European Commission

Key Performance Indicators for the Chemicals Strategy for Sustainability

Final report

Written by WSP Environment & Infrastructure Solutions GmbH
December 2022

EUROPEAN COMMISSION

Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs
Directorate F — Ecosystems I: Chemicals, Food & Retail
Unit F.2 — Bioeconomy, chemicals & cosmetics

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European Commission

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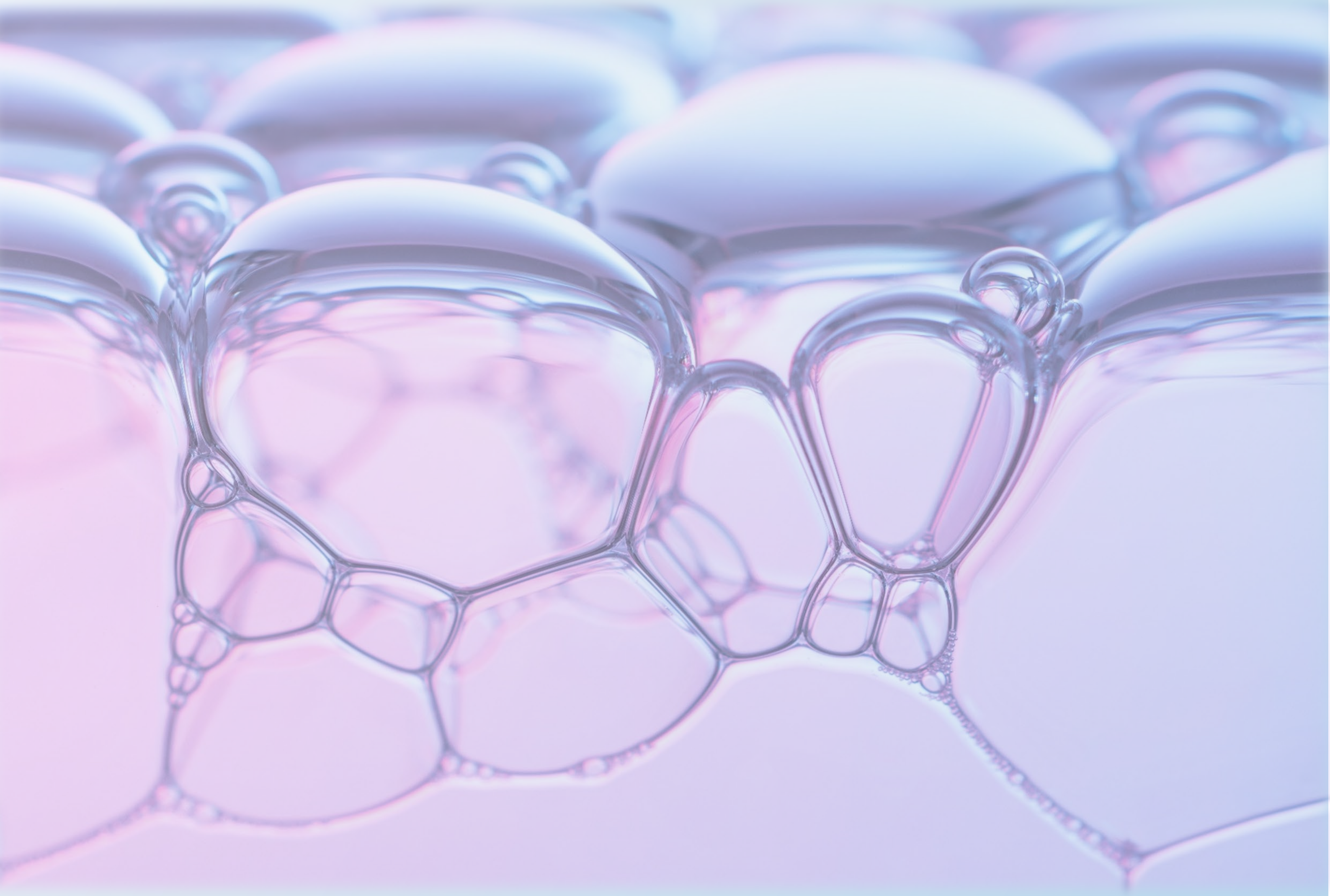
Final Report



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Report for

European Commission (DG GROW)
Directorate-General for internal market, entrepreneurship, and SMEs
Ecosystems I: Chemicals, Food & Retail
Unit F2: Bioeconomy, chemicals & cosmetics

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3	Revised final report	28/09/22
4	Revised final report (formatted)	08/11/22
5	Final report – last amendments	05/12/22

Executive summary

Purpose of this study

This study aimed to support DG GROW in the identification and recommendation of key performance indicators (KPIs) to measure the industrial transition towards the production of safe and sustainable chemicals.

In 2020, the European Commission set out a sustainability roadmap for the EU chemical industry, demonstrating the intention to move towards a toxic-free environment and improve resource and energy efficiency, circularity, climate neutrality, and global competitiveness. This roadmap is communicated in the Chemicals Strategy for Sustainability (CSS)[1] and relates to the broader EU sustainability agenda underpinned by the European Green Deal[2].

A critical question for policy makers is how to monitor the progress towards these sustainability goals. In fact, the CSS commitment to develop KPIs to monitor the transition to safe and sustainable chemicals is the main driving force for this study. Monitoring progress through indicators is key to identify whether goals are being achieved and to determine how much and what type of further action is required to achieve the desired outcomes.

Methods used

Under this study, WSP conducted evidence gathering activities (Q1-Q2 2022) to determine what existing indicators and what potential new indicators could be used to monitor the transition. Existing indicators included those for which data is already collected, analysed, and presented to demonstrate change over time (e.g., Eurostat and European Environment Agency indicators). New indicators included those for which data exist but are not yet synthesised into an indicator as well as those for which data could be collected in the future.

The scope boundaries for relevant indicators included those which relate to any aspect of the transition to safe and sustainable chemicals. At the time of writing, there is no politically agreed definition of what this transition looks like, beyond the thematic areas described in the CSS. Given that safety and sustainability are both broad concepts with no universally agreed definition, the project team aimed to further define the scope of the transition by further investigating and describing what the concepts of safety and sustainability mean in the context of the industrial transition. Based on the CSS text, literature sources, and consultation outputs, a list of key aspects of safety and sustainability was compiled to set the scope for what should be monitored by KPIs.

The starting point for identifying indicators was a literature review, which involved searching for and reviewing both scientific and grey literature, as well as online indicator dashboards. Information on indicators was extracted systematically to allow appraisal based on factors such as relevance, data quality and availability, and frequency of update of each indicator. The most useful indicators were compiled and presented to stakeholders in interviews and a workshop, to gather feedback on the suitability of each indicator.

[1] Communication from The Commission to The European Parliament, The Council, The European Economic and Social Committee and The Committee of the Regions. Chemicals Strategy for Sustainability Towards a Toxic-Free Environment. COM(2020) 667 final

[2] Communication from The Commission to The European Parliament, The European Council, The Council, The European Economic and Social Committee And The Committee Of The Regions The European Green Deal COM(2019) 640 final

Based on evidence provided by stakeholders during consultation, the aspects of safety and sustainability, list of existing indicators, and potential new indicators were further developed by adding critical analysis of the findings and supplementing the lists with new evidence and ideas.

Key findings and recommendations

The key findings and recommendations are based on the evidence gathering, synthesis, and analysis which was largely completed in **Q1 – Q2 2022**, therefore the recommendations do not reflect more recent developments in indicators and safe and sustainable by design (SSbD) criteria.

The following indicators are recommended to be used for KPIs to monitor the transition to the production of safe and sustainable chemicals. In some cases, recommendations to modify the indicators have been made (and summarised below).

- Consumption of chemicals by hazard class (ENV_CHMHAZ), Eurostat
  - Modification of this indicator to not exclude exports is recommended. The current hazard classification-based monitoring system could be improved to focus on hazards targeted by the CSS (e.g., substances of concern are those with chronic effects for human health and the environment).
- Greenhouse gas (GHG) emissions by source sector (env_air_gge), Eurostat
- Total energy consumption in the EU chemical industry by source, Eurostat
- Total hazardous and non-hazardous waste in the EU chemicals industry, EEA / E-PRTR
- Industrial pollutant releases to water in Europe, E-PRTR / EEA.

Existing indicators were assessed as insufficient to fully monitor the transition to safe and sustainable chemicals. For example, they cover only material consumption as a reflection of circularity, hazardousness, GHG emissions, and energy consumption. The following new indicators are recommended for development to be used for KPIs to monitor the transition to the production of safe and sustainable chemicals.

- Production value/market share of safe and sustainable chemicals
- Number of safe and sustainable chemicals on the market
- Number of substances of concern on the market
- Production and consumption of chemicals by type (including safe and sustainable chemicals and substances of concern)
- Carbon intensity (carbon consumption for energy and feedstock production per unit chemical product)
- Eco-innovation index for the chemical industry (chemical innovation resulting in progress towards sustainable development)
- Research and innovation spending on safe and sustainable chemicals.

To make these indicators functional, "safe and sustainable chemicals" must be defined. This falls under scope of on-going work by the European Commission on SSbD chemicals and materials, under which criteria will become available to define chemicals as safe and sustainable.

Contents

Abbreviations

Abbreviation	Meaning
A. SPIRE	European Association which is committed to manage and implement the SPIRE Public-Private Partnership dedicated to innovation in resource and energy efficiency enabled by the process industries
BAT-AELs	Best available technique associated emissions levels
CAPEX	Indicator for capital expenditures
CARACAL	Competent Authorities for REACH and CLP
CLP	Classification, labelling and packaging of substances and mixtures (Regulation (EC) No 1272/2008)
COMEXT	Eurostat's reference database for detailed statistics on international trade in goods
CSRD	Corporate Sustainability Reporting Directive
CSS	Chemicals Strategy for Sustainability
DG COMM	Directorate-General for Communication
DG ENV	Directorate-General for the Environment
DG GROW	Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs Directorate-General for Research and Innovation
DG SANTE	Directorate-General for Health and Food Safety
DPSIR	Driver pressure state impact response framework
Eco- IS	European Eco-Innovation Scoreboard
ECHA	European Chemicals Agency
EEA	European Environment Agency
EGSS	The environmental goods and services sector
EPO	European patent Office
E-PRTR	The European Pollutant Release and Transfer Register
EU	European Union
EU27	27 EU Member State countries
EUR	Euro

Abbreviation	Meaning
FOAK	First-of-a-kind
GDP	Gross domestic product
GHG	Greenhouse gas
ICT	Information and communications technology
INSPIRE	infrastructure for spatial information in Europe to support environmental policies
ISO	International Organisation for Standardisation
JRC	Joint Research Centre
KPI	Key Performance Indicator
LIFE	EU funding instrument for the environment and climate action
NACE	Statistical classification of economic activities in the European Community
NGO	Non-governmental organisation
OECD	Organisation for Economic Co-operation and Development
OPEX	Indicator for operating expenses
P4Planet	Processes4Planet public-private Partnership
PATSTAT	Worldwide patent statistical database maintained by the European Patent Office
PCN	Poison centre notification
PRODCOM	EU statistics on the production of manufactured goods carried out by enterprises on the national territory of the reporting countries
RAPEX	European Rapid Alert system for dangerous products
REACH	Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals
SAICM	Strategic Approach to International Chemicals Management
SCIP database	Database for information on Substances of Concern in articles as such or in complex objects (Products) (maintained by the European Chemicals Agency)
SME	Small to medium sized enterprise
SSbD	Safe and sustainable by design
SVHCs	substances of very high concern
TOC	Total organic carbon

Abbreviation	Meaning
TRL	Technical Readiness Level
UBA (DE)	Umweltbundesamt (German Environment Agency)
UNEP	The United Nations Environment Programme
UNIDO	United Nations Industrial Development Organisation
WBCSD	World Business Council for Sustainable Development
WWTP	Wastewater treatment plants

1. Introduction

1.1 Purpose of this report

This is the **revised final report** for the study on Key Performance Indicators (KPIs) for the Chemicals Strategy for Sustainability, delivered by WSP (formerly Wood E&IS), under contract to the European Commission (DG GROW). This report sets out the project background, scope, methodology, and main findings as well as recommendations, taking into account the evidence gathered through literature review and consultation.

Structure of this report

This report is organised as follows:

- Section 2 covers the project methodology;
- Section 3 covers aspects of safety and sustainability suggested for monitoring by KPIs;
- Section 4 outlines recommendations for existing indicators;
- Section 5 outlines recommendations for new indicators; and
- Section 6 provides the conclusions.

1.2 Project background

Policy context

In 2020, the EU adopted the Chemicals Strategy for Sustainability (CSS)[3] to guide transformation of the chemical sector in line with the ambitions of the European Green Deal[4]. The ambition focuses on moving towards a toxic-free environment, resource and energy efficiency, circularity, climate neutrality, and global competitiveness.

This transformation is critical for two key reasons. Firstly, according to the CSS, chemical production is one of the most polluting and energy and resource-intensive sectors. This is due to many factors, including emissions of hazardous substances, emissions of greenhouse gases, energy requirements for high operating temperatures and pressures, and reliance on non-renewable sources such as fossil resources for chemical feedstocks. Secondly, society is reliant on chemicals due to their use in most articles and products on the market. For example, chemicals can be the building blocks of low-carbon, zero pollution and energy- and resource-efficient technologies, materials, and products, and therefore are critical to support the overall green transition of the EU. As such, growth of the EU chemical industry is important to the EU economy, however, must be decoupled from any potential exacerbation of the already high environmental impact of the sector.

[3] Communication from The Commission to The European Parliament, The Council, The European Economic and Social Committee and The Committee of the Regions. Chemicals Strategy for Sustainability Towards a Toxic-Free Environment. COM(2020) 667 final

[4] Communication from The Commission to The European Parliament, The European Council, The Council, The European Economic and Social Committee And The Committee Of The Regions The European Green Deal COM (2019) 640 final

A key commitment communicated in chapter 2.1 of the CSS is to "*establish, in close cooperation with stakeholders, Key Performance Indicators to measure the industrial transition towards the production of safe and sustainable chemicals*". This is stated in the context of innovation for safe and sustainable chemicals, which includes reference to safe and sustainable-by-design chemicals, global competitiveness, and socio-economic consequences including employment impacts on specific regions, sectors, and workers.

Objectives

In line with the commitment from the CSS, the objective of this study was to develop an initial list of **existing, and potential new, Key Performance Indicators** (KPIs) which could be used to measure the **industrial transition to safe and sustainable chemicals**. To contextualise the indicators, the study also aimed to identify and define the **main elements (aspects) which should be monitored** to measure the transition.

Tasks

The study consisted of the following tasks:

- Task 1: Desk research and interviews to compile information on indicators.
- Task 2:
  - Task 2a) Identify, assess, and refine potential existing indicators; and
  - Task 2b) Define potential new indicators/criteria.
- Task 3: Support and process the outcome of a targeted stakeholder consultation, including drafting a synopsis report of all consultation activities.

Scope

This study aimed to identify key performance indicators which could be used to measure the industrial transition to safe and sustainable chemicals, with a particular focus on production and innovation (given the context of the commitment to develop KPIs in the Chemicals Strategy for Sustainability).

In a recent publication on Safe and Sustainable by Design chemicals and materials, the JRC (Joint Research Centre) state that an indicator[5], is a "*parameter, or a value derived from parameters, which points to, provides information about, or describes the state of a phenomenon, with a significance extending beyond that directly associated with its value" (*based on the OECD definition).

For the scope of indicators covered under this project, the "*significance extending beyond that directly associated with its value*" (as required in the above definition) can be interpreted as the indicator having a significant meaning in terms of the industrial transition to safe and sustainable chemicals, for example, greenhouse gas emissions have an extended significance due to their contribution to climate change. Indicators within scope included:

- Indicators monitoring progress towards safety or sustainability objectives in the context of chemicals;
- Indicators representing change at a sectoral level to reflect the EU chemical industry, not only individual companies, chemical processes, substances, or sub-sectors; and

[5] JRC (2022), Safe and Sustainable by Design chemicals and materials, Review of safety and sustainability dimensions, aspects, methods, indicators, and tools

- Indicators reflecting changes over time in order to reflect a “transition”.

To further inform the scope for indicators, this project has drawn on the parallel work on safe and sustainable by design criteria (based on available materials at the time or writing) as well as the aspect mapping under Task 2 as detailed in section 3 of this report.

2. Methodology

2.1 Overview

The methodology for this project was devised based on the following tasks:

- Task 1: Desk research and interviews to compile information on indicators;
- Task 2:
  - Task 2a) Identify, assess, and refine potential existing indicators: and
  - Task 2b) Define potential new indicators.
- Task 3: Support and process the outcome of a targeted stakeholder consultation, including drafting a synopsis report of all consultation activities.

The starting point for the project was the desk-based research conducted under Task 1, used to compile evidence on existing and potential new indicators from the available literature in order to build up an understanding of the 'state-of-play'. Relevant literature was also consulted to help map aspects of safety and sustainability which should be measured by indicators. Stakeholder consultation activities (interviews under Task 1 and a workshop under Task 3) were undertaken to further improve the evidence base by gathering information and views on relevant indicators and aspects. The findings from both the literature and stakeholder consultation were used to critically appraise the existing indicators and aspects of safety and sustainability identified, and to provide suggestions for existing and new indicators.

The methodology is further described below, in terms of desk-based research and consultation, and the limitations to the methodology.

2.2 Desk-based research

A literature review was undertaken to identify existing and potential new KPIs to measure the industrial transition to safe and sustainable chemicals. The study team utilised a Rapid Evidence Assessment type approach to gather information systematically and transparently. The steps undertaken are described below.

Development of a search protocol

A search protocol was developed to identify the most relevant literature in accordance with the scope of the project, and to answer the following research questions:

- Primary research question 1: ***What are existing Key Performance Indicators to measure the industrial transition towards the production of safe and sustainable chemicals?***
- Primary research question 2: ***What new Key Performance Indicators could help measure the industrial transition towards the production of safe and sustainable chemicals?***

The study team defined nine search protocols based on different combinations of key words such as "*chemical*", "*indicator*" and "*sustainability*". Other relevant terms included "*industry*", "*green transition*", "*social*", "*economic*" and "*safety*" to ensure coverage of relevant dimensions of safety and sustainability. The key word "*indicator*" was also enhanced to "*key performance indicator*". The term "*patent*" was incorporated in search #9 to generate references related to innovation and research/ development. Key words were combined with the Boolean operator "AND" to generate search terms. The search protocols were provided to the Commission in an Excel file.

Search for evidence

Google Scholar and Google were used to apply the search protocols described above. Google Scholar searches were limited to results published within the last ten years. For each search protocol, the first 50 results returned by the search engine were screened by source title, abstract, and/or meta description to identify those most relevant. "Most relevant" were identified based criteria that there must be a direct reference to indicators related to at least one aspect of safety and/or sustainability. In total, 116 literature sources were screened and included for full-text review, including:

- Scientific literature;
- Policy reports and studies;
- Grey literature (e.g., industry association briefings, consultancy reports); and
- Proceedings of conferences, symposia, and meetings.

Indicators were extracted from 43 of these sources. All sources are listed in the Excel file provided to the Commission.

Evidence review

The literature was screened to determine the type of information contained and the extent to which the data provided was reliable and sound. Relevance, adequacy, and robustness were assessed as part of this first screening of whether to include the literature source. Sources which contained information on relevant indicators were further explored in sheet 3 of the data inventory which was used to capture and analyse information on existing indicators, drawing out the following information to help appraise the usefulness of each indicator to measure the industrial transition to safe and sustainable chemicals:

- Relevance to the chemical sector;
- Functionality as an indicator (as opposed to guidance or other criteria);
- Evidence of practical implementation (e.g., is the indicator already applied at an EU sectoral level);
- Aspects of safety and sustainability measured by the indicator;
- Data source;
- Assumptions and methodology used to create the indicator;
- Temporal relevance (frequency of update, most recent update, anticipated future update);
- Strengths;
- Weaknesses; and
- How readily the indicator could be applied as a useful indicator to measure the transition.

Additionally, information on aspects of safety and/or sustainability which could be measured by indicators was extracted in a final tab of the data inventory, to help guide the scope for indicators.

Outputs from the desk-based research

The evidence review from Task 1 fed into the recommendations for existing indicators (Task 2) using a system of categorisation for usefulness of each indicator (from high to low). Indicators with high usefulness were selected based on evidence of successful implementation at an EU-wide scale, with representation of the chemical sector, and coverage of at least one important aspect of safety and sustainability. Excluded indicators with lower relevance were those which could not readily be applied to the EU chemical sector to measure the transition, for example, hypothetical/conceptual indicators (with no evidence of implementation at a relevant scale), indicators focused on individual chemicals or companies (rather than a sectoral scope), and indicators limited in their relevance to safety/sustainability.

Information on safety and sustainability fed into the aspect mapping exercise to help define the scope for what should be measured by KPIs for the industrial transition, and to identify gaps where important aspects of safety and sustainability are not currently measured by appropriate existing indicators.

Considering these gaps, as well as information from the literature on ideas for indicators / indicators currently under development, ideas for new indicators were proposed.

2.3 Consultation

10 interviews and a workshop with 36 participants were held to gather further evidence and views related to KPIs for the CSS, and to validate/challenge initial findings from the literature. Information and feedback were requested on the topics of safety and sustainability, existing indicators, and new indicators.

Stakeholders were invited to partake based on expertise of safe and sustainable chemicals, green chemistry, chemical innovation, chemical systems and the chemical economy, and indicators related to safety and/or sustainability in the chemical sector.

Further details on the approach to the interviews and workshop were provided to the Commission in a synopsis report.

2.4 Limitations

The key limitations of the study methodology included:

- The methodology was limited by a lack of consensus on the scope of sustainability. For example, the final criteria for safe and sustainable by design chemicals were not available at the time of project delivery. This limited the extent to which relevance of identified indicators could be assessed; and
- In terms of scope boundaries, it was not clear whether indicators for general safety and sustainability for the entire sector should be included. For example, indicators for fair wages, equality, and occupational accidents (due to physical rather than chemical hazards), are applicable to sustainability of the sector, but are less dependent on the identity of chemicals on the EU market. For example, improvements in equality could happen regardless of which chemicals are produced, in contrast to other aspects of safety and sustainability such as hazardousness of chemicals which directly depend on the identity of the chemicals on the market. Similarly, different chemicals have different requirements for energy consumption during manufacturing, therefore energy consumption is dependent on the identity of the chemicals on the market. Due to the different extents to which indicators are dependent on the identity of chemicals on the EU market, the applicability of some indicators was uncertain. This was explored to some degree in consultation with stakeholders, where representatives from academia

and NGOs suggested to focus on indicators on hazardousness of chemicals (and other aspects directly dependent on the identity of chemicals) because it would be too ambitious and less relevant to look at wider sustainability aspects. Stakeholders showed diverging views as others requested that sustainability was covered in a holistic way, e.g., arguing that 'sustainability' should take into account the conditions under which the product was made (e.g., fair wages), which would suggest including less direct aspects.

3. Aspects of safety and sustainability considered in the study

The usefulness of an indicator depends on its ability to measure progress towards a specific target. In the context of this project, the target is the "industrial transition to safe and sustainable chemicals". This is a moving target given that the EU ambition for safety and sustainability evolves over time (e.g., based on changing threats to the environment and society). To help set the scope for identifying useful indicators, we aimed to describe this target, by further exploring the **dimensions** of **safety and environmental, social, and economic sustainability**. This exercise was carried out in recognition that the overall concept of sustainability is complex and, at the time of writing this report, lacks a universally agreed definition, for example, while the three dimensions of sustainability are well-recognised[6], it's still unclear how they should be integrated and operationalised (JRC, 2022a)[7]. Safety is also recognised as a wide dimension with multiple facets (JRC, 2022a). At the time of researching this study, the criteria for safety and sustainability had not been defined and could not steer the desk research. These definitions are now available and have been included in this report for completeness. The (now published) *JRC Framework for the definition of criteria and evaluation procedure for chemicals and materials (2022b)*[8] report defines:

- **Sustainability** as the 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. The dimensions of sustainability are environmental, social, and economic.
- **Safety** as a transversal concept to all sustainability dimensions (environmental, social, and economic) is related to the absence of unacceptable risk for humans and the environment, preferably ensured by avoiding chemicals with intrinsic hazard properties.

Each of the **four dimensions** (safety, environmental sustainability, social sustainability, and economic sustainability) was described in terms of sub-components, "**aspects**", to improve granularity and help define what the industrial transition to safe and sustainable chemicals should look like in order to guide what should be monitored by indicators.

This chapter presents an overview of the four dimensions, followed by a summary of the supporting evidence used to identify aspects, and a final list of aspects to describe what the transition to safe and sustainable chemicals should look like.

3.1 Overview of dimensions

The following dimensions were used to help categorise aspects, aiming to ensure a holistic approach to covering safety and sustainability:

- Safety;
- Environmental sustainability;
- Economic sustainability; and

[6] Environmental, social, and economic sustainability.
[7] JRC (2022a) Safe and sustainable by design chemicals and materials - Review of safety and sustainability dimensions, aspects, methods, indicators, and tools
[8] JRC (2022b) Safe and sustainable by design chemicals and materials - Framework for the definition of criteria and evaluation procedure for chemicals and materials

- Social sustainability.

The scope for **safety** was understood as the prevention of risks from chemicals as defined above, for example, through reducing exposure to chemicals or reducing the hazardousness of chemicals which is relevant to UN Sustainable Development Goal (SDG) **SDG3** health[9].

Environmental sustainability encompasses resource consumption within planetary boundaries. This covers environmental impacts which are a result of the production, use, and emissions of hazardous chemicals.

The concept of sustainability is more complex when considering **economic and social sustainability**. Within this study, these dimensions were included to holistically address all three pillars of sustainability. According to the JRC (2022a), there is no shared definition of economic sustainability. Under this project, economic sustainability was investigated and its scope was understood as sustained economic growth and development which does not compromise the needs of the future in terms of natural resources and environmental services.

Social sustainability is described conceptually by the JRC (2022b) to cover equity/equality, human wellbeing, human rights and livelihood. The JRC (2022b) reports that the following eight SDGs are most relevant to social sustainability goals whilst other SDGs have clear links to specific environmental or technological aspects (e.g. **SDG6** water and sanitation):

SDG1 poverty eradication	**SDG4** education	**SDG10** reduce inequalities
SDG2 food security	**SDG5** gender equality	**SDG16** peace and justice
SDG3 health	**SDG8** decent work	

It should be emphasised that true sustainability requires all dimensions to perform well, therefore no dimension should be considered in isolation. As noted by Anastas et al. (2019), advances in sustainability should lead to progress in all criteria, not in just one or a few at the expense of others.[10]

3.2 Supporting evidence to identify aspects of safety and sustainability

The following sub-sections provide an overview of the sources and inputs used to provide more detailed descriptions of safety and sustainability. This information was used to identify the key components, 'aspects', of safety and sustainability.

The Chemicals Strategy for Sustainability

Given the overall aim of this project to identify KPIs for the Chemicals Strategy for Sustainability, the CSS was the first source reviewed to align aspects with the Commission's vision for a safe and sustainable chemical industry.

Key terms used to describe safety and sustainability in the CSS include those related to all dimensions of sustainability: **environmental** (ambition for energy efficiency, circularity, climate neutrality, innovation, achievement of a toxic-free environment, protection of the environment, safe and sustainable-by-design chemicals and bio-based chemicals, new and cleaner production processes and technologies), **economic** (global competitiveness, resilience of supply of sustainable chemicals, research and development of business models to ensure more efficient use

[9] https://sdgs.un.org/goals

[10] The Power of the United Nations Sustainable Development Goals in Sustainable Chemistry and Engineering Research | ACS Sustainable Chemistry & Engineering

of chemicals, investment in sustainable innovation), and **social** (up-skilling chemical workers, protection of human health including workers and consumers).

Other work related to the CCS was reviewed, including outputs from a CSS working group (involving the Commission, European Chemicals Agency (ECHA), and the European Environment Agency (EEA)). A concept paper drafted by the working group in December 2021[11] specifies that progress towards the goals of the CSS may be made through monitoring the **drivers of chemicals** (human activities, including policies applied onto economic sectors involved in the production and use of chemicals, and how they progress in the industrial transition to safe and sustainable chemicals), **impacts of chemicals** (emissions and occurrence in environmental matrices and in humans compared against effect levels, and, where possible, their impacts on human health and the environment), and **effectiveness of the chemicals legislation** (in achieving its goals in terms of health, environmental and socio-economic goals).

Ongoing work on safe and sustainable by design (SSbD) criteria

Secondly, we intended to align this work as far as possible with the SSbD criteria currently under development by DG RTD and the JRC. As the criteria are not yet established, we have kept in mind developments from recent and on-going work, noting that these are not the finalised criteria.

The first source reviewed on SSbD criteria was the DG RTD (2021) mapping study which includes a structure for proposed criteria, containing the following: reduced **environmental emissions, circularity (further detailed in terms of durability, functionality, recyclability, recycled material content and reparability), sustainable sourcing of raw materials, waste management, information, restriction of substances, and social responsibility**.

The most recent publication (at the time of conducting the aspect mapping exercise) on SSbD criteria identified was a review of safety and sustainability dimensions, aspects, methods, indicators, and tools[12]. This publication considers which aspects of safety and sustainability are addressed by existing frameworks in relation to safe and sustainable chemicals. The report defines an aspect as an element of an organisation's activities, products or services that interacts or can interact with the environment/ society/ economy. Further information on each aspect (listed in the table below) is provided in the chapters of the JRC (2022a) report.

Table 3.1 Aspects of safety and sustainability identified by the JRC (2022a)

Dimension	Aspects
Safety	Aspects are not explicitly listed, but the report refers mostly to hazards, exposure, and risks, both for humans and the environment. The report refers to the purpose of safety frameworks, giving examples which may be useful to inform aspects under this study: developing new and less hazardous chemicals and substitution of existing hazardous chemicals with safer alternatives).
Resources, processing and product related aspects	• Resources: types, quantity, and efficiency considerations; • Circularity; • Biodegradability; and Energy.
Environmental	Pressure level aspects: • Atmospheric emissions;

[11] European Commission, EEA, and ECHA, (2021) (*unpublished*), Concept paper for WG8 under the Chemical Strategy for Sustainability – Developing a framework of indicators to monitor the drivers and impacts of chemicals pollution.
[12] JRC (2022a), Safe and Sustainable by Design chemicals and materials Review of safety and sustainability dimensions, aspects, methods, indicators, and tools

Dimension	Aspects
	• Water emissions (Emissions to soil are mentioned in the text but not listed as an aspect); and • Other pressure-based indicators. Impact level aspects: • Climate change; • Ecotoxicity and human toxicity; • Ionising radiation; • Resources: fossil and mineral, land, and water; • Acidification. • Eutrophication; • Ozone depletion; • Photochemical ozone formation; • Particulate matter; and Integrated assessment of environmental impacts
Social	• Supply chain responsibility; • Customer protection; • Occupational health & safety; • Human rights; and Labour rights.
Economic	• Product cost; • Profitability; • Life cycle cost and externality cost; and • Market-related criteria.

The project team also reviewed information on the aspects of safety and sustainability from the draft SSbD criteria definition framework (JRC, 2021 [*unpublished*]).[13] A revised version of this report has since been published (JRC, 2022b)[14] and highlights the following aspects with regard to safety and sustainability. It should be noted that there is little differentiation between the aspects reported by JRC (2022b) and those reported in Table 3.1 as the two published reports are aligned to one another:

- Safety is highlighted as relevant to the following SDG targets: 12.4 (safe management of chemicals), 8.8 (safe working conditions), 6.1 (access to drinking water), 6.3 (water quality), 3.8 (safe medicines), 3.9 (hazardous chemicals), and 2.1 (access to safe food).
- Safety includes human health, environmental, physical and chemical hazards, as well as exposure pathways for humans and the environment. These aspects are elaborated in Figure 13 of the JRC report.
- Environmental sustainability aspects include eco toxicity, human toxicity, ionising radiation, climate change, acidification, eutrophication, ozone depletion, photochemical ozone formation, water use, land use, fossil/ mineral depletion, biodiversity, and human health (Figure 12 of the JRC report).
- Social sustainability aspects include supply chain responsibility, customer protection, occupational health and safety, human rights, labour rights (Figure 12 of the JRC report).

[13] JRC (2021) [*unpublished*], Framework for the definition of safe and sustainable by design criteria for chemicals and materials, draft report for consultation (provided to the project team in April 2022)
[14] https://publications.jrc.ec.europa.eu/repository/handle/JRC128591

- Economic sustainability aspects include product cost, profitability, value chain cost, market-related aspects (stakeholders requirements and product performance (Figure 12 of the JRC report).

The available material related to SSbD was reviewed as the primary source to inform the mapping exercise in order to maximise the coherence of this study with other on-going activities related to the topic of safe and sustainable chemicals. However, given that the focus of this exercise was to describe what a transition to safe and sustainable chemicals would look like, the aspects have been reworded to improve specificity of what exactly should be monitored and which direction (e.g. positive / negative or increase / decrease) of change would support the transition. For example, "reduced human health impacts of chemicals" is a more tangible concept than simply "human health" alone. Stakeholders in consultation supported including directionality in the aspects, but we note that any indicators used to monitor aspects should be neutral.

UN Sustainable Development Goals

In a broader sense, beyond the chemical industry, aspects of sustainability could be identified by considering the UN SDGs which represent the global sustainability agenda. The 17 UN SDGs are listed below:

SDG 1: No Poverty

SDG 2: Zero Hunger

SDG 3: Good Health and Well-being

SDG 4: Quality Education

SDG 5: Gender Equality

SDG 6: Clean Water and Sanitation

SDG 7: Affordable and Clean Energy

SDG 8: Decent Work and Economic Growth

SDG 9: Industry, Innovation and Infrastructure

SDG 10: Reduced Inequality

SDG 11: Sustainable Cities and Communities

SDG 12: Responsible Consumption and Production

SDG 13: Climate Action

SDG 14: Life Below Water

SDG 15: Life on Land

SDG 16: Peace and Justice Strong Institutions

SDG 17: Partnerships to achieve the Goal

Other information sources

Beyond the CSS and JRC work on SSbD, a number of other publications describing safety and sustainability were identified from the literature. These were reviewed and are described below.

The recent Cefic report on SSbD[15] describes safety and sustainability in terms of "dimensions" (assessment areas), which the authors recommend should be considered in innovation.

Table 3.2 Cefic (2022) list of safety and sustainability dimensions

Dimension	Cefic SSbD "Dimensions of improvement/assessment"
Environmental sustainability	• Climate change mitigation; • Energy consumption (min ecological footprint); • Resource use of renewable and circular feedstock; • Biodiversity and ecosystems impacts; • Reduction of emissions into air, water, soil; and • Sustainable use and protection of water.

[15] https://cefic.org/app/uploads/2022/04/Safe-and-Sustainable-by-Design-Guidance-A-transformative-power.pdf

Dimension	Cefic SSbD "Dimensions of improvement/assessment"
Social sustainability	• Health & safety; • Hunger & poverty; • Human rights / child labour / forced labour; • Affordability & competitiveness; • Working conditions remuneration, gender equality, fair salary; and • Public health.
Economic sustainability	• Profitability; • Production cost; • Life cycle cost; • Resilience; • Economic and technical sovereignty; and • Creation of jobs.
Safety	• Human health hazards; • Environmental hazards; and • Recyclability and circularity (substances in material cycle).

Considering the underlying principles of green chemistry which underpins environmental sustainability in the field, we reviewed the 12 principles of green chemistry.[16] These include reference to sustainable consumption (atom economy[17], energy efficiency, prevention, reduce use of derivatives, use of renewable feedstocks, and catalysis), occupational / lab safety (safer chemistry for accident prevention), intrinsic safety of chemicals (design for degradation, less hazardous chemical syntheses, safer solvents, designing safer chemicals), and safety measures to control industrial chemical processes (real time analysis for pollution prevention).

Additional sources reviewed include the Safe(R) Innovation Approach (OECD, 2021) which lists aspects of safety by consumer exposure, environmental hazard, human hazard, release to the environment, and worker exposure to chemical hazards as well as worker safety during production (in terms of physical hazards). The OECD (2020) also note (in the context of nanomaterials) that safety should be considered from design, through product use, and industrial production.[18]

Some further aspects were identified from a handful of other sources, including occupational diseases, sustainability information on production, and total percentage of women (and women in managerial positions) (UBA (DE), 2016)[19]. Economic performance was a parameter included in the Chemical Leasing Indicator CheckList by UNIDO (2020)[20] and protection of ecosystems was included by the EEA (2021) in a briefing on safe and sustainable-by-design[21].

A similar exercise to this aspect mapping was conducted as part of a study by Öko-Institut e.V. and Ökopol GmbH on behalf of UBA (DE) (2020)[22], in which 12 main "elements" of sustainable chemistry were identified. Many of these elements reflect (at least in similar terms) the already mentioned aspects (e.g., circular economy and inherently safer chemicals) and some additional elements included: substitution; increased market opportunities ("applications of substances that have hitherto been recognised as problematic should trigger market chances for enterprises which

[16] Anastas and Warner (1998) as cited by the American Chemical Society, 12 Principles of Green Chemistry - American Chemical Society (acs.org)
[17] Atom economy means maximising the incorporation of material from the starting material or reagents into the final product. I.e., aims to reduce pollution by reducing the number of intermediary steps.
[18] Moving Towards a Safe(r) Innovation Approach (SIA) for More Sustainable Nanomaterials (oecd.org)
[19] Contributions to the sustainable development strategy: reduction of resource consumption in the chemical sector by instruments of sustainable chemistry (umweltbundesamt.de)
[20] Indicator Checklist | Chemical Leasing
[21] Designing safe and sustainable products requires a new approach for chemicals — European Environment Agency (europa.eu)
[22] Advancing REACH - REACH and sustainable chemistry - UBA (umweltbundesamt.de)

offer alternative innovative solutions"); transparency and accessibility of data (hazardous properties, exposures, risks); ambitious and enabling legislations; training and education; consumer awareness; internalisation of costs (polluter pays rather than externalised health costs or remediation costs for example).

Notably, there are some overlaps between aspects listed between sources and the scope for each aspect is difficult to define. For example, the Öko-Institut and Ökopol study list inherent chemical safety and substitution as separate aspects, while in other frameworks (the SSbD draft framework) only a broader reference to hazardousness is made. Therefore, the degree of granularity of the different aspects is important to consider.

Suggestions from stakeholder consultation

Feedback on aspects received from stakeholders included:

General views:

- Differing views were received on how/whether to cover social and economic dimensions in addition to the environmental dimension (e.g., some stakeholders considered that broadening from the environmental dimension is too complex and less focused on the problem of hazardous chemicals, while other stakeholders emphasised that sustainability is multifaceted and to be holistic, all dimensions should be covered);
- Several stakeholders highlighted the need for a life cycle approach to ensure that aspects covered all stages of a chemical's lifespan from raw material extraction, through production, use, and disposal. For example, some stakeholders noted the importance of cradle-to-gate thinking. One interviewee (NGO) expressed concern regarding "life cycle thinking", indicating that it should not result in trade-offs between different areas of sustainability;
- There were several discussions on legal considerations, e.g., compliance and governance. Some suggested that compliance should be the bare minimum / expectation so therefore should not be a target. However, others noted that REACH compliance is key for safety especially given stakeholder concerns that current compliance is low. Others suggested that the effectiveness of governance is an important aspect, rather than governance itself. One stakeholder (international organisation) stated there could be value in researching whether EU legislative principles were applied in global production, e.g., developing countries. Another stakeholder similarly expressed interest in how EU policy is helping global sustainability through global supply chains;
- There were some comments on what level the aspects should describe (e.g., driver, pressure, state, impact, response under the DPSIR framework[23]). One interviewee suggested to focus on measuring actual change, considering what are the tangible outputs (not just inputs). For example, more green innovation does not necessarily mean that the innovation outputs are of good quality and being utilised to achieve the transition;
- Some stakeholders suggested that transparency, data needs and digitalisation should be covered as transversal aspects (across all four dimensions);

[23] The DPSIR framework is used for indicators on environmental quality. More information is available here: https://www.fao.org/land-water/land/land-governance/land-resources-planning-toolbox/category/details/en/c/1026561/#:~:text=The%20Driver%2DPressure%2DState%2D,be%20made%20in%20the%20future.

- There were suggestions to focus more on the positive transition to safer alternatives / increase in non-harmful substances, rather than the transition away from harmful substances; and
- Stakeholders showed diverging views on the level of granularity to be aimed for in the aspect mapping. Some stakeholders suggested that the list of aspects is already too exhaustive and should be narrowed down to only monitor a smaller number of more important aspects. Other stakeholders suggested to include more aspects to a finer level of detail, for example, concern that “circularity” is too broad a concept.

Safety aspects:

- There were suggestions to include the following aspects: emissions to soil, exports and imports of hazardous/safe chemicals (not only production), enforcement of legislation in Member States, recyclability, governance, environmental emissions, environmental exposure, operational safety, equipment safety, restrictions, safety at end-of-life, safe use of chemicals, availability of toxicity data (safety reporting);
- A topic of discussion was whether to include the safe handling / management of chemicals (e.g., risk management measures, operational safety, physical hazards, etc.), or whether to focus only on inherent safety of the chemicals themselves (human health and environmental hazard properties). Most stakeholders suggested that the scope should be limited to the safety and sustainability of the chemicals themselves (e.g., hazard properties and structural design of chemicals), rather than the chemical sector, however, there were other suggestions to add aspects related to operating safety; and
- One interviewee suggested that safety compliance, e.g., with REACH is not very meaningful, and instead that influence of EU legislation on the safety of global chemicals production would be more meaningful. However, others noted that the current limited compliance with REACH shows that compliance would be a good aspect to measure.

Environmental aspects:

- There were suggestions to include the following aspects: land use, biodiversity impacts, environmental performance, environmental footprint, share of non-fossil carbon consumed, pollution to all compartments (air/water/soil), corporate sustainability reporting, production/use of secondary raw materials, durability, recyclability, biodegradability, reduction of substances of concern, and EU Taxonomy objectives (climate change mitigation, climate change adaptation, the sustainable use and protection of water and marine resources, the transition to a circular economy, pollution prevention and control, the protection and restoration of biodiversity and ecosystem);
- In terms of resource consumption, it was raised that raw materials (including minerals) and feedstocks should be sustainably sourced;
- Multiple stakeholders also emphasised that type of energy consumed is important, as energy sources may be renewable but have other sustainability issues, e.g., biomass and land use issues;
- Interviewees suggested to modify aspects to focus on intensity (e.g., GHG emissions, land use, waste production, or water use, per unit chemical consumption/production), to have more meaning. Although others suggested that absolute consumption is more meaningful (e.g., in terms of living within planetary boundaries); and

- The aspect suggested by the project team on "use of chemicals in sustainable solutions" received mixed views from stakeholders. One interviewee showed concerns that use of hazardous chemicals in renewable technologies etc. would be considered sustainable, but they cautioned that use of a hazardous chemical should never be viewed as sustainable. Other stakeholders in the workshop were supportive to include an aspect for chemicals contributing to sustainable technologies.

Social aspects:

- There were suggestions to include the following aspects: Diversity (gender, age, inclusion of immigrants), education (in green chemistry), human rights (including several references to vulnerable groups, labour rights, hunger, poverty, labelling (transparency and safety reporting), reduced exports of harmful chemicals, proportion of local suppliers and local procurement;
- One interviewee noted that accounting for social sustainability along the value chain is important to avoid shifting sustainability issues to regions outside of the EU. Reportedly, there is work in Germany on policy to account for this. This point was also raised in the workshop by an attendee who noted that reduced production of hazardous chemicals could be misleading if it represents the movement of production to other countries rather than a real decrease in production;
- One stakeholder from an EU agency suggested that both academic and professional education (e.g., training) should be included and that human heath should be classified under the social rather than safety dimension;
- In the workshop, one stakeholder suggested that geographic factors should be accounted for, e.g., to show how different Member States are contributing towards the transition;

Economic aspects:

- There were suggestions to include the following aspects: investment, R&I spending, state of global trade and trade balance / trade surplus, sustainable procurement practices, creation of jobs, supply chain security, digitalisation, SME friendliness, costs of healthcare and environmental remediation attributed to chemicals, price difference between safe and sustainable chemicals and other chemicals (rather than profitability);
- In the workshop, there were further comments on employment, for example, to consider jobs created as a result of the CSS; and
- A stakeholder in the workshop argued that economic aspects should be included because safe and sustainable chemicals will not contribute to the transition if they are not marketable.

3.3 Final list of aspects

Considering the abovementioned sources, a list of key aspects, used as a reference in the remainder of this study, is compiled in the table below.

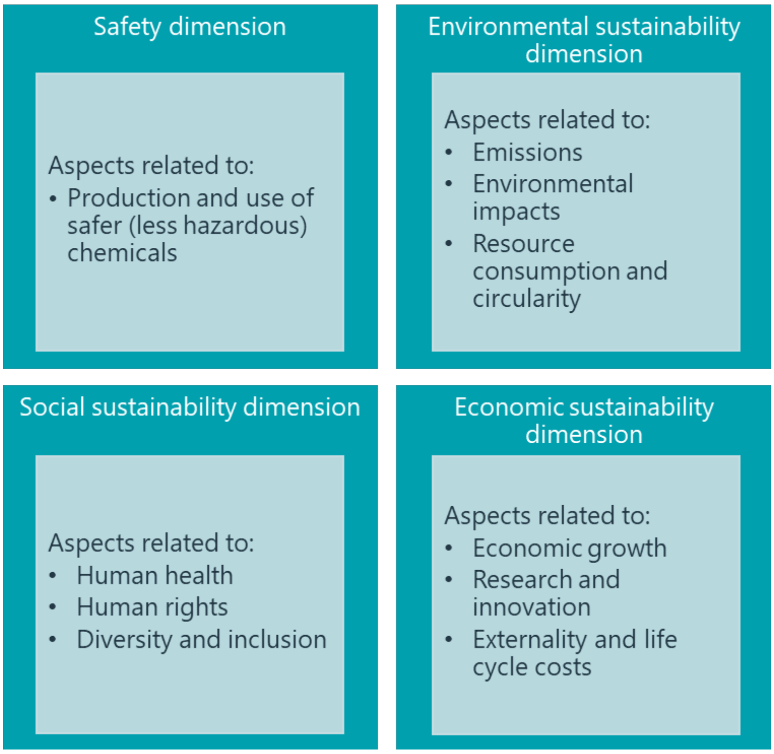
Table 3.3 Aspects of safety and sustainability which should show what the transition to safe and sustainable chemicals looks like

Safety or sustainability dimension	Aspects
Safety	• Production, importation, and use of safer chemicals (reduced human health and environmental hazards); • Reduced presence of hazardous chemicals in materials and products, including recycled materials; • Reduced emissions of hazardous chemicals; • Reduced human exposure to hazardous chemicals; • Reduced environmental exposure to hazardous chemicals; • Substitution of substances of concern with safer alternatives; • Increased transparency and safety reporting; and • Effective governance facilitating the transition to safer alternatives.
Environmental sustainability	• Reduced atmospheric emissions; • Reduced emissions to soil; • Reduced water emissions; • Climate change mitigation; • Reduced ecotoxicity impacts; • Reduced ozone depletion potential of substances; • Reduced eutrophication impacts; • Reduced acidification impacts; • Reduced intensity of fossil resources consumption; • Reduced intensity of mineral and metals consumption; • Reduced land use intensity; • Reduced water use intensity; • Minimised ecological footprint of energy consumption; • Transition to a circular economy (reduced waste, increased uptake of secondary raw materials, increased use of non-fossil carbon, and increased biodegradability of chemicals); and • Protection and restoration of biodiversity and ecosystems.
Social sustainability	• Improved supply chain responsibility; • Improved occupational health & safety (acknowledging that this overlaps with the safety dimension); • Improved human rights; • Improved diversity and inclusion; • Improved labour rights; • Reduced human health impacts of chemicals; • More training and education in sustainable chemistry; and • Increased transparency and sustainability reporting.
Economic sustainability	• Reduced life cycle costs (from production, through use and disposal/re-use); • Reduced externality costs (internalisation of costs); • Reduced costs and improved profitability of safe and sustainable chemicals (and chemical products); • Increased market opportunities/market share for safe and sustainable chemicals; • Increased research and innovation in safe and sustainable chemicals; • Use of chemicals in sustainable solutions; and • Use of digitalisation to reduce the environmental footprint of chemical production.

*These aspects are given directionality to show what the transition should look like, but we note that any indicator should be phrased in a neutral way so as to not pre-empt the direction of change.

A more concise summary of aspects is presented in Figure 3.1 below.

Figure 3.1 Dimensions and aspects of safety and sustainability



Limitations in the aspect mapping

Some challenges were identified due to the complexity of chemical systems and the lack of definition of sustainability:

- Interdependence between aspects;
  - Classification of aspects is challenging due to the interlinkages between certain aspects. For example, emissions and exposure (under the safety dimension) are interlinked with the impacts described in the environmental and social dimension; and
  - Achieving a suitable level of granularity is challenging because we intend for the list to be comprehensive but not repetitive, which could occur because of interdependencies.
- Complexity of chemical supply chains;
  - Sustainability and safety should be considered from raw material extraction, through feedstock production, chemical production / processing, distribution, and retail. Tracking safety and sustainability through all these stages is complicated, in particular, when speciality chemicals end up in complex products. Monitoring safety and sustainability may need to be conducted differently for chemicals used as intermediates in comparison to chemicals ending up in products.
- Complexity of chemical life cycles;

- Impacts occur throughout the life cycle, beyond chemical supply chains and through use, disposal, and recycling.

- Complexity of the chemical sector;
  - It has been raised whether safety and sustainability should be considered for only chemicals themselves or also for the wider chemical sector. For example, whether the scope should be limited to inherent properties of chemicals, or extended to chemical manufacturing processes, or to an even wider level across the chemical sector (for example sustainability of organisations and people employed), and downstream users of chemicals; and
  - This complexity is recognised in similar terms for example, as the ISC3 (2021) highlight "systems thinking" as a key characteristic of sustainable chemistry[24]. Constable (2020) highlights the following contributors for systems thinking in green and sustainable chemistry; chemical engineering, civil and environmental engineering, communications and marketing, quality and regulatory compliance, supply chain and logistics, business and macro-economic, environmental life cycle inventory and assessment, environmental, health, and safety, hazard and risk assessment, environmental sciences, and biology and synthetic biology[25].

[24] ISC3_Sustainable_Chemistry_key_characteristics_20210113.pdf
[25] Green and sustainable chemistry – The case for a systems-based, interdisciplinary approach - ScienceDirect

4. Recommendations for existing indicators

4.1 Overview

This chapter covers:

- A description of existing indicators (identified from the literature and consultation) which were assessed to have significant potential to monitor the industrial transition to safe and sustainable chemicals.
- A mapping of these indicators against aspects of safety and sustainability to show how comprehensively they monitor the transition.
- A tabular comparison between indicators (based on key points from the analysis) which was used to develop a final shortlist of recommended indicators.

4.2 Indicators considered for recommendation

The most relevant existing indicators identified from Task 1 are described below.

1. Production and consumption of chemicals by hazard class (online data code: ENV_CHMHAZ), Eurostat[26]

This Eurostat dataset consists of two indicators (one showing production of chemicals by hazard class and one showing consumption of chemicals by hazard class[27]) combined in one interactive dashboard. The indicators are highly relevant due to their representation of the inherent safety of chemicals produced and consumed in the EU, as a proportion of total production, as well as representation of material consumption (relevant to the circular economy). The indicators have potential to communicate trends in both of these aspects over time, which may be considered a good picture of the overall transition to safe and sustainable chemicals as the aspects are considered important to stakeholders.

On the Eurostat Data Browser, the user can visualise either production or consumption of chemicals (in million tonnes), disaggregated by 13 hazard classes or viewing total hazardous and non-hazardous. There are several options for displaying the data, for example, selecting the line graph option allows comparison between the volume of chemicals in different hazard classes. The indicators are measured using PRODCOM market and production data and updated annually. Net import data is obtained from COMEXT. Time series data are available on the Eurostat Data Explorer backdating to 2004.

These indicators were not developed with the aim to measure the transition to safe and sustainable chemicals, and consequently have some limited applicability in being used for this purpose. The following limitations are elaborated below: 1) the indicators have not shown the transition so far; 2) the hazard classification system could be improved; 3) the indicators do not show the sum of production and imports; and 4) some stakeholders would prefer to see the data disaggregated for chemicals that are only used as intermediates.

[26] Production and consumption of chemicals by hazard class | Eurostat (europa.eu),
[27] Consumption = production + imports - exports

As it stands, this indicator has not been successful in measuring the transition (as the volume of hazardous chemicals produced has remained steady since at least 2011 as shown by the line graph available on Eurostat Data Browser[28]). This is concerning given that improvements in chemical regulations have occurred over the same time period. This trend is perhaps misrepresentative of the real trend in hazardous chemicals because it is influenced by improvements in the identification of hazardous chemicals (therefore the indicator presents more chemicals as hazardous as a result of improvements in safety reporting). This problem is likely to persist, given that hazards are not well-documented for a large share of chemicals already on the EU market[29] and the CLP Regulation is being amended to introduce new hazard classes, and therefore more chemicals will qualify as 'hazardous' in the future even if there is no change in production or use of chemicals.

A key limitation with these indicators identified by stakeholders was the lack of clarity in meaning of the hazard classification system[30] which stakeholders suggested should be harmonised (e.g., using CLP classification). For example, "hazardous to health" is a vague classification and does not disaggregate hazard classes such as respiratory / skin sensitisation, eye damage / irritation, acute toxicity etc. Some stakeholders noted that general "hazardousness" is less useful than looking at specific hazards which allow substances to be identified as substances of concern. A stakeholder from an EU agency suggested that some hazards are less important to monitor, for example, acute toxicity is not as severe as other hazard classes (such as carcinogenicity), and therefore the hazard classes could be refined. The most useful hazard class might be for carcinogenic, mutagenic and reprotoxic health hazards, as substances with these hazard classes qualify as "most harmful substances", according to the CSS definitions, and are therefore a priority for phasing out in order to achieve the transition to safe and sustainable chemicals.

Some stakeholders also suggested that physical hazards were less of a priority in monitoring the transition. On the contrary, physical hazards are an element of the SSbD framework and so considered relevant. Disaggregation of data between different hazard types could help show which areas of safety and sustainability are improving, for example, CMR production is relevant to consumer safety while production of substances with physical hazards may be relevant to occupational safety for example.

The EU is responsible for producing and importing hazardous chemicals, however, the indicators do not show the overall picture of both aspects. The production indicator does not account for imports, and therefore could misleadingly indicate progress towards the transition even if more hazardous chemicals are being imported from overseas (potentially leading to more human/environmental exposure to hazardous chemicals in Europe). This risk may be considered likely as chemical supply chains are becoming increasingly globalised and chemical production is growing faster in areas outside of Europe (e.g. Asia and North America). The consumption indicator accounts for imports, but excludes exports and therefore does not reflect total EU production. This could misleadingly indicate progress if more hazardous chemicals are exported, as a result of the unsustainable shifting of the burden of hazardous chemicals to non-EU countries.

Ideally, to reflect sustainability in a global sense, an indicator would include production and imports, without excluding exports, therefore, modification of the consumption indicator would be beneficial.

There was a suggestion from stakeholders that the indicators should exclude chemicals which are consumed in industrial processes. For example, chemicals which end up in consumer products are generally of greater concern than chemicals which are consumed during production processes (for

[28] Production and consumption of chemicals by hazard class | Eurostat (europa.eu)
[29] The European environment state and outlook report (EEA, 2019) estimates that approximately 70,000 of the 100,000 chemicals on the EU market are poorly characterised for their hazards and exposures.
[30] 13 hazard classes include Hazardous; hazardous to health; carcinogenic, mutagenic and reprotoxic health hazard; chronic toxic health hazard; very toxic health hazard; toxic health hazard; harmful health hazard; hazardous to the environment; severe chronic environmental hazard; significant chronic environmental hazard; moderate chronic environmental hazard; chronic environmental hazard; significant acute environmental hazard.

which human and environmental exposure is typically less likely). Therefore, alongside monitoring the hazardousness of chemicals, it is important to also monitor how these chemicals are used. Overall, the transition should see **both** an increase in safe management of chemicals and a decrease in inherent hazardousness of chemicals, therefore we recommend that chemicals with lower exposure are not excluded from the indicator, but the indicators are contextualised, e.g., by showing the proportion of hazardous chemicals which end up in consumer products and proportion which are consumed within industrial processes, as well as total production and consumption.

A few other broad comments were raised during the consultation, without clear elaboration. Firstly, there was some concern about the data quality of the indicator, and secondly, there was some concern that not all Member States submitted data every year. These points could not be validated by the project team as limited additional information about the indicators was identified (e.g. no metadata). One stakeholder added that economic cycles are not considered in these indicators which could bias the findings of a report; for example, reduced consumption during the coronavirus (COVID-19) pandemic does not represent a transition to safe and sustainable chemicals. Another stakeholder suggested that this issue could be overcome by modifying the indicator to monitor 'intensity' of production rather than total production, which we view could be complementary, but could not replace total production and consumption.

2. Consumption of chemicals by hazardousness (EU 28 (sdg_12_10), Eurostat[31]

This indicator is part of the EU Sustainable Development Goals (SDG) indicator set and used to monitor progress towards SDG 12 on sustainable consumption and production patterns. It is similar to the abovementioned indicator, with the key differences being that it is shows only consumption data (whereas the above indicator shows consumption and production) and that the hazard classification system is simpler, with data disaggregated into only four classes (hazardous and non-hazardous total, hazardous, hazardous to health, and hazardous to the environment). Production volume is obtained from the same data sources as the above-described indicator (PRODCOM and COMEXT). The visualisation options are the same. Time series data is available backdating to 2004.

This indicator was praised by stakeholders for its simplicity as a high-level indicator. One industry association criticised the indicator for not taking into account the "safe handling" of hazardous chemicals. This reiterates the question regarding scope for indicators, in terms of limiting to intrinsic properties of chemicals or considering safety and sustainability at an organisational level.

The less granular hazard classification system (with four instead of 13 hazard classes) may also make the indicator less useful (although, the hazard classes under the previous indicator could also be improved). Similar to the abovementioned indicator, the indicator is limited in its ability to reflect the transition as more substances are classified as 'hazardous' under CLP, and therefore the quantity of 'hazardous' chemicals being consumed could appear to be inflated as result of improved hazard identification and reporting.

3. Greenhouse gas emissions by source sector (overall online data code: env_air_gge), Eurostat[32,]

This indicator is based on is the greenhouse gas emissions data compiled by Eurostat from the emissions inventory created by the European Environment Agency (EEA)[33].

[31] Consumption of chemicals by hazardousness | Eurostat (europa.eu)
[32] Greenhouse gas emissions by source sector | Eurostat Data Browser (europa.eu), Greenhouse gas emissions by source - Eurostat Data Explorer (europa.eu)
[33] Annual European Union greenhouse gas inventory 1990–2019 and inventory report 2021 — European Environment Agency (europa.eu)

The indicator is relevant to monitor progress toward climate change mitigation. The indicator monitors emissions of carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride, and nitrogen trifluoride (in CO_2 equivalents). The indicator is not specific to the chemical industry, but can be filtered by source sector, for example, filtering SRC_CRF (source sector) to 'CRF2B' provides results for the chemical industry only. Indicator values are provided annually from 1990 to 2019.

Whilst this indicator is not directly linked to the chemicals being produced and used, it measures the broader sustainability performance of the sector by indicating the energy consumption in producing chemicals. However, caution should be taken in using this indicator, as it is not a direct measure of the inherent safety or sustainability of a given unsustainable chemical as the same chemical could be produced using a better optimised or alternative process (which reduces energy requirements) or using alternative energy sources (e.g. renewable or nuclear).

In general, stakeholders showed support for use of this indicator, although there were a few concerns regarding the differences in reporting between Member States and the scope for which sectors should be included in the indicator (e.g., downstream users as well as chemical manufacturers). Member States report this data using different methodologies, activity data or country-specific emission factors (despite being in accordance with Intergovernmental Panel on Climate Change and United Nations Framework Convention on Climate Change guidelines). Indirect CO_2 emissions (i.e. some scope 2 and 3 emissions[34]) are not currently captured by all Member States. Therefore, the EU total only includes indirect CO_2 emissions if they were voluntarily reported. Furthermore, indirect N_2O emissions are also not included[32]. If this indicator were to be taken forward, a consistent methodology for reporting greenhouse gas emissions at a national level for all Member States would provide a better measure of the transition to safe and sustainable chemicals. However, the feasibility of including indirect emissions of all greenhouse gases across all member states should be considered.

One stakeholder raised concern over burden shifting. For example, if companies move production outside of the EU, this will have the effect of reducing EU GHG emissions but does not ameliorate global sustainability concerns. This also makes specifically measuring the impact of the policy difficult. They recommended that measurement of emission intensities would be a better indicator.

There were also some comments that overall GHG emissions are less useful than GHG intensity, taking into account economic trends in production volume, e.g., to demonstrate that economic growth is less energy intensive. However, we consider that both are important given that as an increase in GHG emissions is not environmentally sustainable regardless of economic growth, and this would not be captured by intensity alone. A stakeholder noted that there is an alternative Eurostat dataset 'env_ac_ainah_r2', which presents data about the GHG emissions by the industry NACE C20 'manufacture of chemicals and chemical products'. This data can also be used to calculate carbon intensity of the NACE C20, if you divide by the gross value added of the same industry.

4. R&I spending by the EU27 chemical industry, OECD and Cefic Chemdata International[35]

This indicator provides R&I spending by Europe's chemical industry. Time series data is available in a bar and line graph showing the indicator from 2002 to 2020, quantified as capital spending in absolute terms (EUR billions) and in terms of percentage added value (showing greater indication of economic sustainability).

[34] Scope 2: Emissions that an organisation causes indirectly when the energy it purchases and uses is produced. Scope 3: Emissions resulting from activities from assets not controlled by the reporting organisation that indirectly impacts in its value chain

[35] Capital & R&I Spending - cefic.org

The indicator is presented by Cefic using data from the OECD and Cefic Chemdata international although it is unclear specifically how the data has been processed. The OECD maintains many indicators for R&D spending, for example, gross domestic expenditure on R&D by sector of performance and type of R&D.[36] This data can only be disaggregated to the government, business enterprise, higher education, and private non-profit sectors (not industrial sectors such as the chemical industry). One OECD indicator targets business enterprise R&D expenditure by industry by sector (e.g., including the manufacturing of chemicals and chemical products), and therefore this likely constitutes a fraction of the data presented by Cefic (less than 10% when comparing the numbers).[37] Government budget allocations for R&D are presented for broad fields such as the environment and health, but not by industrial sector.[38]

The indicator, as presented by Cefic, monitors global competitiveness as it shows R&I spending by region for the largest investors (e.g., China, EU27, Japan, USA, etc.), comparing the difference between 2010 and 2020 as an indication of growth by region.

The indicator is seemingly too narrow in scope to reflect the transition to safe and sustainable chemicals, as there is no consideration for the field of R&I, therefore the extent to which R&I is supporting the transition to safe and sustainable chemicals. Another stakeholder also raised the point that investment in R&I is limited as an indicator because it reflects an input not an output. That is, investment in R&I does not directly measure how successful the R&I is, and specifically, it does not measure the degree to which new sustainable technology is up-scaled and deployed to replace less sustainable technology.

5. Total energy consumption in the EU27 chemical industry by source (nrg_cb), Eurostat[39]

The [nrg_cb] data from Eurostat provides data on energy consumption from each fuel source (crude oil, petroleum products, natural gas and manufactures gases, electricity and derived heat, solid fossil fuels, renewables, and wastes) covering energy consumption from supply through transformation to final consumption. A stakeholder noted that there is an alternative Eurostat dataset ‘ENV_AC_PEFASU’, which presents data about the energy use by the industry NACE C20 ‘manufacture of chemicals and chemical products’ with breakdowns by type of energy source (renewable and not-renewable, etc).

Data for each source is available on Eurostat Data Explorer and can be disaggregated to represent only the chemical sector.[40] This has potential to demonstrate the transition to environmental sustainability through achieving sustainable resource consumption and mitigation of climate change through decreased reliance on fossil fuels. The indicator has been applied, for example, by the EEA showing temporal trends from 2005 to 2017 in all sectors[41].

On Eurostat, annual data is available from 1990 to 2020. However, one stakeholder mentioned in an interview that they have analysed this indicator and found some issues with the dataset. For example, energy consumption based on renewables and biofuels appeared to be better in 1990 than today. A large decrease of 75% was observed from 1999 to 2000, which was mainly driven by a reduction of ‘renewables and biofuels’ consumption in Finland. This decrease is thought to be due to a different method of reporting/allocation, rather than actual reduced energy consumption.

[36] https://www.oecd-ilibrary.org/science-and-technology/data/oecd-science-technology-and-r-d-statistics_strd-data-en
[37] https://stats.oecd.org/Index.aspx?DataSetCode=BERD_INDU
[38] https://stats.oecd.org/Index.aspx?DataSetCode=GBARD_NABS2007
[39] Supply, transformation and consumption - commodity balances (nrg_cb) (europa.eu), Energy Consumption - cefic.org
[40] Renewable and waste - Data Explorer (europa.eu), Gas - Data Explorer (europa.eu), Oil and petroleum products - Data Explorer (europa.eu)
[41] Primary energy consumption by fuel type — European Environment Agency (europa.eu)

This demonstrates the need for adequate quality control of the data and the need for in-depth analysis of unexpected trends.[42].

As with the GHG indicator, there were concerns among stakeholders over whether the scope of the indicator should go beyond the chemicals sector to cover sustainable use of chemicals in other sectors (including upstream & downstream sectors).

This indicator does not reflect the broader sustainability of energy consumption (e.g., land use impacts which can be associated with renewable energy technologies).

6. Total hazardous and non-hazardous waste in the EU27 chemicals industry, EEA / E-PRTR[43]

This indicator presents trends in non-hazardous and hazardous waste transfers based on data reported by Member States to the EEA[44]. The indicator shows the trend in EU production of hazardous and non-hazardous waste annually from 2007 to 2019, and therefore is relevant to demonstrate the transition to a circular economy with reduced waste, and indirectly, the transition to safer (non-hazardous) chemicals. The EEA presents the indicator alongside gross value added for industry (in EUR billion), which can help demonstrate how the changing nature of chemical production (to safer chemicals) is accompanied by economic growth of the sector, therefore representing economic sustainability.

This indicator is relevant to the transition to safe and sustainable chemicals as different chemicals have different production processes involving different levels of waste production throughout the supply chain. However, total hazardous waste generation is not necessarily a direct indication of the transition to use of SSbD chemicals as waste reduction could be caused by improved resource efficiency rather than a change in production method, chemical or product. Nevertheless, reduced waste production across the supply chain indicates circular economy implementation.

One stakeholder raised concern over quality checking in this indicator and suggested that there should be engagement with industry to interpret this data accurately (note that under this study, the data quality has not been assessed). Stakeholders also highlighted concerns over data quality across E-PRTR indicators put forward for consideration, in this case, due to gaps in reporting from Member States (Germany, Iceland, Italy, Lithuania, Malta and Lichtenstein in recent years[45]). Notably, the E-PRTR evaluation found weaknesses in data regarding waste.[46]

A stakeholder from the EEA highlighted that reduction of waste is not necessarily a good indication of the transition, as diversion of hazardous waste to recycling would have negative sustainability impacts as substances may re-enter products, resulting in further exposure to humans and/or the environment. A stakeholder suggested that an alternative Eurostat dataset 'ENV_WASGEN', also presents data about waste generation by the industry NACE C20 'manufacture of chemicals and chemical products' with breakdowns by type of waste and hazardousness. This stakeholder also suggested to normalise the indicators with the gross value added of the chemicals manufacture sector and/or the employment in that sector.

[42] Energy Balances (europa.eu)
[43] Total annual E-PRTR reported quantity of hazardous and non-hazardous waste transfers (excluding data for the waste sector), and annual GVA value for industrial activities — European Environment Agency (europa.eu)
[44] Industrial Reporting under the Industrial Emissions Directive 2010/75/EU and European Pollutant Release and Transfer Register Regulation (EC) No 166/2006 — European Environment Agency (europa.eu)
[45] Industrial Reporting under the Industrial Emissions Directive 2010/75/EU and European Pollutant Release and Transfer Register Regulation (EC) No 166/2006 — European Environment Agency (europa.eu)
[46] https://ec.europa.eu/environment/industry/stationary/e-prtr/evaluation.htm

7. EU+ State of enforcement of REACH/CLP, European Commission[47]

This indicator is a composite enforcement indicator to measure compliance with the two central pieces of EU chemicals legislation (REACH (Regulation 1907/2006/EC) and CLP (Regulation 1272/2008)). This was assessed as highly relevant because REACH aims to improve the protection of human health and the environment through the better and earlier identification of the intrinsic properties of chemical substances (e.g., improvement of safety reporting) and to enhance innovation and competitiveness (economic sustainability aspects) of the EU chemical industry[48]. CLP is also relevant because it requires classification, labelling and packaging of hazardous substances (improving safety reporting). This indicator is a composite indicator combining 12 sub-indicators on compliance, enforcement actions, training, forum, and harmonised enforcement. Three of these sub-indicators are detailed below as 'medium – high' importance. Time series data for the EU+ indicator are available with values for the indicator from 2007 to 2019, however, it is not clear when the next report will be available. Given the uncertainty regarding future unavailability, this indicator should be considered with caution.

Stakeholders generally supported the premise that that monitoring the implementation of REACH would be a good indicator, however, one stakeholder suggested that, as REACH compliance is mandatory in Europe, it is not a good enough indicator to provide a measure of the transition.

Some of the sub-indicators may be considered more relevant, and therefore the indicator could potentially be adapted to focus on those most relevant, for example:

7.1 RAPEX Alerts (European Rapid Alert system for dangerous products)[49]

RAPEX is an EU-wide rapid information exchange system for products (except food, pharmaceutical and medical devices) found to pose a serious health and/or safety risk. The list of products is updated by the European Union weekly and previously issued alerts may also be viewed on the European Commission website.

Some of the notifications relate to products in the EU market non-compliant with REACH and/or CLP requirements. Note that not all non-compliant products with REACH and CLP are notified in RAPEX as not all non-compliant products represent a serious risk following the RAPEX criteria. Alerts can be exported to Excel and filtered by year, product category, country, risk type, alert type and product user.

RAPEX Alerts are currently used as an indicator to measure REACH and CLP enforcement by comparing how many of the alerts that the countries report to RAPEX every year correspond to non-compliance with REACH or CLP. The indicator is calculated as the ratio between the number of alerts not relating to serious risk caused by chemicals and the total number of alerts. Therefore, higher values mean that fewer REACH/CLP alerts have been notified to RAPEX. For example, a value of 80 means that 20% of the alerts relate to REACH and CLP cases. Notably, trends in the indicator may be influenced by trends in other types of alerts.

This indicator could be used to represent the transition towards safe and sustainable chemicals as it reflects danger to consumers from chemicals in products. It is therefore an indirect measure of several aspects of safety (human exposure, use of hazardous chemicals). For example, an indicator showing decreased number of RAPEX notifications related to chemicals would indicate a reduction in exposure to consumers of hazardous chemicals.

One stakeholder raised concerns that RAPEX notification reporting methodologies vary between Member States. Therefore, this indicator would not be a reliable indicator of the transition to safe and sustainable chemicals and care must be taken to report and interpret the data appropriately.

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47 REACH and CLP enforcement - Publications Office of the EU (europa.eu)
48 REACH - Chemicals - Environment - European Commission (europa.eu)
49 RAPEX Alerts https://ec.europa.eu/safety-gate-alerts/screen/webReport

7.2 EU1 REACH compliance, European Commission

This indicator measures the percentage of compliant cases found in official REACH controls in the EU. It was included in a report by the Commission which applied a statistical methodology to measure enforcement of REACH. Data on number of controls and number of non-compliant controls are reported by countries in the European Economic Area to the Commission. The indicator is compiled using all types of obligations set by REACH, some directed to legal/natural persons and others to products. Time series data is available for each year between 2007 and 2019.

Some stakeholders suggested that implementation of REACH is a good indicator given concerns that current compliance is low, for example, the CSS states that only one third of registration dossiers are fully compliant. Furthermore, compliance with legislation is considered important to facilitate the transition by several stakeholders as discussed in interviews. However, one stakeholder from academia suggested that compliance should be the bare minimum, not a target.

Overall, this is considered a valuable indicator as an indirect proxy of the transition (as compliance does not necessarily mean safer and more sustainable chemicals are being produced), but that more specific indicators would also be required to fully monitor the transition to safe and sustainable chemicals. Another stakeholder suggested that a REACH-centred indicator could be valuable if it demonstrated the influence of EU REACH on the global chemical industry.

7.3 EU2 CLP compliance, European Commission

This indicator is part of the same indicator set as the abovementioned indicator (EU1). It measures percentage of compliance with CLP duties and therefore is relevant as an indicator in this context to measure progress in increased safety reporting (transparency and awareness of the safety of chemicals, which can enable safe handling of chemicals and incentivise the production and use of safer chemicals).

7.4 EU4 Compliance established by ECHA, European Commission

This indicator presents the percentage of compliant cases. It differs from the above mentioned indicator (EU1) in that it focuses on ECHA controls (ECHA compliance checks) rather than official REACH controls (compiled Member State level data). The outcome value is obtained by averaging compliance rates across information duties and dossier evaluation cases. The data was provided by ECHA Secretariat and reflects two combined aspects of compliance exercised by ECHA: 1) compliance of registration dossiers (CCh) and dossier evaluation cases (DEV); 2) compliance rates found in registration dossiers for some information requirements (substance identity, SME status, hazardous information). Values for the indicator are available from 2007 to 2019. As with EU1, stakeholders suggested that implementation of REACH is a valuable indicator to monitor basic safety requirements set by REACH, but that it does not fully extend to the transition to safe and sustainable chemicals.

Other enforcement indicators

In complement to the indicators established under the EU+ work by the Commission, other EU-wide activities have been undertaken to monitor enforcement of chemicals legislation. For example, the ECHA enforcement forum set out a list of indicators in 2019.[50] These indicators are considered too indirect to be used as a measure of the transition to safe and sustainable chemicals.

[50] https://echa.europa.eu/documents/10162/17088/forum_indicators_report_2018_en.pdf/b38bc309-c60f-2a5e-99e6-50e19cce04ff?t=1546622611162

8. Total number of accidents at work in the EU27 industry, Eurostat[51]

This indicator shows the trend in total number of accidents at work annually between 2008 and 2019. This is presented as number of accidents and incidence rate for both fatal and non-fatal accidents at work, as reported by Member States to Eurostat under the NACE[52] datasets (HSW_N2_01 and HSW_N2_02). The data can be filtered to the chemical industry on the Data Explorer webpages by selecting for example, the NACE_R2 code C20 “Manufacture of chemicals and chemical products”. This can be further disaggregated to chemical sub-sectors such as manufacture of basic pharmaceutical products and pharmaceutical preparations (C21), which could help target priority areas where improvements in safety are required. As demonstrated for example by Cefic[53], the trends can be compared across sectors, which could allow comparison of progress towards improved occupational safety measures between the chemical sector and other industrial sectors.

The relevance of this indicator depends on the scope of definition for the transition to safe and sustainable chemicals. Indirectly, the indicator is likely to be largely comprised of accidents due to chemical hazards. However, accidents caused by physical hazards and process safety may not necessarily be regarded under the scope, unless the concept of safety is used in this context to encompass safety of the overall sector, in which case this indicator would be highly relevant.

There was stakeholder concern that number of accidents includes many factors other than the safeness of chemicals produced/used. There were some strong opinions that this should be beyond the scope as it is too indirect. One stakeholder suggested that this indicator could be used in combination with other indicators as part of a compound indicator to measure safety in chemicals production. Another stakeholder from an EU agency suggested that accidents at work are not linked to SSbD.

9. EU27 trends of acidifying emissions, EEA / E-PRTR[54]

This indicator is relevant to measure reduction in acidifying emissions (and therefore relates to avoiding impacts on ecosystems due to acidification of soils and water bodies). Data is available overall and by disaggregation to the chemical sector.[55]

Several versions of this indicator have been produced by the EEA utilising E-PRTR data reported by Member States in accordance with the National Emission reductions Commitments Directive (2016/2284/EU). Between 1990 and 2006 the data was presented as an aggregated trend in emissions of nitrogen oxides, sulphur oxides, and ammonia in kilo tonnes of acid equivalent and as an index benchmarked against 1990 levels (set at a value of 100).[56] This indicator was archived and the updated dashboard (providing data from 2005 – 2019) demonstrated emissions for each pollutant in 1,000 tonnes by sector.[57]

In the workshop, one participant highlighted it as one of the most useful indicators. However, another stakeholder expressed concern that there were errors in the data applied in E-PRTR indicators. No evidence of specific errors was identified, however, the evaluation of E-PRTR found weaknesses in data.[58] One industry stakeholder suggested that this indicator could be useful as a

[51] HSW_N2_01| Eurostat (europa.eu), HSW_N2_02 | Eurostat (europa.eu), HSW_N2_01 - Data Explorer (europa.eu), HSW_N2_02 - Data Explorer (europa.eu)
[52] NACE is the statistical classification of economic activities in the European Community, used to help identify different types of economic activities in the EU.
[53] Environmental Performance - cefic.org
[54] National Emission reductions Commitments (NEC) Directive emission inventory data — European Environment Agency (europa.eu)
[55] National air pollutant emissions data viewer 1990 – 2019 — European Environment Agency (europa.eu)
[56] Emission trends of acidifying pollutants (EU-27 - EU-15) — European Environment Agency (europa.eu)
[57] National air pollutant emissions data viewer 1990 – 2019 — European Environment Agency (europa.eu)
[58] https://ec.europa.eu/environment/industry/stationary/e-prtr/evaluation.htm

composite indicator if used in combination with a measure for chemical hazardousness, for example, to measure relative intensity of emissions over time.

10. EU27 Emissions of water pollutants (total organic carbon), EEA / E-PRTR[59]

This indicator utilises E-PRTR data to present total organic carbon (TOC) as an indication of the organic contamination load of wastewater. It therefore serves as a high-level indication of water quality, taking into account chemical emissions and other organic matter including bio-matter. It is also visualised by the EEA in an indicator which disaggregates the data by country and backdates to 2004 (presenting data for 2004, 2007, 2009, and 2012).

Whilst TOC provides an indication of aquatic health, it is not specific to emissions and risks from chemicals, therefore it may be less directly relevant to the transition to safe and sustainable chemicals in comparison to other indicators.

11. Industrial pollutant releases to water in Europe, E-PRTR / EEA[60]

This indicator tracks trends of EU industrial emissions of selected water pollutants, including certain heavy metals (cadmium, nickel, mercury, and lead), nutrients (nitrogen and phosphorus) and a global parameter to indicate the load of organic matter (total organic carbon). This is relevant to monitor safety and environmental sustainability based on trends in environmental exposure and emissions. This indicator measures specified industrial chemicals which can be mapped to specific chemical sectors, processes, and products. Therefore, it can act as a more granular measure of the chemicals sector than the abovementioned TOC emissions indicator.

The indicator is presented as an index benchmarked to 2010 levels which are set at a value of 100. It is updated annually, and current values are available for 2010 – 2019. At a country-specific level, percentage change in release of each pollutant is provided for the overall time period, allowing identification of countries which need to take further action to reduce emissions.

One interviewee highlighted that data quality for the chemical sector is limited as emissions are monitored at WWTP rather than directly from the chemical industry. The interviewee also suggested that the selection of pollutants monitored may not be best suited for the CSS. Instead, the stakeholder suggested that pollutants which meet the criteria of being SVHCs (substances of very high concern), E-PRTR monitored, and have enough representativeness (number of Member States, number of facilities reporting, frequency of reporting), should be monitored.

During consultation, an international organisation stakeholder suggested the proposal for an Industrial Emissions Portal Regulation that could result in more data than is currently reported in existing indicators on water emissions (i.e; E-PRTR data).[61] An EU agency was also supportive that new data under this regulation would allow for a more dynamic list of pollutants and a quicker introduction of new pollutants. The EU agency confirmed that the new proposal envisages a more dynamic process to introduce new pollutants in the scope of this Regulation, which would result in a quicker availability of data on emerging pollutants. The proposal is currently going through the co-decision process.

The EEA have proposed similar indicators more geared for the CSS, for example, selecting E-PRTR pollutants that were also SVHCs and well-reported. Gross value added and production volume was considered to normalise emissions. A finalised list of pollutants has not been agreed.

[59] Total organic carbon emission intensity of the chemical industry — European Environment Agency (europa.eu)
[60] Industrial pollutant releases to water in Europe (europa.eu)
[61] https://eur-lex.europa.eu/resource.html?uri=cellar:51908d0e-b5ad-11ec-b6f4-01aa75ed71a1.0001.02/DOC_1&format=PDF

In addition to this, indicators will be developed for the urban WWTP sector based on sector-level reporting obligations (not E-PRTR).

12. Harmonised risk indicator for pesticides (HRI1, SDG_02_51), Eurostat and DG SANTE[62]

This indicator estimates the trends in risk from pesticide use in the EU and its Member States as part of the EU SDG indicator set[63]. It is used specifically to monitor progress towards SDG 2 on ending hunger and malnutrition (a social aspect of sustainability) which is embedded in the European Commission's Priorities under the Green Deal, specifically in relation to the EU Farm to Fork Strategy[64] which aims to significantly reduce the use and risk of hazardous pesticides, as well as the use of fertilisers and antibiotics. The indicator is presented as an index relative to the average results for the period 2011–2013. The indicator is calculated based on statistics of the quantity of active substances placed on the market in plant protection products, provided to Eurostat by DG SANTE under Annex I of Regulation (EC) No 1185/2009 on statistics on pesticides[65]. Those data are categorised into 4 groups (based on level of risk) and multiplied by risk weighting factors for different groups of active substances.

The main limitation is the indicator's scope which only reflects one chemical sub-sector (pesticides). The indicator is a good example of one of the few relevant composite indicators but is too narrow in scope to be applied in isolation.

Summary

The indicators described above are listed below in a summary table.

Table 4.1 Summary table of the indicators considered for recommendation

Indicator number	Indicator name	Data source
1	Production and consumption of chemicals by hazard class	Eurostat
2	Consumption of chemicals by hazardousness	Eurostat
3	Greenhouse gas emissions by source sector	Eurostat
4	R&I spending by the EU27 chemical industry	OECD and ChemData international
5	Total energy consumption in the EU27 chemical industry	Eurostat
6	Total hazardous and non-hazardous waste in the EU27 chemicals industry	E-PRTR
7	EU+ State of enforcement of REACH/CLP	European Commission
8	Total number of accidents at work in the EU27 industry	Eurostat
9	EU27 acidifying emissions	E-PRTR

62 Statistics | Eurostat (europa.eu)
63 https://ec.europa.eu/eurostat/web/sdi
64 Farm to Fork Strategy (europa.eu)
65 Regulation (EC) No 1185/2009 of the European Parliament and of the Council of 25 November 2009 concerning statistics on pesticides (europa.eu)

Indicator number	Indicator name	Data source
10	EU27 Emissions of water pollutants (total organic carbon)	E-PRTR
11	Industrial pollutant releases to water in Europe	E-PRTR
12	Harmonised risk indicator for pesticides (HRI1)	Eurostat

4.3 Mapping of indicators against aspects of safety and sustainability

Table 4.2 shows the identified existing indicators mapped against the aspects of safety and sustainability to demonstrate to what degree (directly or indirectly) each indicator measures each aspect of safety and sustainability. Most of the aspects are only partly or very indirectly monitored by existing indicators.

Table 4.2 Aspects of safety and sustainability monitored by each of the existing indicators (D = directly monitored; I = indirectly monitored)

		Indicator number											
Dimension	**Aspect**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Safety	Production, importation, and use of safer chemicals	D	D				I						
	Reduced presence of hazardous chemicals in materials and products	I	I				I						
	Reduced emissions of hazardous chemicals									I	I	I	
	Reduced human exposure to hazardous chemicals							I					
	Reduced environmental exposure to hazardous chemicals									I	I		
	Substitution with safer alternatives												
	Increased transparency and safety reporting							D					
	Effective governance facilitating the transition to safer alternatives							D					
Environmental sustainability	Reduced atmospheric emissions			D		I							
	Reduced emissions to soil									I			I
	Reduced water emissions									I	I	D	
	Climate change mitigation			I		I							
	Reduced ecotoxicity impacts									I	I	I	I
	Reduced ozone depletion potential of substances												
	Reduced eutrophication impacts										I	I	I
	Reduced acidification impacts									D	I	I	I
	Reduced intensity of fossil resources consumption	I	I	D		D							
	Reduced intensity of mineral and metals consumption	I	I										
	Reduced land use intensity												I

		Indicator number											
Dimension	**Aspect**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
	Reduced water use intensity												
	Minimised ecological footprint of energy consumption			I		I							
	Transition to a circular economy	I	I				D						
	Protection and restoration of biodiversity and ecosystems									I	I	I	I
Social sustainability	Improved supply chain responsibility							I	I				
	Improved occupational health & safety								D				
	Improved human rights												
	Improved diversity and inclusion												
	Improved labour rights												
	Reduced human health impacts of chemicals												
	More training and education in sustainable chemistry												
	Increased transparency and sustainability reporting							I					
Economic sustainability	Reduced life cycle costs					I	I						
	Reduced externality costs							I					
	Reduced costs and improved profitability of safe and sustainable chemicals (and chemical products)												
	Increased market opportunities/market share for safe and sustainable chemicals												
	Increased research and innovation in safe and sustainable chemicals				D								
	Use of chemicals in sustainable solutions												
	Use of digitalisation to reduce the environmental footprint of chemical production												

4.4 Prioritisation of indicators and recommendations

The table below provides a comparison between the indicators in order to identify the most suitable ones which could be applied as KPIs to monitor the transition to safe and sustainable chemicals.

Table 4.1 Comparison between existing indicators which could be used as KPIs to monitor the industrial transition to safe and sustainable chemicals

Indicator	Relevance	Directness	Level of support from stakeholders	Any known issues with this indicator	Recommended for use as a KPI?
1. Production and consumption of chemicals by hazard class (online data code: ENV_CHMHAZ), Eurostat	Very high- addresses both safety of chemicals being produced and imported, as well as volume which is key to material consumption and the circular economy.	Very high- one of the most direct indicators related to hazards and production.	Mixed- was recommended as a 'most useful' indicator during interviews and the workshop due to its simplicity and ability to communicate both safety and circularity. However, others noted that the indicator has shown limited usefulness over the last decade.	Hampered by changing hazard classifications and improvements in identification and classification of hazards. identification/reporting. Granularity by specific hazard type is lacking. The hazard classification system could be improved. The production indicator fails to account for imports. Subtraction of exports from the consumption indicator may result in burden shifting (exports of hazardous chemicals).	Yes – The consumption indicator is recommended but suggested to not exclude exports. The carcinogenic, mutagenic, and reprotoxic hazard class is most useful, but overall, revision of the hazard classification is suggested (e.g., so that data can be focused only on SVHCs or most harmful chemicals (under the CSS), or to exclude substances with only physical hazards). Disaggregation by use type would be useful to allow focus on the more concerning substances, e.g., so that intermediates or substances used in closed systems could be excluded. The new baseline for such an indicator should be set once the CLP Regulation has been amended.

Indicator	Relevance	Directness	Level of support from stakeholders	Any known issues with this indicator	Recommended for use as a KPI?
2. Consumption of chemicals by hazardousness (EU 28 (sdg_12_10), Eurostat	Very high- as above.	Very high- as above.	Mixed- as above.	Similar issues to indicator 1, with less granularity for hazard classes.	No- This information is covered by the above indicator with better granularity (more options for hazard classification).
3. Greenhouse gas emissions by source sector (overall online data code: env_air_gge), Eurostat	Very high- addresses several environmental aspects, namely climate change mitigation and reduced fossil resources consumption.	Very high- directly measures fossil resource consumption and climate change mitigation.	High- some stakeholders suggested this is the most useful indicator, as it relates both to climate change and resource consumption. Some stakeholders thought the scope should be broadened to cover upstream and downstream sectors, not only chemical manufacturing.	Stakeholders raised concern regarding reporting inconsistencies between Member States. Scope 2 & 3 emissions not reported by some countries	Yes
4. R&I spending by the EU27 chemical industry, data from OECD and Chemdata International displayed as an indicator by Cefic	Medium- addresses increased research and innovation, but not specifically related to safe and sustainable chemicals.	Low- increased R&I spending does not reflect the quality and impact of R&I.	Medium- stakeholders raised concerns that the indicator is reliant on voluntary disclosure by the private sector; there is no information available to predict the continuity of data collection. Some stakeholders were very supportive of indicators covering investment.	Data by sub-sector is not presented over time.	No

Indicator	Relevance	Directness	Level of support from stakeholders	Any known issues with this indicator	Recommended for use as a KPI?
5. Total energy consumption in the EU27 chemical industry by source, Eurostat	Very high- addresses several environmental aspects, namely climate change mitigation and reduced fossil resources consumption.	Very high – direct measure of fossil fuel consumption and climate change mitigation.	High- the indicator was considered relevant. As with indicator 4, stakeholders disagreed over the scope of the indicator.	The indicator is not currently presented by Eurostat in a functional way (e.g., types of energy sources are in different datasets, the EEA presents an overall indicator, but it is not specific to the chemical sector). One stakeholder claimed there are data quality issues.	Yes- however, data quality assurance is required.
6. Total hazardous and non-hazardous waste in the EU27 chemicals industry, EEA / E-PRTR	Very high- addresses the aspect on transition to a circular economy.	High– transition to a circular economy is directly measured, and indirectly measures the safety of chemicals used in the EU.	Medium- issues related to data quality were raised. Engagement with industry to interpret this data accurately was suggested.	As mentioned by stakeholders, there are concerns over the quality of the data with errors and data assurance issues cited.	Yes- data quality assurance is required however.
7. EU+ State of enforcement of REACH/CLP, European Commission	High- addresses the aspect of effective governance facilitating the transition.	Low- this indicator does not directly indicate that chemicals in the EU are safer and more sustainable.	Mixed – while some stakeholders were against the inclusion of compliance, others suggested this is very useful.	Some of the component indicators are less relevant. The regularity of update of the indicator is unknown. Reporting between Member States is inconsistent (e.g., RAPEX alerts)	No– the indicator is too indirect and future availability uncertain.
8. Total number of accidents at work in the EU27 industry, Eurostat	Medium- the indicator is influenced by the safeness of chemicals used in the EU sector, however, the relevance of wider occupational	Low- the safety of chemicals is only one contributing factor to this indicator. Other physical hazards may skew the meaning of the indicator.	Low- limited feedback was obtained on this indicator, with one key comment that its scope is too broad therefore should not be used.	None identified.	No– the indicator is too indirect.

Indicator	Relevance	Directness	Level of support from stakeholders	Any known issues with this indicator	Recommended for use as a KPI?
	health and safety has been a point of uncertainty in this study.				
9. EU27 trends of acidifying emissions, EEA / E-PRTR	Medium- addresses only one narrow aspect which may be considered less relevant to the overall transition (reduced acidification impacts).	Medium- the indicator directly measures emissions but is unclear whether data specific to the chemical industry is available.	Medium- it was suggested that this indicator be part of a composite indictor in combination with a measure for chemical hazardousness. Another stakeholder noted that they had identified errors in this dataset.	Quality assurance of the dataset is required based on a stakeholder comment.	No- the aspect is narrow and emissions may ne unrelated to the safety and sustainability of chemicals being produced.
10. EU27 Emissions of water pollutants (Total Organic Carbon), EEA / E-PRTR	Medium- addresses reduced water emissions aspect. The indicator only covers pollutants which contribute to total organic carbon.	Low- total organic carbon is an indirect measure of water quality, therefore is influenced by factors other than chemical pollution.	Limited feedback was obtained, however, one stakeholder raised concern over the validity of E-PRTR indicators.	Quality assurance of the dataset is required based on a stakeholder comment.	No- the indicator is too indirect, and the below indicator covers this aspect to a better degree.
11. Industrial pollutant releases to water in Europe, E-PRTR / EEA	Medium- addresses reduced water emissions aspect and reduced emissions of hazardous chemicals aspect. However, only a few named chemicals are currently monitored. Proposed updates to this indicator will be more holistic in its approach.	High- the indicator is a direct measure of industrial emissions.	Limited feedback, one comment that non-chemical industry sources could influence this indicator.	This indicator is based on the E-PRTR database which stakeholders have raised concerns over quality assurance.	Yes - note that this indicator is currently being considered for improvement by EEA.

Indicator	Relevance	Directness	Level of support from stakeholders	Any known issues with this indicator	Recommended for use as a KPI?
12. Harmonised risk indicator for pesticides (HRI1, SDG_02_51), Eurostat and DG SANTE	Medium- addresses several aspects including reduced ecotoxicity impacts and reduced human health impacts of chemicals. However, the scope is too narrow as only a subclass of chemicals are covered.	High- the indicator covers the risks of substances placed on the market therefore is a very direct indication of the safety and sustainability of chemicals.	One stakeholder raised that limiting the measurement to a particular sub-sector of chemicals use was not a good indicator of the overall transition.	None.	No – scope is too narrow as only one chemical sub-sector is covered.

Based on the above comparison, the following four indicators have been recommended as useful existing indicators which could be used to measure the transition to safe and sustainable chemicals:

- Consumption of chemicals by hazard class (ENV_CHMHAZ), Eurostat;
  - This indicator could be improved through harmonisation of the hazard classification system and inclusion of exported chemicals (to avoid reflecting a shift in hazardous chemical production to non-EU countries).
  - The new baseline for KPIs should be set once the CLP Regulation has been amended (keeping in mind it will take several years until all chemicals are reclassified according to the new rules).
- Greenhouse gas emissions by source sector (overall online data code: env_air_gge), Eurostat;
  - This indicator is already functional.
  - It should be noted that this indicator is not always directly linked to the chemicals being produced and used and may be a result of a broader sustainability performance of the sector (i.e. energy consumption). Caution should be taken in using this indicator; for example, an inherently unsafe or unsustainable chemical could be produced using a better optimised or alternative process which does not satisfy some aspects of SSbD. Nevertheless, this still represents a transition to more safe and sustainable chemical production.
  - Further consideration required to assess feasibility of including indirect emissions across all member states.
- Total energy consumption in the EU27 chemical industry by source, Eurostat;
  - This indicator is already functional. Data reliability should be further checked.
  - As above, this indicator measures a broader sustainability performance of the sector. However, it does not reflect other sustainability issue related to energy consumption (e.g., land use impacts of renewable energy technologies).
  - There are concerns as to whether the scope of the indicator should extend beyond the chemicals sector to cover sustainable use of chemicals in other sectors.
- Total hazardous and non-hazardous waste in the EU27 chemicals industry, EEA / E-PRTR;
  - This indicator is already functional. Data reliability should be further checked.
  - Reduced waste production indicates circular economy implementation. This indicator should be contextualised so that it does not reflect an unsustainable diversion of hazardous material from waste to recycling.
  - Waste reduction could be caused by improved resource efficiency rather than a change in production method, chemical or product.
- Industrial pollutant releases to water in Europe, E-PRTR / EEA
  - This indicator is under consideration for improvement which will improve its functionality as an indicator to monitor the transition to safe and sustainable chemicals.

5. Recommendations for new indicators

5.1 Overview

This chapter identifies gaps in existing indicators in terms of aspects of safety and sustainability (section 3) which are not currently monitored. Based on gaps, and contributions from stakeholders, avenues for new indicators were explored. These include conceptual ideas and evidence of indicators currently being considered or developed under other initiatives.

The potential new indicators were appraised to give final recommendations, presented in the final part of this chapter.

5.2 Gaps in existing indicators

Based on an analysis of the existing indicators and the listed aspects (as shown in Table 4.2), it appears that most aspects are only indirectly monitored by existing indicators, or there are other problems limiting the existing indicators. For example:

- Effective governance is only partly covered by the indicator on REACH and CLP compliance, which only indirectly measures success and is limited by lack of regular update; and
- Indicators on energy consumption were identified, but not covering the full scope of energy consumption with minimised ecological footprint.

Some key aspects not monitored by the identified indicators include:

- Substitution of substances of concern with safer and more sustainable alternatives;
- Environmental impacts including ozone depletion potential of substances;
- Resource consumption aspects (land use, water use); and
- Most social and economic sustainability aspects.

5.3 Ideas for new indicators

The following new indicators are considered below: **environmental footprint** indicators (based on SSbD chemicals, registration requirements under REACH, eco-label, green claims, and the sustainable products initiative); indicators for **sustainable activities**; indicators on **recycling and secondary raw material use**; **economic** indicators; indicators on the presence of **substances of concern in products**; indicators on **innovation** (patents; eco-innovation; EU research programmes); REACH **authorisation applications**; **poison centre** notifications; poison centre calls; and **digitalisation**.

1. Environmental footprint indicators

Several ongoing initiatives relating to environmental footprint methods (i.e., methods to measure the environmental performance of a good or service throughout its entire life cycle) could be used to develop indicators for the transition to safe and sustainable chemicals. Some of these initiatives relate directly to chemicals (SSbD and environmental footprint requirements under REACH) and some relate more broadly to products and services, therefore may require adaptation (eco-label, green claims, and sustainable products). Environmental footprint indicators would be particularly useful as they cover life cycle environmental impacts, reflecting a number of aspects of safety and sustainability.

1.1. Safe and sustainable by design criteria

The safe and sustainable by design criteria being developed by the European Commission are directly relevant to the transition to safe and sustainable chemicals, with broad coverage of safety and sustainability aspects. Indicators could be produced to monitor several trends in regard to SSbD chemicals, e.g., the number, volume, or proportion of chemicals meeting the criteria, as well as the number of products containing SSbD chemicals or the number of products replacing substances of concern with SSbD chemicals. There was general support from stakeholders on this idea, although some stakeholders are not sure how safe and sustainable by design criteria will apply and therefore how an indicator could be developed. As the SSbD criteria are intended to act as guidance for research and innovation, such an indicator could be beneficial from a perspective of innovation (a key aspect of the CSS).

This indicator received support from most stakeholders in terms of its relevance to the transition. Stakeholders suggested such an indicator would be valuable because it frames the transition positively (i.e., focussing on increased substitution, rather than decrease in hazardous chemicals). However, industry stakeholders expressed concern over comprehensiveness and consistency of voluntary datasets.

A stakeholder from an EU agency suggested that focussing only on consumption of safe and sustainable chemicals may fail to cover all types of substitution, in particular, substitution with materials, products and services. They suggested that the overarching goal should be to move away from hazardous chemicals rather than focussing on substance-by-substance substitution.

Recommendations for indicators related to SSbD are limited by the current uncertainty of how the criteria will apply, for example, whether they will rely on self-assessment by companies and to what degree the standards will be taken up by industry (e.g., if voluntary, reporting may be low).

1.2. Environmental footprint requirements under REACH

Under the revision of REACH, there is a proposal to introduce environmental footprint information requirements within registration. This could help capture a wide range of aspects of sustainability. The feasibility of this indicator depends on the outcome of the revision of REACH. Such an indicator would be directly applicable to measure the sustainability of chemicals, and to measure the transition, such an indicator could look at annual trends in the average environmental footprint of newly registered chemicals (although only REACH chemicals could be monitored, and therefore trends for non-REACH chemicals such as pharmaceuticals, biocides, pesticides would not be reflected).

Notably, an Austrian competent authority presented a proposal to include sustainability indicators under REACH at the CARACAL-45 meeting on 06 July 2022 (presentation slides available on CIRCABC[66]). Further collaboration with this Member State may therefore be useful if REACH is considered as an information source for indicators.

1.3. Eco-label

The number of certified chemical products brought to market with eco-labels could potentially be used as a measure of the transition towards safe and sustainable chemicals.

[66] CARACAL (europa.eu)

The EU Ecolabel is awarded to products and services meeting high environmental standards throughout their life cycle, from raw material extraction, production, distribution and disposal[67]. Methods to measure and communicate the environmental performance of products (both goods and services) and organisations across their whole lifecycle, are available[68]. At present, over 83,000 products across 24 product groups in the EU market have the Ecolabel, encouraging producers to generate less waste and less CO_2 emissions during the manufacturing process.

It is expected that the safe and sustainable by design criteria, will incorporate similar environmental impacts as the Ecolabel which could further facilitate the development of a KPI to monitor the proportion of chemicals on the market which meet the criteria. The barrier to develop such an indicator currently is largely a lack of data, as there are no reporting systems/ requirement for companies to report the environmental performance of their products.

In addition to the availability of data, there are implementation challenges associated in introducing a labelling channel. The scope of chemicals/products which qualify to be labelled would need to be defined. This is particularly important should the eco-label be mandatory in which case there may be significant resistance from industry. A representative from DG ENV commented in feedback via email that the EU Ecolabel could be a good basis for an indicator, which was echoed by many stakeholders during consultation. However, one comment in the workshop raised concern that Ecolabels are granted for a fixed proportion of products which have the best environmental performance – relative to other products on the market. If this proportion is fixed, an indicator over time would not see and improvement of number of products achieving the status.

A stakeholder suggested that the methodology or criteria for granting eco-labelling could be updated in order to measure the number of applications or granted eco-labels over time. It was also noted that currently chemicals themselves cannot be labelled, only end-products.

1.4. Green claims initiative

This initiative will require companies to substantiate claims made around the environmental footprint of their products/services by using standard methods for quantifying them[69]. It is proposed that the initiative makes use of the proposed EU Product and Organisation Environmental Footprint methods[70] to measure the environmental performance of the product throughout its value chain and using 16 defined environmental impact categories. As such, the number of green claims per year for chemical products could be a potential new indicator.

1.5. Sustainable products initiative

The sustainable products initiative will introduce technical standards for sustainability for all products placed on the EU market.[71] These standards will take into account environmental and social impacts over the life cycle of products. Circularity aspects such as durability, re-usability, repairability, and recyclability will be included, as well as energy efficiency and the presence of harmful chemicals in products. This initiative will replace the Eco-design Directive, broadening the scope for products covered.

An indicator could be developed to monitor the performance of chemical products based on the level of sustainability they are achieving according to the technical standards.

Importantly, the eco-label, green claims, and sustainable products initiatives are not designed specifically to address chemicals.

67 EU Ecolabel - Environment - European Commission (europa.eu)
68 Environmental footprint methods (europa.eu)
69 Environmental performance of products & businesses – substantiating claims (europa.eu)
70 Environmental footprint methods (europa.eu)
71 https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12567-Sustainable-products-initiative_en

2. Indicators on the effectiveness of REACH

An international network established by a Member State authority suggested that new indicators could be developed based on the methodologies from the REACH baseline studies.[72] This would reflect the effectiveness of REACH in contributing to the transition to safer chemicals, an aspect which was supported by several stakeholders for monitoring.

Two REACH baseline studies have been conducted, one in 2012 and one in 2016. These present trends in risk reduction (‘risk scores’) and quality of data available for the assessment of chemicals (‘quality scores’) based on analysis of 237 reference substances considered representative of the chemicals available in the EU market. Risk scores are reflective of risk characterisation ratios, therefore, show changes in toxicity, emissions and predicted environmental and human exposure to chemicals on the EU market. As such, an indicator reflecting change in risk scores over time would demonstrate improvements in chemical safety.

However, in theory, the use of substances registered under REACH should be safe based on the chemical safety assessment required under the registration process. Low tonnage substances (1 – 10 tonnes per year) (for which chemical safety assessment is not required, and therefore could potentially have unacceptable risks) were seemingly not addressed under the baseline studies.

Creating such an indicator may also be challenging because the number of REACH chemicals has risen, and continues to rise, significantly. Therefore, identifying a ‘representative’ sample and extracting and analysing data from REACH registration dossiers may be difficult.

3. Indicators related to sustainable activities

Several suggestions from stakeholders referred to wider organisational / behavioural aspects of sustainability (rather than inherent sustainability of chemicals). For example, environmental economic accounting and sustainability reporting can be used as tools to monitor and report sustainable activities.

The number of chemical companies participating in sustainability reporting could be developed as a potential indicator. EU law requires large public-interest companies with more than 500 employees to engage with non-financial reporting on the way they operate and manage social and environmental challenges under the Corporate Sustainability Reporting Directive (CSRD)[73]. This covers approximately 11,700 large companies and groups across the EU, but no reference to chemical companies was identified.

The information gathered under the CSRD, such as GHG emissions, pollution emissions and extraction of natural resources, are within the scope of the CSS objectives. Although currently uncertain, it is predicted that most chemical companies will be required to report under the CSRD. Furthermore, the European Sustainability Reporting Standards are expected to bring guidance for the chemical sector. under the CSRD.

The use of environmental economic accounting was also suggested as an indicator to measure sustainable activities, specifically, through the economic contribution of the goods and services produced by the chemical industry that serve an environmental purpose. This could help monitor the aspect ‘use of chemicals in sustainable solutions’.

The environmental goods and services sector (EGSS) consists of all entities in their capacity as 'environmental producers', i.e., undertaking the economic activities that result in products for environmental protection and resource management[74].

[72] REACH Baseline Study, final report (europa.eu), REACH baseline study 10 years update - Publications Office of the EU (europa.eu), REACH BASELINE - 5 YEARS UPDATE (europa.eu)
[73] Corporate sustainability reporting | European Commission (europa.eu)
[74] seea_technical_note_-_egss_july_8_2016_draft.pdf (un.org)

There are a wide range of economic variables that can be considered in the context of EGSS activities but owing to the complexity of the measurements in this area, the focus is on key variables that give an indication of economic size and contribution of the EGSS. Thus, the main variables included are output, value added, employment, and exports, allowing for EGSS statistics to come directly from national accounts and associated data sets such as employment, with minimal adjustment. A guide has been produced by Eurostat outlining a methodology for EGSS accounts using existing data sources, most of them EU-wide sources[75]. Availability of data for the chemical sector is uncertain.

It is important to remember that increased spend in environmental management may not directly relate to the safety and sustainability of chemicals being produced by companies. Additionally, activities which constitute environmental protection and resource management in the chemical industry would need to be defined, which could be done by considering the economic activities under the EU Taxonomy Regulation,[76] and in the future, the red, amber, green classification system for activities based on environmental performance being developed by the EEA.

4. Indicators on recycling and secondary raw material use

The literature review highlighted an existing indicator which is not relevant to the chemical sector but could be taken as inspiration for an indicator on the transition to safe and sustainable chemicals, specifically in terms of circularity. For example, the Eurostat indicator on *Patents related to recycling and secondary raw materials (cei_cie020)*[77] is relevant to the transition to a circular economy but not specifically within the chemical sector. The indicator is used to monitor progress towards a circular economy and reduced consumption in terms of innovation. Data to generate this indicator is extracted by the JRC from PATSTAT (online database managed by the European Patent Office (EPO)) using relevant codes according to the Cooperative Patent Classification[78]. The indicator is presented as absolute number of patents as well as number of patents per million inhabitants. Data is available annually between 2000 and 2016. Date for expected update of the indicator is not clear. The indicator is part of the eco-innovation index[79] (further explored as its own indicator in the later part of this chapter on economic indicators) and would need to be adapted for the chemical industry specifically to increase its applicability.

Some concern regarding the meaningfulness of patent data was raised during consultation as the number of patents does not necessarily translate to success in uptake of new technologies; one NGO stakeholder suggested EU circular economy indicators such as production, consumption, waste management, secondary raw materials, and competitiveness and innovation could be adapted to create new indicators for the chemical sector by disaggregating by NACE code.

There was also a suggestion to develop an indicator to reflect monetary value added by the use of secondary raw materials in products. Another suggested that the number of countries achieving high levels of material circularity without toxic chemical recycling could provide a useful high-level indicator.

Several stakeholders suggested to consider indicators based on tools used for companies. For example, the World Business Council for Sustainable Development (WBCSD) has developed a circular economy programme[80] that creates new standards, tools, advocacy, insights and experiences to help companies move towards a circular economy. The Circulytics assessment from the Ellen MacArthur Foundation[81] was also recommended, for example, to measure how many companies achieve a good assessment. Company-level assessment tools suggested by

[75] 3196a7bc-c269-40ab-b48a-73465e3edd89 (europa.eu)
[76] EU taxonomy for sustainable activities | European Commission (europa.eu)
[77] Eurostat - Data Explorer (europa.eu)
[78] https://www.epo.org/searching-for-patents/helpful-resources/first-time-here/classification/cpc.html
[79] The Eco-Innovation Scoreboard and the Eco-Innovation Index | Eco-innovation Action Plan (europa.eu)
[80] https://www.wbcsd.org/Programs/Circular-Economy
[81] https://ellenmacarthurfoundation.org/resources/circulytics/overview

stakeholders are not designed to be applied as sectoral KPIs to measure the overall transition of the chemical industry but may be applicable if modified. For example, one stakeholder suggested that an indicator could be produced by sending a survey to companies. Such a survey could include sustainability assessment, however, information supplied would need to be validated to ensure reliability.

5. Economic indicators

The literature review revealed several functional economic indicators related to the chemical sector, available from structural business statistics on Eurostat[82], however, none focus specifically on sustainability, they only show general economic trends: for example, number of enterprises (V11110), production value (V12120), persons employed (V16130), share of value added in manufacturing total (V94210), and value added at factor costs (V12150). The Data Explorer allows the data to be filtered to the chemical sector using NACE codes (e.g. C20). The indicators are all provided in EUR million annually from 2005 to 2020. Furthermore, some of the indicators included are relevant for the social dimension of sustainability, such as V16150 on hours worked by employees.

If further contextualised, e.g., data were refined or calculated to incorporate other data on sustainability, new indicators could be developed. For example, V12120 would need to show production value of safe and sustainable chemicals, not all chemicals. Refinement beyond that allowed by the current NACE filters would therefore be required.

This idea was supported in interviews, where stakeholders from industry and NGOs also emphasised that looking at data specifically for different ‘types’ of chemicals (e.g., substances of concern, SVHCs, SSbD chemicals etc), e.g., to view the economic performance of safe and sustainable chemicals in comparison to those which are not safe and sustainable, allowing insight on the share of economic growth attributed to safer alternatives. One workshop participant stressed that neutral indicators such as one measuring ‘price-difference’ (between safe and sustainable chemicals and other chemicals) should be developed rather than ‘profitability’ for example.

Several stakeholders suggested that indicators looking at investment would be useful. For example, economic indicators to monitor the amount of investment in green chemistry education programmes.

GDP and jobs attributed to green chemistry were suggested to measure sustainable economic growth of the chemical sector.

The EEA is looking into indicators to measure sustainable finance based on the best available technique associated emissions levels (BAT-AELs). However, it is not clear how compliance with these will be reported.

Another stakeholder suggested that an indicator similar to one in the US on the market share of sustainable products[83] could be created in the EU for chemical products.

6. Indicators on the presence of substances of concern in products

In several stakeholder interviews and the workshop, it was suggested that the SCIP database (the database for information on Substances of Concern in articles as such or in complex objects (Products)) could be used to produce an indicator.

The SCIP database was established under the Waste Framework Directive. Companies supplying articles containing SVHCs on the Candidate List in a concentration above 0.1% weight by weight

[82] Eurostat - Data Explorer (europa.eu), Statistics | Eurostat (europa.eu)
[83] Sustainable Market Share Index™ - NYU Stern

(w/w) on the EU market have to submit information on these articles to ECHA. The SCIP database then ensures that the information on articles containing Candidate List substances is available throughout the whole lifecycle of products and materials, including at the waste stage. The database is made available to waste operators and consumers.

An indicator developed from the SCIP database could communicate the presence of SVHCs in articles over time, thus, representing the transition away from substances known not to be safe and sustainable – which may be interpreted as an indirect measure of the transition to safer and sustainable chemicals. However, other factors are more likely to influence the trend. For example, improvements in identification of hazardous chemicals would negatively influence the indicator. Moreover, a reduction in SVHCs does not necessarily mean an increase in safe and sustainable chemicals, as regrettable substitution could ensue, with other substances of concern being used to replace SVHCs in products.

A Commission working group for the CSS reviewed the potential use of the SCIP database to produce an indicator to track the presence of Candidate List substances in articles and concluded that this would not be suitable because of a large number of duplicates and gaps, including the limited coverage of SVHCs, the lack of methodology to assess and interpret trends[84]. The CSS emphasises EU policy ambitions to minimise the use of all substances of concern, not only Candidate List Substances. The information in SCIP is at the submission/notification level and, it is not currently possible to track unique articles or complex assemblies. Due to the architecture of the database, the information at the notification level includes a high level of duplicate submissions from duty holders, thus trends cannot be readily identified.

7. Indicators to measure research and innovation (R&I)

The transition to safe and sustainable chemicals relies on the creation and identification of new chemicals through research and innovation (R&I) to develop new technologies (e.g., products, processes, and services). No existing indicators were identified specifically focusing on R&I for safe and sustainable chemicals (the most relevant existing indicators are too broad in scope, e.g., R&I spending (OECD and Chemdata International) is not specific to safety and sustainability).

Potential new indicators related to R&I are explored below in terms of patents, eco-innovation, and EU research programmes.

Although some stakeholders expressed interest in innovation, others (from academia and industry) expressed concern that measuring innovation may have limited significance, as innovation may not necessarily translate to the uptake and use of safe and sustainable chemicals (e.g., depending on the success of innovation and the level of market uptake of new technologies). The limitation that effort/investment may not translate to outputs/impacts should be borne in mind when considering KPIs related to innovation.

7.1 Indicator on patents related to safe and sustainable chemicals

During consultation, there were numerous suggestions from stakeholders across most sectors that patents could be used to measure innovation in green and sustainable chemistry[85]. It was noted that the OECD has previously conducted work on patent indicators, including green growth indicators and areas for "environment-related technologies"[86] and a working group for the CSS are reportedly working on an R&I investment indicator.

[84] Unpublished document made available to the project team - Indicator fiche received as part of version 1 of the CSS framework.
[85] What Do Patents Tell Us about the Implementation of Green and Sustainable Chemistry? | ACS Sustainable Chemistry & Engineering
[86] https://www.oecd.org/env/indicators-modelling-outlooks/green-growth-indicators/

Based on the literature review, research into the number of patents related to green and sustainable chemistry over the past few decades in Europe (i.e., within the EPO), is lacking. However, a recent study by Constable, (2020) found that since 1990, out of 882,823 chemistry-related patents, only 12,473 unique patents were related to green and sustainable chemistry (according to America's patent allocation). In 1990, about 0.5% of patents granted that year were related to green chemistry, in comparison to approximately 1.5% per year by the end of 2019, with an average of 1.2% over the 30-year period[87]. In a similar vein, trends in patent applications related to sustainable chemistry could be monitored overtime to assess progress in innovation within the EU.

Existing patent classifications are not directly applicable to monitor patents related to safe and sustainable chemicals, although there are some relevant classes, for example, within the EPO system.

The EPO aims to support innovation, competitiveness, and economic growth across Europe through enabling inventors, researchers, and companies from around the world to obtain protection for their inventions in up to 44 countries[87]. This is completed through a centralised and uniform procedure consisting of a single application. An indicator could therefore be based on EPO patent applications.

At present, the EPO's Patent Index 2020 provides a summary of the trends in patent applications across technology fields. Of relevance is the number of patent applications in "Chemistry – Environmental technology" which experienced an -8% decline from 2019 to 2020. This technology field covers a number of international patent classification codes, some of which are relevant to the transition to safe and sustainable chemicals, as they reflect R&I and use of chemicals in sustainable solutions. These codes are:

- Relevant: B09B and B65F (related to waste management), B09C (reclamation of contaminated soil), C02F (treatment of wastewater/ sludge), E01F and F01N (related to reduced noise pollution), F23G and F23J (related to waste combustion); and
- Less clearly relevant: A62C (related to firefighting), B01D (related to separating techniques for liquids and gases), and G01T (related to spectroscopy techniques).

The relevant codes indicate chemistry technologies which contribute to sustainable solutions (waste management, toxic-free environment, and reduced noise pollution (and thereby harm to the environment and human health)). The indicator is currently limited in the context of this study which some of the codes included not directly relevant to the safe and sustainable chemicals strategy, as shown above. Furthermore, the publicly available data only presents the trend from 2019 to 2020 (which cannot be extrapolated to demonstrate the transition without ambiguity).

Further, the indicator is not comprehensive and could be improved by including some of the additional Cooperative Patent Classification codes, e.g., Y02P 20 includes climate change mitigation technologies within the chemical industry.[88]

[87] EPO - About us

[88] Relevant sub-classes include: Y02P 20/10 on process efficiency; Y02P20/129 on energy recovery, e.g., by cogeneration, H2 recovery or pressure recovery turbines; Y02P20/133 on renewable energy sources, e.g., sunlight; Y02P20/141 on feedstock; Y02P20/143 on the feedstock being recycled material, e.g., plastics; Y02P20/145 the feedstock being materials of biological origin; Y02P20/151 on reduction of greenhouse gas [GHG] emissions; Y02P20/20 on improvements relating to chlorine production; Y02P20/30 on improvements relating to adipic acid or caprolactam production; Y02P20/40 on improvements relating to fluorochloro hydrocarbon, e.g., chlorodifluoromethane [HCFC-22] production; Y02P20/50 on improvements relating to the production of bulk chemicals; Y02P20/52 on using catalysts, e.g., selective catalysts; Y02P20/54 on using solvents, e.g., supercritical solvents or ionic liquids; Y02P20/55 on design of synthesis routes, e.g., reducing the use of auxiliary or protecting groups; Y02P20/582 on recycling of unreacted starting or intermediate materials; Y02P20/584 on recycling of catalysts; Y02P20/155 on perfluorocarbons [PFC]; hydrofluorocarbons [HFC]. hydrochlorofluorocarbons [HCFC]; chlorofluorocarbons [CFC]; Y02P20/156 on methane [CH4].

Additionally, the classification C in the EPO database includes patents related to general chemistry, and therefore could potentially be used to indicate economic sustainability through innovation and competitiveness. This category is not specific to all safe or sustainable innovation, although some classes could be relevant. For example, C02F includes chemistry patents on the treatment of water, wastewater, sewage, or sludge, and is therefore relevant as it indicates R&I, as well as the social aspects of sustainability.

Constable (2020) suggests that a robust search strategy to analyse historical patent applications with connections to green and sustainable chemistry is difficult[87]. However, the EU could look into self-disclosure options by future patent candidates to denote application of chemically benign processes/products to measure the extent to which innovation-based research in green and sustainable chemistry is being translated into commercial reality.

7.2 Eco-innovation index

The Eco-innovation Index is a cross-sector indicator that could be adapted to the chemical sector to help measure the transition to safe and sustainable chemicals by monitoring environmentally sustainable innovation. The Index is a composite indicator obtained by taking an unweighted average of 16 sub-indicators through the following 5 dimensions:

- **Eco-innovation Inputs**: Investments (financial or human resources) aiming to trigger eco-innovation activities;
- **Eco-innovation Activities**: This includes indicators to monitor the scope and scale of the activities undertaken by companies, focusing on efforts rather than actual activity;
- **Eco-innovation Outputs**: These describe the immediate results of eco-innovation activities.
- **Eco-Innovation Resource Efficiency Outcomes**: These intend to increase the resource efficiency performance of sectors and countries; and
- **Socio-economic Outcomes**: These depict wider effects of eco-innovation activities for society and the economy.

The composite result for each Member State is then compared to the EU average through the European Eco-Innovation Scoreboard (Eco- IS)[89].

The Eco-innovation Index was suggested by stakeholders as an indicator which could be modified to target the chemical sector (currently, it is a cross-sector indicator which monitors environmentally sustainable innovation across Member States).

At present, the data set has perhaps too comprehensive a focus that may minimise the specific relevance to safe and sustainable chemicals. For some dimensions it may be more appropriate to incorporate sustainable/more benign chemical consumption under the criteria of a particular sub-indicator, whilst in others, application of dimension to the chemical sector as a whole may, be more appropriate. Current data for the Index is collected from Eurostat, the Eurobarometer Survey, Patstat, Scopus, the EEA, and other sources.[90] Feasibility of refining data collection to focus on the chemical sector would need to be investigated for each indicator in the Eco-innovation Index. Table 5.1 outlines the indicators included in the index, as well as a high-level assessment of applicability.

[89] The Eco-Innovation Scoreboard and the Eco-Innovation Index | Eco-innovation Action Plan (europa.eu)
[90] https://ec.europa.eu/environment/ecoap/sites/default/files/eco-innovation_index_eu_2019_technical_note.pdf

Table 5.1 Eco-Innovation Scoreboard Indicator Breakdown

Thematic area	Indicator	Source	Applicability
1. Eco-innovation inputs	1.1 Governments environmental and energy R&D appropriations and outlays	Eurostat	Medium- might be difficult to identify chemical related research.
	1.2 Total R&D personnel and researchers	Eurostat	Medium- might be difficult to identify chemical related research.
	1.3 Total value of green early-stage investments	Cleantech	High- but information likely difficult to locate.
2. Eco-innovation activities	2.1 Firms having implemented innovation activities aiming at a reduction of material input per unit output	Eurobarometer Survey (DG COMM)	High
	2.2 Firms having implemented innovation activities aiming at a reduction of energy input per unit output	Eurobarometer Survey (DG COMM)	High
	2.3 ISO 14001 registered organizations	ISO Survey of Certifications	Low
3. Eco-innovation outputs	3.1 Eco-innovation related patents	Patstat	High
	3.2 Eco-innovation related academic publications	Scopus	Medium- high levels of research activity do not necessarily translate to commercial applications.
	3.3 Eco-innovation related media coverage	Meltwater	Low
4. Environmental outcomes	4.1 Material productivity	Eurostat	High- Demonstrates the decoupling of economic growth from material consumption. High material productivity does not automatically imply low levels of absolute material consumption per capita.
	4.2 Water productivity	Eurostat	High
	4.3 Energy Productivity	Eurostat	High
	4.4 GHG emissions intensity	EEA	High
5. Socio-economic outcomes	5.1 Exports of products from eco-industries	Eurostat	High- information may be difficult to obtain.
	5.2 Employment in eco-industries	Eurostat	High – may be difficult to assess what qualifies as an ‘eco-industry’ in the chemical sector.
	5.3 Turnover in eco-industries	Eurostat	High – may be difficult to assess what qualifies as an ‘eco-industry’ in the chemical sector.

On inspection of data sources for the eco-innovation index, the Eurostat indicators on R&D, do not appear to be available by NACE code, i.e. by sector. Government budget allocations for R&D [gba_nabsfin07] can only be disaggregated by socio-economic objectives.[91] For the patent sub-indicator, the technical note provided on the eco-innovation webpage only details that the indicator is based on OECD's scoping of patents in environmentally related technologies, and the PATSTAT database of the European Patent Office, but no links or direct references are provided. Sub-indicator 3.2 on eco-innovation related academic publications, is currently sourced based on a key word search of Scopus (eco-innovation, energy efficient /efficiency, material efficient/efficiency, resource efficient/efficiency, energy productivity, material productivity, resource productivity), which could be modified to address safe and sustainable chemicals.

Eurostat data on gross value added in environmental goods and services (i.e., goods and services produced for environmental protection or resource management) is also utilised by the Index. This data is available disaggregated to 21 NACE codes, but currently also not to a fine enough level to allow for disaggregation to the chemical sector.

Although data are reported by Member States, ultimately the data will likely need to be gathered from chemical companies through self-disclosure; the extent to which the required information will be possible to obtain is unclear, as is what legal mechanisms the Commission can deploy to ensure chemical companies comply with disclosure.

7.3 Indicators related to EU research programmes

A CSS working group at the Commission are developing an R&I investment indicator through the Processes4Planet (P4Planet) Partnership, a partnership which aims to transform the cement, chemical and steel industries, amongst others, to achieve circularity and overall climate neutrality at a regional level by 2050, while still yet enhancing global competitiveness[92]. P4Planet is a public-private Partnership established between A. SPIRE – the private entity – and the European Commission in the context of the Cluster 4 (Digital, Industry and Space) of the Horizon Europe funding programme. The following KPIs are defined for the partnership and will be included in the monitoring and reporting[93]:

- Capital expenditures (CAPEX)- i.e., funds used to undertake new projects or investments by a company- and Operating Expenses (OPEX)- i.e. the day-to-day expenses a company incurs to keep its business operational- reductions through the new innovations;
- Marbles (First-of-a-kind plants at Technical Readiness Level (TRL) 9)- A. SPIRE members have indicated their intention to invest in First-of-a-kind (FOAK) large scale plants of one or more new technologies, integrated within the value chain(s), and deployed by the process industry. The goal is to bring the FOAKs to TLR9- System Test, Launch and Operations- to confirm the market potential of the innovations termed 'Marbles'*;* and
- Number of new jobs and job profiles.

Such indicators would be appropriate to monitor the objectives of the CSS. Additionally, the EU chemical industry is reportedly struggling with low levels of investment in new capacity[94] and thus monitoring of CAPEX and OPEX, and identifying specific shortfalls along the value chain, would aid in helping the industry to maintain global competitiveness. The chemical industry would need to disclose this information, which would require the creation of an appropriate platform. For the

[91] Government budget allocations for R&D (GBARD) (gba) (europa.eu), Eurostat - Data Explorer (europa.eu)
[92] About Processes4Planet | SPIRE (aspire2050.eu)
[93] c_2021_4113_f1_annex_en_v3_p1_1213806.pdf (europa.eu)
[94] Chemicals (europa.eu)

chemical companies not under the scope of the P4Planet programme, the Commission can extend requests for participation and disclosure of data.

Horizon Europe is an EU funding programme for research and innovation with a budget of €95.5 billion to address climate change, help achieve the UN's Sustainable Development Goals and boosts the EU's competitiveness and growth[95]. The aim of the programme includes job creation, engagement of the EU's talent pool, boosting economic growth, promoting industrial competitiveness, and optimising the investment impact within a strengthened European Research Area. The EU LIFE Programme is a €290 million fund for nature, environment, and climate action projects[96]. The new LIFE projects intend to help Europe become a climate-neutral continent by 2050, recover Europe's biodiversity by 2030, and contribute to the EU green recovery post-COVID-19.

The number of safe and sustainable chemical research programmes in both of these EU funded initiatives has been suggested as a potential indicator. This data is available in the public domain but, according to an individual from an EU institution, is not currently usable as an indicator and would require a data mining tool. In the stakeholder interview, concern was raised around the difficulty and resource demands to identify and process the data. Another suggestion was to create an indicator to monitor the extent of private sector involvement in EU research initiatives.

8. REACH authorisation applications

The number of REACH authorisation applications has been suggested as a potential indicator. This would reflect the demand for and use of Candidate List substances (SVHCs), therefore, a reduced number of authorisation applications may reflect a transition away from harmful chemicals. As with the SCIP database, the use of authorisation applications as an indicator is limited by indirectness, as there may be several other contributing factors. For example, if more substances are added to the Candidate List and authorisations applied for, this may reflect better identification of SVHCs which would be a positive step towards the transition to safe and sustainable chemicals. That is, more applications might reflect better regulation of SVHCs rather than more use of SVHCs.

Recommendations for indicators based on REACH are limited by the uncertainty regarding the on-going revision of the legislation. For example, if the authorisation title is removed, this indicator would not be possible. One stakeholder suggested that the authorisation process is too limited to be used as a useful indicator.

9. Poison Centre Notifications (PCNs)

Under Article 45 of the CLP Regulation should a company wish to place on the EU market hazardous mixtures, classified as hazardous on the basis of their health or physical effects, the company is obliged to provide information to a relevant national body[97]. The national bodies then make this information available to poison centres so that in the event of an emergency, the centres can give advice to citizens or medical personnel. Measuring the number of PCNs across the EU, was suggested as an indicator by an EU institution / agency stakeholder

Some limitations to this indicator would be that export-only products are not required to oblige. Additionally, only mixtures with human health hazards are subject to submission obligations, and therefore, this indicator would overlook safety in terms of the environment[98]. Thus, to meet the overarching aims of the CSS vision in reducing the production of hazardous chemicals, the scope currently contained in PCN obligations would need to be extended.

95 Horizon Europe | European Commission (europa.eu)
96 LIFE Programme (europa.eu)
97 About us – Poison centres - ECHA (europa.eu)
98 How to Comply with New Poison Centre Notification Requirements for Hazardous Mixtures in EU (chemsafetypro.com)

10. Poison centre calls

Measuring and monitoring the number of calls received annually by EU poison centres, was suggested as an indicator. In the EU, poison centres answer at least 600,000 calls per year from the general public or physicians (about 1,700 calls per day). Lower number of hazardous chemicals, particularly within consumer products, could translate into reduced accidents and subsequently reduced calls. This would further be relatively inexpensive to implement as the data is also already available with ECHA. However, such an indicator would be influenced by calls unrelated to chemical accidents (e.g., technical requests and test exercises).

The data from such an indicator may not be entirely reflective of the CSS transition as approximately half of all calls are related to accidental exposure involving children[99]. This suggests that accidents are as a result of ingestion or high levels of exposure, which might occur to a similar degree even with less hazardous chemicals in consumer products. Ultimately, the number of poisoning centre calls are not only dependent on the safety of chemicals produced in the EU, but also on how chemicals are handled. Thus, a reduction in calls could be due to improvements in the safe handling of chemicals, rather than improvements in the inherent safety of chemicals on the EU market.

There is noted uncertainty whether the scope of safety under the transition to safe and sustainable chemicals should focus only on the inherent safety of chemicals (hazardous properties) or also include safe chemical handling.

11. Digitalisation

Digitalisation is a key aim of the CSS and a powerful tool that can be deployed to aid the transition towards safe and sustainable chemicals. Digitalisation is slow to propagate in the chemicals sector and there remain significant opportunities to potential to use digital technologies in the chemical industry[100]. However, given the increased customer demand for leading-edge products and the threat of frontrunner start-ups in the sector, digital development has increasingly become a business strategy rather than simply an IT function[101]. Digitalisation can be used to optimise chemical processes and identify new molecules and production methods through the use of machine learning potentially resulting in numerous SSbD benefits including more inherently safe chemicals, safer reaction pathways, and efficient operation. Digitalisation can also enable deeper understanding of chemical supply chains and develop decision support tools to enable more sustainable choices[102]. Technologies like AI and blockchain can support increased worker safety, new business models, improve the scientific-technical evaluation process and comply with regulation, enable research data exchange and open science[103].

Therefore, the transition to safe and sustainable chemicals as a result of digitalisation would be a useful indicator. However, measuring the benefits as a result of digitalisation at a sector level is challenging. The widescale deployment of digitalisation requires rapid development of standards for chemical data and knowledge models, as well as the adoption of scalable infrastructure for data sharing and sustainability assessments. Data on the level of adoption is therefore not yet collected at a sectoral level[102] and linking this to sustainability benefits is challenging.

Existing tools that measure digitalisation at a wider level could be used as a proxy to indicate the transition to safe and sustainable chemicals. For example, the OECD's Toolkit for Measuring the Digital Economy report contains more than 30 key existing indicators and methodology proposals

[99] https://ec.europa.eu/growth/sectors/chemicals/poison-centres_en
[100] Deloitte, 2019, Achieving the next frontier of chemicals excellence - Digital maturity model to help ease the transition
[101] Strategy&, Chemicals Trends 2018-19, https://www.strategyand.pwc.com/gx/en/insights/industry-trends/2018-chemicals.html
[102] Fantke, P. et al (2021) Transition to sustainable chemistry through digitalization
[103] Accenture, 2019, AI & Blockchain: Chemical industry insights and actions

to monitor and assess the size and penetration of the digital economy[104]. However, this indicator is not contextualised in the frame of sustainability and does not provide a direct measure of the chemical industry. Nevertheless, within the Toolkit, the indicator 'value added of information industries', could be modified to the value added of information departments in chemical companies. To further gain an insight into the digitalisation capacity of the industry, the following indicators, also contained within the 'Toolkit' could be considered:

- ICT-related patents [for chemicals];
- Business enterprise expenditure on R&D and information industries; and
- ICT staff size.

Aside from ICT-related patents for chemicals which, could be measured using a similar approach as to measure patents related to safe and sustainable chemical products and processes as already discussed, the other indicators would largely depend on self-disclosure by companies[105].

5.4 New indicators being explored under other initiatives

The identification and development of indicators should be undertaken bearing in mind the on-going developments under other initiatives which could be used in the future for KPIs to measure the transition to safe and sustainable chemicals. This section details some of the other on-going or anticipated work taking place related to the transition to safe and sustainable chemicals, based on sources available to the project team, to guide future work and collaboration which may be beneficial to this topic.

This section includes description of a prototyped indicator by **ECHA**; **Cefic**'s Sustainable Development Indicators; EEA and global work on **biodiversity** indicators; EEA work on **zero pollution** and **water emissions**; EU work on **carbon intensity**; and reference to the **Strategic Approach for International Chemicals Management**.

12. ECHA's relative change in the number of substances identified as substances of concern (reference: TS1-4)

The following two separate indicators are currently being considered for development based on a proposal from a CSS working group at the Commission. The indicators will be prototyped in late 2022 in order to measure both the effectiveness of authorities in identifying substances of concern and the progress of industry in implementing safe and sustainable by design products. The indicators include:

A) Number of substances identified as substances of concern after the substances were first known to authorities (relative change/trend over time)

B) Number of substances already identified with substance of concern hazards at the time they become known to authorities (relative change/trend over time)

The objectives of indicators A and B are to promote SSbD chemicals, materials and products and clean production processes and substitute substances of concern as much as possible. Indicator A has the further objective of minimising and controlling the risks through stepping up risk management measures for hazardous chemicals on the EU market (including from imports).

The indicators will be based on registration and process data that are already available. The processing of these data to produce the indicators will be carried out by ECHA. Updates of the indicators are likely to be limited by the updates of registration dossiers (typically annually).

[104] G20-Toolkit-for-measuring-digital-economy.pdf (oecd.org)
[105] What the Commission is doing (europa.eu)

Enforcing more frequent dossier updates, or enforcing that dossiers are updated if new use and exposure information is available would improve the time responsiveness and reliability of the indicators.

REACH registrations provide the required information regarding number of substances, hazard information as well as uses. A methodology for identifying or defining substances of concern, and interpreting trends is yet to be established.

The separation of the indicators is based on the time the substances become known to authorities. For example, a substance may be first registered under REACH and only later on be identified with a particular substance of concern hazard. Another substance may already be identified with a particular SoC hazard at the time of registration. The substances can be further filtered based on reported uses (e.g. consumer uses), regulatory status, etc.

Downstream uses covered by granted authorisations are currently recorded by ECHA[106]. The data set only presents substances for which there are upstream authorisations since 2016 (currently 18). They include authorisations applied for by the manufacturers and importers of chemicals covering their downstream uses and sometimes their own use. As with the abovementioned indicators, the number of authorisations is likely to change as more chemicals are listed as SVHCs, therefore must be interpreted carefully to provide a contextualised picture of the transition. This is already demonstrated in the existing data as the number of authorisations grew significantly between 2020 and 2022 as additional substances were added. Furthermore, the dataset does not provide volumes of use therefore it does not provide the scale of use of these chemicals. Nevertheless, this data is useful to identify whether the use of specific substances is decreasing.

It should be noted that REACH does not cover all chemicals (e.g pharmaceuticals, agricultural chemicals, etc.), therefore additional reporting obligations under other legislation or better integration of existing legislation would be needed to overcome this limitation.

13. Cefic's Sustainable Development Indicators (SDIs)

Cefic's collection of SDIs are being developed to reflect how the European chemical sector is contributing to the transition towards a safe, resource efficient and circular economy within a climate-neutral Europe[107].

The SDIs are organised around the four sustainability focus areas of Cefic's Sustainability Charter: Create, Conserve, Connect and Care. In each of the four areas, key industry activities have been identified which will be further developed to represent all key Cefic recognised industry activities by 2023. The focus areas are:

- **Create** low carbon economy; these indicators are centred on energy consumption and energy efficiency;
- **Conserve** resource efficiency; indicators here seek encourage alternative material design to reduce waste and improve resource efficiency;
- **Connect** circular economy; indicators here aim to monitor progress towards the circular economy; and
- **Care** for people and planet; these indicators aim to address both social and environmental issues.

The indicators are being developed over the course of 2020 to 2023 based on existing frameworks for sustainability reporting. A draft proposal for final list of Sustainable Development Indicators was provided to the WSP project team in June 2022 in which a longlist of indicators was narrowed

[106] Downstream uses covered by granted authorisations - ECHA (europa.eu)
[107] Cefic Sustainable Development Indicators - cefic.org

down to 50 indicators to take forward for further investigation at various levels of development. Of these, 14 were already published on the Cefic website, 8 had identified available data but analysis was yet to be undertaken, 10 'probably' had available data but analysis was yet to be undertaken, 7 could be developed based on company-reported data (based on the draft European Sustainability Reporting Standards) and 11 were at an early stage of development and required further investigation. Cefic suggested in an interview that the final list of their indicators will be available in September 2022, including suggestions for how to collect data.

The indicator mapping exercise by Cefic shares similarities with this project, for example, the indicators listed are largely sourced from Eurostat and the E-PRTR database. During the stakeholder interview with Cefic, it was mentioned the organisation was interested in developing the circular economy indicators currently available at EU level for the chemical industry[108].

14. Biodiversity indicators

During consultation, biodiversity was suggested as an important environmental aspect by NGOs as it is influenced by several other aspects (emissions, exposure etc.)

The EEA (European Topic Centre on Human Health and the Environment and European Topic Centre on Biodiversity) is undertaking a scoping study to propose an indicator on chemical impacts on terrestrial ecosystems. It will propose a methodology and identify relevant datasets that could support the production of such an indicator[109].

Ongoing work on global biodiversity targets (e.g; the 'Post-2020 Global Biodiversity Framework'[110]) may also have relevance to the EU transition as it contains targets related to chemicals including pollution.

15. EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil'[111]

Indicators proposed to monitor the zero-pollution action plan[112] are mentioned within Annex 2 of the recently released European Commission 'Towards a monitoring and outlook framework for the zero-pollution ambition' report, to be developed by 2024 or beyond[113]. The report identifies an indicative list of indicators to be explored to cover chemical pollution, including Indicator 1 on chemical pollution of groups of priority substances (EEA and ECHA using the INSPIRE mechanism (infrastructure for spatial information in Europe to support environmental policies)[114] and linked to the Information Platform for Chemical Monitoring[115])[113].

16. Sustainable carbon cycles and carbon intensity

Carbon consumption is relevant to the sustainability of the chemical sector for two key reasons: 1) chemical production is energy intensive, driving consumption of **fossil fuels** for energy; and 2) chemical production is material intensive, driving consumption of **fossil resources** to produce organic chemical feedstocks.

The first issue is addressed by existing indicators on greenhouse gas emissions. However, stakeholders suggested that intensity, as well as absolute volume, would be useful to show trends

[108] Indicators - Circular economy - Eurostat (europa.eu)
[109] This insight was gained through a report completed by WSP and partners for the European Environment Agency (EEA) to provide support in undertaking a review of potential indicators to be used in the planned 2022 Zero Pollution Monitoring Framework Assessment,
[110] iucn_proposed_targets_based_on_sbstta23-2-add.4_121119.pdf
[111] 20210324_Draft_SWD_ZP_monitoring-outlook_V6.1-ISC LWformat (europa.eu)
[112] https://environment.ec.europa.eu/strategy/zero-pollution-action-plan_en
[113] 20210324_Draft_SWD_ZP_monitoring-outlook_V6.1-ISC LWformat (europa.eu)
[114] https://inspire.ec.europa.eu/inspire-directive/2
[115] https://ipchem.jrc.ec.europa.eu/

in fossil fuel consumption in the context of economic growth, i.e., to show the decoupling of economic growth from carbon intensive processes.

Such an indicator is being investigated by the EEA to monitor greenhouse gas emissions per unit (EUR) marginal revenue within the chemical sector. In communications with the EEA, it was indicated that, as of November 2024 (first reporting year: 2023), production data in "tonnes of products" will be made available through E-PRTR which can be used to show emissions intensity (emissions per tonne of product produced) at a sectoral level. The carbon intensity indicator has also been evaluated by chemical sub-sectors (agricultural, basic and speciality), and therefore could have high value in granularity allowing targeted action within the chemical industry in sub-sectors.

It is recommended that any indicator on carbon intensity should be viewed alongside indicators for absolute emission volumes, as an overall reduction is important for climate change mitigation regardless of economic trends.

Regarding the second issue, on fossil resource consumption, no existing monitoring system was identified. Notably, the European Commission has adopted an action plan on sustainable carbon cycles to address carbon consumption, emissions, and removal from the atmosphere. The action plan includes a target that at least 20% of carbon used in industrial products should be from sustainable non-fossil sources by 2030.[116] Therefore, monitoring of this target for the chemical sector could be particularly valuable to reflect sustainable resource consumption. Monitoring may be possible following the implementation of the CSRD (see section 5.3 on indicators related to sustainable activities), if information on non-fossil carbon consumption is included in reporting requirements.

At this stage, it is unclear whether the carbon intensity indicator being investigated would address only fossil fuel consumption or whether it would also address fossil resource consumption. For example, whether it would take into account carbon consumption for producing feedstocks, so-called "molecular carbon" embedded in chemical materials and products.

Stakeholders also highlighted the importance of monitoring the type of energy source used in terms of overall sustainability, not only renewability (e.g., to consider impacts on land and water use etc.), a consideration which would be relevant when monitoring the transition to non-fossil energy sources.

17. Strategic Approach to International Chemicals Management (SAICM)

In early 2020, the United Nations Environment Programme (UNEP) released an assessment of chemicals and waste management's linkages with other issues identified as clusters[117]. These include health, world of work, biodiversity, climate change, agriculture and food, sustainable consumption and production, and human rights. The report recognised the need for a multi-sectoral and multi-stakeholder cooperation to advance the sound management of chemicals and waste and the SDGs.

Consideration of SAICM was suggested by an interviewee, who noted that although delayed by COVID-19, as part of the programme, a framework on the sound management of chemicals and wastes beyond 2020 is under development. This will include recommendations for a process to establish indicators[118], thus progress in SAICM should be monitored as part of developing CSS

[116] Sustainable carbon cycles (europa.eu)
[117] UNEP Assesses Links between Chemicals and Waste Management and Other Issues | News | SDG Knowledge Hub | IISD
[118] https://sdg.iisd.org/news/virtual-working-groups-advancing-beyond-2020-chemicals-framework/#:~:text=Officials%20have%20established%20four%20working%20groups%20to%20help,on%20Chemicals%20Management%20%28ICCM5%29%20planned%20for%20July%202021.?msclkid=f00fadb7c21a11ec8ca7c9315c0a6561

objectives and aligning the strategy with international efforts around the safe management of chemicals.

A stakeholder from an international organisation suggested that aligning indicators with SAICM could be important to ensure that the EU shares the same goals as the global sustainability agenda. Further developments currently taking place might be of value to future work on indicators for the CSS[119].

5.5 Suggestions for new indicators

Table 5.2 lists the new indicators considered for recommendation, based on the above text. Indicators highlighted green have been carried forward for recommendation.

Table 5.2 Key reason(s) for recommendation or exclusion of new indicators

Indicator	Key reason(s) for recommendation or exclusion	Recommended or excluded
Production value/market share of safe and sustainable chemicals	• This indicator could utilise the anticipated safe and sustainable by design criteria to identify safe and sustainable chemicals. This is directly relevant to the transition and is expected to have holistic coverage of the aspects of safety and sustainability. Social and economic aspects may not be covered under the criteria (which are not available at the time of writing), however, framing this indicator in terms of production value and market share allows the economic dimension to be covered. • The main limitation with this recommendation is the current uncertainty on how the SSbD criteria will be implemented.	Recommended
Eco-innovation index for safe and sustainable chemicals	• Indicator could be modified to target the chemical sector. This is recommended as a good reflection of innovation in safe and sustainable chemicals which would allow comparison between Member States' performance. • The main limitation with this recommendation is the uncertainty whether granular data is available to allow focus on the chemical sector. For some of the indicators applied in the overall index (based on Eurostat and EEA data), this is predicted to be feasible, but for others (e.g., private sector indicators), this may not be feasible. Furthermore, the reliability of private sector data may present a concern.	Recommended
Number of safe and sustainable chemicals on the market	• This indicator could utilise the anticipated safe and sustainable by design criteria to identify safe and sustainable chemicals. This indicator would complement the other proposed indicator on production value/market share, as it would reflect the rate and breadth of uptake of the criteria (for example, more	Recommended

[119] Virtual Working Groups Advancing Beyond 2020 Chemicals Framework \| News \| SDG Knowledge Hub \| IISD

Indicator	Key reason(s) for recommendation or exclusion	Recommended or excluded
	SSbD chemicals could be indirectly indicative of more chemical uses across sectors involving SSbD chemicals. ● This indicator may be considered limited as it does not take into account safer alternatives at a material or service level. This indicator could be modified to measure the number of safe and sustainable chemical alternatives (including SSbD chemicals, materials, and products), however, data collection for such an indicator may be too complex.	
Number of substances of concern on the market	● ECHA are prototyping two indicators on the relative change in the number of substances identified as substances of concern. The overall change in number of substances of concern could be used to reflect substitution with safer alternatives (a key aspect of the transition). In particular, this could complement the above recommended indicator by allowing direct comparison of the 'types' of chemicals (SSbD and substances of concern). ● Similar concerns to this indicator as raised for 'Presence of SVHCs in products'	Recommended
Production and consumption of chemicals by type (including safe and sustainable chemicals and substances of concern)	● This indicator is suggested to reflect the volume of different types of chemicals produced and used in the EU. Monitoring volume is suggested because use volume is a contributing factor to the predicted risk of hazardous chemicals (e.g., emissions and exposure are more likely), therefore, this would be valuable to monitor substances of concern. For safe and sustainable chemicals, this would be a good indication that SSbD chemicals are being taken up by the market to a high degree. For example, an increase in number of safe and sustainable chemicals may not be sufficient to indicate the transition if these chemicals are only used at very low volumes.	Recommended
Number of ecolabelled chemical products	● Concern that only end-products are included (not individual chemicals). ● Concern that the eco-label applies to a fixed proportion of products and therefore change over time in number of products meeting the criteria is not expected (only if overall number of products increases).	Excluded
Effectiveness of REACH in reducing chemical risks	● The method applied under the REACH baseline studies for estimating the influence of REACH on chemical risks over time was not considered appropriate as it mostly reflects trends in the risk characterisation ratios of REACH registered substances. To be registered under REACH, substances should have risk characterisation ratios which demonstrate adequate	Excluded

Indicator	Key reason(s) for recommendation or exclusion	Recommended or excluded
	control of risks, therefore, this indicator may not be as meaningful as other indicators focusing specifically o hazards of concern.	
Number of products without hazardous chemicals (e.g., based on number of green claims or number of products meeting technical requirements under the sustainable products initiative)	• This indicator could be developed based on the green claims initiative or sustainable products initiatives, however, the feasibility is uncertain at the time of writing based on uncertainties regarding how the initiatives will be implemented.	Excluded
Patents related to recycling and secondary raw materials in chemical products	• Concern regarding the meaningfulness of patent data as the number of patents does not necessarily translate to success in uptake of new technologies by the market.	Excluded
Number of countries leading in the circular economy without toxic chemical recycling	• Achieving a circular economy and preventing the recycling of toxic chemicals in materials are key aims of the CSS, therefore a related indicator would be highly beneficial, however it is very unclear how such an indicator would be developed. For example, how it would be determined that countries are leading in the circular economy and how it would be measured that recycling systems do not recycle toxic chemicals.	Excluded
Number of companies achieving good sustainability assessment using existing business assessment tools (e.g. Circulytics, ChemScore)	• This indicator would reflect the overall sustainability of chemical companies which may be less relevant to the safety and sustainability of chemicals being produced. This indicator is not recommended as the stakehoders are divided on whether the scope should focus on the inherent safety and sustainability of chemicals or look at wider organisational aspects of safety and sustainability. ChemScore may be more relevant but relies on self-reporting by companies and therefore may not be reliable.	Excluded
Investment in green chemistry education programmes	• Concern that a measure of ‘effort’ may not translate to effectiveness in the transition.	Excluded
Jobs created in green chemistry	• Concern over difficulty in defining and measuring 'green' jobs.	Excluded
Profitability / price difference of chemicals by type	• Production value/market share is considered a better indicator to monitor this same aspect (economic sustainability),	Excluded

Indicator	Key reason(s) for recommendation or exclusion	Recommended or excluded
Chemical impacts on terrestrial ecosystems	• The time lag between production, emissions and impacts means that this indicator would not be suitable for monitoring change in production.	Excluded
Carbon intensity indicator	• This indicator is being developed by the EEA and would help frame how carbon intense chemical production is. It is recommended to include both fossil consumption for energy and fossil consumption for feedstocks, i.e., "molecular carbon". • This indicator should be viewed alongside overall GHG emissions as a more meaningful measure of the overall contribution of the chemical sector to climate change.	Recommended
Presence of SVHCs in products	• This indicator was assessed as not suitable by a CSS working group at the Commission due to shortfalls in the SCIP database.	Excluded
Patents for chemicals used in sustainable solutions (the codes B09B and B65F)	• Patent data in general was questioned by stakeholders in terms of ability to demonstrate the transition, as number of patents does not necessarily reflect uptake of new technologies.	Excluded
Patents for climate change mitigation in the chemical sector	• As above.	Excluded
Number of REACH authorisation applications	• The REACH regulation is currently under revision and removal of the authorization title is a policy option (which would render this indicator not usable). • There was also concern that indicator would be negatively influenced by improvements in banning hazardous chemicals, as this would be a positive step towards the transition but would also likely be accompanied by increased requests for authorisations.	Excluded
Number of poison centre notifications	• Concern that export-only products are not required to oblige. and certain mixtures, e.g., with environmental hazards only, are not required to oblige.	Excluded
Number of poison centre calls	• Concern that calls unrelated to chemical accidents would be captured (e.g., technical requests) and that many calls relate to the safe handling of chemicals rather than the inherent safety and sustainability of chemicals. Stakeholders are divided on whether safe handling of chemicals should be included as an aspect to monitor the transition, therefore this is deemed less relevant.	Excluded
Number of chemical companies partaking	• Concern over the reliability of self-reporting.	Excluded

Indicator	Key reason(s) for recommendation or exclusion	Recommended or excluded
in sustainability reporting	• Sustainability reporting is a key aspect but is not directly indicative that safe and sustainable chemicals are being produced.	
R&I spending on safe and sustainable chemicals	• R&I was recognised as one of the most important economic aspects to monitor. • Some stakeholders were less supportive of indicators related to R&I as it does not necessarily result in changes to the safety and sustainability of chemicals on the EU market, however, it is valuable to discern the amount of effort which is being made to support the transition.	Recommended
EGSS produced by the chemical industry	• Concern over complexity of indicator due to wide variety of economic variables considered within this indicator.	Excluded
Digitalisation	• Digitalisation is a key aim of the CSS and it is viewed as a way to support the transition to safe and sustainable chemicals, however, it is not directly indicative that more safe and sustainable chemicals are being produced.	Excluded

New indicators to take forward

The following indicators have been taken forward for recommendation based on the reasons shown in Table 5.2.

- Production value/market share of safe and sustainable chemicals
- Eco-innovation index for safe and sustainable chemicals
- Number of safe and sustainable chemicals on the market
- Number of substances of concern on the market
- Production and consumption of chemicals by type (including safe and sustainable chemicals and substances of concern)
- Carbon intensity
- R&I spending on safe and sustainable chemicals.

Conclusions

6.1 Recommendations for KPIs

The following recommendations are based on the evidence gathering, synthesis, and analysis which was largely completed in **Q1 – Q2 2022**, therefore the recommendations do not reflect more recent developments in indicators and SSbD criteria.

The following indicators are recommended for use as KPIs to monitor the transition to safe and sustainable chemicals:

- **Existing indicators** (with some suggestions for modifications which are set out below)
  - Consumption of chemicals by hazard class (ENV_CHMHAZ), Eurostat
  - Greenhouse gas emissions by source sector (overall online data code: env_air_gge), Eurostat
  - Total energy consumption in the EU27 chemical industry by source, Eurostat
  - Total hazardous and non-hazardous waste in the EU27 chemicals industry, EEA / E-PRTR.
  - Industrial pollutant releases to water in Europe, E-PRTR / EEA
- **New indicators**
  - Production value/market share of safe and sustainable chemicals
  - Eco-innovation index for safe and sustainable chemicals
  - Number of safe and sustainable chemicals on the market
  - Number of substances of concern on the market
  - Production and consumption of chemicals by type (including safe and sustainable chemicals and substances of concern)
  - Carbon intensity indicator
  - R&I spending on safe and sustainable chemicals.

Given that data quality was raised as an issue by stakeholders, for example, regarding E-PRTR indicators, we recommend that for any indicators taken forward for development, a structural data quality control method is developed. This would assure a transparent objective assessment of the transition to safe and sustainable chemicals based on robust data. Several existing indicators take into account data quality, for example, the REACH baseline studies present 'quality scores' for the assessment of chemicals based on analysis of 237 reference substances considered representative of the chemicals available in the EU market. Baldoni et al. (2021) applied a data Quality Index to data sources to indicate the robustness of the data. A similar approach could be taken to ensure transparency and consistency across indicators.

Existing indicators

Consumption of chemicals by hazard class (ENV_CHMHAZ), Eurostat

This indicator is recommended to monitor overall material consumption by the chemical sector (as a reflection of the transition to a circular economy) and to monitor the change in production of hazardous chemicals as a proportion of all chemicals (as a reflection of the transition to safer chemicals). Modifications are suggested to improve the usefulness of the indicator. First, it is recommended that the hazard classification system is modified to better reflect the ambition of the CSS. Although general hazardousness is useful, the CSS emphasises that substances of concern (with chronic effects for human health and the environment) are priority for substitution. Second, it is recommended that the indicator is changed from 'consumption' to 'production and importation'. Subtraction of exports is undesirable as it means that not all production is taken into account. Furthermore, imports should be included because humans and the environment are exposed to chemicals regardless of whether the chemical was imported or produced in the EU.

Greenhouse gas emissions by source sector (overall online data code: env_air_gge), Eurostat

Greenhouse gas emissions are a well-recognised measure of the contribution to climate change. Data is already available through this indicator for the chemical sector, therefore this indicator is recommended to monitor the transition to safe and sustainable chemicals.

Total energy consumption in the EU27 chemical industry by source, Eurostat

This indicator is a direct measure of fossil fuel consumption and climate change mitigation. The indicator is not currently presented by Eurostat in a functional way, although the EEA presents an overall indicator that is not specific to the chemical sector.

Total hazardous and non-hazardous waste in the EU27 chemicals industry, EEA / E-PRTR

Similar to the indicator on consumption of chemicals by hazard class, this indicator could help reflect the transition to a circular economy and reduced production of hazardous chemicals. The presentation of data against gross value added contextualises the indicator in terms of economic sustainability as it has potential to show improvements in circularity and the reduction of hazardous chemicals alongside economic growth. Although data quality was found to be an issue under the evaluation of the E-PRTR, the revision of E-PRTR aims to address this problem.[120] A suggestion to improve this indicator would be to frame it alongside data which looks at the proportion of materials (hazardous and non-hazardous) which are recycled. This would more clearly show how waste is being diverted and also reflect trends in the presence of hazardous chemicals in recycled products (which should decrease based on ambition of the CSS).

Indicator on industrial water emissions (industrial emissions portal regulation)

Existing indicators on water emissions from E-PRTR were identified to have limited relevance due to the limited scope of chemicals currently monitored. However, the revision of the E-PRTR, including a proposal for an industrial emissions portal regulation, is expected to increase the number of substances monitored. Therefore, it is predicted that a new indicator will be developed with better relevance to the transition to safe and sustainable chemicals. The identity of chemicals to be monitored is not clear yet, although the EEA are currently considering which pollutants to select. For example, monitoring of SVHCs has been considered.

[120] The European Pollutant Release and Transfer Register (E-PRTR) - Environment - European Commission (europa.eu)

New indicators

Production value/market share of safe and sustainable chemicals

This indicator could utilise the anticipated safe and sustainable by design criteria to identify safe and sustainable chemicals. This is directly relevant to the transition and is expected to have holistic coverage of the aspects of safety and sustainability. Social and economic aspects may not be covered under the criteria (which are not available at the time of writing), however, framing this indicator in terms of production value and market share allows the economic dimension to be covered. The main limitation with this recommendation is the current uncertainty on how the SSbD criteria will be implemented.

Eco-innovation index for safe and sustainable chemicals

Innovation was recognised as one of the most important economic aspects to monitor as it is valuable to discern the amount of effort which is being made to support the transition. This indicator could be modified to target the chemical sector to reflect of innovation in safe and sustainable chemicals and allow comparison between Member States' performance. The index covers many aspects of innovation, including investments, innovation activities, patents, and employment. Further data collection would likely be required to modify this indicator to target the chemical sector.

Number of safe and sustainable chemicals on the market

This indicator could utilise the anticipated safe and sustainable by design criteria to identify safe and sustainable chemicals. This indicator would complement the other proposed indicator on production value/market share, as it would reflect the rate and breadth of uptake of the criteria (for example, more SSbD chemicals could be indirectly indicative of more chemical uses across sectors involving SSbD chemicals.

This indicator may be considered limited as it does not take into account safer alternatives at a material or service level. It could be modified to measure the number of safe and sustainable chemical alternatives (including SSbD chemicals, materials, and products), however, data collection for such an indicator may be too complex.

Number of substances of concern

This indicator is recommended based on on-going work by ECHA on prototyping two indicators on the relative change in the number of substances identified as substances of concern. The overall change in number of substances of concern could be used to reflect substitution with safer alternatives (a key aspect of the transition). In particular, this could complement the above recommended indicator by allowing direct comparison of trends between 'types' of chemicals (e.g., to monitor the rate at which safe and sustainable by design chemicals are substituting substances of concern).

Production and consumption of chemicals by type (including safe and sustainable chemicals and substances of concern)

This indicator is suggested to reflect the volume of different types of chemicals produced and used in the EU. Monitoring volume is suggested because use volume is a contributing factor to the predicted risk of hazardous chemicals (e.g., emissions and exposure are more likely), therefore, this would be valuable to monitor substances of concern. For safe and sustainable chemicals, this would be a good indication that SSbD chemicals are being taken up by the market to a high degree. For example, an increase in number of safe and sustainable chemicals may not be sufficient to indicate the transition if these chemicals are only used at very low volumes.

Carbon intensity indicator

The EEA are developing an indicator to monitor emission intensity per unit of marginal revenue across the chemical industry. This is recommended to monitor the transition towards chemicals which have a lower climate change impact in the context of economic sustainability, demonstrating a decoupling of economic growth from fossil fuel consumption. This should be framed alongside the indicators on overall GHG emissions and energy consumption, in recognition that the overall contribution of the chemical sector to climate change is dependent on absolute emissions.

In addition to **fossil fuel** consumption, an indicator reflecting **fossil resource** consumption would be useful. This is suggested because the chemical sector relies on fossil resources for material purposes (i.e., "molecular carbon" which is integrated and locked into the chemical product) as well as fossil fuels for energy purposes. It would be important to monitor the carbon intensity of fossil fuel derived carbon to compare against renewable or biobased carbon. Such an indicator would help monitor not only the CSS but the action plan on sustainable carbon cycles[121].

R&I spending on safe and sustainable chemicals.

Investment in R&I is covered as one of the sub-indicators in the eco-innovation index. A standalone indicator monitoring spending in R&I related to safe and sustainable chemicals is recommended as a simpler indicator to interpret in comparison to the eco-innovation index (although less comprehensive). Such an indicator already exists for general R&I spending in the chemical sector (from the OECD), however, more granular data would be required to focus on safe and sustainable chemicals. A system for categorising and reporting R&I as relevant for safe and sustainable chemicals would be required.

6.2 Further considerations

Some suggestions from stakeholders referred to methodological approaches rather than specific indicator topics. For example, an interviewee from academia suggested that industry surveys could be issued to create a new indicator, collecting annual data from a representative sample of industry. Another stakeholder suggested that industry should be involved in data interpretation to ensure that it is not misinterpreted, based on concerns that this has happened with existing indicators (e.g., based on E-PRTR data).

Following suggestions of recommended indicators to take forward, there also remain some critical gaps in addressing aspects. Some aspects have not been explicitly addressed, for example; transparency and safety reporting, effective governance facilitating the transition, and ecological footprint of energy consumption. Many aspects are also only covered under the indicators monitoring SSbD chemicals as the criteria for SSbD are expected to cover safety and environmental sustainability comprehensively (e.g., covering the aspects related to impacts on the environment). However, this depends heavily on how SSbD criteria are defined.

It should be noted that targets are likely to change over time given that the EU ambition for safety and sustainability evolves based on changing threats to the environment and society. Therefore, whilst the abovementioned indicators have been suggested to take forward, they should be regularly reviewed and updated to ensure their relevance over time.

[121] Sustainable carbon cycles (europa.eu)

wsp.com

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