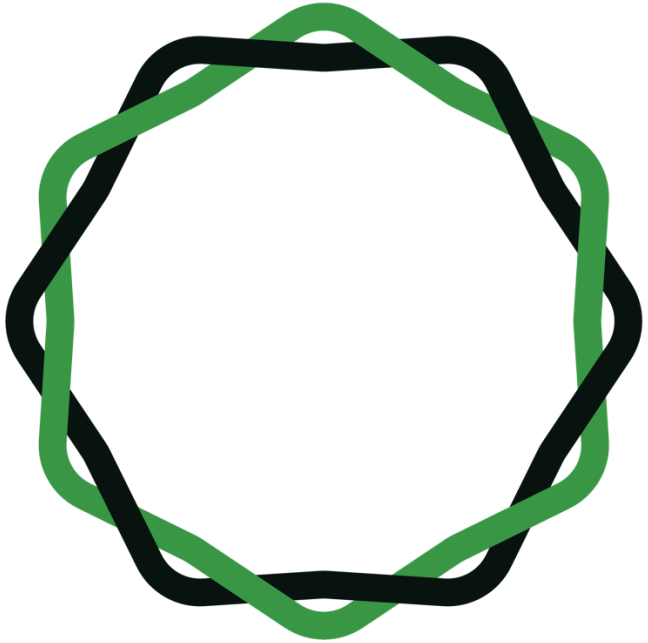

Safe and Sustainable by Design

Green Chemistry Change Management

Tabitha Petchey
Green Rose Chemistry
18 Sep 2024

About Green Rose Chemistry

Green chemistry expertise for every industry

- Independent sustainable chemistry R&D services
- Fast, targeted research and partnering
- Replacing chemicals with safer or bio-based alternatives
- Chemical database, computational tools, market knowledge
- Connections with emerging and established companies

MEET OUR TEAM

CEO & Founder

ANNA ZHENOVA

Scientific Advisor

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MARY AIKEN-WOOD

Associate Consultant

LEENA SCOTT

Agenda

- What is SSbD?
  - EU Context
  - Definitions
  - Motivation
- Putting SSbD into practice
- Conclusions and Further Reading

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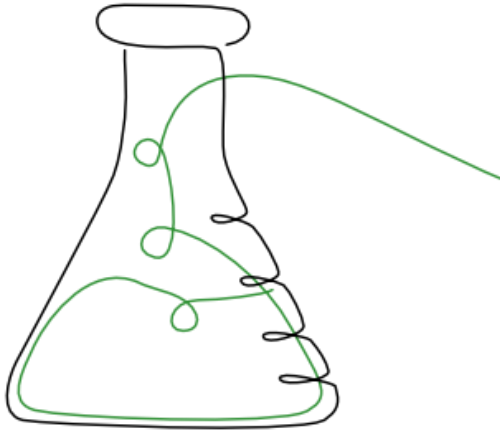
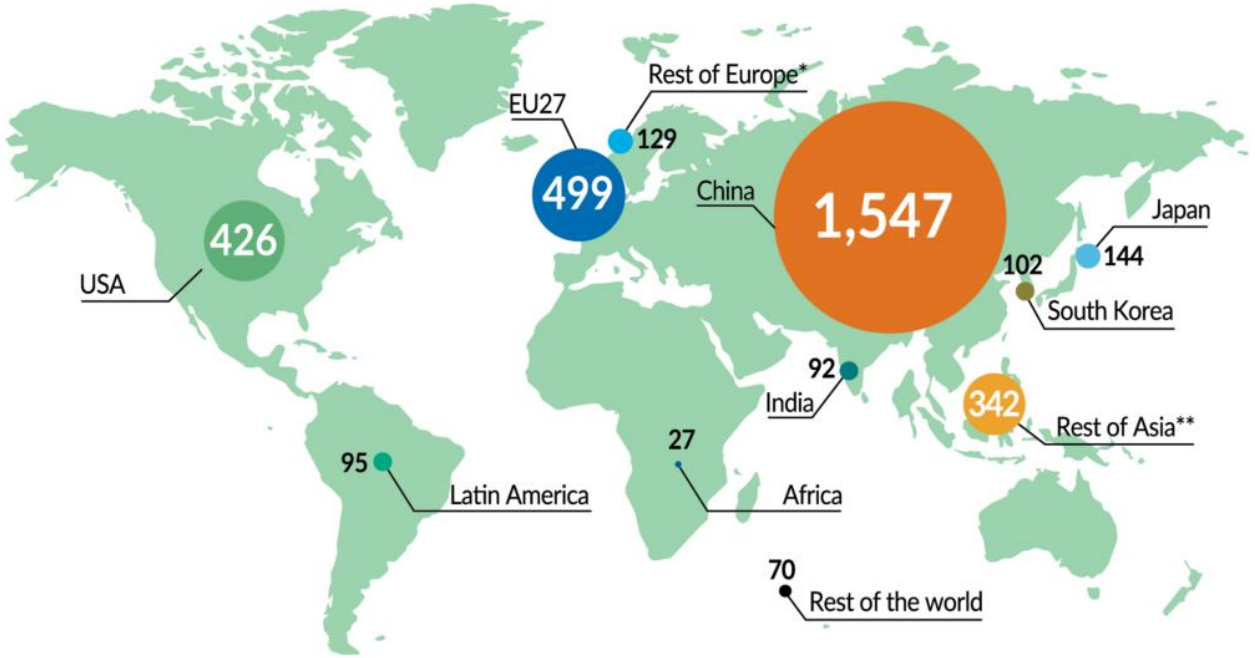
What is SSbD?

EU Context



EU Chemical Industry

Chemical Sales (2020, EUR Billion)



Source: Cefic Chemdata International
* Rest of Europe covers UK, Switzerland, Norway, Turkey, Russia and Ukraine
** Asia excluding China, India, Japan and South Korea

- 4th largest industry in the EU
- 30,000 companies
- 95% of companies are SMEs
- 1.2M people directly employed

Hazardous Chemicals

- Growing concerns about chemical impact on humans and environment
- Presence of hazardous chemicals in our bodies and bloodstreams
- Reduced foetal growth and lower birth rates
- 84% of Europeans are worried about chemical impact on human health, 90% about environmental impact

chemsec
INTERNATIONAL CHEMICAL SECRETARIAT

OCTOBER 3, 2022

We tested our blood for PFAS and this is what we found out

At ChemSec, we knew that we would all have PFAS in our bodies. What we didn't know was how much. A couple of weeks ago, twelve of us sent blood samples to a laboratory that would help us find out. Now, the results are in.

The Guardian

Microplastics found in human blood for first time

SCIENTIFIC AMERICAN®

Polar Bear Cubs at High Risk from Toxic Industrial Chemicals, Despite Bans

Levels in young animals elevated to 1,000 times the acceptable amount in people

Chemicals Strategy for Sustainability

- Released in 2020, following European Green Deal
- Replaces 2001 Strategy for a future Chemicals Policy
- Introduces SSbD concept
- Other tenets include chemical innovation, safe material cycles, greening and digitalising production, supply chain resilience, stronger legislation, international leadership

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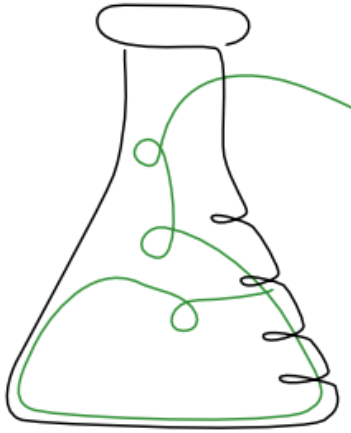
What is SSbD?

Definitions



SSbD Approach

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

SSbD Approach

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Safety

the absence of unacceptable risk for humans and the environment

preferably ensured by avoiding chemicals and materials with intrinsic hazard properties

Sustainability

ability of a chemical/material to deliver its function

without exceeding environmental and ecological boundaries along its entire life cycle

while providing welfare, socio-economic benefits and reducing externalities

(Planetary Boundaries)

environmental and ecological boundaries depicted as 9 planetary boundaries

6/9 already exceeded

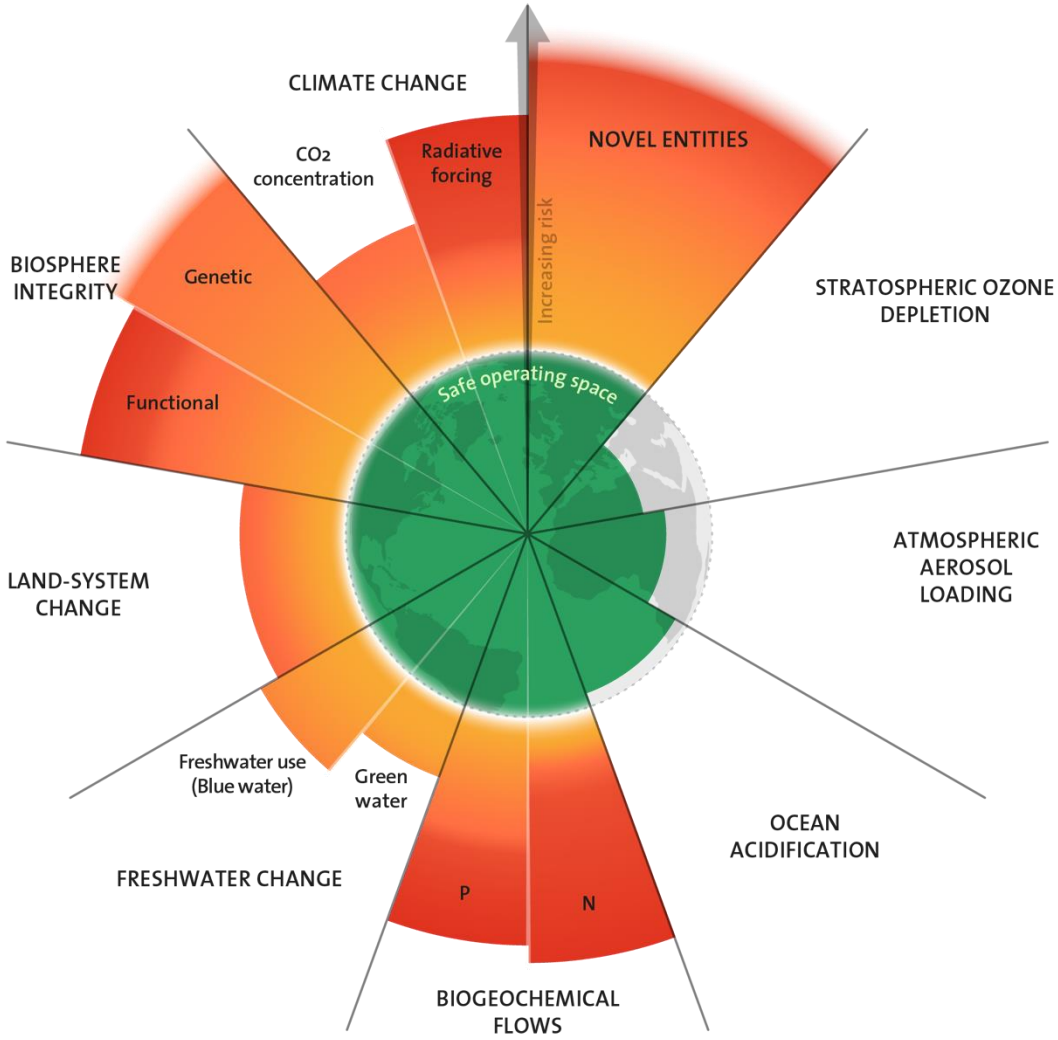
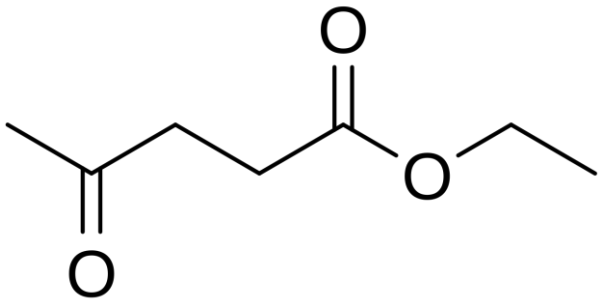


Image credit: Azote for Stockholm Resilience Centre, based on analysis in Richardson et al 2023

By Design

Molecular Design



New substances at the molecular level

Process Design

New or improved processes for chemical production

Product Design

Design of a chemical-containing product that will be used by workers or consumers

Related Concepts

- green chemistry
- green engineering
- sustainable chemistry
- circular chemistry
- safe by design
- circular economy
- bioeconomy
- zero pollution
- alternatives assessment
- life cycle thinking
- sustainable innovation
- responsible research & innovation

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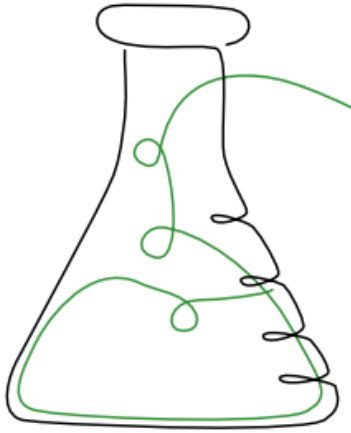
What is SSbD?

Motivation



Motivation

- Address growing concerns about chemical impact on human health and environment
- Building in safety and sustainability at design phase is more effective and efficient
- Saves time and money and achieves better outcomes
- Opportunity for EU chemical industry to regain global competitiveness

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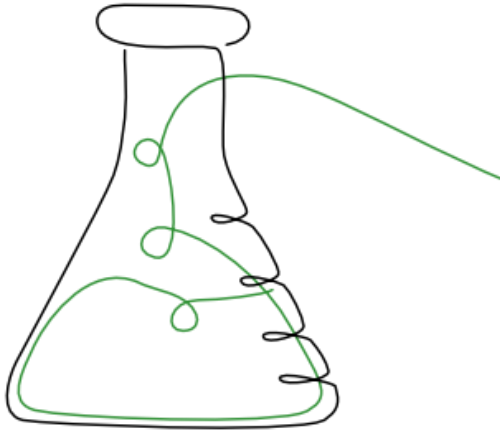
SSbD in Practice



Reduced carbon footprint in production; enabling renewable products and GHG savings downstream; biobased products; renewable energy

Water, soil, carbon sinks; water treatment potential; land use; abiotatic depletion potential; eutrophication potential

Pollution prevention and control; emissions to air, water & soil

Biodegradability or compatibility of products; waste prevention in the production and use phase; support of recycling opportunities in the value chain; use of recycled materials & feedstock; Recyclability, durability, repairability of the product

Reduced water footprint; Raw material scarcity; Enabling downstream resource savings; Use of competing renewable raw materials

Human toxicity; environmental toxicity; abiotic depletion; acidification; eutrophication; ozone layer depletion; photochemical oxidation potential, …

Occupational health risks; H&S of local community' s living conditions; safety management at work; management of workers' individual health; product safety; impact on consumer health

Fair wages; appropriate working hours; no forced labor, human trafficking and slavery; no discrimination; social/employer security and benefits; access to basic needs; respect for human rights and dignity

Skills, knowledge and employability; promotion of skills and knowledge for local community and consumers

Management of reorganization; job creation

Job satisfaction; work-life balance; access to tangible resources; nuisance reduction; community engagement; responsible communication; consumer' s product experience

Source: CEFIC SSbD Guidance

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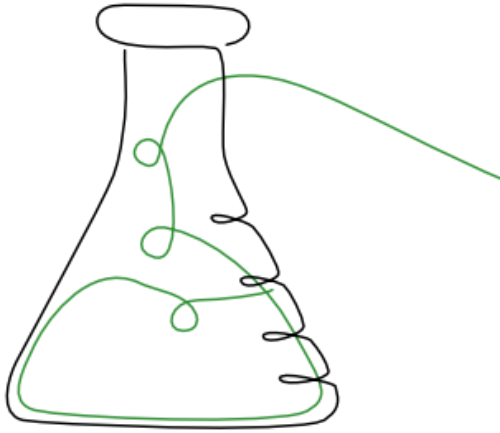
SSbD in Practice

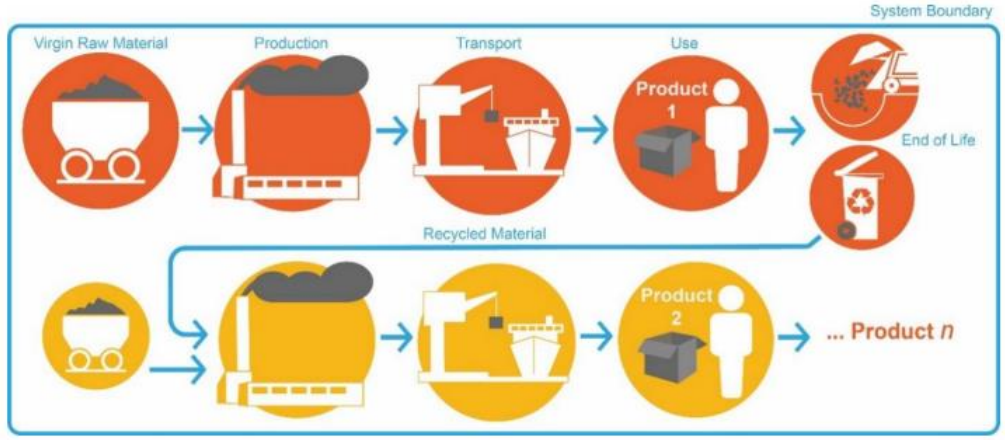
Step by Step



Step 1 – Chemical Hazard Assessment

- Intrinsic hazard properties of the chemical or material
- Aiming for inherent safety as far as possible
- Especially important in circular chemical economy
  - Recycling of hazardous chemicals can change exposure levels

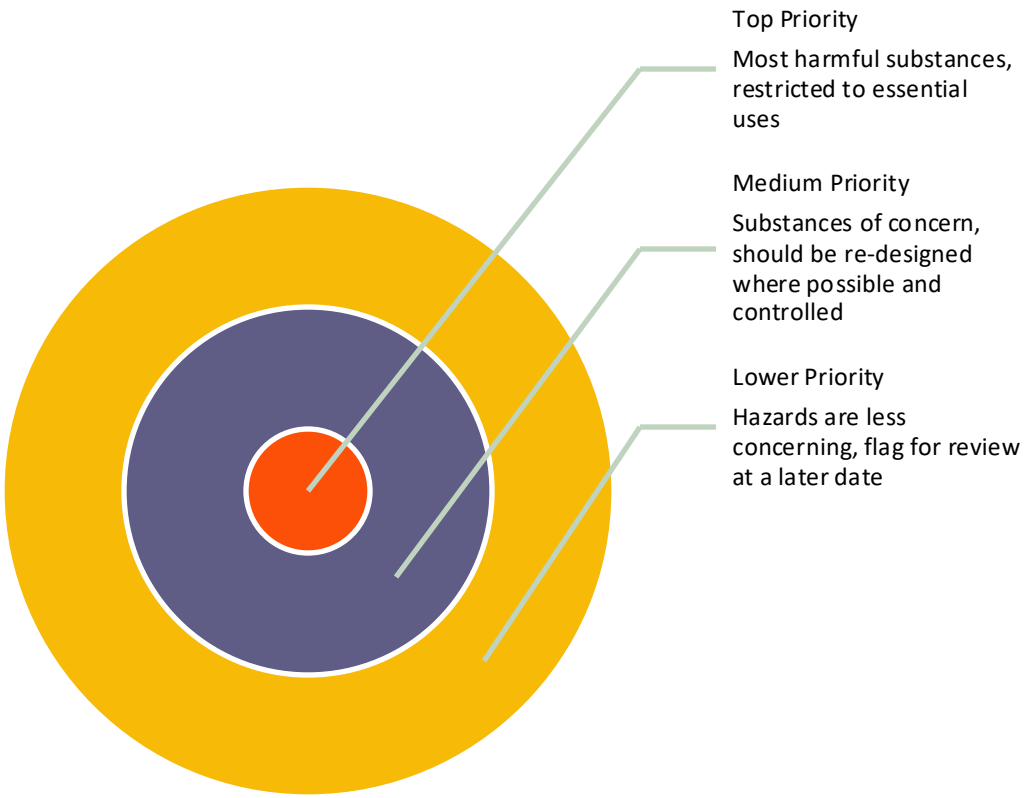
Figure 3: Expanding the LCA System Boundary for Material Circularity



Source: Eunomia, *Chemical Recycling: State of Play*, 2020

Step 1 – Chemical Hazard Assessment

- Adopt a tiered approach for gathering data
  - Screen for promising candidates via models, read-across, etc.
- Prioritise by severity of hazard



Step 1 – Chemical Hazard Assessment

	Group definition	Human health hazards	Environmental hazards	Physical hazards
Top Priority Essential uses only	Includes the most harmful substances (according to CSS (EC, 2020a)), including the substances of very high concern (SVHC) according to REACH Art. 57(a-f)[20],[21] (EU, 2006). These hazard properties form Criterion H1.	• Carcinogenicity Cat. 1A and 1B • Germ cell mutagenicity Cat. 1A and 1B • Reproductive / developmental toxicity Cat. 1A and 1B • Endocrine disruption Cat. 1 (human health) • Respiratory sensitisation Cat 1 • Specific target organ toxicity - repeated exposure (STOT-RE) Cat. 1, including immunotoxicity and neurotoxicity	• Persistent, bioaccumulative and toxic / very persistent and very bioaccumulative (PBT/vPvB) • Persistent, mobile and toxic / very persistent and mobile (PMT/vPvM) • Endocrine disruption Cat. 1 (environment)	
Medium Priority Re-design & control	Includes substances of concern, as described in CSS (EC, 2020a), defined in the Article 2(28) of SPI proposal (EC, 2022b)[22] and that are not already included in Criterion H1. These hazard properties form Criterion H2.	• Skin sensitisation Cat 1 • Carcinogenicity Cat. 2 • Germ cell mutagenicity Cat. 2 • Reproductive / developmental toxicity Cat. 2 • Specific target organ toxicity - repeated exposure (STOT-RE) Cat. 2 • Specific target organ toxicity - single exposure (STOT-SE) Cat. 1 and 2 • Endocrine disruption Cat. 2 (human health)	• Hazardous for the ozone layer • Chronic environmental toxicity (chronic aquatic toxicity) • Endocrine disruption Cat. 2 (environment)	
Lower Priority Flag for review	Includes the other hazard classes not part already in Criteria H1 and H2. These hazard properties form Criterion H3.	• Acute toxicity • Skin corrosion • Skin irritation • Serious eye damage/eye irritation • Aspiration hazard (Cat. 1) • Specific target organ toxicity - single exposure (STOT-SE) Cat. 3	• Acute environmental toxicity (acute aquatic toxicity)	• Explosives • Flammable gases, liquids and solids • Aerosols • Oxidising gases, liquids, solids • Gases under pressure • Self-reactive • Pyrophoric liquids, solid • Self-heating • In contact with water emits flammable gas • Organic peroxides • Corrosivity • Desensitised explosives

Source: JRC SSbD Framework

Step 2 – Risks of Production/Disposal

- Occupational health and safety (OSH) excluding use phase
- Identify chemicals used and produced during all production and processing steps
  - Recycling or waste treatment should be considered as well
- Combine with operational conditions, potential for chemical release, and risk management measures to assess likelihood of exposure, and route

Step 2 – Risks of Production/Disposal

Example scoring system for OSH risk

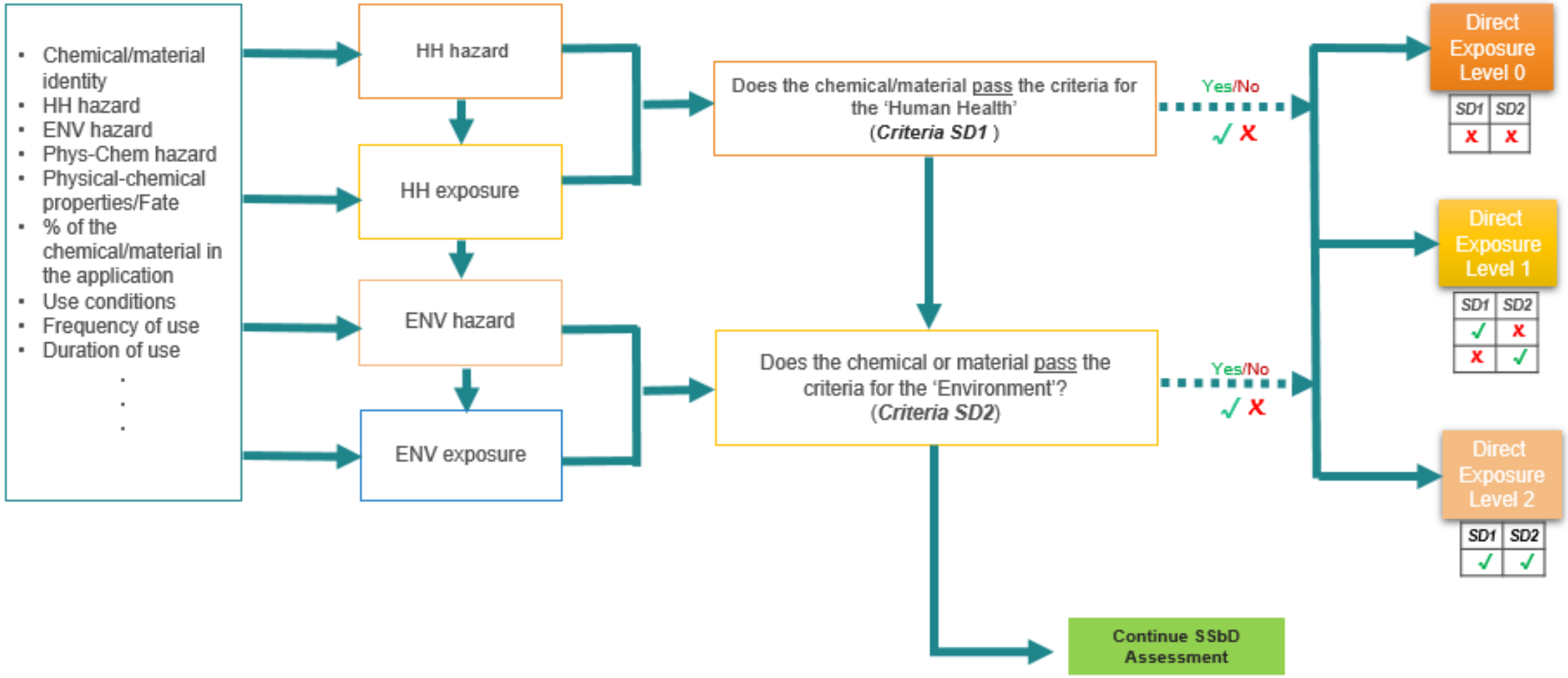
Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Safety	
4	4	5	5	5	21-25	Negligible risk
3	3	4	4	5	16-20	Low-risk
1	2	3	3	4	11-15	Medium-risk
1	1	2	2	3	6-10	High-risk
1	1	1	1	1	0-5	Very high risk

Source: JRC SSbD Framework

Step 3 – Risks of Product Use

- Human and environmental health risks from application
- Chemical hazards combined with exposure during use
- Hazards from Step 1, plus physicochemical properties
  - Physical form
  - Vapour pressure
  - Water solubility
  - Octanol-water partition coefficient

Step 3 – Risks of Product Use

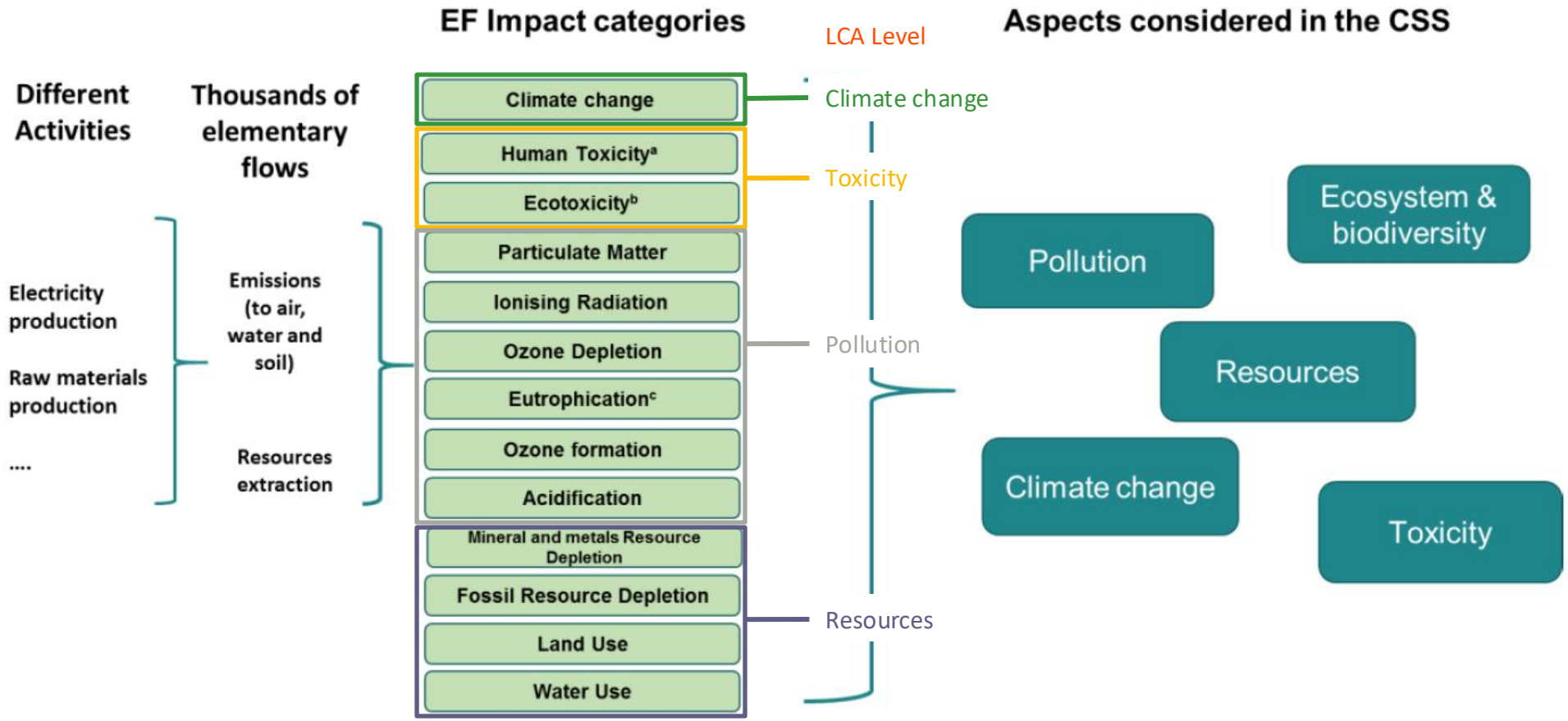


Source: JRC SSbD Framework

Step 4 – Environmental Sustainability

- Function-based sustainability assessment over entire lifecycle
  - If different uses or production routes are possible, need an LCA for each
- Specific SSbD LCA guidance yet to be developed
  - See Product Environmental Footprint method (based on ISO 14040/14044)
- 16 recommended impact categories
  - Criteria should be defined as % reduction in a category relative to ref. value
  - Proposed reductions – 90% (Factor 10) or 50% (EU climate change policy)
- Eventually need to set science-based targets for absolute sustainability within planetary boundaries

Step 4 – Environmental Sustainability



[a] two impact categories: cancer and non-cancer; [b] freshwater; [c] three impact categories: terrestrial, freshwater, and marine eutrophication

Source: JRC SSbD Framework

Step 5 – Socio-economic Sustainability

- Concept needs further development
- Social sustainability: protect rights of individuals and communities, while maximising benefits for society as a whole
  - Assess how operations affect workers, local community, and consumers
  - Look at own operations as well as supply chain
- Economic sustainability: controversial
  - Is continued economic growth compatible with a sustainable planet?
  - Externalities must be quantified through monetisation
  - One approach is life cycle costing (LCC)

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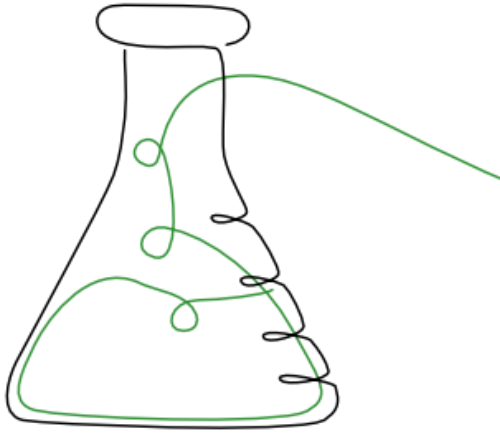
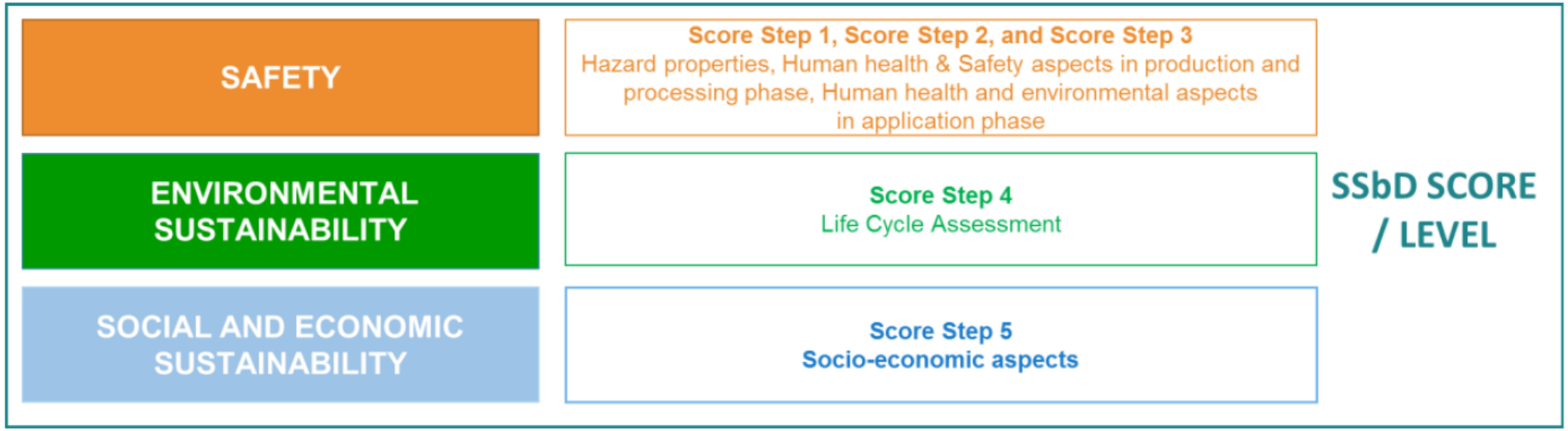
SSbD in Practice

Putting It All Together



Multi-Criteria Decision Analysis (MCDA)

- Aggregation of different aspects of SSbD is challenging
- MCDA studies decision-making involving multiple evaluation dimensions
- Multiple methods exist and will be evaluated by the EC in future



Source: JRC SSbD Framework

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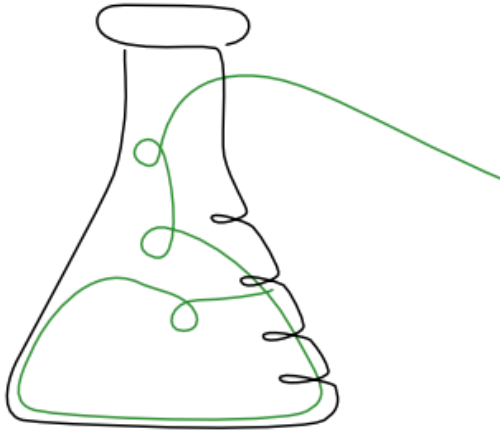
Conclusions



To sum up…

- SSbD is an ambitious concept to transform the EU chemical industry and create a toxic-free environment
- Goes beyond green chemistry principles and considers complete picture of sustainability
- Framework and tools are still under development
- Start by minimising intrinsic hazards and work your way up to multi-impact LCA and socio-economic assessment

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Further Reading

- 2020 EU Chemicals Strategy for Sustainability
  https://environment.ec.europa.eu/strategy/chemicals-strategy_en
- 2022 JRC Framework for SSbD Chemicals and Materials
  https://publications.jrc.ec.europa.eu/repository/handle/JRC128591
- 2022 CEFIC SSbD Guidance
  https://cefic.org/a-solution-provider-for-sustainability/safe-and-sustainable-by-design/

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Questions?

Contact Tabitha Petchey at tabitha.petchey@greenrosechemistry.com.