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

Baseline analysis of SSbD criteria per value chain - specificities and common grounds

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1. Executive summary

The goal of this deliverable is to provide input to WP1 of the IRISS project and to analyse whether the Safe and Sustainable by Design (SSbD) criteria mapped in WP1 are of relevance for the respective value chains and where overlap exists. Based on the analysis in T4.1 and taking the input from ongoing developments in WP1 as a baseline, each value chain partner has verified 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 (Caldeira 2022) and this was used as a starting point for the value chain specific criteria analysis.

Although the SSbD concept is relatively recent, the concept of sustainable development or sustainability has been applied from as early as 2015 as the Sustainable Development Goals started in this year when the concept was initiated as early as 1992 by the United Nations. Sustainability typically covered economic, environmental, and social dimensions founded on stakeholder engagement. Typically, the sustainability function within companies resides in the health, safety, security & environment, or product stewardship function of companies with a close connection to the research & innovation function. Nowadays, most large, or mid-size (chemical) companies are pursuing sustainability and issue annual sustainability reports. More and more smaller companies are also pursuing sustainability.

As a first step, each of the value chain partners have identified their most relevant SSbD criteria - in close collaboration between them through a common workshop in M6 (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 have been mapped using a life cycle thinking approach, taking into account: the manufacture (or sourcing) of raw materials, the production stage, the use stage and the end-of-life stage. Although 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), there are also many commonalities, such as environmental emissions reduction needs at the production stage.

SSbD does not only result in tackling various challenges but may also bring new opportunities for innovative processes, materials, or products, for example those associated with a reduced environmental impact. The main SSbD challenges, opportunities and their associated criteria are described for the following value chains:

1. Packaging (represented by IPC)
2. Textiles (represented by Textile ETP)
3. Construction (represented by EFCC)
4. Automotive (represented by CLEPA)
5. Energy (represented by EMIRI)
6. Electronics (represented by INL)
7. Fragrances (represented by IFRA)

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2. Introduction

Over the past decades, many sustainability indicators have been used, for example, in sustainability reports of companies, but also in Life Cycle Inventories or Live Cycle Analyses covering raw materials, chemicals, materials and end-of-live options, such as recycling or re-use. Furthermore, publications of public authorities and academics have addressed the life cycle performance of different sectors/value chains and/or life cycles.

Moreover, safety and/or sustainability criteria have been developed and/or used for research and (social) innovation by academic institutions, authorities, and industry.

The EU Commission defined the concept of Safe and Sustainable by Design (SSbD) as a key element of the EU's Chemicals Strategy for Sustainability. This aims to be a pre-market approach to chemicals and materials that focuses on providing a function (or service), while avoiding volumes and chemical properties that may be harmful to human health or the environment, in particular, groups of chemicals likely to be (eco)toxic, persistent, bio-accumulative, or mobile. In a holistic approach, the overall sustainability should also be ensured by minimising the environmental footprint of chemicals and materials, in particular on, climate change, resource use, ecosystems including circularity and biodiversity from a lifecycle perspective (EC 2020).

2.1. State-of-the-art of gathered SSbD criteria

A review of the State-of-the-Art concerning potential SSbD criteria has shown that many SSbD criteria are being used to steer Research and (Social) Innovation activities and initiatives. A list of relevant references has been included under 'Section 8. Additional references used in the evaluation criteria'.

Safe and Sustainable by design (SSbD)

The SSbD concept allows for identifying sustainability (safety (risks concerning humans and the environment), environmental including circularity and social and/or economic impacts) hotspots at the early stages of product innovation and development processes to minimize potential hazard(s) and/or exposure (OECD 2020) and to maximize sustainability. The description of the SSbD concept can be found in the EU Chemical Strategy for Sustainability (EU-CSS): "safe and sustainable-by-design can be defined as a pre-market approach to chemicals that focuses on providing a function (or service), while avoiding volumes and chemical properties that may be harmful to human health or the environment, in particular groups of chemicals likely to be (eco) toxic, persistent, bio-accumulative, or mobile. Overall sustainability should be ensured by minimizing the environmental footprint of chemicals, in particular on climate change, resource use, ecosystems and biodiversity from a life cycle perspective"(EC 2020).

For the human and environmental safety dimensions, the EC Joint Research Centre (JRC) has developed the framework for SSbD criteria where a two-phase approach is recommended: a (re)-design phase in which guiding principles are proposed to support the design of chemicals and materials and a step-wise hierarchical approach to address chemical safety, direct toxicological/ecotoxicological impact, and aspects of environmental sustainability (Caldeira 2022) see Figure 1 Two-phase process in the JRC framework for

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the definition of criteria and evaluation procedure for chemicals and materials (adapted from JRC Report, 2022 .

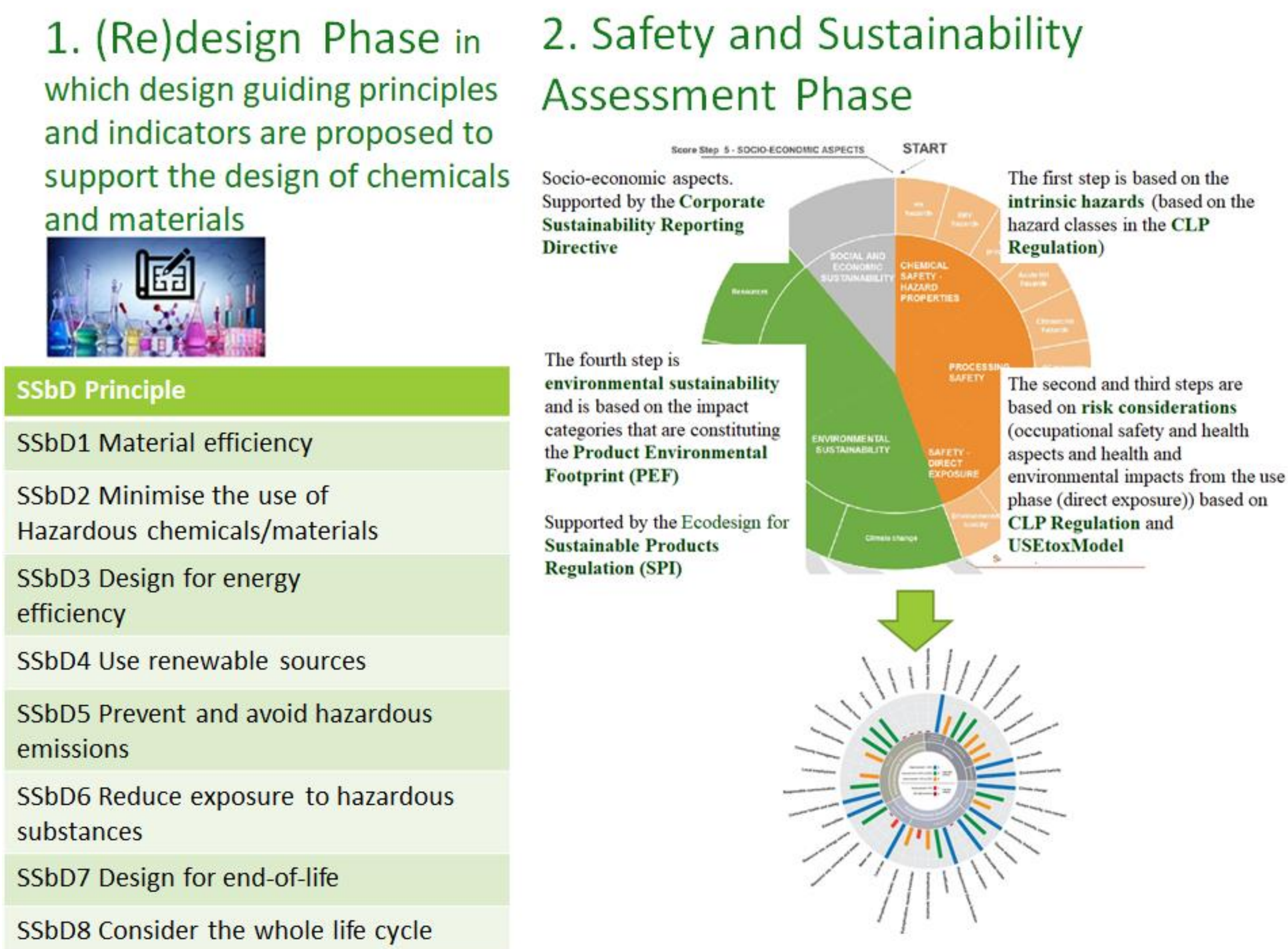

Figure 1 Two-phase process in the JRC framework for the definition of criteria and evaluation procedure for chemicals and materials (adapted from JRC Report, 2022 (Caldeira 2022)

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'by-design' phase

In the (re)design phase, SSbD principles have been identified by the EC JRC including:

1. *SSbD1 Material efficiency,*
2. *SSbD2 Minimise the use of hazardous chemicals/materials,*
3. *SSbD3 Design for energy efficiency,*
4. *SSbD4 Use renewable sources,*
5. *SSbD5 Prevent and avoid hazardous emissions*
6. *SSbD6 Reduce exposure to hazardous substances*
7. *SSbD7 Design for end-of-life,*
8. *SSbD8 Consider the whole life cycle* (Caldeira, Farcal, Tosches, et al. 2022).

In the context of the framework of SSbD criteria definition for chemicals and materials, the JRC report (Caldeira 2022) defines the term 'by-design' in 3 levels:

1. **Molecular design**: this is the design of new chemicals and materials based on the atomic level description of the molecular system. This type of design effectively delivers new substances, whose properties may, in principle, be tuned to be safe(r) and (more) sustainable.
2. **Process design**: this is the design of new or improved processes to produce chemicals and materials. Process design does not change the intrinsic properties (e.g., hazard properties) of the chemical or material, but it can make the production or use of the substance safer and more sustainable (e.g., more energy or resource efficient production process, minimising the use of hazardous substances in the process). The process design includes upstream steps, such as the selection of feedstocks.
3. **Product design**: this is the design of the product in which the chemical/material might be used with a specific function that will eventually be used by industrial workers, professionals, or consumers.

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Table 1 List of SSbD design principles and associated definition, and examples of actions and indicators that can be used in the design phase (Caldeira 2022)

SSbD principle (based on)	Definition	Examples of Actions	Examples of indicators related to the SSbD principle (see Annex 2 for definition)
SSbD1 Material efficiency (GC2, CC2, GC8, GC9, GC5, CC5, GC1, SC2)	Pursuing the incorporation of all the chemicals/materials used in a process into the final product or full recovery inside the process, thereby reducing the use of raw materials and the generation of waste.	- Maximise yield during reaction to reduce chemical/material consumption - Improve recovery of unreacted chemicals/materials - Optimise solvent for purpose (amount, typology and recovery rate) - Select materials and processes that minimise the generation of waste - Minimise the number of chemicals used the production process - Minimize waste generation - Identify occurrence of use of Critical Raw Material[17], towards minimizing or substituting them	- Net mass of materials consumed (kg/kg) - Reaction Yield - Atom Economy - Material Intensity index - E-factor (%) -Purity of recovered solvent (%) - Solvent selectivity [-] - Yield of extraction (%) - Water consumption (m^3/kg) - Recycling efficiency/recovery rate (%) - Total amount of waste (kg/kg) - Amount of waste to landfill (kg/kg) - Critical Raw Material presence (yes/no)
SSbD2 Minimise the use of hazardous chemicals/materials (GC3, SC1, GR1, GC4, GE1, GR3, GC5)	Preserve functionality of products while reducing or completely avoid using hazardous chemicals/materials where possible.	- Reduce and/or eliminate hazardous chemicals/materials in manufacturing processes - Verify possibility of using hazardous chemicals/materials in close loops when they cannot be reduced or eliminated - Eliminate hazardous chemical/materials in final products	- Biodegradability of manufactured chemical/material - Classification of raw chemicals/materials as SVHC (yes/no)
SSbD3 Design for energy efficiency (GC6, CC4, GE4, GE5, CC8, GE8, GE10, GE3, GR7, GC8, GC9, CC10)	Minimise the overall energy used to produce a chemical/material in the manufacturing process and/or along the supply chain.	Select and / or develop (production) processes considering: - Alternative and lower energy intensive production/separation techniques - Optimize energy efficiency of solvent recovery - Maximise energy re-use (e.g. heat networks integration and cogeneration) - Fewer production steps (e.g applying lean thinking) - Use of catalysts, including enzymes - Reduce inefficiencies and exploit available residual energy in the process or select lower temperature reaction pathways	- Boiling temperature (°C) - Heat of vaporisation (MJ/kg) - Energy consumption (kWh/kg or MJ/kg) - Energy efficiency (%) - Solvent selectivity [-] - Yield of extraction (%)
SSbD4 Use renewable sources (GC7, CC3, GE12, SC2)	Target resource conservation, either via resource closed loops or using renewable material/ secondary material and energy sources.	Verify the possibility of selecting feedstocks that: - are renewables or secondary materials - do not create land competition and / or processes that: - use energy resources which are renewable and with low carbon emissions	- Renewable or fossil feedstock? (yes/no) - Recycled content (%) - Share of Renewable Energy (%)
SSbD5 Prevent and avoid hazardous emissions (GE11, GC11, CC6, SC2)	Apply technologies to minimise and/or to avoid hazardous emissions or pollutants in the environment.	Select materials and / or processes that: - minimise the generation of hazardous waste - minimise generation of emissions (e.g. Volatile Organic Compounds, acidifying and eutrophying pollutants, heavy metals etc.)	- Critical air mass (%) - Critical water mass (%) - Biological oxygen demand (g/kg) - Chemical oxygen demand (g/kg) - Total organic carbon (g//kg) - Non-Aqueous Liquid Discharge (m^3/kg) - Wastewater to treatment (m^3/kg) - Amount of hazardous waste (kg/kg)
SSbD6 Reduce exposure to hazardous substances (GC12, GR4, SC1)	Eliminate exposure to chemical hazards from processes as much as possible. Substances which require a high degree of risk management should not be used and the best technology should be used to avoid exposure along all the life cycle stages.	- Eliminate or minimise risk through reduction of the use of hazardous substances - Analyse and avoid as much as possible the use of substances identified as SVHC - Consider value chain-specific regulations - Reduction and/or elimination of hazardous substances in manufacturing processes	- Biodegradability of manufactured chemical/material (yes/no) - Classification of raw chemicals/materials as SVHC (yes/no)
SSbD7 Design for end-of-life (GC10, CC1, CC7, GE11, CC9, GE9, GE6, GE7)	Design chemicals/materials in a way that, once they have fulfilled their function, they break down into products that do not pose any risk to the environment/humans. Design for preventing the hindrance of reuse, waste collection, sorting and recycling/upcycling.	- Avoid using chemical/materials that hamper the recycling processes at end-of-life - Select processes (and material) that minimise the generation of waste. - Select materials that are (where appropriate): - more durable (extended life and less maintenance) - easy to separate and sort - valuable after their use (commercial after life) - truly biodegradable for uses which unavoidably lead to dispersion into the environment or wastewater	- Recyclable? (yes/no) - Durability (years) - Disassembly/reparability design (yes/no)
SSbD8 Consider the whole life cycle (GE6, GR2, SC3, GR6, GR8)	Apply the other design principles thinking through the entire life cycle, from supply-chain of raw materials to the end-of-life in the final product	Consider for example: - Using reusable packaging for the chemical/material under assessment and for chemicals/materials in its supply-chain - Consider the most likely use of chemical/material and if there is the possibility to recycle it -. Energy-efficient logistics (i.e. reduction of transported quantities, change in mean of transport) - Reducing transport distances in the supply-chain -Applying responsible sourcing principles	- Recyclable? (yes/no) - Disassembly/reparability design (yes/no) - Durability (years) - Value-based resource efficiency indicator (VRE) - Material Circularity Indicator (MCI) - Biodegradability of manufactured chemical/material (yes/no)

GC: Green Chemistry Principle (Anastas and Warner, 1998), GE: Green Engineering Principles (Anastas and Warner,2003), SC: Sustainability Chemistry Criteria (UBA, 2009), GR: UBA Golden Rule (UBA, 2016), CC: Circularity Chemistry Principles (Keijer et al. 2019). See Annex 2 for information on the principles

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The development of a new chemical/material is often brought on through an innovation process that is often structured in a stage-gate approach, especially by industry. The process/technology development is monitored using the Technology Readiness Level (TRL) and at each stage quantitative and qualitative new information may be available for the assessment. The safety and sustainability assessment (green box, in Figure 2) should be performed as early as possible (to the extent possible, especially according to data availability) in the TRL monitoring to ensure that applying the principles gives good performance (Figure 2).

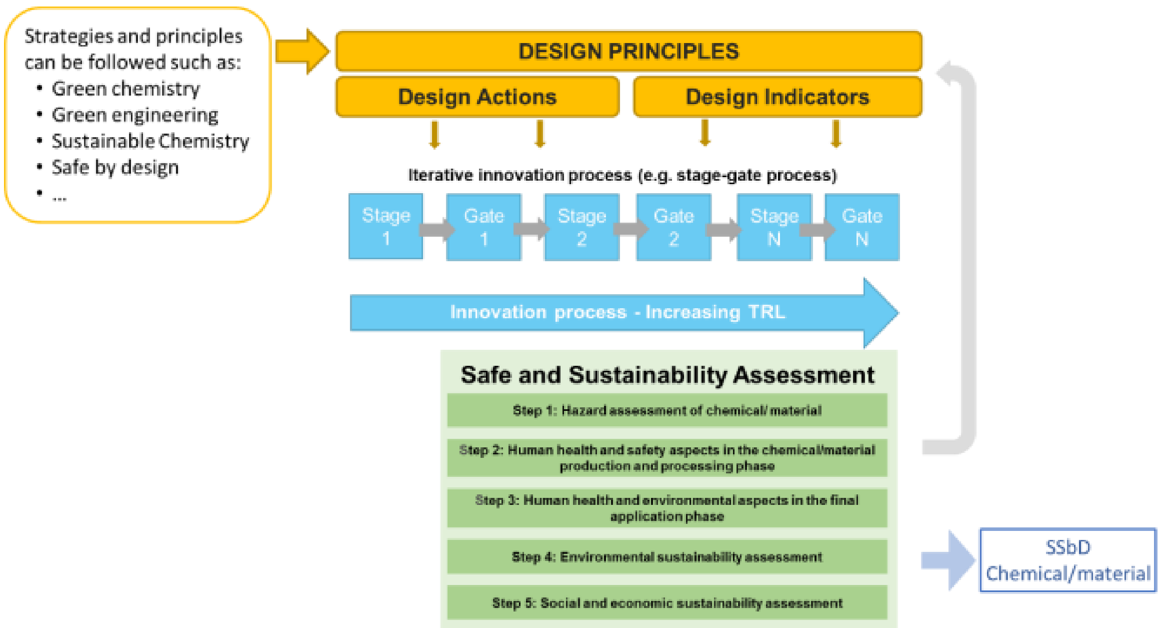

Figure 2 Integration of SSbD in the innovation cycle including principles to be considered in the design phase of SSbD chemicals and materials, TRL, Technology Readiness Level (Caldeira 2022)

Sustainability assessment and introduction to the JRC framework:

Sustainability covers and integrates safety, economic, environmental, and social aspects to avoid harm to humans and the environment (Caldeira, Farcal, Moretti, et al. 2022). Sustainability also supports the EU Green Deal (EC 2021) whose ambitions include becoming climate neutral; protecting human life, animals and plants by cutting pollution; helping companies become world leaders in clean products and technologies; and helping ensure a just and inclusive transition (EC 2019). 'In the context of chemicals, sustainability can be seen as the ability of a chemical, material, product or service to deliver its function without exceeding environmental and ecological boundaries along its entire life cycle, while providing welfare and socio-economic benefits (Caldeira, Farcal, Moretti, et al. 2022; Caldeira, Farcal, Tosches, et al. 2022)'.

In the JRC proposed framework, five steps were provided for defining criteria for SSbD chemicals and materials, see Table 2. The first step is based on the intrinsic hazards (based on the hazard classes in the

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CLP Regulation). The second and third steps are based on risk considerations (occupational safety and health aspects and health and environmental impacts from the use phase (direct exposure)) based on the CLP Regulation and USEtoxModel. The fourth step is environmental sustainability and is based on the impact categories that constitute the Product Environmental Footprint (PEF) and its support from the Ecodesign for Sustainable Products Regulation (SPI) (Zampori 2019; EC 2013, 2016). The fifth step would cover socio-economic aspects.

Table 2 Components of the proposed SSbD criteria definition framework (adapted from JRC Report, 2022 *(Caldeira 2022)*)

Step	Assessment Dimension	Assessment aspects	System Scope	Aspect/Indicator	Criteria
1	**Hazard assessment**	The assessment focuses on the hazard properties (human health, environmental and physical hazards) of the manufactured chemicals and materials	Chemical/Material intrinsic properties	See Table 3	See Section 4.4.1 and Table 4
2	**Human health and safety aspects in the production and processing phase**	Assessment of the human health and safety aspects during the production phase of the chemical/material from the used raw materials (production) and the manufactured chemical/material (processing, waste stage).	Chemical/material production and processing	See Section 4.2.2	See Section 4.2.2
3	**Human health and environmental aspects in the final application phase**	This step evaluates the human health and environmental impacts during the chemical/material final application phase.	Chemical/material application	See section 4.2.3	The indicator values should be below the safe levels. For details see section 4.2.3.
4	**Environmental sustainability (Life Cycle Assessment)**	Assess life cycle environmental impact categories for: Toxicity and Eco-toxicity Climate Change Ozone Depletion, Particulate Matter, Ionising radiation, Photochemical Ozone Formation, Acidification, Eutrophication Resources, Land Use, Water Use	Chemical/Material entire life cycle	See Table 7	Reduction by X% compared to the current state of the art for intended use. The 'X' might differ depending on the impact category. For details see section 4.2.4.
5	**Social Sustainability, Economic Sustainability**	This step is at an exploratory phase. It present an overview of social aspects that could be considered in the future. For the economic pillar, the step focuses on non-financial aspects, i.e. the identification and monetization of externalities arising during the life cycle of a chemical or a material.	Chemical/Material entire life cycle (for the economic part) Chemical/Material production and relevant suppliers (for the social part)	See Table 10 for examples	To de defined.

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Table 3 List of aspects and indicators (hazard properties) relevant for Step 1 (Caldeira 2022))

Group definition	Human health hazards	Environmental hazards	Physical hazards
Includes the most harmful substances (according to CSS (EC, 2020a)), including the substances of very high concern (SVHC) according to REACH Art. 57(a-f)[20],[21] (EU, 2006). These hazard properties form Criterion H1.	• Carcinogenicity Cat. 1A and 1B • Germ cell mutagenicity Cat. 1A and 1B • Reproductive / developmental toxicity Cat. 1A and 1B • Endocrine disruption Cat. 1 (human health) • Respiratory sensitisation Cat 1 • Specific target organ toxicity - repeated exposure (STOT-RE) Cat. 1, including immunotoxicity and neurotoxicity	• Persistent, bioaccumulative and toxic / very persistent and very bioaccumulative (PBT/vPvB) • Persistent, mobile and toxic / very persistent and mobile (PMT/vPvM) • Endocrine disruption Cat. 1 (environment)	
Includes substances of concern, as described in CSS (EC, 2020a), defined in the Article 2(28) of SPI proposal (EC, 2022b)[22] and that are not already included in Criterion H1. These hazard properties form Criterion H2.	• Skin sensitisation Cat 1 • Carcinogenicity Cat. 2 • Germ cell mutagenicity Cat. 2 • Reproductive / developmental toxicity Cat. 2 • Specific target organ toxicity - repeated exposure (STOT-RE) Cat. 2 • Specific target organ toxicity - single exposure (STOT-SE) Cat. 1 and 2 • Endocrine disruption Cat. 2 (human health)	• Hazardous for the ozone layer • Chronic environmental toxicity (chronic aquatic toxicity) • Endocrine disruption Cat. 2 (environment)	
Includes the other hazard classes not part already in Criteria H1 and H2. These hazard properties form Criterion H3.	• Acute toxicity • Skin corrosion • Skin irritation • Serious eye damage/eye irritation • Aspiration hazard (Cat. 1) • Specific target organ toxicity - single exposure (STOT-SE) Cat. 3	• Acute environmental toxicity (acute aquatic toxicity)	• 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

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Table 4 Recommended models for the Environmental Footprint method including indicator, units and models; relevant for Step 4 (adapted from (Caldeira 2022))

LCA Assessment level	Impact category	Indicator	Unit	Recommended default LCIA model
Toxicity	**Human toxicity, cancer effects**	Comparative Toxic Unit for humans (CTU_h)	CTUh	based on USEtox2.1 model (Fantke et al., 2017) adapted as in (Saouter et al., 2018)
	Human toxicity, non-cancer effects	Comparative Toxic Unit for humans (CTU_h)	CTUh	based on USEtox2.1 model (Fantke et al. 2017), adapted as in Saouter et al., 2018)
	Ecotoxicity freshwater	Comparative Toxic Unit for ecosystems (CTU_e)	CTUe	based on USEtox2.1 model (Fantke et al. 2017), adapted as in Saouter et al., 2018)
Climate Change	**Climate change**	Global warming potential (GWP100)	kg CO_2 eq	Bern model - Global warming potentials (GWP) over a 100-year time horizon (based on (IPCC, 2013)
Pollution	**Ozone depletion**	Ozone Depletion Potential (ODP)	kg CFC-11eq	EDIP model based on the ODPs of the World Meteorological Organisation (WMO) over an infinite time horizon ((WMO, 2014)+ integrations)
	Particulate matter/Respiratory inorganics	Human health effects associated with exposure to $PM_{2.5}$	Disease incidences[37]	PM model (Fantke et al., 2016) in (UNEP, 2016)
	Ionising radiation, human health	Human exposure to ^{235}U	kBq ^{235}U	Human health effect model as developed by Dreicer et al., 1995 (Frischknecht et al, 2000)
	Photochemical ozone formation	Tropospheric ozone concentration increase	kg NMVOC eq	LOTOS-EUROS (Van Zelm et al., 2008) as applied in ReCiPe 2008
	Acidification	Accumulated Exceedance (AE)	mol H+ eq	Accumulated Exceedance (Posch et al., 2008; Seppälä, et al., 2006)
	Eutrophication, terrestrial	Accumulated Exceedance (AE)	mol N eq	Accumulated Exceedance (Seppälä et al. 2006, Posch et al, 2008)
	Eutrophication, aquatic freshwater	Fraction of nutrients reaching freshwater end compartment (P)	kg P eq	EUTREND model (Struijs, et al. 2009)as implemented in ReCiPe 2008
	Eutrophication, aquatic marine	Fraction of nutrients reaching marine end compartment (N)	kg N eq	EUTREND model (Struijs et al, 2009) as implemented in ReCiPe 2008

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Resources	**Land use**	Soil quality index[38] aggregating: Biotic production, Erosion resistance, Mechanical filtration and Groundwater replenishment	Dimensionless*	Soil quality index based on LANCA model (De Laurentiis et al., 2019) and on the LANCA CF version 2.5 (Horn and Maier, 2018)
	Water use	User deprivation potential (deprivation weighted water consumption)	m^3 water eq of deprived water	Available WAter REmaining (AWARE) model (Boulay et al., 2018; UNEP, 2016)
	Resource use, minerals and metals	Abiotic resource depletion (ADP ultimate reserves)	kg Sb eq	CML (Guinée et al., 2002) and (Van Oers et al. 2002)
	Resource use, energy carriers	Abiotic resource depletion – fossil fuels (ADP-fossil)[39]	MJ	CML (Guinée et al., 2002) and (Van Oers et al. 2002)

*dimensionless index[40] resulting from the aggregation of the individual indicators for soil covering: biotic production (kg biotic production/ (m^2*a)); Erosion resistance (kg soil/ (m^2*a)); mechanical filtration (m^3 water/ (m^2*a)); and groundwater replenishment (m^3 groundwater/ (m^2*a)).

Table 5 Safety Criteria levels, descriptions, and observations

Criteria	Description	Observations (in alignment with CSS)
Criterion H1	The criterion refers to the **most harmful substances**, according to CSS, including the substances of very high concern (SVHC) according to REACH Art. 57(a-f) and additional hazard properties, as defined in Table 3. This is a cut-off criterion, establishing a minimum set of hazard requirements that need to be fulfilled by a chemical or material in order to be considered eventually SSbD after the other assessments are performed. Therefore, the assessment of the other aspects can be performed in order to understand the overall SSbD performance (e.g. safety during the use assessed in Step 3, other environmental sustainability aspects assessed in Step 4) if this helps the innovation process.	The chemicals and materials which do not pass this criterion should be: - Prioritised for substitution - Re-designed in order to reduce their adverse effects - Only allowed in uses proven essential for society (e.g. if their use is necessary for health, safety or is critical for the functioning of society and if there are no alternatives that are acceptable from the standpoint of environment and health)[24] - Safely used and emissions/exposure be controlled along the whole life cycle while activities are undertaken to develop alternatives as soon as possible and their use is phased out as soon as less hazardous alternatives are available - Tracked through their life cycle
Criterion H2	The criterion refers to the hazard class categories and hazardous substances which are part of the **substances of concern** described in CSS and not included already in criterion H1, as defined in Table 3. For the chemicals or materials with hazard properties a safety level or score will be assigned, while the SSbD assessment will continue with the evaluation of the other safety and sustainability aspects, in order to assess their overall SSbD performance.	The chemicals and materials that do not pass this criterion should be: - Substituted as far as possible - Re-designed in order to reduce their adverse effects - Safely used and emissions/exposure be controlled along the whole life cycle, until less hazardous alternatives are available - Tracked through their life cycle
Criterion H3	The criterion refers to the group of **other hazard classes**, including here all hazard properties not covered by criteria H1 and H2, as defined in Table 3. Following a similar approach described above, a safety level or score will be assigned to the chemicals or materials under this category in order to be integrated in the overall SSbD assessment.	The chemicals and materials that do not pass this criterion should be: - Flagged for review and eventually reduce toxic effects - Ensure their safety along the life cycle until less hazardous alternatives are available

3. Methodology

Criteria choices towards a baseline analysis of criteria for the value chains

An overview of key SSbD safety, environmental, social and market-related criteria were identified taking into account all the references, but mainly from the JRC SSbD framework ((Caldeira 2022) (Table 6, Table 7, Table 8, and Table 9). Although Social and Economic criteria are not yet part of the JRC framework, it has been considered as mostly relevant and have been consequently listed.

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Table 6. General safety criteria (adapted mainly from the JRC framework (Caldeira 2022))

SAFETY CRITERIA	Human Health Hazard	Environmental hazards	Physical hazards
	SVHC / PMT	SVHC / PMT	Explosives
	Cytotoxicity	Ecotoxicity	Flammable gases, liquids, solids
	Inflammation	Environmental safety aspects of production and processing	Aerosols
	Oxidative stress	Environmental safety aspects in the final application phase	Oxidising gases, liquids, solids
	Genotoxicity	Environmental safety aspects in the end-of-life treatment (between end-of-life and recycling)	Self-reactive
	Endocrine disruption (ED)		Pyrophoric liquids, solids
	Acute human health		Self-heating
	Chronic human health		In contact with water emits flammable gas
	Process-related hazards (processing and recycling)		Organic peroxides
	Human health and safety aspects of production and processing		Corrosivity
	Human health and safety aspects in the final application phase		Desensitises explosives
	Human health and safety aspects in the end-of-life treatment (between end-of-life and recycling)		

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Table 7. General environmental criteria (adapted mainly from the JRC framework (Caldeira 2022))

ENVIRONMENTAL CRITERIA	**Reduce climate impact, mitigate & adapt to climate change**	**Preserve & restore natural resources quality**	**Protect & restore biodiversity and ecosystems services**	**Improved circularity potential**	**Use of alternative feedstocks: components**	**Sustainable use of natural resources**	**Safety, Health & Environmental profile**
	Reduced carbon footprint in production	Water, soil, carbon sinks, water treatment potental	Pollution preventtion and control	Biodegradability or comportability of products	Use of waste/ recycled material	Reduced water footprint (use)	Human toxicity (cancer and non-cancer)
	Enabling renewable products and GHG savings downstream	Land use	Emissions to air, water and soil	Waste prevention (production, use)	Use of biobased feedstocks/components	Raw material scarcity	Aquatic and terrestrial ecotoxicity
	Biobased products	Abiotic depletion potential		Support of recycling opportunities in the VC		Enabling downstream resource savings	Abiotic depletion
	Renewable energy	Eutrophication potential		End of life management		Use of competing renewable raw materials	Acidification
	Energy consumption			Recyclability		Fossil resources	Eutrophication (terrestrial, fresh water, marine)
	Climate change (GWP)			Durability (lifetime extension)		Solvent use	Ozone layer depletion and ozone layer formation
				Repairaibility of the product			POCP
							Particulate matter
							Ionizing Radiation

Table 8 General social criteria (adapted mainly from the JRC framework (Caldeira 2022)); OHS, occupational health and safety; H&S, Health and safety

SOCIAL CRITERIA	**Health & Safety**	**Basic human rights & needs**	**Skills & Knowledge**	**Employment**	**Well-being**
	OHS risks	Fair wages	Skills, knowledge & employability	Management of reorganisation	Job satisfaction
	H&S local communities	Appropriate working hours	Promotion of skills & knowledge local communities and conssumers	Job creation	Work-life balance
	Management of workers H&S	No forced labour			Access to tangible resources
	Product safety	human trafficking and slavery			Nuisance reduction
	Impact on consumer health	No discrimination			Community engagement
		Social/ employee security and benefits			Responsible communication
		Access to basic needs			Consumers' product experience
		Respect for human rights & dignity			

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Table 9 General market-related criteria (adapted mainly from the JRC framework (Caldeira 2022)) and from value-chain perspective

MARKET RELATED CRITERIA	Transparency and information
	Value chain collaboration
	Product performance
	Stakeholder requirements
	Cost analysis/economic viability

The methodology has been developed by Cefic and EFCC based on the JRC Framework Report. The publications in 'Section 8. Additional references used in the evaluation criteria' have been used to draw up a list of value-chain specific State-of-the-Art SSbD criteria. They have been used by each value chain to select those potential SSbD criteria/indicators that are most relevant for their value chain.

A spreadsheet has been prepared that provides a broad set of SSbD indicators as well as a set of extended social indicators.

The key SSbD indicators covered a life cycle thinking approach including:

- the manufacture (or sourcing) of raw materials
- the production stage
- the use stage
- the end-of-life stage.

Each of the Value Chain partners has identified the key SSbD indicators for their Value Chain.

4. General observations

A commonality between the seven Value Chains is the **complexity** of the value chains: most VCs selected for the evaluation of the SSbD criteria are long and diverse. This makes a reliable comparison of the validity of SSbD criteria challenging. Therefore, in most cases a selection has been made of (**sub) value chain(s)** that allow a comparison of the validity of the SSbD criteria. Nevertheless, even for these (sub) value chains, it continues to be a challenge because of their complexity and the numerous stages of the VCs. Conversely, there are a high number of **common** SSbD criteria among all VCs chains that warrant further evaluation and, where possible, quantification, for example through Life Cycle Assessment (LCA).

It is important to note that the SSbD concept not only provides challenges, but also opportunities to improve the safety and sustainability of the VCs involved. All VCs have in common that currently research, development and innovation activities often focus on improving the sustainability of the VCs, where feasible through improved design of the VC and/or substitution of some critical raw materials or substitution of very harmful substances or recyclability improvement.

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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.

Although there are many commonalities among the VCs, such as the use of restricted substances at the raw materials stage (most VCs) or emissions to the environment at the production stage (most VCs), there are also significant differences, for example in the geographic coverage: textiles (global) and construction (local).

Common SSbD criteria across almost all VCs are (some differences exist at the end of life, e.g., for fragrances):

- **Raw materials stage**
  - sustainable sourcing of raw materials
  - restricted substances related to environmental and/or human health hazards.
- **Production stage**
  - emissions (air, water, soil)
  - energy consumption
  - water consumption
  - restricted substances related to environmental hazards.
- **Use stage**
  - use of sustainable resources
  - energy efficiency / consumption
  - water consumption
- **End-of-Life stage**
  - waste
  - recyclability / circularity potential

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5. Findings per value chain

5.1. Packaging

The VC of the packaging sector is rather complex, therefore for the purpose of the IRISS project, the focus will be on the sub-value chain of **plastic packaging** as visualized in Figure 3. Moreover, inputs from other areas: paper and glass packaging will be covered. The plastic packaging value chain is described in Figure 3.

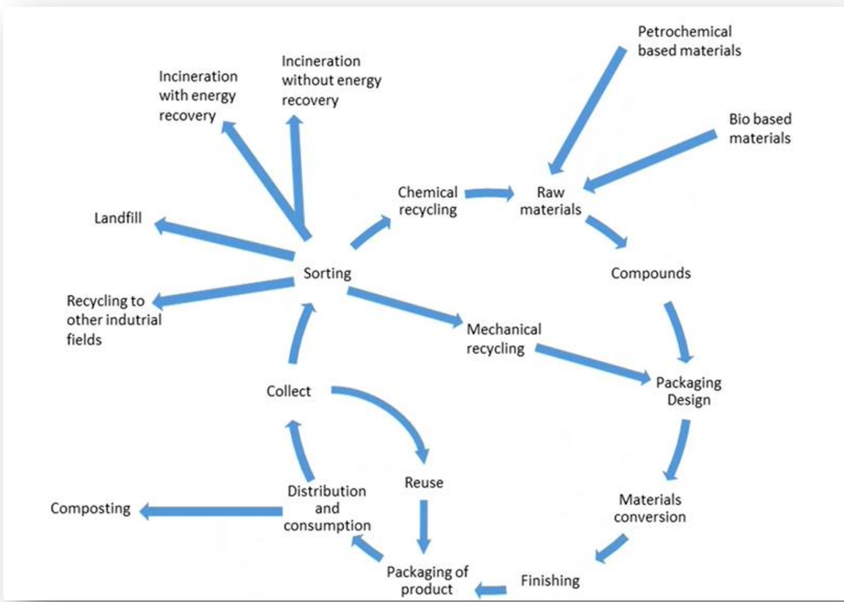

Figure 3 (Plastic) packaging supply chain

Safe and Sustainable criteria are already applied in the packaging VC, especially for new design. This is particularly due to existing regulations in EU and other regions of the world. The EU Packaging and Packaging Waste Directive (PPWD) will be replaced by an EU Regulation, which provides a great example of regulations-driven application of Safe and Sustainable criteria.

Safe criteria represent key aspects of packaging design:

- Design teams address intrinsic hazards and select raw materials on the allowed list of ingredients (no Substances of Very High Concern for example).
- Food contact applications are even stricter on ''Safe'' criteria with practice of specific regulations and safety criteria.
- End of life treatment and waste management are developing new processes. These introduce new SSbD criteria for human health and environmental safety. An example is a scientific study on

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microplastics' release and toxicity (ecotoxicity and cytotoxicity), with development of new safety assessment methods.

- Risk exposure during production is addressed in EU facilities. New safety assessment methods are being developed to widen the scope of measured exposure and to better integrate production safety aspects during packaging design. Consideration of Non-Intentionally Added Substances is an example of a new, developing area.

Concerning Environmental criteria, key Sustainable criteria are:

- Sustainable use of natural resources with EU targets on:
    - Resources use reduction. Coming PPW Regulations foresee mandatory recycled content for packaging. A global target is to reduce the use of packaging materials. This also includes a change in consumers' experience with practice of reuse or refill for example. Reducing the use of fossil energy resources is also part of the resources use reduction.
    - Waste reduction. Waste reduction targets are established by EU regulations for packaging.
    - Food waste reduction. Most of plastic packaging embed food preservation functionalities that are key to avoid food waste and ensure safe use of packaged food.
- Environmental criteria are considered all along the entire life cycle of the plastic packaging Value Chain: materials, production, use, end of life. This is due to the multitude of environmental impacts. For materials, use of alternative feedstock / components is deployed: bio-based plastics, recycled plastics. A key point is to develop and obtain bio-based and recycled plastic materials suitable for food contact applications. Finding ways to recycle plastic offer a huge potential to improve the economy circularity.
- For social criteria key aspects are:
    - Impact on consumer health
    - Land rights and access to material resources. For example, these criteria are considered during development of bio-based materials for packaging applications.
    - Consumer's product experience with on-going change such as waste management, deployment of reuse or refill models.

Table 10 presents an exhaustive list of SSbD criteria for packaging Value Chain.

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Table 10. Criteria for packaging value chain

PACKAGING - PLASTIC PACKAGING VALUE CHAIN	ENVIRONMENTAL CRITERIA	SAFETY CRITERIA	SOCIAL CRITERIA
RAW MATERIALS	Reduce climate impact, mitigate & adapt to climate change	CLP / SVHC / PMT	Access to material resources (water, minerals, land, biological resources)
	Use of alternative feedstocks/components: Use of waste/ recycled material	Ecotoxicity	Land rights
	Use of alternative feedstocks/components: use of biobased feedstocks/components	Cytotoxicity	Public commitments to sustainability issues
	Sustainable use of natural resources: Use of competing renewable raw materials		
	Preserve & restore natural resources quality: Abiotic depletion potential		
	Sustainable use of natural resources: fossil resources		
	Safety, Health & Environmental profile: Human toxicity (cancer and non-cancer)		
PRODUCTION STAGE	Reduce climate impact, mitigate & adapt to climate change: Reduced carbon footprint in production	Process-related hazards (processing and recycling)	Contribution to economic development
	Safety, Health & Environmental profile: Human toxicity (cancer and non-cancer)	Human health and safety aspects of production and processing	OHS risks
	Sustainable use of natural resources: Raw material scarcity	CLP / SVHC / PMT	Management of workers H&S
	Sustainable use of natural resources: Enabling downstream resource savings	Environmental safety aspects of production and processing	
	Sustainable use of natural resources: fossil resources	Flammable gases, liquids, solids	
	Sustainable use of natural resources: Reduced water footprint (use)	Oxidising gases, liquids, solids	
USE STAGE	Sustainable use of natural resources: Enabling downstream resource savings	Environmental safety aspects in the final application phase	Product safety
	Improved circularity potential: Waste prevention (production, use)	Human health and safety aspects in the final application phase	Impact on consumer health
	Improved circularity potential: Durability (lifetime extension)	Cytotoxicity	Consumers' product experience
	Reduce climate impact, mitigate & adapt to climate change: Enabling renewable products and GHG savings downstream	Ecotoxicity	Community engagement
	Safety, Health & Environmental profile: Human toxicity (cancer and non-cancer)		
	Sustainable use of natural resources: fossil resources		
	Safety, Health & Environmental profile: Particulate matter		
END_of_LIFE	Improved circularity potential: Waste prevention (production, use)	Environmental safety aspects in the end-of-life treatment (between end-of-life and recycling)	Community engagement
	Improved circularity potential: Support of recycling opportunities in the VC	Human health and safety aspects in the end-of-life treatment (between end-of-life and recycling)	Responsible communication
	Improved circularity potential: Recyclability	Ecotoxicity	promotion of skills & knowledge local communities and conssumers
	Improved circularity potential: Biodegradability or comportability of products	Cytotoxicity	End-of-life responsibility
	Improved circularity potential: end of life management		Public commitments to sustainability issues
	Safety, Health & Environmental profile: Particulate matter		
	Sustainable use of natural resources: Raw material scarcity		
	Sustainable use of natural resources: fossil resources		
	Sustainable use of natural resources: Reduced water footprint (use)		

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5.2. Textiles sector

The Textiles VC is rather complex (cf. Figure 4 depicting hierarchy and relational complexity):

Figure 4 Textiles supply chain

In the Textiles VC, key SSbD criteria include worker conditions in raw materials manufacture, restricted substances related to worker health & safety in production, emissions (air, water, soil) in the production, use and end-of-life stages, and energy and water consumption as well as microplastics in the use and end-of-life stages.

Increasingly SSbD criteria are considered in the design, product development and manufacturing of textiles, both on a strategic as well as operational level. Like in the other VCs, reduction of the overall carbon footprint is looked for, throughout the VC through low $C0_2$ energy sources, reduced transportation, increased durability, etc (Table 11).

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Table 11. Criteria for textiles value chain

TEXTILES - Work wear and protective clothing	ENVIRONMENTAL CRITERIA	SAFETY CRITERIA	SOCIAL CRITERIA
RAW MATERIALS	Antimony (synthetic fibres)	Agrochemical exposure of farmers	Subsistence of farming (espec. smallholders)
	Waste fibres (as raw materials)	Working conditions / worker safety in fibre plants	Child and forced abour
	Desertification & biodiversity loss due to intense farming		Fair trade
PRODUCTION STAGE	Emissions (air, water, soil)	Safe handling of chemicals in production	Fair pay & human rights in suply chain
	Energy consumption	Restricted substances related to worker health & safety hazards	Worker protection/OHS risks
	Water consumption	General working conditions / worker safety in factories	Skills, knowledge and employability
	Recycling of production waste		Work-life balance
	Recovery of process chemicals		
USE STAGE	Emissions (air, water, soil)	Substances of concern in final articles	Creativity & self-expression (fashion & interiors)
	Energy consumption	Safe product use and care (e.g. protective clothing)	Affordability
	Water consumption		
	Microplastics		
END_of_LIFE	Emissions (air, water, soil)		
	Inappropriate disposal in mixed waste streams and landfills		
	Microplastics		

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5.3. Construction chemicals sector

There are many construction materials VCs, most of the VCs are based on natural materials such as adobe, bamboo, clay, stone, straw and wood, there are basically two VCs that use chemicals as raw materials: concrete admixtures, such as super-plasticizers, for concrete, and polystyrenes or polyurethanes for flooring, windows, etc. In first instance, the focus has been on the VCs involving super-plasticizers. Consequently, also the evaluation of SSbD criteria is also focused on these (sub) VCs.

The construction chemicals' supply chain (focusing on concrete) is visualized in Figure 5:

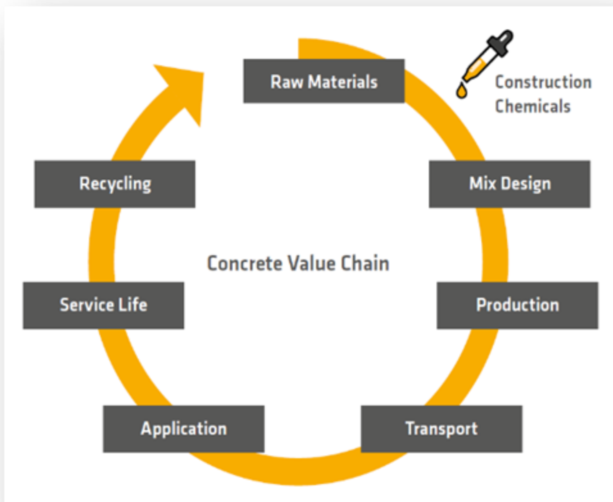

Figure 5 Construction chemicals' supply chain

The main VC that uses construction chemicals is the one involving concrete, which is by far the most used material in construction. Concrete is a composite made of several materials, including cement and concrete admixtures (the latter are construction chemicals).

The key SSbD criteria for this VC are: the use of restricted substances related to human health and/or environmental hazards of raw of materials manufacture or in the production of construction chemicals, emissions to air, water and soil at the production and use stages, recycled materials (concrete waste) in production, energy and water consumption at the production and use stages, durability at the use stage, and, recyclability and reuse at the end-of-life stage (Table 12).

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Table 12. Criteria for construction value chain

CONSTRUCTION - EFCC	ENVIRONMENTAL CRITERIA	SAFETY CRITERIA	SOCIAL CRITERIA
RAW MATERIALS	Sustainable sourcing of raw materials - natural resources		Social responsibility
raw materials	Restricted substances related to environmental hazards	Restricted substances related to health & safety hazards	
PRODUCTION STAGE	Emissions (air, water, soil)		
	Energy consumption		
Super-plasticizers	Water consumption		
	Waste generation	Safe handling of raw materials and products	
	Restricted substances related to environmental hazards	Restricted substances related to health & safety hazards	
USE STAGE	Emissions (air, water, soil)		Social responsibility
	Energy consumption		
	Reduced carbon footprint in use		
	Water consumption	Physical safety hazards	
Concrete	Functionality (fitness for use)		
	Recycled material content		
	Durability		
	Repairability		
END_of_LIFE	Recyclability		Social responsibility
Construction waste	Waste		

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5.4. Automotive sector

The value chain of the automotive industry is very complex (see Figure 6) and is composed of different tiers of suppliers, namely: Tier 1 – Building and supplying finished components, ready for vehicle assembly, Tier 2 – Supplying parts and components, e.g., electronics and semiconductors, not only for the automotive industry, and Tier 3-n – Suppliers of raw or unfinished materials, e.g., minerals, metals, and plastics. These tiers ultimately supply to **OEM**s (Original Equipment Manufacturers), i.e., carmakers.

In Figure 6, a procedural depiction of the value chain and its relation to product flow and demand flow are given.

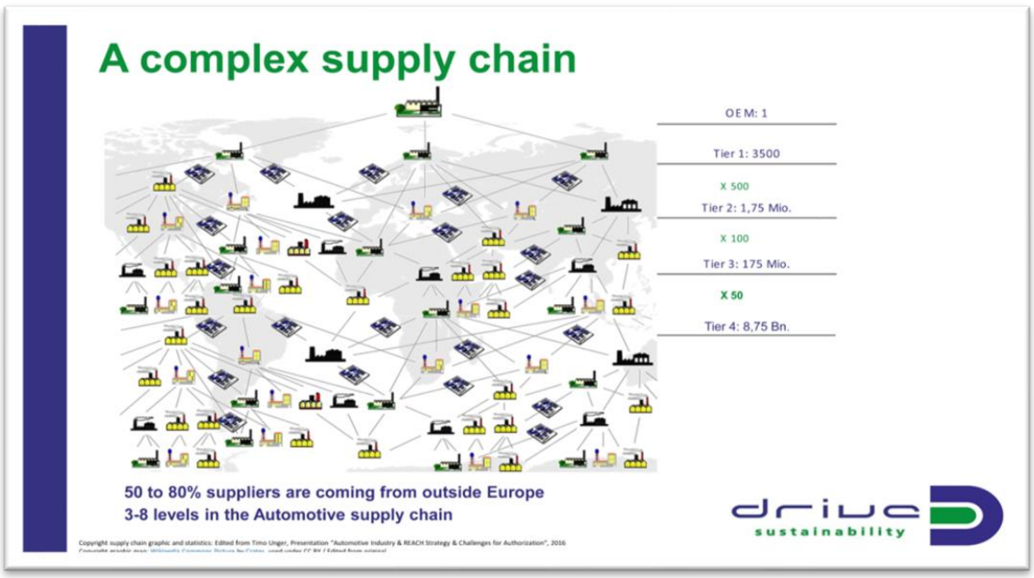

Figure 6 Supply chain complexity in the automotive sector

Safety and sustainability are aspects that are deeply engraved in the life cycle of automotive products and even more so, following the Green Deal and the tendency towards ‘cleaner mobility’, which has often translated into a push towards Electrification. At the same time, Circularity and Digitalisation requirements ramp up. These triple-threat is pressuring suppliers and OEMs to adapt the product design, choice of materials and chemicals to comply with the many substance restrictions, due diligence requirements and other sustainability demands. The supply chains will need logistic rethinking, to adapt to increased data and traceability obligations. For example, electrification is enhancing the focus on responsible procurement and circularity of raw materials to help address the expected shortage of critical materials (e.g., rare earths, lithium, cobalt, etc). Also, digitalization will help to close the material loops by providing accurate information on the availability, location, and condition of vehicle components. Already, automotive stakeholders are implementing sustainability initiatives such as the increased use of recycled and bio-based materials, selection of lighter materials to reduce the vehicle weight, reduction of waste during manufacturing and increased recovery of materials from End-of-Life vehicles.

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OEMs and automotive suppliers are dynamically developing capacities and building dedicated teams to work on several aspects of sustainability, such as circularity, LCA or sustainable material choices. Moreover, the *End-of-Life Vehicle Directive* has requirements on circularity: at least 80% of a vehicle's weight has to be repaired or recycled, which is easily achieved, considering that the metal parts of a car can be easily recycled.

The key SSbD criteria identified for the automotive sector are listed below in Table 13. To name a few: ethical sourcing of raw materials, such as the reduction or substitution of hazardous substances related to human health and environmental pollution, material, energy and water consumption during the production stage, energy (fuel) efficiency and of renewable energy sources during the use stage, considerations on driver safety, end-of-life disassembly, and recyclability.

The automotive supply chain is so complex and includes linkages between this value chain and others represented in this project such as electronics, energy materials and textiles. Nevertheless, it is important to map and understand the specific criteria of each final product, as the different applications often translate in different challenges and opportunities across value chains (Table 13).

Table 13. Criteria for automotive value chain

AUTOMOTIVE - CLEPA	ENVIRONMENTAL CRITERIA LIST	SAFETY CRITERIA LIST	SOCIAL CRITERIA
RAW MATERIALS	Ethical sourcing of raw materials - natural resources	Restricted substances related to human health hazards	Consumer perspective on ethical implications of CRMs
	Restricted substances related to environmental hazards	Selection of materials based on mechanical and durability properties	Consumer preferences as a guideline for material choice
	Import dependency	Ethical sourcing of raw materials - safety of workers in unregulated work environments in third countries	Biobased materials in competition with food source
PRODUCTION STAGE	Emissions (air, water, soil)	Working conditions / worker safety	Job losses and gains due to ban on vehicles in cities, ban on ICEs
	Design for circularity (e.g. modularity; standardisation of materials and parts; etc.)	Product design based on safety specifications	Reskilling and upskilling due to electrification, circular economy, digitalisation, LCa, ...
	Restricted substances related to environmental hazards		User-centric design/fit for purpose vehicles
	Material and energy consumption		
	Water consumption		
USE STAGE	Emissions (air, water, soil)	Use of Safety specific components - airbags, seatbelt, etc.	User comfort
	Energy efficiency and use of renewable energy sources	Automation as a solution for road accidents	Personalisation of vehicles
	Repairability (e.g. availability of spare parts)		Shared-use business model
	Upgradability (e.g. software updates)		Access to repair shops - affordability of repair/reman
END_of_LIFE	Recyclability - Design for recycling	Safe disassembly of EoL components ; Safe deactivation of batteries	Knowledge on procedure for handling EoL (costs, obligations, ...)
	Waste management	State of Health of EoL components when planning for second life applications	Export to third-countries (that rely on European ELVs)

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5.5. Energy materials sector

The energy materials VC focuses on renewable energy solutions: photovoltaics, windmills, and batteries, with a focus on the battery VC.

The battery value chain and its key players are depicted in Figure 7:

Figure 7 Energy materials' supply chain

The electrification of the energy and transport sectors is a huge transformation. The world has never known a period of such rapid technological, industrial, and societal change. With the rapidly growing demand for batteries, it is beyond contest that we must chart a path forward in which batteries are designed and manufactured in such a way as to not repeat mistakes of the past and leave a burden for future generations. SSbD criteria basically cover all segments of the batteries VC.

Key SSbD criteria are linked:

- at the raw material stage, with the exponential demand for raw materials, such as Lithium, Nickel, and Cobalt: resource depletion, sustainable and ethical sourcing of primary and secondary raw materials, the use of restricted substances related to human health and environmental hazards, and the imposed use of waste/recycled material
- at the production stage, with the rapid deployment of new manufacturing gigafactories: emissions to air, water and soil, the use of renewable energy sources, the use of restricted substances (NMP) related to environmental, health & safety hazards; materials and energy efficiency, the recycling of production scraps; and nuisance reduction for acceptance by local communities
- at the use phase, with the needed acceptance of the transition to EVs: environmental footprint (renewable electricity), safety (flammability) and durability (reparability), and affordability for consumers
- at the end-of-life stage, with the mandatory circularity of batteries (ref. new sustainable battery directive: https://www.europarl.europa.eu/news/en/press-room/20221205IPR60614/batteries-

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deal-on-new-eu-rules-for-design-production-and-waste-treatment): second use, recyclability, and waste management. End-of-life treatment and recycling of batteries are already a high priority in the sector. The Battery Directive has requirements on circularity, imposing minimum percentage of recycled materials (Table 14).

Table 14. Criteria for energy value chain

ENERGY - EMIRI - battery - energy storage	ENVIRONMENTAL CRITERIA	SAFETY CRITERIA	SOCIAL CRITERIA
RAW MATERIALS	Resource depletion		Ethical sourcing of raw materials - natural resources
	Sustainable use of natural resources: fossil resources	Restricted substances related to worker health & safety hazards	
	Use of alternative feedstocks/components: Use of waste/ recycled material		
PRODUCTION STAGE	Emissions (air, water, soil)		Local community: nuisance reduction
	Renewable energy use		
	Reduce climate impact, mitigate & adapt to climate change: Reduced carbon footprint in production		
	Restricted substances related to environmental hazards (NMP)	Restricted substances related to worker health & safety hazards	
	Recycling of production waste		
	Material and energy consumption		
USE STAGE	Environmental footprint	Flammability of materials	Consumers: affordability
	Improved circularity potential: Durability (lifetime extension)	Self-heating	
	Repairability (e.g. availability of spare parts)		
END_of_LIFE	Improved circularity potential: Recyclability	Environmental safety aspects in the end-of-life treatment (between end-of-life and recycling)	
	Improved circularity potential: end of life management		
	Waste management		

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5.6. Electronics sector

The electronics VC can be represented by an inverted-pyramid diagram (see Figure 8) in terms of its market size (the values presented are based on pre-pandemic data).

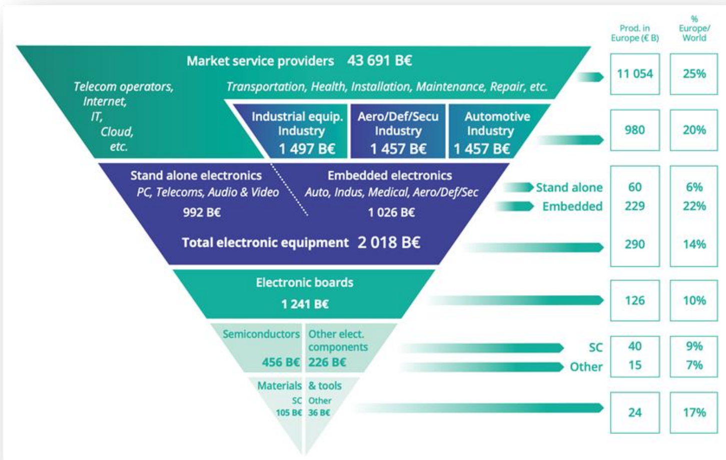

Figure 8 The supply chain of the electronics sector

SSbD criteria related to raw materials are mainly related to the apex of the electronics VC (Figure 8), so at the level of producing semiconductors and electronic components, and their integration into packages and electronic boards.

The key SSbD criteria for the electronics VC are sustainable sourcing of raw materials such as metals, the use of restricted substances related to human health & safety and environmental hazards at the raw materials and production stages, the use of conflict minerals as raw materials, emissions to air, water and soil at the production stage, energy consumption at the production stage, energy consumption and functionality and the use stages and waste at the production and end-of-life stages.

At the production stage, the unique feature of the electronics VC is the use of clean rooms, so protection of human health from exposure to dangerous substances is typically a positive side-effect of operating in a cleanroom environment (Table 15).

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Table 15. Criteria for electronics value chain

ELECTRONICS - INL	ENVIRONMENTAL CRITERIA	SAFETY CRITERIA	SOCIAL CRITERIA
RAW MATERIALS	Sustainable sourcing of raw materials		Social responsibility
	Restricted substances related to environmental hazards	Restricted substances related to health & safety hazards	
	Conflict minerals		
PRODUCTION STAGE	Emissions (air, water, soil)		
	Energy consumption		
	Water consumption		
	Restricted substances related to environmental hazards	Restricted substances related to worker health & safety hazards	
	Waste		
USE STAGE	Energy consumption	Often controlled by design, as restricted substances are encapsulated	
	Functionality (fitness for use)		
END_of_LIFE	Recyclability		Large volume of electronic waste exported to low-income countries
	Waste		

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5.7. Fragrance sector

The fragrance VC, unlike the other Value Chains involved in the IRISS project, is linear as it is largely non-recyclable (see Figure 9):

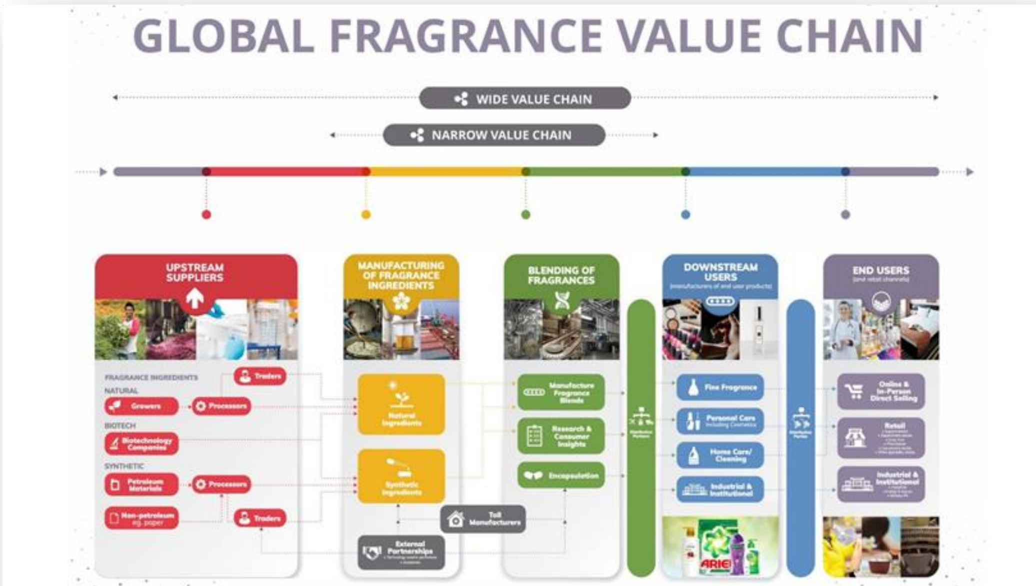

Figure 9 Fragrances supply chain

The fragrance VC is different in many respects compared with the other Value Chains and therefore also has a different set of key SSbD criteria. One major difference is its linearity, resulting in a priority for biodegradation of fragrances since recycling and circularity aren't among the options. Furthermore, additional specific sustainability criteria are e.g., deforestation, agricultural impact such as land and water use and biodiversity for the fragrances sourced naturally.

Nevertheless, there are also common SSbD criteria, such as the sourcing and use of natural raw materials, restricted substances related to human health (raw materials, production and use stages), emissions to air, water and soil at production and use stages, and energy consumption at the production stage especially for synthetically produced fragrances.

Some of the social SSbD criteria are very different from the other VCs, such as, cultural heritage, small farmers, child labour, diversity and fair trade at the raw materials stage, community integration and work-life balance at the production stage, and affordability and consumer needs at the use stage, and appropriate disposal procedures at the end-of-life stage.

Safe-by-design principles have been applied and have been evolving in the fragrance VC for the past 20 years. Safety and safe use are key criteria for fragrances, and early screening and designing of safe fragrances for consumer use are at the core of innovation. Besides the hazard criteria of most harmful

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substances such as CMR, ED, PBT/vPvB, PMT/vPvM), skin sensitization has a special focus because of consumer use of the end products (Table 16).

Table 16. Criteria for the fragrance value chain

FRAGRANCES - IFRA	ENVIRONMENTAL CRITERIA	SAFETY CRITERIA	SOCIAL CRITERIA
RAW MATERIALS	Sustainable sourcing of raw materials (natural resources - renewable raw materials - fossil materials)	Restricted substances related to human health hazards	Cultural heritage
	Bio-inspired synthetic raw materials	Working conditions / worker safety	Access to basic needs - well-being
	Renewable carbon resources, renewable feedstocks and bio-sourced ingredients		Smallholders including farmers
	Biodiversity and land use		Respect for human rights & dignity
	Water, soil, carbon sinks, water treatment potential		Social/ employee security and benefits
	Re-use/ recycling and/or disposal of waste streams		Fair wages
			Child labour
			Diversity
			Fair trade
PRODUCTION STAGE	Emissions (air, water, soil)	Environmental safety aspects of production and processing	Work-life balance
	Energy consumption	No most harmful chemical substances	OHS risks
	Restricted substances related to environmental hazards	Alternatives to animal testing for safety assessment	Skills, knowledge and employability
	Reduced carbon footprint in production	Restricted substances related to worker health & safety hazards	Community integration
		Human health and safety aspects of production and processing	
USE STAGE	Emissions to air, water and soil	Environmental safety aspects in the final application phase	Consumers' product experience
	Restricted substances related to environmental hazards	Restricted substances related to worker health & safety hazards	Essential consumer's functional and emotional needs
		No most harmful chemical substances	Affordable
		Human health and safety aspects in the final application phase	
		Standards for the safe use of fragrances and mixtures	
END_of_LIFE	Biodegradability - low environmental toxicity	Low environmental ecotoxicity	No polution - no waste
	Appropriate disposal procedures	Environmental safety aspects in the end-of-life treatment (between end-of-life and recycling)	End-of-life responsibility
		Appropriate disposal procedures	

6. Next steps

The follow-up work of this Deliverable will be done during the case studies' exercise that the VCs have volunteered for, in order to support the JRC Framework testing phase. The ultimate objective is to get quantitative data for the key SSbD criteria in each VC as far as possible.

Some VCs will be able to perform and/or provide Safety and Life Cycle Assessments providing such detailed quantitative information, depending on the data availability when they will be testing the JRC framework.

As the JRC framework was not issued at the time the project definition was developed, the other VCs deliverables will now take it into account, using the SSbD criteria presented in this report concretely and quantitatively.

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