Lifecycle analysis mapping

This document presents a summary of deliverable D1.3, the main outcome of the task 1.3 “Lifecycle methods and criteria” and is part of the mapping activity conducted within Work Package 1 (WP1) “Complete overview of Safe and Sustainable by design (SSbD) methods and criteria” of the IRISS project “International ecosystem for accelerating the transition to Safe and Sustainable-by-Design materials, products and processes”.

SSbD is a key component of the European Commission's Chemical Strategy for Sustainability (CSS) and it is a pre-market approach that aims to integrate safety and sustainability as early as possible in the innovation process and throughout the entire product lifecycle. The concept of SSbD aims to ensure that chemical materials and products are designed, produced, and used in a way that does not harm people and does not harm environment.

Life Cycle Assessment (LCA) plays a crucial role in SSbD providing a comprehensive analysis of the environmental impacts associated with a material, product, or process throughout its entire life cycle, covering the assessment of environmental sustainability aspects. LCA provides a scientific basis for decision-making in SSbD in terms of environmental performance. By comparing the environmental impacts of different supply chain configurations, materials, or technologies during the design phase, LCA enables the selection of the most sustainable options, reduction of environmental impacts, and the contribution to a greener future.

A literature review was carried out to elaborate the mapping. Literature sources were public documents (policy documents and papers), public reports, and scientific publications in open databases. The literature review covered the 3 main pillars of sustainability (environmental, social, and techno-economical dimensions). The detailed methodology used for the literature review is described in deliverable “D1.2- Sustainable by design methods and criteria mapping”. This deliverable D1.3 is focused on the **Life cycle environmental assessment dimension.** Within the report, the **standards, methodologies, and tools** (databases, software impact assessment methods, and environmental indicators) have been analysed. This information has been complemented with the results obtained from the **survey** launched within the IRISS network and the identified stakeholders, as well as with the analysis of the relevant identified **SSbD related EU projects.** The survey was online between October 2022 and March 2023 and received a total of 87 valid responses, including 37 responses from companies. The project coordinators from the ongoing relevant identified SSbD related EU projects were contacted, and finally information from seventeen projects was collected.

The work started with a mapping of the main standards and methodologies related to LCA. ISO 10040 and ISO 14044 are the two main standards that are widely accepted and serve as a basis for LCA studies globally. In addition, there are several regional and sector specific LCA guidelines and standards. LCA practitioners should be aware of any additional guidelines or standards specific to their industry or region to ensure compliance and accuracy in their assessments. For a small and medium-sized enterprise (SME), selecting the suitable LCA standard and guideline for a specific product can be a challenging task. Some standards may require extensive data collection, analysis, or modelling, which can be not affordable for SMEs, typically with limited resources. The roadmaps that will be developed within WP3 of IRISS projects should address this issue and propose a LCA methodology that strikes a balance between scientific rigor and practicality for the SMEs.

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One widely used application where the LCA methodology is required is the **Environmental Product Declaration** (**EPD).** The EPDs, also called type III environmental declaration that is compliant with the ISO 14025, are used by companies to demonstrate and communicate the environmental quality of their products and services. The Life Cycle Assessment, forming the basis of the EPDs, must be conducted in accordance with specific **Product Category Rules (PCR**). The EPD is a mature method and comprises a significant number of PCR for different sectors, with **construction** having the highest number of PCRs, followed by the food & beverages sector. However, in other sectors, the number of existing PCRs is very limited or non-existent. This can be attributed to factors such as industry focus, complexity, resource constraints, emerging or niche status, and regional variations. Over time, as sustainability practices become more widespread and industry demand increases, efforts can be made to develop PCRs in these sectors to enhance transparency and facilitate environmental assessments.

The International EPD System proposes to use a list of the default environmental impact and inventory indicators, however requirements or recommendations in a PCR may deviate from the default list. The most recently environmental indicators proposed by the International EPD system are based on **EF (Environmental Footprint)** impact assessment methodology.

Recently, the European Commission has created the **Product Environmental Footprint (PEF)** methodology, which is a LCA based method to measure and communicate the potential life cycle environmental impact of products (goods or services) and organizations, respectively.

The PEF program intends to improve comparability of the environmental performance of a product based on a strictly defined Life Cycle Assessment method that is based on **Product Environmental Footprint Category Rules (PEFCR).** This program is under development and during the pilot phase, twenty-one PEFCRs/OEFSRs have been generated; however, the number of PEFCRs is still very limited. Despite the low number of PEFCRs, efforts are being made to increase their development, particularly in sectors of high environmental significance or where demand for environmental performance information is growing. In the EF all the life cycle stages are mandatory (raw material acquisition and pre-processing, manufacturing, distribution, use stage, end of life); however, for certain products (i.e., intermediate), a cradle to gate assessment can be performed. The EF impact assessment methodology comprises 16 impact category indicators**.**

To ensure comparability of LCA studies that are used in the **SSbD context**, specific guidelines should be developed but in the meanwhile the **SSbD framework** developed by the Joint Research Centre (JRC) [1] **recommends using the PEF method,** which is the European Commission recommended method to assess life cycle environmental performance of products on the market.[2]

There are several tools that can assist in performing a LCA study, including databases, software, impact assessment methodologies, and environmental indicators. LCA databases contain extensive data on the life cycle inventory (LCI) of various materials, products, and processes. Impact assessment methodologies help to quantify environmental impacts, translating LCI data into environmental indicators that measure impacts across different categories, such as climate change, resource depletion, and human health. Specialized LCA software integrates databases,

[1] (Caldeira, 2022) Caldeira, Farcal R, Moretti C, Mancini L, Rauscher H, Rasmussen K, et al. Safe and Sustainable chemicals by design chemicals and materials, Review of safety and sustainability dimensions, aspects, methods, indicators, and tools. 2022. https://doi.org/10.2760/68587.

[2] European Commision recommendations of 16-12-2021 on the use of Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organizations, COM (2021)9332

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environmental indicators, and calculation engines, facilitating modeling, analysis, and interpretation of LCA studies.

Database: Availability of data (of good quality) is one key aspect for Life Cycle modelling. There are different initiatives working in this direction aiming to achieve a wide usage of LCA through better accessibility and interoperability of LCA data. Among them the **GLAD (Global LCA Data Access network)** and **open LCA NEXUS** initiatives can be highlighted.

The most widely used database according to the bibliographical search (Figure 1), the survey and the EU project analysis is **Ecoinvent**, which is the one, with the highest number of datasets. According to the database mapping analysis, the available information along the life cycle indicates that the product conception step (extraction of raw materials, energy, processing, and transport) has more information than the other steps (use and end of life). Analysing the distribution of information by sectors, the textile, electronics, and battery sectors have the lowest LCA data information volume, while the automotive, chemical products and agriculture sectors have the most.

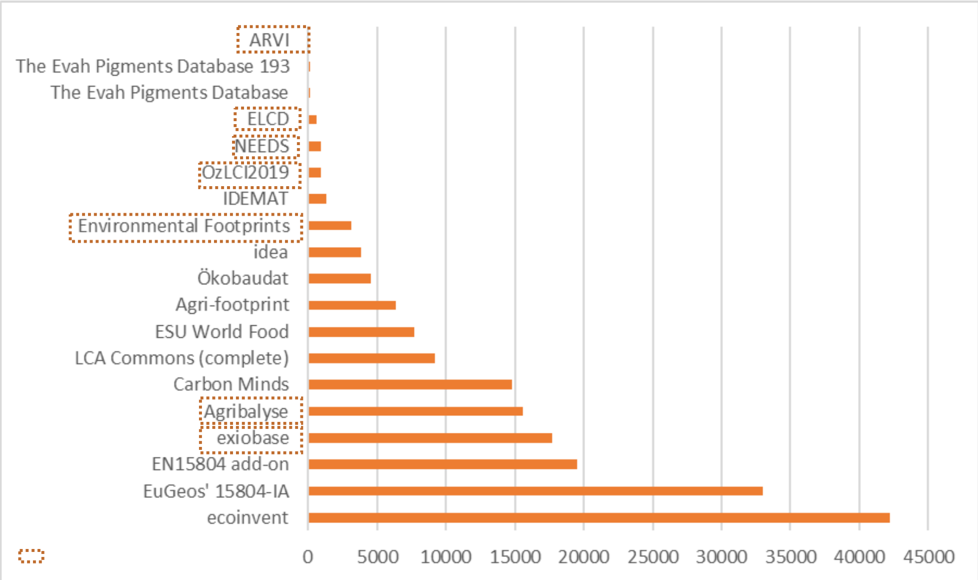
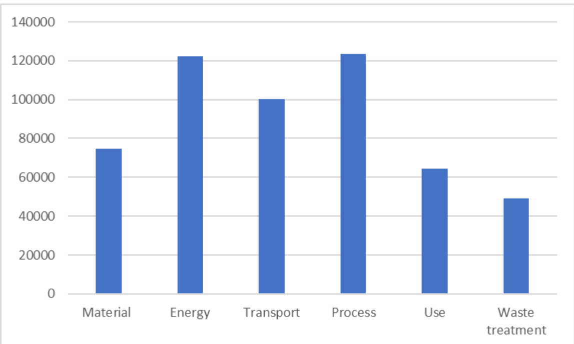
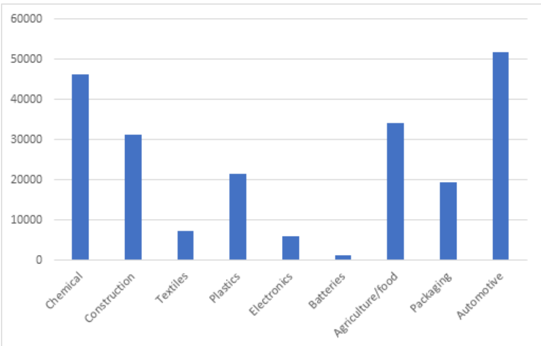


Figure 1-Number of datasets for each database



(a)



(b)

Figure 2- Number of datasets (a) for the different process families involved during lifecycle, (b) per sector

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Software: Currently, a variety of LCA softwares can be found in the market, encompassing both commercial options that require purchase and freely available alternatives (e.g., OpenLCA). The most widely used software according to the literature review, survey and EU projects analysis is **SimaPro,** followed by GaBi and OpenLCA.

Impact Assessment method and environmental indicators: According to the survey results, and the methodologies proposed by on-going Horizon Europe projects, the most used impact assessment methodology is the **EF**. This is in line with the methodology proposed by the JRC SSbD framework. The EF methodology comprises 16 environmental impact assessment indicators, which are also covered by the **ReCiPe** methodology (the second most used impact assessment method in the survey analysis and the most popular in the bibliographical review), but each methodology has its particularities.

LCA stages and circular economy: LCA assesses the environmental impacts of goods and processes from **"cradle to grave"** quantitatively, which covers raw material extraction (also called the "cradle"), processing, transportation, use and end of life ("grave"). Since "**circular economy**" is increasing international attention, **"cradle-to-cradle"** emerged as the ideal for products' life cycles. It exchanges the end-of-life stage with a recycling process that makes it reusable for another product – essentially closing the loop. This tendency is also observed in the literature review where the terms "Renewable", "Recovery" and "Reusability" are gaining attention, together with "Durability". In the PEF method, one crucial aspect in LCA studies is to accurately and consistently model waste and recycled materials, and the **Circular Footprint Formula** (CFF) has been developed for this purpose.

However, in practice, according to the survey results (Figure 2) [3] and the EU projects analysis, the LCA studies continue focusing mainly on production, but not all studies consider the end-of-life.

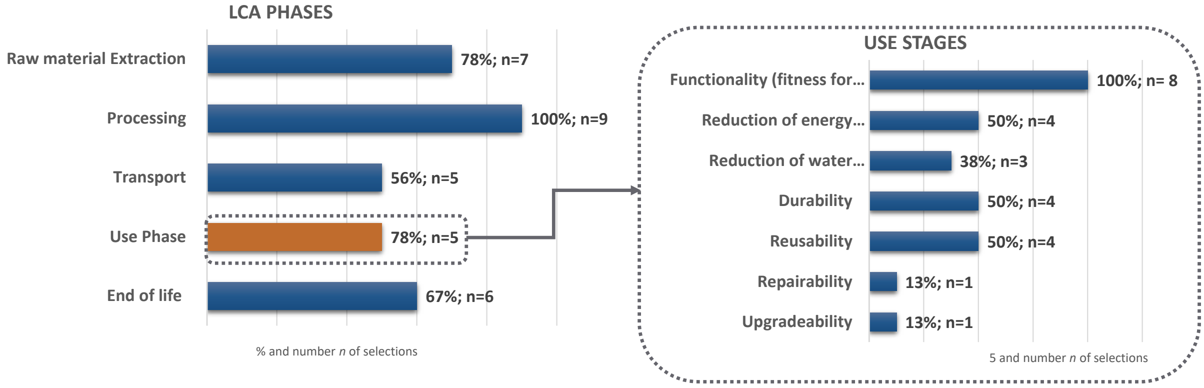

Figure 3- Survey results, number of respondents considering LCA phases and use stages

Just some of survey respondents consider the use stage (the inclusion of use stage is higher within EU projects). The most important aspects considered during use stage are the **functionality and the reduction of energy consumption.** This is in line with the work that analyses the application of

[3] The survey may be not representative for Europe as just a few percent of the companies and stakeholder contacted, answered the questionnaire. These stakeholders, already showed an interest in SSbD. Nevertheless, the survey gives us a unique view on the many aspects and facets of SSbD, within this slightly positively biased group of interested participants.

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JRC SSbD framework to case studies [4], where one key aspect identified was the need to include sector specific performance assessment (e.g., surface conductivity, durability) in the assessment methodology. High performance has a positive impact on the overall sustainability. The durability and repairability are considered approximately by half of the respondents in both the survey and EU projects analysis, but this value is considerably reduced for repairability and upgradability.

Conducting a LCA within the SSbD context poses specific challenges, particularly concerning the low TRL of the technologies involved. When a technology is in an early stage of development with limited maturity, conducting a robust LCA becomes a difficult task due to the high degree of uncertainty regarding specifications at the industrial scale, and the absence of comprehensive large-scale process data. To fill this gap, ex-ante LCA has evolved in recent years, aiming to assess emerging technologies at an early stage of development by exploring, among others, possible scenarios of their future industrial scale implementation. The key principle of ex-ante LCA is to identify and analyse the potential environmental impacts of different design choices and alternatives before they are implemented. Data derived from process simulations and produced from lab or bench scale apparatuses are used to perform ex-ante LCA studies of emerging technologies. However, when using small scales, uncertainty is added and can result in large differences in process efficiencies and operating conditions.

In summary, environmental LCA is vital in SSbD as it helps to identify environmental hotspots, quantify impacts, support decision-making during the design phase, and enhance transparency and accountability. By integrating LCA into the design and management of supply chains, companies can make more sustainable choices, reduce environmental impacts, and contribute to a greener future. However, there are still several methodological challenges that need to be addressed and will be further analysed within IRISS WP2-"gap analysis".

Disclaimer

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Our partners:

[4] Caldeira, C., Garmendia Aguirre, I., Tosches, D., Farcal, R., Mancini, L., Lipsa, D., Rasmussen, K., Rauscher, H., Riego Sintes, J., Sala, S, (2023) Safe and Sustainable by Design chemicals and materials. Application of the SSbD framework to case studies. JRC technical report for consultation. JRC131878

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