# Sustainable by design methods and criteria mapping

This document includes a summary of the results from the activities conducted in task 1.2 "Sustainable by design (SusbD) methods and criteria" of the Work Package (WP) 1 of the IRISS Project "International ecosystem for accelerating the transition to Safe and Sustainable-by-Design materials, products and processes". It aims to explore the methods applied in industry, in previous EU or national projects, as well as in scientific literature, to include sustainability criteria, at the design phase of the material processes and products development.

The methodology applied to identify SusbD methods and criteria consisted to a thorough **literature review**. This review was focused on updating the work previously performed by Caldeira et al, 2022[1]. A new extended Scopus research was conducted and in total 55 documents, covering the three sustainability dimensions (environmental, social and economic), were identified and analysed. Additionally, a **survey** was conducted to understand the status of SSbD application and competencies in both academia and industries. The survey was conducted online between October 2022 and March 2023 and received a total of 87 valid responses, including 37 responses from companies. The background of the responding organizations is shown in (Figure 2 ). Organizations from 19 countries responded to the survey, working in a wide range of sectors with the chemical sector being the most represented (43%).

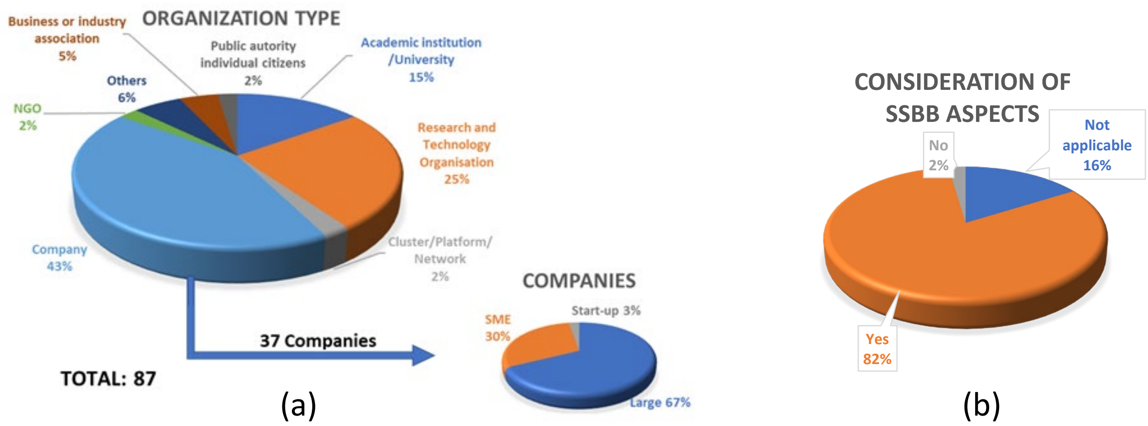


*Figure 1-Background of the survey respondents by organization type*

Out the total respondents, 82% (n=71) consider SSbD aspects in the development of chemicals, materials, products, or processes. This percentage is even higher for the companies (92%). However, survey results might be biased and not represent the real (industry) situation as just a few percentages of the companies and stakeholders contacted fulfilled the survey, who, therefore, 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.

Furthermore, project coordinators from other ongoing relevant identified **SSbD related EU projects** were contacted and asked to complete project sheets to collect further information. In total, information from seventeen projects were collected.

**Comparison of the most relevant SSbD frameworks.** Five main published SSbD frameworks on how to

[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.

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operationalise SSbD have been identified and analysed, a) the frameworks proposed by the EC Joint Research Centre (JRC)[2], b) the European Environment Agency (EEA) [3], c) the Organization for Economic Co-operation and Development (OECD)[4], Working Party on Manufactured Nanomaterials (WPMN) under a policy and regulatory perspective, and d) the frameworks published from an industrial perspective by the Safe and Sustainable Innovation Approach (SSIA) Steering Group, of the European Chemical Industry Council (Cefic)[5] and e) the International Chemical Secretariat (ChemSec) [6]. The JRC framework is the most comprehensive and detailed one (e.g., in recommended dimensions, parameters and tools), while the other approaches can be seen more as conceptual ones. Safety and environmental sustainability dimensions are covered in all regarded SSbD approaches, while all three sustainability pillars (environmental, social, and economic) are only covered by JRC, OECD and Cefic. The social and economic aspects show a low level of implementation and methodological maturity. There is a need for a harmonised and practical SSbD framework with clear procedures and incentives to support the industrial sector, especially SMEs.

**Environmental dimension:** This sustainability pillar has been analysed in detail in Deliverable D1.3, so in this document just a brief summary of the literature review findings is included. According to bibliographical analysis, **Ecoinvent** is the most used database in LCA studies. Within software tools, **SimaPro** is the most frequent database with twice the number of results obtained in comparison to **Gabi**. **OpenLCA** is also often used. The most popular **Lifecycle environmental impact** assessment methods are **ReCiPE** and **CML. ECOTOX** and **PEF** are also used in some studies. This is consistent with the review performed by Caldeira, et al. where the most cited models for addressing the indicators they considered, were Recipe 2016, USEtox and CML (from largest to smallest use). They also showed that the **PEF** method is gaining attention for sustainability metrics.

Social dimension (S-LCA). The main guidelines for S-LCA have been analysed, namely the UNEP (United Nations Environment Program), 2020 Guidelines for Social Life Cycle Assessment of Products and Organizations[7] and the current Handbook for Product Social Impact Assessment (**PSIA**) [8]. The number of studies considering **social dimensions** has increased considerably in the last few years, but continue being **much lower** than those considering environmental and economic aspects (Figure 1). According to the survey results, the **62%** (n=54), of the responding organizations (n=87) perform or intend to perform a Social Life Cycle Assessment (S-LCA) during the design or development phase of a material, product, process (Figure 2). If we focus on companies, this value is higher 76% (n=28), and this may be due to the sustainability consciousness of the companies that responded the survey.

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2 (JRC, 2022) Caldeira, C., Farcal, R., Garmendia Aguirre, I., Mancini, L., Tosches, D., Amelio, A., Rasmussen, K., Rauscher, H., Riego Sintes, J. and Sala, S., Safe and sustainable by design chemicals and materials - Framework for the definition of criteria and evaluation procedure for chemicals and materials, EUR 31100 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-53280-4, DOI 10.2760/487955 (online)

3 (EEA, 2021). European Environment Agency, Designing safe and sustainable products requires a new approach for chemicals, Publications Office, 2021, https://data.europa.eu/doi/10.2800/48128

4 (OECD, 2022). Sustainability and Safe and Sustainable by Design: Working Descriptions for the Safer Innovation Approach. Series on the Safety of Manufactured Nanomaterials No. 105; https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV-CBC-MONO(2022)30%20&doclanguage=en

5 (Cefic, 2022). *Safe and Sustainable-By-Design: A Transformative Power*. April 2022. https://cefic.org/app/uploads/2022/04/Safe-and-Sustainable-by-Design-Guidance-A-transformative-power.pdf

6 (CSS, 2020). Chemical Strategy for Sustainability, Towards a toxic-free environment. EC COM, 67 (https://ec.europa.eu/environment/pdf/chemicals/2020/10/Strategy.pdf)

7 UNEP, 2020. Guidelines for Social Life Cycle Assessment of Products and Organizations 2020. Benoît Norris, C., Traverso, M., Neugebauer, S., Ekener, E., Schaubroeck, T., Russo Garrido, S., Berger, M., Valdivia, S., Lehmann, A., Finkbeiner, M., Arcese, G. (eds.). United Nations Environment Programme (UNEP). Available at: https://www.lifecycleinitiative.org/library/?filter_data-and-methods=social-lca

8 Goedkoop, M.J.; de Beer, I.M; Harmens, R.; Peter Saling; Dave Morris; Alexandra Florea; Anne Laure Hettinger; Diana Indrane; Diana Visser; Ana Morao; Elizabeth Musoke-Flores; Carmen Alvarado; Ipshita Rawat; Urs Schenker; Megann Head; Massimo Collotta; Thomas Andro; Jean-François Viot; Alain Whatelet; Product Social Impact Assessment Handbook - 2020, Amersfoort, October 1st, 2020. Available at: https://www.social-value-initiative.org/handbook/

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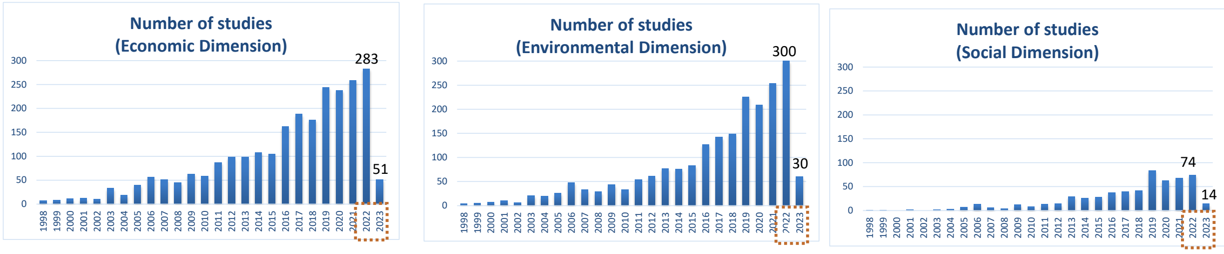


*Figure 2- Number of studies published within the last 26 years considering the different sustainability pillars [9]*

The mentioned guidelines proposed several social impact assessment indicators. Among them the workers´ "**Health and safety" is the most popular** social indicator according to the survey results (Figure 2), EU project analysis and literature review. So, considerations about Occupational health & safety and Customer protection aspects are taken into consideration. Harmonization between the current approaches, such as the UNEP and the Social Value initiatives, would be required to select the impact categories.

The analysed EU projects consider social aspects in different ways, but there is a lack of a common methodology. For instance, some address social issues related to the **origin of the raw material,** while others are focused on the adaptation of production and consumption **to avoid threats to human health and environment.**

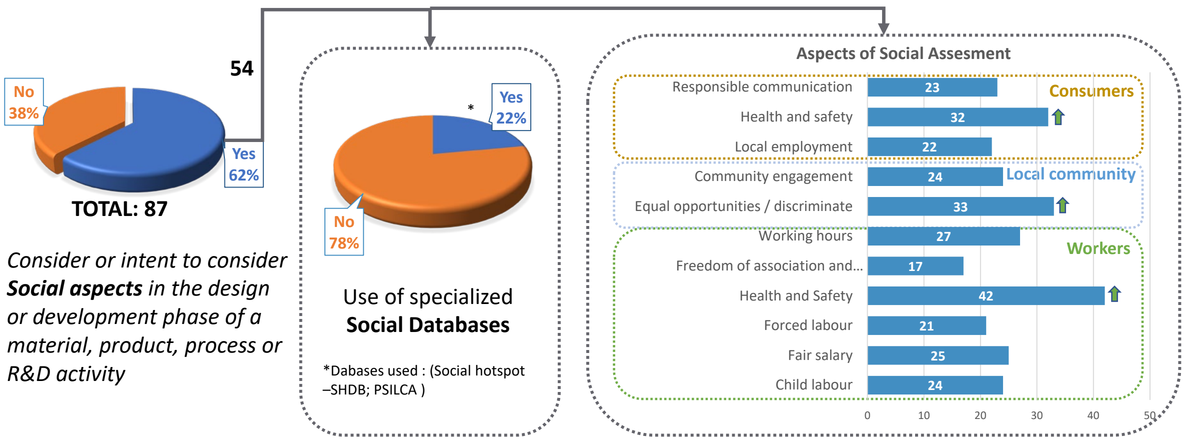


*Figure 3-Squeme of the survey results (social dimension)*

Concerning the databases, two main databases are frequently used by S-LCA practitioners: Social Hotspots Database (SHDB) and Product Social Impact Life Cycle Assessment database (**PSILCA).** However, according to the survey results, just some entities use these specialized databases when performing S-LCA studies. Among the 55 studies analysed, three of them utilized the PSILCA database, while four used the SHDB database.

**Economic dimension (LCC)**. In life cycle sustainability assessment, the economic pillar is usually addressed through the Life Cycle Costing (LCC) methodology. Three different types of life cycle cost analysis need to be considered: conventional LCC (cLCC), environmental LCC (eLCC) and social LCC (sLCC).

[9] Search terms detailed in D1.2 annex I

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The traditional LCC, assessing internal cost is part of the usual business administration. Similar to cLCC, eLCC can be used to detect cost drivers and potential for improvement opportunities throughout the life cycle of a product. However, eLCC's scope is larger, as it includes also (monetized) environmental externalities projected to be internalized. These might include e.g., future waste management costs, emission controls or environmental taxes and/or subsidies. In addition, eLCC usually takes a more future-oriented approach (i.e., during the design phase) compared to the more retrospective cLCC conducted for existing products.

Life cycle cost is by far the predominant term reported in the studies, but several studies consider environmental externalities (eLCC), as an additional cost. However only isolated studies include the sLCC.

It will be critical to establish how **economic metrics** should complement **the social and environmental results.** To do so, a first step consists in defining the economic indicators of interest to policymakers and then, ensuring that these do not overlap with metrics provided in LCA or S-LCA when calculating aggregated scores. While single scores can facilitate a decision-making process to prioritize choices, they come with some limitations in terms of transparency and interpretation (by experts).

**Modelling and characterization tools**. In this section special attention has been paid to engineering tools for model-based product design and manufacture (i.e. high-TRL). A small number of software developers provide such tools for sustainable engineering design and manufacture of products. Sustainable engineering tools work in correlation with sustainability assessment with the aim of designing products that do not only satisfy technical requirements, but also environmental ones. Existing tools mainly focus on material and process selection for sustainability but there is a lack of dedicated engineering tools for holistic end-of-life concepts and circular economy aspects.

- The use **of CAE, simulation,** and predictive tools for "materials selection and product design for the CE" is limited to a small percentage of "piloting" enterprises and academic institutions. While the tools for material and process selection in the product design cycle are principally available (for sustainability by design), there is a lack of engineering tools considering holistic approaches to circular economy and End-of-life concepts, such as design for durability, design for re-use or repair, etc. As a positive trend, it is possible to highlight that Academia, R&D&I Institutions, and industry have developed handbooks, guidelines, best practices, and reports on success and failures. These documents ought to be collected and distributed or made available within the SSbD product design ecosystem. In conclusion, IRISS could assume a role in the driver seat in the sub-topic of product design.

- **Tribology**. High performance has a positive impact on overall sustainability. Tribology is a tool that helps in the design of sustainable materials, products and processes ensuring the functionality of a material/product for the selected application(s), controlling the friction, and consequently increasing the energy efficiency during processing and use and taking also into account the wear resistance, durability and repairability. Frequently, lab-scale tests are conducted in accelerated mode and small-scale which could have the risk of overlooking time or scale effects. To overcome these limitations, it is necessary to reproduce the failure mechanism at the laboratory, and to combine experiments with computer-based simulations to properly link "field to lab" and "lab to field". Tribologists should combine the resources of experimental, simulation, and LCA towards the growth and implementation of sustainable tribology not only for research purposes, but also from commercial applications point of view.

**Challenges and Opportunities**

The Safe-and-Sustainable-by-Design (SSbD) concept is a central component of the EC Chemical Strategy for Sustainability, but there is still a need for a common understanding and practical implementation.

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Safety-related design principles are widely applied in the design phase, while the sustainability-related design principles exhibit marginally lower application rates. The social and economic aspects show a low level of implementation and methodological maturity.

The survey of actual SSbD relevance, practice, and application has identified several barriers and shortcomings on the road to broad and comprehensive future for Safe and Sustainable Designs. Despite some SSbD tools and software solutions for sustainability assessment (including LCA) during the product design stage are available; widespread application is not yet established, and design for "end-of-life" and CE (circular Economy)-oriented design are still underdeveloped. There is a need for engineering tools to support "design for end-of-life" and circular economy principle. Modelling and characterization tools, including CAE, simulation, and tribology, are identified as important for the design of sustainable materials, products, and processes.

Future IRISS workshops will hopefully improve the situation. The question of access to materials and process data needs to be addressed, especially for advanced materials. Through the IRISS consortium, PARC[10], the JRC[11], AMI2030[12] and the future IM4EU Partnership[13], with the involvement of SSbD EU Financed project stakeholders, progress can be achieved. Engineers need more SSbD skills, and development teams need eco-design capacities. IRISS can support training and education in this field.

## Disclaimer

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**Our partners:**

10 Partnership for the Assessment of Risks from Chemicals | Parc (eu-parc.eu)

11 Materials 2030 Initiative | (ami2030.eu)

12 Safe and sustainable by design (europa.eu)

13 21 Sep 2023: AMI2030 contribution to the SRIA of the IM4EU partnership on advanced materials – Kick-Off | Materials 2030 Initiative

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