The international ecosystem for accelerating the transition to Safe-and-Sustainable-by-design materials, products and processes.

Gap analysis for SSbD criteria from all value chains

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Table of Contents

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Abbreviations and Acronyms

Abbreviation	Definition
Cefic	The European Chemical Industry Council
CSS	Chemical Strategy for Sustainability
D	Deliverable
EC	European Commission
ED	Endocrine Disruption
EPD	Environmental Product Declarations
EVOH	Ethylene and Vinyl Alcohol copolymer
GHG	Greenhouse Gas
JRC	Joint Research Centre
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
M	Project Month
MNL	MultiNanoLayered
MSDS	Material Safety Data Sheet
NAM	New Approach Methodologies
PA	Polyamide
PBT	Polybutylene terephthalate
PCF	Product Carbon Footprint
PCR	Product Categories Rules
PE	Polyethylene
PEF	Product Environmental Footprint

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PEG	Polyethylene glycol
PFAS	Per- and Polyfluorinated Alkyl Substances
PMT	Persistent, Mobile, and Toxic
PP	Polypropylene
PPE	Personal Protective Equipment
PS	Polystyrene
PSA	Portfolio Sustainability Assessments
PU	Polyurethane
R&D	Research and Development
R&I	Research and Innovation
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
SbD	Safe-by-Design
SME	Small and medium-sized enterprise
SSbD	Safe and Sustainable by Design
SusbD	Sustainable-by-Design
T	Task
TRL	Technology Readiness Level
VC	Value chain
WP	Work Package

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1 Executive summary

In this report we endeavoured to set up mapping gaps in the Safe and Sustainable-by-Design (SSbD) criteria by building on the findings of Work Package 2 (WP2) and the work done in WP4, notably the case-studies prepared by the value chains. Each value chain completed a detailed gap analysis using a template prepared by CLEPA which made use of the list of gaps prepared in Deliverable (D)2.1. The gap analysis results for each value chain are shared in the Annex in detail and summarized in Chapter 5.

The gap analysis results show that for the safety dimension steps, many of the criteria were not considered for several case studies. The identified gaps were "Lack of harmonized and easy to apply tools and protocols", "Unavailability of open databases with rich datasets ", "Uncertainty of the safety impacts at early stage of the development", "Lack of risk assessment considering also exposure of material quantities at early stage of the design phase" and "Limited number of internal experts". The assessment was deemed not to be applicable for complex products made with multiple materials and chemicals instead of a single chemical substance or material. At least a few Hazard classes were not applicable in some case-studies for instance as they apply to some of the process chemicals, not the material itself.

The evaluation of intrinsic hazard properties requires deep knowledge on both the materials' or products' composition and toxicity as well as full access to hazard data for all used ingredients. Toxicity studies are as a rule not available to the industry players buying and using ingredient for their production. The completion of Step 1 for the ingredients that are not REACH registered or registered in a lower tonnage band or for substances without a harmonised classification and labelling, is also more challenging. Another gap is that the full SSbD evaluation can only happen during the final stages of a development process, when specific data are available. Generating hazard data for each substance that is tested in early stages of Research and Development (R&D) and will potentially never be used due to lack of technical performance is not economically feasible. Instead, screening criteria should be used based on structural information. This approach, however, is not useful as an evaluation tool for R&D or redesign: because at that late stage, it is no longer possible to change the design without expensive or time consequences. Step 2 requires a lot of specific information for the production process of the substance in scope. Assumptions regarding working conditions are likely to be made and it was demonstrated that these assumptions have a direct impact on the results.

The proposed recommendations are to increase awareness and education about Material Safety Data Sheets (MSDS) and to provide additional guidance on the tool to be used depending on the data available (for Step 2) or the final product sector (Step 3) as well as the overall assessment method (aspects, indicators, how to deal with data gaps, etc.). It is also recommended to better communicate and share data along the Value Chain with respect to their confidentiality, for instance through Digital Product Passports. Wherever appropriate, it would be recommended to use a reference to the outcome of a REACH assessment instead of the entire REACH chemical safety assessment.

The gap analysis for the environmental sustainability criteria shows a high level of variability for the criteria considered in the case studies showing that the relevance of the criteria

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depends on the substance/material being assessed in combination with its application. For at least one case-study, potential improvement was identified on several of the criteria but it was too complex to quantify with any certainty.

The completion of Step 4 is expected to be challenging due to the anticipated lack of access to information. For chemicals already available on the market, the purpose of the comparison to a reference and the choice of the reference in Step 4 is questionable. Comparison also raises some issues when data quality is heterogeneous. Life Cycle Assessments (LCA) can only be carried out for substances with fixed production processes etc. Therefore, for new substances, we recommend the adoption of other indicators, such as Product Carbon Footprint (PCF) instead of LCA.

For certain products there are is a clear necessity for trade-offs for instance between functionality and sustainability. Functionality and performance must often be prioritized, particularly where very strict legal and technical standards must be met. These trade-offs in product design must also be better reflected in the SSbD framework.

Many of the social and economic sustainability criteria were not considered for several casestudies. Some of these criteria were considered uncritical for EU producers in at least one of the case studies, linked to the fact that they are highly dependent on location of non-EU produced materials/goods. Here again, data availability is the biggest challenge. They refer to steps of the production process which often happen outside of the EU and therefore there is little visibility and control over those parameters. It was recommended to take a TIER approach (initial, intermediate and full evaluation) and to focus on hotspots and on obtaining specific data.

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2 Introduction

The field of safe and sustainable by design has seen significant advancements in recent years, driven by increasing awareness of environmental impacts and the need for enhanced safety evaluation during product development. This approach integrates sustainability into the design process from the very beginning, ensuring that products, systems, and processes are not only functional but also environmentally responsible and safe for human use. Modern practices emphasize the reduction of waste, energy efficiency, and the use of non-toxic materials. Innovative techniques such as lifecycle assessments (LCA) and circular design principles are now commonly applied to evaluate and optimize the sustainability of products throughout their entire lifespan, from raw material extraction to end-of-life disposal.

The European Union's Chemicals Strategy for Sustainability (CSS) aims to catalyse the shift towards chemicals, materials and products that are safe and sustainable by design (SSbD) throughout their life cycles. Developing SSbD criteria for chemicals and materials is one of the key actions foreseen in the CSS, contributing to reducing negative impacts on human health and the environment associated with chemicals, materials, products and services produced, used or marketed in the EU. To support the CSS implementation concerning SSbD, the European Commission's Joint Research Centre (EC JRC) developed a framework for the definition of SSbD criteria for chemicals and materials. The framework puts together safety, environmental and socio-economic dimensions of sustainability[1,2].

The SSbD framework proposes a hierarchical approach in which the safety aspects are considered first, followed by environmental and socio-economic aspects. For each step several critical criteria are selected and incorporated. Safety involves ensuring that products are free from harmful substances, do not pose risks during their use, and are designed with user safety in mind. Second environmental impact focuses on factors such as resource consumption, emissions, and waste generation. This includes assessing the use of renewable resources, energy efficiency, and the potential for recycling or reusing materials. Finally, social and economic factors are considered, including the product's impact on communities and its economic viability. Sustainable designs should contribute positively to society and offer economic benefits, such as reducing costs over time through efficiency and durability.

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[1] Caldeira, C., Farcal, L., Garmendia Aguirre, I., Mancini, L., Tosches, D., Amelio, A., Rasmussen, K., Rauscher, H., Riego Sintes, J., Sala, S., Safe and sustainable by design chemicals and materials – Framework for the definition of criteria and evaluation procedure for chemicals and materials, Publications Office of the European Union, Luxembourg, 2022, https://data.europa.eu/doi/10.2760/487955

[2] Caldeira, C., Garmendia Aguirre, I., Tosches, D., Mancini, L., Abbate, E., Farcal, R., Lipsa, D., Rasmussen, K., Rauscher, H., Riego Sintes, J., Sala, S. Safe and Sustainable by Design chemicals and materials. Application of the SSbD framework to case studies, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/329423, JRC131878

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Following the JRC approach, “Criteria” is defined as an aspect (e.g. climate change) with an assessment method and a minimum or maximum threshold or target values on which a decision may be based. While a careful selection process was done for the SSbD criteria used in the JRC framework, it is well recognised that challenges remain, including the need for standardized metrics and frameworks for evaluating sustainability and safety across different industries. Addressing these challenges requires ongoing research, collaboration between stakeholders along value chains, and the development of comprehensive guidelines that can adapt to new technologies and evolving standards. As the focus on sustainability and safety continues to grow, the integration of these principles into design processes is expected to become increasingly sophisticated and widespread.

2.1 IRISS previous work

The IRISS methodology is designed to contribute to achieving high-level EU and societal goals and is summarised as follows: First, existing life cycle analysis methods and tools, Safe-by-Design (SbD) and other sustainability assessment methods will be used to develop a new set of Sustainable-by-Design (SusbD) principles applied to materials, products and processes (WP1). These findings feed into a gap analysis to identify and describe the key dimensions and methodologies needed, and knowledge/research/innovation gaps for integration into product and process sustainability performance assessment (WP2). Based on the findings of the criteria mapping and gap analysis, a set of roadmaps will be developed focusing on key value chains (VCs) and high impact sectors to be prioritised for SSbD and relevant tools for industry actors (WP3). These activities involve extensive engagement and communication with key stakeholder groups (WP5) including dissemination actions, dialogue activities and harmonization efforts with EU projects. Running in parallel to all these activities is the development of the permanent network, which involves building the basis for long-term cooperation between the network members and consortium partners during and after the project (WP6). A value proposition-based, service offering design and match-making strategy will be employed using both digital and in-person activities, prioritizing members with a track record for starting self-funding networks between research, small and medium-sized enterprises (SMEs) and industry.

The first deliverable (D4.1) of WP4 provided an analysis of the value chains in a cradle-to-cradle approach and mapped the relevant value chain stakeholders. Overall, the outcomes were heterogenic since each value chain chose the most appropriate level of granularity and detail. This first deliverable and its update (D4.8) establishe a baseline for further work on VC-specific roadmap development (WP3/WP4) supporting the operationalisation of SSbD within the VCs examined.

Some value chains have put some focus on specific sub value chains, others have given a different level of detail, but all are of direct interest and show how complex the challenge is.

For the purpose of this deliverable D4.3, the work done in Task 4.2 (T4.2) and reflected on in D4.2 “Baseline analysis of SSbD criteria per value chain - specificities and common grounds” is of higher relevance. The goal of that deliverable was to analyse whether the SSbD criteria mapped in WP1 are applicable for the different value chains and to identify potential overlap. Based on the analysis in T4.1 and input from ongoing developments in WP1, each value chain partner verified

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the applicability of the defined SSbD criteria within their remit. An overview of aspects and indicators for SSbD were provided in the JRC Framework Report[3] and this was used as a starting point for the value chain specific criteria analysis.

As a first step, each of the value chain partners identified their most relevant SSbD criteria - in close collaboration amongst each other through a common workshop in project month (M)6 (November 2022) – focusing on commonalities and specificities. The workshop methodology has been developed by Tekniker (D4.2) and the activities have been organised by EFCC and Cefic. Overall sustainability can be achieved, for example, by minimising the environmental impact of chemicals and materials' production, use and re-use or disposal. The key SSbD criteria for each of the value chains was mapped using a life cycle thinking approach, considering: the manufacture (or sourcing) of raw materials, the production stage, the use stage and the end-of-life stage.

There are many commonalities among the value chains, such as, the use or emissions of restricted substances at the raw materials stage (most value chains), the geographic coverage: e.g., textiles (global) and construction (local).. A second workshop organised by Cefic in M20 where criteria with their challenges and solutions were shared, confirmed those commonalities.

The deliverable D4.2 included a list of commonly mentioned SSbD criteria among the VC (Table 1). This exercise showed that a commonality between the seven VCs is their complexity, which makes a reliable comparison of the validity of SSbD criteria challenging. In most cases a selection has been made of (sub) VC(s) however the challenge of their complexity and the numerous stages of the VCs remains applicable. Conversely, there are a high number of common SSbD criteria among all VCs that warrant further evaluation and, where possible, quantification, for example through LCA. Also worth noting that a conclusion of this report was that LCAs should focus on key SSbD criteria and would allow to get valuable insights in the magnitude of the sustainability opportunities and challenges for certain VCs.

The deliverable D2.1 translates the main outcomes of T2.1 'Harmonised methodology to establish the gap analysis approach'. It summarises the gaps identified in the state-of-the-art mapping of SSbD methods and criteria in IRISS WP1, VC-specific gaps as well as gender-specific gaps that are also relevant in the context of SSbD and recommends steps that will offer opportunities for gap closure.

For the VC specific gaps, a series of interviews were performed with key stakeholders involved in the primary value chains (part of IRISS project). The study therefore encompassed seven key sectors: textiles, construction, electronics, fragrances, packaging, automotive, and energy. The main gaps identified are related to the need to develop harmonized, general and easy to apply tools and protocols to implement SSbD. In the case of SbD, new approach methodologies (NAMs) could help to determine safety impacts at early stages of materials development. To avoid animal testing, in silico or in vitro test protocols would be preferable. There is a need to develop common ontologies, defining the

[3] Caldeira, C., Farcal, L., Garmendia Aguirre, I., Mancini, L., Tosches, D., Amelio, A., Rasmussen, K., Rauscher, H., Riego Sintes, J., Sala, S., Safe and sustainable by design chemicals and materials – Framework for the definition of criteria and evaluation procedure for chemicals and materials, Publications Office of the European Union, Luxembourg, 2022, https://data.europa.eu/doi/10.2760/487955

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required terminology in a structured way to facilitate the understanding of materials stakeholders and computers.

Table 1 - Commonly mentioned SSbD criteria by the VCs

Stages of lifecycle	SSbD Criteria
Raw materials	1. Sustainable sourcing of raw materials 2. Restricted substances related to environmental and/or human health hazards
Production	3. Emissions (air, water, soil) 4. Energy consumption 5. Water consumption 6. Restricted substances related to environmental hazards
Use	7. Use of sustainable resources 8. Energy efficiency / consumption 9. Water consumption
End-of-Life	10. Waste 11. Recyclability / circularity potential

Concerning the SSbD JRC framework, it is important to take into account the functionality, the durability, and the risk assessment, considering exposure of material quantities at an early stage of the design phase.

During the assessment of SbD tools and frameworks, it was observed that the framework does not adequately cover material functionality, which is an essential aspect of all innovation. Including considerations of chemical or material functionality within the framework would help align the objectives of SbD with the industry's emphasis on functionality-oriented approaches. In most cases, the reason for marketing a chemical product is not based on the product itself, but on the functionality it provides. To ensure overall sustainability, it is also important to look beyond 'chemical by chemical' substitution in the search for alternatives and explore non-chemical /material solutions. This is currently a major gap in the SSbD approach. While this issue is briefly mentioned in the JRC SSbD framework, the framework itself focuses exclusively on the case where a chemical or material alternative is being assessed.

Furthermore, linked with LCA phases and use stages, the survey results and the EU projects showed that in practice the LCA studies still focus mainly on the production phase. Not all studies consider the end-of-life phase and only some of the respondents consider the use phase (the inclusion of the use phase is higher in the EU projects). The main aspects considered during use are functionality and reduction of energy consumption. Durability and reusability are considered by about half of the respondents in both the survey and the EU projects and repairability and upgradeability are rarely considered. There is a need to include sector specific performance aspects (e.g., surface conductivity, durability) in the assessment methodology.

Below is a list of all gaps identified in D2.1. and which were used as basis for the gap analysis on SSbD criteria in T4.3.:

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Design

- Design for long-lasting technologies, and design for end of life should be further developed and considered in the design tools for materials, processes, components, and devices.

Risk and Sustainability Governance

- Need for an integral risk and sustainability governance,
- Rules for FAIR Data accessibility along the value chain vs competitiveness should be clarified,

Data management

- Need to develop common ontologies, terminology structured to be used by materials stakeholders and computers,
- Lack of consideration to the gender-environment nexus in order to make progress towards a more equitable and sustainable development, as environmental factors have different impacts on different genders,
- Closing the gender data gap, e.g., by building a data ecosystem with gender- and minority-disaggregated data.
- Tools and methods
- Need to have harmonized, general and easy to apply tools and protocols to implement SSbD,
- NAMs could help to determine at early stage of the development, the safety impacts,
- Risk assessment should be taken into account considering also exposure of material quantities, at early stage of the design phase,
- LCA simplification, availability of open database with rich datasets should still be improved,
- Ex-Ante LCA is necessary to evaluate the environmental impact at early stage of the design phase,
- Product Environmental Footprint (PEF) impact assessment methods and Product categories Rules (PCR) specific for each sector, needs to be further analyzed. It is necessary to define the meaning of high/low carbon footprint in each case.
- Conventional, environmental, social Life Cycle Costing (c-LCC, e-LCC, s-LCC) considerations could help to monetize the social and environmental impact,
- S-LCA methodologies and databases should be further developed in the future,
- 9R (e.g., recyclability, repairability, reuse) concept should be further incorporated in the different value chains, with clear objectives (e.g., % recycled materials in new designs) in function of the type of materials,

Skills competencies and education needs

- Education and training on SSbD aspects is needed, e.g., training schools, online courses, and university programmes,
- Gender aspects should be integrated into education material for SSbD and the SSbD university module that will be initiated by the IRISS academic partners during the project runtime (T5.4).

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Knowledge sharing needs

- A trusted knowledge sharing platform where rules for FAIR Data accessibility along the value chain vs competitiveness are clarified,
- A common global SSbD indicator needs to be addressed,
- Guidelines for common practices.

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3 Objectives

T4.3 “Value chain SSbD criteria gap analysis” had the goal of following the baseline analysis in T4.2 and the value chain mapping of T4.1 to highlight the gaps related to the uptake of the SSbD approach in the value chains. The value chain partners were asked to identify where there is a missing approach. That may mean the lack of a clearly described concept, framework or the related SSbD criteria. All these gaps describing lack of clear approach or compliance with criteria, have been gathered by CLEPA, using a dedicated template and reported per value chain in D4.3. The collected input will be made available then be used by WP2 for the preparation of T2.4.

The T4.3 builds on the work done for the case-studies, prepared for the JRC framework assessment consultation. This was the approach agreed within WP4, since performing a gap analysis for all criteria of the SSbD framework considering an entire value chain would neither be feasible nor provide relevant insights. Therefore, the value chains were asked to prepare a gap analysis on SSbD criteria based on their selected case study. On the one hand this helps narrow down the scope of the analysis, on the other hand it helps to provide concrete feedback on the existing gaps for that specific case study (which can be a substance, materials, product or process).

Beyond the IRISS project, the results of this gap analysis can be used as intelligence and additional feedback to the JRC consultation on the SSbD framework, notably as a complement to the information provided through the case studies.

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4 Methodology

The value chains of the IRISS project were requested to perform an assessment of the gaps existing in the SSbD criteria, for the specific case study of their choice. In order to deliver uniform results, a list of proposed gaps was prepared based on the work of Deliverable 2.1. of WP2 (Table 2). The motivation to use a common list of gaps was to avoid redundancy and allow maximum homogeneity/comparability of results possible. The criteria judged for this analysis were those proposed by the JRC in the report "Safe and sustainable by design chemicals and materials - Framework for the definition of criteria and evaluation procedure for chemicals and materials"[4].

A template was prepared by CLEPA and eas provided to the value chains for the gap analysis. The template was discussed during the workshop of the 18 January and was subsequently approved by the value-chains. Each value-chain was asked to fill out the template with:

- the SSbD criteria that were considered for the case study and the respective gaps/challenges
- the SSbD criteria that were not considered in the case study and why

The VCs were also asked to provide a few recommendations to address the gaps identified in the case studies. The results of the analysis can be found in the Annex and are discussed in Chapters 5. Chapter 6 further elaborates on the gaps and the recommendations proposed by the VCs.

Table 2 - List of Gaps used for Task 4.3. adapted from IRISS D2.1.

1. Lack of harmonized and easy to apply tools and protocols
2. Lack of common ontologies and terminology
3. Insufficient Circular economy considerations: fair/balanced assessment of all 9Rs
4. Unclear rules for FAIR Data accessibility along the value chain vs competitiveness
5. Unavailability of open database with rich datasets
6. Absence or incomplete/inconsistent datasets
7. Lack of guidance on how to deal with data gaps and uncertainties, how to evaluate trade-offs.
8. Lack of Ex-Ante LCA to evaluate the environmental impact at early stage of the design phase,

[4] Caldeira, C., Farcal, L., Garmendia Aguirre, I., Mancini, L., Tosches, D., Amelio, A., Rasmussen, K., Rauscher, H., Riego Sintes, J., Sala, S., Safe and sustainable by design chemicals and materials – Framework for the definition of criteria and evaluation procedure for chemicals and materials, Publications Office of the European Union, Luxembourg, 2022, https://data.europa.eu/doi/10.2760/487955

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9. Lack of consideration to the gender-environment nexus (towards a more equitable and sustainable development, as environmental factors have different impacts on different genders)
10. Overly complex LCA methodologies
11. Underdeveloped Product Environmental Footprint (PEF) impact assessment methods and Product categories Rules (PCR) specific for each sector.
12. Insufficient LCC (c-LCC, e-LCC, s-LCC) considerations
13. Underdeveloped Social-LCA methodologies and databases
14. If the company itself is not producing final products solely, the SSbD concept can only be applied until last gate
15. Carrying out LCAs on all applications may not be feasible for substances with vary broad uses.
16. Lack of a weighting step and guidance on the reference product for LCA part
17. Insufficient harmonisation of LCAs, PCFs, PEF calculations
18. Lack of acknowledgement of biogenic carbon and mass balance in PEF/PCF calculations
19. Insufficient education and training on SSbD aspects e.g., training schools, online courses, and university programmes
20. Limited number of internal experts
21. The framework does not adequately cover material functionality
22. Unclear how to integrate intermediates and complex chemical processes in SSbD
23. Lack of risk assessment considering also exposure of material quantities at early stage of the design phase
24. Insufficient focus on intrinsic hazard properties without taking into account exposure (substance quantities, uses) or any risk mitigation measures etc.
25. Uncertainty of the safety impacts at early stage of the development
26. Excluding all harmful chemicals from the assessment will exclude those chemicals and materials which depend on a functionality inherently linked with hazards.
27. Lack of focus on process chemicals
28. Unclear scope of what needs to be assessed (e.g. substance vs. mixture vs polymer)
29. Inconsistencies between the proposed SSbD framework and other EU policy areas e.g. taxonomy, green claims, Ecodesign, REACH
30. Other

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5 Value chains perspectives on Gap analysis

5.1 The Automotive value chain

5.1.1 Introduction of the case study

In this case study an SSbD assessment was done for the two basic components of polyurethane (PU), polyol and isocyanate, and of the reacted PU, using both the JRC approach[5] and the Cefic one[6]. This assessment was done both for a basic recipe - named 'Standard' – and an improved one, named 'Pioneer'. In both cases, generic recipes were used.

The Pioneer recipe replaces parts of the basic polyol mixture by natural oil and adapts the catalyst package accordingly. These recipes are typically developed in R&D with the goal of improving the Product Carbon Footprint (PCF) by increasing the bio-content and consequently reducing the overall emissions of the final product.

This case study had the intention of testing the applicability of the JRC framework to a reacted material, while identifying challenges of implementation. A comparison between the Standard and Pioneer recipes aimed to portray the process of re-design or development of alternatives and associated considerations. In addition, for the same case study we applied the Cefic guidance, notably for the assessment of the Pioneer recipe compared to the Standard one. Through this additional analysis we hoped to understand if there is value added in the Cefic approach and to identify potential best practices that can be implemented by the JRC.

Table 3 – Automotive SSbD Case study description

Group of chemicals	Application	Short description
Reacted Polyurethane (PU) and its components	Automotive seats	Assessment of the individual components used for the PU production in addition to assessment of the reacted PU directly. When assessing the individual components, a comparison is made between a 'Standard' and a 'Pioneer' recipe. In both cases, generic recipes are used.

[5] Abbate, E., Garmendia Aguirre, I., Bracalente, G., Mancini, L., Tosches, D., Rasmussen, K., Bennett, M.J., Rauscher, H. and Sala, S., Safe and Sustainable by Design chemicals and materials - Methodological Guidance, Publications Office of the European Union, Luxembourg, 2024, doi:10.2760/28450, JRC138035
[6] Cefic. (2024). Safe and Sustainable - A guidance to unleash the transformative power of innovation. https://cefic.org/app/uploads/2024/03/Safe-and-Sustainable-by-Design-a-guidance-to-unleash-the-transformative-power-of-innovation.pdf

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5.1.2 Results of gap analysis

This case study allows to demonstrate that for materials like PU, where the final product is the outcome of a chemical reaction (and not just the outcome of a physical mixture), there will often be substances upstream in the industrial process not passing Step 1 of the JRC approach. That is the case even if these substances are no longer present in the final product.

In addition, the JRC approach does not distinguish between industrial, and consumer uses, which is a consequence of the blanket hazard-based approach disregarding exposure in the first step. Consequently, in upstream processes, many supply chains will have substances that will not pass step 1 of the JRC process. It is not clear yet, if the downstream materials (substances and articles) will be considered as sustainable or not. The required data volume for each substance in the mixtures equals potential studies to be carried out in the financial order of magnitude of about 2-3 Mio€ for the hazard analysis. If new substances are assessed, there is no production process which could be a basis for an LCA, and the details of further processes in the supply chain and end of life are not known because they do not exist at that stage yet.

Reactive chemistry and processes to produce chemicals under controlled conditions are not considered in the JRC model. When considering the Pioneer recipe of our case study, the JRC SSbD approach fails to reflect the targeted improvement in SSbD properties, as it stops at step 1 due to the blanket hazard-based approach. Besides it requires a high amount of data at a very early stage of the R&D phase. It is not applicable for products derived from a chemical reaction; it can target only chemicals without consideration of previous steps.

The Cefic approach foresees guiding design principles for a selected set of safety and sustainability considerations or dimensions to be assessed at the level of product-application combination in a stage gate-like approach during innovation.

While the JRC approach looks at a single substance/recipe at a given time, where a huge amount of data must be available (equivalent of Tier 1 REACH registration of each component of a mixture in addition to a complete LCA analysis of each component of a mixture), the Cefic approach allows for comparison of certain developments of recipes. It is more process oriented and allows to generate data with increasing market entrance probability. It highlights the importance of defining the use case, particularly for determination of the exposure scenarios. Unlike the JRC approach, it makes a differentiation between industrial/production process use and the consumer use phase, including professional use in addition to end-of-life considerations. The Cefic approach works under the principle that classified substances (e.g. respiratory sensitisers) are handled safely in industry according to REACH requirements and OSH requirements (risk-based approach).

5.1.3 Main conclusions and recommendations

The general conclusion for this case study is that the JRC framework, as it stands, is partly workable for existing high-volume substances with existing REACH Tier 1 registrations, but mostly unworkable for mixtures even if they contain existing high-volume substances within the recipes (exemplified by the 'Standard' recipe) and the further developments on R&D, or

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simply development of alternative substances/materials (exemplified by the 'Pioneer´ recipe).

The level of detailed data required to fulfill the JRC SSbD safety assessment is unrealistic. Wherever appropriate, we would recommend using a reference to the outcome of a REACH assessment instead of the entire REACH chemical safety assessment.

The JRC SSbD framework is currently not applicable for the development of alternatives/R&D since a lot of the data requested refers to processes, use phase and end of life which is not known at that stage of the process. For instance, LCA assessments can only be carried out for substances with fixed production processes etc. Therefore, for new substances, we recommend the adoption of other indicators, such as PCF instead of LCA.

It is not possible to generate hazard data worh 2-3 Mio € in terms of studies that would need to be carried out for each substance that is tested in early stages of R&D and will potentially never be used due to lack of technical performance. Instead, screening criteria should be used based on structural information.

One potential solution to make this framework more implementable is to allow for more generic answers, or a selection of indications. Portfolio Sustainability Assessments (PSA) is an established industry-wide methodology to steer and develop companies' product portfolios towards improved safety and sustainability outcomes on a single product level and recommended as a well proven and hands-on assessment framework for alternative SSbD approaches.

The Cefic approach shows improvements in SSbD properties in real-life R&D examples while JRC approach fails at early stage. Reactive chemistry and processes to produce chemicals under controlled conditions are not considered in the JRC model.

When considering the Pioneer recipe of our case study, the JRC SSbD approach fails to reflect the targeted improvement in SSbD properties, as it stops at step 1 due to the blanket hazard-based approach. Besides it requires a high amount of data at a very early stage of the R&D phase. It is not applicable for products deriving from a chemical reaction, it can target only chemicals w/o considering pre-steps.

The Cefic SSbD approach is better suited to show improvements in targeted focus dimensions:

- reduced amount of classified substances and improve the overall safety & health profile of the final product
- reduced emissions of final product
- reduced CO2-footprint due to the increased use of bio-based material

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5.2 The Packaging value chain

5.2.1 Introduction of the case study

The report describes the approach and conclusions of two case studies resulting from application of the SSbD framework in the packaging sector, covering both SURPASS and BUDDIE-PACK Horizon Europe projects.

SURPASS - MultiNanoLayered (MNL) films to replace multi-layer films for food packaging

Multilayer plastic films are currently used in packaging for the protection of food – because of their unique barrier properties enabling significant extension of food preservation. They are traditionally composed of multiple high-performance layers (e.g. polyolefin (PE (polyethylene) and PP (polypropylene) - 55% of multilayers streams), PA (polyamide), EVOH (Ethylene and Vinyl Alcohol copolymer), etc. but also aluminum or cardboard). Most current designs and the widespread absence of sorting and recycling technologies for such multilayers make them unsuitable for recycling in an economically and environmentally sustainable way.

SURPASS proposes to evaluate feasibility to develop MNL produced polymeric systems. In the MNL process, the combination of polymers at the interfaces is forced by the flows instead of governed by chemical interactions between components (Van der Waals interactions). This effect of nano-structuring allows the realization of multi-nanocomponent films with good barrier, mechanical and optical properties, theoretically without compatibilizing agents, in order to reduce material costs and improve the recyclability of the final product.

BUDDIE-PACK - Production of new reusable packaging to replace single use plastic trays for food

Currently, food tray packaging from BUDDIE-PACK partner is composed of PP trays, rigid PP lid or thermos-sealed film. It is so produced with Black color PP for tray and lid but can be produced with clear PP. They are produced by injection process, same mold for lid and tray. It is also possible to integrate in-mold labelling, PP label with inks (not removable after). However, these packagings are produced for single-use packaging, and the design limits reuse applications (print name of supermarket, specific food, etc.).

The objective of this study case is to produce a new packaging designed to reuse it and able to be recycled at the end of its life. The analysis has to include the packaging production but also the logistic and the washing steps according to the reuse of the packaging. The selected packaging is a catering packaging for food consumption, made of a case and a lid; the respective plastic materials are Polybutylene terephthalate (PBT) and PP. The basis for the case study corresponds to a business to customer model, where end users hold the packaging and return it for reuse with a deposit system. Industrial washers wash the packaging after each use cycle.

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Table 4 - Packaging SSbD Case study description

Project	Group pf chemicals/material	Application	Short description
SURPASS – Design of intermediate product	PE	Packaging film for thermoforming of packaging trays	Material for case study and reference baseline
BUDDIE-PACK – Design of product	PBT	Reusable Plastic Packaging	Material for case study
	PP	Single Use Plastic Packaging	Material for reference baseline

5.2.2 Results of gap analysis

The design teams of the SURPASS and BUDDIE-PACK Horizon Europe projects, respectively, have a different awareness of the JRC SSbD framework. The SURPASS design team practices and operationalizes the SSbD framework, while BUDDIE-PACK discovered it during the performance of the case study proposed by IRISS for contributing to the JRC feedback period. A resulting gap is that SSbD awareness is very varied and depending on the type of design activity; this particularly concerns the familiarity with safety rules among other factors.

The SSbD evaluation framework has a wide scope. Applying all of its criteria to an on-going design process would require a large and unrealistic effort. During the two case studies, it was only possible to carry out part of the evaluation. The steps selected were the onesfor which the design team had the proper expertise and benefits of specific data available.

When specific data is available or built by the design team, the SSbD evaluation enables the team to compare the new solution to a selected baseline. In absence of specific data, generic data replaces it. Generally, the team averages the calculation and this results in a non-differentiated evaluation between new solution and baseline. This also means that the full SSbD evaluation can only happen during the final stages of a development process, when specific data are available. This experience was made on both the SURPASS and the BUDDIE-PACK project. At such late stages of the projects, it is no longer possible to change the design without considerable expenses or unfavourable effects on timelines.

Application of SSbD framework Step 1, the evaluation of intrinsic hazard properties, requires deep knowledge on both the materials or the products' composition and toxicity. Both the SURPASS and the BUDDIE-PACK design team could not undertake the evaluation of Step 1 during the reporting period. The SURPASS consortium includes toxicity specialists who will be conducting a hazard evaluation at the end of the project. Nevertheless, this evaluation will be partial due to lack of access to hazard data for some of the used ingredients. Generally speaking, available hazard data are Material Safety Data Sheets (MSDS). They do not exhaustively relate all toxicity studies performed to validate the ingredient. Toxicity studies might have been performed but are not available to industrial players buying and using this ingredient for their design.

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5.2.3 Main conclusions and recommendations

Awareness about the SSbD evaluation framework is very varied and can even be non-existent for design teams. Educating and training innovators on the SSbD recommendation and the SSBD framework published by the EC is very paramount. Basic education modules in the form of digitally accessible trainings or webinars are recommended to deploy SSbD practices.

A major purpose of the SSbD framework is to select innovative solutions with better safety and sustainability performance. While carrying out the case studies we noticed that the SSbD assessment in its entirety can only be carried out at the end of the R&D project when it is too late to trigger major changes. Therefore a tiered approach is essential for SSbD. The SSbD Methodological guidance[7] published in May 2024 by EC JRC for this case proposes an initial, intermediate and full assessment.

Case studies on packaging have shown that evaluations using generic data lead to non-differentiating evaluation results of the innovative solution compared to the baseline. The SSbD evaluation looks more consistent when specific data are used. Due to the number of criteria and parameters along the supply chain, it looks unrealistic to carry out a SSbD evaluation for all ingredients and processes present in the supply chain during the whole life cycle. The identification of SSbD hotspots would be helpful for these cases. It enables innovators to concentrate on major aspects and proceed for their evaluation with use of specific data.

Sometimes design team have a few levers on existing SSbD hotspots. As an example, the plastic material production frequently is the biggest contributor in the assessment of sustainability criteria compared to the rest of a plastic product life cycle. The design team depends on SSbD improvements undertaken by plastic materials manufacturers. But it does not mean that no SSbD improvement can be achieved by the design team; for example, they could work on plastic recycling processes for the developed plastic products. In such a context, global SSbD roadmaps per application sector could help to determine the respective contribution of each VC actor.

Both the SURPASS and the BUDDIE-PACK case study highlighted the complexity of carrying out the Step 1 evaluation of intrinsic hazard properties. We recommend enlarging the awareness and education about MSDS. Their content and information about safety should be findable and understood by more actors in the design team. Educating future engineers as well as current engineers is key for better implementation of safety considerations during product design.

Another important way to facilitate the carrying out of safety evaluations is to develop ways to interoperate SSbD data along a VC. Approaches need to respect data confidentiality and manufacturer know-how. Inclusion of SSbD data inside Digital Product Passports could be a means to progress on the interoperability of data.

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[7] Abbate, E., Garmendia Aguirre, I., Bracalente, G., Mancini, L., Tosches, D., Rasmussen, K., Bennett, M.J., Rauscher, H. and Sala, S., Safe and Sustainable by Design chemicals and materials - Methodological Guidance, Publications Office of the European Union, Luxembourg, 2024, doi:10.2760/28450, JRC138035

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5.3 The Textiles value chain

5.3.1 Introduction of the case study

The report describes the approach and conclusions of a case study of applying the SSbD framework in the textile sector. The case study was carried out between September 2023 and February 2024 as part of WP 4 of the IRISS project. The work was coordinated by Textile ETP in collaboration with several other IRISS project partners such as EMPA and RIVM and involved representatives from the European textile and clothing value chain with a special focus on personal protective equipment (PPE), workwear and functional sportswear. This particular subsector of the textile VC was chosen due to its strong reliance on advanced materials and functionalisation chemicals to achieve the functional properties these products require. The purpose of this case study was to test the applicability of the emerging SSbD framework and some of its components such as the SSbD design principles in a concrete industrial VC and derive recommendations as to its best use or to overcome identified limitations.

Table 5 - Textiles SSbD Case study description

Group of chemicals/material	Application	Short description
Textiles with multi-protective functionalities	Workwear, personal protective equipment (PPE) and functional sportswear	Application of the SSbD concept in general and the eight SSbD Design principles in the functional workwear sector

5.3.2 Results of gap analysis

To make an abstract framework more approachable for companies to start with, it was decided in this case study to focus on the (re)design phase with its design principles as outlined in the SSbD scoping analysis of the JRC's methodological guidance document[8]. As molecular (re)design was out of scope for the input collection, process and product elements were looked at.

[8] Abbate, E., Garmendia Aguirre, I., Bracalente, G., Mancini, L., Tosches, D., Rasmussen, K., Bennett, M.J., Rauscher, H. and Sala, S., Safe and Sustainable by Design chemicals and materials - Methodological Guidance, Publications Office of the European Union, Luxembourg, 2024, doi:10.2760/28450, JRC138035

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The list of SSbD design principles and associated definitions that can be used in the design phase[9] was used to explore how the SSbD framework can be applied in the specific value chain of workwear and PPE and identify its challenges and opportunities.

The following paragraphs discuss the state of the SSbD framework in the workwear and PPE industry, highlighting challenges in implementing SSbD. In workwear and PPE, functionality is critical, particularly in protective applications where safety cannot be compromised. This focus often hinders the replacement of hazardous materials, as alternatives may not meet the high degree of performance required for durability and protection in technical standards for such products that are derived from regulations such as the EU PPE directive.

In specialized applications, small quantities of highly functional but potentially non-compliant materials may still be necessary. The market is fragmented, dominated by SMEs that struggle to adopt SSbD due to limited resources and their limited control over only parts of the value chain. Safety is well-prioritized, supported by internal and external stakeholders, but economic factors often take precedence, creating trade-offs between cost, safety, and sustainability.

Sustainability faces significant hurdles, including a lack of comprehensive data, standards, and long innovation cycles in the chemical industry. The phase-out of hazardous chemicals like per- and polyfluorinated alkyl substances (PFAS) for water- and oil repellent textile finishes or chlorine or bromine-based chemicals for fire-retardant properties pose particular challenges for balancing environmental sustainability with maintaining high levels of functionality.

Efforts to integrate safety and sustainability have been made, particularly by larger companies, but the transition is slow. Innovations like biobased fibre feedstocks and recycled materials are emerging, but radical breakthroughs are rare as complex processing steps during production and durability guarantees during long use and maintenance cycles can easily invalidate innovative approaches. Economic, social, and environmental sustainability must be balanced with market demands and profitability. Cross-cutting challenges include supply chain collaboration, data management, and regulatory adaptation.

5.3.3 Main conclusions and recommendations

This case study on workwear, PPE, and functional sportswear highlights a trade-off between functionality and sustainability when applying the SSbD framework in the textile value chain. Functionality is prioritized, especially in PPE, where very strict legal and technical standards must be met. This often limits the use of sustainable materials if they compromise product performance or compliance. In consumer sports- and outdoor wear, where technical requirements are lower, sustainable material and processing alternatives can be more easily explored, although price sensitivity of the end market remains a major constraint.

[9] Caldeira, C., Farcal, L., Garmendia Aguirre, I., Mancini, L., Tosches, D., Amelio, A., Rasmussen, K., Rauscher, H., Riego Sintes, J., Sala, S., Safe and sustainable by design chemicals and materials – Framework for the definition of criteria and evaluation procedure for chemicals and materials, Publications Office of the European Union, Luxembourg, 2022, https://data.europa.eu/doi/10.2760/487955, **p. 25ff.**

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The adoption of SSbD in the workwear and PPE sector is hindered by several challenges: market fragmentation in a supply chain dominated by SMEs (which often lack resources for full SSbD assessments), the need for highly functional materials in specialized, high-risk environments, and the lack of comprehensive data and standards to assess sustainable alternatives. In smaller, niche markets, conducting SSbD assessments is often not economically viable.

Despite these challenges, progress is being made, particularly by larger companies incorporating safety and sustainability into their processes. For SMEs, the SSbD framework can provide a structured approach to sustainability, allowing for prioritization based on available resources and needs. Flexibility is recommended in applying SSbD, encouraging different actors in the value chain to adapt the framework to their capabilities. Regulators are urged to support further promotion of SSbD and provide guidance and tools tailored to specific stakeholders and material value chains.

5.4 The Construction value chain

5.4.1 Introduction of the case study

The gap analysis of the Construction value chain is focused on two value chains: the value chain of concrete admixtures and the value chain of chemicals-based insulation materials.

In the concrete admixtures value chain, a range of concrete admixtures, additives to cement are used to improve the performance of concrete (the final product). A range of concrete admixtures are used, including admixtures based on formaldehyde, melamine and napthalene, in addition to, for example, PEG based admixtures. The use of the first three is under pressure as a result of their classification and labelling in the EU.

In the chemicals-based insulation value chain, there are essentially two types of insulation: (i) based on polyurethanes (PU), and (ii) based on polystyrene (PS). In terms of insulation materials, these are not the largest in terms of volume, as insulation value chains based on inorganic mineral derived materials are much larger in the EU. From an SSbD perspective, the main challenge is the PU-based Value Chain as a result of the potential health & safety impact on professional users.

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Table 6 - Construction SSbD Case study description

Group pf chemicals/material	Application	Short description
Concrete admixtures	Additives to cement to improve the properties of concrete and allow less energy use, associated Greenhouse Gas (GHG) emissions, and lower water use during the manufacture of buildings and infrastructure using concrete.	Case study on different concrete admixtures.
Polymer based insulation materials	Two types of polymer-based insulation materials are covered: Polyurethane (PU)- based and Polystyrene (PS)- based insulation.	Case study focused on PU-based insulation materials as there are challenges in their application as a result of their possible impact on human health (of the professional users). The entire value chain has developed a very comprehensive training package in all EU languages for such professional users.

5.4.2 Results of gap analysis

The gap analysis of the concrete admixtures VC focused on the substitution of (some) raw materials of concrete admixtures, in particular, formaldehyde, melamine and naphtalene-based concrete admixtures.

5.4.3 Main conclusions and recommendations

The concrete admixture industry has been developing concrete admixtures using alternative raw materials and PEG (polyethylene glycol) in particular, that do not attract a serious classification and labelling in the EU, and offer significant advantages in terms of Greenhouse Gas (GHG) emission reduction and reduction of water use (in the process of manufacturing concrete).

The construction sector (including EFCC) has recently published a complete overhaul / update of applicable Environmental Product Declarations (EPD), as they are widely used in the construction sector to assess the environmental impact of, for example, concrete admixtures.

The entire European PolyUrethane (PU) industry has developed a very comprehensive training for professional users to ensure that the raw materials, i.e. di-isocyanates, of

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polyurethanes can safely be used. The main challenge here was to ensure that professional users can safely use them. The training is provided in all the EU languages.

5.5 The Energy value chain

5.5.1 Introduction of the case study

SSbD Case study Li Ion batteries: solid electrolyte instead of liquid electrolytes
The market takes off now and has strong growth potential. Three technologies are in development for the solid electrolyte (gen 4 Li Ion batteries):

- 1) Oxide based e.g. LLZO ($Li_7La_3Zr_2O_{12}$), 2) Sulphide based e.g. LISICON ($Li_{3.4}Si_{0.4}P_{0.6}S_{0.4}$) or $Li_2S–SiS_2$ or $Li_2S–P_2S_5$ and 3) Dry Polymer (SPE) based e.g. polyethylene oxide (PEO), Polyacrylonitrile (PAN), Polyethyleenglycol (PEG)

They replace the liquid organic flammable electrolyte in present gen 3 batteries. Liquid battery electrolyte composition is mainly composed of three parts:
(1) Solvent: cyclic carbonate (PC, EC), chain carbonate (DEC, DMC, EMC): used to dissolve lithium salt
(2) Lithium salt: usually $LiPF_6$
(3) Additives: film-forming additives, conductive additives, flame retardant additives, overcharge protection additives…
The SSbD case study is developed for a solid electrolyte with emphasis on efficiency, absence of F- salts in the electrolyte and improved safety. Solid electrolytes will be much safer, some trade-offs are to be made.

Table 7 - Energy SSbD Case study description

Group pf chemicals/material	Application	Short description
Oxides, sulphides or polymers	Solid state Li Ion batteries	SSbD case is developed for solid electrolyte with emphasis on efficiency, absence of F- salts in the electrolyte and improved safety. Solid electrolytes will be much safer, some trade-offs are to be made.

5.5.2 Results of gap analysis

Main gaps in the analysis are amongst other the following:

- Unavailability of open databases with rich datasets
- Absence or incomplete/inconsistent datasets

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- Lack of Ex-Ante LCA/LCC/S-LCA to evaluate the environmental impact at early stage of the design phase,
- Unclear scope of what needs to be assessed (e.g. substance vs. mixture vs polymer): the materials are complex compositions

5.5.3 Main conclusions and recommendations

Solid electrolytes are still in the development phase and currently subject of several EU Horizon R&D studies (focusing Technology Readiness Level (TRL) 5). Choices still need to be made between best compositions where functionalities are in the scope (energy/power density, lifetime, fast charge, cost...) and where safety improvement is evaluated. A wide variety of possible products is under consideration and LCA, LCCA and S-LCA are being developed. Present case study is work in progress and will be further completed once in a few years all information will be available.

The resulting recommendation is to further collect data, closely follow international developments (solid state developments in China, South Korea, US...), create international collaborations...Once more information is available on the material choices made, the case study will be completed.

5.6 The Electronics value chain

5.6.1 Introduction of the case study

Semiconductor chips for power control are an excellent example of an Electronics sub value chain that both has its own SSbD considerations and plays a critical enabling role in sustainability efforts of other value chains, e.g., both Energy and Automotive value chains in IRISS.

Electrification is considered to be one of the critical approaches for reaching long-term sustainability in many activities, whether performed by individuals or at industrial scales. For example, in transport, switching from engines powered by fossil fuels to electric motors will dramatically reduce the associated carbon footprint as the economies switch to renewable energy sources. In many cases, electrified systems and devices are also able to support additional sustainable practices, by taking advantage of “smart” functionalities, such as adaptive lighting, heating, and cooling systems in buildings.

Fundamental to all the electrified systems is the challenge of power management. More specifically, the challenge of efficiently controlling and transforming electrical power from generation, to transmission, to storage, to its final use. Along this chain, electrical power often needs to be transformed between alternating and direct current (AC and DC) and/or to control the voltage and current. In modern systems, these control and transformation functions are typically performed by specialized semiconductor chips.

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A team of researchers from CEA-Leti RTO in Grenoble, France recently published the first public systematic evaluation of a GaN power transistor; this publication was the primary source for the use-case information.[10]

Table 8 - Electronics SSbD Case study description

Group pf chemicals/material	Application	Short description
GaN Semiconductors	Power-control electronics	Cradle-to-Gate Life Cycle Assessment (LCA) of GaN Power Semiconductor Device

5.6.2 Results of gap analysis

The overall challenge in applying the template and associated methodology to the Electronics VC is that the standard evaluation process effectively assumes large-scale production and use of materials as the main causative factors for the impacts. In contrast, the most energy- and resource-intensive processes in electronics are those of materials transformation, whereby small (often, vanishingly small) amounts of materials are transformed and structured at the nanoscale. Accordingly, most of the impacts are associated with the energy and other resources used in the different processing steps, many of which are not strongly material-specific, e.g., a comparably large amount of ultra-pure water is used in processing of different semiconductor materials.

5.6.3 Main conclusions and recommendations

Information for evaluating the health and environmental impacts is available for the production phase, not for the individual material. Furthermore, all these safety aspects contributed less than 20% of the total impact, so indicators were not considered in detail.

Resource use, minerals and metals; resource use, fossils; and climate change, account for 82% of the overall impact score, making those priority areas to be addressed. Such measures are also likely to reduce the scores for safety aspects, which are primarily related to the use of energy and resources as well as emissions produced in the process.

The gap in evaluating the health and environmental impacts, accordingly, is the uncertainty in the methodology for evaluating the impacts that is larger than the fraction of the scores that can be directly associated with a specific material, rather than with a production process that is similar for most of the semiconductor fabrication.

For evaluating the use-phase stage, a specific application needs to be defined, with realistic load and charging scenario, the location, frequency and length of use, and market adoption projections. Key variables for comparing the different materials in this case are the energy efficiency gains, the use intensity, and the product lifetime. This requirement to consider very specific details for each product and application is the main gap in being able to

10 Vauche, L.; Guillemaud, G.; Lopes Barbosa, J.-C.; Di Cioccio, L. Cradle-to-Gate Life Cycle Assessment (LCA) of GaN Power Semiconductor Device. *Sustainability* **2024**, *16*, 901. https://doi.org/10.3390/su16020901

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compare the effects, for example, of transitioning from Si-based to GaN-based power electronics or between different generations of power-control devices.

Direct emissions of greenhouses gases such as fluorinated compounds during deposition or dry-etching processes have a high impact on climate change, which can be reduced with appropriate gas-abatement systems. While such systems are energy-intensive, their inclusion in the evaluation typically lowers the overall impact scores on climate change. Nevertheless, this is a good example of a gap associated with the intrinsic trade-offs between the safety and sustainability aspects of the production phase.

Significant materials hazards are associated with the end-of-life stage, where potentially larger amounts (tons) of electronics are aggregated for the final handling and processing. The gap here is that these steps are poorly understood because currently they are mainly carried out in low-income countries to which electronics waste is exported from Europe. There are individual reports of damage to health and environment around such processing sites (which often use artisanal methods), but attribution of impacts to a specific material, such as GaN, is very difficult.

5.7 The Fragrances value chain

5.7.1 Introduction of the case study

A fragrance is a chemical mixture, and it is a unique and complex combination of natural and synthetic ingredients that are added to products to give them a distinctive smell or to cover base malodour.

A fragrance is typically a mixture of around 60 to 80 ingredients in household products and can go up to several hundred in fine fragrances (perfumes), representing a small contribution by volume in the final product but playing a big role in consumer choice, product appreciation and self-perception.

The purpose of the fragrance VC case study is to analyse and test the applicability of the EC SSbD framework in terms of safety and sustainability assessment for the use within the fragrance industry.

Given the complexity of analysing a fragrance mixture, only one fragrance ingredient as a single chemical is considered for the case study: Methyl Salicylate.

Methyl salicylate (CAS: 119-36-8; EC number: 204-317-7) is the INCI name of methyl 2-hydroxybenzoate, an ingredient produced by many species of plants, particularly wintergreens. It is also produced synthetically, and it is used in many fragrance mixtures and as flavouring and soothing agent in oral hygiene products.

The case study applies the second phase of the SSbD framework where the safety and sustainability of methyl salicylate is assessed. The case study performs on the already existing chemical, the safety, environmental sustainability, but not the social and economic sustainability assessments.

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In order to ensure that the whole VC is covered from upstream to downstream by the case study, two different sources and two different final uses were considered. Methyl Salicylate is produced both naturally and synthetically and is assessed in two different final products: in a cosmetic product (toothpaste) and in a detergent (surface cleaner).

Table 9 - Fragrances SSbD Case study description

Group of chemicals/material	Application	Short description
Methyl salicylate	Cosmetic product (toothpaste)	Case-study on the application of the SSbD framework to methyl salicylate
Methyl salicylate	detergent (surface cleaner)	Case-study on the application of the SSbD framework to methyl salicylate

5.7.2 Results of gap analysis

A relevant number of challenges stemming from the application of SSbD framework were identified:

- Data sharing and access to information through the value chain.
- Most companies (especially SMEs) are unlikely to have the required resources and level of in-house expertise to cover the different steps of the SSbD framework.
- The completion of Step 1 for the ingredients that are not REACH registered or registered in a lower tonnage band or for substances without a harmonised classification and labelling is anticipated to be more challenging.
- Step 2 requires a lot of specific information for the production process of the substance in scope. Assumptions regarding working conditions are likely to be made and it was demonstrated that these assumptions have a direct impact on the results.
- Considering aspects (hazard properties), indicators (parameters which define the hazard rating) and criteria are not yet clearly defined by the SSbD framework, the completion of Step 2 and Step 3 were more difficult than Step 1.
- For chemicals already available on the market, the purpose of the comparison to a reference and the choice of the reference in Step 4 is questionable. Comparison also raises some issues when data quality is heterogeneous.
- The completion of Step 4 in the fragrance industry is expected to be challenging due to the anticipated lack of information access.
- Concluding on whether the chemicals in scope are considered Safe and Sustainable by Design is not feasible considering the SSbD framework does not clearly lay out all the criteria, tools, evaluation methods and pass/fail criteria for the different Steps of the study.

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5.7.3 Main conclusions and recommendations

The objective of the case study was to evaluate the feasibility of applicability of the SSbD framework on methyl salicylate considering two different sources (natural and synthetic) and two different final uses (toothpaste and surface cleaner).

Step 1 focusing on the intrinsic properties of the chemical was easily performed based on robust data as methyl salicylate is an already existing chemical which is REACH registered and has a Harmonised Classification in Annex VI of the CLP regulation (ATP 17). Methyl salicylate passes the H1 cut-off criterion which corresponds to the most harmful substances but falls under the H2 criterion that refers to the substances of concern (SSbD level 1) as it is classified for some human health hazard classes (reproductive toxicity and skin sensitisation) and one environmental hazard class (chronic aquatic toxicity).

Step 2 evaluating the risk to human health and safety during the production and processing of the chemical was the most difficult step to perform as it requires a lot of information on the production process and is the least robust as several assumptions regarding working conditions considerations were made. Regardless of the origin, the formulation of products containing methyl salicylate presents a negligeable risk.

Step 3 assessing whether the use of final products containing methyl salicylate poses any risk for the consumer or for the environment was straightforward as information required is more easily accessible and most of it were readily available in methyl salicylate extended Safety Data Sheet SDS. Methyl salicylate passes both human health and environmental criteria for the use phase and reaches the highest SSbD level (well below safe limit) thanks to the low concentration in both final products (less than 0.65% in toothpaste and less than 0.1% in surface cleaner).

It can be concluded from the safety assessment that the main safety risks are related to the intrinsic properties of methyl salicylate (Step 1) and the exposure risks during the production of the ingredient if the production process is not in a closed loop or if the maximum protective measures are not implemented (Step 2). However, the substance can be used safely in several applications due to its low concentration in the final products (Step 3 assessment).

Step 4 covers the assessment of the environmental sustainability aspects of methyl salicylate, along its entire life cycle by means of LCA. The application of the EC SSbD framework for this Step requires to derive the SSbD score for each impact category to reflect the degree of improvement relative to the reference, chosen to be synthetic methyl salicylate in this study. Based on the assumptions made, natural methyl salicylate used in the two applications (toothpaste and surface cleaner) has a greater environmental impact than synthetic methyl salicylate on the 16 impact categories. As data quality assessment highlighted, a lower data quality was obtained for the production of natural methyl salicylate than for the synthetic version.

Several recommendations regarding the SSbD framework can be made following this case study:

- To ensure Step 2 and Step 3 are consistent regardless of who performs it, additional guidance should be provided on the tool to be used depending on the data available

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(for Step 2) or the final product sector (Step 3) as well as the overall assessment method (aspects, indicators, how to deal with data gaps, etc.).

- For the overall assessment, if a single score for the SSbD evaluation is deemed necessary to facilitate communication and decision-making, guidance should be provided on the aggregation method to ensure consistency between studies.
- Considering that Steps 2 and 4 really depend on who/where/how the substance in scope is produced, the SSbD framework should be regarded as a way to look at one's own production process, flag the hotspots and refine each step with internal data and practices rather than a tool to provide a definite result for all.
- It also appears that a slightly different methodology should be detailed in the framework depending on whether the substances are in R&D stage or commercialised.

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6 Summary of SSbD Criteria Gap analysis

The VCs of the IRISS project were requested to perform an assessment of the gaps existing in the SSbD criteria, for the specific case study of their choice. In order to deliver uniform results, a list of proposed gaps was prepared based on the work of D2.1 of WP2 (Table 2). The motivation to use a common list of gaps was to avoid redundancy and to allow maximum homogeneity/comparability of results possible. The criteria judged for this analysis was that proposed by the JRC.

Using a template prepared by CLEPA each VC was asked to fill out the template with:

- the SSbD criteria that were considered for the case-study and the respective gaps/challenges
- the SSbD criteria that were not considered in the case study and why

In this chapter we summarise the results of this analysis following the replies provided by the VCs using the template. The full results can be consulted in Tables 11-15 the Annex.

Human Health criteria

Many of the criteria were not considered for several case studies (Table 11). The identified gaps were “Lack of harmonized and easy to apply tools and protocols”, “Unavailability of open databases with rich datasets", “Uncertainty of the safety impacts at early stage of the development”, “Lack of risk assessment considering also exposure of material quantities at early stage of the design phase” and “Limited number of internal experts”. It is also mentioned that deploying intrinsic hazard evaluation within material or product design is a very complex process. For at least one case the criteria were not considered due to the nature of the case study which was not a single chemical substance or material, but a category of end products made using a wide range of material combination and chemicals used in the processing or functionalisation stages of intermediate materials, components or final products. Furthermore it was pointed out that there is uncertainty of the safety impacts at early stage of the development.

It was also mentioned that the completion of Step 1 for ingredients that are not REACH registered or registered in a lower tonnage band or for substances without a harmonised classification and labelling is anticipated to be more challenging.

Environmental hazards criteria

Similar to the above, many of the criteria were not considered for several case studies (Table 12. The identified gaps and recommendations were the same as listed above. It was further added that no clear Endocrine Disruption (ED) mode of action can be defined considering the only two available studies, and the a priori level of concern cannot be determined to propose a robust testing strategy for the environmental species. Regarding persistent, mobile, and toxic (PMT) properties it was highlighted that this since has been newly introduced in the revised CLP regulation and therefore new guidance will only be later in 2024.

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Physical hazards criteria

Similar to the above, many of the criteria were not considered for several case studies (Table 13). The identified gaps were "Lack of focus on process chemicals", "Limited number of internal experts ", and "Unavailability of open database with rich datasets". At least a few Hazard classes were not applicable in some case studies for instance as they apply to some of the process chemicals, not the material itself. Furthermore it was pointed out that even if a broad range of chemicals may be used in the production processes, including some in very small amounts, most of them are confined to automated tools, because any significant leaks would destroy the product, so the environment inside the production "clean rooms" is highly controlled.

Environmental sustainability criteria

The gap analysis for this category shows high level of variability for the criteria considered in the case studies clearly showing that the relevance of the criteria depends on the substance/material being assessed (Table 14). The identified gaps were "Lack of harmonized and easy to apply tools and protocols", "Insufficient Circular economy considerations" and "Unavailability of open database with rich datasets". It was also mentioned that the collection of primary data to perform an LCA is very difficult. For at least one case study there was identified potential for improvement on several of the criteria but it was too complex to quantify with any certainty. It was also noted a specific data gap on additives, loss rates, geographical/technical representativity. Furthermore the main impacts' contributors (ex: plastic material manufacturing) can be outside acting scope of the design team.

Social and economic sustainability criteria

Many of the criteria were not considered for several case studies (Table 15). The identified gaps were "Absence or incomplete/inconsistent datasets". It was also mentioned that such assessment can only provide consistent results with specific data. Some of these criteria were considered uncritical for EU producers in at least one of the case studies, linked to the fact that they are highly dependent on location of non-EU produced materials/goods.

It was recommended to take a TIER approach (initial, intermediate and full evaluation) and to focus on hotspots and acquisition of specific data.

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7 Conclusions and Recommendations

In this report we set out to map gaps in the SSbD criteria by building on the findings of WP2 and the work done in WP4 notably the case studies prepared by the VCs (Table 10). Each VC completed a detailed gap analysis using a template prepared by CLEPA which made use of the list of gaps prepared in D2.1. The results and specific context of the value chain were further explained in the report in chapter 4. In this chapter we summarize the results of the gap analysis and respective recommendations provided by the VCs.

Table 10 - Overview of case studies per value chain

Value chain	Group of chemicals	Application	Short description
Automotive	Reacted Polyurethane (PU) and its components	Automotive seats	Assessment of the individual components used for the PU production and as well is used to assess the reacted PU directly. When assessing the individual components, a comparation is made between a 'Standard' and 'Pioneer' recipe. In both cases, generic recipes are used.
Packaging	PE	Packaging film for thermoforming of packaging trays	Material for case study and reference baseline
	PBT	Reusable Plastic Packaging	Material for case study
	PP	Single Use Plastic Packaging	Material for reference baseline
Textiles	Textiles with multi-protective functionalities	Workwear, personal protective equipment and functional sportswear	Application of the SSbD concept in general and the 8 SSbD Design principles in the functional workwear sector
Construction	Concrete admixtures	Additives to cement to improve the properties of concrete and allow less energy use, associated GHG emissions, and lower water use during the manufacture of buildings and infrastructure using concrete.	Case-study on different concrete admixtures.
	Polymer based insulation materials	Two types of polymer-based insulation materials are covered:	Case study focused on PU-based insulation materials as there are challenges in their application as

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		Polyurethane (PU)-based and Polystyrene (PS)- based insulation.	a result of their possible impact on human health (of the professional users). The entire value chain has developed a very comprehensive training package in all EU languages for such professional users.
Energy	Oxides, sulphides or polymers	Solid state Li Ion batteries	SSbD case is developed for solid electrolyte with emphasis on efficiency, absence of F- salts in the electrolyte and improved safety. Solid electrolytes will be much safer, some trade-offs are to be made.
Electronics	GaN Semiconductors	Power-control electronics	Cradle-to-Gate Life Cycle Assessment (LCA) of GaN Power Semiconductor Device
Fragrances	Methyl salicylate	Cosmetic product (toothpaste)	Case-study on the application of the SSbD framework to methyl salicylate
	Methyl salicylate	detergent (surface cleaner)	Case-study on the application of the SSbD framework to methyl salicylate

Step 1 – 3 criteria

The evaluation of intrinsic hazard properties in Step 1 requires deep knowledge of both the materials' or products' composition and toxicity as well as full access to hazard data for all used ingredients. Generally speaking, available hazard data are MSDS. They do not exhaustively relate all toxicity studies performed to validate the ingredient. Toxicity studies might have been performed but are not available to industrial players buying and using this ingredient for their design. The completion of Step 1 for the ingredients that are not REACH registered or registered in a lower tonnage band or for substances without a harmonised classification and labelling is also more challenging.

Furthermore the full SSbD evaluation can only happen during the final stages of a development process, when specific data are available. This approach is hence not useful as an evaluation tool for R&D or redesign because at that late stage, it is no longer possible to change the design without expensive or time consequences.

We recommend **enlarging the awareness and education about MSDS**. Their content and information about safety should be findable and understood by more actors in the design team. Educating future engineers as well as current engineers is key for better implementation of safety during design. Furthermore, to ensure Step 2 and Step 3 are consistent regardless of who performs it, **additional guidance should be provided on the tool to be used depending on the data available** (for Step 2**) or the final product sector** (Step 3) as well as the overall assessment method (aspects, indicators, how to deal with data gaps, etc.).

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Step 2 requires a lot of specific information for the production process of the substance in scope. Assumptions regarding working conditions are likely to be made and it was demonstrated that these assumptions have a direct impact on the results. Therefore, it would be advisable to rather use the **SSbD framework as a way to look at one's own production process, flag the hotspots and refine each step** with internal data and practices rather than a tool to provide a definite result for all.

Concluding on whether the chemicals in scope are considered Safe and Sustainable by Design is not feasible considering the SSbD framework does not clearly lay out all the criteria, tools, evaluation methods and pass/fail criteria for the different Steps of the study. A **clear definition of aspects (hazard properties), indicators (parameters which define the hazard rating) and criteria** is still missing in the SSbD framework, making the completion of Step 2 and Step 3 more challenging than Step 1.

Overall it is not possible to generate hazard data for 2-3 Mio € for each substance that is tested in early stages of R&D and will potentially never be used due to lack of technical performance. Instead, screening criteria should be used based on structural information. **When appropriate we would recommend using a reference to the outcome of a REACH assessment instead of the entire REACH chemical safety assessment.**

It is also recommended to **better operate data along the Value Chain with respect of their confidentiality for instance through Digital Product Passports**.

Step 4 criteria

The completion of Step 4 is expected to be challenging due to the anticipated lack of access to information.

For chemicals already available on the market, the purpose of the comparison to a reference and the choice of the reference in Step 4 is questionable. Comparison also raises some issues when data quality is heterogeneous.

LCAs can only be carried out for substances with fixed production processes etc. **Therefore, for new substances, we recommend the adoption of other indicators, such as PCF instead of LCA.**

For certain products there are clear trade-offs for instance between functionality and sustainability when applying the SSbD framework in the textile value chain. Functionality and performance must often be prioritized, particularly where very strict legal and technical standards must be met (e.g. workwear and PPE or automotive seating). This often limits the use of sustainable materials if they compromise product performance or compliance. **These trade-offs in product design must also be better reflected in the SSbD framework** as they are essential aspects of the industry's reality.

Step 5 criteria

Here again data availability is the biggest challenge. The critera refer to steps of the production process which often happen outside of the EU and therefore there is little visibility and control over those parameters.

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It was recommended to take a TIER approach (initial, intermediate and full evaluation) and to focus on hotspots and obtention of specific data.

Other recommendations

- Educating on the SSbD recommendation and the SSbS framework published by the EC is very important. Basic education modules in form of digitally accessible trainings or webinars are recommended to deploy SSbD practice.
- Regulators are urged to support further promotion of SSbD and provide guidance and tools tailored to specific stakeholders and material value chains. For SMEs, the SSbD framework can provide a structured approach to sustainability, allowing for prioritization based on available resources and needs. Flexibility is recommended in applying SSbD, encouraging different actors in the value chain to adapt the framework to their capabilities.
- Develop ways to interoperate SSbD data along a VC. This should happen respecting data confidentiality and manufacturers know-how.
- For the overall assessment, if a single score for the SSbD evaluation is deemed necessary to facilitate communication and decision making, guidance should be provided on the aggregation method to ensure consistency between studies.
- It also appears that a slightly different methodology should be detailed in the framework depending on whether the substances are at the R&D stage or commercialised.
- Identification of SSbD hotspots is helping for that. It enables innovators to concentrate on major aspects and proceed for their evaluation with the use of specific data.

Considering that most value chains are global it is also recommended to closely follow international developments and create international collaborations on materials and substances in the context of SSbD.

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8 Annex

8.1 Results of Gap analysis

Table 11 - Gap analysis for Human Health criteria

	Human health criteria													
	Carcinogenicity	Germ cell mutagenicity	Reproductive / developmental toxicity	Endocrine disruption (human health)	Respiratory sensitisation	Specific target organ toxicity - repeated exposure (STOT-RE) , including immunotoxicity and neurotoxicity	Skin sensitisation	Acute toxicity: oral	Acute toxicity: dermal	Acute toxicity: inhalation	Skin corrosion/irritation	Serious eye damage/eye irritation	Aspiration hazard	Specific target organ toxicity - single exposure (STOT-SE)
Was this criteria considered in your case-study?														
Electronics	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
Packaging	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Energy	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Fragrances	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Textiles	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Construction	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
Automotive	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Select from the drop down menu at least one applicable gap/challenge														
Electronics	Lack of harmonized and easy to apply tools and protocols Unavailability of open database with rich datasets													
Packaging	Limited number of internal experts													
	Unavailability of open database with rich datasets It is very complex to deploy intrinsic hazard evaluation within material or product design.													
Energy	Limited number of internal experts Unavailability of open databases with rich datasets													
Fragrances														
Textiles	Human health criteria were not assessed individually because the subject of the textile case study was not a single chemical substance or material, but a category of end products (protective garments) which are made using a wide range of material combination and chemicals used in the processing or functionalisation stages of intermediate materials, components or final products.													
Construction														
Automotive	Uncertainty of the safety impacts at early stage of the development Limited number of internal experts Lack of risk assessment considering also exposure of material quantities at early stage of the design phase One of the components for the production of PU does not pass Step 1 as they are respiratory sensitizers and the JRC Step 1 is a pure hazard-based approach. Even if the isocyanates are fully consumed during production of polyurethanes, as used in the final application and therefore do not contribute to any risk in the use phase. No													

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	further assessments are carried for Step 2-5 of polyol and Isocyanate component and therefore PU raw materials would be considered not SSbD. Although the starting materials (polyol component and isocyanate component) do not pass the SSbD Step 1 criteria, the final reaction product (reacted Polyurethane) is "not classified" (according to CLP classification).
Comment about existing gaps/challenges	It is very complex to deploy intrinsic hazard evaluation within material or product design.
Comment on recommendations	• Some raw materials for concrete admixtures attract a CLP classification, in particular formaldehyde, melamine and naphtalene) - for carcinogenicity, mutagencity or reproductive toxicity • Step 1 focusing on the intrinsic properties of the chemical was easily performed based on robust data as methyl salicylate is an already existing chemical which is REACH registered and has a Harmonised Classification in Annex VI of the CLP regulation (ATP 17). The completion of Step 1 for the ingredients that are not REACH registered or registered in a lower tonnage band or for substances without a harmonised classification and labelling is anticipated to be more challenging. • Some raw materials for concrete admixtures attract a CLP classification, in particular formaldehyde, melamine and naphtalene) - for carcinogenicity, mutagencity or reproductive toxicity • Better operate data along the Value Chain with respect of their confidentiality: have them as mandatory items in Digital Product Passports?

Table 12 - Gap analysis for Environmental hazard criteria

	Environmental hazards					
	Persistent, bioaccumulative and toxic / very persistent and very bioaccumulative (PBT/vPvB)	Persistent, mobile and toxic / very persistent and mobile (PMT/vPvM)	Endocrine disruption (environment)	Hazardous for the ozone layer	Chronic environmental toxicity (chronic aquatic toxicity)	Acute environmental toxicity (acute aquatic toxicity)
Was this criteria considered in your case-study?						
Electronics	No	No	No	Yes	Yes	No
Packaging	No	No	No	No	No	No
Energy	No	No	No	No	No	No
Fragrances	Yes	Yes	Yes	Yes	Yes	Yes
Textiles	No	No	No	No	No	No
Construction	No	No	No	No	No	Yes
Automotive	No	No	No	No	No	No
Select from the drop down menu at least one applicable gap/challenge						

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Electronics	Lack of harmonized and easy to apply tools and protocols
Packaging	Limited number of internal experts Unavailability of open database with rich datasets
Energy	Limited number of internal experts Unavailability of open database with rich datasets
Fragrances	n.a.
Textiles	Human health criteria were not assessed individually because the subject of the textile case study was not a single chemical substance or material, but a category of end products (protective garments) which are made using a wide range of material combination and chemicals used in the processing or functionalisation stages of intermediate materials, components or final products.
Construction	n.a.
Automotive	Uncertainty of the safety impacts at early stage of the development Limited number of internal experts Lack of risk assessment considering also exposure of material quantities at early stage of the design phase One of the components for the production of PU does not pass Step 1 as they are respiratory sensitizers and the JRC Step 1 is a pure hazard-based approach. Even if the isocyanates are fully consumed during production of polyurethanes, as used in the final application and therefore do not contribute to any risk in the use phase. No further assessments are carried for Step 2-5 of polyol and Isocyanate component and therefore PU raw materials would be considered not SSbD. Although the starting materials (polyol component and isocyanate component) do not pass the SSbD Step 1 criteria, the final reaction product (reacted Polyurethane) is "not classified" (according to CLP classification).
Comment about existing gaps/ challenges	It is very complex to deploy intrinsic hazard evaluation within material or product design.
Comment on recommendations	• Better operate data along the Value Chain with respect of their confidentiality: have them as mandatory items in Digital Product Passports? • No clear ED mode of action can be defined considering the only two available studies, and the a priori level of concern cannot be determined to propose a robust testing strategy for the environmental species. • PMT is part of the newly introduced hazard classes in the revised CLP regulation. New guidance is under development and will be available by mid-2024. • Napthalene attracts a CLP classification

Table 13 - Gap analysis for Physical hazards criteria

	Physical hazards											
	Explosives	Flammable gases, liquids and solids	Aerosols	Oxidising gases, liquids, solids	Gases under pressure	Self-reactive	Pyrophoric liquids, solid	Self-heating	In contact with water emits flammable gas	Organic peroxides	Corrosivity	Desensitised explosives
Was this criteria considered in your case-study?												
Electronics	No	No	No	No	No	No	No	No	No	No	No	No
Packaging	No	No	No	No	No	No	No	No	No	No	No	No
Energy	Yes	Yes	No	Yes	Yes	Yes	Yes	n.a.	n.a.	n.a.	n.a.	n.a.
Fragrances	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No
Textiles	No	No	No	No	No	No	No	No	No	No	No	No
Construction	No	No	No	No	No	No	No	No	No	No	No	No
Automotive	No	No	No	No	No	No	No	No	No	No	No	No
Select from the drop down menu at least one applicable gap/challenge (please feel free to add more than one)												
Electronics	Lack of focus on process chemicals (except for Explosives and Desensitised explosives - not applicable											
Packaging	Limited number of internal experts											
Energy	Unavailability of open database with rich datasets for flammable gases, liquids and solids; oxidising gases, liquids, solids and pyrophoric liquids, solid											
Fragrances	Hazard class not applicable for Aerosols. Gases under pressure and Desensitised explosives											
Textiles	Human health criteria were not assessed individually because the subject of the textile case study was not a single chemical substance or material, but a category of end products (protective garments) which are made using a wide range of material combination and chemicals used in the processing or functionalisation stages of intermediate materials, components or final products.											
Construction	n.a.											
Automotive	Uncertainty of the safety impacts at early stage of the development Limited number of internal experts Lack of risk assessment considering also exposure of material quantities at early stage of the design phase One of the components for the production of PU does not pass Step 1 as they are respiratory sensitizers and the JRC Step 1 is a pure hazard-based approach. Even if the isocyanates are fully consumed during production of polyurethanes, as used in the final application and therefore do not contribute to any risk in the use phase. No further assessments are carried for Step 2-5 of polyol and Isocyanate component and therefore PU raw materials would be considered not SSbD. Although the starting materials (polyol component and isocyanate component) do not pass the SSbD Step 1 criteria, the final reaction product (reacted Polyurethane) is “not classified” (according to CLP classification).											
Comment about existing gaps/ challenges	These apply to some of the process chemicals, not the material itself											
Comment on recommendations	A broad range of chemicals is used in the production processes, some in very small amounts, but essentially all of them are confined to automated tools, because any significant leaks would destroy the product, so environment inside the production "clean rooms" is highly controlled											

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Table 14 - Gap analysis for Environmental sustainability criteria

	Environmental sustainability criteria												
	Climate change	Ozone depletion	Particulate matter/Respiratory inorganics	Ionising radiation human health	Photochemical ozone formation	Acidification	Eutrophication aquatic freshwater	Eutrophication aquatic marine	Eutrophication terrestrial	Land use	Water use	Resource use minerals and metals	Resource use energy carriers
Was this criteria considered in your case-study?													
Electronics	Yes	Yes	No	Yes	Yes	No	No	No	No	No	Yes	Yes	Yes
Packaging	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Energy	Yes	Yes	No	No	No	No	No	No	No	No	No	Yes	n.a.
Fragrances	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Textiles	Yes	No	Yes	No	No	Yes	Yes	Yes	No	Yes	Yes	No	Yes
Construction	Yes	No	No	No	No	No	No	No	No	No	Yes	No	
Automotive	No	No	No	No	No	No	No	No	No	No	No	No	No

Comment about existing gaps/challenges	
Electronics	Lack of harmonized and easy to apply tools and protocols
Packaging	Unavailability of open database with rich datasets
Energy	Unavailability of open database with rich datasets
Fragrances	The collection of primary data to perform an LCA is very difficult.
Textiles	Absence or incomplete/inconsistent datasets for all category considered relevant for the case-study. Considered of little relevance were Ozone depletion. Ionising radiation human health Photochemical ozone formation Potential for reduced virgin material input thanks to use of recycled material content, but too complex to quantify with any certainty Significant potential savings of water use thanks to low water processes and water recovery/closed loop systems, but too variable to quantify with certainty Potential to reduce fossil carbon resources as material feedstock and process energy provider but too variable to quantify with certainty

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Construction	Insufficient Circular economy considerations: fair/balanced for the criteria on climate change Lack of harmonized and easy to apply tools and protocols for the criteria Particulate matter/Respiratory inorganics
Automotive	Unavailability of open database with rich datasets No LCA assessment was carried out due to lack of resources and data, for instance the needed LCA data is not available for all additives not manufactured by case-study ownder. As a proxy, the PCF was used instead, being aware that other LCA data that is not available now might change the overall picture.
Comment about existing gaps/ challenges	Existing data gaps on additives, loss rates, geographical/technical representativity. Main impacts' contributors (ex: plastic material manufacturing) can be outside acting scope of the design team.

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Table 15 - Gap analysis for Social and economic sustainability criteria

	Social and economic sustainability criteria																						
	Children in employment	Living wage	Minimum wage	sector average wage	trafficking in persons	Frequency of forced labour	Goods produced by forced labour	Goods produced by forced labour	Rate of non-fatal accidents at workplace	DALYs due to indoor and outdoor air and water	Rate of fatal accidents at workplace	Presence of sufficient safety measures	Workers affected by natural disasters	Violations of mandatory health and safety	Trade union density	Right to strike	Right to association	Right of collective bargaining	Weekly hours of work per employee	Women in the sectoral labour force	Gender wage gap	Presence of indigenous populations	Indigenous people rights protection index
Was this criteria considered in your case-study?																							
Electronics	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Packaging	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Energy	N	N	N	N	N	N	N	N	Y	n.a.	Y	N	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Fragrances	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Textiles	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	N	N
Construction	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Automotive	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N

Select from the drop down menu at least one applicable gap/challenge (please feel free to add more than one)	
Electronics	Unavailability of open database with rich datasets
Packaging	Absence or incomplete/inconsistent datasets Evaluation gives consistent results only with specific data. Focus on hotspots and obtention of specific data for them is better.
Energy	Unavailability of open database with rich datasets for Rate of non-fatal accidents at workplace and Rate of fatal accidents at workplace
Fragrances	
Textiles	Absence or incomplete/inconsistent datasets for almost all criteria Considered of little relevance: trafficking in persons , workers affected by natural disasters,. Ppresence of indigenous populations,indigenous people rights protection index Almost all criteria were considered uncritical for EU producers, highly dependent on location of non-EU produced materials/goods
Construction	Largely not relevant in the construction industry, although female construction workers are rare

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Automotive	No assessments were carried for Step 2-5 of polyol and Isocyanate component and therefore PU raw materials would be considered not SSbD. Although the starting materials (polyol component and isocyanate component) do not pass the SSbD Step 1 criteria, the final reaction product (reacted Polyurethane) is "not classified" (according to CLP classification).
Comment about existing gaps/ challenges	Recommend TIER approach (initial, intermediate and full evaluation)

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