An EU policy perspective on the integration of sustainability considerations in LCA

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European Commission, Joint Research Centre (JRC)

Wadenswil, 22 November 2024

DF LCA Forum 88

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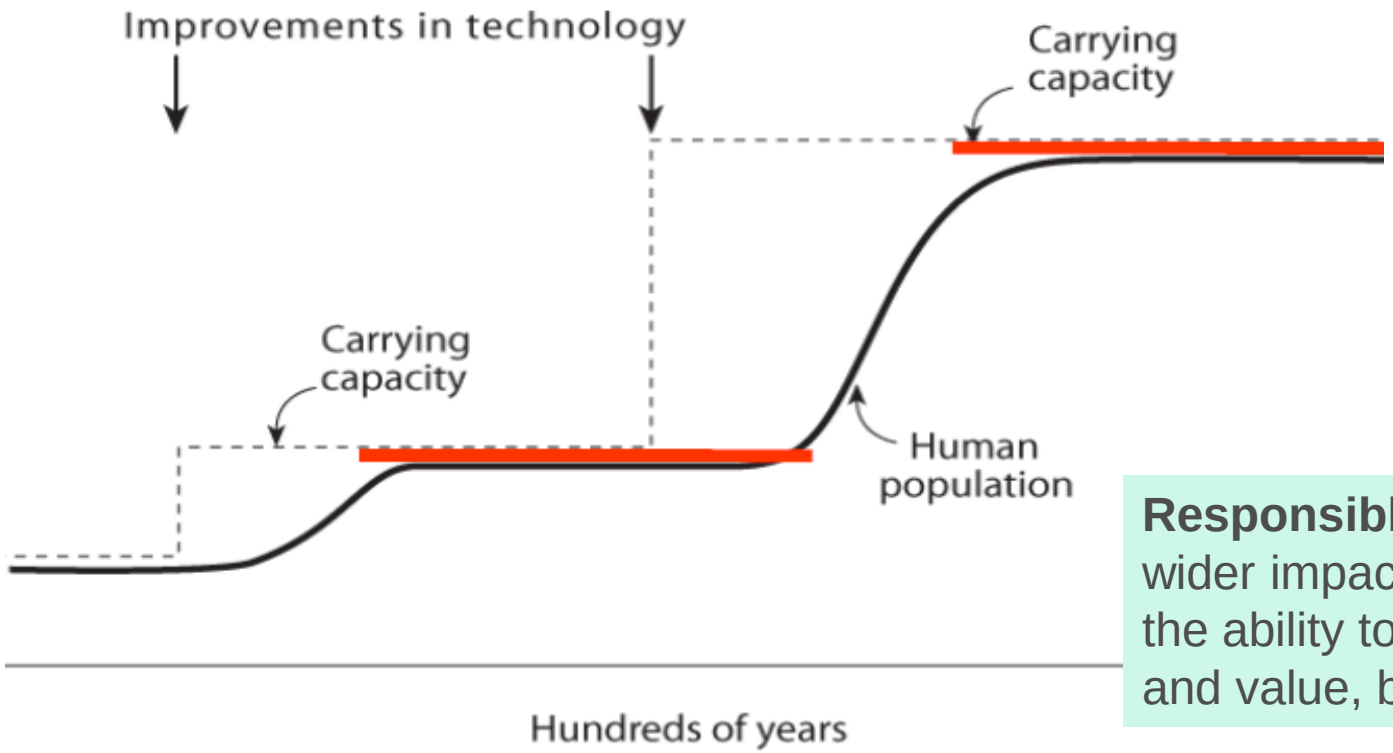
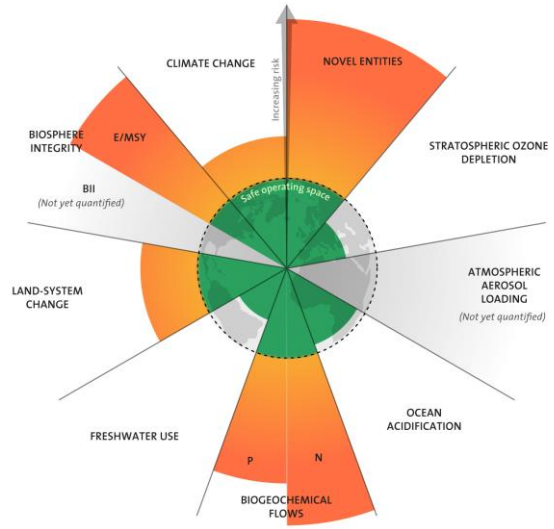
In the Anthropocene, we change the world faster than we understand it



Vitousek. Human domination on Earth Ecosystems



Designed by Azote for Stockholm Resilience Centre, based on analysis in Persson et al 2022 and Steffen et al 2015

Responsible Research Innovation (RRI) refers to the wider impacts of science and innovation. Research has the ability to not only produce understanding, knowledge and value, but also unintended consequences

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SUSTAINABLE BY DESIGN

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TECHNOLOGY

Google Scientists Discovered 380,000 New Materials Using Artificial Intelligence

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The Materials Project, an open-access database for new materials, is revolutionizing how researchers discover and develop materials for future technologies, with Google DeepMind contributing 400,000 new compounds. This synergy of AI, supercomputing, and experimental data speeds up the creation of materials for applications like renewable energy, efficient electronics, and environmental solutions. (Artist's concept). Credit: SciTechDaily.com

The expansion of the open-access resource is instrumental for scientists in developing novel materials for future technologies.

New advancements in technology frequently necessitate the development of novel materials – and thanks to supercomputers and advanced simulations, researchers can bypass the time-consuming and often inefficient process of trial-and-error.

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New substances

New products

New materials

New services

New processes and tech

New infrastructures

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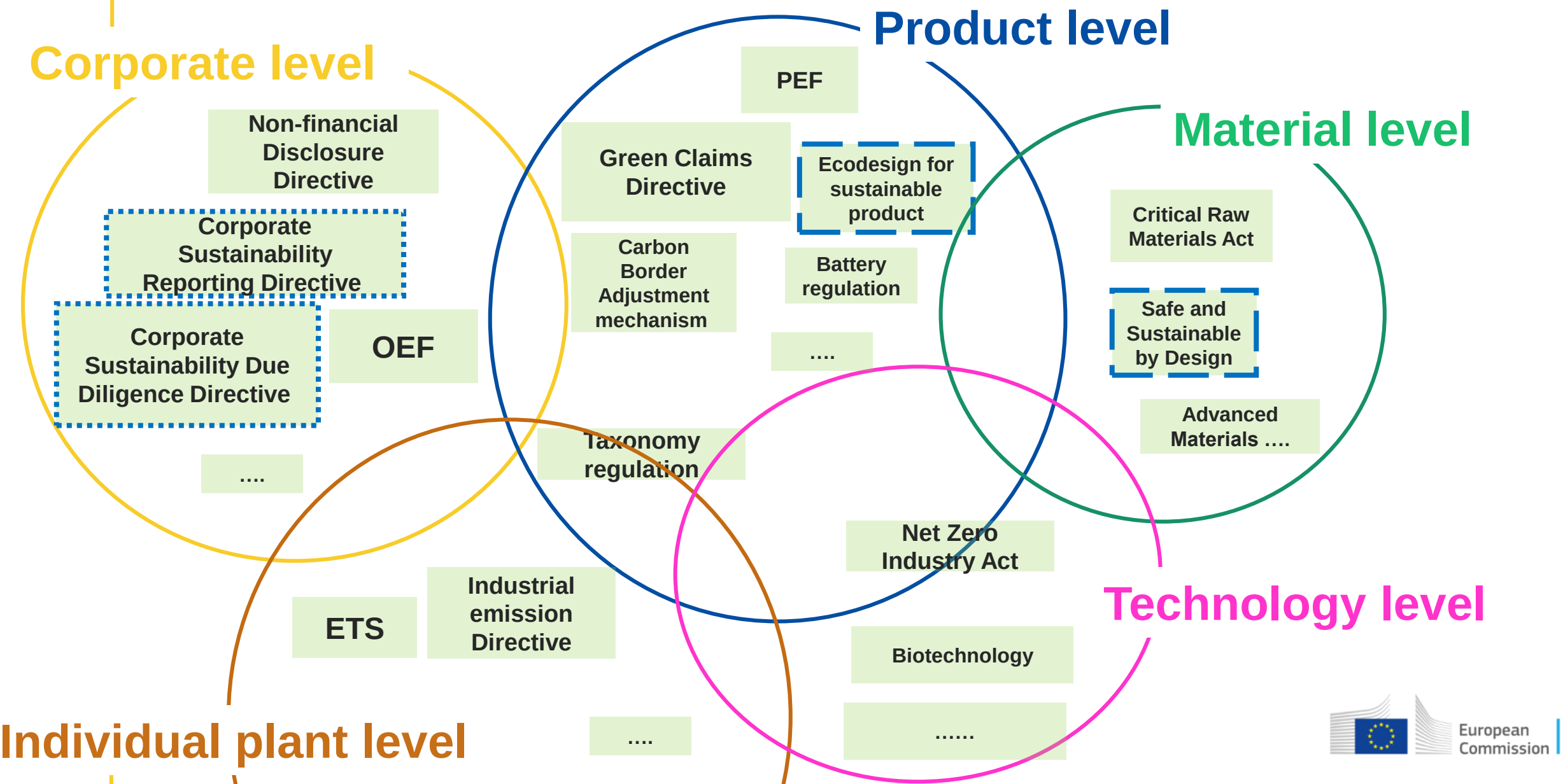
Policies acts at different levels



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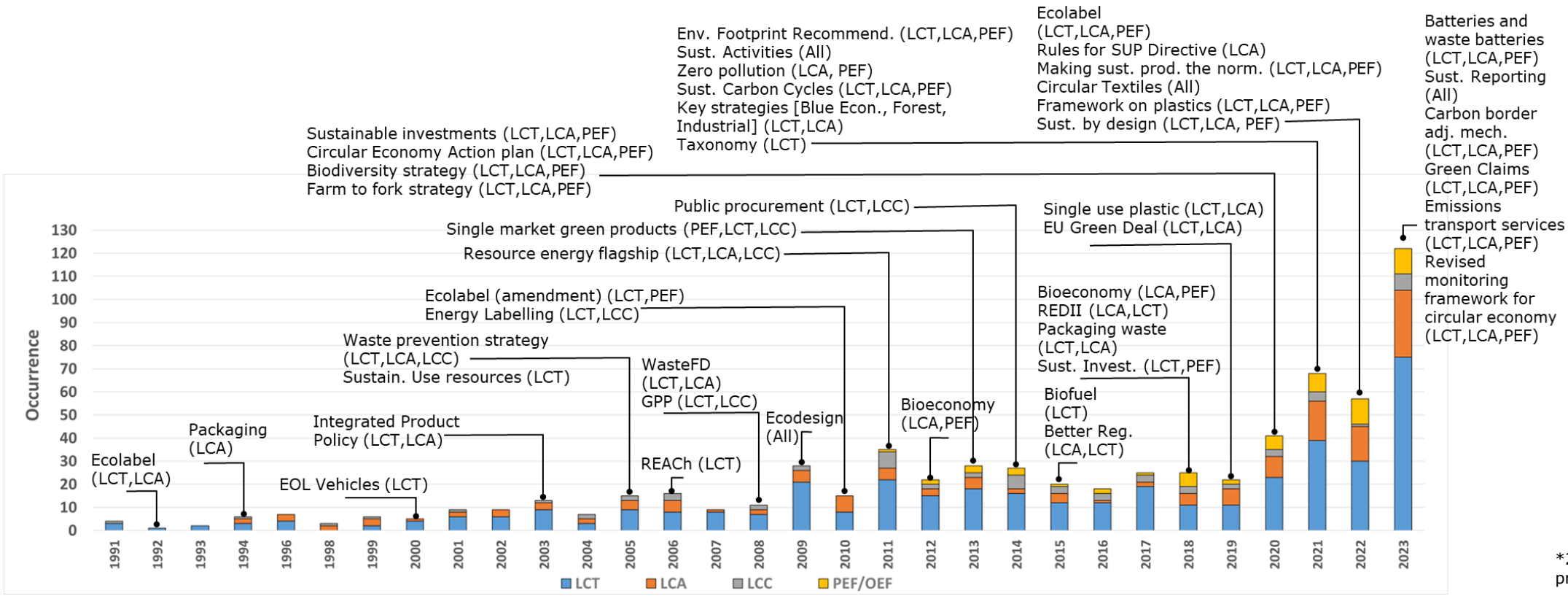
Evolution of LCA in EU policies over the last 30 years



*2024 updates in progress

Updated from Sala et al. (2021). The evolution of life cycle assessment in European policies over three decades. *The International Journal of Life Cycle Assessment*, 26, 2295-2314.

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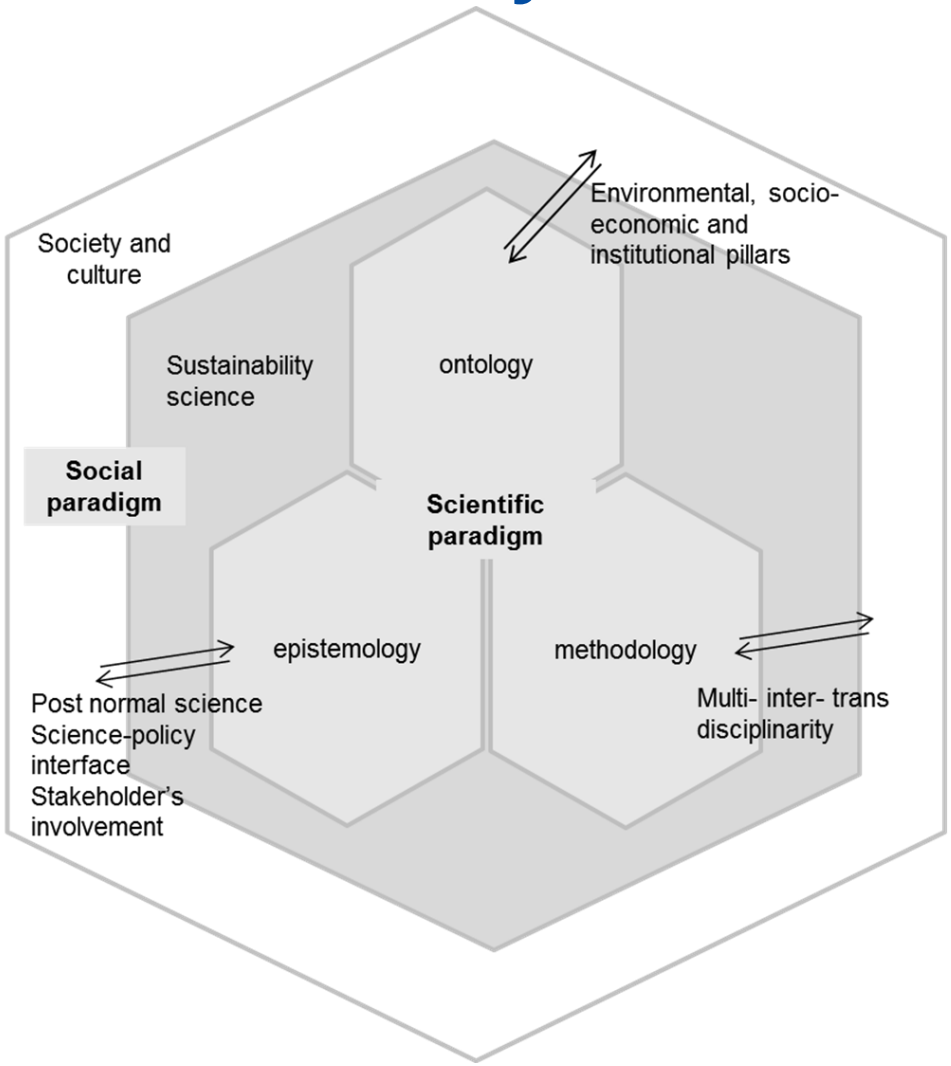
Sustainability science



- '**solution-oriented discipline** that studies the complex relationship between nature and humankind, conciliating
- the **scientific and social reference paradigms** which are mutually influenced- and covering multi temporal and spatial scales.
- The discipline implies a holistic approach, able to **capitalize and integrate sectorial knowledge as well as a variety of epistemic and normative stances** and methodologies towards **solutions' definition'**

Sala, S., Farioli, F., & Zamagni, A. (2013). Progress in sustainability science: lessons learnt from current methodologies for sustainability assessment: Part 1. *The international journal of life Cycle Assessment*, *18*, 1653-1672.

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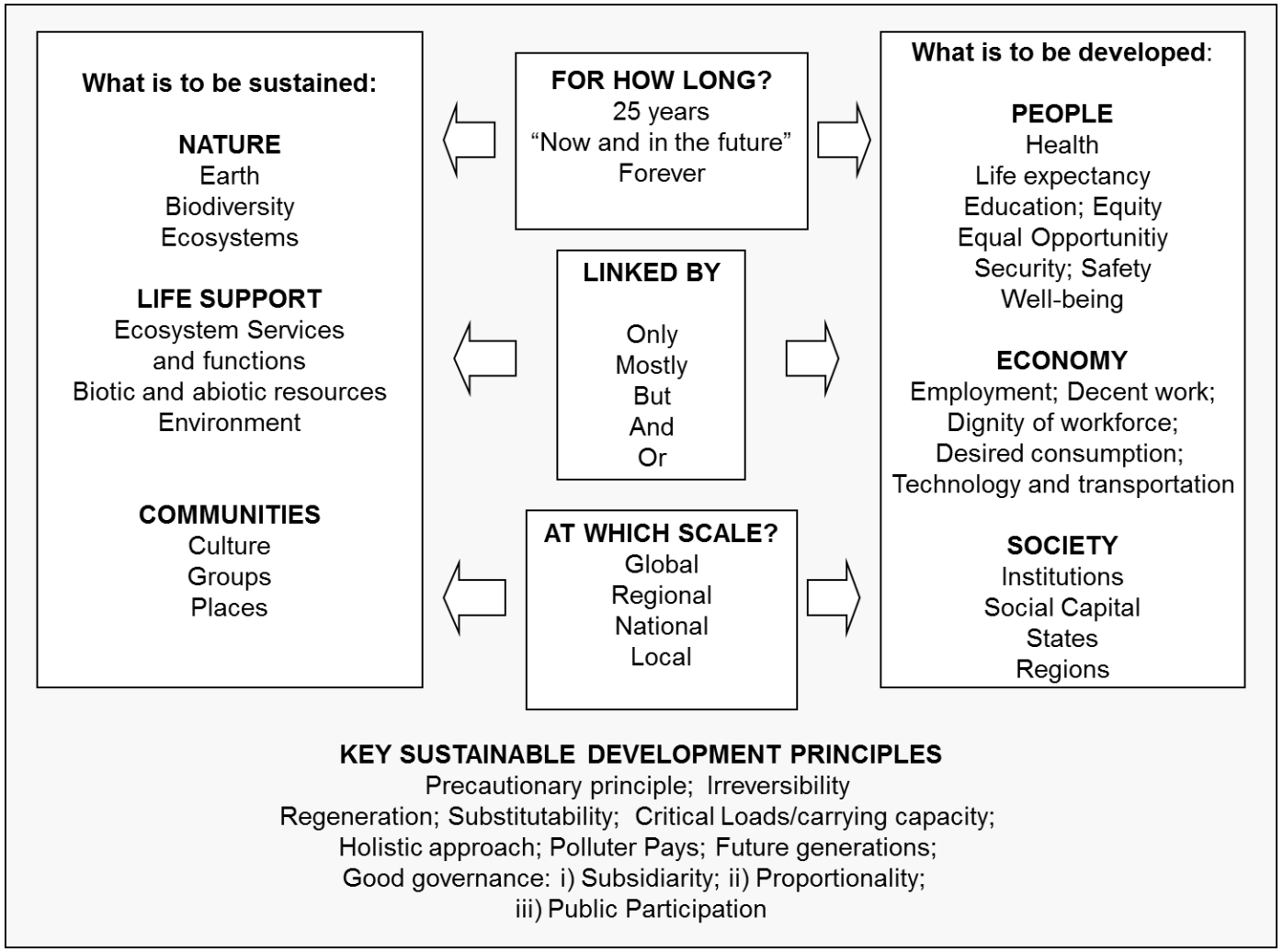
Back to the basic questions we would like to reply?



Contextual perspective in sustainability: from fairness to competitiveness

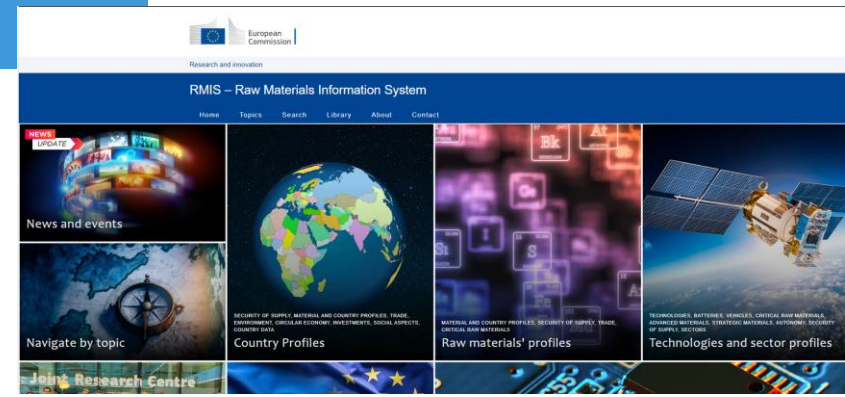
Critical for SPECIFIC SECTORS

Critical for OVERALL ECONOMY

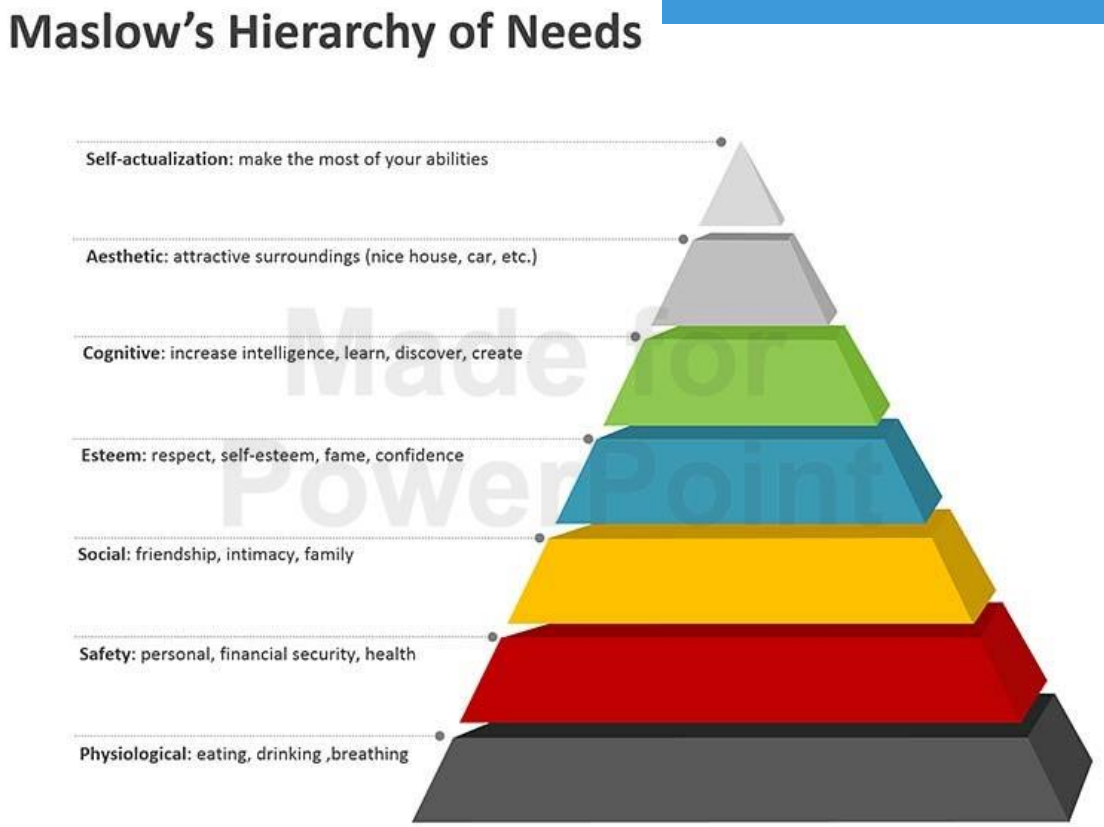
Critical for HUMAN BASIC NEEDS

Critical for LIFE SUPPORT

CRITICAL AND STRATEGIC RAW MATERIALS



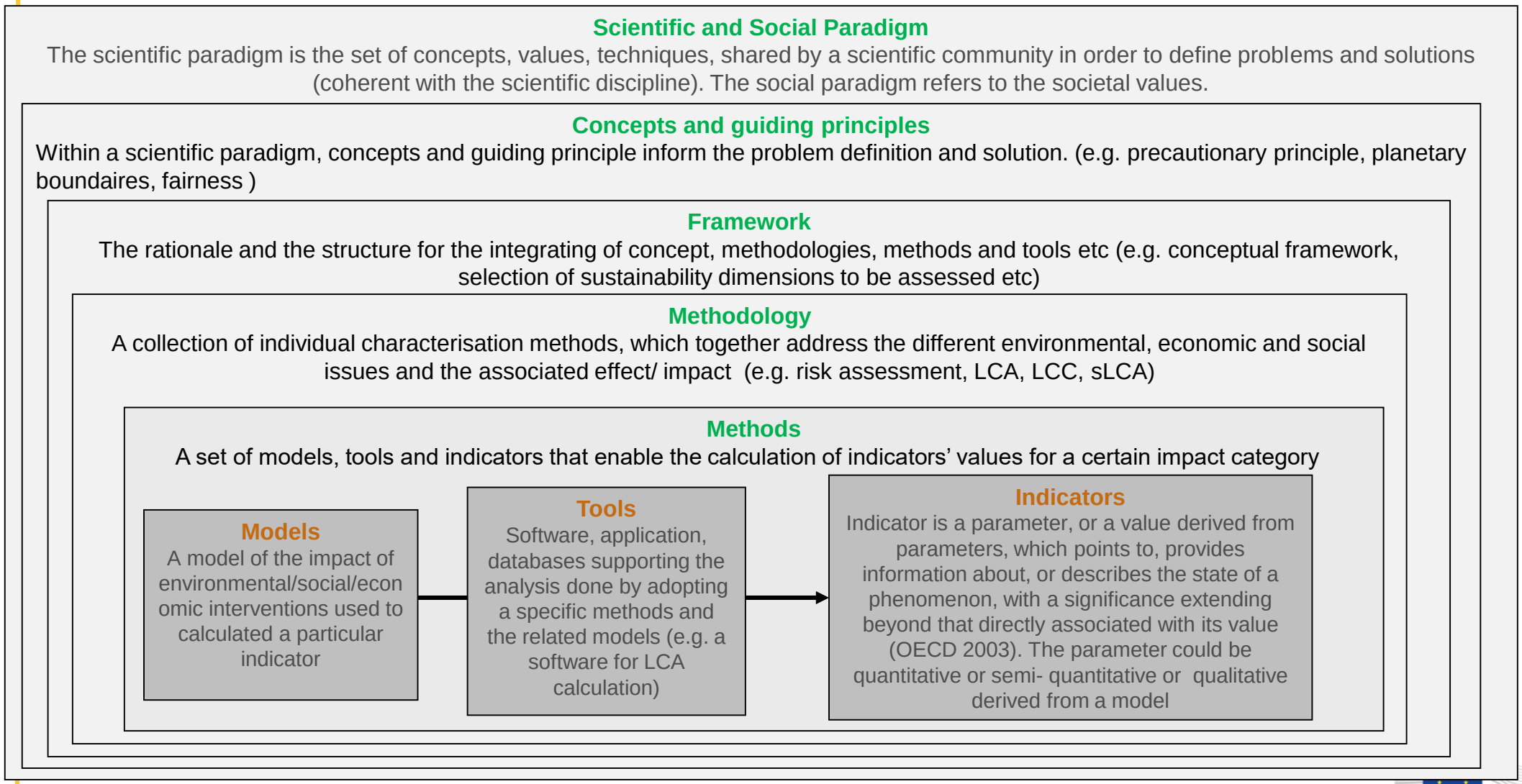
https://rmis.jrc.ec.europa.eu/



HUMAN AND ECOSYSTEMS LIFE SUPPORT

https://ecosystem-accounts.jrc.ec.europa.eu/

What is a framework for sustainability assessment?



Modified from: Sala S., et al (2013) Progress in sustainability science: lessons learnt from current methodologies for sustainability assessment (Part I). International Journal of Life cycle Assessment 18:1653-1672

Sustainable assessment frameworks for chemicals and materials

Green Chemistry

ROYAL SOCIETY OF CHEMISTRY

CRITICAL REVIEW

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Cite this: DOI: 10.1039/d3gc04598f

Safe and sustainable chemicals and materials: a review of sustainability assessment frameworks†

Carla Caldeira,‡ Elisabetta Abbate, Christian Moretti, Lucia Mancini and Serenella Sala *

In the context of the EU Chemicals Strategy for Sustainability, a key action regards the development of a framework to identify criteria for safe and sustainable by design chemicals and materials. The integration of safety and sustainability considerations is challenging, and this systematic review investigates how aspects pertaining to sustainability have been implemented in 155 frameworks proposed by scholars, industry, governments and non-governmental organizations. In particular, this review scrutinizes methods, models and indicators for environmental, social and economic aspects in frameworks combining multiple sustainability dimensions. Furthermore, the application of such frameworks to an early stage of chemicals and materials development was also analysed. The review unveiled that the majority of the frameworks are purely conceptual/theoretical, while some attempts are made by others towards providing

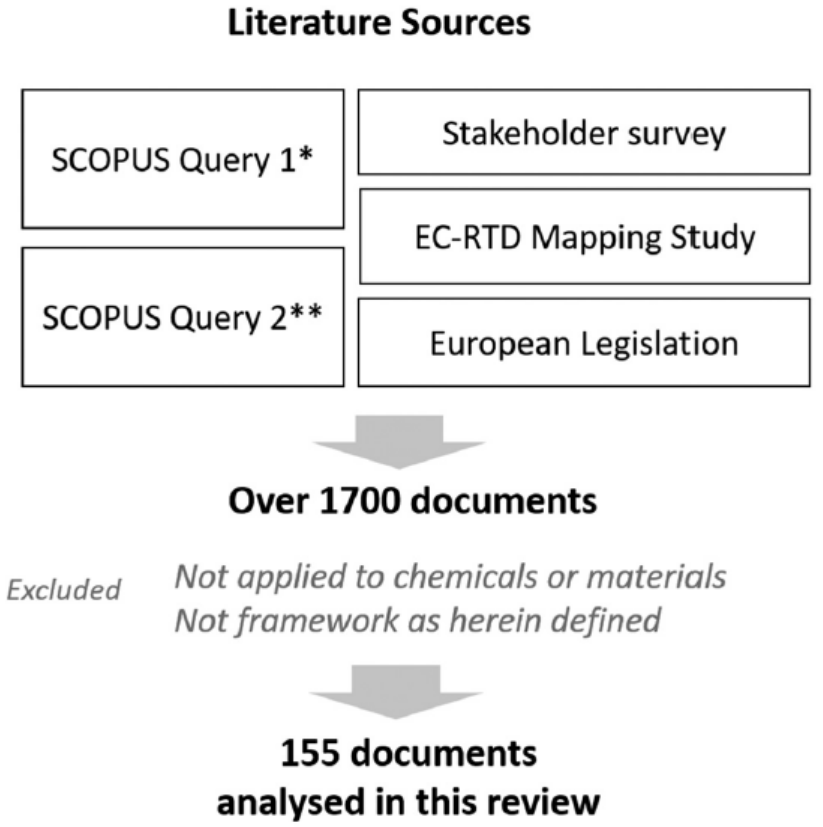

Fig. 1 Sources for the frameworks considered in this review. *as in Caldeira *et al.*[23] updated to May 2023. **new query considered for this review.

Caldeira, C., Abbate, E., Moretti, C., Mancini, L., & Sala, S. (2024). Safe and sustainable chemicals and materials: a review of sustainability assessment frameworks. *Green Chemistry*.26, 7456-7477

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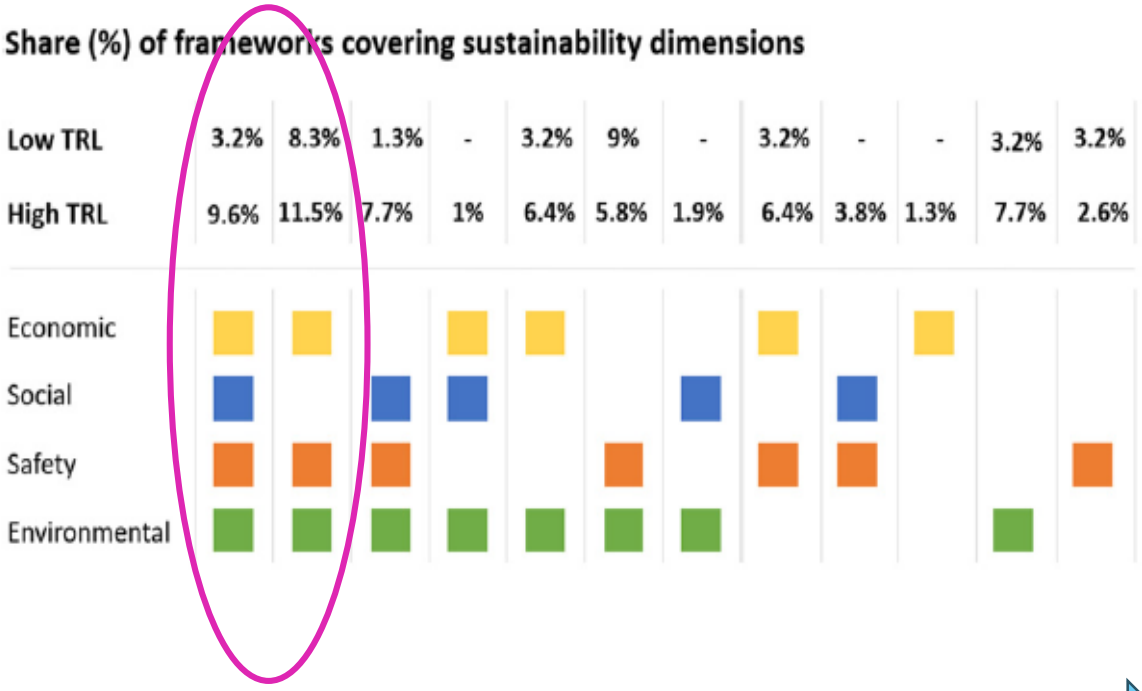
Evolution of safety and sustainability assessment for chemicals and materials



Scope of the application	Total of frameworks	Life cycle consideration	Early stage application	Decision procedure	Uncertainty
Chemicals	**89**	**59**	**35**	**48**	**12**
Drug	1			★ 1	
Energy carrier	1			★ 1	★ 1
Flame retardants	3	★ 2	★ 2	★ 1	
Fluorinated greenhouse gases (F-gases)	1	■ 1			
Fragrance	2	★ ▲ 2	★ 1	★ 1	
Fuels	8	★ 3	★ 2	★ 8	★ 3
Metals	1	★ 1		★ 1	★ 1
Polymers	1	★ 1		★ 1	
Precursor	2	★ 2	★ 2	★ 2	
Solvents	33	★ 16	★ 16	★ 18	★ 5
Surfactant	1	★ 1		★ 1	
Not specified	35	● ★ 30	● ★ 12	★ 13	◆ 2
Materials	**43**	**30**	**13**	**29**	**11**
Additive manufacturing	1	★ 1		★ 1	
Bioplastics	1	★ 1	★ 1		
Building materials	18	▲ ★ 11	★ 7	★ 17	★ 8
Carbon fiber	1	★ 1			
Composites	1	★ 1		1	
Nanomaterials	3	★ 5	★ 3	1	★ 1
Plastics	4	★ ▲ ● 5	★ 1	★ 1	
Protective membrane	1		★ 1	★ 1	★ 1
Textiles	4	▲ 1			
Vehicle (carrier)	2	★ 1		★ 2	
Not specified	6	★ 3		★ 5	★ 1
Products	**20**	**14**	**1**	**4**	**1**
Batteries	1	★ 1			
Chemical industry	1	★ 1		★ 1	
Cosmetics	1		★ 1	★ 1	
Electronics	2	▲ 2			
Energy	2	■ ★ 2			
Financial	1	■ 1			
IT	1				
Not specified	11	■ ◆ ● ▲ 7		● 2	● 1
Chemicals and materials	1	★ 1	★ 1		
Chemicals and products	1				
Materials and Products	1	▲ 1			

▲ Certification ● Guidance ■ Regulation ★ Scientific paper ◆ Tool

Caldeira, C., Abbate, E., Moretti, C., Mancini, L., & Sala, S. (2024). Safe and sustainable chemicals and materials: a review of sustainability assessment frameworks. *Green Chemistry*.26, 7456-7477

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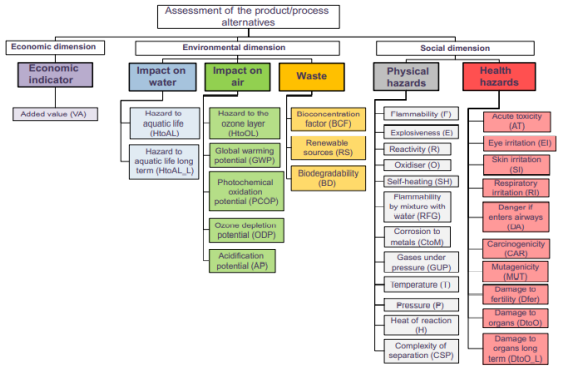
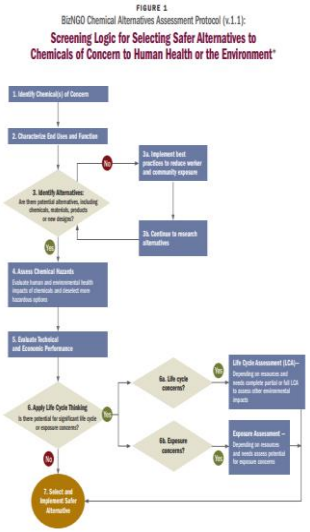
Conceptual and operational frameworks

Conceptual → Operational → Including criteria and scoring systems





SSG class	Solvent	Environ-mental - Waste	Environ-mental - Impact	Health	Safety	LCA ranking
Alcohols	Ethylene glycol	4	9	8	9	9
	1-Butanol	5	8	8	8	5
	Diethylene glycol butyl ether	5	7	10	9	7
	Isoamyl alcohol	7	7	7	8	6
	2-Ethylhexanol	9	6	8	7	6
	2-Butanol	4	7	7	7	6
	1-propanol	3	7	5	8	7
	Ethanol	3	8	10	7	9
	2-propanol	3	9	9	7	5
	t-butanol	3	10	7	7	8
	Methanol	3	10	5	8	9
Esters	t-butyl acetate	7	10	7	7	7
	Butyl Acetate	7	8	9	8	5
	n-Propyl acetate	6	7	8	7	5
	Isopropyl acetate	5	8	8	7	6
	Ethyl Acetate	4	8	8	4	6
	Methyl acetate	3	10	7	5	7
	Dimethyl carbonate	3	7	8	7	8
Aromatics	p-Xylene	8	2	7	5	7
	Toluene	7	3	6	4	7
	Fluorobenzene	4	2	4	5	1
Ketones	Methyl isobutyl ketone	7	6	6	7	2
	Acetone	3	9	8	5	3
	Methyl ethyl ketone	3	6	8	5	3
Polar Aprotics	N-Methyl-2-pyrrolidone	4	6	8	9	3
	dimethyl acetamide	4	7	2	10	3
	Dimethyl formamide	4	6	2	8	6
	Dimethylpropylene urea	5	7	5	9	4
	Dimethylsulphoxide	4	4	8	3	6
	Formamide	3	7	2	10	8
	Acetonitrile	3	6	6	8	4
Acids	Propionic acid	5	8	4	9	7
	Acetic acid	3	8	4	8	8
Alkanes	Cyclohexane	5	6	8	2	7
	Methyl cyclohexane	5	7	8	2	7
	Heptane	6	3	9	1	7
	2-Methylpentane	5	3	5	1	7

Caldeira, C., Abbate, E., Moretti, C., Mancini, L., & Sala, S. (2024). Safe and sustainable chemicals and materials: a review of sustainability assessment frameworks. *Green Chemistry*.26, 7456-7477

The SSBD framework structure

(RE) DESIGN PRINCIPLES

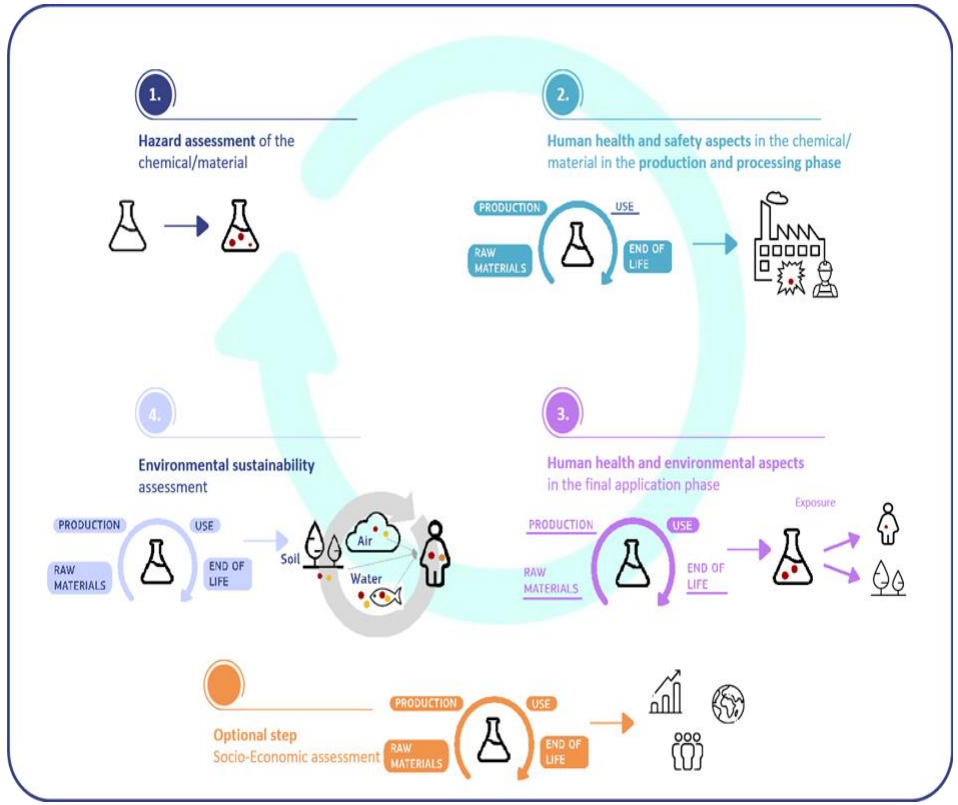
	SSBD principles
SSBD1	Material efficiency
SSBD2	Minimise the use of hazardous chemical/materials
SSBD3	Design for energy efficiency
SSBD4	Use renewable sources
SSBD5	Prevent and avoid hazardous emissions
SSBD6	Reduce exposure to hazardous substances
SSBD7	Design for end-of-life
SSBD8	Consider the whole life-cycle
SSBDX	**Others principles**

Molecular (Re)Design

Process (Re)Design

Product (Re)Design

SAFETY and SUSTAINABILITY ASSESSMENT



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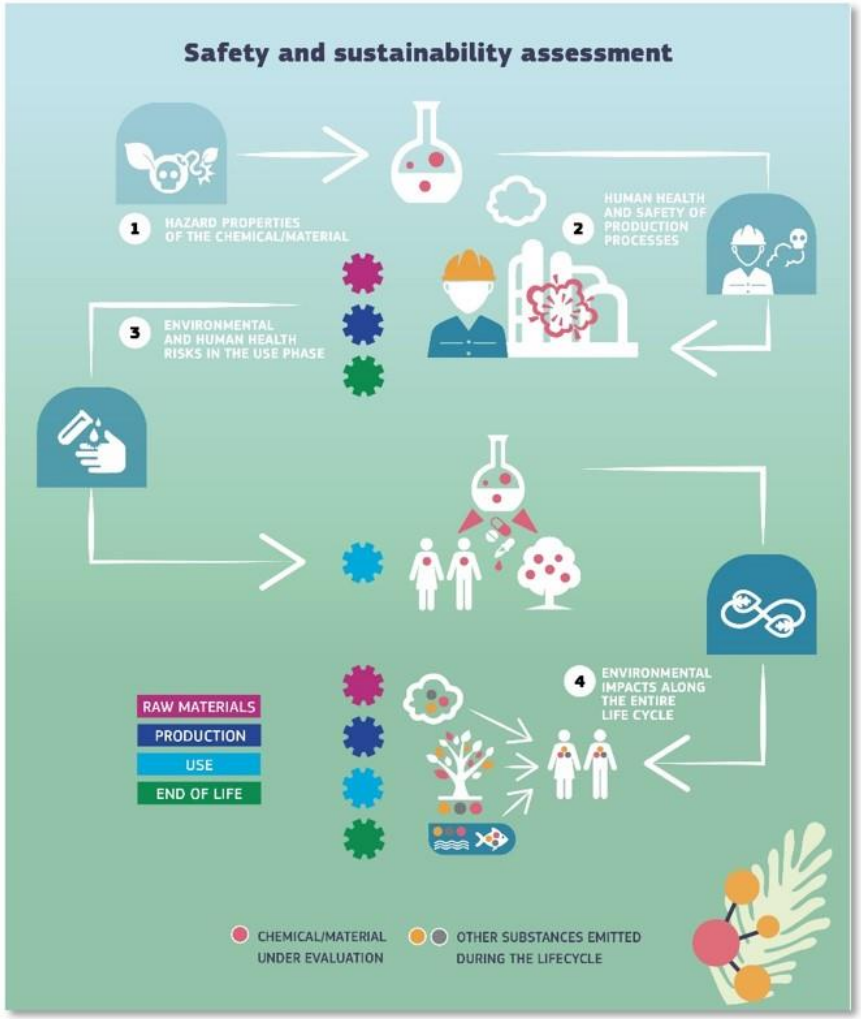
SSbD framework: the life cycle perspective and the assessment



The safety and sustainability assessment follows the life cycle:

- **Step 1** - Hazard assessment of the **chemical/material**
- **Step 2** - Human health and safety aspects in the chemical/material **production and processing** phase
- **Step 3** - Human health and environmental aspects in the final **application phase**
- **Step 4** - Environmental sustainability
- **Step 5** - Socio-economic sustainability

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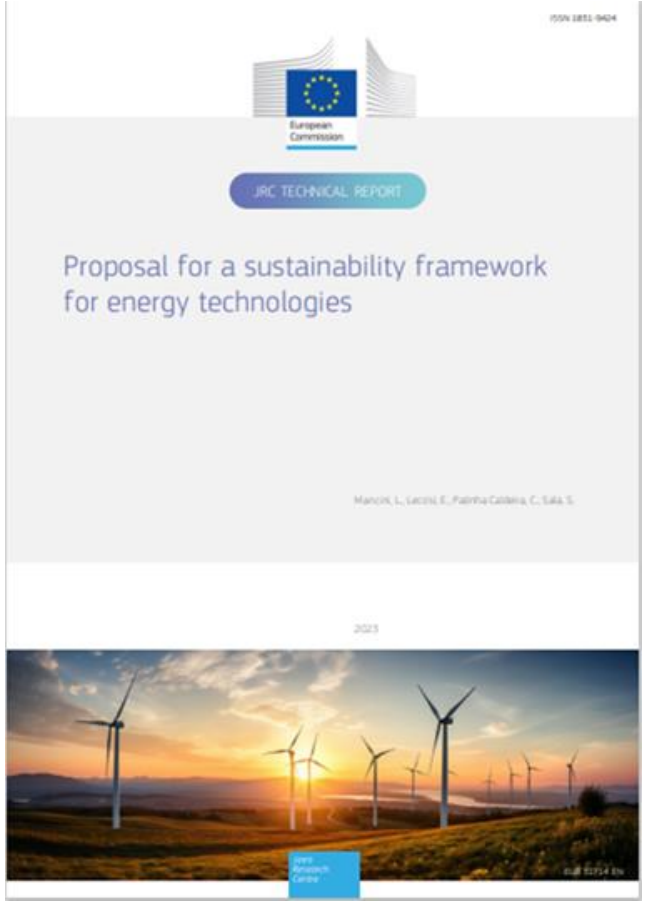
Sustainability Assessment Framework

- **Scope of the framework**: provide a coherent and holistic structure for the sustainability assessment of energy technologies
- Support to the Clean Energy Technologies Observatory (CETO) in the assessment of technologies
- Based on the Safe and Sustainable by Design framework
-



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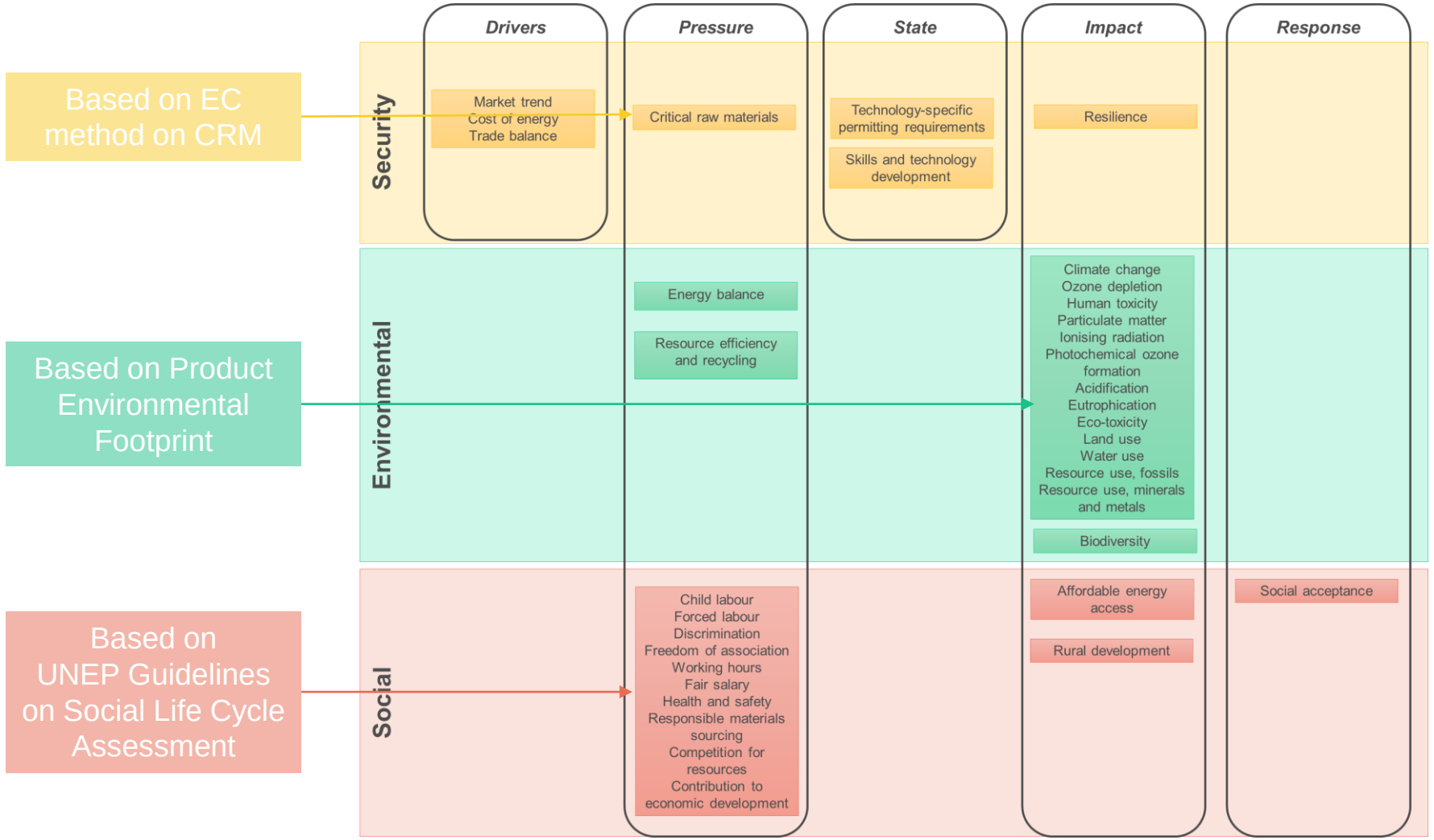
Sustainability Assessment Framework

- Identification of:
  - Sustainability aspects
  - Methods
  - Indicators
  - Data sources
- Driver-Pressure-State-Impact-Response framework
- Uptake from existing Life Cycle-based methodologies
- Integration of energy-specific aspects: e.g. access to energy, social acceptance



Source: Mancini et al. 2023 *Proposal for a sustainability assessment framework for energy technologies*

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An interdisciplinary research agenda, where the socio economic dimensions are already interconnected to the environmental ones

Spatial differentiation of driver of impacts/impacts and **local benefits**

Impacts not yet fully addressed/modelled

Externalities addressing **reversibility** of impacts

Data challenges and artificial intelligence support all along LCSA, including for **agent-based modelling**

Further integration of **behavioural economics** in LCA-based studies

Absolute sustainability and **fair principles of allocations of the boundaries**

Further development of (prospective) LCA considering **evolution of socio-economic context**

Definition of **benchmarks and criteria of sustainability**

Integration of **semiquantitative or qualitative information**

Trandisciplinary LCSA

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Outlook

- Sustainability in absolute terms is a *mirage*, context dependent
- LCSA role to help understand the context and optimise what is quantifiable → dashboard of optimisation rather then pushing integration and single score
- Link with risks and natural resources dependencies

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Thank you

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