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

Preliminary report

Mapping of Skills

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Project acronym	IRISS
Work Package	WP1
Report n° and title	PR1.5 Mapping of Skills
Report Leader	Leuphana
Type	PR – Preliminary Report
Dissemination Level	Public
Submission Date	31/05/2023
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Our partners:

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Abbreviations and Acronyms

Abbreviation	Definition
BbD	Benign by Design
CAS	Certificate of Advanced Studies
CBS	Certificate of Basic Studies
CCaLC	Carbon calculations over the life cycle
Cedefop	European Centre for Development of Vocational Training
Cefic	European Chemical Industry Council
CFP	Corporate Financial Performance
ChemSec	International Chemical Secretariat
CLP	Classification, labelling, and packaging of chemicals regulation
CMR	Carcinogenic, mutagenic, or reprotoxic
CSS	Chemicals Strategy for Sustainability
EEA	European Environment Agency
EHS	Environmental Health and Safety
ESCO	European Skills, Competences, Qualifications and Occupations
ESG	Environment, Social, Governance
ETHZ	Swiss Federal Institute of Technology Zurich
FAIR data	Findable, accessible, interoperable, and reusable data
H2020	Horizon 2020
HE	Horizon Europe
ICT	Information and Communication Technologies
JRC	Joint Research Centre
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
M.Eng.	Master of Engineering
M.Res.	Master of Research

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Abbreviation	Definition
M.Sc.	Master of Science
MCDA	Multiple-criteria decision analysis
NAM	New Approach Methodologies
NKUA	National and Kapodistrian University of Athens
NMBP	Nanotechnologies, advanced materials, biotechnology and advanced manufacturing and processing
NTUA	National Technical University of Athens
OECD	Organisation for Economic Co-operation and Development
OHS	Occupational Health and Safety
PEF	Product Environmental Footprint
PGDip	Postgraduate Diploma
POPs	Persistent Organic Pollutants
PR	Preliminary report
R&I	Research & Innovation
RMM	Risk Minimisation Measure
ROHS	Restriction of Hazardous Substances
RRI	Responsible Research and Innovation
SDGs	Sustainable Development Goals
SG	Steering Group
SRIP	Strategic Research and Innovation Plan
SSbD	Safe-and-Sustainable-by-Design
SIA	Safe(r) Innovation Approach
SSIA	Safe(r) and Sustainable Innovation Approach
SVHC	Substances of very high concern
UN	United Nations
VC	Value Chain
WP	Work package
WPMN	Working Party on Manufactured Nanomaterials

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1. Executive summary

Safe-and-Sustainable-by-Design (SSbD) is a design concept that integrates safety and sustainability (environmental, social, and economic) aspects at early stages of the chemical, material, or product innovation. The focus is on providing a desired functionality, while avoiding volumes and chemical properties that may be harmful to human health or the environment and adopting a life cycle perspective. With the launch of the SSbD framework by the Joint Research Centre (JRC) of the European Commission (EC), current work in the field of SSbD is focused on enabling the uptake of this framework in industrial applications.

The work presented in this preliminary report PR1.5 is part of the mapping activity conducted within IRISS Work Package (WP) 1 and is the main outcome of Task 1.5 'Mapping skills availability and needs'. It provides up-to date information on needed SSbD skills and their availability in industrial and research practices, as well as educational activities. The methods of this work comprised a literature review and stakeholder surveys by means of questionnaires.

The results highlight the interdisciplinary nature of the SSbD approach and provide an overview of the wide range of policy ambitions and regulations as well as scientific principles and disciplines of which SSbD actors need to be aware. The application of SSbD in practice requires broad design and assessment skillsets. These include knowledge of the entire life cycle, from the supply-chain of raw materials to the end-of-life of the final product, as well as interpersonal skills to work in multidisciplinary design teams and to collaborate across supply chains and with all actors along the product's life cycle. Systems thinking skills are also needed to consider the whole life cycle already at the design stage. Furthermore, the results highlight the pressing need for knowledge and skills related to understanding the JRC framework and performing the required assessments, in particular in terms of data collection and use of available tools.

Regarding industrial and research practices and educational activities, the results show that a wide range of SSbD aspects (e.g., Benign by Design (BbD), Life Cycle Assessments (LCA), modelling tools, circular business models) are well embedded in today's academic education, but there is little interaction between these aspects, which is necessary for the application of SSbD. The results also show that safety aspects are more often considered in practice, especially in companies, than sustainability related aspects - with the exception of EU projects, where there is a focus on life cycle thinking. Alternative business models are only rarely considered or even applied by companies.

Training modules to be developed should be tailored to small and medium enterprises (SMEs) and should support a better understanding of the JRC framework and its implementation. There is a greater need for training on sustainability and circularity aspects than on safety ones: in particular, training related to performing an LCA (mainly environmental, but also social and economic) and applying appropriate tools is needed. Strong coordination and knowledge transfer between SSbD actors along the whole life cycle is also necessary to share the relevant expertise, data, and information.

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2. Introduction

2.1 Background of the Safe-and-Sustainable-by-Design (SSbD) concept

The European Green Deal is integral to implementing the United Nations (UN) Sustainable Development Goals (SDGs) and aims to transform the EU's economy for a sustainable future (European Commission, 2019). Key aspects of the European Green Deal and its green transition are zero-pollution, climate neutrality, resource-efficiency, circular economy, decoupling of economic growth and resource use, and protection from environment-related risks (European Commission, 2019). Achieving these ambitious long-term goals will require new approaches that go beyond current regulatory compliance.

In October 2020, the European Commission published the Chemicals Strategy for Sustainability (CSS) as a core element to achieve the European Green Deal ambitions (European Commission, 2020b). In the strategy's vision of a toxic-free environment, *"chemicals are produced and used in a way that maximises their contribution to society […], while avoiding harm to the planet and to current and future generations"* (European Commission, 2020b). The CSS calls for a transition to chemicals and materials that are safer and more sustainable and also gives a first proposal for the definition of Safe-and-Sustainable-by-Design (SSbD) "*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 minimising the environmental footprint of chemicals in particular on climate change, resource use, ecosystems and biodiversity from a life cycle perspective"* (European Commission, 2020b). The strategy sees the transition to SSbD as both a social urgency and a great economic opportunity for the EU chemical industry to regain competitiveness (European Commission, 2020b).

This urgent need for SSbD was taken up in the recently published Strategic Research and Innovation plan (SRIP) and in the Transition Pathway for the Chemical Industry (European Commission, 2022d, 2023b). The Transition Pathway names developing, commercialising, deploying, and promoting the uptake of SSbD substances and materials as one action to achieve international competitiveness that should start as soon as possible, and also lists other actions to support the market uptake in the short- and medium-term.

In 2022, the Joint Research Centre (JRC) published a review of safety and sustainability dimensions, aspects, methods, indicators, and tools (Caldeira et al., 2022a), followed by a framework for the definition of criteria and evaluation procedure for SSbD chemicals and materials (Caldeira et al., 2022b) along with an EC recommendation promoting this framework (European Commission, 2022a). The JRC framework recommends a two-phase SSbD approach: The first phase is the (re-) design phase, which proposes eight SSbD guiding design principles, and the second phase is the assessment phase consisting of five steps covering both safety and sustainability (environmental, social, and economic) aspects and taking into account the entire life cycle of a chemical or material. The framework is currently in a testing phase and the engagement of industry and Member States is encouraged (European Commission, 2022a, 2023b).

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2.2 European policy ambitions related to skills

The European Skills Agenda (European Commission, 2020a) calls for a paradigm-shift in skills to strengthen sustainable competitiveness, ensure social fairness, and build Europe's resilience. This includes investing in the skills of people who will develop and apply green technologies, products, services, and business models as well as providing up-skilling and re-skilling opportunities for all people, regardless of their age, gender, or nation of origin. The right to life-long learning is even included in the European Pillar of Social Rights (Figure 1). Training opportunities can be supported, for example, through the 'Pact for Skills' which is a key action of the Skills Agenda. Also as part of the CSS, the European Commission plans to support the re-skilling and up-skilling of workforces involved in the production and use of chemicals (European Commission, 2020b).

> *Everyone has the right to quality and inclusive education, training and life-long learning in order to maintain and acquire skills that enable them to participate fully in society and manage successfully transitions in the labour market.*

Figure 1: Principle 1 of the European Pillar of Social Rights (European Parliament, 2017)

The SRIP delivers and highlights research and innovation (R&I) areas that are crucial for making chemicals and materials safer and more sustainable (European Commission, 2022d). As one key aspect, the plan sees the need to boost skills, education, and training to enhance sustainability management in industry. Specifically, SRIP calls for

i) an integrated approach in academic training for future workforces that includes environmental, social, and economic dimensions and provides an understanding of the complex relationship between society and environment,
ii) a stronger academia-industry collaboration to exchange knowledge and better meet the R&I needs of companies,
iii) societal education including (case studies) training programmes for different stakeholders.

This is supported by the Transition Pathway for the Chemical Industry (European Commission, 2023b). In the Transition Pathway, skills are included as an important building block (Figure 2) and linked to several actions.

The SRIP also sees innovation in business models as an important driver of the green transition. By focusing on the function or service a product delivers, the economic growth of these new business models (e.g., leasing or service approaches) no longer depends on selling as much as possible but on providing the function or service with optimised resource efficiency (European Commission, 2022d).

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Figure 2: The eight building blocks considered to develop the transition pathway for the chemical industry (European Commission, 2023b; Figure 2)

2.3 Meaning & description of "skills"

In order to gain an overview of the education needs within a specific domain, it is essential to delineate how these needs are identified. A common approach to delineating desired professional behaviour is to describe what would be perceived as 'professional competence' and then deconstruct that notion into its constituent components (Fernandez et al., 2012). These learning outcomes are then often described at a particular level or depth of learning using a learning taxonomy, the most well-known being Bloom's taxonomy (Irvine, 2021). This step is beyond the scope of this report but may become relevant when assessing or developing educational materials. A review of descriptions suggests that competency is generally perceived to consist of knowledge, skills, attitudes, abilities, values, judgement and personal or character attributes (Fernandez et al., 2012). In general, discourse judgement is less commonly used and personal/character attributes are to lesser extent subject of education, so these are omitted. The other concepts are described below in commonly used terms.

1. **Knowledge:** a grasp of facts, information, experience, concepts, or procedures,
2. **Value:** a sense of something that ought or ought not to be, directs choices,
3. **Skill:** proficiency in executing a specific goal-oriented behaviour,
4. **Ability**: possession of the means and/or skill to do something,
5. **Attitude:** a way of thinking or responding to situations based on values, beliefs and/or emotions,
6. **Competency:** an integrated concept: the capability to apply an integrated set of knowledge, skills, and attitudes to achieve a certain end.

The terms skill and competency are often used interchangeably. For example, in the description used by Cedefop, the European Centre for Development of Vocational Training, the term 'Green Skill' refers to "*the knowledge, abilities, values and attitudes needed to live in, develop and support a society which reduces the impact of human activity on the environment*" (Cedefop, 2012). The current report will use a slightly adapted but largely similar definition: **The term 'skill' refers to the functionally linked complex of knowledge, values, abilities, and attitudes that facilitate the implementation of SSbD in practice by a diverse range of actors.**

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3. Objectives

The objective of PR1.5 is to summarise the results from the mapping activities carried out in Task 1.5. It provides an overview of project information, industrial practices, research, and education in terms of needed skills in relation to SSbD and their availability within the IRISS consortium, its stakeholders, and other EU projects.

3.1 Description of work in WP1

Work Package (WP) 1 aims to obtain a complete overview of the SSbD methods and criteria. An important input has been previous EU projects and other research/activities in the areas of Benign by Design (BbD) and SSbD, including Life Cycle Assessment (LCA) tools. These methods form the basis for SSbD implementation and application by the framework proposed by the JRC report (Caldeira et al., 2022b). In WP1, the recommended methodology and SSbD criteria have been mapped against state-of-the-art approaches for product and process development in the different value chains (VCs) used as examples within IRISS at all product development phases of the innovation processes. The tools (instruments, testing methods, models) developed by current H2020 projects (e.g., NMBP-15 and NMBP-16-2020 calls and other related projects) have been systematically collected and analysed. Other research and educational activities and industrial practices have also been researched. Consideration was given to whether these methods are already addressing new materials (e.g., advanced or smart materials) and how safety and sustainability criteria are considered in present regulations. Specific attention has been given to evaluating whether existing methodologies to set sustainable-by-design criteria have considered differences in exposure and/or effects for different population groups (gender, age, behavioural patterns, etc.). An SSbD landscape analysis has been performed, identifying stakeholders and roles, their drivers/agendas for implementing SSbD, skills and competences, regulatory barriers, identification of liability issues and so on.

WP1 has collaborated closely with the IRISS value chains. In several iterations, outputs (e.g., mapping of SSbD criteria in tasks 1.1 to 1.4 and skills task 1.5; Table 1) have received input from the value chain representatives (WP4) providing information and feedback. WP1 will feed these mapping results to WP2 to complete a gap analysis and to WP3 to develop a roadmap. WP1 will also connect with WP5 for workshop organisation and with WP6 for future updates of the mapping activities and creation of training courses.

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Table 1: Overview of tasks within WP1

Task	Title	Timeframe
1.1	Safe-by-design methods and criteria	June 2022 – May 2023
1.2	Sustainable-by-design methods and criteria	June 2022 – May 2023
1.3	Life cycle methods and criteria	June 2022 – May 2023
1.4	Design for circular economy	June 2022 – May 2023
1.5	Mapping skills availability and needs	June 2022 – May 2023

3.2 Description of work in task 1.5

Task 1.5 'Mapping skills availability and needs' involves the analysis of project information, industrial practice, research and education in terms of skills in SSbD criteria, the skills availability (who knows what) and the skills need (to whom skills need to be transferred).

This task also includes the analysis of the available university education of IRISS academic partners. This will be used later to support the transfer and/or translation of the needed (VC-specific) skills and knowledge (this preliminary report PR1.5 and D4.4) into university and other educational curricula. This part was done in collaboration with Task 4.4.1.

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4. Methods

The methods applied to identify needed SSbD skills and their availability consist of

- a literature review to identify needed SSbD related skills (Chapter 4.1),
- an analysis of university educational offerings of IRISS partners (Chapter 4.2),
- a WP3 co-creation session to identify additional SSbD skills (Chapter 4.3),
- a survey to collect information on SSbD-related practices and needed skills from IRISS partners and stakeholders (Chapter 4.4), and
- projects sheets to collect information on SSbD-related practices and needed skills from other ongoing EU projects related to SSbD (Chapter 4.5).

The results of this work are presented in Chapters 5.1 to 5.5.

4.1 Literature review

A literature review was performed to map needed SSbD related skills. Literature sources were public documents: scientific publications in open databases, policy documents and databases, and public reports. The literature databases used were Scopus and Google Scholar.

A first search in Scopus and Google Scholar using the keywords shown in Table 2 did not reveal any list or collection of SSbD specific skills. Therefore, other keywords such as 'sustainability skills/competences' and 'circular economy design skills/competences' were used to find related skill lists of at least partial relevance to SSbD.

Table 2: Keywords used to search for relevant literature in open scientific databases.

Keywords	Results
"safe-and-sustainable-by-design" AND skill OR competence and, alternatively, "safe and sustainable by design" AND skill OR competence	No results found in Scopus. In Google Scholar, 17 results were found. In most cases, however, the terms 'skill' and 'competence' were used to indicate that skills and/or competences are needed, e.g., by suggesting 'competence centres' (Ujaczki et al., 2022). None listed or named specific SSbD skills/competences.
SSbD AND skill OR competence	In Scopus, 10 documents were found that included only one topic-related publication from the ASINA project (Furxhi et al., 2022). The other publications referred to autism and behaviour disorders in general. A search in Google Scholar showed more than 1,100 results but, with only few exceptions, all publications also referred to behaviour disorders and autism as 'SSBD' is a commonly used abbreviation for 'systematic screening for behaviour disorders'.

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As a further source, the European Skills, Competences, Qualifications and Occupations (ESCO) classification was used to identify relevant skills. ESCO is a Europe 2020 initiative that identifies, describes and categorises professional skills, competences, and occupations relevant for the EU labour market as well as education and training (European Commission, 2023c).

Furthermore, in collaboration with WP3 (development of roadmaps), five recently published SSbD approaches (Table 4) were identified and compared, including the SSbD framework developed by the JRC. The comparison is described in preliminary report PR1.2. While these documents do not give specific SSbD skills, they do provide a solid basis of SSbD considerations and aspects. Therefore, these documents (with a focus on the JRC framework) were used to derive relevant SSbD skills.

The results of the literature review are presented in Chapter 5.1 and aim to give an overview of skills that are (according to current knowledge) relevant to successfully implement and apply the SSbD concept. The focus is on key skills at a low level of detail. Information on specific methods and criteria for main SSbD aspects (Safety, Sustainability, Life Cycle, and Circularity) can be found in the reports of tasks 1.1 to 1.4 (Table 1).

4.2 Academic education offerings of IRISS partners

The educational offerings of the IRISS academic partners (Leuphana University of Lüneburg, University of Birmingham, and National Technical University of Athens (NTUA)) as well as teaching activities of the IRISS research partners IVL and Empa were analysed with regard to SSbD related aspects (Chapter 5.2). This will later support the translation of identified (VC specific) skills gaps and mismatches (Task 2.5) into an academic education module (one activity in Task 5.4).

This limitation to IRISS partners has been made in view of the academic education module to be developed, which will be anchored in existing university curricula; therefore, this study provides only an exemplary overview. The authors are aware that, in particular, environmental-, LCA- or modelling-related courses are part of the curricula at many universities, although often separately without the necessary interaction to provide information on all aspects of SSbD.

4.3 WP3 co-creation session

A WP3 co-creation session was held online on 2 December 2022 to identify skills, competences, and education needs to apply SSbD early in the innovation process (Chapter 5.3). An interactive 'Mentimeter' poll was used to collect this information from the IRISS consortium.

4.4 Survey

An online survey was designed within WP1 and coordinated by Tekniker as WP1 leader to collect information on the application of SSbD principles and criteria from IRISS partners and stakeholders (Chapter 5.4). A transcript of the survey is included in Annex A. Partners and stakeholders were

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contacted by email and asked to participate in this survey; a document with background information on SSbD was also included in this email. The questionnaire could be completed online via FORMS and included questions for 12 thematic blocks. The questions asked to each participant varied according to the answers given: for example, only companies were asked about the company size and company policy and only representatives of a research and innovation projects were asked for the project name and acronym. The survey was online between October 2022 and March 2023.

4.5 Project information

Information from other ongoing EU-funded projects related to SSbD was collected and is described in Chapter 5.5. For this purpose, the project coordinators of the most relevant identified H2020 projects and HE projects related to SSbD aspects were contacted and asked to complete the template presented in Annex B. Projects were contacted in January and February 2023. The deadline for collecting project information was the end of March 2023. Efforts were focused on H2020 projects, as the HE projects have only recently started. The analysis of HE projects will be continued in WP2.

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5. Results

5.1 Literature review on SSbD skills

The aim of this chapter is to map identified SSbD related skills as retrieved from literature, including general skills for sustainability (Chapter 5.1.1), design skills for a circular economy (Chapter 5.1.2) and relevant skills from the ESCO's Green Skills Collection (Chapter 5.1.3). Chapter 5.1.4 analyses different SSbD approaches to derive further SSbD skills, with a focus on the JRC's SSbD framework that was the base document within WP1.

5.1.1 Skills for sustainability

Wiek et al. (2011) developed a reference framework for academic program development and defined five key competencies for sustainability that were embedded into this framework (Figure 3). The key competencies should be seen in addition to 'regular' competencies, such as 'critical thinking' and 'basic communication' skills, to develop the required knowledge and skill profile of students in the field of sustainability.

The identified key competencies for sustainability are:

1. **Systems thinking competence** "*is the ability to collectively analyze complex systems across different domains (society, environment, economy, etc.) and across different scales (local to global), thereby considering cascading effects, inertia, feedback loops and other systemic features related to sustainability issues and sustainability problem-solving frameworks*" (Wiek et al., 2011, p. 207);
2. **Anticipatory competence** *"is the ability to collectively analyze, evaluate, and craft rich ''pictures'' of the future related to sustainability issues and sustainability problem-solving frameworks*" (Wiek et al., 2011, p. 207/209);
3. **Normative competence** "*is the ability to collectively map, specify, apply, reconcile, and negotiate sustainability values, principles, goals, and targets. This capacity enables, first, to collectively assess the (un-)sustainability of current and/or future states of social-ecological systems and, second, to collectively create and craft sustainability visions for these systems"* (Wiek et al., 2011, p. 209);
4. **Strategic competence** *"is the ability to collectively design and implement interventions, transitions, and transformative governance strategies toward sustainability"* (Wiek et al., 2011, p. 210); and
5. **Interpersonal competence** *"is the ability to motivate, enable, and facilitate collaborative and participatory sustainability research and problem solving. This capacity includes advanced skills in communicating, deliberating and negotiating, collaborating, leadership, pluralistic and trans-cultural thinking, and empathy"* (Wiek et al., 2011, p. 211).

These five key competencies are also included in the list of key competencies for sustainability identified by UNESCO to advance sustainable development (Figure 4).

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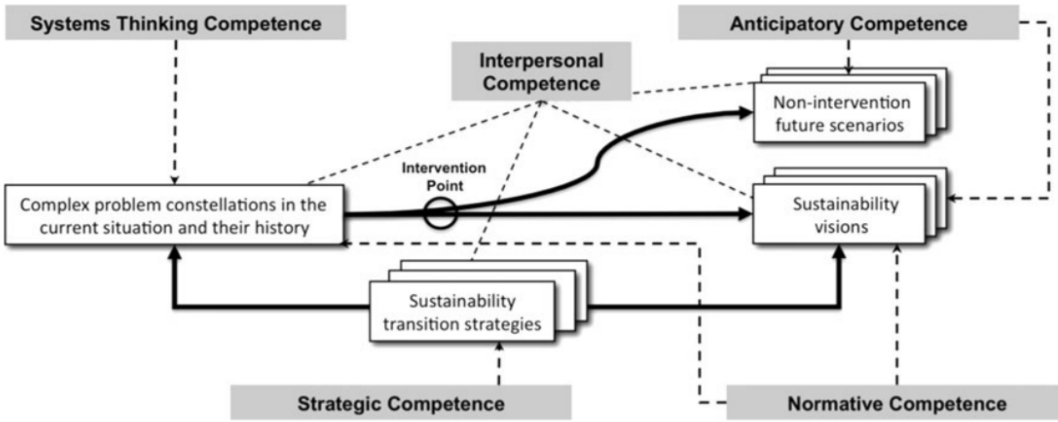

Figure 3: The five sustainability competencies and how they are linked to a sustainability research and problem-solving framework (Wiek et al., 2011, Figure 2).

Box 1.1. Key competencies for sustainability

Systems thinking competency: the abilities to recognize and understand relationships; to analyse complex systems; to think of how systems are embedded within different domains and different scales; and to deal with uncertainty.

Anticipatory competency: the abilities to understand and evaluate multiple futures – possible, probable and desirable; to create one's own visions for the future; to apply the precautionary principle; to assess the consequences of actions; and to deal with risks and changes.

Normative competency: the abilities to understand and reflect on the norms and values that underlie one's actions; and to negotiate sustainability values, principles, goals, and targets, in a context of conflicts of interests and trade-offs, uncertain knowledge and contradictions.

Strategic competency: the abilities to collectively develop and implement innovative actions that further sustainability at the local level and further afield.

Collaboration competency: the abilities to learn from others; to understand and respect the needs, perspectives and actions of others (empathy); to understand, relate to and be sensitive to others (empathic leadership); to deal with conflicts in a group; and to facilitate collaborative and participatory problem solving.

Critical thinking competency: the ability to question norms, practices and opinions; to reflect on own one's values, perceptions and actions; and to take a position in the sustainability discourse.

Self-awareness competency: the ability to reflect on one's own role in the local community and (global) society; to continually evaluate and further motivate one's actions; and to deal with one's feelings and desires.

Integrated problem-solving competency: the overarching ability to apply different problem-solving frameworks to complex sustainability problems and develop viable, inclusive and equitable solution options that promote sustainable development, integrating the above-mentioned competences.

Figure 4: Key competences for sustainability identified by UNESCO (UNESCO, 2017).

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5.1.2 Skills for a Circular Economy

Today's economy is changing from a linear 'take-make-use-waste' model to a circular model, which aims to keep materials and products in the loop as long as possible at their highest possible value. Designing chemicals, materials, products, and processes for circularity and to fit into circular models is one important aspect of SSbD. Still, it has to be noted that this is not possible for all type of products and that "circular" does not necessarily mean more sustainable. An overview of the methods, criteria, and limitations for designing materials, processes and products for a circular economy is given in the IRISS report PR1.4. This chapter focuses on the skills identified in the literature.

ESCO lists the knowledge concept of **circular economy** in their Green Skills Collection (Table 3) and links it to two narrower skills and knowledge concepts (ESCO, 2023a):

- **Product life cycle** (knowledge): The management of the life cycle of a product from the development stages to the market entry and market removal.
- **Identify new recycling opportunities** (skill): Investigate ideas and spot opportunities to improve the collection, process, and recycling of waste materials.

In the context of SSbD, the skills required in the design phase of material and product development are particularly important.

In 2020 and 2021, Sumter et al. published two studies on design competencies for a circular economy (Sumter et al., 2020, 2021). For the first study (Sumter et al., 2020), the authors performed a literature review and conducted interviews with design practitioners to identify circular economy competencies for design. They identified seven design competencies for a circular economy and linked these to the sustainability competencies proposed by Wiek et al. (2011). In a second study (Sumter et al., 2021), the authors used an online survey to evaluate the extent to which the identified competencies are recognized by international designers and whether any competencies are missing. They identified two further competencies and reformulated the previous one. This resulted in nine design competencies for a circular economy that were arranged into a circular design competencies wheel (Figure 5).

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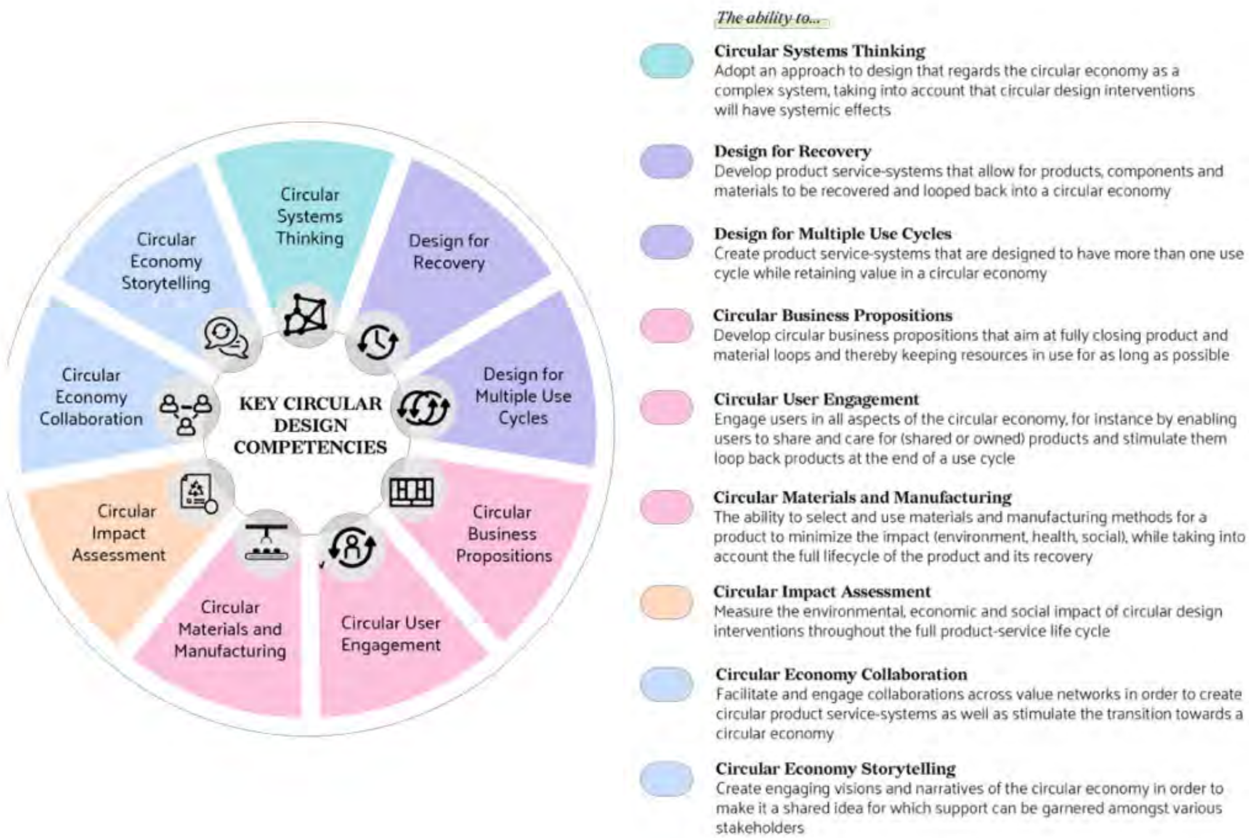

Figure 5: The circular design competency wheel (Sumter et al., 2021; Figure 4). Same colours were used to show a relationship between competencies.

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5.1.3 Skills for the Green Transition

In January 2022, the European Commission published a new taxonomy of skills for the green transition in the ESCO portal (European Commission, 2022b, 2022c). This 'Green Skills Collection' includes 386 skills and 185 knowledge concepts[1]. The listed skills and knowledge concepts are either occupation- or sector-specific (e.g., for textile or food industry) or apply cross-sector. The collection also includes five transversal skills. In this taxonomy, the term 'green skills' refers to skills, that reduce the impact of human activity on the environment (European Commission, 2022b).

Out of these 571 skills and knowledge concepts, 75 entries were identified within WP1 as the most relevant for SSbD and its successful implementation (Table 3). It must be noted that these skills refer mainly to the sustainability aspects of SSbD and not to the safety aspects. None of these skills and knowledge concepts are specific to the design phase. Furthermore, only key performance indicators (KPIs) related to food waste reduction are mentioned in the entire collection ('design indicators for food waste reduction'). For SSbD, many further KPIs will be needed to be defined for the design phase. Therefore, the Green Skills Collection does not include all skills and knowledge concepts that will be needed for SSbD. Nevertheless, the collection can be seen as one valuable source for the mapping of desired SSbD related skills. As the implementation of the SSbD concept has just started and the JRC framework is still in a testing phase, this assessment of relevant SSbD skills can change over time and with more practical experience. Therefore, it should be re-evaluated at a later stage (e.g., within the gap analysis of WP2).

It should also be noted that the differentiation within the Green Skills Collection between skills/competences and knowledge concepts only provides superficial insight in related education needs. For example, describing a term such as 'Corporate Social Responsibility' as knowledge concept raises the question of whether the underlying education need is merely awareness, or whether the need is for actors to learn how to act in a socially responsible way (the latter of which requires a far broader development of skills). Similarly, the skill/competence 'promote environmental awareness' may be interpreted literally, in which it implies a need to develop proficiency in promoting a specific topic. Alternatively, it may be interpreted as 'demonstrating environmental awareness within one's work and communication', in which case it requires developing a particular value. Each implies different teaching methods and content. This means that the knowledge and skills/competencies listed in the Green Skills Collection will require further specification or reclassification prior to developing specific learning materials, but this goes beyond the scope of this report.

The ESCO portal was also searched for (health and) safety related skills, but the identified entries seem not to be applicable in the SSbD context as there is no distinction between 'hazard' and 'risk' and between 'assessment' and 'management'. I.e., the skill 'risk management' is used as a synonym for both ‚hazard management' and ‚risk assessment' (ESCO, 2023b).

[1] The full list is available for download in the **ESCO Portal > Download > Version: ESCO dataset - v1.1.1**.

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Table 3: Selected skills and knowledge concepts of the ESCO's Green Skills Collection identified within WP1 as the most relevant for SSbD.

Type	Label	Description
Knowledge	by-products and waste	Concepts of by-product and waste. Types of waste and European waste codes industries. Solutions for textile by-products and wastes recovery, reuse and recycling.
Knowledge	challenging issues in the textile industry	The efficiency aims and environmental issues posed by challenges in the textile industry.
Knowledge	circular economy	The circular economy aims to keep materials and products in use for as long as possible, extracting the maximum value from them while in use and recycling them at the end of their life cycle. It improves resource efficiency and helps to reduce the demand for virgin materials.
Knowledge	climate change impact	The impact of climate change on biodiversity and life conditions for plants and animals.
Knowledge	corporate social responsibility	The handling or managing of business processes in a responsible and ethical manner considering the economic responsibility towards shareholders as equally important as the responsibility towards environmental and social stakeholders.
Knowledge	ecological principles	The understanding of how an ecosystem functions and its relationship to environmental planning and design.
Knowledge	energy efficiency	Field of information concerning the reduction of the use of energy. It encompasses calculating the consumption of energy, providing certificates and support measures, saving energy by reducing the demand, encouraging efficient use of fossil fuels, and promoting the use of renewable energy.
Knowledge	environmental legislation	The environmental policies and legislation applicable in a certain domain.
Knowledge	environmental policy	Local, national and international policies dealing with the promotion of environmental sustainability and the development of projects which reduce negative environmental impact and improve the state of the environment.

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Type	Label	Description
Knowledge	environmental threats	The threats for the environment which are related to biological, chemical, nuclear, radiological, and physical hazards.
Knowledge	green computing	The use of Information and Communication Technologies (ICT) systems in an environmentally responsible and sustainable manner, such as the implementation of energy-efficient servers and central processing units (CPUs), reduction of resources and correct disposal of e-waste.
Knowledge	hazardous waste types	The different types of waste which poses risks to the environment or public health and safety, such as radioactive waste, chemicals and solvents, electronics, and mercury-containing waste.
Knowledge	health and safety regulations	Necessary health, safety, hygiene and environmental standards and legislation rules in the sector of particular activity.
Knowledge	ICT environmental policies	The international and organisational policies which deal with the assessment of the environmental impact of innovations and developments in the field of ICT, as well as with methods for reducing negative impact and applying ICT innovations to aid the environment.
Knowledge	pollution legislation	Be familiar with European and National legislation regarding the risk of pollution.
Knowledge	pollution prevention	The processes used to prevent pollution: precautions to pollution of the environment, procedures to counter pollution and associated equipment, and possible measures to protect the environment.
Knowledge	sustainable building materials	The types of building material which minimize the negative impact of the building on the external environment, throughout their whole life cycle.
Knowledge	sustainable development goals	The list of 17 global goals set by the United Nations General Assembly and designed as a strategy to achieve a better and more sustainable future for all.
Knowledge	sustainable installation materials	The types of installation material which minimize the negative impact of the building and its construction on

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Type	Label	Description
		the external environment, throughout their whole life cycle.
Knowledge	waste management	The methods, materials and regulations used to collect, transport, treat and dispose of waste. This includes recycling and monitoring of waste disposal.
Knowledge	water consumption	The factors which are involved in the calculation and estimation of water consumption in a residence or facility, and methods in which water consumption can be lowered or made more efficient.
Skill/ Competence	abide by regulations on banned materials	Comply with regulations banning heavy metals in solder, flame retardants in plastics, and phthalate plasticisers in plastics and wiring harness insulations, under EU RoHS/WEEE Directives and China RoHS legislation.
Skill/ Competence	adopt ways to reduce negative impact of consumption	Apply principles, policies and regulations aimed at environmental sustainability, including the reduction of waste, energy and water consumption, the reuse and recycling of products, and the engagement in the sharing economy.
Skill/ Competence	adopt ways to reduce pollution	Apply measures to reduce air, noise, light, water or environmental pollution, for example by using public transports, not leaving any waste in the natural environment, and reducing unnecessary light and noise emissions, particularly during the night.
Skill/ Competence	advise customers on building materials	Provide customers with detailed advice on various building materials; recommend sustainable development and promote the use of green materials such as wood, straw and bamboo; promote recycling and the use of renewable or non-toxic materials.
Skill/ Competence	advise on environmental risk management systems	Evaluate requirements and advise on systems for environmental risk management. Ensure the customer does his part in preventing or limiting adverse environmental impact through the use of technology. Ensure required licenses and permits are obtained.
Skill/ Competence	advise on mining environmental issues	Advise engineers, surveyors, geotechnical staff and metallurgists on environmental protection and land rehabilitation related to mining activities.

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Type	Label	Description
Skill/ Competence	advise on pollution prevention	Advise individuals and organisations on the development and implementation of actions which aid in the prevention of pollution and its related risks.
Skill/ Competence	advise on sustainability solutions	Advise companies on solutions to develop sustainable production processes, improve material efficiency and reuse and reduce carbon footprint.
Skill/ Competence	advise on sustainable management policies	Contribute to planning and policy development for sustainable management, including input in environmental impact assessments.
Skill/ Competence	advise on sustainability solutions	Advise companies on solutions to develop sustainable production processes, improve material efficiency and reuse and reduce carbon footprint.
Skill/ Competence	apply transportation management concepts	Apply transport industry management concepts in order to improve transportation processes, reduce waste, increase efficiency, and improve schedule preparation.
Skill/ Competence	assess environmental impact	Monitor environmental impacts and carry out assessments in order to identify and to reduce the organisation's environmental risks while taking costs into account.
Skill/ Competence	assess environmental impact in aquaculture operations	Measure the environmental impact of a company's aquaculture operations. Take into account factors such as quality of the sea and surface water, fish and sea plant habitats and risks regarding the quality of air, odour and noise.
Skill/ Competence	assess groundwater environmental impact	Estimate environmental impact of groundwater abstraction and management activities.
Skill/ Competence	assess harvesting impact on wildlife	Monitor wildlife populations and habitats for the impact of timber harvesting and other forest operations.
Skill/ Competence	assess hydrogen production technologies	Compare technological and economic characteristics of different options to produce hydrogen. This includes comparing sources (natural gas, water and electricity, biomass, coal) and related technologies.
Skill/ Competence	assess impact of industrial activities	Analyse data to estimate the impact of industrial activities on resource availability and groundwater quality.

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Type	Label	Description
Skill/ Competence	assess the life cycle of resources	Evaluate the use and possible recycling of raw materials in the whole product life cycle. Consider applicable regulations, such as the European Commission's Circular Economy Policy Package.
Skill/ Competence	avoid contamination	Avoid the mixing or contamination of materials.
Skill/ Competence	carry out environmental audits	Use equipment to measure various environmental parameters in order to identify environmental problems and investigate manners in which they can be resolved. Perform inspections in order to ensure compliance with environmental legislation.
Skill/ Competence	carry out training in environmental matters	Perform staff training and ensure all members of the workforce understand how they can contribute to improved environmental performance.
Skill/ Competence	communicate on the environmental impact of mining	Prepare talks, lectures, consultations with stakeholders and public hearings on environmental issues related to mining.
Skill/ Competence	conduct ecological research[2]	Conduct ecological and biological research in a field, under controlled conditions and using scientific methods and equipment.
Skill/ Competence	conduct ecological surveys[2]	Conduct field surveys to collect information about the numbers and distribution of organisms.
Skill/ Competence	conduct energy audit	Analyse and evaluate the energy consumption in a systematic manner in order to improve the energy performance.
Skill/ Competence	conduct environmental surveys	Conduct surveys in order to collect information for analysis and management of environmental risks within an organisation or in a wider context.
Skill/ Competence	conduct research on fauna[2]	Collect and analyse data about animal life in order to discover the basic aspects such as origin, anatomy, and function.
Skill/ Competence	conduct research on flora[2]	Collect and analyse data about plants in order to discover their basic aspects such as origin, anatomy, and function.

[2] needed for biodiversity impacts

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Type	Label	Description
Skill/ Competence	develop energy saving concepts	Use current research results and collaborate with experts to optimise or develop concepts, equipment, and production processes which require a lesser amount of energy such as new insulation practices and materials.
Skill/ Competence	develop environmental policy	Develop an organisational policy on sustainable development and compliance with environmental legislation in line with policy mechanisms used in the field of environmental protection.
Skill/ Competence	develop waste management processes	Develop equipment, methods, and procedures which can be applied in various types of waste treatment and disposal facilities in order to improve efficiency of waste management processes, reduce environmental impact, and ensure the safety of staff operational in waste management.
Skill/ Competence	dispose waste	Dispose waste in accordance with legislation, thereby respecting environmental and company responsibilities.
Skill/ Competence	ensure compliance with environmental legislation	Monitor activities and perform tasks ensuring compliance with standards involving environmental protection and sustainability, and amend activities in the case of changes in environmental legislation. Ensure that the processes are compliant with environment regulations and best practices.
Skill/ Competence	ensure correct goods labelling	Ensure that goods are labelled with all necessary labelling information (e.g. legal, technological, hazardous and others) regarding the product. Ensure that labels respects the legal requirements and adhere to regulations.
Skill/ Competence	follow health and safety procedures in construction	Apply the relevant health and safety procedures in construction in order to prevent accidents, pollution and other risks.
Skill/ Competence	follow procedures to control substances hazardous to health	Adhere to the Control of Substances Hazardous to Health (COSHH) procedures for activities that involve hazardous substances, such as bacteria, allergens, waste oil, paint or brake fluids that result in illness or injury.
Skill/ Competence	identify new recycling opportunities	Investigate ideas and spot opportunities to improve the collection, process and recycling of waste materials.

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Type	Label	Description
Skill/ Competence	implement biodiversity action plans	Promoting and implementing local and national biodiversity action plans in partnership with local/national statutory and voluntary organisations.
Skill/ Competence	implement environmental action plans	Apply plans that address the management of environmental matters in projects, natural site interventions, companies, and others.
Skill/ Competence	implement environmental protection measures	Enforce environmental criteria to prevent environmental damage. Strive for the efficient use of resources in order to prevent waste and reduce costs. Motivate colleagues to take relevant steps to operate in an environmentally friendly manner.
Skill/ Competence	implement sustainable procurement	Incorporate strategic public policy goals into procurement procedures, such as green public procurement (GPP) and socially responsible public procurement (SRPP). Contribute to reducing the environmental impact of procurement, to achieving social goals and to improving value for money for the organisation and for society at large.
Skill/ Competence	manage environmental impact	Implement measures to minimise the biological, chemical and physical impacts of mining activity on the environment.
Skill/ Competence	manage environmental impact of operations	Manage the interaction with and impact on the environment by companies. Identify and assess environmental impacts of the production process and related services, and regulate a reduction of the effects on the environment and on people. Organise action plans and monitor any indicators of improvement.
Skill/ Competence	measure company's sustainability performance	Keep track of sustainability indicators and analyse how well the company is doing in sustainability performance, in relation to the Sustainable Development Goals or the global standards for sustainability reporting.
Skill/ Competence	minimise environmental impact on the surrounding area	Minimise the waste of materials and dispose of debris correctly. Minimise the damage to plants, features and surrounding areas.

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Type	Label	Description
Skill/ Competence	mitigate waste of resources	Evaluate and identify opportunities to use resources more efficiently with continuously striving to reduce waste of utilities.
Skill/ Competence	perform cleaning activities in an environmentally friendly way	Undertake all cleaning duties in a manner which minimises environmental damage, follow methods that lessen pollution and wastage of resources.
Skill/ Competence	promote environmental awareness	Promote sustainability and raise awareness about the environmental impact of human and industrial activity based on the carbon footprints of business processes and other practices.
Skill/ Competence	promote responsible consumer behaviour	Promote policies, actions and education programmes that encourage healthy lifestyles and proactive participation in sustainable consumption, and that lead to changes in consumers' attitudes, shopping habits and expectations.
Skill/ Competence	promote sustainable packaging	Apply safe and healthy packaging policies; maximise the use of recycled or renewable source materials; implement clean production technologies.
Skill/ Competence	propose alternative rubber compound ingredients	Identify potentially toxic ingredients inside rubber compounds and propose alternative ingredients or compounds with similar functionality.
Skill/ Competence	select sustainable technologies in design	Produce a holistic design, which includes passive measures that are complemented by active technologies in a sensible way.
Skill/ Competence	use environmental friendly materials	Work with ecofriendly materials such as water based finishing materials systems or formaldehyde free adhesives.
Skill/ Competence	use sustainable materials and components	Identify, select environmentally friendly materials and components. Decide on the substitution of certain materials by the one that are environmentally friendly, maintaining the same level of functionality and other characteristics of the product.

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5.1.4 Skills derived from SSbD approaches

In 2022, a framework for the definition of criteria and evaluation procedure for chemicals and materials was published by the JRC (Caldeira et al., 2022b) along with a recommendation promoting this framework (European Commission, 2022a). Currently, the framework is still in a testing phase and the engagement of industry and member states is encouraged (European Commission, 2022a, 2023b). Other institutions such as the European Environment Agency (EEA), the European Chemical Industry Council (Cefic), the OECD Working Party on Manufactured Nanomaterials (WPMN) Safe(r) and Sustainable Innovation Approach (SSIA) Steering Group (SG) and the International Chemical Secretariat (ChemSec) have also published their views on how to operationalize SSbD (Cefic, 2021, 2022; ChemSec, 2021; European Environment Agency, 2021; OECD, 2022).

An overview of the SSbD approaches as mentioned above is given in Table 4. The survey (Annex A) and project template (Annex B) were based on the JRC's SSbD framework as the leading SSbD document within WP1. Within WP3, a comparison of these approaches was conducted regarding a wide range of aspects, including design principles, implementation strategies, safety and sustainability assessment parameters, proposed tools and identified gaps. The comparison is part of the manuscript 'State of the art of safe-and-sustainable-by-design approaches and moving towards practical applicability through value chain perspectives' by Apel et al., 2023 (submitted). Descriptions of these SSbD approaches and a sustainability-focused summary of the comparison can be found in preliminary report PR1.2.

Table 4: Overview of SSbD approaches

SSbD Approach	Date/Type	Title	Reference
EEA	Feb 2021 Briefing	Designing safe and sustainable products requires a new approach for chemicals	European Environment Agency (2021)
ChemSec	Jun 2021 Position Paper	Safe and Sustainable By Design Chemicals	Chemsec (2021)
Cefic	Oct 2021 Report	Safe and Sustainable-by-Design: Report Boosting innovation and growth within the European chemical industry	Cefic (2021)
	Apr 2022 Report	Safe and Sustainable-by-Design: A Transformative Power	Cefic (2022)
EC JRC	July 2022 Framework	Safe and Sustainable by Design chemicals and materials: Framework for the definition of criteria and evaluation procedure for chemicals and materials	Caldeira et al. (2022b)
OECD WPMN SSIA SG	Sep 2022 Working Description	Sustainability and Safe and Sustainable by Design: Working Descriptions for the Safer Innovation Approach.	OECD (2022)

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The following section starts with an analysis of the underpinning principles, approaches, and related policy ambitions of SSbD to give on overview of the desired background knowledge. Afterwards, an analysis of the two-phase approach proposed in the JRC framework is conducted. The aim here is mainly to describe the approach and to identify key skills. A complete systematic document analysis, and thus a solid baseline for an education agenda, is beyond the scope of this report. While the focus of this chapter is on the JRC framework, the other SSbD approaches were also analysed and identified key skills were added wherever necessary.

Desired background knowledge

The underpinning principles, approaches, and related policy ambitions of SSbD are shown in Figure 6. These and further background knowledge mentioned in the other SSbD approaches are summarised and described in Table 5. Understanding the origins and objectives of the SSbD approach requires a great deal of interdisciplinary background knowledge at the policy, regulatory and scientific levels.

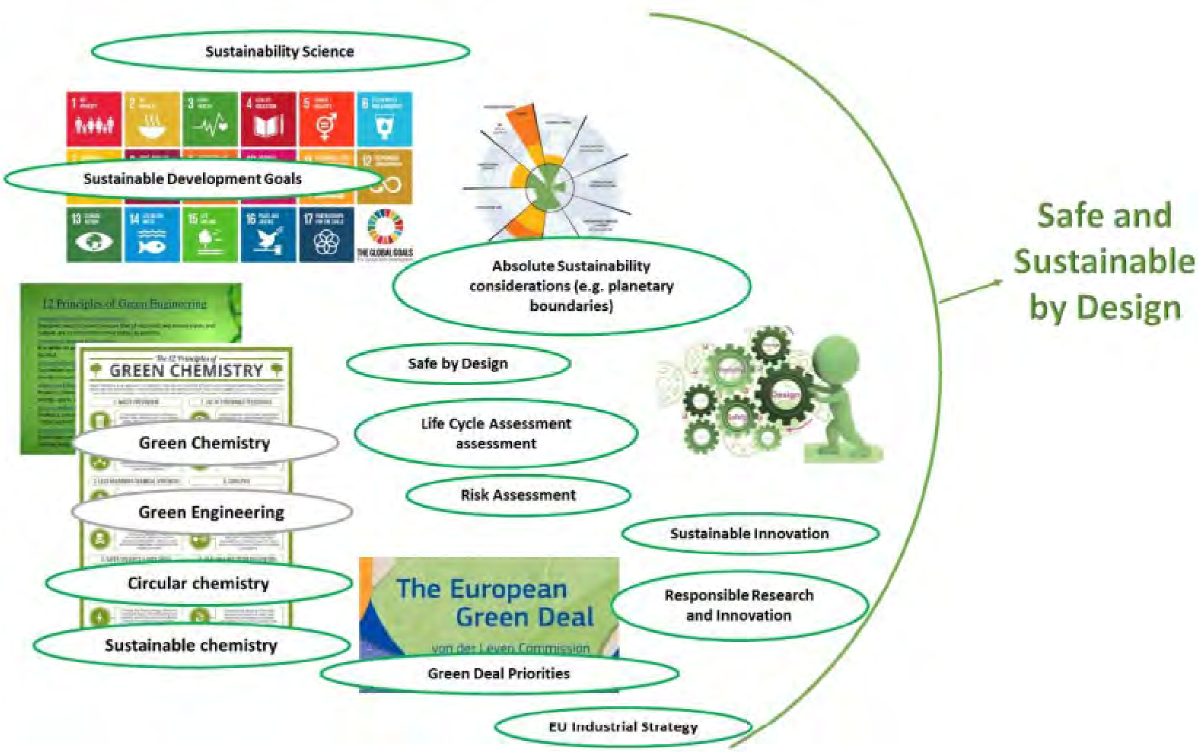

Figure 6: Underpinning principles and approaches informing the JRC's SSbD framework (Caldeira et al., 2022b, Figure 3).

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Table 5: Background knowledge on SSbD addressed in the different SSbD approaches

Knowledge concepts	Description
Policy/regulatory background	
Chemical Strategy for Sustainability (CSS)	The CSS is a core element of the European Green Deal to meet the zero-pollution ambition. The strategy strives for a toxic-free environment, "*where chemicals are produced and used in a way that maximises their contribution to society including achieving the green and digital transition, while avoiding harm to the planet and to current and future generations*" (European Commission, 2020b). The strategy promotes the SSbD approach to chemicals as a key element to achieve this goal.
European Green Deal	The European Green Deal (European Commission, 2019) is integral to implementing the UN SDGs and aims to transform the EU's economy for a sustainable future. The overarching objective is to become climate neutral by 2050.
European Industrial Strategy	The European Industrial Strategy was published in 2020 and updated in 2021 (European Commission, 2020c, 2021b). The strategy aims to ensure that European industry becomes a leader in the green and digital transitions.
European policy objectives for sustainable development	Knowledge of recent European policy developments, e.g., the EU Green Deal (European Commission, 2019), EU CSS (European Commission, 2020b) or the EU Zero Pollution Action Plan (European Commission, 2021a).
Responsible Research and Innovation (RRI)	RRI is a European policy framework in which "*societal actors work together during the whole research and innovation process in order to better align both the process and its outcomes, with the values, needs and expectations of European society*" (European Commission, 2014). RRI is embedded in Horizon 2020.
Safe(r) Innovation Approach (SIA) and Safe(r) and Sustainable Innovation Approach (SSIA)	In 2020, the OECD published a report on SIA which combines the concepts of Safe-by-Design, Regulatory Preparedness, and Trusted Environment (OECD, 2020). SIA enables an early dialogue between industry and regulators and anticipates the regulatory challenges posed by emerging technologies. In 2022, SIA was further developed to SSIA to include more sustainability aspects and to comply with the planetary boundaries (OECD, 2022).
Sustainable Development	Sustainable development is a global development concept that aims to meet *"the needs of the present without compromising the ability of future generations to meet their own needs"* (WCED, 1987).

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Knowledge concepts	Description
Sustainable Development Goals (SDGs)	In 2015, 17 SDGs were announced in the United Nation's 2030 Agenda for Sustainable Development (United Nations, 2015) to stimulate action in critical areas for humanity and the planet. Also included in the ESCO's Green Skills Collection (Table 3).
Sustainable Innovation	Sustainable Innovation reconciles sustainability goals from economic, social and environmental dimensions in order to achieve a 'win-win-win' situation (Afeltra et al., 2021).
Scientific principles and disciplines	
Absolute sustainability considerations	Absolute (environmental) sustainability assessments relate the environmental impacts of products to ecological limits at regional or planetary scale, e.g. the planetary boundaries (Bjorn et al., 2020; Kosnik et al., 2022)**.** This approach differs from a relative sustainability assessment which compares the environmental impacts of different candidates, without relating them to absolute values or limits.
Circular Chemistry	Circular Chemistry, or chemistry for the circular economy, is a framework analogue to Green Chemistry that has been adapted to the need of a circular economy. It is based on 12 principles that are in part identical or similar to Green Chemistry, but also cover some aspects of circular economy, policy, and environmental science (Keijer et al., 2019; Mutlu & Barner, 2022). However, Circular Chemistry addresses neither reduction of substance and material flows, nor alternative business models or ethics and other social aspects.
Green Chemistry	Green Chemistry is a framework that strives to reduce the environmental impact and hazard of the synthesis of chemicals and processes by synthesising chemical products with less energy, less waste, fewer hazardous auxiliaries and using renewable resources. It is described by 12 principles (Anastas & Warner, 1998). Based on the 10th principle 'Design for Degradation', the Benign by Design (BbD) concept aims for environmental (bio)degradability, in the best-case full mineralisation, of chemicals/materials that disperse the into the environment during use or at their end-of-life (Kümmerer, 2007, 2010). Green chemistry addresses neither circularity nor sustainability aspects, neither material nor reduction of substance and material flows, neither alternative business models, ethics, nor social aspects. It originated from organic synthesis and is still mostly focused there.

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Knowledge concepts	Description
Green Engineering	Green Engineering is a framework for scientists and engineers that focuses on science and technology to achieve sustainability. It is based on 12 principles (Anastas & Zimmerman, 2003).
Life Cycle Assessment (LCA)	LCA is a methodology to assess the environmental, social, or economic impacts of products or processes, taking their complete life cycle into account. For more information on LCA methods and criteria and how LCA relates to SSbD, see IRISS report PR1.3.
Planetary Boundaries	Introduced in 2009, the Planetary Boundaries concept defines nine interlinked environmental limits (planetary boundaries) within which humanity can safely operate and thus avoid unacceptable environmental changes (Rockström et al., 2009; Steffen et al., 2015).
Risk Assessment	Identification and evaluation of the potential risks of a chemical, material, product, or process considering both hazard properties and potential exposure. It is important to note that hazard assessment and risk assessment cannot be used synonymously. A hazard assessment focuses on intrinsic hazard properties (e.g., carcinogenic, mutagenic, reprotoxic (CMR) or endocrine disrupting properties) and therefore evaluates the intrinsic safety of a chemical, material, or product, whereas a risk assessment also considers the intended use and the associated potential exposure, and thereby also takes into account existing risk minimization measures (RMMs).
Safe-by-Design	Concept that includes safety aspects at the earliest possible stage of product and process development. For more information on the Safe-by-Design concept and how it relates to SSbD see IRISS report PR1.1.
Sustainability Science	Sustainability Science is an academic discipline that deals with issues related to sustainability and sustainable development. The focus lies more on contributing to practical solutions than on the principles themselves.
Sustainable Chemistry	Sustainable Chemistry is a guiding framework on how to develop and apply chemical products and processes to comply with sustainability principles and contribute to a sustainable development as set out in the Agenda 2030 (Blum et al., 2017; ECOSChem, 2023; Kümmerer, 2017; Kümmerer et al., 2021). It starts with service and function needed before thinking of a specific chemical product to deliver it. There are differing definitions for Sustainability Chemistry. ECOSChem (2023), for example,

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Knowledge concepts	Description
	does not include alternative business models in their definition. Their way to achieve a desired service or function is quite similar to Green Chemistry. Others (Kümmerer, 2017, Kümmerer et al., 2021) denied the need of a definition on the one hand because chemistry and its products is so manifold that a satisfying working definition is hardly possible; on the other hand, sustainable chemistry will probably never be reached 100% and has the character of a guiding principle to be pursued, trying to come as close as possible. Sustainable Chemistry starts with service and function needed, asks for system thinking to address reduction of substance and material flows, alternative business models, ethics, and other social aspects.

Desired skillsets for the (re)-design and assessment phases

The two-phase approach by the JRC framework is shown in Figure 7. It comprises eight SSbD design guiding principles for the (re-)design phase (Table 6) and five safety and sustainability assessment steps (Table 7), that can be performed either subsequently or (at least partially) in parallel, for the assessment phase. In general, two different skillsets are required: design skills and assessment skills.

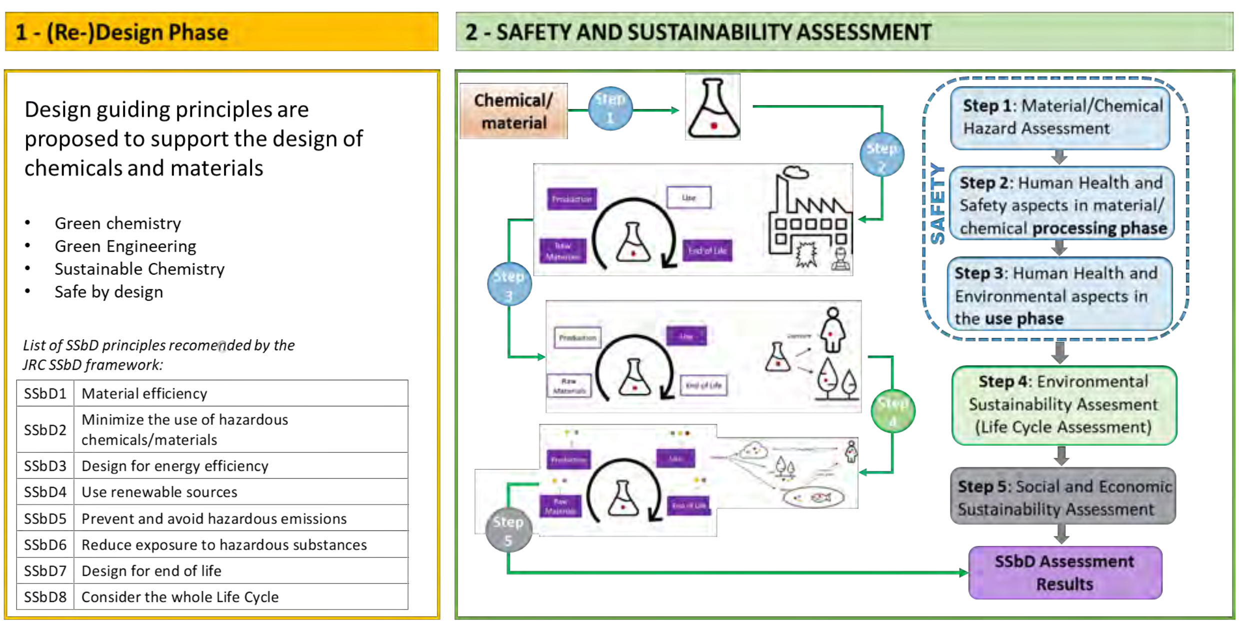

Figure 7: Two phase approach proposed in the JRC framework.

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Table 6: Overview of SSbD guiding design principles and descriptions for the (re-)design phase proposed by the JRC framework (Caldeira et al., 2022b, Table 1).

SSbD design principle	Definition
SSbD1 – Material efficiency	Pursue 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.
SSbD2 – Minimise the use of hazardous chemicals/ materials	Preserve functionality of products while reducing or completely avoid using hazardous chemicals/materials where possible.
SSbD3 – Design for energy efficiency	Minimise the overall energy used to produce a chemical/material in the manufacturing process and/or along the supply chain.
SSbD4 – Use renewable sources	Target resource conservation, either via resource closed loops or using renewable material/ secondary material and energy sources.
SSbD5 – Prevent and avoid hazardous emissions	Apply technologies to minimise and/or to avoid hazardous emissions or pollutants in the environment.
SSbD6 – Reduce exposure to hazardous substances	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.
SSbD7 – Design for end-of-life	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.
SSbD8 – Consider the whole life cycle	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.

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Table 7: Assessment steps for the safety and sustainability assessment proposed by the JRC framework (Caldeira et al., 2022b, Table 2)

Step	Assessment Dimension	Assessment aspects
1	Hazard assessment	The assessment focuses on the hazard properties (human health, environmental and physical hazards) of the manufactured chemicals and materials
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)
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.
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
5	Social Sustainability, Economic Sustainability	This step is at an exploratory phase. It presents 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.

The concept of SSbD focuses on avoiding potential adverse impacts on people and ecosystems at an early stage of the chemical, materials, product, or process development. This means that SSbD principles must be implemented at early phases of the product design process to achieve the greatest benefits. This requires a set of design skills, both general and SSbD-specific ones. An overview is presented in Table 8.

In SSbD, the first step of the design phase focuses on the desired functionalities a product should deliver rather than the form the product takes. To achieve this, a multidisciplinary design team, comprising product designers, material engineers, chemists, toxicologists and sustainability experts is recommended (European Environment Agency, 2021) with the following skills:

- focusing on a function or service a product provides, and
- participating in a multidisciplinary design team.

The SSbD design principles as proposed by the JRC framework were presented in Table 6. Each of these principles implies and requires a set of specific skills and extensive knowledge to enable successful implementation in the product design. In addition to the background knowledge listed in

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Table 5, SSbD actors need to be aware of the relevant internal company processes, including all inputs and outputs, and of the entire VCs for a novel chemical or material; from the supply-chain of raw materials to the end-of-life in the final product.

Each SSbD design principle is also connected to different indicators and assessment methods. A list is provided in the JRC framework in Table 1 and in Annex Table A2.4. These are only examples, and more specific indicators (e.g., sector-specific) will be needed in the future when applying the SSbD framework. Therefore, the following knowledge and skills are needed:

- identify indicators,
- assess indicators, and
- design new indicators.

Table 8: Desired skillset for the (re-)design phase

SSbD design principle	(Design) Skill	Description [3]
SSbD1	design chemicals and materials for material efficiency	This includes the • ability to define and optimize materials inputs and outputs along the production process by altering both input materials and production processes; including, e.g., type, number and quantity of materials and solvents used, yields of reactions and extractions, and the amount of waste generated, • ability to design of chemicals and materials for increasing durability during use.
SSbD2	minimise the use of hazardous chemicals/ materials	This includes the • knowledge of used and/or required chemicals and materials and their hazard profile, • ability to reduce and/or eliminate hazardous chemicals/materials in manufacturing processes and in the final product, • ability to verify closed loop recycling possibilities for hazardous chemicals/ materials that cannot be reduced or eliminated, • ability to predict toxicity of novel chemicals and prevent the use of hazardous ones.

[3] Some of the required abilities or knowledge could be directly derived from Table 1, Column „Examples of Actions“, of the JRC framework (Caldeira et al., 2022b).

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SSbD design principle	(Design) Skill	Description[3]
SSbD3	design chemicals and materials for energy efficiency	This includes the • ability to define and minimize the energy use in the manufacturing process and/or along the supply chain, • knowledge of the entire supply chain and energy requirements for manufacturing materials and chemicals, • knowledge of the working conditions and weight of the materials to reduce energy consumption during use phase, • ability to collaborate with partners across the supply chain; particularly so called 'soft' skills or interpersonal competencies (Chapter 5.1.1).
SSbD4	use renewable sources	This includes the • knowledge of suitable renewable and secondary material sources, • ability to prioritize feedstock selection according to predefined indicators, • ability to consider resource closed loops in the product design phase, • knowledge to support use of and replacement with bio-based renewable materials, • ability to test at the laboratory the function and durability of the renewable alternatives to fossil fuel sources.
SSbD5	prevent and avoid hazardous emissions	This includes the • ability to define and minimize generated hazardous waste and emissions (e.g., environmental pollutants), • knowledge of suitable technologies to minimise waste and emissions, • ability to install, operate and/or maintain such technologies.
SSbD6	reduce exposure to hazardous substances	This includes the • **minimising use of hazardous chemicals/ materials (SSbD2),** • knowledge on risk management, • knowledge of value chain-specific regulations, • ability to access and use exposure modelling tools, • knowledge of suitable technologies to reduce/avoid exposure, • the ability to install, operate and/or maintain such technologies,

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SSbD design principle	(Design) Skill	Description[3]
		• training on Occupational Health and Safety (OHS) and Environmental Health and Safety (EHS).
SSbD7	design chemicals and materials for end-of-life	This design skill includes two different aims depending on the use of the chemicals/materials. For uses that disperse the chemicals/materials into the environment during use or at their end-of-life this includes and requires the • knowledge of the connection between structure and properties of chemicals, • knowledge about the transformation of chemicals and materials during use, • knowledge on remaining life of the materials, taking into account the possibility to repair, reuse, • knowledge of suitable chemistry concepts (e.g., Benign by Design), • ability to access and use suitable tools (e.g., QSAR models). For uses that allow a collection of the chemical/material at their end-of-life this additionally includes and requires • knowledge of circular economy and the waste hierarchy, • knowledge of end-of-life options in the specific value chain, • knowledge of waste treatment systems specific to the relevant geography (city, area, country, etc.). Design skills for a circular economy are presented in Chapter 5.1.2. For more information on how to design material and products for circularity, see IRISS report PR1.4.
SSbD8	consider the whole life cycle	This includes • a system thinking competence (see Chapter 5.1.1) and Life Cycle Thinking training, taking the entire life cycle of a product into account, • knowledge of the entire value chain(s) for a novel chemical/material; from supply-chain of raw materials to the end-of-life in the final product, • understanding the durability of products and its relevance during the use-phase,

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SSbD design principle	(Design) Skill	Description[3]
		• understanding the possibility to monitor the durability during use, using sensors.
General	focus on a function or service a product provides	Focusing on the function or service a product provides requires particular 'critical thinking' and 'problem-solving' competences (Chapter 5.1.1).
General	participate in a multidisciplinary design team	Participating in a multidisciplinary design team requires so called 'soft' skills or interpersonal competencies (chapter 5.1.1) which are transversal to a particular way of working rather than a specific scientific/technical specialization. It requires • communicative skills around translating one's own disciplinary perspective in lay-man's terms to make it understandable to others, • a critical and reflexive attitude that facilitates questioning both one's own disciplinary assumptions (e.g., are my own assumptions about the process compatible with the team) as the development of mutual understanding between participants of different disciplines (e.g., common understanding of SSbD), and • ideally one would also strive for participants that already have some knowledge about the differences and complementarities between the disciplinary perspectives.
General	identify indicators	Knowledge of key performance indicators (KPI) for the respective design principles. Examples of indicators for each design principles are given in the JRC framework (Table 1), e.g. • Recycled content (%) • Water consumption (m^3 /kg) • Disassembly/reparability design (yes/no) • Durability (years) • Value-based resource efficiency indicator • Material Circularity Indicator • Biodegradability of manufactured chemical/material (yes/no) • Classification of raw chemicals/materials as Substances of very high concern (SVHC) (yes/no)

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SSbD design principle	(Design) Skill	Description[3]
General	assess indicators	As each KPI is measured with an assessment method, this includes the abilities to • identify assessment methods and • apply these to the indicators.
General	design indicators	This includes the abilities to • determine new KPIs for SSbD design guiding principles and • evaluate assessment methods.

During the process of developing a new chemical, material, product or process, safety and sustainability assessments need to be performed, in best-case iteratively to optimise the results, for the identification of the safest and most sustainable option.

The five safety and sustainability assessment steps proposed by the JRC framework are presented in Table 7. Each of these assessment steps implies and requires several narrower skills to be able to perform the required assessment. An overview is presented in Table 9. As each assessment step is data intensive, additional general skills are required for:

- gathering data,
- generating data,
- dealing with data gaps, and
- promoting data traceability.

Performing an assessment also includes the knowledge of applicable tools and databases as well as the ability to ensure comparability of the produced assessment data. Several tools and data sources are compiled in Chapter 4.4 of Caldeira et al. (2022a). To ensure the comparability of, e.g., LCA studies (Step 4), the JRC (as well as ChemSec, Cefic, and EEA) promotes the use of the Product Environmental Footprint (PEF) method until SSbD specific guidance has been developed. Also important in the context of SSbD are new approach methodologies (NAMs). NAMs refer to non-animal testing methods along with exposure information to generate data also at early stages of the product development process (Caldeira et al., 2022b).

Each assessment step is also connected to several aspects/indicators, an appropriate assessment method, and (cut-off or exclusion) criteria that allow to evaluate if a chemical or material can be considered SSbD. Therefore, two further important SSbD skills are:

- identifying the most appropriate criteria, and
- performing an evaluation (incl. trade-offs).

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Table 9: Desired skillset for the safety and sustainability assessment phase

Step	Assessment skill/knowledge	Description[4]
1	perform a hazard assessment of the chemical's/material's intrinsic properties	Performing a hazard assessment includes the • ability to access and collect data of the intrinsic properties of a chemical/material (human health, environmental and physical hazards), • knowledge of regulatory relevant hazard data (e.g., collected under REACH or CLP), • ability to use NAMs to generate data.
1	New approach methodologies (NAMs)	NAMs are a tool to generate data and information for chemical safety assessments while avoiding animal testing. They can be particularly helpful at early stages in the product development.
2	assess human health and safety aspects in the chemical/material production and processing phase	Assessing human health and safety aspects in the chemical/material production and processing phase includes • knowledge of the production process including all chemicals/materials used (from raw material extraction (natural resources) to production of the chemical/material and waste management), operational conditions, potential of releases, and RMMs in place, • ability to access and collect hazard data of the chemicals/materials used in the process, • ability to determine the potential exposure of workers, • ability to access and use respective OHS or exposure modelling tools.
3	assess human health and environmental aspects in the final application phase	Assessing human health and environmental aspects in the final application phase includes the • knowledge on the final application/intended use of the chemical, material, or product, • ability to access and collect hazard data of the chemicals/materials (Step 1), • ability to determine the use-specific exposure to a chemical/material, • ability to perform a risk assessment.
4	perform an environmental sustainability assessment	Performing an environmental sustainability assessment includes and requires the • knowledge-transfer along the entire supply chain, • knowledge of the intended use of the chemical, material, or product (Step 3),

[4] Some of the required abilities or knowledge could be directly derived from Chapter 4.2 of the JRC framework (Caldeira et al., 2022b).

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Step	Assessment skill/knowledge	Description[4]
		• knowledge of environmental impacts along the entire chemical/material life cycle, e.g., climate change, pollution, resource use, human toxicity (via indirect exposure) and eco-toxicity, • knowledge on LCA methodologies, e.g., PEF method, • ability to access and use respective LCA tools and databases.
4	Product Environmental Footprint (PEF) method	PEF is a LCA based method to quantify the environmental impacts of products (goods or services) (European Commission, 2023a). For more information on LCA methods, tools, and criteria and how it relates to SSbD see report PR1.3.
5	perform a social sustainability assessment	Performing a social sustainability assessment includes and requires the • ability to assess social aspects for different stakeholder categories, • ability to assess own operations using primary data, • ability to assess the supply chain, and scrutiny of suppliers' operations using primary or secondary data, • knowledge of social Life Cycle Assessment (s-LCA) methodologies, • knowledge of data sources for primary and secondary data, • ability to access and collect primary data from the company or local communities, • ability to access and use respective s-LCA tools and databases. S-LCA methods, tools and criteria are mapped in report PR1.2.
5	perform an economic sustainability assessment	Performing an economic sustainability assessment includes and requires the • ability to assess non-financial aspects, e.g., the identification and monetization of externalities arising during the life cycle of a chemical or a material, • knowledge of Life Cycle Costing (LCC) methodologies, • ability to access and use respective LCC tools and databases. LCC methods, tools and criteria are mapped in report PR1.2.
General	gathering data	Gathering robust data (both at manufacturing level as well as supply-chain level) is a principal challenge in SSbD assessments, which includes and requires the • knowledge of existing primary and secondary data sources, • ability to access and use respective databases.

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Step	Assessment skill/knowledge	Description[4]
General	generating data	Generating data can be done in different ways, which include and require the • ability to perform laboratory studies to create data, • knowledge of and ability to use *in silico* tools, e.g., QSAR models, to predict data, • knowledge of and ability to use NAMs.
General	dealing with data gaps	Dealing with data gaps requires the • knowledge of gap-filling approaches, • ability to perform or test these approaches.
General	promoting data traceability	Promoting data traceability includes the • ability to ensure that the data/information is traceable along the entire value chain, • knowledge of traceability schemes, e.g., the Digital Product Passport, • adherence of FAIR data principles.
General	identifying the most appropriate criteria (for each aspect/indicator)	Knowledge of criteria for each assessment step. Examples of criteria for each step are given in the JRC framework Chapter 4.2.
General	performing an evaluation	Performing an evaluation requires • knowledge of and the ability to apply evaluation systems, including exclusion criteria and how to handle trade-offs, • knowledge on hierarchical evaluation principles, • knowledge on multiple-criteria decision analysis (MCDA).

5.2 University education offerings of IRISS partners related to SSbD

This chapter analyses the university education offerings of IRISS partners from academia and the contents of the curriculum to later support the translation of the needed SSbD skills (this preliminary report) and value chain-specific skills (D4.4) into university curriculum.

Three universities are part of the IRISS consortium. These are:

- Leuphana University of Lüneburg, Germany,
- University of Birmingham, United Kingdom, and
- National Technical University of Athens (NTUA), Greece.

Furthermore, two Research and Technology Organisations are teaching SSbD aspects at universities. These are:

- IVL Swedish Environmental Research Institute at Stockholm University, and
- Empa - Swiss Federal Laboratories for Materials Science and Technology.

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5.2.1 Leuphana University of Lüneburg

At the Leuphana University, SSbD aspects are part of several educational offerings at the Leuphana Graduate School (Master and Doctorate) and Leuphana Professional School (Executive Education). An overview is given in Table 10. The Master's programme 'Sustainable Chemistry' for professionals is listed among the United Nations SDG Good Practices for its active contribution to the achievement of SDGs 4, 9, 12 and 17 (United Nations, 2023).

Largely involved in these educational offerings is the professorship for Sustainable Chemistry and Material Resources, which teaches and does research on the concepts and aspects of Sustainable Chemistry, BbD, environmental fate and behavior, and the role of chemistry within a circular economy.

Table 10: SSbD related educational offerings at the Leuphana University

Type of Education	Programme/Course	Modules/Content
Master's programme	Master Sustainable Science Degree: M.Sc. (Master of Science)	1st Semester • Ecosystem Responses to Chemical Pollution • Earth Systems and Climate Change • Sustainable Chemistry 1: Concepts of Sustainable Chemistry • Sustainability Communication • Market-oriented Sustainability Management • Sustainability Governance 2nd Semester • Conservation Biology • Ecosystem processes: a biogeochemical perspective • Geochemical parameters and Sustainable Chemistry 2: Chemical Structure and Biological effect • Sustainable Chemistry 3: Degradation of Chemicals in the Environment • Sustainability Performance Measurement and Management • Sustainability Economics • Sustainability, Digital Media, and Information Society • Sustainability, Governance and Law 3rd Semester • Sustainable Chemistry 4: Fate, Modelling and Design of Chemicals • Sustainable Energy • Macroecology and Global Change Biology

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Type of Education	Programme/Course	Modules/Content
		• Models in Global Change Research • Social Ecology – Conceptual and Methodological Principles, Social-Ecological Space Research • Sustainability, Culture and Education • Sustainability and Social Developments Complementary studies • Engaging with Knowledge and Sciences • Reflecting on Research Methods • Connecting Science, Responsibility and Society
Master's programme (for professionals)	Professional Master in Sustainable Chemistry Degree: M.Sc.	• Concepts of Sustainable Chemistry • Environmental Chemistry • Toxicology and Ecotoxicology • Modelling of Chemical Properties and Fate • Green Chemistry • Sustainable Chemistry and Renewable Energy • Benign by Design • Resources, Recycling and Circular Economy • Sustainability Assessment • Law, International Regulations and Chemicals Management • Business Models and Strategies • Chemistry, Sustainability, and the Agenda 2030 (Project Work) • Society and Responsibility
Master's programme (for professionals)	Master of Business Administration Sustainable Chemistry Management Degree: MBA (Master of Business Administration)	• Principles of Sustainability Management • Perspectives of Sustainability Management • Conditions for Sustainability Management • Applied Sustainability Management • Concepts of Sustainable Chemistry • Resources, Recycling and Circular Economy • Regulations and International Conventions • Tools for Sustainable Chemistry • Society and Responsibility
Certificate Course (for professionals)	Sustainable Chemistry and Benign by Design Degree: CAS (Certificate of Advanced Studies)	• Environmental Chemistry • Toxicology and Ecotoxicology • Modelling of Chemical Properties and Fate • Benign by Design

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Type of Education	Programme/Course	Modules/Content
Certificate Course (for professionals)	**Sustainable Chemistry and Regulatory Affairs** Degree: CAS	• Environmental Chemistry • Toxicology and Ecotoxicology • Law, International Regulations, and Global Chemicals Management • Chemistry, Sustainability, and the Agenda 2030 (Project Work)
Certificate Course (for professionals)	**Practices of Sustainable Chemistry** Degree: CAS	• Concepts of Sustainable Chemistry • Resources, Recycling and Circular Economy • Regulations and International Conventions • Tools for Sustainable Chemistry
Certificate Course (for professionals)	**Circular Economy** (in German) Degree: CBS (Certificate of Basic Studies)	• Framework conditions and goals of the circular economy • Circular business models and innovations • Instruments of the Circular Economy • Circular product design
Certificate Course (for professionals)	**Sustainable Supply Chain Management** (in German) Degree: CBS	• Framework conditions and goals • Strategies and concepts • Methods and instruments of sustainable supply chain management • Cooperation and collaboration along supply chains

5.2.2 University of Birmingham

At the University of Birmingham, SSbD aspects are part of the curriculum at the School of Chemical Engineering and at the School of Geography, Earth and Environmental Sciences. Both schools offer courses for undergraduates and postgraduates. An overview is given in Table 11.

Table 11: SSbD related educational offerings at University of Birmingham

Type of Education	Programme/Course	Modules/Content
Master's programme	**Chemical Engineering** Degree: M.Eng. (Master of Engineering)	Year 1 • Chemistry and Materials • Introduction to Transport Phenomena • Labs and Data Analysis

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Type of Education	Programme/Course	Modules/Content
(for under-graduates)	(also a three-year Bachelor of Engineering degree version is offered)	• Modelling Concepts and Tools • Process Design and Analysis • Reaction, Equilibria and Thermodynamics Year 2 • Computing for Chemical Engineers • Mass, Heat and Momentum Transport • Process Integration and Unit Operations • Process Systems and Principles of Process Control • Product Design Exercise • Reactors, Catalysis and Thermodynamics • Sustainable Process Engineering Year 3 • Advanced Reactors and Thermodynamics • Design Project • Multiphase Systems Optional modules themed in • Industry o Petrochemical Engineering o Plant Optimisation • Healthcare o Introduction to Healthcare Technologies • Formulation o Processing for Formulation o Engineering of Food • Energy o Efficient Use of Energy o Energy Economics Year 4 • Advanced Transport Processes • Research Project Optional modules themed in • Industry o Food Safety Management Systems o Sustainability in the Food Industry o Explosion Science, Prevention and Protection o Food Chain Security o Minerals Engineering: a Modern Perspective o Business and Strategy Development o Project Management (Business Strategy Delivery) • Healthcare o Fermentation Cell Culture

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Type of Education	Programme/Course	Modules/Content
		○ Design and Development of Drug Delivery Systems ○ From Bench to Market, Development of Pharmaceutical Products ○ Plant Design and Manufacturing Principles for (Bio)pharmaceutical Production ○ Frontiers in Tissue Engineering ○ Applied Synthetic Biology ○ Advanced Biomaterials for Healthcare Tech ○ Additive Manufacture and 3D Printing for Healthcare Applications ○ Pharmaceuticals and Therapeutic Biologicals from Bench to Market • Formulation ○ Advanced Reaction System ○ Chemical NanoEngineering ○ Future Engineering of Food ○ Interfaces in Products and Processes • Energy ○ Introduction to Electrochemistry ○ Techniques for Fuel Cell Characterisation ○ Fuel Cell and Hydrogen Technology ○ Advanced Electrochemical Applications ○ Energy Engineering Design ○ Energy Systems Design ○ Renewable Energy Systems ○ Thermal Energy Conversion, Storage and Application ○ Energy Storage
Master's programme (for post-graduates)	**Advanced Chemical Engineering** Degree: M.Sc./PGDip (Postgraduate Diploma)	• Bioscience for Graduates of other disciplines • Process Engineering Fundamentals • Applied Synthetic Biology • Measurement, Sensors and Design of Experiments • Non-ideal materials Optional modules themed in • Hydrogen Energy ○ Advanced Electrochemical Applications ○ Fuel Cell and Hydrogen Technology ○ Introduction to Electrochemistry ○ Techniques for Fuel Cell Characterisation • Food Engineering and Safety ○ Chemical Contamination of Food and Water ○ Food Chain Security ○ Food Structure for Performance ○ Future Engineering of Food ○ Sustainability in the Food Industry

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Type of Education	Programme/Course	Modules/Content

		• Pharmaceutical Technology
		  o Design and development of drug delivery systems
		  o From bench to market: the development of pharmaceutical drug products
		• Healthcare Technology
		  o Additive Manufacturing and 3D Printing for Healthcare Applications
		  o Advanced Biomaterials for Healthcare Technologies
		  o Advanced Therapeutic Medicine Products
		  o Frontiers in Tissue Engineering
		  o Medical Devices
		  o Sensor Systems in Medicine
		• Bioprocessing
		  o Bioseparations
		  o Cell Factories
		• Business Studies
		  o Business and Strategy Development
		  o Project Management (Business Strategy Delivery)
		• Energy
		  o Energy Storage
		  o Energy Systems and Policy
		  o Energy Systems Design
		  o Energy Systems Modelling
		  o Renewable Energy Systems
		• Core Process Engineering Skills
		  o Chemical NanoEngineering
		  o Explosion Science, Prevention and Protection
		  o Industry 4.0 and Big Data

Master's programme (for under-graduates)	**Environmental Science** Degree: M.Sc. (also a Bachelor of Science degree version is offered)	Year 1 • From Molecules to Materials: Deconstructing the Environment • Ecological Concepts and Plant Sciences • Statistical Methods and Applied Geographical Information Systems • Research Methods in Environmental Science • Environmental Research Frontiers • Global Challenges in the Anthropocene Year 2 (partly optional modules) • Dissertation Labs: theory and practice for Physical Geography and Environmental Science • Field Research Skills • Environmental Pollution and Management • Hydroclimatology: Climate and Water • Ecological Systems

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Type of Education	Programme/Course	Modules/Content
		• Critical Issues for 21st Century Ecosystems • Plant Sciences: From Cells to Environment • Geological Natural Hazards • Hydrology and Geomorphology • Digital data capture and analysis Year 3 (mostly optional modules) • Physical Geography and Environmental Science Research • Advanced Fieldwork Research • Conservation: Theory into practice • Climate Change in the Earth System • Conservation Practice: Genes to Ecosystems • Pollution Impacts and Environmental Management • Catchment Processes, Environmental Change and Restoration • Environmental Research in High Latitudes • Responses to Global Environmental Change • Resource Governance • Professional Placement • Micrometeorology: Weather, Climate and Society Year 4 (mostly optional modules) • Field, Research and Communication Skills • Causes and Effects of Air Pollution • Environmental Analysis and Modelling • Conservation Practice: Genes and Ecosystems • River Ecology • Chemical and Biological Incident Management • Air Pollution Chemistry • River Habitats and Biogeochemistry • Responses to Global Environmental Change • Hydrogeomorphology and Catchment Management
Master's programme (for under-graduates)	**Global Environmental Change and Sustainability** Degree: M.Sc. (also a Bachelor of Science degree version is offered)	Year 1 (partly optional modules) • The Earth System • One Planet Thinking and Living • Global Environmental Issues • Environmental Research Frontiers • Earth Materials • Introduction to Evolution and Animal Biology • Ecological Concepts and Plant Sciences • Young People and Social Change

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Type of Education	Programme/Course	Modules/Content
		• Moral and Political Philosophy Year 2 (mostly optional modules) • Earth Resources, Environmental Impacts and Sustainability • Developing Solutions • Geological Natural Hazards • Palaeoecology • Hydrology and Geomorphology • Sedimentology • Ecological Systems • Critical Issues for 21st Century Ecosystems • Animal Biology: Principals and Mechanisms • Plant Sciences: From Cells to the Environment • The Ethics and Politics of Climate Change • Science and Nature Year 3 (mostly optional modules) • Sustainability Research Project • Engineering Geology and Pollution Hydrogeology • Exploring the Energy Transition • Climate Change in the Earth System • Palaeoclimates • Environmental Research in High Latitudes • Resource Governance • Professional Placements • Conservation: From Theory into Practice • Conservation Practice: From Genes to Ecosystems • Animal Behaviour: From Theory to Application • Responses to Global Environmental Change • Vanished: Extinction from the Dodo to Extinction Rebellion • Humans and Environments • Learning Entrepreneurial Skills • Entrepreneurial Start Up • Efficient use of Energy • Energy Economics • The Mess We're In: Towards a History of Our Times Year 4 (mostly optional modules) • Funding Science • Research Developments and Scientific Communication • Conservation Practice: Genes to Ecosystems

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Type of Education	Programme/Course	Modules/Content
		• Responses to Global Environmental Change • Animal Behaviour: From Theory to Applications • Engineering Geology and Pollution Hydrogeology • Exploring the Energy Transition • Climate Change in the Earth System • Palaeoclimates • Professional Placement • Energy Systems and Policy • Renewable Energy Systems
Master's programme (for post-graduates)	**Environmental Health** Degree: M.Sc.	• Food Microbiology and Safety • Food Control and Hygiene Management • Occupational Health and Safety • Environmental Protection and Climate Change • Health Protection • Housing and Law • Public Health Integration
Master's programme (for post-graduates)	**Air Pollution Management and Control** Degree: M.Sc./PGDip	• Causes and Effects of Air Pollution • Theoretical Meteorology: Atmospheric Physics and Composition • Small-scale and Air Pollution Meteorology • Air Pollution Chemistry • Air Pollution Management and Control Technology • Carbon Management • Air Quality Data Analysis and Interpretation
Master's programme (for post-graduates)	**Health, Safety and Environment Management** Degree: M.Sc./PGDip	• Health, Safety and Environment Management • Assessing and Controlling Workplace Health • Environmental Protection and Climate Change • Health, Safety and Environment Management • Assessing and Controlling Workplace Health • Environmental Protection and Climate Change • Research Methods
Master's programme (for post-graduates)	**Environmental and Biological Nanoscience** Degree: M.Res. (Master of Research)	• Environmental and Biological Nanoscience • Molecular and cellular mechanisms of (nanomaterial) Toxicology • Research Methods

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5.2.3 National Technical University of Athens (NTUA)

Many educational offerings at NTUA are focused on engineering, i.e. on Civil Engineering, Mechanical Engineering, Electrical & Computer Engineering, Chemical Engineering, Rural, Surveying and Geoinformatics Engineering, Mining & Metallurgical Engineering, and Marine Engineering. NTUA offers several undergraduate and post-graduate courses which can be considered currently or potentially relevant to SSbD, according to the description of their content.

The most relevant ones in terms of SSbD aspects are presented in Table 12. In the same table an LCA e-learning course for professionals offered by the National and Kapodistrian University of Athens (NKUA) is also included. It should be noted that the above-mentioned courses mostly cover the Sustainability side of SSbD. Certain courses exhibit no registered focus on SSbD, though elements of SSbD thinking inevitably exist in their content; such courses will be enriched towards SSbD as of the next academic year.

Table 12: SSbD related educational offers at NTUA (kindly provided by NTUA).

Type of Education	Programme/Course	Modules/Content
Undergraduate course	**Environmental Assessment and Optimization of Industrial Processes** Included in the Chemical Engineering Curriculum of NTUA, taught during the 9th semester.	• Criteria and "tools" for environmental assessment in the design and operation of industrial processes. • Introduction to the logic and necessity of rational use of raw materials and energy in industry. • Environmental Technologies and Reuse and Recycling Technology. • Water and carbon footprint. • Circle of life. 'Boundary point' analysis as a 'tool' for the evaluation and environmental optimization of industrial processes. • Design of "clean" industries based on the "limit" of water use. • Methodology for designing industrial processes to minimize waste generation. • Methodology for the design of industrial processes for the re-use of generated waste. • Design methodology for the recycling of processed waste through the analysis of the boundary point. • Integrated industry design methodology to minimize the production of waste while optimizing the required heat loads. • Integrated Design to minimize waste generation and value-added production. • By-products of bio-refineries.

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Type of Education	Programme/Course	Modules/Content
Certificate Course (for professionals)	**Life Cycle Assessment (LCA) based on ISO 14040/14044** Degree**:** Certificate of Attendance E-learning course included in the Lifelong Learning Program of NKUA.	1. European Legislative framework • Regulations and Directives for Chemicals use (REACH, Rohs, Pops) • Classification, Labelling and Packaging (CLP) Regulation for chemicals 2. Environmental Analysis • Introduction to the Lifecycle Analysis Methodology • Sustainability Indices • ISO 14040/14044 based Lifecycle Analysis 3. Environmental impact assessment methodologies • Environmental Data categories and Inventory analysis • Methodologies for the calculation of Sustainability indices 4. Application fields for LCA Methodology • Industrial production units • Consumer products 5. LCA Softwares and Case studies • LCA softwares and databases • Tutoring in the use of CCaLC and SimaPro softwares • Case studies on Environmental LCA of Industrial processes and Products.
Undergraduate course	**Process Design II** Included in the Chemical Engineering Curriculum of NTUA, taught during the 8th semester	The aims of the course are: • Acquisition of design knowledge in specialized areas of integrated design of a chemical plant. • Development of skills in the selection of different types of chemical reactors and separators. • Development of skills in redesigning and expanding an existing unit. • Familiarization with holistic evaluation techniques of the unit. • Skills development. • Examination of environmental parameters and Life Cycle Analysis of the proposed design solution. • Using simulation software to achieve all of the abovementioned goals for specific design

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Type of Education	Programme/Course	Modules/Content
		specifications each time. The course provides a process design project.
Undergraduate course	**Products Design** Included in the Chemical Engineering Curriculum of NTUA, taught during the 6th semester	The course aims to familiarize the Chemical Engineer with the background knowledge and methodology for answering the key questions: "what product should be manufactured" and "how will it be manufactured", in order to present the best economic and technical characteristics and meet the current environmental requirements and specifications. The course content provides information and knowledge on: • Needs: Identifying consumer or customer needs and converting them into measurable product features with relevant specifications. • Ideas: Gathering ideas that may deliver the desired result to meet the needs of the consumer or customer. Evaluate concentrated ideas and select a small number of the best ones. • Detailed calculations for the best ideas and selection of the idea to be realized. Calculations refer to technical and financial figures, as well as Life Cycle based environmental impact assessments, early enough, starting from the product design phase. • Production: Designing the industrial production of the new product (mainly processes).
Undergraduate course	**Green Chemistry and Engineering** Included in the Chemical Engineering Curriculum of NTUA, taught during the 8th semester	Green Chemistry and Green Engineering Development Framework: Objectives, Principles, Tools. • Indicators for measuring the efficiency of reactions and processes (metrics). • Reaction and process efficiency. • Calculation of atomic yield and chemical reaction mass. • Process optimization, modifications and product re-design. • Alternative Raw Materials, Solvents and Catalysts in the Chemical Industry. • The contribution of Green Chemistry to sustainable agriculture. • Performance evaluation based on chemical structure, chemical reaction and chemical transformation. Examples and exercises of green raw materials,

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Type of Education	Programme/Course	Modules/Content
		reactions, reagents, solvents, reaction conditions and chemicals. • Large-scale case studies of green processes. • The role of ionic liquids and deep eutectic solvents. • Chemical reactions of increased energy efficiency. • High Energy Techniques (microwave, ultrasound). • New Trends in Green Chemistry and Engineering - Biomimetic and Multifunctional Systems. Laboratory of Green Chemistry and Engineering: • Synthesis and characterization of ionic liquids and deep eutectic solvents. • Organic compositions with green processes. • Synthesis of natural compounds and bio-degradable materials by green techniques. • Synthesis of polymers from natural materials. • Use of renewable raw materials in processes. • Acquisition of natural waste materials through green techniques. Characterization of green secondary products.
Undergraduate course	**Polymer Materials Production Engineering** Included in the Chemical Engineering Curriculum of NTUA, taught during the 9^{th} semester	The course aims to understand the polymerization processes, presenting the mechanisms and techniques used to produce polymers. In this way, a chemical-mechanical view of the respective processes is achieved, giving examples of the most important commercial polymers. At the same time, alternative technologies are introduced to design environmentally friendly polymer products and to develop recycling technologies for plastic waste.
Undergraduate course	**Metallic Materials Science and Engineering** Included in the Chemical Engineering Curriculum of NTUA, taught during the 9^{th} semester	The aim of the course is to introduce students to the fundamental principles, structure, properties of metals and their alloys, as well as to the treatments/processes applied to obtain the desired properties according to their final application. The main aims of the course are the student to: • Understand the connection of the structure and properties of these materials, as well as relate them to the process / treatment applied and their applications as finished products, • To know the latest techniques and methods of characterization of these materials,

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Type of Education	Programme/Course	Modules/Content
		• To develop skills in selecting a suitable metallic material and refining it according to material applications.
Undergraduate course	[Advanced Ceramic Materials] Included in the Chemical Engineering Curriculum of NTUA, taught during the 5th semester	The main aim of the course is the presentation of modern methods of developing advanced ceramic materials with specific properties. • A focus will be made on new innovative technologies for the production and application of ceramic materials and glasses. • The relationship between structure and properties of ceramics and electroceramics will be explained, emphasizing on solid mass transfer and conductivity in ceramic materials. • In addition, a focus will be made on the thermal properties of the materials and how they affect the final product. • Industrial applications of advanced ceramic materials with emphasis on energy applications will be developed. • The role of production quality, the life cycle of materials, as well as the sustainability in the field of advanced ceramic materials and their energy applications will be explained.
Undergraduate course	[Industrial Waste Management] Included in the Chemical Engineering Curriculum of NTUA, taught during the 8th semester	• Categories - General characteristics of solid wastes - Classification codes. • Hazardous wastes: Characterization (toxicity, corrosivity, flammability, etc.). • Risk storage and transportation. • Physico-chemical, biological and thermal methods for the treatment and disposal of hazardous wastes. • Risk assessment. Environmental impacts. • Special types of Solid Wastes: End-of-Life Vehicles, Used Tires, Excavation, Construction and Demolition Wastes, Wastes of Electrical and Electronic Equipment, agricultural wastes, hospital wastes.
Undergraduate course	[Building materials II]	***SSbD related course material*** • Sustainable Materials: Calculation of carbon footprint in the production of materials and their use (construction-operation-maintenance).

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Type of Education	Programme/Course	Modules/Content
	Included in the Civil Engineering Curriculum of NTUA, taught during the 8th semester	• Thermal behaviour and performance. • Sustainability and design service life. • Energy saving, waste recovery and recycling. • Economic sustainability assessment. • Compliance with the European Climate Change Directives.
Undergraduate course	**Environmental Impact** Included in the Civil Engineering Curriculum of NTUA, taught during the 9th semester	• Environmental Licensing • Calculation of Impact-Life Cycle Assessment (LCA) • Presentation Of Waste Management Case Study • Elaboration of EIA for real technical work
Undergraduate course	**Design of innovative mechanical products** Included in the Mechanical Engineering Curriculum of NTUA, taught during the 9th semester	Through a design project, students apply knowledge and skills acquired during diverse courses, designing an innovative product combining high functionality, ease production methods, low ecological footprint and usability. The scope is to understand through experience the stages of industrial design –from the conceptual design to the prototype evaluation–. Students are supervised by at least two faculties with different specialization.
Undergraduate course	**New and Renewable Energy Sources** Included in the Mechanical Engineering Curriculum of NTUA, taught during the 7th semester	• Introduction: RES and the energy problem • Historical evolution of energy technologies • The present situation: energy sources and energy consumption (worldwide, in Europe, in Greece) • Towards a sustainable energy future- The development of RES in Europe and in the world • RES in Greece • Short and long term perspectives of RES (worldwide, in Europe, in Greece). • The potential of RES- Methods of analysis and estimation: wind potential – solar radiation – biomass – hydroelectric potential – geothermal resources – ocean waves/ ocean currents. Technologies - applications – systems of RES: Wind turbines- Passive solar systems – Bioclimatic architecture – Active solar thermal systems – Photovoltaic systems – Bioenergy – Small hydro – Marine energy systems – Geothermal energy– Hydrogen – Fuel cells.

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Type of Education	Programme/Course	Modules/Content
		• Techno-economic analysis of RES systems: Energy costs (conventional, environmental, external) • Environmental impacts and their economic evaluation - Avoided costs of conventional fuels • Analysis of investments and their application in energy systems • Management of energy systems including RES.
Post graduate course for MSc Students	**Environmental Management and Control – Environmental Policies** Included in the "Environment and Development" MSc Programme Curriculum of NTUA.	The course includes the following topics (among other ones): • LCA - Case studies • Eco-Design - Case studies • Eco-Label • Integrated product policy • Circular economy and environmental management • Integrated control and prevention of pollution
Post graduate course for MSc Students	**Clean Technologies** Included in the "Environment and Development" MSc Programme Curriculum of NTUA.	Clean Power production technologies, along with heat generation and storage for their integration in primary and tertiary sector applications are discussed. Energy and carbon footprint, as well as carbon capture technologies are presented.
Post graduate course for MSc Students	**Environmental Technology and Management** Included in the "Energy Production and Management" MSc Programme Curriculum of NTUA.	Introduction to the Ecological engineering approach, environmental technologies, recycling and reuse technologies and "clean" technologies. LCA of energy production systems.
Undergraduate course	**Metallurgy of Welding – Technology & Control of Weldments** Included in the Mining & Metallurgical Engineering	Basic principles of welding Metallurgy. • Welding thermal cycle, welding zones, phase transformations, microstructure evolution and residual stresses • Arc welding techniques (e.g. TIG, MIG, etc.), beam welding (laser, electron beam) and solid state welding methods/techniques (e.g. friction stir, ultrasonic, diffusion)

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Type of Education	Programme/Course	Modules/Content
	Curriculum of NTUA, taught during the 8th semester	• Protective atmosphere, available protection means (gasses, powders, slags etc.) • Current and voltage, main equipment & techniques • Main welding defects and non-destructive testing techniques, weldment control • Health safety
Undergraduate course	**Powder Metallurgy & Additive Manufacturing (emphasis on 3D printing)** Included in the Mining & Metallurgical Engineering Curriculum of NTUA, taught during the 9th semester	• Introduction, production methods of powders in metallurgy, properties of powders (particle size distribution, specific surface, additives), thermal treatment of powders • Compression and shaping, thermal coagulation (mono- or multi-component) • Powder metallurgy products: iron and steel, copper, nickel and super alloys, hard metals, high-melting-temperature metals, metal composites
Undergraduate course	**Casting & Forming Processes of Metals** Included in the Mining & Metallurgical Engineering Curriculum of NTUA, taught during the 9th semester	The students learn how to evaluate process steps, microstructures, properties and to select proper forming operations to fit the given purpose for all modern applications and metals/alloys. • Basic principles of solidification and main casting techniques/methods. • Plasticity theory and background to plastic deformation. Introduction to plasticity of metals, hardening, elastic and plastic deformation, the Bauschinger effect etc. • Introduction to the main methods/techniques of plastic deformation in metals/alloys (rolling, extrusion, forging, wire drawing, sheet metal forming e.g. deep drawing), thermomechanical processes, reduction and rolling schedules (roll pass design, deformation rate etc.) • Influence of thermomechanical deformation in the microstructure evolution and control, recrystallization, grain size and microstructure-properties relationships. • Main defects from deformation processes (e.g. during rolling, extrusion, forging etc.) • Anticipation of the manufacturing footprint and value chain.

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Type of Education	Programme/Course	Modules/Content
Undergraduate course	**Technology of Cement and Concrete Production** Included in the Mining & Metallurgical Engineering Curriculum of NTUA, taught during the 8th semester	• The Greek Cement Industry. • Structure and Mineralogical Composition of Cements. • Cement Types, Composition and Uses. • Raw Materials and Calculation of Raw Mix Composition. • Size Reduction Operations. • Pyroprocessing Technology. • Hydration of Cements. • Metallurgical Processes in Cement Production. • Chemical Behavior of Cement in Production and Use of Concrete. • Methods of Aggregates production. • Test Methods for Aggregates Materials for Proper Concrete (Particle Size Composition, Shape, Mineralogical Characteristics, Strength, etc.). • International and Greek Standards for Cement Testing. • Environmental Aspects of Production and Use of Cement and Concrete.
Undergraduate course	**Processing and Utilisation of Industrial Minerals** Included in the Mining & Metallurgical Engineering Curriculum of NTUA, taught during the 8th semester	The scope of the course is the studying of basic chemical methodologies that used for the processing and the valorization of industrial minerals and, as well as, the examination of various applications of industrial minerals and the description of complex materials with advanced physicochemical properties.

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5.2.4 IVL Swedish Environmental Research Institute

IVL teaches LCA in several modules in the Master's Programme in Sustainable Chemistry at the Stockholm University (Table 13), i.e. in the modules Introduction to Sustainable Chemistry and Chemistry of Sustainable Recycling.

Table 13: Educational offerings at Stockholm University in which IVL participates.

Type of Education	Programme/Course	Modules/Content
Master's programme	**Master's Programme in Sustainable Chemistry** Degree: M.Sc.	1st Semester • Introduction to Sustainable Chemistry • Materials Chemistry for Environmental Applications • Chemistry of Renewable Materials • Chemistry of Renewable Energy Generation and Storage 2nd Semester • Toxicology for Environmental Scientists • Sustainable Organic Chemistry • Chemistry of Sustainable Recycling • Characterization Methods in Sustainable Materials Chemistry (elective course) 3rd Semester • Electron Microscopy for Materials Characterization (elective course) • Analytical Chemistry, Advanced Separation Methods (elective course)

5.2.5 Empa - Swiss Federal Laboratories for Material Science and Technology

Empa widely organizes and supports university courses in Switzerland, Germany, and Austria. Courses performed in 2022 are listed in Table 14.

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Table 14: University courses organized or supported by Empa in 2022.

University	Course/module
Swiss Federal Institute of Technology Zurich (ETHZ)	Anthropogenic Particles in the Environment Audience: Master
ETHZ	Prospective Environmental Assessments Audience: Master
ETHZ	Sustainable Materials Management: Concepts, Methods and Principles Audience: Master
ETHZ	Experimental and Computer Laboratory Audience: Master
ETHZ	Battery Integration Engineering Audience: Master and PhD
Zurich University of Applied Sciences	Biomass as a Resource (in German) Audience: Bachelor
Eastern Switzerland University of Applied Sciences	Recycling and disposal (in German) Degree: CAS Audience: Professionals
University of Applied Sciences and Arts Northwestern Switzerland	Waste Management and Recycling (in German) Audience: Bachelor
University of St. Gallen	The Power of Games - How Simulation Games Can Foster Sustainability Transitions Audience: Bachelor
University of Bern	**Sustainability –also an issue in/for the field of biomechanical engineering?** Audience: Master
Bern University of Applied Sciences	**Packaging from an ecological perspective** (in German) Audience: Bachelor
Albstadt-Sigmaringen University	Technology Assessment Audience: Bachelor
IMC University of Applied Sciences Krems	**Principles of Sustainable Development** Audience: Master

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5.3 Skills needed to apply SSbD early in the innovation process

During an online WP3 co-creation on the 2nd of December 2022, several skills, competences and education needs required for applying SSbD early in the innovation process were collected via Menti. In total, 24 replies (often covering more than one aspect) were received. In the following section, coloured text visualizes the Menti responses.

So far, a common understanding of SSbD is missing. This was mentioned as required skill/knowledge by two repliers:

- Creating a common understanding of SSbD **(n = 2)**.

Three of the mentioned skills directly relate to 'systems thinking', one key competency of sustainability:

- Systems thinking and understanding of sustainability in its broadest meaning,
- Life cycle thinking already at the design phase,
- "By-design" thinking.

Several of the mentioned skills relate to the safety and sustainability assessments required by the JRC framework; LCA-related skills in particular were mentioned several times:

- Skills on LCA **(n = 3)**,
- Skills on LCC,
- Skills on Hazard Assessment and Risk Assessment,
- Knowledge of risks and environmental impacts of your products,
- Knowledge about the production of the chemical/materials and their uses,
- Skills on methods and criteria to assess materials performance, durability, and energy consumption during use along the innovation process.

Also, knowledge and skills related to tools were mentioned repeatedly:

- Skills in using the available tools,
- Tools catered to disciplinary expertise,
- Tiered tools and processes,
- Modelling and digital technologies,
- SSbD toolbox (incl. social criteria(s) as part of LCA).

As SSbD is an integrated approach, skills relating to the integration of SSbD aspects into the innovation process are required:

- Integration of risk assessment, sustainability assessment and innovation,
- Integration of economic consideration.

Further (soft) skills that were mentioned:

- Multidisciplinary interaction expertise,
- Further strengthening compliance abilities,
- Promoting of SSbD, e.g., through publishing,

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- Sustainability/product stewardship for research scientists in advanced materials and chemicals.

In addition to skills and competence needs, the participants were also asked for education needs and had the following replies:

- Standardized, structured and harmonized syllabus in SSbD,
- SSbD training to material scientists,
- Knowledge on chemistry (or materials science),
- The IRISS SSbD network should make sure to have the updated info for academia.

The skills, competences, and education needs collected in this WP3 co-creation underline the importance of systems thinking competences for SSbD. They also show the great need for knowledge and skills related to performing the assessments required by the JRC framework and using the available tools.

5.4 Skills availability and needs of IRISS partners and stakeholders

This chapter maps industrial practice, research and education in terms of skills availability and needs based on the WP1 survey (Annex A) replies. In total, 99 responses (IDs 1 to 99) were recorded. Out of these, ten responses were excluded as they either didn't acknowledge the data protection notice (IDs 47, 55, and 88), were a test reply to check the functionality of the survey (ID19) or did not include any (valid) answers (IDs 17, 18, 21, 31, 33, and 44). Two responders represented EU-funded research projects and were analysed in Chapter 5.5 (IDs 28 and 53). This results in **87 valid responses** in total.

5.4.1 Participant information

The background of the responding organisations is shown in Figures 8 and 9. Representatives of organisations from 19 countries responded to the survey, including companies (n = 37; 43%), research and technology organisations (n = 22; 25%), academic institutions such as universities (n = 13; 15%), business or industry association (n = 4, 5%), public authority individual citizens (n = 2; 2%), clusters/platforms/networks (n = 2; 2%), other non-governmental organizations (NGOs) (n = 2; 2%) and other organisation types that were not further specified (n = 5; 6%). Of the companies, most were large companies (n = 25; 67%), followed by small and medium enterprises (SMEs) (n = 11; 30%) and start-ups (n = 1; 3%). The responders are working in a wide range of sectors, with the chemical sector (n = 35; 43%) being the most represented in this survey.

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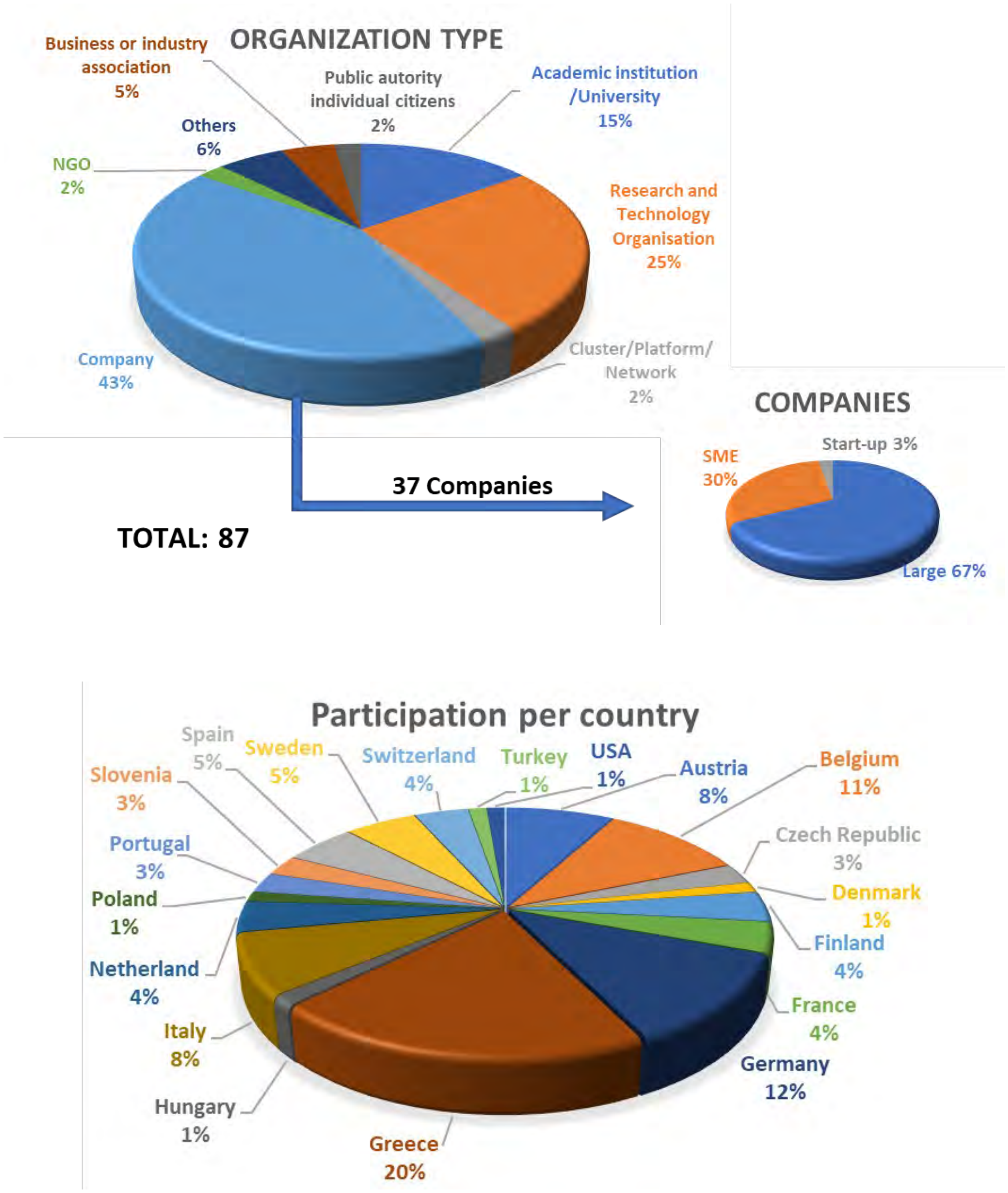

Figure 8: Background of the respondents' organization type and country.

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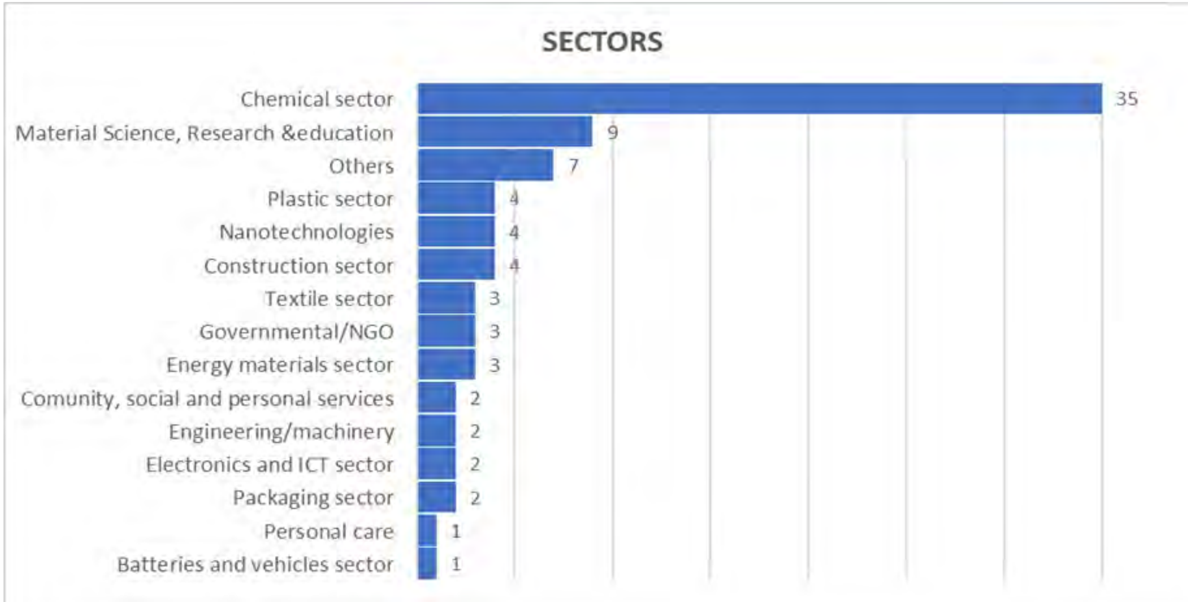

Figure 9: Background of respondents' sectors.

Of the total respondents, 82% (n = 71) already consider SSbD aspects in the development of chemicals, materials, products, or processes (Figure 10). This shows that the responding organisations to this survey are very conscious about safety and sustainability. It must be noted that the results might be biased and not represent the real (industry) situation as mainly IRISS partners and stakeholders were contacted who, therefore, already showed an interest in SSbD.

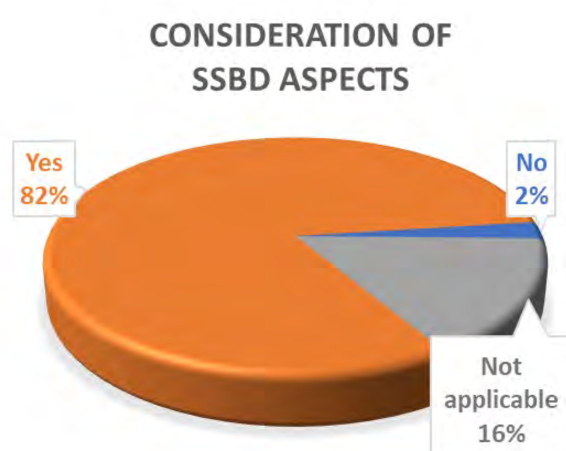

Figure 10: Consideration of SSbD aspects in the development of chemicals, materials, products or processes.

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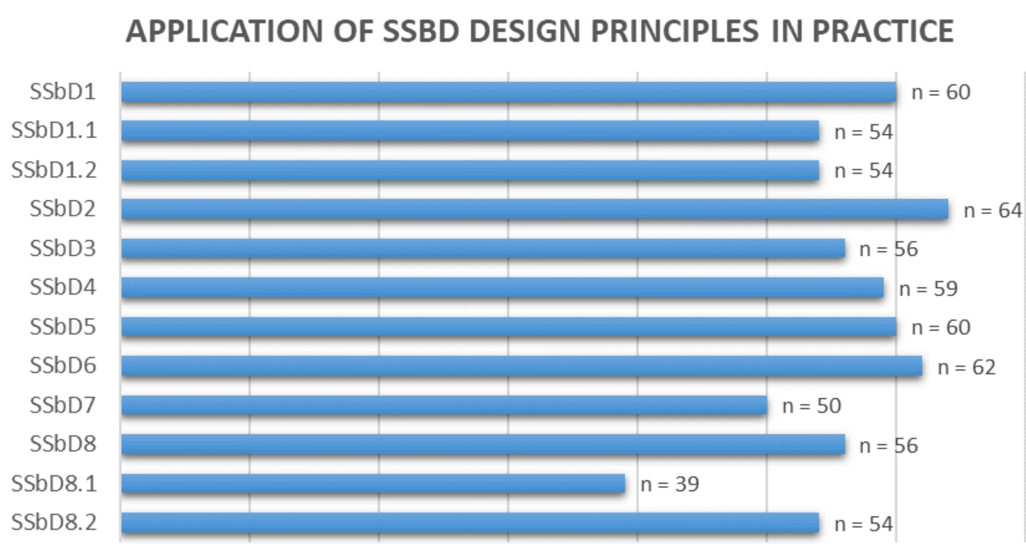
5.4.2 SSbD principles applied in practice

The following Figure 11 summarises the results of the SSbD design principles in practice derived from the survey. A detailed analysis of these results is done in IRISS report 1.2.

Both human safety related design principles SSbD2 and SSbD6 as well as the environmental safety related principle SSbD5 show high application rates (n = 60 to 64; 78% to 83%). This shows that safety considerations related to the use of SVHC and the reduction of emission to the environment are widely applied in the design phase. The sustainability related design principles show marginally lower application rates.



SSbD1	**Material efficiency** (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)
SSbD1.1	**Identify occurrence of use of critical raw material, towards minimizing or substituting them**
SSbD1.2	**Minimize the volume of solvents and water in the processes of manufacturing, production or use**
SSbD2	**Minimize the use of hazardous chemicals/materials**
SSbD3	**Design for energy efficiency** (minimise the energy used during the chemical material production and along the supply chain)
SSbD4	**Use renewable sources**
SSbD5	**Prevent and avoid hazardous emissions**
SSbD6	**Reduce exposure to hazardous substances**
SSbD7	**Design for end of life** (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)
SSbD8	**Consider the whole Life Cycle** (apply the other design principles thinking through the entire life cycle, from supply chain to the end-of-life in the final product)
SSbD8.1	**Design to last** (predict materials durability at the design phase of the product)
SSbD8.2	**Efficient recyclability of (raw) materials and/or products**

Figure 11: Application of SSbD design principles in practice

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The following reasons were given for not applying (all) design principles:

- The other principles are not relevant/applicable in the specific (research) field **(n = 12)**,
- Missing know-how or lack of education **(n = 10)**,
- Missing information/(FAIR) data and/or data transparency **(n = 9)**,
- Whole life cycle of the final product is hard to consider at an early development stage or at the beginning of the supply chain **(n = 5)**,
- Limited impact/influence along the value chain; successful implementation needs a shared effort along the value chain **(n = 3)**,
- The JRC framework and the proposed criteria/design principles lack maturity or are not fit for purpose for certain chemicals/materials **(n = 3)**,
- Cost effectiveness **(n = 2)**,
- Lack of resources **(n = 2)**,
- Missing technology or suitable models **(n = 2)**,
- The selection of principles depends on requirements **(n = 1)**.

Other sustainable principles and aspects considered by the respondents during the design phase of the material, product, or process development are:

- Design for reduced consumption,
- Design for product efficacy,
- Design for inherently safe or less hazardous materials,
- Design for reduced climate impact **(n = 3),**
- Design for bio-compatibility **(n = 2),**
- Design for SDGs **(n = 2),**
- Design for reduced amount of resources,
- Design for circular business models,
- Design for circularity (e.g., sorting, reuse, repairability, recycling, upcycling) **(n = 5),**
- Design for biodegradation,
- Design for reduced waste **(n = 2)**,
- Design for economic sustainability.

Some of the mentioned principles are already included in the SSbD design principles proposed by the JRC, i.e., both 'Design for circularity' and 'Design for biodegradation' are end of life options and included in SSbD7 'Design for end of life'. The principle 'Design for reduced waste' is included in both SSbD1 'Material efficiency' and SSbD7 'Design for end of life' as waste reduction is an important aspect for both JRC design principles. These results indicate that some design principles, particularly SSbD7, were underrated in this survey (Figure 11).

The mentioned principle 'Design for inherently safe or less hazardous materials' is one of the key goals of SSbD, but the safety-related SSbD design principles (as proposed by JRC) are mainly focused on reducing use, exposure, emissions of hazardous chemicals/materials (SSbD2, SSbD5, SSbD6) and not directly on designing them. This aspect is, however, also included in SSbD7 as hazardous materials would hinder the reuse, waste collection, sorting and recycling/upcycling and,

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furthermore, chemicals/materials should be designed to break down (after they have fulfilled their function) into products that do not pose any risk to the environment/humans.

Further aspects that the respondents consider in the design phase are:

- Green finance,
- Stakeholder analysis and public perception,
- Market research on how customers/consumers understand the information or claims provided,
- Plan of risk communication,
- Critical tools and contingency plan as far as chemical and physical routes processes are concerned,
- Chemical reactivity (instead of hazard),
- Auto-generated energy,
- Green Hydrogen,
- Proximity of raw material resources used **(n = 2),**
- Sustainable sourcing of renewable materials and avoiding conflict minerals[5],
- Non-regrettable substitution or elimination of priority substances from the portfolio.

The reduction of transport distances in the supply chain is listed as one example of actions for SSbD8 'Consider the whole life cycle' (Table 1 of Caldeira et al., 2022b). The social aspects of sourcing are not directly included in the eight design principles proposed by JRC but are part of assessment step five.

[5] 'Conflict minerals' such as tin, tungsten, tantalum, and gold (3TG) are linked with human rights abuses and financing armed conflicts.

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5.4.3 Safety and sustainability aspects applied in practice

This chapter gives an overview of the application rates of safety, social LCA, environmental LCA, and circular economy aspects by the respondents as well as of the most considered aspects. Detailed analyses of the survey results related to these aspects are done in the IRISS reports PR1.1, PR1.2, PR1.3, and PR1.4, respectively.

Table 15: Application rates of safety, social, environmental LCA, and circular economy aspects.

Aspect	Application rate	
	All respondents	Companies
Safety	70%/72%	92%
Social LCA	62%	76%
Environmenral LCA	64%	70%
Circular Economy	73%	78%

An overview of application rates is provided in Table 15. Safety and circular economy aspects are applied more often in practice than social and environmental LCA aspects. In general, all aspects are more commonly applied by companies compared to all respondents, particularly safety aspects.

Of all respondents, 70% (n = 61) perform **hazard assessments** for new materials and chemicals applied in their products and 72% (n = 63) consider **occupational health and safety (OHS) factors, human health**, and **environmental risks** during the manufacturing or use-phase of new materials and chemicals (Figure 12). The use of the JRC framework for hazard assessments is very low (n = 8; red box in Figure 12). Looking at companies only, 92% (n = 34) perform hazard assessments and consider OHS factors, human health, and environmental risks. This shows that safety aspects are widely embedded in company procedures, among other reasons due to the need to comply with many safety regulations such as REACH that nearly all companies (n = 32) applied.

Of all respondents, 62% (n = 54) perform or intend to perform an **s-LCA** during the design or development phase of a material, product, or process with 'Workers' Health and Safety' being the most considered aspect (Figure 13). Looking at companies only, the percentage of the companies using s-LCA is higher (n = 28, 76%). This may be because the companies that responded to the survey are very conscious about sustainability.

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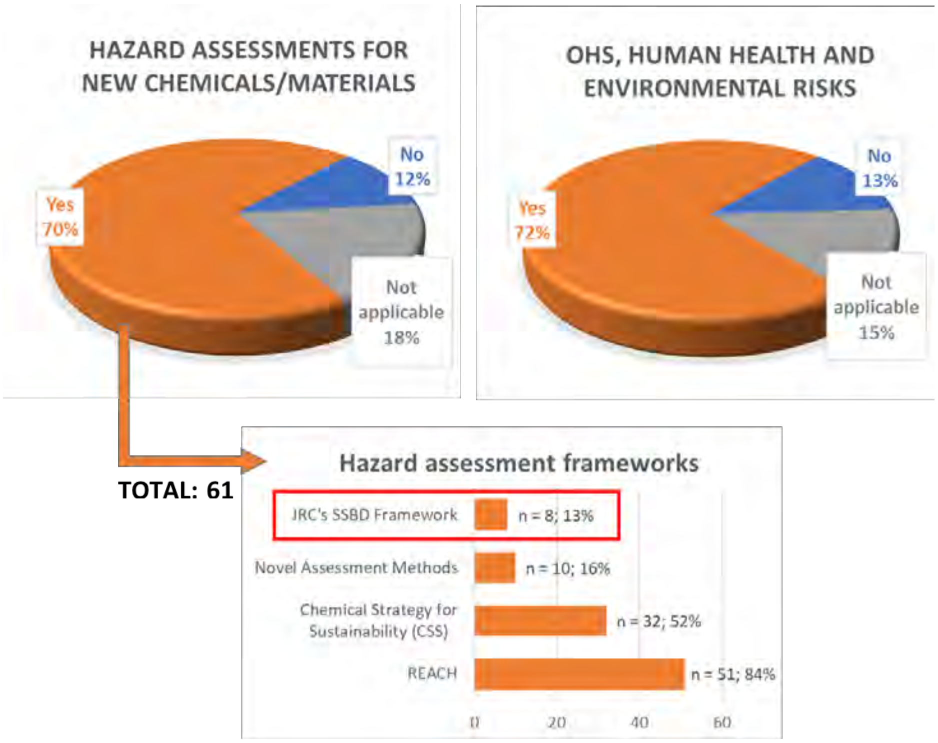

Figure 12: Percentage of respondents that consider safety aspects.

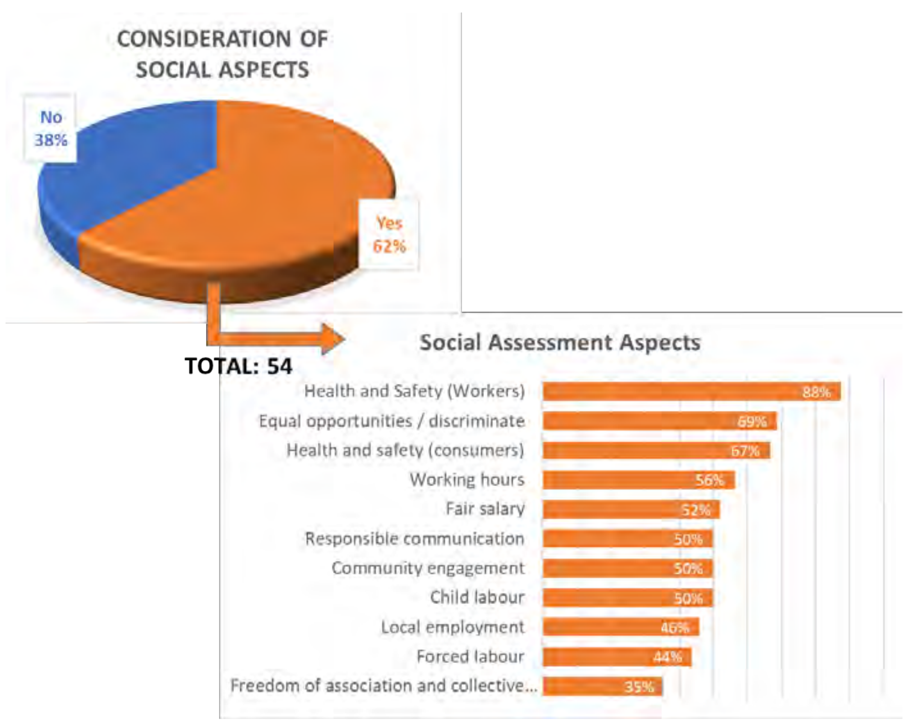

Figure 13: Percentage of respondents that consider social aspects.

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Of all respondents, 64% (n = 56) perform or intend to perform an **environmental LCA** during the design or development phase of a material, product, or process (Figure 14). With only three exceptions, the processing phase is considered by all respondents that perform LCA, while the use phase is only considered by roughly every second respondent (94% and 53%, respectively). Regarding the use phase aspects, 'reduction of energy consumption' is the most considered one, while 'upgradability' is the least considered one (76% and 21%, respectively). Looking at companies only, the percentage is slightly higher with 70% (n = 26) performing or intending to perform a LCA. No major deviations were observed for LCA phases and use phase aspects.

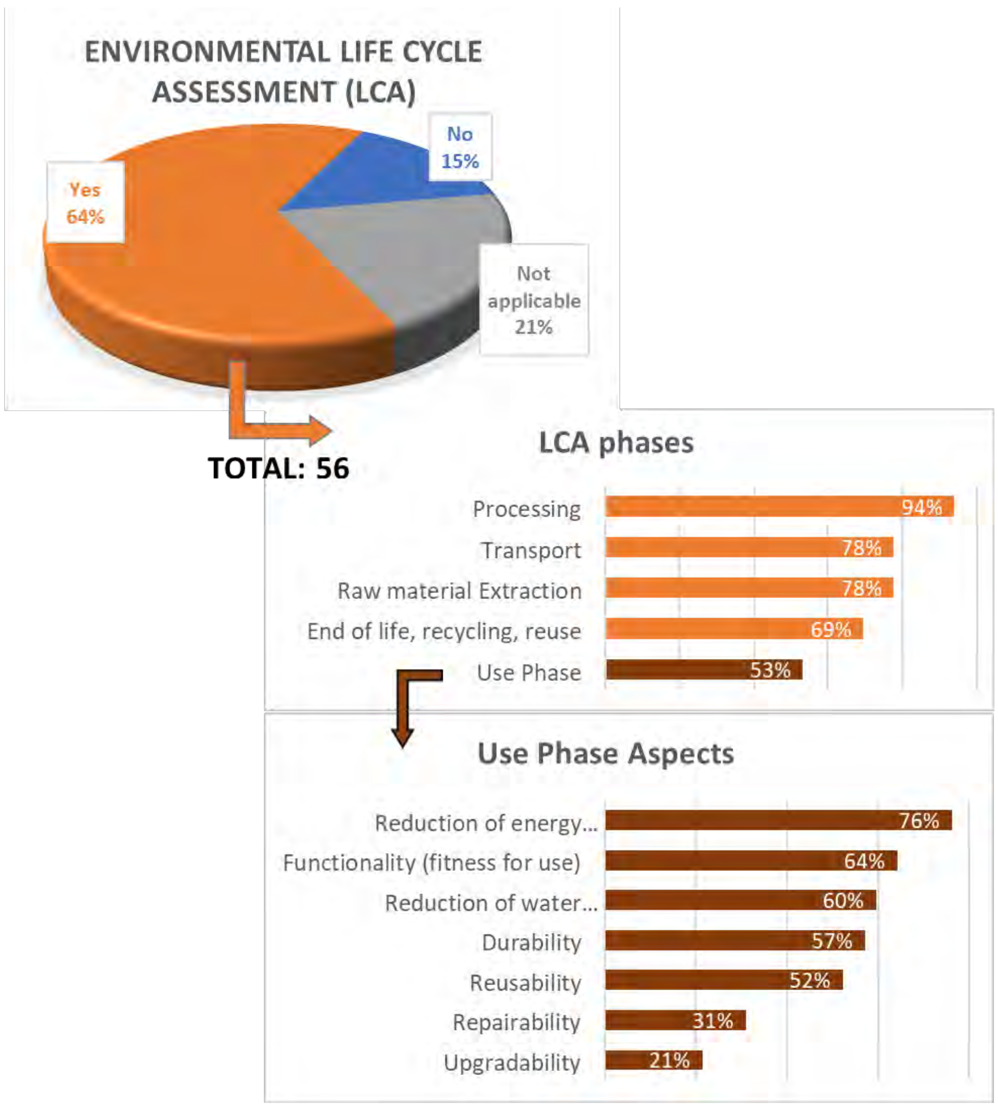

Figure 14: Percentage of respondents that consider environmental LCA and use phase aspects.

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Of all respondents, 73% (n = 63) consider or intend to consider circular economy aspects in the design or development phase of a material, product, process, or R&D activity (Figure 15). Looking at companies only, an even higher number, 78% (n = 29), answered positively. For the product's end of life, 'recyclability' and 'reduction of waste' are the most commonly considered aspects (both 75%) while 'refurbish' and 'repurpose' were found to be the least considered aspects (both 16%). Both least-considered aspects refer to circular economy strategies aiming to extend the product's life span (see IRISS report PR1.4). Regarding the raw materials use, 'use of renewable feedstock' is the most considered aspect (73%, n = 41).

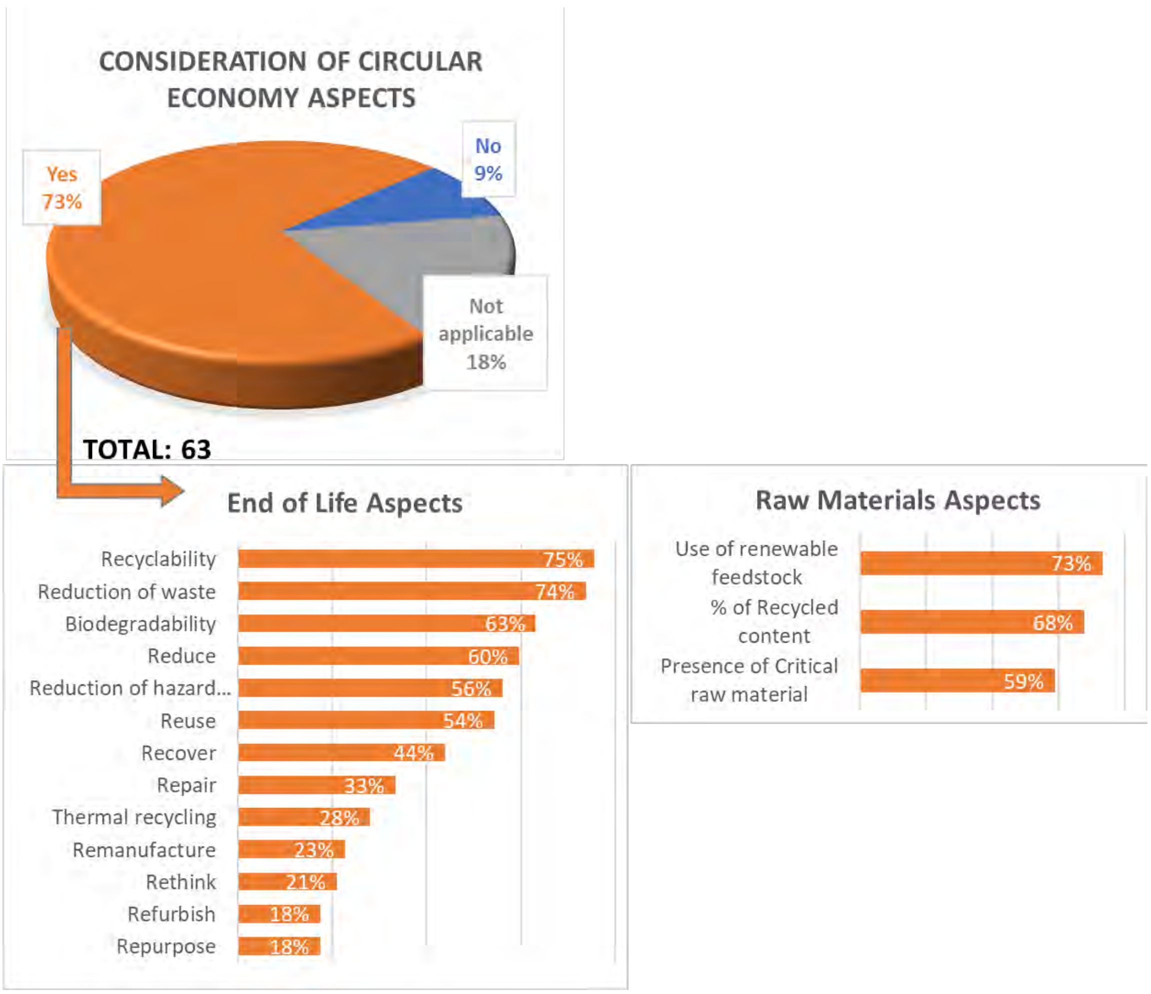

Figure 15: Percentage of respondents that consider circular economy aspects and considered aspects of end of life and raw material used.

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5.4.4 Education and training

The questions asked in relation to teaching experience on SSbD issues and in-house-trainings (only companies) are presented in Table 16.

Table 16: Summary of training and teaching experiences.

SURVEY SECTION – Skills and Companies			
Question number	Question	Number of respondents	
		Total	Companies
59	Do you have experience in teaching on Safe-and-Sustainable-by-Design-issues?	78	33
60	If yes, please give more information about what type of teaching skills (e.g., internal training, university curriculum).	23	8
18	Does your company perform in-house trainings/workshops regarding the SSbD concept?	-	37
19	If yes, please give some bullet points on the covered aspects.	-	14

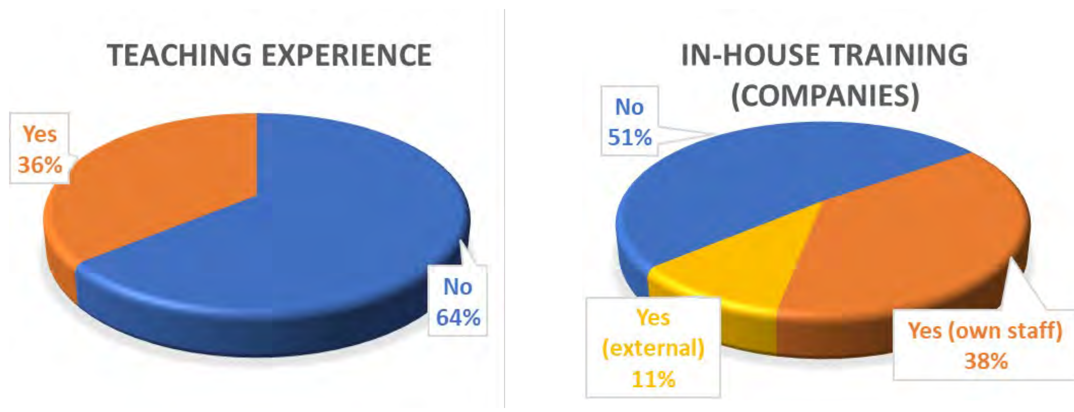

Figure 16: Training and teaching experience of respondents

In total, 28 respondents (36%) indicated, that they have experience in teaching about SSbD issues (Figure 16, left). The teaching experience includes university courses, guest lectures, internal and external trainings, EU project training schools, and facilitating discussions.

The educational offerings of the IRISS partners Leuphana University of Lüneburg, University of Birmingham, the National Technical University of Athens (NTUA), IVL Swedish Environmental Research Institute, and Empa - Swiss Federal Laboratories for Material Science and Technology are analysed in detail in Chapter 5.2.

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Nine companies indicated that they have experience in teaching on SSbD issues. This mostly includes internal trainings (n = 8), but also guest lectures (n = 2) and facilitating discussions (n = 1).

To get more information about company-specific trainings, companies were also asked if and on which SSbD aspects they perform in-house trainings (Table 16; Questions 18 and 19).

Around half of the companies (n = 18; 49%) perform in-house trainings on SSbD aspects, predominantly performed by own staff (Figure 16, right). The trainings cover both safety and sustainability (including circularity) related aspects as well as regulatory requirements:

- Safety (general safety training),
- Harmonised tier safety approach,
- Safety screenings on hazard classes,
- Risk assessment **(n = 2),**
- Sustainability aspects, e.g., definition of sustainability **(n = 3),**
- Sustainability goals to instil a culture of sustainability,
- Sustainability criteria and ranking according to performed safety and sustainability assessments,
- Sustainability metrics reduction,
- Sustainable materials, processes, manufacturing plants,
- Environmental awareness,
- Water and energy reduction programs,
- Cradle to cradle,
- LCA **(n = 3),**
- LCC,
- Carbon Footprint,
- Corporate Financial Performance (CFP),
- Environment, Social, Governance (ESG),
- Circular economy,
- Waste,
- Regulatory requirements.

Two companies additionally named target groups of the training as examples:

- All staff,
- R&D,
- Product Supply,
- Purchasing, and
- Marketing.

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5.4.5 Alternative business models

To ensure overall sustainability, one important SSbD aspect mentioned in SRIP, the Transition Pathway for the Chemical Industry, and in the JRC framework is the uptake of new/alternative/innovative business models. Developing new business models can also be seen as an important, though very broad, skill for SSbD. The questions asked to all companies in relation to new business models are presented in Table 17.

Table 17: Summary of questions related to new business models in the questionnaire.

SURVEY SECTION – Companies			
Question number	Question	Number of respondents	
		Total	Companies
16	Does your company consider or have experience with alternative business models? E.g., chemical leasing; functional or service-based approach.	-	37
17	If yes, please elaborate	-	7

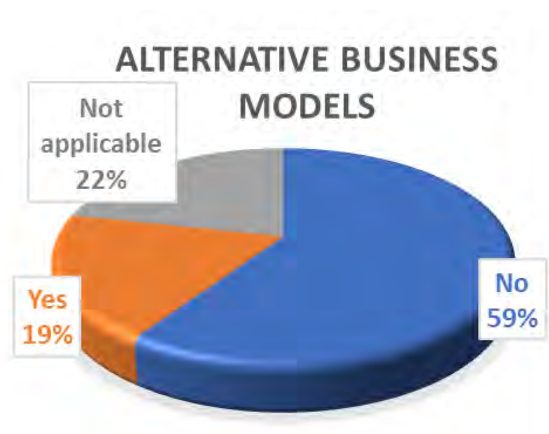

Figure 17: Experience of companies with alternative business models.

Only seven (19%) companies indicated that they consider or have experience with new business models (Figure 17). The answers of two companies did not name an alternative business model and were therefore excluded.

- Two companies have experience with service-based business models (sales not based on chemical volume sales);
- One company has experience with chemical leasing and models based on knowledge sharing;
- One company considers to expand circular models;
- One company is piloting alternative business models (not further specified).

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5.4.6 Skills needed

The questions asked in relation to skills needs are presented in Table 18.

Table 18: Summary of questions related to Skills needs in the questionnaire.

SURVEY SECTION – Skills			
Question number	Question	Number of respondents	
		Total	Companies
57	Are you interested in improving your skills in Safe-and-Sustainable-by-design?	86	36
58	If yes, please give more information about what type of skills and regarding which SSbD aspects.	45	20

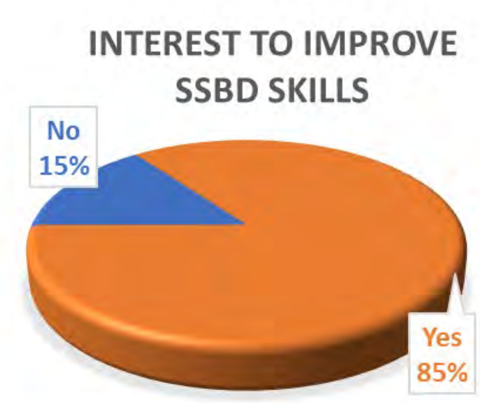

Figure 18: Interest of respondents to improve their skills in SSbD.

In total, 73 respondents (85%) were interested in improving their skills in SSbD (Figure 18). Regarding the SSbD aspects that the respondents want to improve, the replies ranged from very general such as 'all SSbD skills' to very specific such as 'multicriteria decision making tools' or the 'PEF method'. It has to be noted that three replies were excluded (IDs 20, 27, and 48) as they did not refer to any kind of SSbD skill but were general comments.

Some very general skills mentioned are:

- All skills,
- All SSbD aspects,
- Product design,
- Integrated approaches,
- Methodological approaches.

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Some of the mentioned skills relate directly to the understanding and implementation of the JRC framework or SSbD in general, including its benefits:

- General insights and learning on how SSbD can bring benefits in practice,
- Implications of SSbD concept on business operations and R&D,
- Better understanding of the SSbD framework **(n = 3),**
- How to implement the JRC's framework; applicability to specific sectors **(n = 3),**
- How to meaningfully develop the SSbD framework,
- Better understanding of criteria, application, impact assessment, and best practices **(n = 2),**
- Skills on the definition of parameters for the implementation of SSbD as well as their analysis and processing of these data.

Several of the mentioned skills relate to the safety and sustainability assessments required by the JRC framework; particularly LCA related skills were mentioned several times:

- Assessment steps 2, 3, and 4 of JRC SSbD framework,
- Knowledge and skills related to **safety:**
    - Safety aspects (e.g., related to human health) **(n = 3),**
    - Risk and hazards with impact,
    - Toxicity evaluation,
    - New safety methods,
- Knowledge and skills needs related to **LCA:**
    - General knowledge and training in LCA **(n = 3),**
    - Environmental impact categories for LCA,
    - Latest LCA assessment methods,
    - PEF,
    - LCA for companies early in the supply chain,
    - LCA methods applicable to early design stage, e.g., at the level of a chemical structure,
    - LCAs that can include accounting more accurately for chemistry,
    - ESG and LCA cradle to cradle instead of cradle to gate,
- Knowledge and skills needs related to **social dimensions** and **s-LCA:**
    - S-LCA **(n = 2),**
    - Social dimensions;
    - Incorporating social aspects **(n =2),**
- Knowledge and skills needs related to **financial aspects** and **LCC:**
    - LCC,
    - Financial aspects,
    - Responsible finance,
- Knowledge and skills needs related to **End of Life:**
    - Circular economy **(n = 3),**
    - Repair aspect,

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- Recyclability,
- How to analyse for Circularity and End of Life if several stakeholders are involved in the production phase,

- Knowledge and skills related to **tools**:
  - Use of tools **(n = 2),**
  - Tools and assessment techniques,
  - Social and economic analysis tools,
  - Tools for various stages of assessment: especially process safety and exposure,
  - Multicriteria decision making tools,
  - Sustainability appraisal tools in general (which tools to use and how),
  - Computational toxicology,
  - Implementation of NAMs in the SSbD approach,
  - Implementation of safety tools in context of SSbD,
  - Implementation of Chemoinformatics methods,
- How to conduct quantitative sustainability appraisal since the data is very limited in the design phase,
- Verify quality of data used,
- Setting metrics.

Further skills are:

- Communication methods,
- Certificates demands,
- Consumer insights regarding sustainability,
- Training across the organization,
- Practical examples and templates,
- New innovations to drive SSbD,
- More sustainable chemical mixing products,
- Renewable alternatives.

5.5 Skills availability and needs of SSbD related EU projects

5.5.1 Overview of projects

Fifteen projects completed the project template (Annex B). Two additional EU projects responded to the WP1 survey (IDs 28 and 53; Chapter 5.4) and were analysed in this chapter as well, resulting in **seventeen** projects in total (Table 19). It should be noted that not all projects are directly involved in any chemical, material, or product development.

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Table 19: List of projects that provided information

Project Acronym and Logo	Project Title and Description
Horizon 2020 SSbD projects	
ASINA	***Title***: Antimicrobial and self-depolluting nano-structured coatings in clean technologies. ***Brief description and skills contribution to SSbD***: Variations of Silver Nanomaterials (AgNPs) for coated antimicrobial functional textiles. Variations of active Titanium Dioxide Nanomaterials (TiO_2) for coated photocatalytic functional textiles. At the basis of NMs selection there are criteria of safety and sustainability, combined with efficiency, regulatory and cost requirements, that are designed or will be re-designed to maximise the safety and sustainability profile with respect to the traditional NMs considered as benchmark NMs within the project.
BreadCell	***Title***: Upgrading of cellulose fibres into porous materials ***Brief description and skills contribution to SSbD***: BreadCell develop radically new technologies to produce porous lightweight low-density materials based on natural resources. Our main material is wood pulp fibres that are commonly used for paper manufacturing. BreadCell develops foaming processes that use wood fibres and wood macromolecules. We convert the renewable raw materials to high value, lightweight, energy-absorbing and load-transferring composites such as those used in sports and safety components of cars.
DIAGONAL	***Title***: Development and scaled Implementation of sAfe by design tools and Guidelines for multicOmponent aNd hArn nanomateriaLs ***Brief description and skills contribution to SSbD***: DIAGONAL aims to bring new methodologies to guarantee long-term nanosafety along the multicomponent nanomaterials and High Aspect Ratio Nanoparticles life cycle: from design and production to their application into nano-enabled products, the product use and end of life phases. To be able to do so, DIAGONAL will analyse the materials' physicochemical properties, toxicology, behaviour, and environmental exposure, as well as human safety along their life cycle. For that, the project will develop and validate multi-scale modelling tools able to predict and characterise nano-specific properties. Additionally, DIAGONAL will build on seven industrial cases facilitating the re-design of nanomaterials, nano-enabled products design and manufacturing processes. The project will also approach the standardisation of risk management, assessment and governance facilitating their use by industry.
Gov4Nano	***Title:*** Implementation of Risk Governance: meeting the needs of nanotechnology ***Brief description and skills contribution to SSbD:*** Nanotechnology is an increasingly growing field of scientific innovation offering societal benefits. However, nanotechnology poses significant challenges to risk governance structures and processes. The EU-funded Gov4Nano project will design and create a self-sustained

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Project Acronym and Logo	Project Title and Description
	Nano Risk Governance Council (NRGC) to implement the Risk Governance Framework for managing nanotechnology risks relevant to social, environmental and economic benefits. The team will develop an operational transdisciplinary Nano Risk Governance Model for nanotechnologies lying on a framework developed by the International Risk Governance Council. The NRGC will engage and coordinate stakeholders to overcome the fragmentation of existing knowledge and information, prepare its transfer, and establish a self-sustainable Nanosafety Governance Portal for dialogues between stakeholders.
HARMLESS HARMLESS	***Title:*** Advanced High Aspect Ratio and Multicomponent materials: towards comprehensive intelLigent tEsting and Safe by design Strategies ***Brief description and skills contribution to SSbD:*** HARMLESS develops a novel, multifaceted Safe Innovation Approach to complex multi-component, hybrid nanomaterials and High Aspect Ratio Nanoparticles (MCNM & HARNs) by integrating a toolbox of New Approach Methodologies, which can test key data according to latest scientific insights into MCNM & HARNs. To ensure that industries operating at differing scale, including SMEs, pick up our approach, HARMLESS create a user-friendly decision support system and validate it iteratively at scale in different case studies. To be viable for industry, Safe-by-Design approaches have to predict how the multidimensional design space may affect the functionality for the intended use. Conventional characterisation and testing methods are inefficient in this regard and not flexible enough for different innovation stages and industry sectors. In particular outside large industries, potential users of Safe-by-Design suffer from the complexity and variety of testing methods. To better guide them through intelligent decision choices throughout their entire design cycles and production, HARMLESS develops a user-friendly Safe-by-Design decision support tool. The tool includes machine/deep learning algorithms that support: i) automatic and intelligent selection of methods/models, ii) fusion of heterogeneous model outputs to predict the single outcome for risk assessment, and iii) knowledge integration for assessing the risk of new materials.
i-TRIBOMAT i-TRIBOMAT Intelligent Open Test Bed for Materials Tribological Characterisation Services	***Title*:** Intelligent Open Test Bed for Materials Tribological Characterisation Services ***Brief description and skills contribution to SSbD*:** i-TRIBOMAT aims to establish a Sustainable Open Innovation Test Bed for intelligent Tribological Materials Characterisation, paving the way for new collaborative approaches in sharing infrastructure, competence, and data for the benefit of the European industry to support industrial innovation, to improve materials up-scaling efficiency and to bring new materials into world-wide competitive products. i-TRIBOMAT services combine conventional laboratory level tribotests and experimental surface characterization techniques with Artificial Intelligence tools, such as database searches, computer simulation and modelling, which allow up-scaling laboratory test results to infer

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Project Acronym and Logo	Project Title and Description
	friction and wear behaviour of real components. This is an excellent tool to predict and reduce energy consumption during use.
NanoHarmony NanoHarmony	***Title***: Towards harmonised test methods for nanomaterials ***Brief description and skills contribution to SSbD***: The NanoHarmony project, funded through Horizon 2020, has the mission to support the development of Test Guidelines and Guidance Documents for eight endpoints where nanomaterial-adapted test methods have been identified as a regulatory priority. NanoHarmony coordinates the collection and use of available data and information to support the finalisation of the test method development and to organise a sustainable network for the needed exchange, also for future regulatory development needs.
NanoMECommons nanoMECommons	***Title:*** Harmonisation of EU-wide nanomechanics protocols and relevant data exchange procedures, across representative cases; standardisation, interoperability, data workflow ***Brief description and skills contribution to SSbD:*** EU-funded NanoMECommons will form an EU-wide research and innovation network aiming to develop harmonised and widely accepted characterisation protocols, utilising high-speed nanoindentation (including multi-technique protocols) and focused ion beam. These protocols will be integrated into real industrial environments to boost material, process, and product reliability with reduced measurement discrepancy, improved data interoperability and traceability (TRL 6). NanoMECommons aims to provide a unique and interoperable metadata structure (iCHADA) to enhance data quality and information management. iCHADA will support the establishment of data-driven structure-properties relations to assist the quality assurance and material design procedures in the industry. The goal is the standardisation of testing to contribute directly to Industry Commons and facilitate reusability and transferability of characterisation data across multiple manufacturing sectors.
ReSOLUTE ReSolute	***Title***: Research empowerment on solute carriers ***Brief description and skills contribution to SSbD***: The ReSolute project will scale a unique process to create an entirely new value chain. It will use cellulosic biomass to produce the platform molecule levoglucosenone (LGO) and its derivative Cyrene™, a safe and high performing biosolvent, and convert waste by-products for beneficial utilisation. The main technological objectives of ReSOLUTE project are: • To build and successfully operate a first operate a first of its kind Flagship Plant sustainably producing a bio-based building block – levoglucosenone (LGO) – and the high performing solvent Cyrene™ with a capacity of 1,000 metric tons per year. • To cover the whole value chain from feedstock supply to the production of high value-added products.

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Project Acronym and Logo	Project Title and Description
	• To valorise Cyrene™ production residues – bio-char – by converting them into activated carbons instead of burning them.
RiskGONE	***Title***: Science-based Risk Governance of Nano-Technology ***Brief description and skills contribution to SSbD***: RiskGONE is a H2020 project (NMBP-13), which aimed to provide solid procedures for science-based inter-disciplinary risk governance for engineered nanomaterials, based on a clear understanding of risks, risk management practices and societal risk perception, by all stakeholders. The risk governance framework, tools and guidance documents developed within RiskGONE can be considered applicable also for advanced materials, thus ensuring that innovation progresses in a sustainable manner. The topics that have been at the core of RiskGONE's activities include: governance of nano- and advanced materials, development of a risk governance framework, safe and sustainable by design (SSbD) tools, standardization and harmonization towards test guidelines and guidance documents (TG/GDs), Cloud platform and digital IT solutions.
SAbyNA	***Title***: Simple, robust and cost-effective approaches to guide industry in the development of safer nanomaterials and nano-enabled products (SAbyNA) ***Brief description and skills contribution to SSbD***: The main objective of SAbyNA is to develop an overarching integrative and interactive web-based guideline "The SAbyNA SbD Guidance Platform" to support the development of safer nano-enabled products and safer processes along the product life cycle, with advanced functionalities tailored to different industrial sectors (Paints and Additive Manufacturing). A panel of safe-by-design strategies and risk mitigation measures will be incorporated in the Guidance workflows with hierarchies and decision trees to facilitate the identification of most suitable approaches for each case.
SbD4Nano	***Title***: Computing infrastructure for the definition, performance testing and implementation of safe-by-design approaches in nanotechnology supply chains ***Brief description and skills contribution to SSbD***: The final aim of SbD4Nano project is to develop a user-friendly e-infrastructure to promote, assist and guide industry, regulator, and civil society in the definition of well-balanced SSbD approaches. To this end, the platform will be developed as a modular infrastructure implementing interfaces for data storage, searching and sharing, toxicity and exposure modelling, cost analysis, and product performance "function" evaluation, creating an innovative framework to accelerate the collaboration between scientist and industry, and closely aligning the SbD4Nano infrastructure with user needs to promote the implementation of SSbD approaches by the industry. The e-infrastructure will be designed to be interoperable with resources already existing, maximizing crosstalk and interaction with available databases and modelling approaches. This will include graphical user interfaces (GUIs) adapted to the capabilities and knowledge of end users.

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Project Acronym and Logo	Project Title and Description
Horizon Europe SSbD projects	
greenSME	***Title:*** Driving manufacturing SME transformation towards green, digital and social sustainability. ***Brief description and skills contribution to SSbD:*** The European manufacturing sector is facing the challenge of achieving Green Deal goals while remaining competitive. The EU-funded GreenSME project will support manufacturing SMEs towards green, digital and social sustainability by strengthening their capacity to adopt advanced technologies (AT) and become competitive and climate neutral. The project will establish a green SME hub with a SME sustainable pathway. The hub will provide sustainability awareness and industry engagement activities, ecosystem networking opportunities and tailored advisory services to SMEs. Moreover, GreenSME project will deliver a sustainability assessment tool, an advanced sustainability action plan (ASAP) definition methodology, and finally, an AT implementation practices white book.
RELIANCE	***Title*:** Smart response self-disinfected biobased nanocoated surfaces for healthier environments ***Brief description and skills contribution to SSbD*:** RELIANCE project aims to design and develop smart response self-disinfectant antimicrobial nanocoatings based on a new range of smart antimicrobial nanoparticles. They will consist of mesoporous silica nanoparticles with metallic copper in their structure, modified with biobased bioactive compounds: Antimicrobial peptides based on protein containing waste streams, and essential oils coming from non-edible plants. The antibacterial action of these additives will be adjusted to the specific application, according to the dosages and durability requirements. Applications: • Antimicrobial coatings for interior part for automotive sector • Antimicrobial and water repellent protective clothing coatings for pharmaceutical and medical sector. • Antimicrobial and water repellent coatings for home appliance surfaces.
SUSAAN	***Title:*** SUStainable Antimicrobial and Antiviral Nanocoating ***Brief description and skills contribution to SSbD:*** SUSAAN project aims at developing sustainable antiviral and antimicrobial nanocoatings, from active biobased and Inorganic nanoparticles, applied to different high traffic objects (plastic and metallic) and textiles. The products will be validated in real products, by covering three different applications: sockets & switches, bathrooms elements, and textile manufacture industries. SUSAAN project will work from the beginning in the production of sustainable by design nanocoatings with a holistic approach, considering main challenging aspects such as fast response and durable effects, low toxicity and environmental impact, scalability, and regulatory requirements.
TransPharm	***Title:*** Transforming into a sustainable European pharmaceutical sector

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Project Acronym and Logo	Project Title and Description
	Brief description and skills contribution to SSbD: TransPharm two-track approach focusses on the one hand on the compounds itself by identifying greener and more sustainable-by-design Active Pharmaceutical Ingredients (APIs) and on the other hand on reducing the environmental impact and resilience of the manufacturing process by optimizing the synthesis route of new APIs in continuous flow and by proposing greener alternative solvents. The aim of the project is to (i) analyse and predict flow behaviour and environmental biodegradability of APIs and their synthesis pathways; (ii) identify greener and more sustainable alternatives to pharmaceutical products / APIs of concern; (iii) reduce the footprint and create important shortcuts in synthetic schemes of APIs; and (iv) assess the sustainability of pharmaceuticals over their entire life cycle. To reach the envisaged aims, the project will deliver four toolboxes (consisting of digital tools and guidelines) for the development of greener pharmaceutical products and APIs. These toolboxes will be used to (v) assess the potential to move towards the transition to greener, more agile pharmaceutical production. In addition, TransPharm will elaborate on the business case for sustainable pharmaceutical products or APIs and what is needed to bring them to the market. The project will also make sure that (vi) key project results and knowledge are properly transferred towards targeted stakeholders. TransPharm's outcome contribute to a Europe, that is self-sufficient by reducing dependence on API production in third countries; making the EU healthcare industry more competitive, sustainable and reliable, ensuring timely supply of essential medicines from particularly complex or critical supply and distribution chains and positioning EU as a leader in innovative technologies.
Other SSbD projects	
DaNa4.0	***Title***: Data on new, innovative and safe application related materials ***Brief description and skills contribution to SSbD***: The main mission of the project DaNa is to extract relevant information on material safety related to humans and the environment from scientific literature and compile comprehensive profiles for materials/material classes; this information provides the scientific basis for a SSBD process highlighting potential issues related to a material hazard, exposure routes and the current state of the art derived from literature.

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5.5.2 SSbD aspects applied in practice

The SSbD criteria application in projects is analysed in detail in the IRISS reports PR1.1 to PR1.4.

In the project activities, the design principle SSbD8 'Consider the whole life cycle' is the most commonly considered aspect (n = 14, 82%), showing the strong implementation of a life cycle thinking in current EU funded research projects. The application rate of safety and sustainability assessments as well as social and circular economy aspects are shown in Figure 19. Most projects (n = 9 to 11; 53% to 65%) perform or consider hazard assessments, OHS factors, human health, and environmental risks, environmental LCA, social and circular economy aspects. The JRC framework is applied by six projects for hazard assessment.

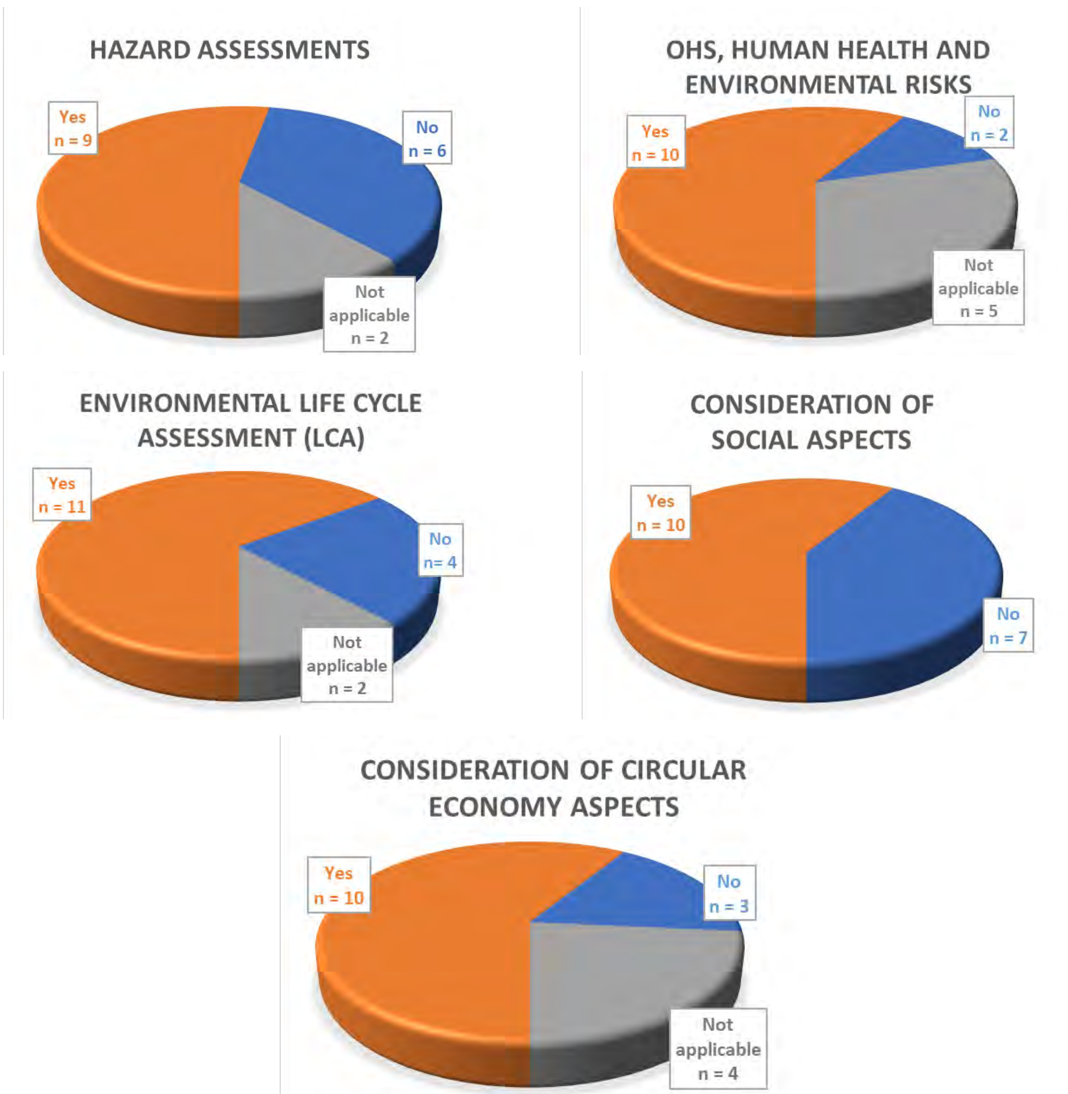

Figure 19: Application rates of safety and sustainability aspects in EU projects.

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5.5.3 Skills needed for the implementation of SSbD

The template further asked which skills were identified within the respective project as necessary for the implementation of SSbD.

The responses highlight the need for (SME tailored) training, knowledge-transfer, and strong coordination required to implement SSbD:

- Trainings such as provided in the NanoSafety Training School (15-20 May 2022 in Venice, Italy),
- Tailored training for SMEs on the SSbD concept and principles concepts,
- Data shepherd to allow the knowledge transfer,
- Strong coordination is required to allow the cooperation of life cycle stages,
- The coordination and communication between the different partners are very important since the SSbD approach is an iterative process, therefore a proper workflow is necessary when it comes to SSbD implementation success,
- Strong feedback with nanomaterial and product designers/innovators for the definition of design hypothesis.

Also, the need for criteria checklists, practical use cases and a more user-friendly guidance adapted for the respective data availability are mentioned:

- Updating/expanding the criteria checklist with SSbD relevant aspects,
- Practical use cases and relevant criteria,
- A more user-friendly guidance depending on the data availability for each of the areas integrated in the SSbD concept (i.e., phys-chem data, hazard and exposure data, sustainability data, accessibility to costs on different materials and processes), otherwise specific expertise to generate the data requested is needed to run all the assessments needed in such a framework,
- Standardisation and validation,
- Development of OECD testing guidelines.

Furthermore, additional skills, e.g., related to tools, are mentioned:

- Access and use of existing tools and database,
- Development of NAMs for risk assessment,
- Computational skills to be able to develop new models for their integration,
- Skills that enable the inclusion of service lifetime prediction of materials and mechanical components in LCA studies,
- Process engineering skills to scale up the processes from laboratory scale to production,
- Background and knowledge for the understanding the topics involved (Safe and Sustainability),
- Knowledge on eco and human toxicology, (process) chemistry, and sustainability,
- Material specific experts to target the right assessments that need to be done at each stage of development.

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6. Conclusions and next steps

6.1 General conclusions

In order to make chemicals, materials, products, and processes safer and more sustainable, a wide range of interdisciplinary background knowledge, skills, and cooperation across supply chains and between actors along the entire product's life cycles are needed.

The main conclusions of the literature review are:

- Understanding the origins and objectives of the SSbD approach requires an interdisciplinary background knowledge at policy, regulatory and scientific levels.
- The implementation and application of SSbD requires broad design and assessment skillsets.
- SSbD actors need to be aware of the relevant internal company processes, including all inputs and outputs, and of the entire life cycles for a novel chemical or material; from the supply-chain of raw materials to the end-of-life in the final product.
- The derived assessment skillset highlights the importance of data collection, access to tools, and knowledge-transfer across supply chains and along the life cycles to perform the required assessments.
- SSbD cannot be done by single actors but is a team effort that requires strong collaboration and knowledge/data exchange along the entire life cycles.
- Interpersonal or 'soft' skills are required to work in multidisciplinary design teams and to collaborate across supply chains and along the entire life cycles.

The skills, competences, and education needs collected during the WP3 co-creation highlight the importance of systems thinking competencies for SSbD, particularly life cycle thinking. They also underline the pressing need for knowledge and skills related to performing the assessments required by the JRC framework and using the available tools.

The survey results show that human safety assessments are widely embedded in company procedures, among other reasons due to the need to comply with many safety regulations such as REACH. This supports the general findings of IRISS report D4.4. Looking at all SSbD stakeholders, both safety and sustainability aspects are less frequently applied than in companies with social and environmental LCA being the least considered aspects.

Some additional conclusions of the survey results are:

- Training on the SSbD design principles is needed to improve their understanding and application (particularly on SSbD7 'End of Life' that also includes circular economy and circularity aspects as well as environmental ones).
- The respondents apply sustainability principles not proposed by JRC framework, e.g., green finance and stakeholder analysis and public perception.
- Circular economy aspects are more commonly applied by the respondents than environmental and social LCA; with 'recyclability' and 'reduction of waste' being considered most often.

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- Around half of the companies answering the questionnaire perform in-house trainings on SSbD aspects, predominantly performed by their own staff. The trainings cover both safety and sustainability (including circularity) related aspects as well as regulatory requirements.
- Alternative business models are only rarely considered or even applied by companies.
- Some of the mentioned skills needs relate to the understanding and implementation of the JRC framework, including its benefits. The JRC framework at current stage is not user-friendly and often difficult to translate to specific sectors.
- Most of the mentioned skills needs relate directly to the safety and sustainability assessments required by the JRC framework; particularly LCA related skills and using appropriate tools were mentioned several times.

The number of responding projects was quite small (17 projects in total) and not all projects are directly involved in any chemical, material, or product development. Generally, the project results show that a life cycle thinking is strongly implemented in current EU funded projects, while safety aspects are less in focus. The mentioned skills needs highlight the requirement of (SME tailored) training, knowledge-transfer, and strong coordination to implement SSbD along with a more user-friendly guidance and practical cases.

6.2 Knowledge-transfer "from whom to whom"

This chapter evaluates the survey replies regarding the required knowledge transfer and aims to be the basis for the training modules to be developed within WP6 or other IRISS activities that support the implementation of SSbD.

Companies have a high chemical safety related skillset because they have had to comply with safety legislation for a long time, i.e., with REACH and CLP as well as sector-specific legislation. These EU legislations aim to ensure that chemicals are produced and used safely for humans and the environment, even though they do not necessarily require that safety considerations are integrated at the design stage of the chemical or product development.

Training, e.g., for SMEs, should therefore focus more on sustainability aspects, which are less regulated in most sectors. Skills needs related to performing an LCA (mostly environmental, but also social and economic) and applying appropriate tools were frequently mentioned. For training development, the expertise of IRISS partners already teaching on sustainability aspects can be used as a basis (Chapter 5.2).

Trainings should also support a better understanding of the JRC framework and how to implement it. The JRC framework at its current stage is not user-friendly and often difficult to translate to specific materials and sectors. The training should also cover the SSbD design principles as there seems to be uncertainty about their meaning and application (particularly on SSbD7 'End of Life', which also includes circular economy and circularity aspects as well as environmental ones). Also, the benefits of applying the JRC framework, or generally SSbD, for companies and consumers should be well defined.

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Furthermore, knowledge-transfer is necessary between SSbD actors along the full life cycle. To consider the whole product life cycle, e.g., for performing an LCA, collaboration is needed to share the relevant expertise, data, and information. In this case, the IRISS network can support this collaboration, e.g., through implementing collaboration channels and VC-specific hubs.

6.3 Next steps

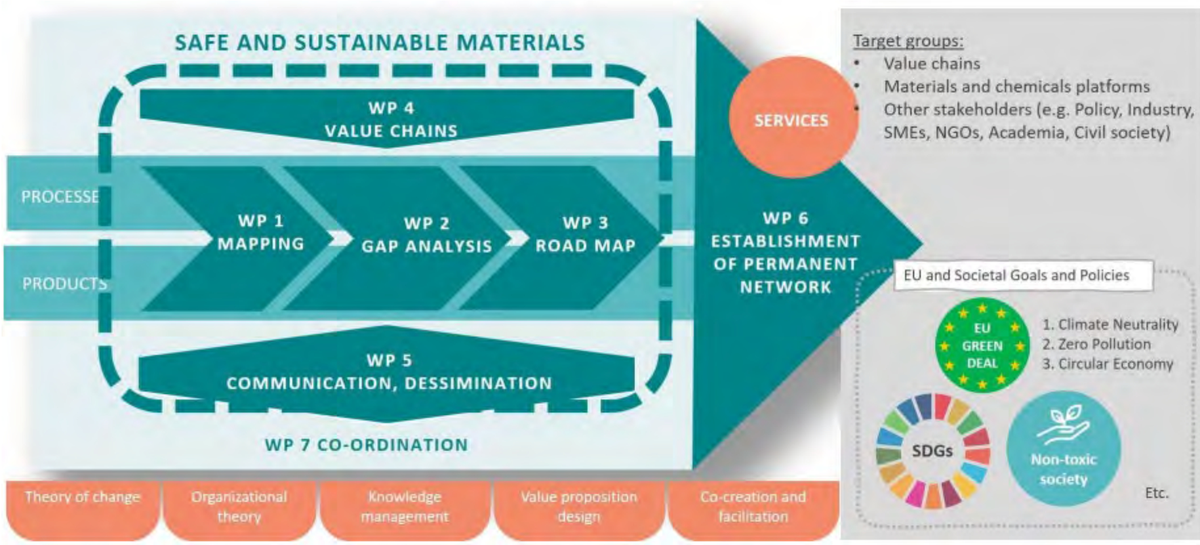

Figure 20: The IRISS methodological framework showing applied methods (Figure 2 of IRISS Grant Agreement).

The results of the mapping activities in WP1 (PR1.1 to PR1.5) will feed directly into the gap analysis performed in WP2 (Figure 20). The required skills and knowledge will be transferred and/or translated into training and other educational offerings that will introduce SSbD to a range of audiences, from students (schools, universities) to industry, regulators, and the general public, thereby supporting the enhancement of adequate skills. One example of such educational offerings is the university degree module on SSbD, anchored in existing curricula (Chapter 5.2), which will be initiated during the project runtime by the IRISS academic partners (Task 5.4).

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Annexes

Annex A - Survey on the Mapping of Safe and Sustainable by Design (SSbD) Initiatives

IRISS : InteRnatIonal ecosystem for accelerating the transition to Safe-and-Sustainable-by design materials, products and processes

IRISS receives funding from the European Union's HORIZON EUROPE research and innovation programme under grant agreement n° 101058245

Survey on the mapping of Safe and Sustainable by Design (SSbD) initiatives

About this Survey

We would like to invite you to participate in this survey that will **support you to analyse** the application of the **Safe&Sustainable-by-Design (SSbD) principles in your organization.**

The information collected will provide valuable input for the EU funded IRISS project to map SSbD activities, define the gaps and to develop a Roadmap to operationalise at EU Level, the SSbD for **materials, products and processes.** A special focus is placed on the initiatives that implement sustainability aspects in material and product R&D.

The project **IRISS, The International Ecosystem for Accelerating the Transition to Safe-and-Sustainable-by Design Materials, Products and Processes**, is a Coordination and Support Action (CSA) funded by the European Commission within the Horizon Europe Framework Programme (Grant Agreement no. 101058245).

This survey is addressed to all interested parties. Your feedback will inform IRISS consortium.

The deadline for replies is 25-2-2023

If you have any questions, please contact IRISS project via Gemma Mendoza (gemma.mendoza@tekniker.es)

Your voice matters and we are grateful to you for taking the time to complete this consultation.

* Obligatory

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1. I acknowledge that I have read the Data Protection Notice https://www.iriss-ssbd.com/download/18.4ea83c64182fa47c26613104/1664443511389/IRISS_Data_Protection_GDPR_Policy_External_Participants_v1_0.pdf) *

◯ Yes

◯ No

2. Name

3. Email address

4. Name of your entity *

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5. Sector or main activity of your company/organization/R&I project *

- ◯ Electronics and ICT sector
- ◯ Batteries and vehicles sector
- ◯ Packaging sector
- ◯ Plastics sector
- ◯ Textiles sector
- ◯ Construction sector
- ◯ Energy materials sector
- ◯ Chemical sector
- ◯ Food, water and nutrients sector
- ◯ Agriculture, Forest and Fishing
- ◯ Personal care
- ◯ Electricity, gas and water supply
- ◯ Transport, Storage and communication
- ◯ Community, Social and Personal services
- ◯ Otras

6. Country of the company/organization

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7. Are you responding to this survey on behalf of/as: *

- ◯ Company
- ◯ Representative of a Research and innovation project
- ◯ Academic institution /University
- ◯ Research and Technology Organisation
- ◯ Cluster/Platform/Network
- ◯ Business or Industry association
- ◯ Other non-governmental organization (NGO)
- ◯ Public authority Individual citizens
- ◯ Trade Union
- ◯ Other (Please specify)

8. Project name and acronym *

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9. Does your company/institution or project consider safety and sustainability aspects in development of chemicals, materials, products or processes?

JRC's definition of safety and sustainability

The safety concept is transversal to all sustainability dimensions (environmental, social and economic) and it is related to the absence of unacceptable risk (in line with REACH art 68 (EU, 2006)) for humans and the environment, preferably ensured by the absence of intrinsic hazard properties of chemicals.

When applied in the context of chemicals, the concept of sustainability could be formulated as the ability of a chemical/material/product/service to deliver its function without exceeding environmental and ecological boundaries along its entire life cycle, while providing welfare and socio-economic benefits.

- ◯ Yes
- ◯ No
- ◯ Not aplicable

10. Can you elaborate on how your company/institution/project considers safety and sustainability in the development of materials, products or processes?

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11. Company size *

- ◯ Start-up
- ◯ SME (Small and Medium Enterprise)
- ◯ Large company

12. Does your company/institution or project consider safety and sustainability aspects in development of materials, products or processes?

JRC's definition of safety and sustainability

The safety concept is transversal to all sustainability dimensions (environmental, social and economic) and it is related to the absence of unacceptable risk (in line with REACH art 68 (EU, 2006)) for humans and the environment, preferably ensured by the absence of intrinsic hazard properties of chemicals.

When applied in the context of chemicals, the concept of sustainability could be formulated as the ability of a chemical/material/product/service to deliver its function without exceeding environmental and ecological boundaries along its entire life cycle, while providing welfare and socio-economic benefits.

- ◯ Yes
- ◯ No
- ◯ Not applicable

13. Can you elaborate on how your company/institution/project considers safety and sustainability in the development of materials, products or processes?

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14. Does your company have an explicit SUSTAINABILITY STRATEGY with SSbD objectives?
Grade 0 – 10 (10 is best)

0	1	2	3	4	5	6	7	8	9	10

Grade 0 Grade 10 (the best)

15. Do (any of) your customers require product sustainability data, environmental indicators, or LCA?
Grade 0 – 10 (10 is best)

0	1	2	3	4	5	6	7	8	9	10

Grade 0 Grade 10 (the best)

16. Does your company consider or have experience with alternative business models? E.g., chemical leasing; functional or service-based approach.

◯ Yes

◯ No

◯ Not applicable

17. If yes, please elaborate

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18. Does your company perform in-house trainings/workshops regarding the SSbD concept?

- ◯ Yes, performed by own staff
- ◯ Yes, performed by external staff/experts
- ◯ No

19. If yes, please give some bullet points on the covered aspects

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Safe-and-Sustainable by Design (SSbD) principles to be applied in the design

20. Does your company/institution/R&I project consider or intend to consider any of these SSbD principles during the design phase of a material, product or process?

- ☐ **SSBD1-Material efficiency** (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).
- ☐ **SSBD1.1**- Identify occurrence of use of critical raw material, towards minimizing or substituting them.
- ☐ **SSBD1.2**- Minimize the volume of solvents and water in the processes of manufacturing, production or use.
- ☐ **SSBD2**-Minimize the use of hazardous chemicals/materials.
- ☐ **SSBD3-Design for energy efficiency** (minimise the energy used during the chemical material production and along the supply chain).
- ☐ **SSBD4**-Use renewable sources.
- ☐ **SSBD5**-Prevent and avoid hazardous emissions.
- ☐ **SSBD6**-Reduce exposure to hazardous substances.
- ☐ **SSBD7-Design for end of life** (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).
- ☐ **SSBD8-Consider the whole Life Cycle** (apply the other design principles thinking through the entire life cycle, from supply chain to the end-of-life in the final product).
- ☐ **SSBD8.1-Design to last** (predict materials durability and facilitate the Disassembly/ Reparability/ Restore/ Remanufacture at the design phase of the product)
- ☐ **SSBD8.2**-Efficient recyclability of (raw) materials and/or products.

21. Other sustainable principles considered by your company/institution during the design phase of the development of a material, product or process.

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22. For principles that you are not considering at the moment: Why are you not considering these principles? *(e.g., missing data/information for certain materials; missing know-how, experience, or lack of education).*

Engineering tools for the implementation of SSbD principles at design stage:

Design of sustainability at early stages

23. Does your modelling and simulation tools (eg CAD, FEM and others) allow for sustainability assessments and optimisation of products and components AT DESIGN STAGE?

0	1	2	3	4	5	6	7	8	9	10

Grade 0 Grade 10 (the best)

24. Do your design tools support Materials selection according to sustainability principles? (Non-toxic, low carbon footprint, durability, energy efficiency during processing and use, low embedded energy, low level of water or air resources, recyclability, etc.?

0	1	2	3	4	5	6	7	8	9	10

Grade 0 Grade 10 (the best)

25. Please, comment your answer.

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26. Do your product development tools and processes support the design of components with circular economy, elements like easy dismantling; end-of-life concept; recollection; components designed for refurbishing - for second life or extended useful lifetime?

0	1	2	3	4	5	6	7	8	9	10

Grade 0 Grade 10 (the best)

27. Please, comment your answer.

28. Do you apply AT DESIGN STAGE predictive design tools and accelerated experiments for predicting and optimizing the product's durability, performance, and energy consumption at maximum useful lifetime?

0	1	2	3	4	5	6	7	8	9	10

Grade 0 Grade 10(the best)

29. Please, comment your answer.

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30. The initiatives listed below are linked to regulation or a certification scheme. Does your material/product follow or intend to follow any of these sustainable initiatives?

- ☐ Ecodesign Directive (2009/125/EC) *(Scope: Energy-related products minimum requirements on energy)*
- ☐ Sustainable Products Initiative *(Scope: All type of products)*
- ☐ Energy Label (EU) No 2017/136913 *(Scope Energy-related products Sustainable)*
- ☐ Sustainable Batteries *(Scope: All batteries)*
- ☐ EU Ecolabel Regulation (EC) No 66/2010) *(Scope: Consumer products and services)*
- ☐ EU GPP criteria *(Scope: Products and services in public procurement)*
- ☐ Sustainable finance (EU 2020/852) *(Scope: Financial products)*
- ☐ TCO Certified *(Scope: IT products)*
- ☐ Nordic Swan Ecolabel *(Scope: Consumer products or products for professional use)*
- ☐ Blue Angel *(Scope: Consumer products)*
- ☐ Natureplus Ecolabel *(Scope: Building and accommodation products)*
- ☐ OEKO-TEX *(Scope: Textiles and leather)*
- ☐ Bluesign *(Scope: Textiles)*
- ☐ Green Seal *(Scope: Consumer products and services)*
- ☐ GreenScreen For Safer Chemicals *(Scope: Consumer products)*
- ☐ Otras

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Safe-by-design (SbD)

31. **Have you applied <u>the SbD tools developed/proposed by EU projects/platforms</u> in your work?** *

- ◯ No
- ◯ Yes

32. If yes, please select the project/s, platfom/s

- ☐ EU Project
- ☐ Gov4Nano
- ☐ SABYDOMA
- ☐ Sabyna
- ☐ SUNSHINE
- ☐ MANDALA
- ☐ DIAGONAL
- ☐ NanoReg2
- ☐ SbD4Nano
- ☐ SAFERA
- ☐ NANOMET
- ☐ PROSAFE
- ☐ NANORIGO
- ☐ OpenRiskNet
- ☐ Otras

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33. If you use any of the SbD tools mentioned in the above list, could you indicate specific use cases?

34. **Do you perform __hazard assessments__ for new materials and chemicals applied in your product?**

- ◯ No, we do not assess the hazard of materials
- ◯ Yes
- ◯ Not applicable

35. If yes, please indicate if you assess the material hazard using one or more of the following frameworks

- ☐ REACH
- ☐ Chemical Strategy for Sustainability (CSS)
- ☐ JRC's SSBD Framework
- ☐ Novel Assessment Methods
- ☐ Otras

36. If you use any of the SbD tools mentioned in the previous list, could you indicate specific use or case example?

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37. **Do you consider <u>occupational health and safety factors, human health and environmental risk</u> during the manufacturing or use-phase of new materials and chemicals?**

- ◯ No, we do not assess occupational health and safety factors
- ◯ Yes
- ◯ Not applicable

38. Do you use one or more of the following tools to assess **Occupation Health and Safety**?

- ☐ COSHH Essentials by British Institute of Occupational Safety (Health and Safety Executive, HSE)
- ☐ International Labor Organization (ILO) Model
- ☐ German Hazardous Substances (GHS) Column Model
- ☐ Easy-to-use Workplace Control Scheme for Hazardous Substances (EMKG) Tool
- ☐ Dutch Stoffenmanager Model
- ☐ Belgian REGETOX Model
- ☐ Targeted Risk Assessment (TRA) tool by ECETOC
- ☐ Chesar by ECHA
- ☐ EUSES2.1
- ☐ ProScale 1.5
- ☐ USEtox
- ☐ Otras

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39. Do you use one or more of the following tools to assess **Human Health Risk?**

- [ ] COSHH Essentials by British Institute of Occupational Safety (Health and Safety Executive, HSE)
- [ ] International Labor Organization (ILO) Model
- [ ] German Hazardous Substances (GHS) Column Model
- [ ] Easy-to-use Workplace Control Scheme for Hazardous Substances (EMKG) Tool
- [ ] Dutch Stoffenmanager Model
- [ ] Belgian REGETOX Model
- [ ] Targeted Risk Assessment (TRA) tool by ECETOC
- [ ] Chesar by ECHA
- [ ] EUSES2.1
- [ ] ProScale 1.5
- [ ] USEtox
- [ ] Otras

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40. Do you use one or more of the following tools to assess **Environmental Risk?**

- ☐ COSHH Essentials by British Institute of Occupational Safety (Health and Safety Executive, HSE)
- ☐ International Labor Organization (ILO) Model
- ☐ German Hazardous Substances (GHS) Column Model
- ☐ Easy-to-use Workplace Control Scheme for Hazardous Substances (EMKG) Tool
- ☐ Dutch Stoffenmanager Model
- ☐ Belgian REGETOX Model
- ☐ Targeted Risk Assessment (TRA) tool by ECETOC
- ☐ Chesar by ECHA
- ☐ EUSES2.1
- ☐ ProScale 1.5
- ☐ USEtox
- ☐ Otras

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Sustainability Environmental dimension: LCA (Life Cycle Assessment)

41. Does your company/institution/R&I project perform or intend to perform an Environmental Life Cycle Assessment (LCA) during the design or development phase of a material, product, process or R&D activity?

- ◯ Yes
- ◯ No
- ◯ Not applicable

42. **Software**

Do you use any specialized software tool to conduct Life Cycle Assessment of your materials, product or processes?

- ☐ SimaPro
- ☐ Gabi
- ☐ TEAM
- ☐ UMBERTO
- ☐ OpenLCA
- ☐ Ecochain
- ☐ Mobious
- ☐ OneClickLCA
- ☐ Otras

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43. **Database**

Do you use any Life Cycle inventory database to conduct the LCA analysis?

- [ ] ECOINVENT
- [ ] EPLCA (European Platform on Life Cycle Assessment) datasets
- [ ] USLCI
- [ ] LCA Food DK
- [ ] ELCD
- [ ] Otras

44. **Impact Assessment Method**

- [ ] PEF (Product Environmental Footprint)
- [ ] ReCiPe
- [ ] CML
- [ ] Impact word
- [ ] Usetox
- [ ] Otras

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45. **LCA phases**

Indicate the phases considered or that you intend to consider in the environmental evaluation of your material, product, process or R&D through a Life Cycle Assessment approach.

- ☐ Raw material Extraction
- ☐ Processing (material or chemical)
- ☐ Processing (product)
- ☐ Transport
- ☐ Use phase
- ☐ End of Life, recycling, reuse
- ☐ Otras

46. In case you consider the **use phase**, could you please indicate the functional unit selected to perform the LCA?

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47. **Use stage aspects**

Indicate if you considered or intend to consider any of these aspects in the environmental evaluation of your material, product, process or R&D through a Life Cycle Assessment approach.

- [ ] Functionality (fitness for use)
- [ ] Reduction of energy consumption during use
- [ ] Reduction of water consumption during use
- [ ] Durability
- [ ] Reusability
- [ ] Repairability
- [ ] Upgradeability
- [ ] Otras

48. Does your company/institution/R&I project consider or intend to consider **circular economy** aspects in the design or development phase of a material, product, process or R&D activity?

- ○ Yes
- ○ No
- ○ Not applicable

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49. **End of life**

If use extension and end of life of your material, product or R&D prototype is considered in the design phase, please indicate if you considered or intend to consider any of these aspects:

- ☐ Reduction of Waste
- ☐ Reduction of hazard waste
- ☐ Biodegradability
- ☐ Refuse
- ☐ Reduce
- ☐ Recover
- ☐ Repurpose
- ☐ Remanufacture
- ☐ Refurbish
- ☐ Repair
- ☐ Reuse
- ☐ Rethink
- ☐ Recyclability
- ☐ Thermal recycling (incineration/combustion)

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50. **Raw material used**

Indicate the circular economy considerations taken in the design of the production phase:

- [ ] Use of renewable feedstock
- [ ] % of Recycled content
- [ ] Presence of Critical raw material
- [ ] Otras

51. **Methods for ensuring circularity**

Do you use methods to measure and/or quantify the circularity of the product?

- ◯ Yes
- ◯ No
- ◯ Not applicable

52. If yes, please comment your answer

53. Does your company/institution/R&I project consider or intend to consider **social aspects** during the design or development phase of a material, product, process or R&D activity?

- ◯ Yes
- ◯ No

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54. If yes, please indicate the aspects you consider in the social assessment.

- ☐ Child labour
- ☐ Fair salary
- ☐ Forced labour
- ☐ Health and Safety
- ☐ Freedom of association and collective bargaining
- ☐ Working hours
- ☐ Equal opportunities /discriminate
- ☐ Community engagement
- ☐ Local employment
- ☐ Consumers Health and safety
- ☐ Responsible communication
- ☐ Otras

55. Do you use any specific **database** to support the **social assessment**?

- ◯ Yes
- ◯ No

56. If yes, please indicate

- ☐ Social hotspot database- SHDB
- ☐ Product Social Impact Life Cycle Assessment - PSILCA
- ☐ Otras

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57. Are you interested in improving your skills in Safe-and-Sustainable-by-design?

- Yes
- No

58. If yes, please give more information about what type of skills and regarding which SSbD aspects.

59. Do you have experience in teaching on Safe-and-Sustainable-by-design-issues?

- Yes
- No

60. If yes, please give more information about what type of teaching skills (e.g.; internal training, university curriculum).

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61. From your prospective, what gaps have been identified for the SSbD approach to be more easily applicable to your company processes?

62. Have you got any proposal to fill these gaps in?

63. Interest for a deeper assessment on SSbD. Please select the next options if you agree:

- [ ] I would agree to a deeper assessment about our SSbD experience (e.g. by interview)
- [ ] I would agree to receive information about future SSbD events organized by the IRISS network

Thank you very much for your collaboration

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Annex B - Template to collect information about the application of Safe & Sustainable-by-Design (SSbD) principles in projects

Project General Information	
Acronym: ***Web***: ***Timeline***:	***Logo***
Title: *Brief description*:	

Safe-and-Sustainable by Design (SSbD) principles to be applied in the design							
SSbD principles considered during the design phase of a material, product or process in your project							
	SSBD1-Material efficiency		**SSBD3-**Design for **energy efficiency**		**SSBD5-**Prevent and avoid hazardous emissions		**SSBD7-**Design for end of life
	SSBD2-Minimize the use of hazardous substances		**SSBD4-**Use renewable sources		**SSBD6-**Reduce exposure to hazardous substances		**SSBD8-**Consider the whole Life Cycle
	Other SSbD principles:						

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Safe by design (SbD)							
An early-stage assessment of hazard, occupational health and safety factors, along with human health and environmental risk is important to develop novel chemicals and materials that are 'Safe-by-design'. **_Has your project applied any of the SbD tools developed/proposed by EU projects in you work?_**							
	No, none of SbD concepts proposed by EU-projects are used						
	Gov4Nano		SUNSHINE		NanoReg2		NANOMET
	SABYDOMA		MANDALA		SbD4Nano		PROSAFE
	Sabyna		DIAGONAL		SAFERA		NANORIGO
	OpenRiskNet		OTHER:				
Does your project perform <u>hazard assessments</u> for new materials and chemicals applied in your product? If yes, indicate if you use one or more the following frameworks							
	NO		REACH		Chemical Strategy for Sustainability (CSS)		JRC's SSBD Framework
	Novel Assessment Methods				OTHER:		

Does the project consider <u>Occupational health and safety factors, human health and environmental risk</u> during the manufacturing or use-phase of new materials and chemicals?

If yes, please indicate if you assess the material hazard using one or more the following frameworks

Tool	Occupational Health and Safety (OHS)	Human Health Risk Assessment	Environmental Risk Assessment
COSHH Essentials by British Institute of Occupational Safety (Health and Safety Executive, HSE)			
International Labor Organization (ILO) Model			
German Hazardous Substances (GHS) Column Model			
Easy-to-use Workplace Control Scheme for Hazardous Substances (EMKG) Tool			
Dutch Stoffenmanager Model			

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Belgian REGETOX Model			
Targeted Risk Assessment (TRA) tool by ECETOC			
Chesar by ECHA			
EUSES2.1			
ProScale 1.5			
USEtox			
Others not mentioned above			

Sustainability Environmental dimension: LCA (Life Cycle Assessment)
Does the project expect to generate environmental benefits?
Does your /R&I project perform or intend to perform and Environmental Life Cycle Assessment during the design or development phase of a material, product, process or R&D activity? ***LCA Software*** used: ***Database/s:*** ***Impact assessment method/s***:
LCA phases considered:

	Raw material Extraction		Transport		End of life		Reuse
	Processing		Use Phase		Recycling		

USE PHASE:

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Functional unit:

Indicate if you considered or intent to consider any of these aspects in the environmental evaluation of your material, product, process or R&D through a Life Cycle Assessment approach

	Functionality (fitness for use)		Reduction of energy consumption during use		Reduction of water consumption during use		Durability
	Reusability		Repairability		Upgradeability		

End of life and Design for circular economy
Does your project consider or intent to consider circular economy aspects in the design or development phase of a material, product, process or R&D activity?
Indicate the circular economy considerations taken in the design of the production phase

	Use of Renewable feedstock		% of Recycled content		Presence of Critical raw material
	OTHERs:				

Sustainability Social dimension: S-LCA
Does your company/institution/R&I project consider or intend to consider social aspects during the design or development phase of a material, product, process or R&D activity?
Do you use any specific database to support the social assessment?

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☐	NO	☐	Social hotspot database- SHDB	☐	Product Social Impact Life Cycle Assessment - PSILCA	☐	OTHER:

Aspects considered in the social assessment

Workers	☐	Child labour	☐	Fair salary	☐	Forced labour
	☐	Health and Safety	☐	Working hours	☐	Equal opportunities /discriminate
Local community:	☐	Community engagement	☐	Local employment	☐	
Consumers	☐	Health and safety	☐	Responsible communication	☐	

Techno-economic dimension

SSbD Gaps

From your perspective, what Gaps have been identified for the SSbD approach to be more easily applicable to your Project?

SSbD Skills

From your perspective, what skills were identified within your project that are needed for the implementation of SSbD?

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