and the results. Limitations and gaps for improvement remain regarding the technological representativeness: data used for LCA were obtained from the literature, and commercial production methods may differ. Moreover, proxy datasets were used in the background system to model different aluminium alloys. Due to relevant uncertainties related to the efficiency of the water electrolyser, two scenarios were assumed to assess how results would change by changing the efficiency parameter. Scenario 0 is based on the assumption that no degradation of the cell occurs and the efficiency is 60%. Scenario 1 is based on the assumption that

	the effect of degradation decreases the efficiency of the cell to 55%. The corresponding LCIA results are reported in the table below.

Impact category	Reference unit	Scenario 0	Scenario 1
Climate change	kg CO2 Equivalents	0.341222981	0.37465
Resource use, minerals and metals	kg Sb equivalents	6.16422E-06	8.20E-06
Resource use, fossils	MJ	4.4730316	5.1836
EF-particulate Matter	disease incidence	3.31534E-08	3.37E-08
Acidification	mol H+ equivalents	0.002078387	0.0027594
.....	...	...	...

Answer	☐Yes

31 - EF-oriented provision		
Question	Characterised results of all EF impact categories shall be calculated and reported as absolute values in the PEF report. The sub-categories 'climate change –fossil', 'climate change – biogenic' and 'climate change - land use and land use change', shall be reported separately if they show a contribution of more than 5% each to the total score of climate change); - Normalised and weighted results as absolute values; - Weighted results as single score; - Results shall be reported for (i) the total life cycle, and (ii) the total life cycle excluding the use stage.	
Example	Figure 3. Full template available in Annex E "PEF report template" of the European Commission Recommendation 2021/2279.	
Answer	☐Yes	☐No

Figure 3. Tables for results interpretation.

Item	At what level does relevance need to be identified?	Threshold
Most relevant impact categories	Normalised and weighted results	Impact categories cumulatively contributing at least **80%** of the total environmental impact
Most relevant life cycle stages	For each most relevant impact category	All life cycle stages contributing cumulatively more than **80%** to that impact category
Most relevant processes	For each most relevant impact category	All processes contributing cumulatively (along the entire life cycle) more than **80%** to that impact category, considering absolute values.
Most relevant elementary flows	For each most relevant process	All elementary flows contributing cumulatively at least to 80% to the total impact for each most relevant processes. If disaggregated data are available: for each most relevant process, all direct elementary flows contributing cumulatively at least to **80%** to that impact category (caused by the direct elementary flows only)

Example:

Most relevant impact category	**[%]**	**Most relevant life cycle stages**	**[%]**	**Most relevant processes**	**[%]**	**Most relevant elementary flows**	**[%]**
IC 1		End of life		Process 1		el. flow 1	
						el. flow 2	
				Process 2		el. flow 2	
		Raw material acquisition and p.p.		Process 4		el. flow 1	
IC 2		Manufacturing		Process 1		el. flow 2	
						el. flow 3	
IC 3		Manufacturing		Process 1		el. flow 2	
						el. flow 3	

Source: Annex E "PEF report template" of the European Commission Recommendation 2021/2279

3.6 Verification and validation

3.6.1 Reviewers and review panel requirements

3.6.1.1 Submission to the reviewer

32 - Basic requirement	
Question	No mandatory requirement.

32 - EF-oriented provision		
Question	Was the study submitted to an eligible verifier according to the EF method (European Commission, 2021)? -is the signed validation statement attached to the report of the PEF study (if this is the case)? - is the verifier's self-declaration of their qualifications available?	
Reference	Section 4.8 of the Commission Recommendation 2021/2279 (Annex I and III).	
Example	Yes, the documentation attesting verifier's competence and experience is attached to the PEF validation/verification report.	
Answer	☐Yes	☐No

3.6.1.2 Review documentation

33 - Basic requirement	
Question	No mandatory requirement.

33 - EF-oriented provision	
Question	Is the verification report available? Either publicly or confidentially. It shall contain Documentation of the verification process and findings, including detailed comments from the verifier(s) and corresponding responses. It shall carry the signature of the verifier or in case of a verification panel, of the lead verifier
Example	Yes (mandatory)

Answer	☐Yes	☐No

4 Conclusions

Conducting LCA studies and producing deliverable documents of good quality are essential steps to assess the potential environmental achievements of research projects of the Clean Hydrogen JU. However, reviews performed by JRC revealed the need of increasing the quality of such studies and deliverables. The main issue was the scarce adherence of the projects to LCA guidelines, such as the HyGuide document for LCAs of fuel cell and hydrogen technologies.

To overcome these issues, an easy-to-follow checklist was developed in this document. The document is intended for the LCA practitioners of the Clean Hydrogen JU projects, but can also be used by any other entity/ practitioner performing LCA on FCH technologies. The checklist covers all aspects required in LCA standards, providing examples related to hydrogen technologies. It is recommended for users to go through all the 33 requirements reported in this document, divided by the main phases of an LCA (goal and scope definition, inventory analysis, impact assessment, interpretation and verification of results).

The requirements are differentiated into two levels: *basic level requirements*, which shall be intended as mandatory to achieve a basic, but complete LCA, and the *EF requirements*, to be fulfilled for improving the quality, reliability and documentation of the study.

Next to the basic requirements, the inclusion of EF methodological requirements can readily support the practitioners in producing studies oriented towards the Product Environmental Footprint (PEF) or Organisation Environmental Footprint (OEF) methods. Additionally, it will enhance the production of EF compliant datasets and the population of the Life Cycle Data Network with high-quality data.

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List of abbreviations and definitions

B2B	business to business
CF	characterization factor
CFCs	Chlorofluorocarbons
CFF	Circular Footprint Formula
DNM	Data Needs Matrix
DQR	Data Quality Rating
EC	European Commission
EF	Environmental Footprint
EI	environmental impact
EoL	End of life
FCH	Fuel cell and hydrogen
FU	functional unit
GHG	greenhouse gas
GWP	global warming potential
ILCD	International Reference Life Cycle Data System
ILCD-EL	International Reference Life Cycle Data System – Entry Level
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organisation for Standardisation
JRC	Joint Research Centre
JU	Joint Undertaking
LC	Life Cycle
LCA	Life Cycle Assessment
LCDN	Life Cycle Data Network
LCI	life cycle inventory
LCIA	life cycle impact assessment
LCT	life cycle thinking
NACE	Nomenclature Générale des Activités Economiques dans les Communautés Européennes
OEF	Organisation Environmental Footprint
OEFSCR	Organisation Environmental Footprint Sector Rules
P	precision

PEF	Product Environmental Footprint
PEFCR	Product Environmental Footprint Category Rules
PEF-RP	PEF study of the representative product
RF	reference flow
RM	raw material
RP	representative product
SB	system boundary
TeR	technological representativeness
TiR	time representativeness
UNEP	United Nations Environment Programme
UUID	Universally Unique Identifier
WRI	World Resources Institute

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