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

Map and address SSbD mismatches and competence gaps

Christina Apel, Lya G. Soeteman-Hernández, Eva Schillinger, Gemma Mendoza, and Klaus Kümmerer

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Abbreviations and Acronyms

Abbreviation	Definition
AI	Artificial Intelligence
CAA	Benign by Design
CEN	European Committee for Standardization
CEO	Chief Executive Officer
C4F	Chemists for Future
CLP	Classification, Labelling and Packaging
CSA	Coordination and Support Action
CSS	Chemicals Strategy for Sustainability
CSR	Corporate Social Responsibility
D	Deliverable
EC	European Commission
ECHA	European Chemicals Agency
ED	Endocrine Disruption
EHS	Environment, Health, and Safety
EPD	Environmental Product Declaration
ESG	Environmental, Social, and Corporate Governance
GC3	Green Chemistry and Commerce Council
IAMC	Innovative Approaches for the Sound Management of Chemicals and Chemical Waste
IDG	Inner Development Goals
ISC3	International Sustainable Chemistry Collaborative Centre
ISO	International Organization for Standardization
JRC	Joint Research Centre
LCA	Life Cycle Assessment
MOOC	Massive Open Online Course
NAMs	New Approach Methodologies
PBPK	Physiologically Based Pharmacokinetic
PBT	Persistent, Bioaccumulative, and Toxic
PCR	Product Categories Rules
PEF	Product Environmental Footprint
PMT	Persistent, Mobile, and Toxic

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PSA	Portfolio Sustainability Assessment
QSAR	Quantitative structure–activity relationship
R&D	Research and Development
R&I	Research and Innovation
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RIVM	Dutch National Institute for Public Health and the Environment
RP	Regulatory Preparedness
SbD	Safe by Design
SDGs	Sustainable Development Goals
SMEs	Small and Medium-sized Enterprises
SPP	Sustainable Public Procurement
SSbD	Safe and Sustainable-by-Design
SSIA	Safe(r) and Sustainable Innovation Approach
STEM	Science, Technology, Engineering, and Mathematics
TE	Trusted Environment
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organisation
VC	Value Chain
WBCSD	World Business Council for Sustainable Development
WP	Work Package
WPMN	Working Party on Manufactured Nanomaterials

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1 Executive summary

Safe-and-Sustainable-by-Design (SSbD) is a pre-market approach to chemicals, materials, production processes and products, that integrates safety and sustainability (environmental, social, and economic) aspects at early stages of the innovation process. The focus is on providing a desired functionality, while avoiding volumes and chemical properties that may be harmful to human health, climate, and the environment in a life cycle perspective. With the launch of the SSbD framework for the definition of criteria and evaluation procedure by the European Commission's (EC) Joint Research Centre (JRC), current work in the field of SSbD is focused on the implementation and operationalisation of SSbD. Whenever a new concept is being introduced, there are always knowledge, skills, and competence gaps at all levels. Making these gaps visible and developing targeted trainings for relevant stakeholders to close these gaps are key steps for the implementation and operationalisation of SSbD on a larger scale.

The work presented in this deliverable D2.5 is part of the gap analysis activity conducted within IRISS Work Package 2 (WP2) and is the main outcome of Task 2.5 'Map and address SSbD mismatches and competence gaps'. It provides an overview of the identified gaps in knowledge and skills, that are currently a source of inertia or even a barrier to the implementation and operationalisation of SSbD. Based on these gaps, training courses have been developed at a conceptual level for different key target groups (i.e. students at school and university, industry, regulators, and the general public), focussing on learning objectives and training content. Suitable training formats for the different target groups have been proposed. In addition, two training sessions were conducted: i) an online session for regulators on 5 March 2024 as part of a bi-weekly 'lunch talk' series held by Bureau REACH, which is part of the Dutch National Institute for Public Health and the Environment (RIVM) and ii) a workshop for members of the Young Chemists Forum of the German Chemical Society on 12 March 2024 in connection with the Spring Symposium 2024 in Ulm, Germany. Both trainings were valuable to refine the learning objectives and content and to gather further input on the SSbD approach and framework from different perspectives. This deliverable D2.5 also provides an overview of the trainings developed and conducted within IRISS and a (non-exhaustive) list of other online trainings and training materials relevant to SSbD that may be useful for future trainings. Compiled training materials from the listed IRISS trainings will be made available in the members' area of the IRISS permanent network.

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2 Introduction

Safe-and-Sustainable-by-Design (SSbD) is a pre-market design approach for chemicals, materials, production processes and products that integrates safety and sustainability considerations at early stages of the innovation process. Thereby, SSbD is actively contributing to the European Green Deal ambition of a toxic free environment and steers innovations towards the green and sustainable industrial transition. SSbD was first proposed in the Chemicals Strategy for Sustainability (CSS) (EC, 2020) as a novel approach to analyse and compare the effects, releases, and emissions of chemicals, materials, and products across all life cycle stages, with the aim of minimising impacts on human health, climate, and the environment. In 2022, the Joint Research Centre (JRC) of the European Commission (EC) published a framework for the definition of criteria and evaluation procedure for SSbD chemicals and materials to support the design, development, production, and use of chemicals and materials (Caldeira et al., 2022a). SSbD is a voluntary approach recommended by the EC (EC, 2022) and goes beyond current regulatory compliance.

SSbD integrates a wide range of scientific disciplines, methodologies, and regulatory objectives (Figure 1), including the principles of Green Chemistry, Green Engineering, and Circular Chemistry, other frameworks and guiding concepts such as Sustainable Chemistry and Safe by Design (SbD), and methodologies such as Life Cycle Assessment (LCA) and Risk Assessment. Learnings and recommendations from SbD for SSbD have recently been analysed in IRISS Work Package 1 (WP1) and published by Sudheshwar et al. (2024).

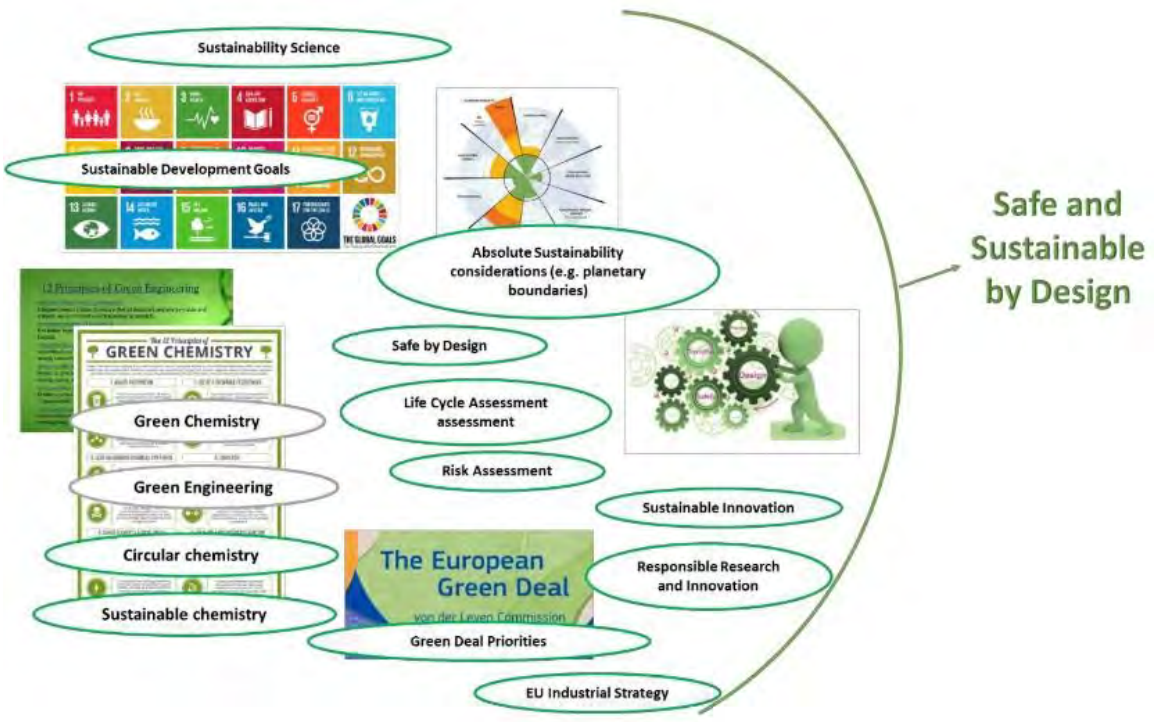

Figure 1: Underpinning principles and approaches informing the SSbD framework (Source: Caldeira et al., 2022a, Figure 3).

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3 Objectives

3.1 Objectives of the IRISS project and WP2

The SSbD concept is at the heart of the IRISS project, a Coordination and Support Action (CSA) funded under Horizon Europe. The IRISS project aims to connect, synergize, and transform the SSbD community in Europe and globally towards a life cycle thinking. IRISS pursues five high-level objectives, including i) the development of a state-of-the-art SSbD ecosystem, ii) the contribution to criteria and guiding principle development, iii) the establishment of a EU-led international and permanent network of experts, that is accessible for all relevant stakeholders, iv) the development of SSbD roadmaps, and v) the development of a monitoring and evaluation programme that scans for state-of-the-art knowledge and information gaps and translates these into specific Research and Development (R&D) questions or governance needs.

The objectives of IRISS WP2 'Gap Analysis in SSbD Activities' are to identify gaps in knowledge and tools for SSbD, to identify missing strategies or structures in the implementation of SSbD in different value chains (VC) and industry, to identify SSbD skills mismatches and competence gaps to support adequate skills at all levels, and to define needs for future Research and Innovation (R&I) activities.

3.2 Description of Task

Task 2.5 maps and addresses SSbD skills mismatches and competence gaps to support the enhancement of adequate skills at all levels - including in university programmes, research, industry and among regulators. The gap analysis results from previous tasks in IRISS WP1, 2 and 4 are used as the basis for the development of training courses aiming to address the need for the novelty of SSbD to be appropriately introduced to a range of audiences, from students at schools and universities to industry, regulators, and the general public.

This deliverable D2.5 'Map and address SSbD mismatches and competence gaps' includes the results from the activities within task 2.5. It presents a mapping and assessment of SSbD skills mismatches and competence gaps and the development of training courses for the above-mentioned target audiences. It further provides (online) sources of training materials that might be useful for the development of future SSbD trainings courses.

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4 Method

The methods applied for Task 2.5 consisted of six main parts:

- Mapping of prioritised SSbD gaps that need to be addressed by training courses to be developed (Chapter 5),
- Identifying key audiences for SSbD learning and training (Chapter 6),
- Defining learning objectives for the identified audiences and target specific training content (Chapter 6),
- Developing and delivering trainings for regulators and young chemists (Chapters 7 and 8),
- Summarising the training activities conducted within IRISS (Appendix 11.1) and collecting related training materials (Appendix 11.2), and
- Collecting further exemplary training materials and resources for different audiences, education levels, and settings (Appendix 11.3).

To achieve the above, the previous IRISS work on gap analysis, summarised in D2.1 'Harmonised methodology for gap analysis', was assessed for knowledge and skill gaps that can be addressed by training courses. This was supplemented by aspects identified as training needs in D4.4 and its update D4.10 'Skills, knowledge and education needs and gaps and mismatches for the uptake of SSbD', and D1.5 'Mapping of Skills'. The list of prioritised gaps for the training development is presented in Chapter 5.

Additionally, key target audiences for SSbD training were described, focusing on their role in implementing and operationalising SSbD. Appropriate training formats and tools to reach these audiences were suggested (Chapter 6). For the latter, learning interventions for green and sustainable chemistry education and learning provided in the specialised manual of the United Nations Environment Programme (UNEP) were used as a starting point (UNEP, 2023).

Based on the identified gaps, training courses have been developed at a conceptual level for different key audiences, namely students at school and university, industry, regulators and the general public. The training development focuses on the required knowledge and skills and the corresponding learning objectives. Lists of training aspects and content relevant to SSbD that should be covered in training courses are also provided (Chapter 6).

Based on the previous defined learning objectives and training content, two training sessions were conducted: i) a lunch-talk for regulators working on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) was organised within RIVM and held online on the 5th of March 2024 (Chapter 7), and ii) a workshop for members of the Young Chemists Forum of the German Chemical Society was jointly developed by Leuphana and the International Sustainable Chemistry Collaborative Centre (ISC3) and held on-site at the University of Ulm on the 12th of March 2024 (Chapter 8).

Training activities and materials that were conducted and developed under this and other IRISS tasks have been compiled and can be used as a basis for future training (Appendix 11.1 and 11.2).

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In addition, other online training courses and materials relevant to SSbD that could be useful for future training were compiled. The starting point was the list of training (materials) for green and sustainable chemistry education and learning provided by UNEP (2023). This was then supplemented by relevant training (materials) known to the IRISS partners involved in this task and by results from simple Google searches using different aspects of SSbD and the keyword 'online training'. Only free courses were included. Links to the relevant websites are provided in Appendix 11.3.

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5 SSbD Skills Gaps and Mismatches

The IRISS report D2.1 'Harmonized methodology for gap analysis' i) summarised gaps identified in the mapping work performed in WP1, ii) analysed value chain specific gaps collected through interviews with representatives of the seven IRISS value chains (automotive, constructions, electronics, energy, fragrances, packaging, and textiles), and iii) looked at gender and minority specific gaps. Further skills gaps and training needs have also been identified in D4.4 'Skills, knowledge and education needs and gaps and mismatches for the uptake of SSbD' and its update D4.10 as well as in D1.5 'Mapping of skills'. In all these reports, the lack of training opportunities, educational offers, internal experts and the resulting lack of knowledge, skills, and know-how was repeatedly mentioned as a key barrier to the implementation of SSbD, showing the urgent need for training development, as is the aim of this report.

This chapter summarises the knowledge and skills-related gaps and training needs identified in the above-mentioned reports that need to be considered in the development of training courses.

In terms of general training needs, the results of the IRISS reports D4.4, D4.10, and D1.5 showed that companies have a high chemical safety related skillset, attributed to their longstanding compliance with safety legislation, i.e., with REACH and CLP (Classification, Labelling and Packaging) as well as sector-specific ones. Skills and knowledge on sustainability aspects are lacking as these are less regulated in most sectors and current efforts are mostly driven by market demand. Specially, there is a **lack of skills related to performing environmental, social, and economic LCAs** as well as **knowledge and skills related to tools that can be applied at the design stage** (where there is often little data available) for the required sustainability assessments.

Several identified gaps relate a **systems thinking competence** that is needed for SSbD and should be included in particular in university education and industry training:

- **Systems thinking** addresses the complexity of global issues as a whole and includes thinking across spatial and temporal scales as well as different disciplines and perspectives. Systems thinking was already introduced as a key concept for chemistry education to move it towards more sustainability (Mahaffy & Elgersma, 2022; Mahaffy et al., 2021; UNEP, 2023).
- **Life cycle thinking and approaches:** Training on life cycle thinking and approaches and tools to perform life cycle assessments were identified as an important need. Currently, life cycle thinking is not widely integrated into chemistry or chemical engineering education, thus explaining the existing lack of knowledge and skills (UNEP, 2023).
- **Stage-gate model as a thinking mechanism** has relatively limited acceptance and promotion in the field of SbD, but it can be valuable for assessing safety and sustainability parameters at different stages of the innovation process. Therefore, the stage-gate model and stage-gate thinking should be further promoted in the context of SSbD.

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- **Reconciliation of stage-gate and life cycle thinking approaches:** SbD frameworks prioritizing the innovation model often lack comprehensive life cycle thinking. These frameworks predominantly focus on the production phase, with limited consideration given to the use and end-of-life stages. This discrepancy highlights the need to reconcile the stage gate model and the life cycle thinking approaches.

Gender aspects should be integrated into all SSbD university curricula to be developed:

- **Gender issues are missing in university curricula:** Gender issues are rarely part of university curricula; especially in natural science such as chemistry.

Further identified gaps need to be addressed in trainings for all SSbD stakeholders:

- **Common understanding of SSbD and its benefits is needed:** A prominent gap that emerged from the IRISS mapping activity was the need for a common understanding of SSbD, both in concept and in practice. There are still open questions, e.g., how SSbD can bring benefits in practice (in general and specific for the company and its customers), how SSbD relates to existing chemicals legislation, whether safety assessments should be hazard- or risk-based, and how to deal with trade-offs.
- **Understanding of the JRC SSbD framework:** The JRC framework in its current state is not user-friendly and often difficult to apply to specific materials and sectors and (at least some) definitions in the framework are too complex or confusing.
- **Solutions beyond 'chemical by chemical' substitution are needed:** To ensure overall sustainability, it is important to look beyond 'chemical by chemical' substitution in the search for alternatives and to explore non-chemical/material solutions; a current gap in the SSbD approach. New/innovative/alternative business models should be included in SSbD training to show that a sustainability-oriented way of work is not a barrier to economic success.
- **Closing the eco-gender gap**: Findings show that men are less likely than women to engage in pro-environmental behaviour, such as sustainable consumption. Therefore, training should explicitly address both men and women.

Several shortcomings of existing standards and guidelines relevant to SSbD have been identified, that relate to a 'Risk and Sustainability Governance' (Apel et al., 2024) and should be brought to the attention of policymakers, regulators, and standardisation bodies:

- **Harmonisation and simplification of LCA standards and guidelines**: In addition to two main and widely accepted LCA standards (ISO 10040 and ISO 14044), several regional and sector specific LCA guidelines exist, along with additional guidelines or standards specific to particular industries or regions. LCA practitioners have to be aware of them to ensure compliance and accuracy in their assessments.
- **Shortcomings of the Environmental Product Declaration (EPD):** The EPD is a mature method and comprises a huge number of product categories rules (PCR) for different sectors. In some sectors, however, the number of existing PCRs is very limited. In addition, many EPDs are based on a cradle-to-gate analysis rather than a cradle-to-grave approach.

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- **Shortcomings of the Product Environmental Footprint (PEF):** The PEF is the EU recommended LCA-based method to measure and communicate the potential life cycle environmental impact of products, goods, or services (EC, 2021). To be applicable for SSbD, the Product Environmental Footprint Category Rules and Organisation Environmental Footprint Sector Rules (currently twenty-one in number) needs to be further developed. For certain products, only a limited number of life cycle stages shall be considered (i.e., excluding the end-of-life for intermediates) resulting in a limited cradle-to-gate analysis for these products. Differences and contradiction to LCA standards (e.g., in term of using weighting) needs to be eliminated. The impact assessment categories, need to be expanded to include land-use impacts and biodiversity.
- **Circular strategies that aim to recycle biological materials are missing:** Legislation, standards, product labels, and design considerations rarely encompass circular strategies aiming to recycle biological materials and substances. In addition, design considerations in the general guidelines tend to focus on the technical sphere rather than the biological sphere.
- **Standardisation structure needs to be changed to adopt circularity:** Historically, standardisation has been linear, from raw material to end product, without considering additional life cycles. This structure now needs to be adapted to circularity. This leads to a new way of delivering and developing standards by standardisation organisations (such as CEN and ISO), with a higher level of involvement of public authorities in the initiation and development of standards.
- **Consideration of the gender-environment nexus in the context of SSbD:** Across all the Sustainable Development Goals (SDGs), less than 10% of the indicators incorporate both gender and environment, despite the gender-environment nexus being an important aspect to consider in achieving the environmental aspects of the 2030 Agenda (OECD, 2021).

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6 Development of Training Courses for Different Audiences

SSbD is a subject that not only addresses and matters to direct SSbD actors, such as decision makers in policy and industry, but is also relevant to a much broader group of stakeholders, including current and future workforces and citizens.

Educating students early is crucial to building a future workforce that is knowledgeable in SSbD and brings state-of the art knowledge on methods and technologies for SSbD to industry. Educating current workforces is another key aspect for the implementation of SSbD, requiring collaboration between industry and academia by delivering trainings and executive study courses on SSbD. In this context, governmental officials also play an important role as they are responsible for developing education policies.

Another important aspect of SSbD education is educating consumers. Public behaviour related to choosing safer and more sustainable products is a result of awareness of SSbD and a sustainable lifestyle as well as socioeconomic status, and it is commonly raised as a major barrier to adoption of more sustainable products and technologies (NSTC, 2023).

These examples highlight the fact that all segments of society are important target audiences for SSbD education and training, as each group has a clear role and specific learning needs.

In the following, learning objectives and key SSbD aspects for training content have been defined for four SSbD stakeholders, namely:

- Students at school and at university (Chapter 6.1),
- Industry (Chapter 6.2),
- Regulators (Chapter 6.3), and
- General Public (Chapter 6.4).

To best reach and educate these different audiences, training formats and tools need to be adapted to each audience. Some suitable training formats are shown in Table 1.

Table 1: Training formats and tools dependent on target audience

Target audience	Training formats
Students at school	Interactive and hands on activities such as a 'kids university' or 'Jugend forscht' (German for 'Youth researches')[1], interactive online tutorials, storytelling, gamification
Students at university	Integration of SSbD aspects into existing university curricula, new and SSbD-focused university curricula, short-term trainings such as summer or winter schools

[1] Jugend forscht is a well-known competition for school students and young people in the fields of science, technology, engineering, and mathematics (STEM) in Germany.

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Industry	In-house trainings, online trainings, boot camps, extra-occupational study courses at university
Regulators	Online webinars or in-house training sessions
General public	Sustainability events and workshops, short videos, online-tutorials, storytelling, gamification, disseminations materials in general, 'SSbD labels', product information, social media campaigns (e.g., YouTube, Facebook, X, and LinkedIn)

6.1 Students

6.1.1 Description of the target audience

Students at each stage of their formal education are a key group for SSbD education and training, as they are the future generation of citizens, workforce, and decision-makers.

It is important to educate primary and secondary school students about sustainability and SSbD. Young students are curious, open to new ideas, and receptive to environmental issues. By being informed early about sustainability can set students on the path towards sustainable behaviours such as sustainable consumption. Training on SSbD for primary and secondary students should be integrated into a broader sustainability education (rather than being taught as a separate subject). Interactive lessons and hands on activities, interactive online tutorials or gamification could be suitable training tools for primary and secondary school students.

At university, SSbD education and training should address both undergraduate and graduate students in chemistry, chemical engineering, material science and related science disciplines. In addition, it is important to educate university students in social or business sciences, as they may later be in potential leadership positions in industry and influence company culture, business model, and company operations, or in leadership roles in governments and regulatory authorities. Trainings for university students can be delivered, for example, by i) integration of SSbD aspects into existing university curricula, ii) development of new and SSbD-focused university curricula, or iii) development of short-term trainings such as summer or winter schools.

6.1.2 Students at School

6.1.2.1 Learning objectives

Students at school need to

- Have basic knowledge on the planetary boundaries and current environmental issues such as climate change, pollution, and biodiversity loss,
- Have basic knowledge on sustainability, including the three pillars of sustainability (environmental, social, economic) and the links between them,

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- Have basic knowledge on the goals of SSbD and its benefits for society,
- Have a basic understanding of thinking in a bigger picture; to focus on a desired functionality a product/solution needs to provide rather than a specific product,
- Have a basic understanding of sustainable behaviours such as sustainable consumption.

Trainings for students should be integrated into a broader sustainability education.

6.1.2.2 Training content

Key aspects that should be covered in a training for school students:

- **Planetary boundaries and the triple planetary crisis**:
    - **Planetary boundaries**: A set of nine planetary boundaries exist that define a safe operating space in which humanity can develop and thrive while maintaining the stability and resilience of our Earth system as a whole (Rockström et al., 2009). Crossing these boundaries increases the risk of large-scale abrupt and/or irreversible environmental changes. Six of the nine boundaries are already transgressed (Richardson et al., 2023).
    - **Climate change**: Referring to long-term shifts in temperatures and weather patterns that causes unwanted changes in the ecosystems. Human activities are the main drivers of climate change.
    - **Pollution** as a major cause of disease and premature death in the world.
    - **Biodiversity loss:** Referring to the decline or disappearance of animal species, plants, and ecosystems.
- **Resources**: Challenges of current and future use of resources (i.e. issues of raw materials), their recycling, and the establishment of a circular economy with respect to sustainability.
- **Sustainable solutions beyond chemical products**: A desired function can be achieved in multiple ways, sometimes also without chemicals or chemical products (designing a roof to protect the facade of a house vs. facade paint containing biocides).
- **SSbD approach and benefits of SSbD products for society**: The aim of SSbD is to produce safer and more sustainable products for society by minimising the environmental impacts of chemicals, materials, products, and processes, in particular on climate change, resource use, ecosystems and biodiversity, from a life cycle perspective. For example, SSbD protects citizens from hazardous chemicals, protects ecosystems from pollution and loss of biodiversity, and preserves our planet for future generations.
- **Sustainable consumption** is a consumer's choice for (SSbD) products and services that are produced with a minimised environmental impact (based on, for example, sustainability labels and certifications), combined with a responsible use and disposal or recycling of the products to stay within the capacity of ecosystems. This

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also includes providing sources of information on (SSbD) products in order to make an informed choice.

6.1.3 Students at University

6.1.3.1 Learning objectives

University students in chemical, engineering, or material sciences programmes and other related disciplines need to

- Have a deepened knowledge on the planetary boundaries and current environmental issues such as climate change, pollution, and biodiversity loss,
- Have basic knowledge on the SDGs,
- Be able to understand and interpret complex systems (systems thinking competence) such as the interconnections between sustainability and the planetary boundaries and chemistry's interface with business, government, and finance,
- Understand the differences between green chemistry and sustainable chemistry and how SSbD is linked to these chemistry concepts,
- Understand the different between hazard and risk and be able to perform respective assessments,
- Understand different life cycle approaches and be able to use respective tools to perform life cycle assessments (environmental, social, and economic),
- Be able to analyse impacts across temporal and spatial scales,
- Be able to collect, analyse, and evaluate data (and to evaluate the quality of the collected data) that can be used for the (re-)design of new chemicals, materials, or products with enhanced functionality and reduced safety and sustainability impacts,
- Be aware of gender issues and the importance of gender equality,
- Be able to work in interdisciplinary teams and communicate their work to different audiences ('soft skills' or 'interpersonal competencies').

University students in social and business sciences need to

- Have basic knowledge on the planetary boundaries and current environmental issues such as climate change, pollution, and biodiversity loss,
- Have basic knowledge on the SDGs,
- Be aware and have a basic understanding of SSbD,
- Understand the benefits of SSbD products for society,
- Know about the impacts of consumer choices and sustainable consumption,
- Know about alternative business models and corporate strategies supportive of SSbD, and

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- Understand chemistry's interface with business, government, and finance.

6.1.3.2 Training content

Key aspects that should be covered in a training for university students in chemical, engineering, or material sciences programmes and other related disciplines:

- **Planetary boundaries:** A set of nine planetary boundaries exist that define a safe operating space in which humanity can develop and thrive while maintaining the stability and resilience of our Earth system as a whole (Rockström et al., 2009). Crossing these boundaries increases the risk of large-scale abrupt and/or irreversible environmental changes. Six of the nine boundaries are already transgressed (Richardson et al., 2023).
- **Environmental impacts of chemical pollution**, e.g., triple planetary crisis (climate change, pollution, biodiversity loss), macro- and microplastics pollution, textile waste pollution, electronic waste pollution (e.g., Welcome to Sodom).
- **Resources**: Challenges of current and future use of resources (i.e. issues of raw materials), their recycling, and the establishment of a circular economy with respect to sustainability.
- **Sustainable Development Goals (SDGs)**: The United Nations 2030 Agenda for Sustainable Development is a roadmap for peace and prosperity for people and the planet, now and into the future (United Nations, 2015). It defines 17 SDGs, which are an urgent call for action. These are 'No Poverty' (SDG1), 'Zero Hunger' (SDG2), 'Good Health and Well-Being' (SDG3), 'Quality Education' (SDG4), 'Gender Equality' (SDG5), 'Clean Water and Sanitation' (SDG6), 'Affordable and Clean Energy' (SDG7), 'Decent Work and Economic Growth' (SDG8), 'Industry, Innovation and Infrastructure' (SDG9), 'Reduced Inequalities' (SDG10), 'Sustainable Cities and Communities' (SDG11), 'Responsible Consumption and Production' (SDG12), 'Climate Action' (SDG13), 'Life below Water' (SDG14), 'Life on Land' (SDG15), 'Peace, Justice and strong Institutions' (SDG16), and 'Partnership for the Goals' (SDG17) (United Nations, 2024).
- **Systems thinking:** Systems thinking addresses the complexity of global issues as a whole and includes thinking across spatial and temporal scales as well as different disciplines and perspectives. Systems thinking was already introduced as a key concept for chemistry education to move it towards more sustainability (Mahaffy & Elgersma, 2022; Mahaffy et al., 2021; UNEP, 2023).
- **Life cycle thinking and approaches:** Life cycle thinking and approaches such as 'cradle to grave' and 'cradle to cradle' and methods/tools to perform life cycle assessments on all three sustainability dimensions (environmental, social, and economic sustainability). Special focus should be given to the PEF method, which is currently recommend for SSbD until SSbD specific guidance is developed (Caldeira et al., 2022a). For SSbD, it is especially critical to already follow a life cycle approach at the design stage.

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- **Stage-gate model as a thinking mechanism:** The stage-gate model as a thinking mechanism can be valuable for assessing safety and sustainability parameters at different stages of the innovation process. It needs to encompass the entire life cycle of a product or material, including production, use, and end-of-life considerations to create a more robust and holistic SSbD approach that covers the entire life cycle, promoting sustainability and addressing potential risks and impacts throughout the entire product lifespan.
- **SSbD approach and benefits of SSbD products for society**: The aim of SSbD is to produce safer and more sustainable products for society by minimising the environmental impacts of chemicals, materials, products, and processes, in particular on climate change, resource use, ecosystems and biodiversity, from a life cycle perspective. For example, SSbD protects citizens from hazardous chemicals, protects ecosystems from pollution and loss of biodiversity, and preserves our planet for future generations; thereby SSbD supports the realisation of the SDGs.
- **SSbD databases and tools**: Trusted databases to collect required quality data for SSbD assessments and suitable methods and tools to perform the different assessments. A list of databases and tools on safety aspects is provided in Table 8 of Caldeira et al. (2022b).
- **Benign by Design (BbD)** is a targeted design approach for more sustainability of molecules, materials and products before synthesis and assembling (Boethling et al., 2007, Kümmerer, 2007, 2010). BbD can be used, for example, to design chemicals for environmental biodegradation if the chemical product cannot be collected and recycled and enters the environment due to its use**.**
- **Sustainable solutions beyond chemical products**: A desired function can be achieved in multiple ways, sometimes also without chemicals or chemical products (designing a roof to protect the facade of a house vs. facade paint containing biocides).
- **Gender equality** is not only a single goal of its own but a crosslinking topic through all sustainability dimensions (environmental, social, and, economic).
- **Strengthening interdisciplinary education** by e.g., by addressing sustainability issues from different perspectives and working in interdisciplinary groups.

Training for university students in social and business sciences programmes should also cover several of the above-mentioned topics as well as additional ones. Key aspects are:

- **Planetary boundaries and the triple planetary crisis**:
    - **Planetary boundaries:** A set of nine planetary boundaries exist that define a safe operating space in which humanity can develop and thrive while maintaining the stability and resilience of our Earth system as a whole (Rockström et al., 2009). Crossing these boundaries increases the risk of large-scale abrupt and/or irreversible environmental changes. Six of the nine boundaries are already transgressed (Richardson et al., 2023).

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- **Climate change**: Referring to long-term shifts in temperatures and weather patterns that causes unwanted changes in the ecosystems. Human activities are the main drivers of climate change.
- **Pollution** as a major cause of disease and premature death in the world.
- **Biodiversity loss:** Referring to the decline or disappearance of animal species, plants, and ecosystems.

- **Sustainable Development Goals (SDGs)**: The United Nations 2030 Agenda for Sustainable Development is a roadmap for peace and prosperity for people and the planet, now and into the future (United Nations, 2015). It defines 17 SDGs, which are an urgent call for action. These are 'No Poverty' (SDG1), 'Zero Hunger' (SDG2), 'Good Health and Well-Being' (SDG3), 'Quality Education' (SDG4), 'Gender Equality' (SDG5), 'Clean Water and Sanitation' (SDG6), 'Affordable and Clean Energy' (SDG7), 'Decent Work and Economic Growth' (SDG8), 'Industry, Innovation and Infrastructure' (SDG9), 'Reduced Inequalities' (SDG10), 'Sustainable Cities and Communities' (SDG11), 'Responsible Consumption and Production' (SDG12), 'Climate Action' (SDG13), 'Life below Water' (SDG14), 'Life on Land' (SDG15), 'Peace, Justice and strong Institutions' (SDG16), and 'Partnership for the Goals' (SDG17) (United Nations, 2024).
- **SSbD approach and benefits of SSbD products for society**: The aim of SSbD is to produce safer and more sustainable products for society by minimising the environmental impact of chemicals, materials, products, and processes, in particular on climate change, resource use, ecosystems and biodiversity, from a life cycle perspective. For example, SSbD protects citizens from hazardous chemicals, protects ecosystems from pollution and loss of biodiversity, and preserves our planet for future generations; thereby SSbD supports the realisation of the SDGs.
- **Sustainable production and consumption:** To produce products and services with a minimised environmental impact, combined with a responsible use and disposal or recycling of the products to stay within the capacity of ecosystems and to communicate this to the costumers, e.g., through sustainability labels and certifications.
- **Alternative business models**: Starting with a service or function which could result in using less or even no chemical products for the same service or function. This also includes 'for rent' models. Thereby, economic growth is decoupled from resource use and number of products sold. Alternative business models present a way to work in a more resource and environmentally friendly way and can improve the standing of a company.

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6.2 Industry

6.2.1 Description of the target audience

Industry is the main actor regarding SSbD implementation and operationalisation. A variety of companies (start-ups, small and medium enterprises (SMEs), large companies) along and across value chains must collaborate to bring SSbD into practice, including companies outside the EU. Previous IRISS reports (D4.4 and D4.10) have analysed who needs SSbD knowledge within companies, which varies depending on the sector, the organisational structure, and the size of companies, as well as their position in the value chain. In general, people involved in the innovation process, the material design step, as well as production/manufacturing need in depth SSbD knowledge. In addition to the lists provided in the above-mentioned reports, the higher management (e.g., chief executive officers (CEOs)) and the sales department needs to know and be supportive of SSbD.

Key roles and functions are:

- Executive Managers (incl. CEOs),
- Design professionals (incl. product developers),
- Product stewardship professionals (incl. regulatory, EU policy, governmental affairs roles),
- Quality managers,
- Sustainability experts (incl. ESG[2], CSR[3], LCA, EHS[4] roles),
- (Technical) sales professionals,
- R&D experts (incl. innovation experts),
- Procurement experts,
- Material engineers,
- Purchasing experts (incl. material sourcing, material supplier),
- Manufacturer specialists.

Many professionals engaged in chemical/material/product innovation, design, and production do have a chemical, chemical engineering, or material science background that not necessarily included education in sustainability aspects. Therefore, executive education and training are needed, either by (in-house) training organised by the company itself (e.g., with the help of external experts) or through extra-occupational courses at university.

Previous IRISS reports (D1.5, D4.4, and D4.10) have also shown that, in general, required knowledge and skills related to chemical safety is already available within companies, because compliance with safety legislation has been in place for some time, i.e., with REACH and CLP as well as sector-specific ones. Therefore, trainings should focus more on providing knowledge and skills on the sustainability side of SSbD.

[2] Environmental, social, and corporate governance
[3] Corporate social responsibility
[4] Environment, health and safety

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6.2.2 Learning objectives

All professionals in a company that are at least indirectly involved in the SSbD implementation need to

- Have a basic understanding of the SSbD approach and its regulatory background,
- Have knowledge on the benefits of SSbD products for society,
- Have a basic understanding of alternative business models to achieve a desired service or function with less or no chemical products.

Professionals directly engaged in the innovation, design, and production process of new chemicals, materials, and products further need to

- Be able to differentiate between Green Chemistry and Sustainable Chemistry and need to be aware of sustainability aspects and challenges,
- Be able to take a systems perspective beyond chemistry by having a broader understanding of sustainability considerations across the life cycle of products,
- Understand how SSbD can be integrated into the workflow of the company's innovation processes,
- Apply 'by design' thinking early in the innovation process when integrating functionality with safety, sustainability, and circularity aspects,
- Be able to collect, analyse, and evaluate data, that can be used for the (re-)design of new chemicals, materials, or products with reduced safety and sustainability impacts (without impairing functionality); this also includes to be able to evaluate the quality of the collected data,
- Be able to (re)design chemicals, materials, products, and processes with reduced safety and sustainability impacts and without compromising functionality by using suitable tools and methods,
- Understand the difference between hazard and risk and be able to perform respective assessments,
- Have in depth knowledge on LCA approaches and suitable tools,
- Be able to apply a life cycle thinking to assess and reduce impacts, e.g., the environmental footprint, of chemicals, materials, products, and processes for all life cycle phases,
- Be able to evaluate and justify trade-offs to optimise the impact–benefit ratio of chemicals, materials, products, and processes from a life cycle perspective.

6.2.3 Training content

Key aspects that should be covered in a training for all people in a company:

- **Regulatory background of SSbD:** SSbD is a voluntary design approach for chemicals, materials, products, and processes that goes beyond current regulatory compliance. SSbD was first proposed in the CSS (EC, 2020) to support the aim of a toxic-free

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environment and contributes to several SDGs, mainly SDG3 'Good Health and Wellbeing', SDG12 'Sustainable Consumption and Production', and SDG6 'Water Quality' (Caldeira et al., 2022a).

- **Benefits of SSbD for companies and its consumers**: SSbD materials and products offer numerous benefits, such as environmental benefits at system level and socio-economic benefits. By incorporating SSbD principles into the design process, companies can create products that are less harmful to the environment, consume fewer resources, and are safer for consumers to use, and thereby avoid unintended shifts of impacts on human and environmental health. In addition, protecting the planet and its inhabitants, there are opportunities for companies in shifting their portfolios to become ever safer and more sustainable, thus potentially creating a competitive advantage of the respective company in the market by increasing consumer confidence in the safety, environmental and social advantages of the respective products.
- **Alternative business models**: Starting with a service or function which could result in using less or even no chemical products for the same service or function. This also includes 'for rent' models. Thereby, economic growth is decoupled from resource use and number of products sold. Alternative business models present a way to work in a more resource and environmentally friendly way and can improve the standing of a company.

Key aspects that should be covered in a training for everyone involved in the company's innovation, design, and production process:

- **Portfolio Sustainability Assessment (PSA)**: In 2018, the World Business Council for Sustainable Development (WBCSD) launched PSA as a framework for chemicals companies to develop portfolio sustainability management methodologies and processes (WBCSD, 2018). A second edition was published 2023 (WBCSD, 2023). PSA is used to evaluate the sustainability performance of a portfolio of investments or assets, including the analysis of various environmental, social, and governance (ESG) factors to determine the overall sustainability impact of the portfolio. PSA helps investors make informed decisions about their investments by considering not only financial returns but also the long-term sustainability and impact of their investment choices.
- **Connecting PSA and SSbD:** The PSA methodology can be used complementary to the application of SSbD principles to achieve synergistic effects. Cefic (2024) proposes focussing the application of any SSbD framework on innovation processes for future chemicals, materials, and production processes, whereas established methodologies such as the PSA should be utilized to analyse a company's existing portfolio of chemicals, products, processes, and services.
- **The JRC SSbD framework:** The SSbD framework consists of i) a (re)design phase in which design guiding principles are proposed to support the design of chemicals and materials and ii) a safety and sustainability assessment phase in which the safety, environmental and socio-economic sustainability of the chemical or material is

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assessed in five steps (Caldeira et al., 2022a). The SSbD framework needs to be implemented early in the supply chain to achieve the highest benefits.

  - **SSbD databases and tools**: Trusted databases to collect required quality data for SSbD assessments and suitable methods and tools to perform the different assessments. A list of databases and tools on safety aspects is provided in Table 8 of Caldeira et al. (2022b).
  - **Trade-offs:** Evaluation and justification of trade-off decisions to optimise the impact−benefit ratio of chemicals, materials, products, and processes from a life cycle perspective.

- **Solutions beyond 'chemical by chemical' substitution:** To ensure overall sustainability, it is important to look beyond 'chemical by chemical' substitution in the search for alternatives and also explore non-chemical/material solutions.
- **Safe(r) and Sustainable Innovation Approach (SSIA):** Within the OECD Working Party on Manufactured Nanomaterials (WPMN) SSIA Steering Group, a system approach is taken reducing the time gap between the emergence of technological innovations and the development of suitable risk assessment tools and frameworks. SSIA combines SSbD with Regulatory Preparedness (RP) in a Trusted Environment (TE).
- **Life cycle thinking and approaches:** Life cycle thinking and approaches such as 'cradle to grave' and 'cradle to cradle' and methods/tools to perform life cycle assessments on all three sustainability dimensions (environmental, social, and economic sustainability). Special focus should be given to the PEF method, which is currently recommended for SSbD until SSbD specific guidance is developed (Caldeira et al., 2022a). For SSbD, it is especially critical to already follow a life cycle approach at the design stage.
- **Reconciliation of stage-gate and life cycle thinking approaches:** Life cycle thinking needs to be integrated into company's innovation model, which is often a (agile) stage-gate model.

6.3 Regulators

6.3.1 Description of the target audience

Regulators are important stakeholders in SSbD as they have to define the framework in which SSbD will operate, i.e. harmonize safety and sustainability assessment methodologies, set the criteria for SSbD in different sectors, and act as arbitrators; thereby counteracting existing uncertainties and confusion about SSbD that currently exists. Regulators also need to connect SSbD with existing regulatory approaches taking a systems approach.

6.3.2 Learning objectives

Regulators need to

- Become aware of SSbD,

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- Have a basic understanding of the innovation processes in industry to avoid new regulations being incompatible with them,
- Understand the need to move from conventional 'risk governance' to 'risk and sustainability governance', that also focuses on sustainability aspects which are currently often less regulated than safety aspects,
- Understand the need of a new mindset in regulation (preventive and not remediation),
- Be able to take a systems approach to link and combine SSbD with existing regulatory approaches.

6.3.3 Training content

Key aspects that should be covered in a training for regulators are:

- **Safe(r) and Sustainable Innovation Approach (SSIA):** Within the OECD WPMN SSIA Steering Group, a system approach is taken reducing the time gap between the emergence of technological innovations and the development of suitable risk assessment tools and frameworks. SSIA combines SSbD with RP and TE.
- **Innovation process within companies:** Regulators need to be knowledgeable on how innovation processes in companies are structured (e.g., Stage-Gate or Agile Stage-Gate innovation models (Cooper, 2014; Cooper & Sommer, 2018)) to align SSbD regulations accordingly.
- **Risk and sustainability governance:**
    - Complexity of the regulatory landscape: Need for harmonisation and simplification of existing regulations to new SSbD supportive regulations and thereby contracting the ever-increasing regulatory burdens put on companies,
    - Need to adjust existing standards and guideline (e.g., EPD and PEF) to be applicable for the required SSbD assessments,
    - Need for validated and standardised test guidelines for safety and all sustainability dimensions,
    - Need for well-defined and acceptable limits for safety and sustainability criteria,
    - Incentives to support the implementation and operationalization of SSbD, for example, incentives to support the development of digital tools for supply chain management and more efficient end of life handling, and
    - Incentives (certification schemes and labels) to strengthen the marketing positioning of SSbD products and sustainability-oriented consumer behaviour.

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6.4 General Public

6.4.1 Description of the target audience

Citizens play a crucial role in the context of SSbD through their purchasing power as consumers. As market demand has been identified as one of the main drivers for sustainability efforts within companies (see D4.4), the demand for more sustainable (and SSbD) products needs to increase for a transition towards SSbD products.

To convey SSbD-related information to the general public, mass communication is needed. Social media platforms such as YouTube, Facebook, X, and LinkedIn can be used for dissemination, interaction, and exchange actions to reach a large number of people. Suitable training formats can be sustainability events and workshops, short videos, online-tutorials, or disseminations materials in general. Also 'SSbD labels' and related product information can inform and guide the general public in their role as consumers and support sustainability-oriented choices.

6.4.2 Learning objectives

Trainings for the general public should put a strong focus on changes needed in terms of attitude (feelings, emotions, beliefs, values) and promote and convey the importance of environment friendly and SSbD supportive behaviour. Thereby, trainings will help to create market demand for SSbD products. It is essential to address both men and women equally to also support closing the eco-gender gap.

The general public need to

- Have basic knowledge on the planetary boundaries and current environmental issues such as climate change, pollution, and biodiversity loss,
- Be aware of the current and future situations regarding resource availabilities,
- Be aware and have a basic understanding of SSbD,
- Understand the benefits of SSbD products for society, and
- Understand the impact of their consumption choices.

6.4.3 Training content

Key aspects that should be covered in a training for the general public:

- **Planetary boundaries and the triple planetary crisis**:
    - **Planetary boundaries**: A set of nine planetary boundaries exist that define a safe operating space in which humanity can develop and thrive while maintaining the stability and resilience of our Earth system as a whole (Rockström et al., 2009). Crossing these boundaries increases the risk of large-scale abrupt and/or irreversible environmental changes. Six of the nine boundaries are already transgressed (Richardson et al., 2023).

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- **Climate change**: Referring to long-term shifts in temperatures and weather patterns that causes unwanted changes in the ecosystems. Human activities are the main drivers of climate change.
- **Pollution** as a major cause of disease and premature death in the world.
- **Biodiversity loss:** Referring to the decline or disappearance of animal species, plants, and ecosystems.

- **Resources**: Challenges of current and future use of resources (i.e. issues of raw materials), their recycling, and the establishment of a circular economy with respect to sustainability.
- **SSbD Approach and benefits of SSbD products for society**: The aim of SSbD is to produce safer and more sustainable products for society by minimising the environmental impact of chemicals, materials, products, and processes, in particular on climate change, resource use, ecosystems and biodiversity, from a life cycle perspective. For example, SSbD protects citizens from hazardous chemicals, protects ecosystems from pollution and loss of biodiversity, and preserves our planet for future generations.
- **Sustainable consumption** is a consumer's choice for (SSbD) products and services that are produced with a minimised environmental impact (e.g., based on sustainability labels and certifications), combined with a responsible use and disposal or recycling of the products to stay within the capacity of ecosystems. This also includes providing sources of information on (SSbD) products in order to make an informed choice.

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7 Training for Regulators on 5 March 2024

7.1 Practical information

A training for regulators was organised within this task and conducted online as a 'REACH lunch talk' on 5 March 2024; which is part of bi-weekly talks held by NL Bureau REACH. The total time of the talk was 1 hour.

7.2 Description of training

7.2.1 Content

The training was framed around SSIA which seeks to enhance the ability of all stakeholders to address the safety and sustainability assessment of innovations in a robust yet agile manner. SSIA aims at reducing the time gap between the emergence of technological innovations and the development of suitable risk assessment tools and frameworks.

The training started with highlighting the complexity of the regulatory landscape and the need of a new mindset that is focused on prevention and not remediation, does no harm to man and the environment, and starts from the innovation process. This was followed by presenting SSIA and the JRC SSbD framework. The following section of the talk was focused on advanced materials, in particular on the potential gaps in REACH for advanced materials and safety and sustainability issues of advanced materials. The talk was finalised with questions related to regulator involvement in the IRISS network.

Some exemplary slides of the training are shown in Figures 2 to 8. The entire presentation will be made available in the members' area of the IRISS permanent network.

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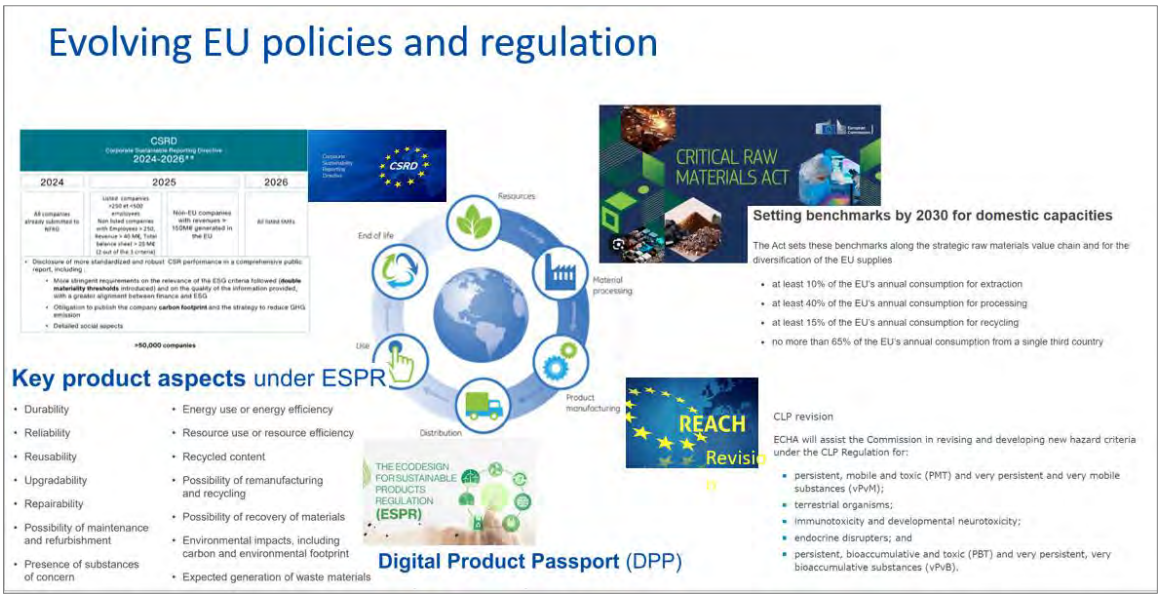

Figure 2: Exemplary slide showing the complexity of the regulatory landscape to support the importance of SSbD.

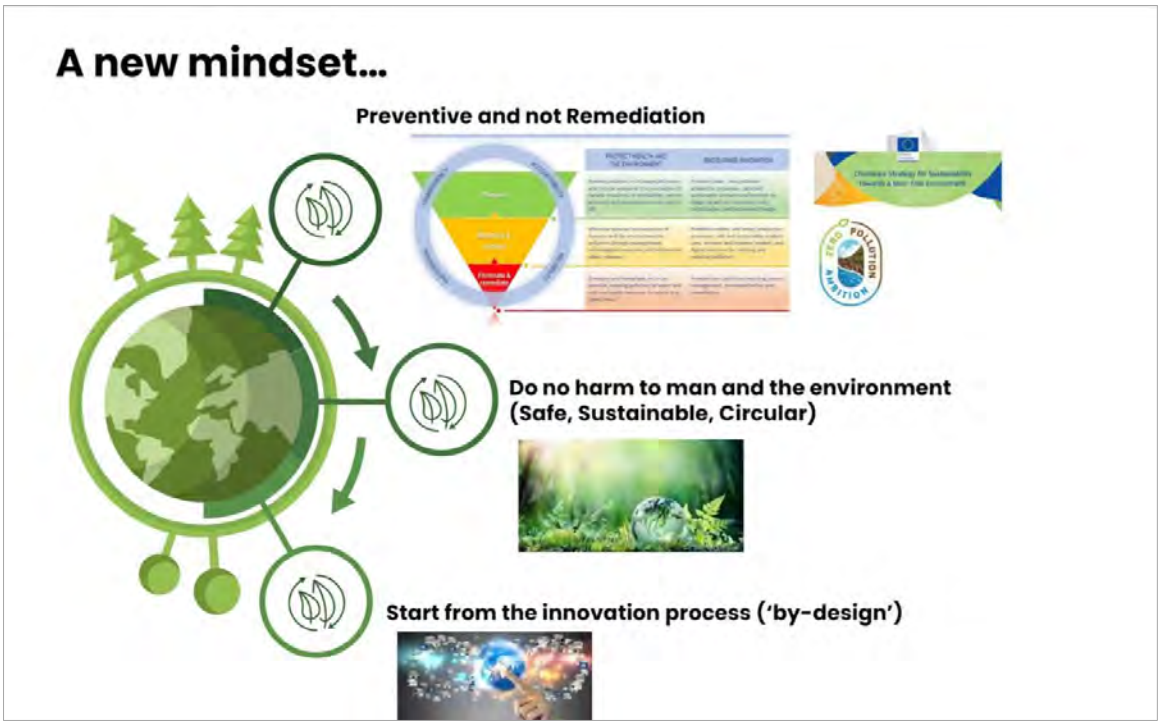

Figure 3: Exemplary slide showing the need of a new mindset.

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Figure 4: Exemplary slide about SSIA which combines SSbD with RP in a TE.

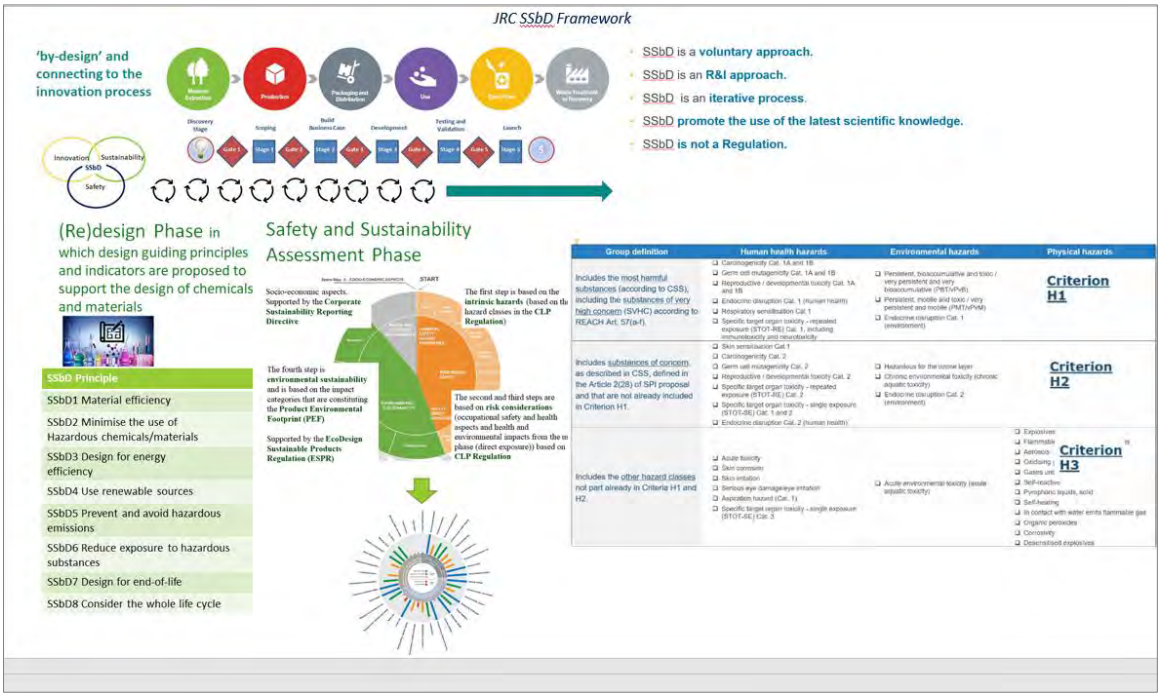

Figure 5: Exemplary slide on the JRC SSbD framework.

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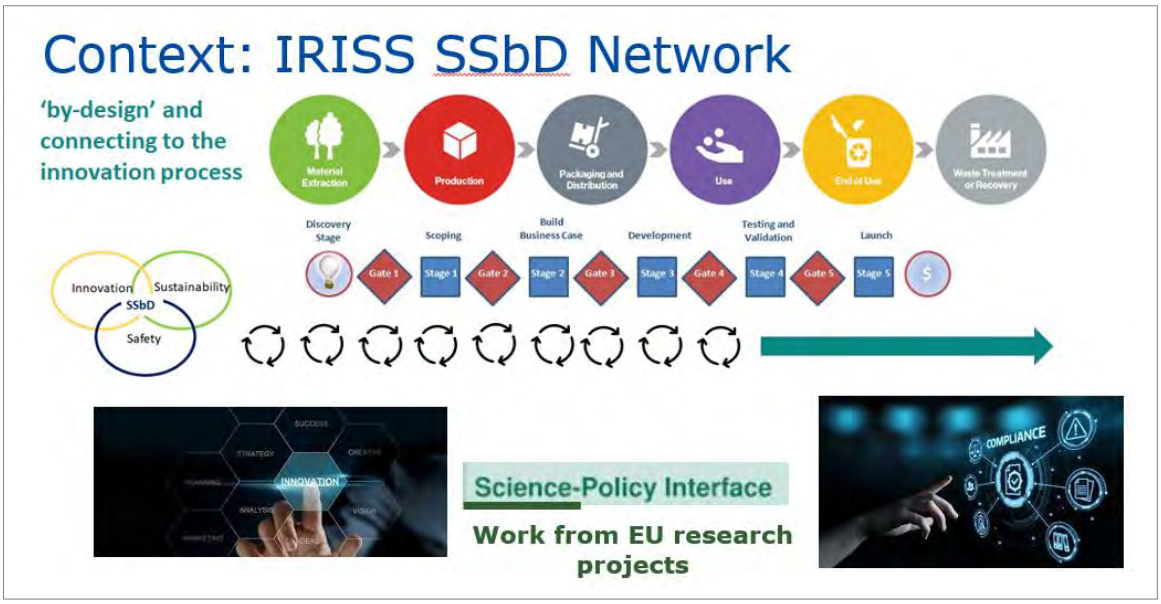

Figure 6: Exemplary slide on the stage-gate model and IRISS' work to integrate SSbD into the innovation model.

Figure 7: Exemplary slide demonstrating the importance of RP in relation to keeping pace with innovation of advanced materials.

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Figure 8: Exemplary slide with questions related to regulator involvement in the IRISS network.

7.2.2 Mentimeter questions and feedback

During the talk, Mentimeter was used to engage with the participants and receive direct feedback on the regulators' perception of engagement with SSbD and inputs on SSbD and the JRC SSbD framework. The following feedback was obtained.

What comes into mind when you hear SSbD?

- Safer substances
- Safety first
- Think about safety before it is too late in the innovation process
- Innovation
- Innovating innovation
- Manufacturing
- SSbD product development screening
- New and emerging risks
- CSS
- Ideal world and environmentally friendly
- Sustainability
- Trade-offs
- Practical?

Do you think regulators have anything to do with SSbD?

All but one regulator responded positively to this question (Figure 9).

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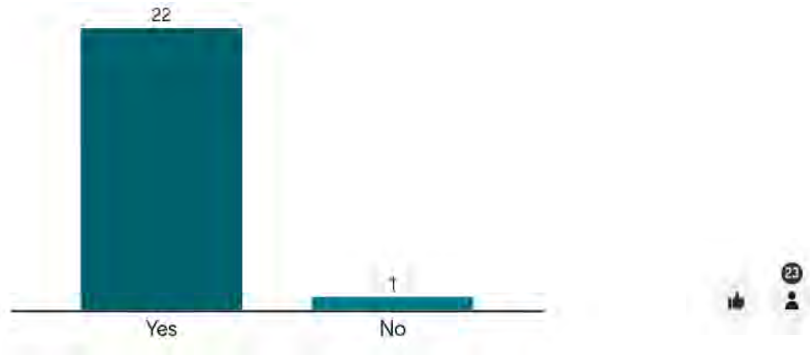

Figure 9: Menti results on the question "Do you think regulators have anything to do with SSbD?"

What are your first thoughts of the EC JRC framework?

Positive points

- Comprehensive
- A good start
- Interesting
- Good initiative
- Needed, very important
- Good discussion starter/kick-starter
- Would like to know more
- Based on available information and how to act early in the innovation process
- Can be a pilot for new regulation
- Quantitative structure–activity relationship (QSAR) models
- Physical-chemical properties
- Learn from all possible mistakes/issues that have been experienced already

Points of concern

- Many data needed
- Proportionality
- Tedious
- Still too abstract
- Practicality
- Good initiative but it will take a long time to get it working
- Good initiative but wonder if CLP is adequate for this
- Clear definition of what SbD and SSbD is

What early hazard/safety assessment tools can be used for SSbD?

- ZZS similarity tool
- Read across
- QSARs/*in silico* screening
- Exposure assessment software tools
- Biodegradability prediction
- *In silico* experts
- Guidance
- Rules and enforcement are needed otherwise the economic factor will predominate innovation
- New approach methodologies (NAMs)
- Physiologically based pharmacokinetic (PBPK) modelling
- Expert judgement
- Multidisciplinary brainstorm
- Artificial Intelligence (AI)
- Machine learning
- Transparent interpretation of outcomes

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What can we learn from REACH and other legislations to support the EC JRC framework (a pre-regulatory approach)?

- It is essential for safety
- Definition is key
- Use carrots and sticks
- Need for it to be practical
- Ensure that regulations are aligned with each other
- Learn from issues that were experienced in REACH already (for instance PBT, PMT, ED substances[5] and incompliant testing)
- The need for clear instructions
- Takes a long time
- Stakeholder commitment
- Enforcement is key
- Guidance is needed
- Grouping
- Focus on substitution

Would you be interested in joining an EU-led SSbD International Network (IRISS)?

All responses received to this question were positive (Figure 10).

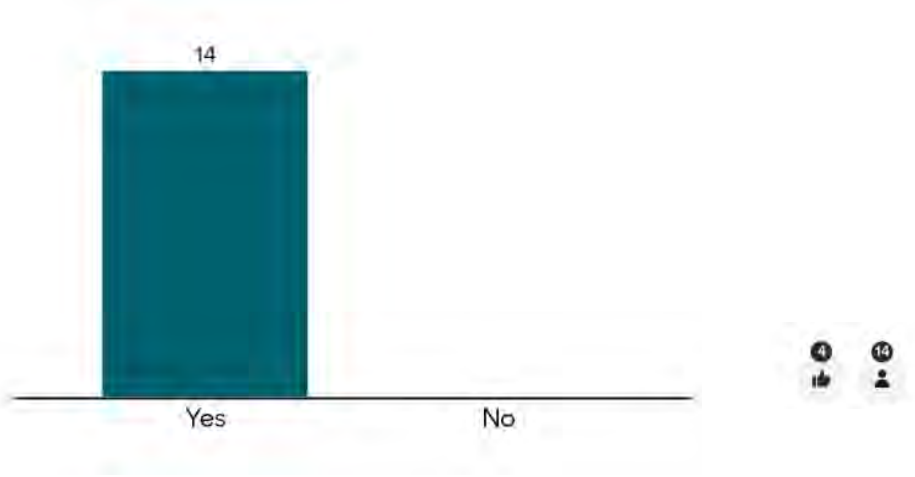

Figure 10: Menti results on the question "Would you be interested in joining an EU-led SSbD International Network (IRISS)?"

Other discussion points:

- The definition of what SbD is will depend on context (difference with for instance Carc Category 1 and 2 is availability of data),
- Consider less exposure,
- Go beyond the molecule and consider whether chemical or product is socially needed,
- Create an environment where SSbD is incentivised and has an advantage,

[5] Persistent, bioaccumulative, and toxic (PBT), persistent, mobile, and toxic (PMT), endocrine disrupting (ED) substances

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- Vocabulary is extremely important,
- Need to understand the different perspectives of what SbD is,
- Clear boundaries, guidance and rules/regulation is needed; including clear legal boundaries,
- It is important to keep a level playing field; particularly when developing regulatory sandboxes.

7.3 Lessons learnt

During the preparation of the workshop, it became clear that the content of the training needed to be adapted to the area in which the regulators were working to be of interest, e.g. either more safety oriented (as in this case) or more sustainability oriented. Also, to highlight the importance of SSbD, the complexity of the regulatory landscape and the need of a new mindset ('by-design' and preventive over remediation) need to be highlighted. This point was added to the training objectives and content of chapter 6.3. The interactivity of the talk not only allowed to transfer knowledge but also to receive valuable feedback on the regulator's perception on engagement with SSbD and on the SSbD framework for further work in IRISS.

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8 Workshop for Young Chemists on 12 March 2024

8.1 Practical information

The workshop was held on 12 March 2024 for members of the Young Chemists Forum of the German Chemical Society in connection with the Spring Symposium at the University of Ulm, Germany. The workshop was developed and conducted in cooperation with ISC3 and was held in German. The total duration of the workshop was three hours.

8.2 Description of workshop

The workshop started with a short introduction round, followed by interactive work on the terms 'greener chemistry' and 'sustainable chemistry' to clarify key aspects and differences between both concepts.

This was followed by two presentations: The first presentation was on SSbD (explaining the policy background of SSbD, the JRC SSbD framework, and how SSbD will innovate the innovation process in industry) and the IRISS project (its objectives, major SSbD gaps identified within IRISS, the IRISS SSbD supportive roadmap, and next IRISS events). The second presentation was about the BbD concept, showing approaches and methods for designing environmentally mineralising chemicals.

After the presentations, the participants discussed how the knowledge and skills of their respective chemical field can support the implementation of SSbD and BbD.

The workshop was finalised with a group work in which each group should think about a (theoretical) case study of their everyday work life and apply the questionnaire developed within the SUNSHINE project as a screening level approach to support companies in making safe and sustainable by design decisions at early stages of innovation (Pizzol et al., 2023).

Some exemplary slides of the workshop are shown in Figures 11 to 17. Parts of the presentation will be made available in the members' area of the IRISS permanent network.

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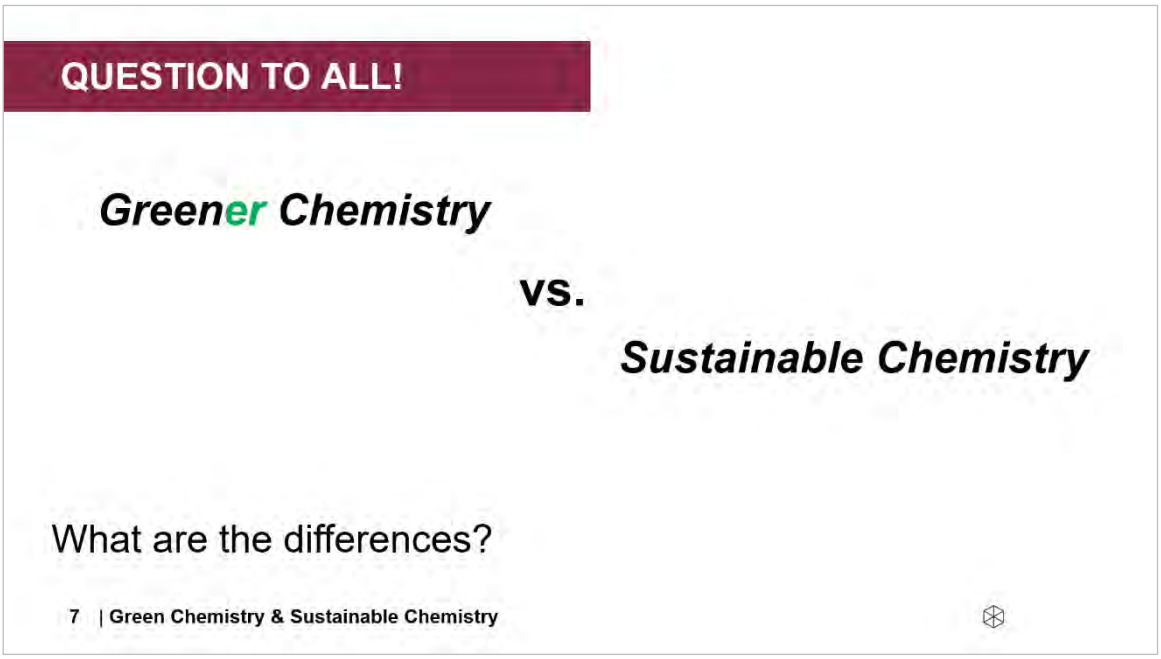

Figure 11: Exemplary slide to work out interactively the differences between greener chemistry and sustainable chemistry (translated from German).

Figure 12: Exemplary slide on the hierarchy in chemicals management and SSbD as a prevention strategy.

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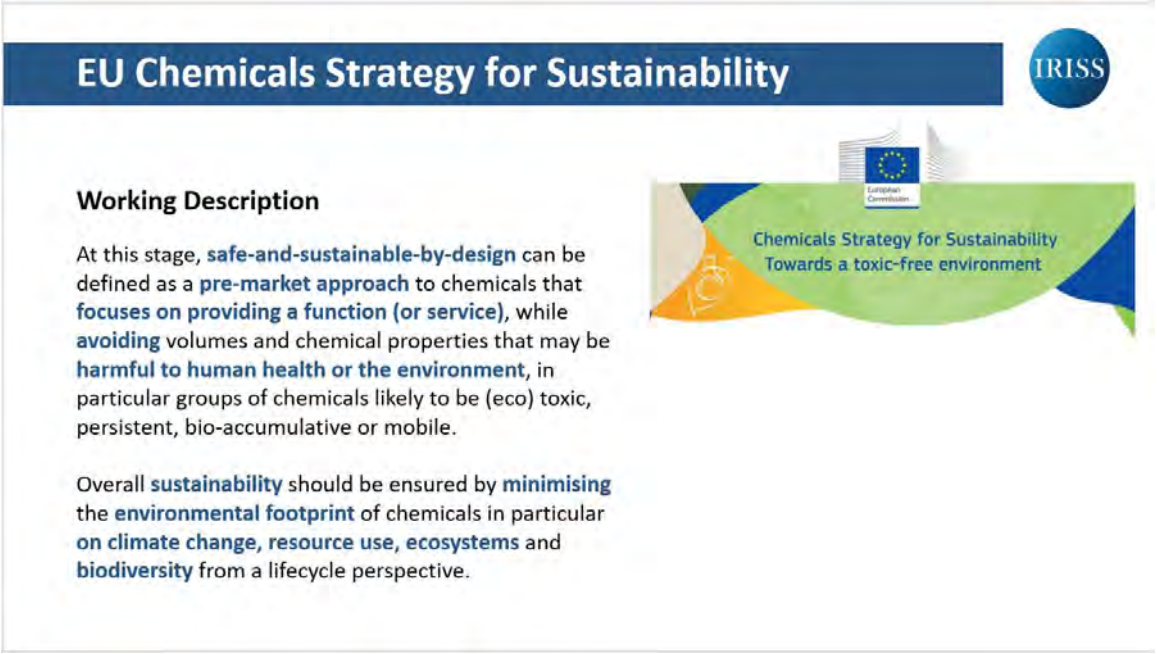

Figure 13: Exemplary slide on the working description of SSbD.

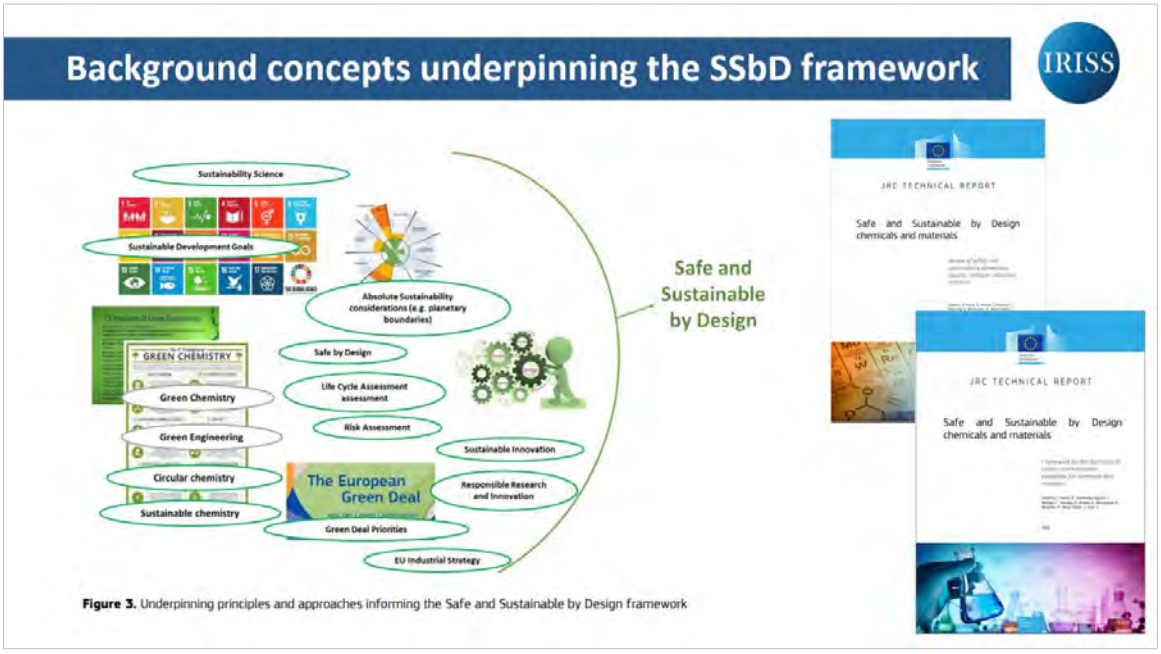

Figure 14: Exemplary slide on the underpinning principles and approaches informing the SSbD framework.

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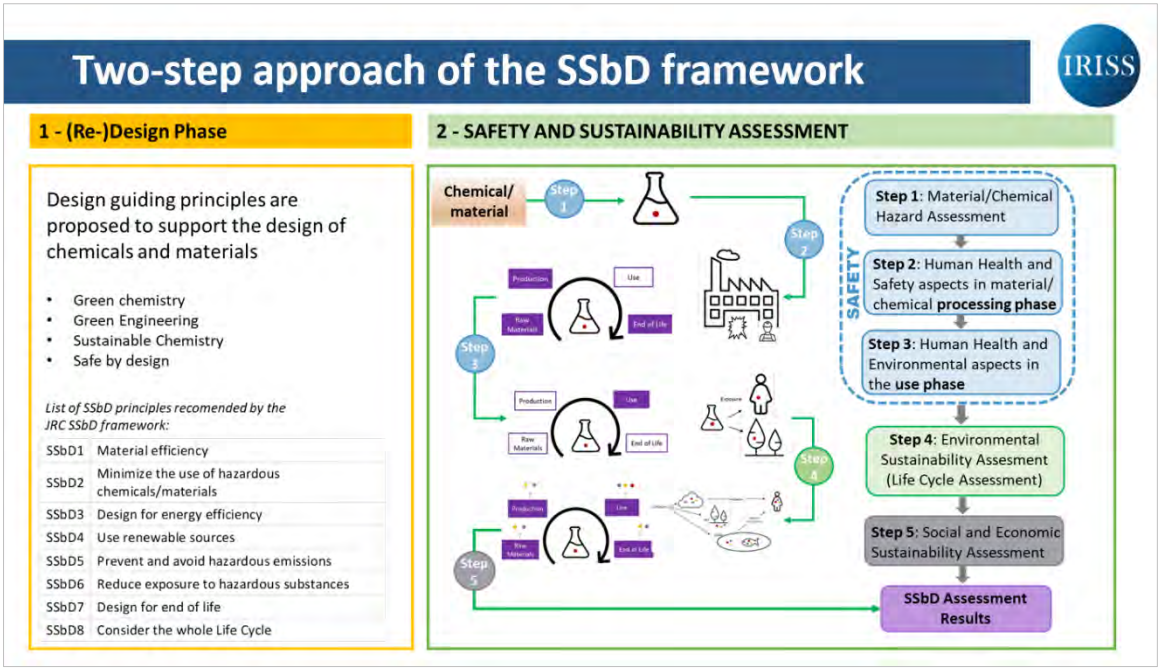

Figure 15: Exemplary slide showing the two-step approach of the SSbD framework.

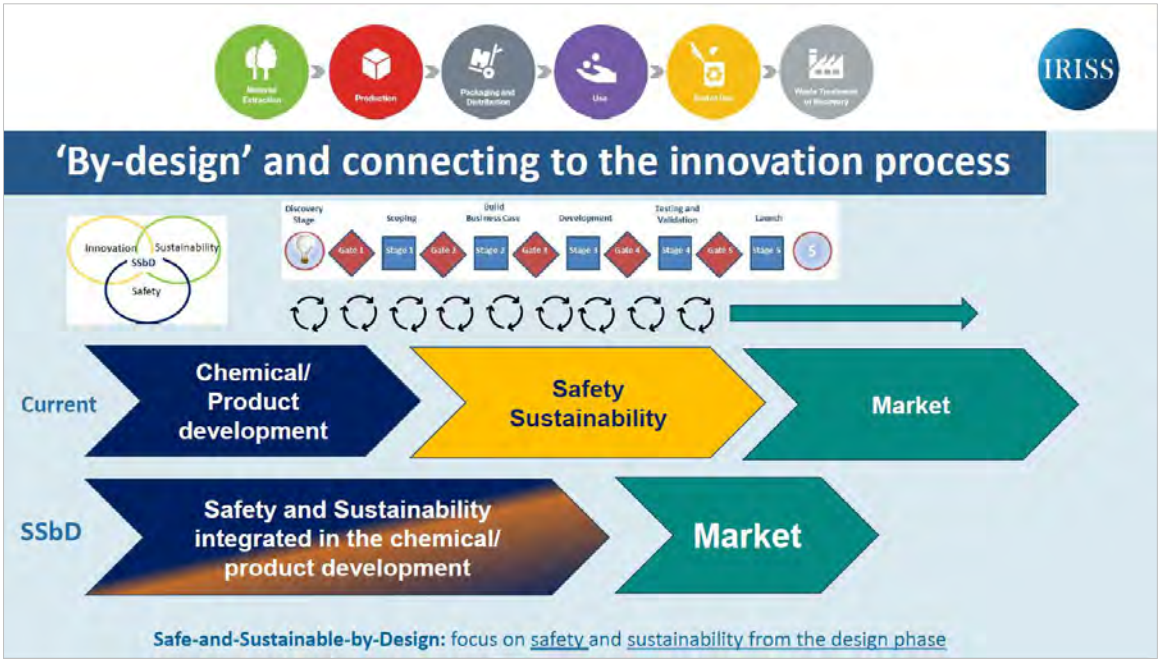

Figure 16: Exemplary slide on how SSbD needs to be integrated into the innovation process in industry.

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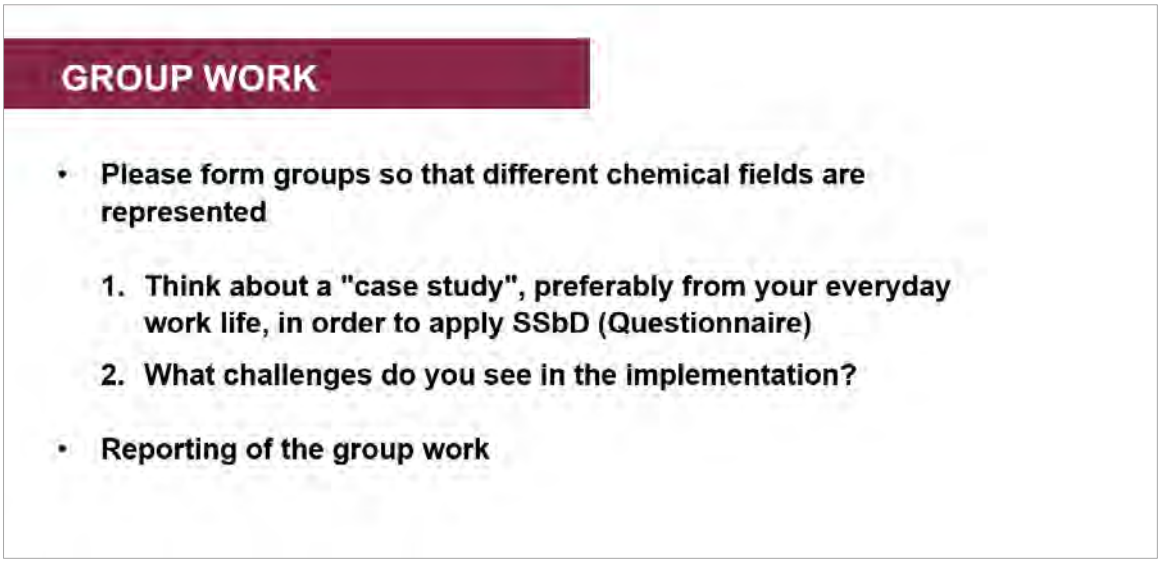

Figure 17: Exemplary slide for group work (translated from German).

8.3 Lessons learnt

The questions and discussions during and after the workshop showed that more time should have been spent for the problem framing – environmental issues which are related to chemicals and chemical production - right at the beginning of the workshop. This has been added to the training objectives and content of chapter 6.1.3. The interactive work on Green Chemistry and Sustainable Chemistry was found very useful by the participants (according to the feedback received after the workshop) and should therefore also be included also in future training courses. In general, the participants felt a low level of engagement with the concepts presented and did not feel able to actively contribute to more sustainability in their daily work. The interdisciplinary nature of sustainability and SSbD and the opportunities for everyone to contribute should be emphasised more in future workshops, e.g. through a longer and more in-depth discussion or group work.

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9 Conclusions and Next Steps

This deliverable describes the activities performed in task 2.5. Trainings on SSbD have been developed on a conceptual level for key target groups (i.e. students at school and university, industry, regulators, and the general public). In addition, an online session for regulators and an onsite workshop for young chemists have been conducted and the feedback received was used to refine the developed trainings.

The defined learning objectives and training content for university students will be used as basis for the university degree module on SSbD with anchors in existing curricula, that will be initiated within IRISS WP5 during the project runtime.

The results from this task will also feed into the education needs of the SSbD supportive roadmap of WP3 to address the training needs for closing identified gaps.

So far, IRISS has not reached out or organised a training for the general public, because i) currently IRISS does not have the reach to really engage with the general public and ii) trainings sessions or events will be much more useful if SSbD is further developed and implemented and there are already SSbD products on the market (e.g. with an SSbD label). If the IRISS outreach and SSbD awareness in general are further developed, 'block texts' (explaining SSbD and relevant aspects in an easy and not too scientific way) on the IRISS website, graphical representations, and further dissemination of (existing) SSbD-related YouTube videos (i.e. the one developed by SUSNANOFAB: What is Safe and Sustainable by Design (SSbD) concept) could be first activities.

With the launch of the IRISS SSbD Community Network in May 2024, existing and future training materials will be made available to IRISS members in a dedicated education and training space.

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11 Appendix

This appendix presents a snapshot in time of trainings that have been carried out or are already planned in IRISS. Many more will be conducted over time. The same applies to the online training courses and training materials listed that aim to show sources of SSbD-related material. The list does not claim to be exhaustive.

11.1 Workshops and trainings conducted within IRISS

11.1.1 Introduction to SSbD at the Summer School on Sustainable Chemistry and Climate Crisis on 10-14 July 2023

An interactive 1-hour lecture on "European Chemicals Strategy for Sustainability – Safe and Sustainable by Design" was given at the Summer School 2023 on Sustainable Chemistry and Climate Crisis. The Summer School was designed for postgraduates and young professionals who deal with or are professionally interested in the topic of sustainable chemistry as a crosscutting issue.

The main objectives of the lecture were:

- To provide basic knowledge about the **policy background of SSbD** (SDGs, Green Deal, CSS),
- To get a better understanding of "**safety**" and "**sustainability**",
- To provide basic knowledge about the **objectives of SSbD** and **the JRC SSbD framework**,
- To provide basic knowledge of the **innovation process in industry** and how SSbD need to be implemented, and
- To provide a basic understanding of **IRISS' objectives and work** in the field of SSbD.

Further information about the Summer School and its programme can be found on the Summer School's website.

11.1.2 Introductory Training for SMEs on 22 September 2023

Within task 6.2.1, an introductory training for SMEs 'Introduction to Safe-and-Sustainable-by-Design (SSbD) tools and case studies' was developed and held online on 22 September 2023.

The main training objectives were:

- To provide basic knowledge about the **SSbD framework** and **how to implement it**,
- To provide a better understanding of **"by-Design" thinking**,
- To provide basic knowledge about the **LCA methodology and suitable tools for SSbD**, and

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- To provide a better understanding of how to **translate** the **framework for SSbD criteria to specific cases.**

A summary of the event and the link to the recording is available on the IRISS website. Further information can be found in D6.5.

11.1.3 Training for Regulators on 5 March 2024

Within this task 2.5, a training for regulators was organised and conducted online as a 'REACH lunch talk' on 5 March 2024.

The main training objectives were:

- To raise awareness of what **SSbD** is and how it **relates to REACH**,
- To provide a better understanding on how to **take a systems approach** to link and combine SSbD with existing regulatory approaches; with the example of **SSIA**,
- To provide a better understanding of the **innovation processes in industry**.

Further information can be found in Chapter 7.

11.1.4 Workshop for Young Chemists on 12 March 2024

Within this task 2.5, an on-site workshop was held for young chemists on 12 March 2024 in connection with the Spring Symposium. The workshop was developed and conducted in cooperation with ISC3 and was held in German.

The main training objectives were:

- To provide a better understanding of **green chemistry** and **sustainable chemistry** and the difference between both concepts,
- To provide basic knowledge on the **SSbD** concept and the JRC SSbD framework,
- To provide basic knowledge on the **BbD** concept,
- To provide an understanding on how the **participants everyday work could contribute to SSbD and BbD**,
- To provide a better understanding on **life cycle thinking**,

Further information can be found in Chapter 8.

11.1.5 Second Training for SMEs on 28 June 2024

Within task 6.2.1, a second training session for SMEs on 'Environmental Biodegradation Design and Case Studies in the context of SSbD' was developed and will be held online on 28 June 2024.

The main training objectives are:

- To provide basic knowledge on the **BbD** concept and how it contributes to SSbD,

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- To provide a better understanding of **"by-Design" thinking** and on **how to integrate biodegradability into the chemicals design**,
- To provide basic knowledge on **biodegradation testing methods** and **criteria**,
- To provide a better understanding on **how to translate the SSbD framework to specific cases**.

A summary of the event and the link to the recording will be available on the IRISS website afterwards. Further information will be available in D6.12.

11.1.6 Summer School on Sustainable Chemistry and SSbD on 8-12 July 2024

Within task 5.4, a Summer School on Sustainable Chemistry and SSbD is jointly organised by Leuphana, ISC3, and IRISS. The Summer School is designed for postgraduates and young professionals who deal with or are professionally interested in the topic of SSbD and sustainable chemistry as a crosscutting issue.

The objectives of the Summer School are:

- To provide a basic knowledge of the chemical concepts of **Green Chemistry, BbD, and Sustainable Chemistry**,
- To provide a better understanding of **circular economy** and **resource use**,
- To provide a better understanding of taking a **systems approach**,
- To provide knowledge of the **SSbD concept** and how it can drive innovation,
- To provide information on **tools** that can be used to define SSbD chemicals and materials,
- To provide knowledge on **gaps and challenges that hinder the implementation** of SSbD and the developed **IRISS SSbD roadmap**, and
- To provide a **value chain perspective** on the implementation of SSbD.

The Summer School programme includes a theoretical part (lectures) as well as practical workshops, group discussions and an excursion to illustrate and deepen practical aspects of sustainable chemistry and SSbD.

Further information and the agenda for the Summer School can be found on the Summer School's website.

11.2 Training Materials developed within IRISS

Material related to IRISS trainings, such as presentation slides and a collection of recorded presentations by topic, will be made available in the members' area of the IRISS permanent network.

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11.3 Further Online Trainings and Training Materials

This chapter compiles links to training courses and materials that can be helpful in the context of SSbD; without claiming to be exhaustive.

11.3.1 Chemical Risk Assessment

PARC – the European Partnership for the Assessment of Risks from Chemicals has created an online knowledge management and community platform called **PARCopedia** addressing professionals in chemical risk assessment.

11.3.2 Critical Raw Materials

The Delft University of Technology (TU Delft) offers two massive open online courses (MOOC) on Critical Raw Materials on the edX platform: 'Critical Raw Materials: Managing Resources for a Sustainable Future' and 'Waste Management and Critical Raw Materials'.

11.3.3 Design Thinking and Design for a Circular Economy

The edX platform offers several online courses on 'Design Thinking', for example the course 'Product Design: The Delft Design Approach' developed by the TU Delft.

More focused on the Design for a Circular Economy are the courses 'Engineering Design for a Circular Economy', 'Designing Electronics for Recycling in a Circular Economy', and 'Sustainable Packaging in a Circular Economy' developed by the TU Delft and the course 'Circular Fashion: Design, Science and Value in a Sustainable Clothing Industry' developed by Wageningen University & Research. All courses are offered on the edX platform.

11.3.4 Gender and the Environment

The United Nations Information Portal on Multilateral Environmental Agreements (InforMEA) offers various online learning courses. One of these courses focuses on 'Gender and the Environment'.

The Stockholm Environment Institute offers the course 'Gender, Environment and Sustainable Development' on the UN SDG:Learn website. The course provides a set of multimedia and learning tools to better understand gender in environment and sustainable development.

11.3.5 Green Chemistry

Training materials for Green Chemistry educators from primary school to university level are developed and disseminated by the non-profit organisation **Beyond Benign**. The material is freely available on their website: https://www.beyondbenign.org/

Change Chemistry, formerly the Green Chemistry and Commerce Council (GC3), offers **Safer Chemistry Training Webinars** focussing on green chemistry, green engineering, and toxicology, designed primarily for professionals. The 'Green Chemistry in Business' webinars,

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e.g., cover topics related to product design, green chemistry market building and supply chain transformation.

The United Nations Industrial Development Organisation (UNIDO) offers a **Green Chemistry Toolkit** to be used by companies, academia and policy makers as well as experts, engineers, consultants or researchers that aims to increase global awareness and develop capacities to create deployable green chemistry approaches for the design of products and processes.

The '**Safer Chemical Design Game**' developed by the Yale Center for Green Chemistry and Green Engineering introduces students to green chemistry and safer chemical design by challenging them to create a new molecule with optimal results by changing molecular parameters while considering trade-offs.

11.3.6 Inner Development Goals

The Inner Development Goals (IDGs) are a framework that helps to identify, understand, communicate, develop, and integrate the inner skills needed for sustainable development. Information can be found on the website innerdevelopmentgoals.org.

11.3.7 Life Cycle Thinking

The Life Cycle Initiative has developed e-learning courses in various languages that give an introduction to life cycle thinking and how it can be used within businesses and policy making.

11.3.8 Non-hazardous Alternatives

The European Chemical Agency (ECHA) offers an online training on '**Analysis of Alternatives**' to hazardous substances intended for practitioners working in authorities, industry and non-governmental organisations.

The OECD offers a '**Substitution and Alternatives Toolbox (SAAToolbox)**' that compiles resources relevant to chemical substitution, selection and alternatives assessment such as tools, guides, frameworks and case studies.

11.3.9 Safe and Sustainable-by-Design

On the official **SSbD website of the EC**, reports and other documents on SSbD can be found as well as workshops and other events, e.g., the JRC Reports 'Review of safety and sustainability dimensions, aspects, methods, indicators and tools' and 'Framework for the definition of criteria and evaluation procedure for chemicals and materials' and the Case Study Report 'Safe and Sustainable by Design chemicals and materials - Application of the SSbD framework to case studies'.

The EC JRC together with PARC organised a **SSbD Bootcamp** in October 2023. The bootcamp has been recorded and the videos are available on the EC Science & Innovation YouTube channel: Day1, Day2, and Day3.

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The SUSNANOFAB project developed a 2-minute video on what SSbD is. The video '**#SUSNANOFAB - Safe and Sustainability by Design**' is available on the INL YouTube channel.

The HARMLESS project has organised a workshop on ***Safe-and-Sustainable-by-Design (SSbD): Advanced Materials in Product Development for small and medium enterprises (SMEs)***, targeted at SME and consultancy companies. A summary of this workshop can be found on the project's website. All workshop's materials (presentations, recording and agenda) are also available: DOI: 10.5281/zenodo.7974563.

11.3.10 Safe(r) and Sustainable Innovation Approach

The OECD website 'Safe(r) and Sustainable Innovation Approach (SSIA): Nano-enabled and other Emerging Materials' describes the combined concepts of SSbD, RP, and TE and provides brochures, publications, and webinars.

11.3.11 Safe by Design

RIVM offers educational material on SbD. For example, the **SbD Serious Game** challenges students to broaden their safety awareness with safety considerations of a technical, societal, social, ethical and legal nature. On the Safe by Design website, also **SbD courses** are offered covering the themes such as the fundamental challenge of SbD, reflecting on one's own role in the innovation system, and different types of safety hazards.

11.3.12 Sound Management of Chemicals

The toolkit 'Innovative Approaches for the Sound Management of Chemicals and Chemical Waste' (IAMC) is aimed at the chemical industry and consultants of the chemical industry. It provides practical tools, techniques, and documentation to improve the Sound Management of Chemicals across a company's products' value chain and addresses SSbD-relevant aspects such as Green Chemistry, chemical process improvements, and hazard management.

11.3.13 Sustainable Chemistry

One of the Chemists for Future (CF4) projects aims to embed sustainability in university chemistry education. To this end, experts have been brought together in an online lecture series. The first lecture in this series was given by Professor Dr. Klaus Kümmerer from Leuphana University on the topic 'From Green to Sustainable Chemistry'. The lecture is available on the C4F YouTube channel.

ISC3 offers a training database with on-demand trainings and self-paced online learning offerings that focusses on Sustainable Chemistry-related topic, e.g., Sustainable Chemistry and Human Rights.

11.3.14 Sustainable Development Goals

Resources for students on sustainable development and the SDGs can be found on the UN SDG website. The resources provided are specifically designed to engage and educate

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students at school, for example through the story of 'Frieda makes a difference' and the 'Go Goals' game.

The website UN SDG:Learn offers a wide range of free online courses connected to specific SDGs. Some examples are 'Human Rights, Human Wrongs: Challenging Poverty, Vulnerability and Social Exclusion' (contributing to SDGs 5 and 16), 'Introduction to Corporate Social Responsibility' (contributing to SDGs 4, 8, and 9), 'Industrial Policies for a Circular Economy' (contributing to SDGs 7, 9, 12, and 13), 'Transforming Economies for Sustainable Development' (contributing to SDGs 8, 13, and 17), or 'Introduction to Green Economy' (contributing to SDG 8).

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