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Final report

Indicators for sustainable management of chemicals

Contributions to upcoming development work under the new Global Framework for Chemicals

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Abstract: Indicators for sustainable management of chemicals

At the end of September 2023, the fifth International Conference on Chemicals (ICCM5) adopted the Global Framework for Chemicals (GFC), the follow-up framework for the Strategic Approach to International Chemicals Management (SAICM). The GFC aims to ensure the sustainable application of chemicals worldwide throughout their entire life cycle, including the products and waste produced from them. In this study, indicators were developed - in parallel to the ongoing discussions on target setting - using the concept of sustainable chemistry. This concept is based on a cross-system approach involving numerous interfaces, such as the use of renewable resources, occupational health and safety, and the recycling of waste. The collection of data should be as simple as possible as well as practicable in developing and newly industrializing countries. To this end, indicators introduced in the Sustainable Development Goals (SDGs), numerous international conventions and existing reporting formats were examined for their applicability. Their suitability was assessed using criteria developed in the project. The criteria take into account importance, specificity, data availability, and key sustainable chemistry fundamentals, among other factors. The project team discussed the criteria and candidate indicators in six international workshops and in dialogue with more than twenty experts from around the world. Interim results were published on a cloud accessible to all participating experts. This resulted in a list of 45 indicators suitable for future work in international chemicals management. These were structured according to various issues. We propose 23 indicators for future work in the "sound management of chemicals and waste". Several of the indicators developed in this project are also suitable for tracking targets of the Chemicals Strategy for Sustainability (CSS) of the European Commission. A preliminary analysis of the targets adopted at ICCM5 in September 2023 showed that the indicators developed in this study make a good contribution to the upcoming discussion on appropriate indicators for the GFC.

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Abbreviation	Explanation
CFP	Chemical footprint
CLP	Classification, Labelling and Packaging (Regulation)
CO_2	Carbon dioxide
$CO_{2\ eq.}$	CO_2 equivalents
CoC	Chemicals of Concern
COFOG	Classification of the Functions of Government (OECD)
CSDDD	Corporate Sustainability Due Diligence Directive (EU)
CSR(D)	Corporate Social Responsibility (Directive) (EU)
CSS	Chemicals Strategy for Sustainability (EU)
DJSI	Dow Jones Sustainability Index
DPSIR	Driving force - pressure - state - impact - response (approach, EEA)
EEA	European Environment Agency
EHS	Environment, health, safety
EMAS	Eco Management and Audit Scheme
EPI	Emerging policy issue (SAICM)
ESAP	European single access point
ESS	European Statistical System
EU	European Union
EuChemS	European Chemical Society
EUROSTAT	Statistical Office of the European Union
ETS	Emissions trading system
FAO	Food and Agriculture Organization of the United Nations
GCO	Global Chemicals Outlook
GDP	Gross domestic product
GFC	Global Framework for Chemicals
GHS	Globally Harmonised System (of Classification, Labelling and Packaging of Chemicals, UN)
GREN	Green and Sustainable Chemistry Conference
GRI	Global Reporting Initiative
HHP	Highly hazardous pesticides
ICCA	International Council of Chemicals Associations
ICCE	International Conference on Chemistry and the Environment
ICCM	International Conference on Chemicals Management
INI	International Nitrogen Initiative
ILO	International Labour Organization
IOMC	Inter-Organization Programme for the Sound Management of Chemicals

Abbreviation	Explanation
IP	Intersessional Process (SAICM)
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	International Panel on Climate Change
IPEN	International Pollutants Elimination Network
ISC_3	International Sustainable Chemistry Collaborative Centre
LCA	Life cycle assessment
LMICs	Low and middle-income countries (World Bank)
MSCI	Morgan Stanley Capital International
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne (Nomenclature of Economic Activities)
NAFTA	North American Free Trade Agreement
OSPARCOM	Commission of the Oslo and Paris Convention
PIC	Prior informed consent (Rotterdam Convention)
POP(s)	Persistent organic pollutant(s) (Stockholm Convention)
PRTR	Pollutant release and transfer register
PSA	Portfolio sustainability assessment
PSR	Pressure - state - response (approach, OECD)
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals (EU)
SAICM	Strategic Approach to International Chemicals Management
SC	Sustainable chemistry
SDG(s)	Sustainable Development Goal(s), UN
SMCW	Sound management of chemicals and waste
SSbD	Safe and sustainable by design (EU)
SusChem	European Technology Platform for Sustainable Chemistry
SVHC	Substance(s) of very high concern (REACH)
TfS	Together for Sustainability
TWG	Technical Working Group (SAICM)
UBA	Umweltbundesamt - German Environment Agency
UN	United Nations
UNCED	United Nations Conference on Environment and Development (UN, Rio de Janeiro)
UNEA	United Nations Environment Assembly
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
VWG	Virtual Working Group (SAICM)
WBCSD	World Business Council on Sustainable Development
WFD	Waste Framework Directive (EU)
WHO	World Health Organization

Summary

The development of indicators for the international management of chemicals and waste in the terms of the Strategic Approach to International Chemicals Management (SAICM) is the focus of this study. Within this framework, the concept of sustainable chemistry is to be given greater consideration and thus contribute to the significant further development of the "sound management of chemicals and waste" (SMCW) in the future.

Political environment

The project was implemented in a dynamically evolving political environment:

- Despite various global standards and agreements (Globally Harmonised System, Stockholm Convention, Basel Convention, etc.), the handling of hazardous chemicals and wastes is still at a very different level of implementation and enforcement; the disparity between industrialized, emerging and developing countries is sometimes considerable.

- The UN Summit in Johannesburg (2002) set, among other things, the goal of minimizing the negative impact of chemicals on human health and the environment from production to use, disposal and recycling by the year 2020 (the "2020 goal"). To this end, the international community has established SAICM as a "*multi-stakeholder multi-sector voluntary policy framework*" under the aegis of UNEP. The goals described in more detail in the Dubai Declaration[1] (2006) were not or only partially achieved by 2020.

- At the same time, global chemical production has increased massively since the beginning of the century, especially its share in emerging countries. This makes it all the more urgent to pursue the targets set, especially outside industrialized countries.

- The findings on pollution of marine biotope in particular on plastic waste, species extinction, progressive climate change, and other global or regional environmental problems are linked to the topic of SAICM and were reflected in corresponding resolutions of the UN Environmental Assembly. The question of the extent to which global exposure to chemicals is already exceeding planetary boundaries cannot be answered yet. However, the increase in production, the low proportions of recovered resources, and the increasing inputs to the environment (all on a global scale), combined with inadequate capacities of monitoring and analysis of adverse effects, point to major difficulties. In any case, given the large capacity deficits in many countries, especially in the Global South, the ongoing "chemical intensification" means that responsible chemical management with globally adequate chemical safety is becoming increasingly difficult.

- In industrialized countries, sustainable chemistry has become an issue: The U.S. Congress passed the Sustainable Chemistry Research and Development Act in 2019. The EU Commission published its Chemicals Strategy for Sustainability (CSS) in 2020. However, both approaches are still strongly oriented toward the existing regulations of chemicals.

In the SAICM Intersessional Process (IP)[2], recommendations for shaping the strategy for the international management of chemicals and (hazardous) wastes for the period after 2020 were

[1] Strategic Approach to International Chemicals Management (2015): SAICM texts and resolutions of the International Conference on Chemicals Management.
https://saicmknowledge.org/sites/default/files/resources/New%20SAICM%20Text%20with%20ICCM%20resolutions_E.pdf (09 June 2023).

[2] SAICM: Strategic Approach and sound management of chemicals and waste beyond 2020 - The Intersessional Process.
http://saicm.org/Beyond2020/IntersessionalProcess/tabid/5500/language/en-US/Default.aspx (06 Sept 2023).

developed starting in 2017. This work was significantly delayed by the COVID-19 pandemic and did not reach its conclusion until ICCM5 in Bonn, Germany, September 25-30, 2023. In the meantime, five overarching "Strategic Objectives" were drafted with broad consensus, and "Targets" were developed from them to operationalize the overarching goals. The working groups set up for this purpose during the IP - most of which met online - were faced with the challenges to:

- formulate generally accepted and understandable, yet ambitious goals,
- link unmet goals for redressing grievances as well as visions for 2030,
- make the link to the SDGs while strengthening the role of chemical management,
- significantly improve the controlling of agreed targets and measures, and
- find a viable model for funding future activities.

Indicators are needed to track paths taken to reach goals, to counteract undesirable developments, and to formulate new interim goals or milestones. Similar challenges apply to indicators as to goals. Each goal should be:

- comprehensive and significant,
- reliable, and
- easy to understand and determine as simply as possible.

Sustainable chemistry

The concept of sustainable chemistry has been developed over the past twenty years. In parallel to the many different scientific approaches, the OECD and the Federal Environment Agency in particular have endeavored to work on the concept for practical application and to anchor it politically. Resolution 2/7 of the UN Environment Assembly (UNEA 2, 2016) should be mentioned as a milestone in establishing the concept at the global level: In it, the UNEA called on national governments, international organizations, and stakeholders to document and evaluate examples of good practice in sustainable chemistry in support of the "sound management of chemicals and waste." Based on a decision of UNEA 4 (2019, Resolution 4/8), the "Green and Sustainable Chemistry: Framework Manual" (see section "Criteria") was developed, which is suitable for applying the concept of sustainable chemistry in companies and administrations alike.

Sustainable chemistry requires the safe handling of chemicals over the entire product life cycle and integrates the principles of "Green Chemistry" with its principles for substance synthesis. However, with its "benign by design" approach, among other things, the concept goes beyond "green chemistry". Through its holistic approach ("systems thinking"), sustainable chemistry takes into account important interfaces, especially with the extraction and use of natural resources, waste management and recycling, climate protection, the preservation of biodiversity, and the protection of the rights and needs of vulnerable groups. Implementing sustainable chemistry therefore means not only looking at the environmental compatibility of a substance, but also taking into account the opportunities and risks of its use, its production, and its recycling or disposal. In this way, the scientific concept of sustainable chemistry can support the political goals of the SDGs with their multiple interfaces and interdependencies. It is thus also suitable as a link between the goals of chemical safety ("sound management of chemicals and waste") and the broad approach of the SDGs and the 2030 Agenda.

Of the five "objectives" developed during the IP, "Objective D" in particular addressed aspects of sustainable chemistry: "Benefits to human health and the environment are maximized and risks are prevented or, where not feasible, minimized through safe[r] alternatives, innovative and sustainable solutions and forward thinking."[3] The ICCM5 adopted seven "Targets"[4] for "Strategic Objective D on safer alternatives and innovative and sustainable solutions" that address various aspects of sustainable development in connection with the use of chemicals, in the spirit of sustainable chemistry.

In the search for indicators, the concept of sustainable chemistry was used in order to be able to track and evaluate future-oriented developments based on the safe handling of chemicals and waste. Overall, this resulted in the challenging task of searching for indicators that:

- Cover all sectors and fields of application relevant to (sustainable) chemistry,
- Take into account the different situations of industrialized, emerging, and developing countries, and
- Use existing conventions wherever possible to avoid additional reporting burden.

Procedure

The development of indicators was an iterative process involving experts from all UN regions in workshops or individual interviews. Their opinions on overarching issues or individual indicators were reviewed by the project team and used for further work. An initial list of possible indicators was generated by evaluating relevant international conventions at global or continental level, working papers of SAICM or its stakeholder groups, reporting requirements based on the SDGs, etc., which were documented in "fact sheets". In parallel, a number of internationally renowned experts were interviewed in the summer of 2020 about:

- Which aspects of sustainable chemistry should be integrated into SAICM,
- Which indicators from existing conventions, chemical industry statistics, or the like are suitable, and
- How investments in sustainable chemistry can be indexed.

In addition, the names and contact addresses of other experts important for the project were identified during the interviews. This resulted in a dynamically growing list of experts, which was used for further interview rounds or workshops. Another round of interviews with a detailed questionnaire was conducted in 2021, focusing on the criteria used for the evaluation of indicators. Scientists from teaching, research, industry and international as well as non-governmental organizations were interviewed. A third round of interviews (starting in the fall of 2021) focused on the interfaces of sustainable chemistry with other global problem areas and corresponding indicators, with the questions being geared to the respective areas of expertise of the interviewees.

In parallel, five workshops with proposals for four to eight indicators each were held with experts from Europe (November 2020), South and East Asia, Australia and Oceania (March

[3] SAICM (2022): Development of recommendations for consideration by the fifth session of the International Conference on Chemicals Management for the Strategic Approach and the sound management of chemicals and waste beyond 2020; SAICM/IP.4/2/Rev.1/Add.1, 15.07.2022 https://www.saicm.org/Portals/12/documents/meetings/IP4/2022/SAICM_IP.4_2_Rev.1_Add.1_Outcome%20of%20VWG1%20on%20targets,%20indicators%20and%20milestones.pdf (06 Sept 2023).

[4] IISD (2023): Summary of the Fifth International Conference on Chemicals Management: 25-30 September 2023 https://enb.iisd.org/iccm5-saicm-intersessional-process-resumed-4-sound-management-chemicals-waste-beyond-2020-summary (05 Oct 2023).

2021), Latin America (June 2021), North America / NAFTA (November 2021), and Africa and the Middle East (March 2022). The workshops lasted approximately five hours each and were held online only due to the pandemic. The assignment to the workshops roughly corresponded to the UN regions; the layout took into account time zones to allow guests to participate roughly within their normal working hours. The first workshop also discussed the criteria used to select the indicators. The sixth and last, a hybrid workshop (March 2023), served to present the complete list of indicators and to discuss a possible prioritization. For this purpose, it was possible to recruit a group of experts from science, international organizations, and industry who had already participated in previous workshops or interviews.

Participants of the workshops received a "thought starter" tailored to the topics in question in advance. In addition to an introduction to the project and the upcoming indicators, specific problems from the perspective of the particular region were presented in two to three presentations.

Interim results from the project were made available to specialists and institutions engaged in the field without delay. Initially, a read-only cloud was made available, which was replaced by an interactive platform in the final phase of the project. Furthermore, partial results were presented at the Stakeholder Forum of the International Sustainable Chemistry Collaborative Center (ISC_3), at two scientific conferences, and at a specialist event for EU policy-makers.

Research for potential indicators

Based on the premises mentioned in the sections "Political environment" and "Sustainable chemistry", international conventions, ESG investment indices, voluntary initiatives, etc. were first evaluated where interfaces with the "sound management of chemicals and waste" or with the concept of sustainable chemistry were to be expected. These include conventions and initiatives that explicitly refer to chemicals or waste (e.g., Minamata Convention, Basel Convention, Responsible Care©, Together for Sustainability (TfS)) or contain specifications for sustainable investment (such as Dow Jones Sustainability Index (DJSI), MSCI ESG Indexes), sustainability reporting (Global Reporting Initiative (GRI)), innovation programs, or action programs (e.g., for health protection, climate protection, biodiversity).

The evaluation of around 50 such documents led to an initial list of potential indicators, each of which could be assigned to one of the five draft "Strategic Objectives" for the SAICM successor system. This showed that the vast majority of the indicators could be assigned to the ideas formulated in "Objective D". An assignment to detailed "Targets" was abandoned in the course of the project because the objectives were revised several times.

Sources of potential indicators - in addition to the evaluation of relevant conventions, etc., described above - continued to be:

- Preliminary results of a Technical Working Group or Virtual Working Group established by SAICM 2020,
- A list of proposals developed by the International Pollutants Elimination Network (IPEN), an association of some 600 local and national initiatives,
- Indicators for individual SDGs that were tested for suitability using keywords such as "chemicals," "waste," "resources," "innovation," "health," and
- Evaluation of workshops and interviews.

Criteria for indicators

The next step was to evaluate the indicators according to their suitability. A good indicator should not only be recognized by its accuracy in relation to the target in question, but should also be easy to measure, reliable, and comprehensible. "Targets" should - according to the specification of the responsible SAICM working group[5] - be "SMART", i.e., "specific," "measurable," "achievable," "relevant," and "timebound." Based on these requirements, criteria were formulated with which an indicator could be assessed as suitable. In addition to the formal requirements, aspects of sustainable chemistry were also to be included in the assessment of an indicator. For this purpose, a first draft was developed and presented for discussion in several interviews with experts as well as in the first workshop. The exchange with the UNEP project "Green and Sustainable Chemistry: Framework Manual"[6] and a dialogue on the "Key Characteristics of Sustainable Chemistry" published by the ISC$_3$[7] were particularly helpful. The criteria were presented in each of the second to fifth workshops. This helped to replace formulations that were not very comprehensible; however, changes in content were not necessary. The criteria now available for the selection of indicators can be found in Table 1. Criteria A-G reflect the requirements for "SMART" goals (see above): The criterion "achievable" is missing, as it can only be meaningfully linked to a goal, but not to an indicator. A criterion for reliability or traceable data collection has been added. The H-criteria H1-H5 are based on key aspects of the sustainable chemistry concept. Various "key characteristics" were grouped into five criteria to limit the number of criteria.

Table 1: Criteria for indicators

General criteria for indicators aiming at Sustainable Chemistry	
A) Specific	The indicator must be precise and unambiguous.
B) Established	The indicator is already in use by other systems, e.g., SAICM, Conventions.
C) Determinable	The collection of the data needed for reporting in the respective sector is easy and cost-efficient.
D) Measurable	Measurable: Either quantities, thresholds or qualitative properties are applicable.
E) Reliable and transparent	The data associated with the indicator are trustable and traceable.
F) Dynamic	Progress over time, a difference in the data associated with the indicator can be measured.
G) Pertinent	The indicator covers relevant aspects for the respective sector and / or area of application.

[5] SAICM (2020): TWG/document/3: Proposal by TWG Co-Chairs: Suggested framework to support the development of targets & indicators http://www.saicm.org/Portals/12/Documents/meetings/TGW/TWG-Doc-3_Suggested_framework.pdf (06 Sept 2023).

[6] UNEP (2020): Green and Sustainable Chemistry: Framework Manual, ISBN No: 978-92-807-3839-1 https://www.unep.org/resources/toolkits-manuals-and-guides/green-and-sustainable-chemistry-framework-manual (06 Sept 2023).

[7] Km merer, K.; Amsel, A. K.; Bartkowiak, D.; Blum, C.; Cinquemani, C. (2021): Key Characteristics of Sustainable Chemistry. Dialogue Paper by the International Sustainable Chemistry Collaborative Centre (ISC3), Bonn, Germany https://www.isc3.org/cms/wp-content/uploads/2022/06/ISC3_Sustainable_Chemistry_key_characteristics_20210113.pdf (06 Sept 2023).

General criteria for indicators aiming at Sustainable Chemistry	
Special sub-criteria focussing on the Concept of Sustainable Chemistry	
H) Sustainability	Systems thinking is the prerequisite to reach the goals of the Agenda 2030: Potential trade-offs can be identified and managed with systems thinking. Sectors dealing with chemical entities contribute to Sustainable Development in compliance with the respective SDG principles and the following sub-criteria.
H1) Responsible innovation	Development of sustainable solutions and safe and non-regrettable alternatives for chemicals of concern through cooperation on innovations, non-chemical alternatives, services like chemical leasing or Extended Producer Responsibility (EPR) mechanisms. Foster collaboration along the value chains to promote circularity.
H2) Inter- and multidisciplinary, holistic approach	Considering interfaces with other urgent issues (health, environment, climate, resources/waste/circularity, biodiversity, nutrition, etc.) throughout the entire life cycle of chemical entities, while avoiding transport of problems to other sectors and future legacies.
H3) Social responsibility	Promoting and ensuring health and safety as well as fair, inclusive, and emancipatory labour conditions, complying with human rights and justice in all its fields including education and science. Reduction of inequalities and fair distribution of benefits.
H4) Transparency and information exchange	Enabling right-to-know throughout the entire life cycle. Promoting knowledge exchange on all levels including all stakeholders (e.g., science, education, business, governments, administration, NGOs).
H5) Resource management and circularity	Sustainable management of resources, materials, and products (raw materials extraction, production, application, logistics, recycling and end of life scenario) and energy, to enable circularity without contamination throughout the entire life cycle.

Indicators

In accordance with the objective of this research work, indicators were developed for the goal of "sound management of chemicals and waste (SMCW)," which, as far as possible, also retain aspects of the concept of sustainable chemistry. Indicators in terms of sustainable chemistry should fulfill one or more of the H-criteria (Table 1). Existing studies on indicators for sustainable chemistry are limited to the framework of "green chemistry" with regard to ecological aspects (e.g., emissions and waste quantities from production) and are therefore more likely to be assigned to the SMCW objective.

As a result of the iterative approach (see section "Approach"), a list of 45 indicators emerged after evaluation in five workshops and about twenty interviews, from which a list of 23 indicators particularly relevant to SMCW was highlighted after the sixth workshop (see Table 2). Table 2 describes, for each selected indicator:

- Assignment to one of the five "Strategic Objectives" (A to E) available in the draft for the SAICM successor project,
- Its origin, e.g., SDG or IOMC indicator, from a convention (e.g., Rotterdam Convention), proposal from a SAICM working group (TWG4), NGO (e.g., IPEN) or workshop participant,

modified by the project team if necessary, or proposal of a new indicator in view of existing data not yet used for SMCW monitoring (e.g., data from Together for Sustainability (TfS)),

- Assignment to the criteria for sustainable chemistry, as well as
- Reference to the SDG targets.

Table 2: List of priority indicators with respect to SMCW

No.	Proposed indicator	Assignment to a SAICM (drafted) Strategic Objective	Origin of the indicator and potential data source	Criteria for sustainable chemistry (bracketed = partially applicable)	Relation to SDGs: bold = directly bracketed = indirectly
1	Share of large/medium/small chemical enterprises of the region (Africa, Asia, Europe ...) that report on their sustainability performance using GRI SRS	D, E	Project team	H2, H3, H4, H5	**12.6**
2	Number of new supplier assessments carried out in the year under review, by region, and change compared with the previous year	A, D	Project team (TfS)	(H2), H3	**12.4, 12.6**
6	Proportion of hazardous waste treated, by type of treatment, e.g., recovered, recycled, incinerated	A, D	Modification of SDG Indicator 12.4.2.	(H2), H3, (H5)	**12.4**
8	Value of fossil-fuel subsidies per unit of GDP (production and consumption) related to Chemical Industry´s energy consumption	D, E	Modification of SDG Indicator 12.c.1	H2, H5	**12.c**
9	Total value inward and outward illicit financial flows related to chemicals and waste measured per unit of product detected used for unintended application and volume of illegally disposed waste	A, C, D	Modification of SDG Indicator 16.4.1	H3, H4	**16.4**
10	Number of companies certified for Environmental Management or Health, Safety, Environment Management System... within the chemical industry... by an independent auditor	D	Modification of a TWG4 Indicator	H4, (H4), (H5)	**12.4, 12.6** (8.3)
12	Share of the world's largest chemical companies having signed on to 2014 Responsible Care Global Charter	A, D	Project team	H3	**12.4**
13	Number or share of parties that have ensured that the public has appropriate access to information on chemical handling and accident management and on alternatives that are safer for human health or the environment than the chemicals listed in Annex III of the Rotterdam Convention	B	Project team	H3, H4	**12.4**

No.	Proposed indicator	Assignment to a SAICM (drafted) Strategic Objective	Origin of the indicator and potential data source	Criteria for sustainable chemistry (bracketed = partially applicable)	Relation to SDGs: bold = directly bracketed = indirectly
16	CO_2eq. Scope 1 & 2 per unit of value added (e.g., gross output [Mg / yr]) of the chemical industry	C, D	Modification of SDG Indicator 9.4.1	H2, H5	**9.4**
19	Share of chemical production based on renewable materials in relation to the global production which is based on renewable materials … [%]	D	Modification of a TWG4 Indicator	H5	**12.2**
20	Reduction of the amount of hazardous chemicals used in design and manufacturing related to the total mass of chemical production by x %	A, D	Modification of IPEN Indicator D.5-2	H1, H3	**12.4** (6.3)
22	Amount of post-consumer plastic waste generated / recycled / incinerated / landfilled / not collected per country	B, C, D	Project team (based on a suggestion by the participants of Workshop #2)	(H2), (H5)	**12.5**
24	Material footprint, material footprint per capita, and per GDP	D	SDG Indicator 12.2.1	(H2), H5	**12.2**
28	Number of countries that adopt policies and instruments that implement agro-ecological strategies and practices that reduce synthetic input such as pesticides and fertilizers and are based on biodiversity and integrated soil nutrition…	D	IPEN Indicator A.1-6	H2, (H5)	**2.4, 2.5**
31	Number of PRTRs with publicly accessible data established	A, B, D	IPEN Indicator A.5-1	(H1), H4	(12.4, 16.10)
33	The percentage of companies with human rights (HR) due diligence procedures for toxic substances used, produced and released in their activities	D	Modification of IPEN Indicator D.6-2	H3, (H4)	(12.4, 10.3)
34	Change in water-use efficiency in the chemical industry ("water footprint")	A	Modification of SDG Indicator 6.4.1	(H2), H5	**6.4**

No.	Proposed indicator	Assignment to a SAICM (drafted) Strategic Objective	Origin of the indicator and potential data source	Criteria for sustainable chemistry (bracketed = partially applicable)	Relation to SDGs: bold = directly bracketed = indirectly
35	Renewable energy share in the... final energy consumption of the chemical industry	A, D	Modification of SDG Indicator 7.2.1	(H2), H5	**7.2**
36	Number of countries that have implemented pesticide legislation based on the FAO/WHO International Code of Conduct	A, B, C	TWG4 (IOMC Indicator)	(H2), H5	**12.4**
37	Number/percentage of countries where the legal framework demands risk assessment and registration / authorization of new chemicals before putting them on the market	A, C	Project team (with reference to the IOMC Toolbox)	H1, H3	**12.4**
38	Number of (share of) countries reducing the emission of reactive N compounds (waste water, exhaust air, agriculture) by legislation	A, C	Project team	(H1), H2, H3	**2.4, 6.3, 13.2**
44	Number of companies conducting an environmental cost-benefit analysis	D	Project team	H4, H5	(12.6)
45	Sum of resource taxes on non-renewable natural resources and their extraction collected by countries	D, E	Project team	(H4), H5	(8.4, 9.4, 11b, 12.2)

The numbers in the first column are linked to the complete list of indicators (see full report, Table 6, and Appendix C).
Abbreviations:
GDP: Gross domestic product
PRTR: Pollutant Release and Transfer Register
SDG Indicator: Indicator for Sustainable Development Goal No...
TWG4: Mapping exercise: existing global and regional data and indicators relevant to the Beyond 2020 Framework (SAICM 2019b)

In the following section, some indicators are explained by way of example; the number given in each case refers to the first column in Table 2.

Process and impact indicators

In environmental protection, the DPSIR system (driver - pressure - state - impact - response) is often applied. The cycle of cause, environmental state, impact, and cause control usually has to be run through several times in order to achieve the desired state. Indicators can refer to all phases of the causal chain of this system-analytical approach. Impact-related indicators are usually best suited to track the development towards a goal (targeted "state"). Process-related indicators can be used to track measures ("response") or the development of triggers of environmental degradation ("driver", "pressure"). Impact indicators are difficult to capture on a global scale. Therefore, process-related indicators are often used, e.g., the number of states that have joined a certain convention. This does not allow any statement on the impacts achieved. For this, production quantities or, even better, environmental impacts of the pollutants regulated in this convention would have to be recorded. Due to the low availability of data for impact-related indicators, it was mostly necessary to resort to indicators describing causes of undesirable developments or corresponding countermeasures (e.g., number of countries with measures against emissions of nitrogen oxides or excessive use of nitrogen in agriculture, No. 38) or the current status (e.g., extent of illegal trade in chemicals and waste, No. 9).

Specificity vs. measurability

As already mentioned in the section "Political environment," data for indicators should, on the one hand, be collectable even in low and middle-income countries (LMICs) (Criteria C and D) and reliable (Criterion E), and, on the other hand, be specific (Criterion A) and relevant (Criterion G). These requirements often cannot be met at the same time. For already established indicators (Criterion B), data are usually available from the individual states or international organizations. This applies to aspects of the "sound management of chemicals and waste" that have already been taken into account. However, these data are usually not specific enough. Therefore, in several cases, it was recommended to consider a sector-specific breakdown of data collected under conventions or for the 2030 Agenda. For example, for water-use efficiency ("Change in water-use efficiency," SDG Indicator 6.4.1), an addition of "in the chemical industry ("water footprint")" is proposed.

Indicators of environmental damage caused by chemicals or their prevention

Another problem with the informative value of the indicators arises from unclear terms and different definitions for the same term. In this case, it is usually helpful to refer to the respective source (e.g., convention, SDGs). If this is not available, a definition is required as part of the establishment of the indicator at SAICM.

Here, numerous indicators can build on existing conventions, which primarily pursue goals in for the SMCW and often only have a reference to the process. These include, for example:

- "Number of companies certified for Environmental Management or Health, Safety, Environment Management System" for the chemical industry sector, where certification should be verified by external audits (No. 10), and
- "Number of countries that have implemented pesticide legislation based on the FAO/WHO International Code of Conduct" (No. 36).

The above indicators also meet some H criteria, such as the Criterion H2 and partly H3.

Indicators for resource consumption

The chemical industry requires resources on a large scale, but can contribute to reducing resource consumption through innovative products. It is also important to monitor the shift from fossil to renewable raw materials. Both aspects are part of the concept of sustainable chemistry. Indicators have been proposed in order to map progress for:

- Resource consumption in relation to economic output, e.g., "Material footprint, material footprint per capita, and per GDP," SDG Indicator 12.2.1, no. 24,
- Waste management and recycling, e.g., "Proportion of hazardous waste treated, by type of treatment" (analogous to SDG Indicator 12.4.2 with the addition of "e.g., recovered, recycled, incinerated"), No. 6, and

- The increase in the share of renewable raw materials, e.g., "Share of chemical production based on renewable materials in relation to the global production which is based on renewable materials [%]," No. 19.

SAICM initially targeted the Dubai Declaration exclusively at hazardous waste. However, the discussions at SAICM indicate that the concept of waste is also being expanded in the sense of a more comprehensive management of resources. Therefore, the list includes an additional indicator on plastic waste (No. 22). Since the switch to renewable raw materials can be accompanied by strong environmental impact due to monocultures, high water consumption, or the like, indicators for careful land management are also provided (see next section).

Interfaces with other global challenges

Global warming, species loss, water consumption and overloading of environmental media with nutrients threaten to exceed planetary boundaries or have already done so. The holistic and systemic approach of the sustainable chemistry concept makes it possible to define meaningful interfaces in targets and indicators.

Climate-relevant gases can be included via an SDG indicator (9.4.1), which is related to the industry: "CO_2 eq. Scope 1 & 2 per unit of value added (e.g., gross output [Mg / yr]) of the chemical industry, No. 16." This indicator is also relevant for the economic dimension. The inclusion of Scope 3 makes little sense for global statistics and would also be an overload for many LMICs. In addition, the indicator "Renewable energy share in the final energy consumption" (No. 35) should be mentioned here (SDG Indicator 7.2.1) with the addition "of the chemical industry."

For the use or overuse of water reserves, an extension of SDG Indicator 6.4.1 was proposed (see above): "Change in water-use efficiency over time" with the addition of "in the chemical industry (water footprint)."

The development of biodiversity is mainly influenced by land use. Ecotoxic chemicals can have a reinforcing effect or endanger certain species. The following indicators are proposed here:

- "Number of countries that adopt policies and instruments that implement agroecological strategies and practices that reduce synthetic inputs such as pesticides and fertilizers and are based on biodiversity and integrated soil nutrition" (No. 28), which was proposed in this form by IPEN, and
- "Number of (share of) countries reducing the emission of reactive N compounds (waste water, exhaust air, agriculture) by legislation" (No. 38), which resulted from discussions with the International Nitrogen Initiative (INI).

Operationalizing the Aichi targets for this interface proved difficult. The targets of the Montreal-Kunming Agreement can be used in the further development of the indicators, predominantly targets 7 and 15, which explicitly refer to companies.[8]

Social indicators

Criterion H3 applies to several indicators that deal with issues of public health, occupational health and safety, or fair pay. Here, among other things, the monitoring of standards in the supply chains is an important instrument. Numerous globally active chemical companies have joined forces in the "Together for Sustainability" (TfS) organization to conduct audits of upstream suppliers in a coordinated manner. The number of audits or the number of

[8] Kunming-Montreal Global Biodiversity Framework: 2030 Targets https://www.cbd.int/gbf/targets/.

improvements achieved during the audits would be an interesting indicator (No. 2), the realization of which depends on the willingness of TfS or the organizer of the audits, EcoVadis, to cooperate. Another problem with this indicator is that small and medium-sized enterprises have not yet participated in these initiatives.

The introduction of the Corporate Sustainability Due Diligence Directive (CSDDD) in the European Union could provide indicators for measuring the social impact of the chemical industry in the future.

An example of a potential indicator is "The percentage of companies with human rights (HR) due diligence procedures for toxic substances used, produced and released in their activities" (modifying a proposal from IPEN), No. 33.

The search for indicators for "gender equity" in the context of sustainable chemistry was unsuccessful. It is to be expected that indicators for this will prove necessary in the future, and the discussions within the SAICM process, for example on the topic of "Women and Chemistry," will become more intensive.

Economic indicators

It proved to be extremely difficult to find indicators for investments or innovations in the direction of sustainable chemistry. There is no corresponding statistical basis. The number of patents applied for, which is often used as an indicator of innovation activity, is not meaningful due to the different strategies of chemical companies in dealing with patent applications and the inflationary use of the term "sustainable" (Criteria A, E, G). The use of the number of companies that carry out a "Portfolio Sustainability Assessment" (PSA) does not lead to comparable and comprehensible statements due to the lack of standardization of PSAs (Criterion E). This can change with a standardization of the method and its implementation, which is being worked on at the WBSCD.

Therefore, indirect aspects were used such as the frequency of GRI reporting ("Share of large/medium/small chemical enterprises of the region (Africa, Asia, Europe ...) that report on their sustainability performance using GRI SRS," No. 1).

In addition, various indicators were found or developed that combine an ecological and an economic component; see the comments in the sections on resource consumption and other global challenges.

Signs of more transparency

Disclosure of the composition of products in the chemical industry as well as education and training in the proper handling of chemicals support the development towards the use of less critical substances and further steps towards sustainable chemistry. Criterion H4 is met by some indicators already mentioned (see section "Indicators of environmental damage from chemicals"). This also includes the introduction of Pollutant Release and Transfer Registers (PRTR), the data of which are publicly accessible (No. 31), the implementation of the Rotterdam Convention with reference to the information rights contained therein (No. 13) or increasing reporting in accordance with the GRI standard (No. 1).

Work of the IOMC

The "Inter-Organization Programme for the Sound Management of Chemicals" is a cooperation project of several international institutions (WHO, ILO, OECD, UNIDO), which is working on indicators for SMCW, among other things, with financial support from the EU. To support the work of SAICM, a list of indicators was already published on the occasion of the ICCM4 (2015), which has been expanded in a multi-stage process to 63 indicators at last count by July 2023.[9] The exchange with members of the corresponding IOMC working group revealed that the indicators developed by IOMC and those in this study coincide in some cases and that both lists complement each other because they are based on different focuses - on the one hand focus on SMCW, on the other hand focus on goals beyond that.

Indicators for European policy

In the European Union, many of the goals that are being pursued at the global level have already been achieved. Chemicals legislation, product liability regulations, labeling requirements, etc., ensure that "sound management of chemicals and waste" is legally anchored, even if implementation and enforcement are not ensured at a high level everywhere. Therefore, many indicators are not applicable to the European level. In the "Chemicals Strategy for Sustainability", the EU Commission points out the necessary strengthening of SAICM and at the same time recognizes: "[...] it is important to use relevant international standards, guides and methodologies when developing EU rules, unless they are ineffective or inappropriate."

The statistical basis for numerous questions is incomparably better in the EU than in many other regions of the world. This was examined specifically on the basis of indicators for which little or no data was available at the global level. Subsequently, a few indicators were proposed that could show progress in terms of sustainable chemistry in Europe:

- Material footprint, and material footprint per capita and per GDP (No. 24),
- Share of chemical production based on renewable materials in relation to the global production which is based on renewable materials (No. 19),
- GHG emissions of the chemical industry per value added (No. 16),
- Reduction of the amount of hazardous chemicals used in design and manufacturing related to the mass of chemical production by x% (No. 20),
- Amount of post-consumer plastic waste generated / recycled / incinerated / landfilled / not collected per country (No. 22),
- Number of companies (within the chemical sector) certified for Environmental Management or Health, Safety, Environment Management System by an independent auditor (No. 10).

For these, either statistical data are available or can be obtained by evaluating the CSR reporting for companies with a turnover of €40 million or more, which will be mandatory from 2025. This approach was discussed in an online workshop at EU level with experts from the Commission, academia, industry and Member States. The Commission will therefore include the list drawn up here in its deliberations.

The indicators, developed in dialogue with numerous experts from all UN regions, provide a bridge between the "sound management of chemicals and waste" and the concept of sustainable chemistry that goes beyond it. On the one hand, the indicators focus on unresolved problems and goals of the Dubai Declaration, and on the other hand, they depict developments that are conducive to the implementation and scaling up of sustainable chemistry or that stand in its way. The concept of sustainable chemistry can support numerous SDGs, as can be seen in the

[9] SAICM (2023): Inventory and analysis report: existing indicators on chemicals and waste management. SAICM/IP.4/INF/39/Rev.1, 08/08/2023, Annex: IOMC Indicators Project Working Group: IOMC: Update to the Inventory and analysis report: existing indicators on chemicals and waste management. 17/07/2023 https://www.saicm.org/Portals/12/documents/meetings/IP4_3/SAICM_IP.4_INF_39_Rev.1.pdf (09 June 2023).

last column of Table 2. Numerous innovations from chemical research, such as highly selective catalysts, the production of platform chemicals in bio-refineries, the resource-efficient extraction of active ingredients from plant precursors, and the "in silico" estimation (i.e., computer-aided modeling) of the properties of new substances, open up many opportunities to transform chemical production in the spirit of sustainable development. The indicators do not map such developments in detail, but show whether their consequences globally point in the direction of the goals set by the 2030 Agenda or by SAICM.

Evaluation of the results

Due to the interdisciplinary nature of the concept of sustainable chemistry, numerous interfaces had to be taken into account, including with finance, the global management of resources, health protection, and even the threat of crossing planetary boundaries. The indicators therefore focus not only on fundamental demands on the properties or handling of chemicals, but also on essential interfaces of the production and use of chemicals with global problems, i.e., climate protection, eutrophication, biodiversity, water scarcity, etc. Considerable gaps remain in the economic indicators with a focus on innovations as well as investments in plants and processes that promote development in the sense of sustainable chemistry. Similar problems apply to social indicators.

Sufficient and reliable data are currently available for only some of the potential indicators. In many cases, further differentiation of statistical data is required, for example, to be able to determine sector-specific indicators. In many cases, a compromise between data availability on the one hand and meaningfulness on the other appeared necessary. This led to the inclusion of process-related indicators, such as the number of signatories to certain international agreements, in the list, although impact-related indicators, such as the measurable positive consequences of such an agreement for people and the environment, would have been more meaningful.

The criteria developed for the evaluation of indicators, which cover both formal (relevance, verifiability) and substantive aspects (systemic thinking, consideration of resource consumption), were met with broad approval at the workshops.

Further procedure

Due to the multiple postponements of ICCM5 and the associated delay in setting "targets" for further work on the SAICM successor instrument, it was not practical to bring the results obtained here to ICCM5.

The successor to SAICM is called the "Global Framework for Chemicals."[10] (GFC – complete title: "Global Framework for Chemicals – For a Planet Free of Harm from Chemicals and Waste"). ICCM5 succeeded in adopting forward-looking goals for SAICM without neglecting previously unachieved objectives. Some of the newly formulated goals go beyond the results achieved in the working groups during the IP. In particular, the extensive set of goals in "Objective D" leaves room for using the concept of sustainable chemistry at the global level. Greater integration of waste management issues can be achieved with a compromise formulation found in the final declaration - "the life cycle of chemicals, including products and waste." The prioritized list of indicators (Table 2) can now be made available to stakeholders who continue to shape the process after ICCM5. This is because under the new "Global Framework for Chemicals," all stakeholders are called upon to report on their implementation efforts and "the progress of indicators and milestones." The broadness of the approach taken here allows these indicators to

[10] The evaluation of the ICCM5 in the final report is mainly based on the evaluation of the Earth Negotiations Bulletin Vol. 15, No. 311, dated 03.10.2023, as well as on inquiries with participants of the German delegation.

be used for many of the "Targets" agreed at ICCM5, particularly in relation to "Objective D". The aforementioned image of a bridge between SMCW and sustainable chemistry may increase acceptance: First, among those who focus on the unmet targets and remaining legacy issues and problems, and second, among those who want to push for much faster development in terms of industrial transformation. Global progress requires patience and consensual, effective solutions.

The criteria developed in the project can be used in this form for the search for further indicators in connection with the development of the chemical industry and downstream production. A publication of the approach chosen here in environmental policy journals and its presentation in discussions related to sustainable chemistry (webinars, congresses) is therefore planned.

A continuation of the exchange on indicators started with the IOMC after the end of the project can contribute to the optimization of the indicators and their database. Due to the participation of the UN Statistics Division in the corresponding IOMC working group, it is much easier to assess the availability and reliability of the required database than it was possible here in the project.

The discussion of sustainable chemistry in Europe is often reduced to the regulation of chemicals or restrictions on their use. This is evident in the many reactions from both non-governmental organizations and industry to the European Commission's "Chemicals Strategy for Sustainability." The members of the "High-Level Roundtable" established by the Commission should be informed about the findings of this project.

The interactive platform, which has been running since February 2023, is a central element for communicating and sharing project information. Here, all relevant results can be downloaded, discussed and exchanged with other experts. This platform serves as an important resource for experts and institutions involved in the transformation of industrial society. The exchange via this platform has already been positively received at various expert conferences and European talks. The documents uploaded so far can be downloaded from the platform and made available to UBA so that these documents can be published on UBA's own website.

1 Background

1.1 Chemicals and waste management: global approaches

Agenda 21 (UNCED 1992), adopted by the UN Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992, devotes a separate chapter to chemicals and hazardous waste, respectively. At that time, there was only one international convention relating to chemicals: the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal. The Rio Conference dealt with all chemicals at this level for the first time and called for, among other things (UNCED 1992, Chapter 19):

- Expanding and accelerating international assessment of chemical risks,
- Harmonization of classification and labelling of chemicals,
- Information exchange on toxic chemicals and chemical risks, and
- Establishment of risk reduction programs.

As a result of the corresponding mandate from the Rio Conference, it was possible in the wake of the UNCED and

- The Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (PIC) in 1998,
- The Globally Harmonized System of Classification and Labelling of Chemicals (GHS) in 2002, and
- The Stockholm Convention on Persistent Organic Pollutants (POPs) in 2004

to create milestones of international chemicals law, which have an effect specifically in a few particularly urgent problem areas. Agenda 21 also emphasized the need for the safe handling of all chemicals and called for national regulations for the handling of chemicals in individual countries. To this end, among other things, the international exchange of experience was to be improved, and widely available dossiers on chemicals were to be compiled.

In order to operationalize these still very general goals, the World Summit on Sustainable Development in Johannesburg in 2002 adopted a "Strategic Approach to International Chemicals Management (SAICM)," with which the goal of "sound management of chemicals throughout their life cycle and of hazardous wastes for sustainable development" was to be realized: "[...] aiming to achieve, by 2020, that chemicals are used and produced in ways that lead to the minimization of significant adverse effects on human health and the environment, using transparent science-based risk assessment procedures and science-based risk management procedures, taking into account the precautionary approach, and supporting developing countries in strengthening their capacity for the sound management of chemicals and hazardous wastes by providing technical and financial assistance" (UN 2002). The international organizations cooperating within the framework of the Inter-Organization Programme for the Sound Management of Chemicals (IOMC) (including UNEP, WHO, ILO, FAO, OECD, and the World Bank) were thus given a corresponding mandate. SAICM was conceived as a "multi-stakeholder multi-sector voluntary policy framework" under the auspice of UNEP, and its development began with the first International Conference on Chemicals Management (ICCM1) in Dubai in 2006. In addition to a declaration, the conference adopted an "Overarching policy strategy" and a comprehensive work program ("Global action plan") with 273 planned activities in which the goals agreed at the Johannesburg Summit were operationalized.

Despite the various global standards and conventions on the management of hazardous chemicals and wastes created since 1992, there is still a wide variation in the level of implementation. This is already noticeable in the number of signatory states to the conventions: 152 of 192 UN Member States have ratified the Stockholm Convention and another 34 have otherwise acceded.[11] To the Basel Convention (53 signatory as well as 138 otherwise acceded states)[12] several important industrialized countries have declared restrictions regarding their signature. In some cases, it takes more than ten years from signing to ratification. There is sometimes a significant gap in enforcement between industrialized, emerging and developing countries. The work at SAICM, which involves not only national governments but also industrial and environmental associations, human rights organizations, etc., suffers from the non-binding nature of implementation, but it does allow for it to:

- Use emerging policy issues (EPI) to address problems that may later be regulated in conventions, e.g., use of lead in paints, use and handling of highly hazardous pesticides (HHP), hazardous substances in electronic products,
- Share experiences on enforcement in chemicals management at the administrative level to improve overall, and
- Transfer knowledge, increase public awareness, and thereby achieve a reduction in the risks associated with the handling of chemicals.

Nevertheless, the evaluation of SAICM's work from 2006 to 2015 criticized "insufficient sectoral engagement; the capacity constraints of national focal points; lack of tools to measure progress; limited financing of activities, and insufficient and uneven advances in substantive areas such as illegal international traffic" (SAICM Secretariat 2018). Reporting on existing indicators leaves much to be desired; in particular, a negative trend is evident (UNEP 2019): "Reporting rates under SAICM exhibit a worrying downward trend: among governments, reporting rates dropped from around 40 per cent (78 submissions out of 194 governments) and 43 per cent (83 submissions out of 194 governments) in the first two rounds to 28 per cent (54 submissions out of 193 governments) in the third round, with data lacking in particular from African countries."

The targets described in the 2006 Dubai Declaration have not been met or have only been partially met by 2020, as noted in the second edition of the Global Chemicals Outlook (GCO II) (see, e.g., Table 3). Among other statements (UNEP 2019):

- In particular, the lack of implementation of conventions is deplored. Progress can be seen in the GHS, among other things,
- Regional chemical and waste management collaborations are moving forward,
- National approaches to SMCW are supported by numerous stakeholders; this also broadens the knowledge base on chemicals,
- Approaches to national chemicals legislation with reference to Chemicals of Concern (CoC) are partly in place,

[11] Acceptance (A), Approval (AA), Accession (a), see "Status of ratification" of **the Stockholm Convention** https://chm.pops.int/Countries/StatusofRatifications/PartiesandSignatoires/tabid/4500/Default.aspx (25 July 2023).

[12] Acceptance (A), Approval (AA), Accession (a), see "Status of ratification" of the **Basel Convention** https://www.basel.int/Countries/StatusofRatifications/PartiesSignatories/tabid/4499/Default.aspx (25 July 2023).

- There continues to be a high need for financial resources to support emerging and developing countries for SMCW, and
- Combating illegal trade in waste and (incorrectly declared) chemicals remains a high priority.

Table 3: Stakeholder perceptions of the degree of success in achieving SAICM objectives (overarching policy strategy - OPS) from 2006 to 2015

OPS objective	Very successful (%)	Some success (%)	Little success (%)	Unsuccessful (%)	Don't know (%)
A. Risk reduction	15	56	16	3	11
B. Knowledge and information changing	22	54	14	2	7
C. Governance	16	47	20	5	12
D. Capacity building and technical cooperation	20	40	25	4	11
E. Illegal international traffic	7	27	18	18	31

Source: GCO II, Table 3.10 (UNEP 2019), citing SAICM Secretariat 2018, p. 24

According to GCO II, chemical industry sales are expected to double between 2017 and 2030 (UNEP 2019). Since the beginning of the century, investments in the chemical and pharmaceutical industry have been rising steeply outside Europe, Japan, and North America: In 2000, more than 50% of all global investments were still made in these industrialized countries; in 2013, this figure was only 35%, with a declining trend, especially in Europe, with China accounting for the majority of investments (Statista 2023). The goals set at SAICM must therefore be pursued all the more urgently outside the "classic" industrialized countries.

The findings on the pollution of marine biotopes in particular with plastic waste, the loss of species, the progressive change of the climate and numerous other regional environmental problems such as nutrient deficiencies or excesses in soils are linked to the topic of SAICM. These problem areas have mostly still been discussed separately at UN conferences, although they influence each other mutually. In the case of one-dimensional views and decisions, progress in the fight against one of the world's pressing problems could be bought by backward steps elsewhere. A well-known example of such a conflict is the use of renewable raw materials as feedstock for hydrocarbons at the expense of land for food cultivation ("plate-tank discussion").

Regional contamination by certain pollutants endangers human health, animal species, and entire ecosystems. Examples include high concentrations of active nitrogen compounds due to overfertilization or over-intensive livestock farming, which lead to species poverty in soils, groundwater pollution, and anaerobic zones in affected marginal seas. Pollution of the outdoor air with nitrogen oxides and ammonia is also partly due to emissions from agriculture, and partly to the operation of internal combustion engines. These problems are now occurring in numerous regions of the world and require concerted action (INI 2021). A corresponding resolution of UNEA 5 (UNEA 2022d) now builds on preliminary work by individual states and scientific associations. The enormous amounts of plastic waste, which enter the oceans via rivers mainly due to inadequate waste collection and a lack of extended producer responsibility, but also due to contamination of soils by microplastics, are to be combated with a global plastics convention. Negotiations have been initiated on the basis of a mandate from UNEA 5.2 (UNEA 2022a) with the aim of presenting a draft international agreement by the end of 2024 that will contain principles for dealing with plastics from the production to the waste stage.

Multiple pollution of large regions or oceans with harmful substances raises the question of the extent to which global exposure to chemicals already exceeds planetary boundaries. For an assessment of "chemical pollution" - extended by (Steffen et al. 2015) to "novel entities"[13] (including microplastics, nanomaterials) - no sufficient data were available at that time in the context of research on planetary boundaries - with the exception of pollution by nitrogen and phosphorus compounds (Rockstr m et al. 2009). However, a policy response to global hazards from chemicals requires firm evidence on their nature and extent. In a comprehensive review, Diamond et al. (2015) concluded from the work available by 2015: "Although it may not be possible to establish a single or even multiple planetary boundary (or boundaries) for chemical pollution at this time, an increasing body of evidence strongly suggests that we need more effective global chemicals management."

The movement for an International Panel on Chemical Pollution (IPCP), which emerged almost ten years ago, took up these concerns and proposed the establishment of a body to advise global policy on chemicals, similar to the IPCC for climate issues. This initiative was supported by thousands of scientists worldwide. In 2019, UNEA 4 identified the need for a science policy interface (SPI). Based on a UNEA 5 resolution (UNEA 2022b), discussions of a working group began in 2022, although it is still unclear whether to convene a similar platform to the IPCC, a link with the Global Chemical Outlook, or issue-specific working groups as needed. Research into potential threats to planetary boundaries from "novel entities" (see, e.g., Persson et al. 2022) is likely to have a major impact on the outcome of this discussion.

1.2 Status of SAICM 2019 and developments until 2023

As the decisions taken in Dubai provided for implementation by 2020, recommendations on the goals and strategy for the international management of chemicals and (hazardous) wastes for the period after 2020 were developed in the framework of the SAICM Intersessional Process (IP, currently chaired by the UK and Uruguay) following ICCM4. This "beyond 2020" process has been significantly delayed by the COVID-19 pandemic and did not conclude until ICCM5, held under the German presidency, in Bonn in September 2023.

In the meantime, five overarching "Objectives" have been formulated with broad consensus, and some 25 "Targets" have been discussed to operationalize the overarching goals. IP4, originally scheduled to adopt a draft in early 2020, had to be postponed and could not start its work until August 2022 (IP4.1 in Bucharest). Since the agenda could only be partially completed, a second date was scheduled for February/March 2023 (IP 4.2 in Nairobi). Remaining items, including the proposals for targets, were dealt with again in a third meeting (IP4.3 in Bonn immediately before ICCM5). A largely consolidated version is now available after ICCM5.

The working groups had to complete the following tasks in particular:

- Formulate generally accepted yet ambitious goals,

[13] "... new substances, new forms of existing substances, and modified life forms that have the potential for unwanted geophysical and/or biological effects. Anthropogenic introduction of novel entities to the environment is of concern at the global level when these entities exhibit (i) persistence, (ii) mobility across scales with consequent widespread distributions, and (iii) potential impacts on vital Earth-system processes or subsystems. These potentially include chemicals and other new types of engineered materials or organisms (...) not previously known to the Earth system, as well as naturally occurring elements (for example, heavy metals) mobilized by anthropogenic activities."

- Link unmet goals for redressing grievances as well as visions for 2030,
- Connect to the SDGs while strengthening the role of chemical management,
- Significantly improve the controlling of agreed targets and measures, and
- Find a viable model for funding future activities.

The complexity of these tasks obviously made it difficult to agree on the lowest common denominator, since - certainly with good reasons - targets can be formulated differently and more or less stringently. The burden of chemicals and the public pressure generated by them vary from country to country, so that the numerous "targets" are needed in their entirety, but individual countries or social groups - from industry associations to non-governmental organizations - set different priorities. However, changes requested from the current draft of the sub-targets (SAICM 2019b) often complicated the "Targets" or addressed issues of regional importance at best. A major point of contention was the inclusion of the topic of waste, as this had previously only been understood to include hazardous waste (exposure to hazardous chemicals). "Objective D" with its future-oriented claim was little affected by the changes during the IP. The overarching approach to sustainability contained in Objective D and its advantage in the interaction of otherwise separately considered economic sectors and environmental media was probably initially underestimated or not understood by some stakeholders. The IOMC addressed this problem in IP 4.2 by attempting to focus on three key issues, namely:

- "developing basic national chemical management systems and capacities in all countries,
- integrating chemicals management in key industry sectors and product value chains,
- integrating chemicals management with sustainable development issues and initiatives",

in order to incorporate and communicate the inclusive nature of the process (SAICM 2022b).

The requests for changes, which go into a great deal of detail, require enormous human resources for processing at the national governments and the SAICM stakeholders. However, these are generally not available, especially since chemicals and waste are not a top environmental policy issue. In addition, countries with low specific GDP in particular make resolving financial issues a condition for adopting targets. The advantage of a multi-stakeholder process in SAICM can also be a disadvantage in negotiations due to the entry of previously inactive associations with new areas of interest. Targeted disruptions related to completely different processes (wars, nuclear proliferation...) are an additional problem in UN bodies.

UNEA 5 emphasized the connection of the burden of waste and chemicals with issues ranging from climate and nature protection to the human right to a healthy environment. With this resolution, UNEA again clarified that the Dubai 2020 targets had been missed, and therefore encouraged participants in the SAICM process "to put in place an ambitious, improved enabling framework to address the sound management of chemicals and waste beyond 2020, reflecting a life-cycle approach and the need to achieve sustainable consumption and production, and addressing the means of implementation of the framework at the ICCM5." It extended the funding mechanism for SAICM, among others, for five years. UNEA 5 also highlighted a number of key issues of concern from the Global Chemical Outlook and tasked UNEP with detailed analysis of additional critical substances, including asbestos (UNEP 2022c).

Without a doubt, a comprehensive international convention would be desirable as a replacement for SAICM (see, e.g., Steinhäuser et al. 2022) and is called for by environmental associations ("global framework convention on sustainable management of substances, materials and resources should link the regulations on chemicals, pollutants, resources and hazardous wastes, while setting binding reduction targets" (BUND 2023)). According to previous experience, most recently with the Minamata Convention, the realization of such a vision will take at least a decade. The results of the ICCM5 do not indicate such an approach. Nor was a proposal for an "International Code of Conduct on Chemicals and Waste Management" adopted. However, the "Targets" that have now been adopted provide scope for internationally coordinated measures, e.g., in connection with the problem of highly hazardous pesticides. Some of the newly formulated targets go beyond the results achieved in the working groups during the IP. In particular, the seven targets formulated for "Objective D" are suitable for using the concept of sustainable chemistry at the global level, whereby waste management aspects are also to play a greater role than before.

1.3 European policy: "Green Deal" and "Chemicals Strategy for Sustainability"

Europe has extensive experience with the regulation of chemicals. The REACH Regulation, which has been in force since 2006, obliges manufacturers and importers of chemicals to record in a register an assessment of the properties of chemicals on the market or intended for the market from a production volume of 1 t per year, and also to disclose information on the safe handling of substances in products. According to REACH, particularly critical substances ("substances of very high concern") may be subject to prohibitions and restrictions on use. The great importance of the European market has led to numerous other countries - especially those that export substances or products to Europe - introducing similar regulations or working on them. The EU responded to the challenges arising from the findings on the global burden of plastic waste with its plastics strategy (see, among others, (EU 2019b)).

The EU Commission's "Green Deal" draws a comprehensive vision of future European economic and environmental policy. Consequently, ways are being sought that go beyond mere regulation to protect against hazards, as realized in REACH. In 2020, the Commission published its "Chemicals Strategy for Sustainability - for a Toxic-free Environment" (CSS), which takes a more integrative approach with a view to climate protection and resource management, among other things, and also refers to the necessary support of SAICM. The Commission presented the idea of substances and materials that can be considered "safe and sustainable by design" (SSbD). This is similar to the "benign-by-design" approach of sustainable chemistry (see Chapter 3). With the SSbD concept, the EU aims to provide incentives to Member States, industry and other stakeholders to promote innovation to largely substitute substances of concern in all sectors.

Thus, to situate the project in global politics, it should be noted:

- The international political environment has a high dynamic. The importance of chemicals and waste management increased significantly and led to groundbreaking decisions by the UNEA.
- This has been accompanied by a broadening of the field of vision, which is now no longer limited to damage caused by chemicals and hazardous waste, but includes interactions with other global problems.
- Sustainable chemistry is now being understood as a useful concept for sustainable chemicals management in both UN and EU policies to address these interrelationships.

- The ongoing work at SAICM suffered from the restrictions of the Corona pandemic. It is apparent at SAICM that the enormous complexity of the subject area is slowing down operationalization at the global level.

2 Sustainable Chemistry

2.1 The concept of sustainable chemistry

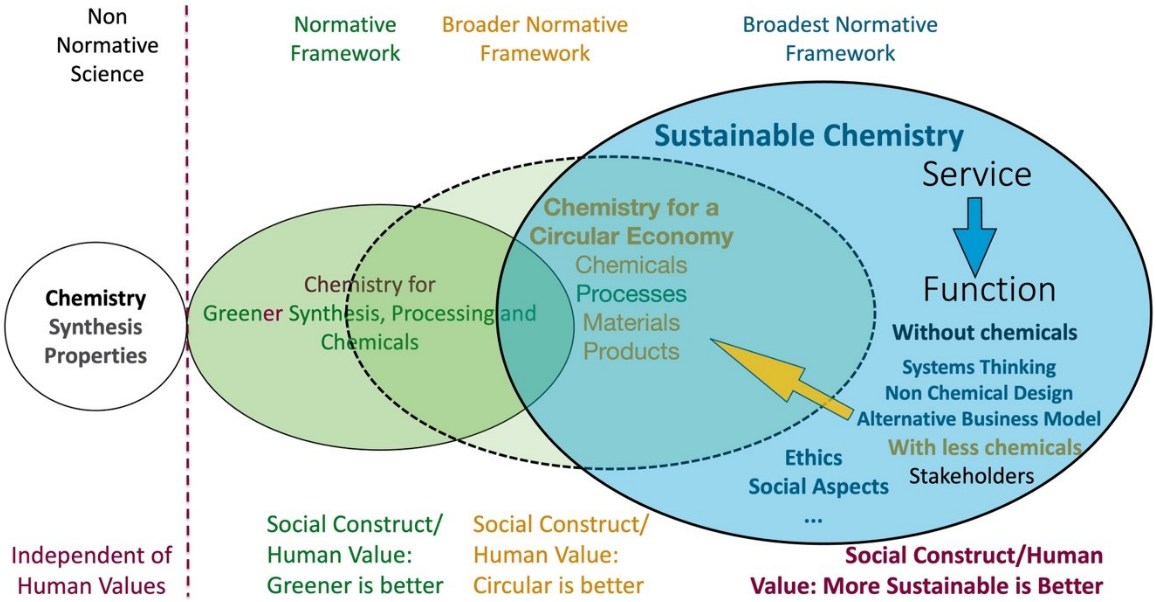
"Sustainable chemistry" is not a new subfield of chemical research but a concept designed to identify possible contributions to sustainable development with the help of chemical products and processes and to promote them in research, development and production. Sustainable chemistry goes beyond the "green chemistry" propagated since the 1990s with its twelve basic rules for the synthesis of substances. "Green chemistry" is concerned with "design, development and implementation of chemical processes and products to reduce or eliminate substances hazardous to human health and the environment" (Anastas / Warner, 1998). The rules of "green chemistry" have now achieved wide acceptance in synthetic chemistry. The OECD (OECD 2012) stated: "Green Chemistry is an approach to chemical synthesis that considers life cycle factors like waste, safety, energy use and toxicity in the earliest stages of molecular design and production, in order to mitigate environmental impacts and enhance the safety and efficiency associated with chemical production, use, and disposal. It takes a life cycle approach to minimize undesirable impacts that can be associated with chemicals and their production." However, it is only possible to evaluate the life cycle of a substance if all its applications in materials and products are taken into account. In this respect, a "green chemical" or a "sustainable material" cannot be readily defined (K merer et al. 2016).

The concept of sustainable chemistry therefore integrates "green chemistry" but goes beyond it. Through its holistic approach ("systems thinking") (Blum et al., 2017), sustainable chemistry takes into account important interfaces, especially with the extraction and use of natural resources, waste management or climate protection. Sustainable chemistry therefore focuses not only on the environmental compatibility of a substance, but also on the opportunities and risks of its use, its production, and its recycling or disposal.[14] By seeking materials that can be separated from products after use and recycled, as well as by largely excluding toxic or ecotoxic additives in materials, this concept supports strategies for an economic approach that is more circular than linear (Friege 2017, Kümmerer et al. 2020). In the sustainable chemistry concept, the desired function of a substance or material is the focus of consideration, so alternative ways of fulfilling the intended function are also taken into account. Therefore, for example, "chemical service" (UNIDO 2016) is an important tool to make the use of chemicals more sustainable.

These relationships are shown in Figure 1 graphically.

[14] The term "sustainable chemistry" has been or is sometimes used in the U.S. literature to refer to "green chemistry" as well (https://gc3sca.com/our-perspective/), although in the meantime even the protagonists of "green chemistry" consider a broadening of the original concept to be necessary (Anastas et al. 2018).

Figure 1: Development towards sustainable chemistry



Source: Graphics by Prof. Klaus Kümmerer

Sustainable chemistry involves contributions from chemistry to all areas of life (mobility, nutrition, clothing, housing). Decisive advances in research can be used for this purpose, for example (selection not exhaustive):

- Use of reagent-free conversions by photochemistry or electrosynthesis,
- Improving the atomic balance and thus the yield of chemical reactions while avoiding waste through more specific synthesis routes,
- Restructuring of the raw material base with the help of biorefineries, among others, which process renewable raw materials and waste of biological origin,
- Optimizing the use of CO_2 and optimizing electrolytic H_2 recovery as a basis for simple hydrocarbons,
- Development of substances and products that are completely degraded after use if they enter the environment as a result of their intended use, such as pharmaceuticals,
- Use of nanomaterials[15] in areas suitable for them, such as energy storage, air and water purification, protection of surfaces, catalysis and drug application, and
- Linking the design, production and application of chemicals with tools provided by digitalization ("Chemistry 4.0") with the aim of replacing today's excessive use of chemicals with substances that are as non-hazardous as possible in much smaller quantities.

A compilation of innovative developments that promise progress towards sustainable chemistry can be found in (Bazzanella et al. 2017). The World Business Council for Sustainable Development (WBCSD 2018) presents a wealth of ways in which innovative concepts in chemistry contribute to achieving the SDGs on an interactive website.

[15] Nanomaterials also belong to the "novel entities". For these, it is still open whether the planetary boundaries have been reached or possibly already exceeded, see Section 1.1. Therefore, the reference to "suitable areas" was chosen.

2.2 Political significance of the concept and SAICM objectives

In the past fifteen years, the development of the concept of sustainable chemistry has been advanced in science (e.g., EuChemS[16]) by using the rules of green chemistry in the use of substances in the industrial sector (e.g., GC3[17]) as well as in international chemical management. The German Federal Environment Agency (UBA 2009, 2011) and the OECD (OECD, 2016) recognized the political relevance of the concept at an early stage. The OECD emphasizes the holistic and innovation-oriented approach and defines sustainable chemistry as a "scientific concept that seeks to improve the efficiency with which natural resources are used to meet human needs for chemical products and services. Sustainable chemistry encompasses the design, manufacture and use of efficient, effective, safe and more environmentally benign chemical products and processes. Sustainable chemistry is also a process that stimulates innovation across all sectors to design and discover new chemicals, production processes, and product stewardship practices that will provide increased performance and increased value while meeting the goals of protecting and enhancing human health and the environment" (OECD 2016).

A milestone in establishing the concept at the global level is UN Environment Assembly Resolution 2/7 (UNEA 2, 2016): In it, the UNEA called on national governments, international organizations and stakeholders to document and evaluate examples of good practice in sustainable chemistry in support of the "sound management of chemicals and waste." Sustainable chemistry is unthinkable without high standards for the approval and management of chemicals and hazardous waste being embedded and implemented globally. Compliance with the requirements of environmentally sound management of chemicals and waste (SMCW) is therefore a basic prerequisite for sustainable chemistry. With regard to SMCW beyond 2020 - see Section 1.1 - there are still deficits in defining a long-term common understanding and vision of how existing management systems should be further developed and better aligned with each other. In view of the Strategic Approach to International Chemicals Management (SAICM) and perspectives for a new mandate until 2030, sustainable chemistry appears to be an excellent overarching guiding concept for its further development. This was also highlighted in the Global Chemical Outlook with reference to SAICM: "Use green and sustainable chemistry criteria to assess that innovations in chemistry are fully compatible with the 2030 Sustainable Development Agenda [...] Strengthen support mechanisms for sustainable chemistry start-ups in universities, research institutes, the private sector and all levels of government [...] Strengthen financial instruments to invest in sustainable chemistry innovation for example through green bonds and venture capital. Review and strengthen innovation policies to ensure they enable, and do not create barriers for sustainable chemistry innovation" (UNEP 2019).

While the SAICM Overarching Policy Strategy (OPS) initially refers explicitly to SMCW enforcement as defined in the 2006 Dubai Declaration, it opens the door to broader and more forward-looking approaches:

- First, in general terms, on the holistic approach to risks "throughout the life cycle of chemicals" and the prevention of damage through "pollution prevention,"
- Second, specifically in paragraph 14 i: "To promote the environmentally sound recovery and recycling of hazardous materials and waste," and

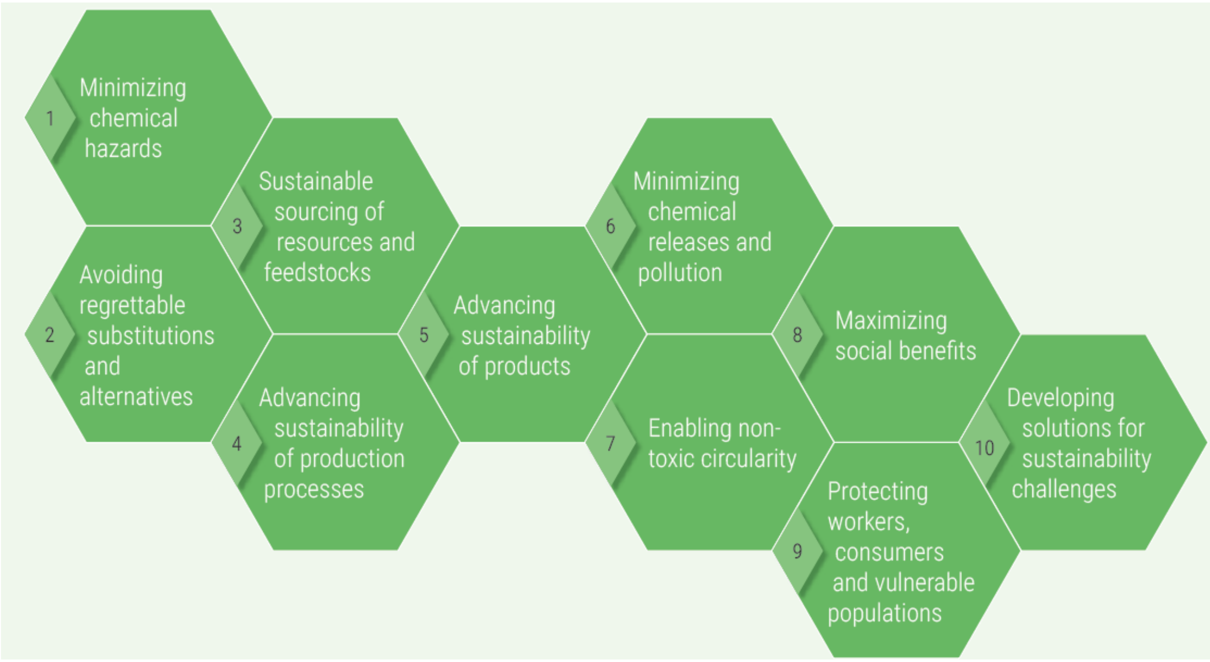
[16] European Chemical Society, Division of Green and Sustainable Chemistry https://www.euchems.eu/divisions/green-and-sustainable-chemistry-2/.

[17] Green Chemistry & Commerce Council (GC3) https://greenchemistryandcommerce.org/about-gc3/introduction. In spring 2023, GC3 rebranded as Change Chemistry. https://member.changechemistry.org/.

- In paragraph 14 j: "To promote and support the development and implementation of, and further innovation in, environmentally sound and safer alternatives, including cleaner production, informed substitution of chemicals of particular concern and nonchemical alternatives."

In execution of a mandate given to UNEP by UNEA Resolution 4/8 (UNEA, 2019), a "Framework Manual" for the practical implementation of green and sustainable chemistry approaches was developed with broad international participation of experts from academia, international organizations, nongovernmental organizations, and industry associations, with ten guiding principles (Figure 2) (UNEP 2020). The manual provides numerous examples of how work based on sustainable chemistry can contribute to sustainable development in numerous sectors and what conditions must be met in each case.

Figure 2: Goals and frame of green and sustainable chemistry



Source: Green and sustainable chemistry: Framework manual (UNEP 2020)

Another key document is the "Key Characteristics of Sustainable Chemistry", which summarizes the state of scientific discussions and the deliberations of the Scientific Advisory Board and the Stakeholder Forum of the ISC_3 (K mmerer et al. 2021). The wording can be found in the box on the following page.

The understanding of sustainable chemistry and its opportunities outlined in both documents is used extensively in this study.

Key characteristics of sustainable chemistry

1. HOLISTIC: Guiding the chemical science and the chemical sector towards contributing to Sustainability in agreement with sustainability principles and general understanding and appreciating potential interdependencies including long-distance interactions and temporal gaps between the chemical and other sectors.

2. PRECAUTIONARY: Avoiding transfer of problems and costs into other domains, spheres and regions at the outset, preventing future legacies and taking care of the legacies of the past including linked responsibilities.

3. SYSTEMS THINKING: Securing its interdisciplinary, multidisciplinary and transdisciplinary character including a strong disciplinary basis but taking into account other fields to meet Sustainability to its full extent. Application as for industrial practice including strategic and business planning, education, risk assessment and others including the social and economic spheres by all stakeholders.

4. ETHICAL AND SOCIAL RESPONSIBILITY: Adhering to value to all inhabitants of planet earth, the human rights, and welfare of all live, justice, the interest of vulnerable groups and promoting fair, inclusive, critical, and emancipatory approaches in all its fields including education, science, and technology.

5. COLLABORATION AND TRANSPARENCY: Fostering exchange, collaboration, and right to know of all stakeholders for improving the sustainability of business models, services, processes and products and linked decisions including ecological, social, and economic development on all levels. Avoiding all "green washing" and "sustainability washing" by full transparency in all scientific and business activities towards all stakeholders, and civil society.

6. SUSTAINABLE AND RESPONSIBLE INNOVATION: Transforming fully the chemical and allied industries from the molecular to the macroscopic levels of products, processes, functions and services in a proactive perspective towards sustainability including continuous trustworthy, transparent and traceable monitoring.

7. SOUND CHEMICALS MANAGEMENT: Supporting the sound management of chemicals and waste throughout their whole life cycle avoiding toxicity, persistency and bio-accumulation and other harm of chemical substances, materials, processes, products and services to humans and the environment.

8. CIRCULARITY: Accounting for the opportunities and limitations of a circular economy including reducing total substance flows, material flows, product flows, and connected energy flows at all spatial and temporal scales and dimensions especially with respect to volume and complexity.

9. GREEN CHEMISTRY: Meeting under sustainable chemistry application as many as possible of the 12 principles of green chemistry with hazard reduction at its core when chemicals are needed to deliver a service or function whenever and wherever this complies with sustainability.

10. LIFE CYCLE: Application of the above-mentioned key characteristics for the whole lifecycle of products, processes, functions and services on all levels, e.g., from molecular to the macroscopic levels and all sectors in a pro-active perspective towards sustainability.

2.3 Sustainability approaches in the chemical industry

In the chemical industry, too, there are numerous approaches to meeting the challenges of climate change, loss of biodiversity and exposure to toxic substances.

The voluntary initiative "Chemie[3]", in which the German Chemical Employers' Association, the Mining, Chemical and Energy Industrial Union (IG BCE), and the German Chemical Industry Association (VCI) are working together to develop sustainability targets and corresponding implementation guidelines, addresses all three fields of action.

One of the most important and best-known initiatives, coordinated in Europe by the European Chemical Industry Council CEFIC, operates in a similar way but on an international level: Responsible Care©. The objectives of this initiative, which is also voluntary, focus on environmental protection, occupational safety, health, and process safety:

- "Continuously improve environmental, health and safety knowledge and performance of our technologies, processes and products throughout their life cycle to prevent harm to people and the environment.
- Efficient use of resources and minimization of waste.
- We report openly on our achievements, successes and shortcomings.
- We listen, engage and work with people to understand and meet their concerns and expectations.
- Work with governments and organizations to develop and implement effective regulations and standards, and meet or exceed them.
- Support and guidance to promote responsible management of chemicals by all those who manage and use them along the product chain."

According to their own information, 90 percent of the top 100 companies in the chemical industry already signed the Responsible Care Charter (until 2016) (CEFIC 2023a).[18] Member companies are offered a web-based tool (CEFIC 2023b) that can be used to assess the maturity of sustainability management at plant level by means of 101 multiple choice questions. This is a self-assessment.

The system and questions are based on ISO 9001, ISO 14001, ISO 50001, ISO 45001, ISO 26000, EMAS, RC 14001 and RCMS. The results are published annually in aggregated form by CEFIC, among others, but not as data of individual companies. The advantage of this closed self-assessment is that it enables companies that are only at the beginning of their development towards more sustainability to carry out a clean status analysis and to use the results initially for their own further development.

Another voluntary initiative is "Together for Sustainability"(TfS), which is primarily aimed at supplier assessments. The approach differs from the other two initiatives in that an analysis and evaluation of suppliers is not carried out by the company itself, but by the "EcoVadis" platform.

TfS also refers to standards such as GRI, but also Responsible Care© and the ISO 26000. In addition to the assessment, an audit is also offered, the results of which are then made available to all members.

[18] "By 2016, more than 90 percent of the world's top 100 petrochemical and chemical manufacturers had signed on to the revised Global Charter."

In terms of content, the focus is on corporate governance issues, environmental protection, health and occupational safety, as well as human rights and social issues.

The results of the assessment and audit result in an action plan to address grievances or improve supply chain collaboration.

TfS is used for the prequalification of new suppliers as well as for the verification of existing suppliers. The advantage for customer companies is the comparability of the results and the derivation of appropriate measures. For suppliers, this can be advantageous because many customer inquiries can be answered with the report by registering with TfS/EcoVadis. A disadvantage is the fact that registration incurs costs and not all companies work with the same platform.

In addition to voluntary initiatives, the chemical industry is currently facing increasing demands for more transparency, on the one hand from various international NGOs, and on the other hand from the regulatory side. One example of an international initiative is the "Global Minimum Transparency Standard" (HEJ Support et al. 2021), which aims to create a globally applicable, binding standard for the declaration of globally available critical substances.

3 Goals and structure of the project

The targets of the Johannesburg Summit on the Safe Management of Chemicals and Hazardous Wastes have not been achieved or had only been partially achieved by 2020 under SAICM (see Chapter 1). The uncontrolled release of chemicals into the environment during production, use, and in the form of waste leads to global pollution of air, water, and soil and can cause massive damage to ecosystems. Improper handling of hazardous substances causes more than one million deaths worldwide each year. Low-income countries and disadvantaged populations bear the greatest burden. At the same time, the production of chemicals is growing, especially in non-OECD countries. Without significant additional efforts, the 2020 target will not be met in the near future. However, innovations through chemicals, new materials, the use of renewable raw materials for chemical production, and increasing efficiency in the use of chemical substances can also contribute to reducing resource consumption, improving the food situation, and switching to renewable energy. The GCO II (UNEP 2019) therefore makes clear that chemicals play a key role in achieving the Sustainable Development Goals (SDGs).

3.1 SAICM: Intersessional Process and ICCM5

The Intersessional Process (IP) and the ICCM5 therefore have the task of developing goals and strategies for this complex field in order to realize the intentions of the Johannesburg Summit as soon as possible and to support the achievement of the SDGs through appropriate activities. The concrete starting point of the project was a proposal by the co-chairs of the Intersessional Process discussed by the ICCM Secretariat in January 2019 to implement the vision "Protect human health and the environment from the harmful effects of chemicals and waste, to ensure healthy lives and a sustainable, safe planet for all" (SAICM 2018). This resulted in five proposed "strategic objectives" (see box on this page) and, mapped to these, a further twenty objectives in detail ("targets") for SAICM's future work. A work program was then to be built on these objectives. Corresponding indicators and milestones were to be used to track progress in achieving the vision and targets for the period after 2020.

Strategic Objectives - Co-chairs' Paper - Draft for consideration of the ICCM5 Bureau (SAICM 2018)

- Strategic objective A: Measures are taken to minimize or prevent harm from chemicals throughout their lifecycle and waste, including the development and implementation of national chemicals management systems in all countries.
- Strategic objective B: Knowledge, data, information and awareness generated, available and accessible to all to enable informed decisions.
- Strategic objective C: Issues of global concern are identified, prioritized and addressed.
- Strategic objective D: Benefits are maximized and risks prevented through innovative solutions and forward-thinking.
- Strategic objective E: The importance of sound management of chemicals and waste to achieve sustainable development is recognized by all, actions are accelerated and necessary partnerships established.

3.2 Goals and structure

Since proposals for ambitious targets were available in 2019, but considerations on indicators were still lacking, the Federal Environment Agency (UBA, hereinafter also "the client") combined its support for the preparation of the ICCM5 under the German presidency with the consideration of taking into account the concept of sustainable chemistry by means of suitable indicators and thus further developing the "sound management of chemicals and waste" into an effective international program for the period of the new mandate. This concept - so the thinking goes - is suitable for linking the chemical safety goals formulated in 2002 at the UN Summit in Johannesburg and the broad approach of the SDGs.

The aim of the project was to define recommendations for monitoring the success of international chemicals management in terms of indicators and milestones. The recommendations were to be carried out as part of a participatory process with national and international experts. The focus was to be on the "strategic objective D" proposed by the co-chairs, as well as other "targets" assigned to other "strategic objectives" (SAICM 2018) that could be used to establish a link to sustainable chemistry. Results were to be presented at ICCM5 and other events as appropriate.

3.2.1 Changes due to the deceleration of the Intersessional Process

As outlined in Section 1.2, there were significant delays in the IP, primarily due to the COVID-19 pandemic starting in late 2019. During 2020, it became clear that a consensual proposal for targets and a work program for submission to ICCM5 would not be achieved in the short term. In a departure from the original objective, after consultation with the Federal Environmental Agency, the development of milestones was postponed and the focus of the work was on indicators. The goal of presenting the indicators at ICCM5 also had to be abandoned, since (see Chapter 1) a submission of the "objectives" and, above all, the "targets" for a decision by ICCM5 had not yet taken place.

3.2.2 Final structure

The structure of the project builds on the terms of reference and the major changes caused by the pandemic and the IP delays (see above) and is as follows:

- Research indicators and reporting systems in Multilateral Environmental Agreements related to chemicals and in the 2030 Agenda for Sustainable Development, as well as under relevant international agreements in the areas of climate, biodiversity, pollution, health, corporate reporting related to the chemical industry, or management of chemicals and waste (see Chapter 4).
- Interviews with more than twenty distinguished experts from academia, government, industry, and nongovernmental organizations who work either on sustainable chemistry or on interfaces between chemicals and other global problem areas:
  - First round of interviews with questions on the relationship between sustainable chemistry and SAICM, indicators in existing international regulatory frameworks, measurement of innovation,
  - Second round of interviews with a comprehensive set of questions on the relationship between sustainable chemistry and SAICM, criteria for evaluating indicators, and experiences with indicators from international regulatory frameworks, and

- Third and fourth interview rounds based on an interview guide or individually tailored questions on, among other things, important interfaces of sustainable chemistry to global challenges or questions that served to fill gaps in the context of the development of indicators. (Rounds 1 to 3 also asked for further contacts of the interviewees with interest in the project in order to invite them to the workshops.)

► Organizing and conducting six workshops with a total of nearly one hundred participants to form opinions on potential indicators:

- Five virtual workshops, each with experts from a UN region with a topic of interest to that region,
- Invitation and implementation of the workshops (for details see Section 8.2):
  - According to a fixed organizational plan: Announcement with a request for confirmation of participation four to eight weeks before the workshop, mailing of a "Thought Starter" about two weeks before the date, another reminder and access data a few days before the workshop,
  - With presentations on the topic by UBA and the project team as well as presentations by invited experts from the respective UN region, and
  - With discussion of some proposed indicators in two parallel working groups with the help of dynamic "traffic light slides" in order to be able to precisely record and log the assessment by the discussion participants.
- Final hybrid workshop with experts who had already been involved in discussions or workshops.

The initial lists of indicators drawn up after evaluation of the literature research were each revised after the interview rounds and workshops and thus optimized in an iterative process (see Chapters 6 and 7). The evaluation criteria developed at an early stage of the project (see Chapter 5) for indicators were used primarily for this purpose.

Since consensual lists of "Objectives" or "Targets" were not available, results from SAICM Virtual Working Groups - meeting online from 2020 - were used. For the development of indicators, the targets from the report of the co-facilitators of VWG 1 (SAICM 2021) were used.

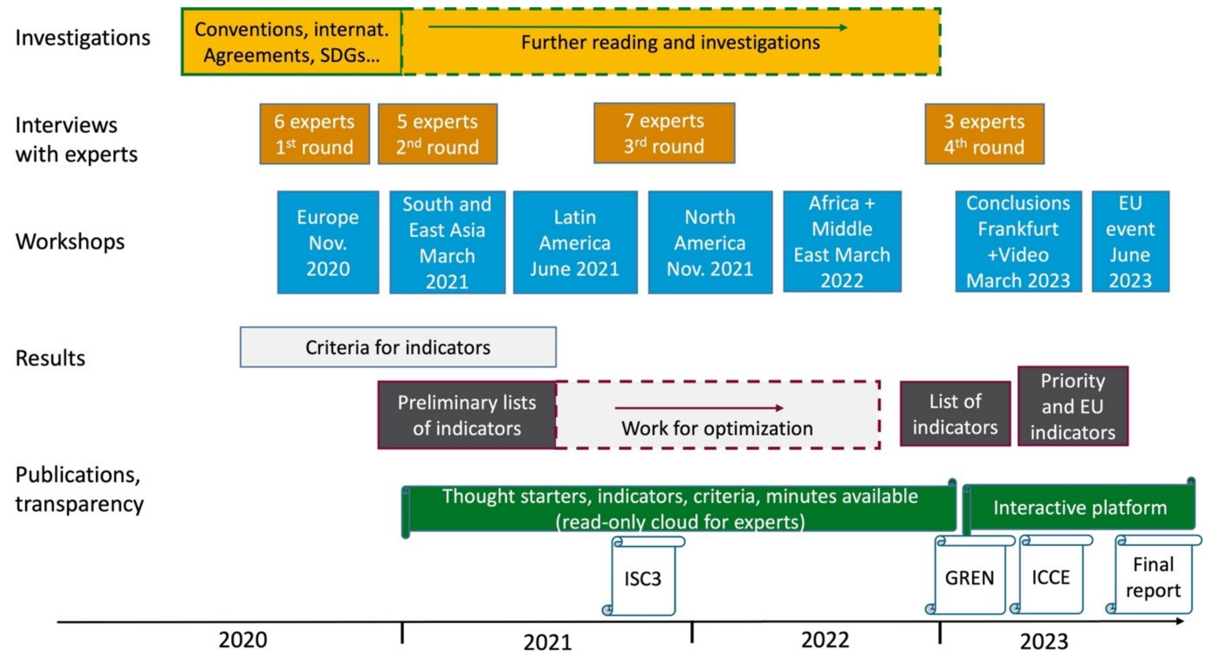
From February 2021, interim results and workshop minutes were initially published on an internet cloud with read-only access (read-only cloud) for all experts participating in interviews, workshops, etc. This was replaced by an interactive platform in order to promote the exchange of information between stakeholders (see Chapter 3). At the beginning of 2023, this was replaced by an interactive platform to promote the exchange among the participants (see Section 8.3).

First consolidated results were presented at the ISC_3 stakeholder forum in November 2021. With presentations at the 7th Green and Sustainable Chemistry Conference (GREN 2023 or GSC VII) and the 18th International Conference on Chemistry and the Environment (ICCE 2023), the project results were introduced into the scientific discussion (see Chapter 9).

Due to the growing importance of indicators of sustainable chemistry for European policy, corresponding databases in Europe were identified and potential indicators for the EU were proposed. These considerations were discussed in two online meetings with the SusChem Board and invited guests (including responsible staff members of the EU Commission) (see Sections 7.3 and 9.3).

Figure 3 shows the process flow in the form of a process diagram.

Figure 3: Structure and time schedule of the project



Source: Own illustration, N³ Thinking Ahead Dr. Friege & Partners

In 25 (mostly online) project discussions between the Federal Environment Agency and the team, partly with the participation of the responsible department of the Federal Environment Ministry, the focus was on progress in the search for indicators, the preparation and implementation of workshops, and developments at SAICM. The project team also informed the client about the project status achieved in each case by means of three interim reports and seven progress reports. The closing meeting of the project took place in Berlin on September 5, 2023.

4 Preliminary research and documentation

4.1 Fact sheets

At the beginning of the project, international agreements, voluntary agreements, standardizations and other frameworks were examined to determine whether indicators mentioned therein could be used or adapted for use in SAICM. A "fact sheet" was developed for this purpose.

Indicators should be as easy to identify as possible or - even better - already exist in existing agreements. As a result of this premise (see explanations in Chapter 3), international treaties, voluntary initiatives, etc., were first evaluated where interfaces with the "sound management of chemicals and waste" and, above all, interfaces with the concept of sustainable chemistry were to be expected. These included conventions and initiatives that explicitly refer to chemicals or waste (e.g., Minamata Convention, Basel Convention, GHS, Responsible Care®) or contain specifications for sustainability reporting, innovation programs, action programs on health, climate protection, or biodiversity, for example. The evaluation of around 40 globally applicable conventions or applicable initiatives, a few exemplary national programs from industrialized and emerging countries, and regionally applicable agreements was documented in detailed fact sheets or - in the case of less suitable foundations - in short check reports. The list of documents evaluated is provided in Appendix E. All "fact sheets" and "check results" were prepared in a uniform format, where a brief description of the document ("preamble") is followed by the evaluation of:

- The transfer potential of the indicators,
- Their connection with a strategic goal (Objective),
- The connection with (preliminary) strategic sub-goals (targets), and
- Indicators that may be used as part of the study.

Similarly, in the second step, thetransfer potential of milestones, the connection with the strategic goals A to E, and milestones that can be transferred to SMCW were then documented. Under the heading "Comments and further potential," numerous fact sheets derive additional suggestions for indicators that build on the respective document. In addition, the fact sheets contain essential contents and objectives, the names of the contracting parties, indicators for the achievement of objectives, significance for sustainable development, and implementation of the respective measures broken down by UN regions (where available). All of the approximately 200 indicators considered to be of potential interest to "SAICM beyond 2020" were tabulated and referenced to:

- The indicators for the SAICM targets (SAICM 2009), and
- The proposals for targets (2019/2020) developed by a technical working group (TWG) by 2020.

The 200 indicators extracted from the original sources were transferred into a table that allowed their evaluation with the criteria developed later. During the course of the project, this list was further reduced in iterative discussions among the team. Some of the indicators identified in advance as potentially useful were brought to the workshops for further discussion. More information on the procedure can be found in Chapter 6.

4.2 Additionally researched sources

In the course of the project, new developments such as the Kunming-Montreal Agreement on Biodiversity were analyzed for potential indicators but no more fact sheets were prepared on them in order to keep the effort within reasonable limits.

Additional standards reviewed include the OECD's Classification of the Functions of Government (COFOG) reporting (2011), the Nagoya Protocol ("Tenth meeting of the Conference of the Parties to the Convention on Biological Diversity" (COP 10 CBD)) and specifically the Aichi Biodiversity Targets (2010), as well as developments from the European Commission's Corporate Social Responsibility Directive (CSRD) and Chemicals Strategy for Sustainability (CSS), and the Global Reporting Initiative (GRI), each of which were included as new information became available.

4.3 Conclusions from the investigations of conventions and other sources

International agreements regulating the management and safe use of chemicals were naturally one of the main sources of indicators either directly related to chemistry (highly hazardous pesticides, hazardous substances, hazardous waste) or indirectly addressing interface issues; biodiversity and occupational health and safety are worth mentioning here. The most suitable sources for potential indicators turned out to be the "global indicator framework" developed for measuring progress on the 2030 Agenda, the work of the SAICM TWG (see above), and a list introduced into the discussion by IPEN.

A challenge in the identification of suitable indicators remains the clear definition of terms such as "natural resources," "rare raw materials," "waste," etc. It is to be expected that within the framework of the upcoming EU regulations, uniform definitions will be established, at least for the EU.

5 Criteria for the selection of indicators

The "sound management of chemicals and waste" (SMCW) is operationalized through targets. An essential next step in the concretization process is the selection of suitable indicators, which are used to verify the degree of target achievement. Sustainable chemistry is a concept used to support SMCW goals. Through its holistic approach ("systems thinking"), it takes into account important interfaces, especially with the extraction and use of natural resources, waste management, or climate protection (see Chapter 2). However, already established indicators, e.g., from existing regulations, should preferably be used, especially in view of the scarce capacities of the LMICs. In order to select indicators from existing sets of rules or from suggestions made by associations in workshops, etc., it is necessary to define quality requirements for the indicators on the basis of decided criteria. These concern the content-related coverage of the target areas of the SMCW or the more process-related framework of sustainable chemistry on the one hand and the fulfillment of formal requirements with regard to possibilities of data collection on the other hand.

5.1 Basic considerations

Indicators of environmental damage and threats to human health as well as their control are mostly systematized according to the PSR (pressure - state - response) model (OECD 2003) or the DPSIR (driving force - pressure - state - impact - response) model (EEA 1999). Both models represent a control loop in which the detection of damage (e.g., increase of a disease pattern - "state") is traced back to a cause (e.g., concentration of certain pollutants - "pressure"), against which measures (e.g., limit values, production restrictions - "response") are taken. In the DPSIR model, "impact" stands for effects caused by changes in state, e.g., reduction of biodiversity due to an increase in nutrient concentration in an environmental medium. Driving forces can subsume mass flows such as the production volume of materials.

The OECD designed the PSR model not only to monitor the combating of environmental damage through appropriate measures, but also to include desirable sustainable developments from the outset, such as the decoupling of production in an economic sector from environmental damage that may be caused by these economic activities. The term "response" is therefore used in the sense of socio-economic measures taken by governments and companies as well as private households. The PSR model is therefore also suitable for integrating the concept of sustainable chemistry into the indicators to be developed.

Indicators for SMCW or sustainable chemistry at the global level can only capture macroscopically detectable states (state indicators) or material flows (driving forces) or their changes (impact indicators), or also map the scope of corrective measures (response indicators).[19]

5.2 Development of formal Criteria A-G

A good indicator should be easy to measure, reliable, and understandable. As part of the SAICM intersessional process, a working group was established at IP3 with a mandate to design targets, milestones on the way to the targets, and indicators. In an interim report submitted in 2020 (SAICM 2020a), many of the proposed targets already had considerations for indicators as well. A working paper for IP3 provides guidance for the development of targets, touching on the issue

[19] In discussions with experts from UNEP or SAICM, the term "process indicator" was often used. In our view, this is a variant of "response indicator", namely the reference to a process that results in action.

of meaningful indicators (SAICM 2019a). "Targets" should therefore be "SMART", i.e., "specific", "measurable", "achievable", "relevant," and "timebound" (see box on this page).

Suggested framework to support the development of targets & indicators (SAICM 2019a)

Specific:

- What data and information?
- What is 'comprehensive'?
- What market?
- Who makes the data available?
- What 'sufficient' and 'knowledge'?
- Available and accessible to who?

Measurable:

- What is the ideal indicator?
- What can realistically be measured?
- What indicators already exist?
- What is the baseline?
- Is this draft target measurable?

Achievable:

- Can comprehensive data and information on chemicals on the market, throughout their lifecycle, be made available and accessible?

Relevant

- Is the target relevant to the Strategic Objective?
- Is the target relevant to other Strategic Objectives or targets?

Timebound

- What is the date by which this must be achieved?

Following these guidelines, criteria were formulated in the project with which an indicator can be assessed as suitable. Accordingly, an ideal indicator should:

- Have a target that is as specific and unambiguous as possible ("specific"),
- If possible, be already used in global agreements or by international organizations to avoid additional data collection efforts ("established"),
- Be based on easily ascertainable data or be cost-efficiently ascertainable ("determinable"),

- Be able to be characterized as far as possible with numerical values, or if numbers are not available, also by qualitative classifications such as compliance with limit values ("measurable"),
- Be based on reliable data whose origin can be traced ("reliable and transparent"),
- Have developments or trends that are trackable over certain periods of time ("dynamic"), and
- Have high relevance for SMCW or SC or the chemical industry sector ("pertinent" instead of "relevant").

A criterion for the reliability of the data or for comprehensible data collection ("reliable and transparent") was added. This is because data for complex issues that are collected in parallel in numerous countries can have quality deficiencies. The criteria "achievable" and "timebound" are missing, as they can only be meaningfully linked to a target but not to an indicator. The criterion "dynamic" takes up the measurability of trends over time.

The general criteria used for the selection of indicators can be found in Table 4.

Table 4: General criteria for indicators aiming at sustainable chemistry

Criteria A-G	Criteria wording
Specific	The indicator must be precise and unambiguous.
Established	The indicator is already in use by other systems, e.g., SAICM, Conventions.
Determinable	The collection of the data needed for reporting in the respective sector is easy and cost-efficient.
Measurable	Measurable: Either quantities, thresholds or qualitative properties are applicable.
Reliable and transparent	The data associated with the indicator are trustable and traceable.
Dynamic	Progress over time, a difference in the data associated with the indicator can be measured.
Pertinent	The indicator covers relevant aspects for the respective sector and / or area of application.

5.3 Development of the criteria for sustainable chemistry (H1-H5)

How can aspects of sustainable chemistry be included in the assessment of an indicator? First of all, it must be clear that sustainable chemistry is based on the proper handling of chemicals and waste (see Chapter 2) and that SMCW and the concept of sustainable chemistry therefore overlap. Indicators will thus often be attributable to both target areas. For the comparison of content with the concept of sustainable chemistry, the following were developed in parallel to the project:

- The Green and Sustainable Chemistry: Framework Manual (UNEP 2020), which was prepared by a wide range of experts following a decision by UNEA 4, and
- A dialogue paper published by the ISC_3 (in cooperation with the Federal Environment Agency) on the "Key Characteristics of Sustainable Chemistry" (K mmerer et al. 2021).

In Table 5, the "H-criteria" H1-H5 are contrasted with these two sources. The characteristics of sustainable chemistry have been grouped into five criteria in order not to unnecessarily complicate the evaluation of indicators. Criterion H is explained in more detail by H1 to H5: A major step from the sectoral view of SMCW to sustainable chemistry is the possibility to establish connections with other problems of sustainable development by systemic thinking and thus to avoid regressions elsewhere or to enable progress in other sectors. For example, Criterion H5 broadens the narrower view of waste (SMCW) to include the problem of dwindling non-renewable and wasted renewable resources.

Table 5: Criteria for sustainable chemistry indicators related to important sources

Key Characteristics of Sustainable Chemistry (Kümmerer et al. 2021)	Criteria wording for indicators focussing on the Concept of Sustainable Chemistry	Green and Sustainable Chemistry: Framework Manual (UNEP 2020)
1. HOLISTIC; 3. SYSTEMS THINKING; 10. LIFE CYCLE	H) Sustainability: Systems thinking is the prerequisite to reach the goals of the Agenda 2030: Potential trade-offs can be identified and managed with systems thinking. Sectors dealing with chemical entities contribute to Sustainable Development in compliance with the relevant SDG principles and the following sub-criteria (H1-H5).	10. Developing solutions for sustainability challenges.
2. PRECAUTIONARY; 6. SUSTAINABLE AND RESPONSIBLE INNOVATION; 7. SOUND CHEMICALS MANAGEMENT; 9. GREEN CHEMISTRY	H1) Responsible innovation: Development of sustainable solutions and safe and non-regrettable alternatives for chemicals of concern through cooperation on innovations, non-chemical alternatives, services like chemical leasing, or Extended Producer Responsibility (EPR) mechanisms. Foster collaboration along the value chains to promote circularity.	1. Minimizing chemical hazards. 2. Avoiding regrettable substitutions and alternatives. 4. Advancing sustainability of production processes. 6. Minimizing chemical releases and pollution.
1. HOLISTIC; 3. SYSTEMS THINKING	H2) Inter- and multidisciplinary, holistic approach: Considering interfaces with other urgent issues (health, environment, climate, resources/waste/circularity, biodiversity, nutrition, etc.) throughout the entire life cycle of chemical entities, while avoiding transport of problems to other sectors and future legacies.	5. Advancing sustainability of products.
4. ETHICAL AND SOCIAL RESPONSIBILITY	H3) Social responsibility: Promoting and ensuring health and safety as well as fair, inclusive, and emancipatory labour conditions, complying with human rights and justice in all its fields including education and science. Reduction of inequalities and fair distribution of benefits.	8. Maximizing social benefit. 9. Protecting workers, consumers and vulnerable populations.
5. COLLABORATION AND TRANSPARENCY	H4) Transparency and information exchange: Enabling right-to-know throughout the entire life cycle. Promoting knowledge exchange on all levels including all stakeholders (e.g., science, education, business, governments, administration, NGOs).	-

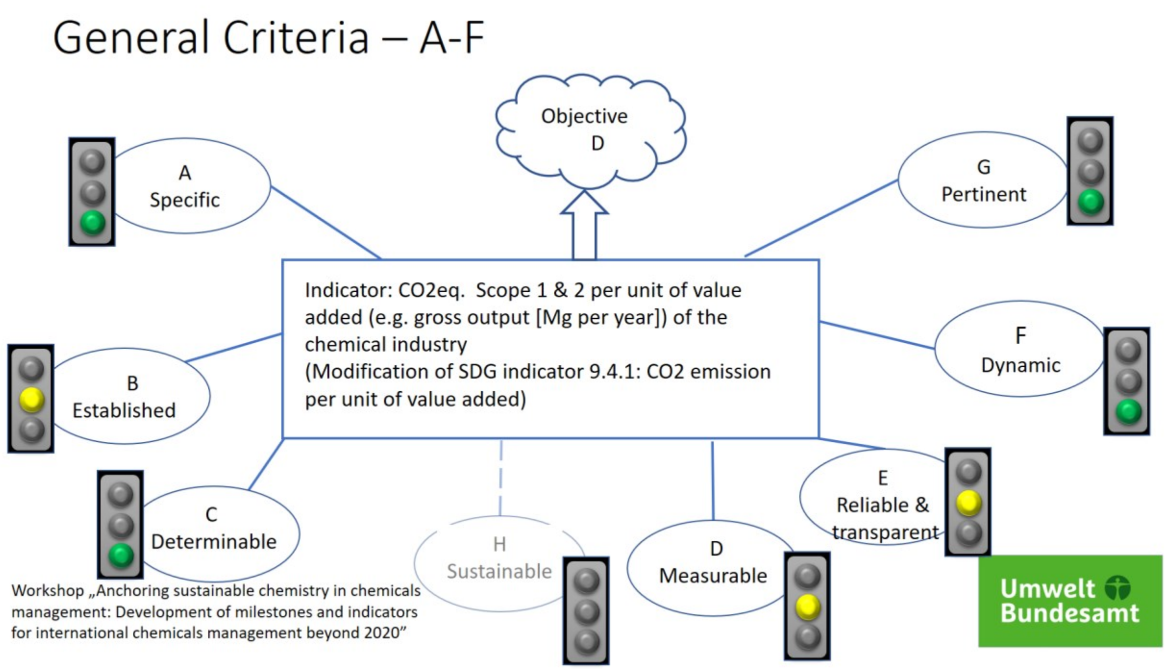
Key Characteristics of Sustainable Chemistry (Kümmerer et al. 2021)	Criteria wording for indicators focussing on the Concept of Sustainable Chemistry	Green and Sustainable Chemistry: Framework Manual (UNEP 2020)
8. CIRCULARITY	H5) Resource management and circularity: Sustainable management of resources, materials, and products (raw materials extraction, production, application, logistics, recycling, and end of life scenario) and energy, to enable circularity without contamination throughout the entire life cycle.	3. Sustainable sourcing of resources and feedstocks. 7. Enabling nontoxic circularity

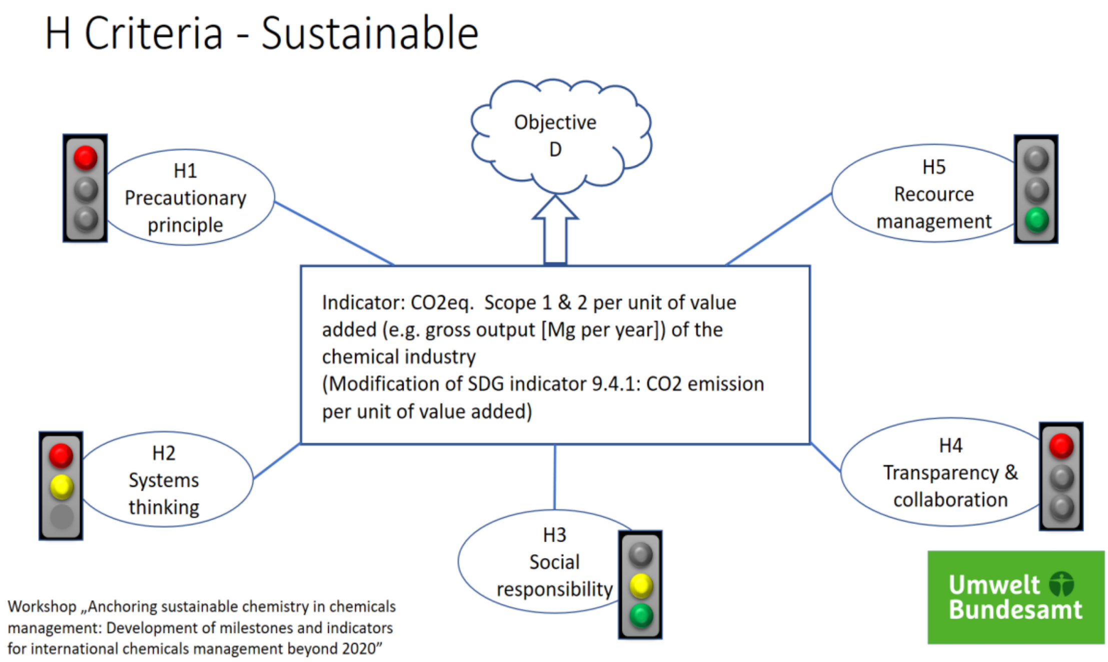
5.4 Reconciliation procedure

A first draft of the criteria was presented for discussion in several interviews with experts, including the lead authors of the "Framework Manual" or the "Key Characteristics", as well as in the first workshop. The subsequently revised version was used as a basis for the evaluation of indicators in further project work as well as in the following workshops. To this end, individual indicators were first presented and then discussed in working groups of about ten participants each on the basis of the criteria. The results were documented online on "traffic light slides" (for an example, see Figure 4). The discussions in the workshops helped to formulate the criteria more precisely but no changes in content were necessary. Only individual formulations for the definition of the criteria in Table 5 were adjusted. The criteria disseminated via the platform (see Chapter 8) were adopted by at least one association (CEFIC) for work on its own indicators, as became apparent at the sixth workshop.

Figure 4: Documentation from workshop No 4: results of the discussion of a potential indicator

The traffic lights were changed on line according to the opinions of the auditorium





Source: Screenshots taken on occasion of workshop No 4

6 Narrowing and selection of indicators

The list of potentially suitable indicators initially contained around 200 entries (see Chapter 4). It was supplemented, modified, and successively reduced to 45 indicators in the course of numerous discussions between the Federal Environment Agency and the project team, interviews with external experts and discussions with various stakeholders in the course of six workshops. Table 6 contains the list of these indicators assessed as useful, with an assignment to the "Strategic Objectives" for further work at SAICM (see box on this page); here, reference was made to the last version submitted before ICCM5. (This is a modification of the 2018 draft, which is documented on page 39.)

SAICM strategic objectives (draft, SAICM 2022a)

- A: [Measures are identified, implemented and enforced in order to prevent or, where not feasible, minimize harm from chemicals throughout their life cycle [and waste];]
- B: Comprehensive and sufficient knowledge, data and information are generated, available and accessible to all to enable informed decisions and actions.
- C: Issues of concern [that warrant [global][and][joint] action] are identified, prioritized and addressed.
- D: Benefits to human health and the environment are maximized and risks are prevented or, where not feasible, minimized through safer alternatives, innovative and sustainable solutions and forward thinking. Further discussion is needed in regards in the use of the term "safe[r]".
- E: [The importance of the sound management of chemicals and waste as an essential element to achieving sustainable development is recognized by all [adequate, predictable and sustainable financial and non-financial resources are [identified and] mobilized; actions are accelerated; and necessary [transparent and accountable] partnerships are established to foster cooperation among stakeholders].]

The criteria presented in Chapter 5 played a central role in the selection of the indicators. Appendix C contains a table detailing the origin (original version, source used, e.g., a convention) or development (e.g., modification by the project team) and classification of the indicators in terms of all criteria (A to G and H1 to H5).

Table 6: Complete list of proposed indicators

No.	Proposed Indicator	Assignment to a SAICM (drafted) Strategic Objective	Origin of the indicator and potential data source	Criteria for sustainable chemistry (bracketed = partially applicable)	Relation to SDGs: bold = directly bracketed = indirectly
1	Share of large/medium/small chemical enterprises of the region (Africa, Asia, Europe …) that report on their sustainability performance using GRI SRS	D, E	Project team	H2, H3, H4, H5	**12.6**

No.	Proposed Indicator	Assignment to a SAICM (drafted) Strategic Objective	Origin of the indicator and potential data source	Criteria for sustainable chemistry (bracketed = partially applicable)	Relation to SDGs: bold = directly bracketed = indirectly
2	Number of new supplier assessments carried out in the year under review, by region, and change compared with the previous year	A, D	Project team (TfS)	(H2), H3	**12.4, 12.6**
3	Number of Inspections (by authorities or independent auditors) undertaken to prove compliance with existing regulation in the relevant industries	A, D	Modification of a TWG4 Indicator (ILO)	H3	**12.4, 12.6**
4	Share of product categories (in relation to all product categories) to which extended producer responsibility applies	D	Modification of a TWG4 Indicator	(H1), H4, H5	**12.3, 12.5**
5	Domestic material consumption, domestic material consumption per capita and per GDP	D	SDG Indicator 12.2.2	(H4), H5	**12.2**
6	Proportion of hazardous waste treated, by type of treatment, e.g., recovered, recycled, incinerated	A, D	Modification of SDG Indicator 12.4.2.	(H2), H3, (H5)	**12.4**
7	Number of countries that have adopted…regulations aiming to disclose chemicals of concern (CoC) in consumer products	B, E	IPEN Indicator A.2-5	(H1), H3	(12.4)
8	Value of fossil-fuel subsidies per unit of GDP (production and consumption) related to the chemical industry´s energy consumption	D, E	Modification of SDG Indicator 12.c.1	H2, H5	**12.c**
9	Total value inward and outward illicit financial flows related to chemicals and waste measured per unit of product detected used for unintended application and volume of illegally disposed waste	A, C, D	Modification of SDG Indicator 16.4.1	H3, H4	**16.4**
10	Number of companies certified for Environmental Management or Health, Safety, Environment Management System... within the chemical industry… by an independent auditor	D	Modification of a TWG4 Indicator	H3, (H4), (H5)	**12.4, 12.6** (8.3)

No.	Proposed Indicator	Assignment to a SAICM (drafted) Strategic Objective	Origin of the indicator and potential data source	Criteria for sustainable chemistry (bracketed = partially applicable)	Relation to SDGs: bold = directly bracketed = indirectly
11	Share of companies belonging to National Associations (having implemented Responsible Care®) in the global turnover of the chemical industry or in the number of employees in the chemical industry worldwide	A, D	Project team	H3, (H4)	**12.4**
12	Share of the world's largest chemical companies having signed on to 2014 Responsible Care Global Charter	A, D	Project team	H3	**12.4**
13	Number or share of parties that have ensured that the public has appropriate access to information on chemical handling and accident management and on alternatives that are safer for human health or the environment than the chemicals listed in Annex III of the Rotterdam Convention	B	Project team	H3, H4	**12.4**
14	Direct economic loss attributed to chemical disasters in relation to global GDP	B	Modification of SDG Indicator 1.5.2	H3	**1.5**
15	Number of countries that have implemented a legal framework to reduce adverse impacts from chemicals throughout their lifecycle and waste	A	Modification of a TWG4 Indicator	H1, H2, H5	**12.4**
16	CO_2eq. Scope 1 & 2 per unit of value added (e.g., gross output [Mg / yr]) of the chemical industry	C, D	Modification of SDG Indicator 9.4.1	H2, H5	**9.4**
17	Number of companies publicly reporting their chemical footprint	D	IPEN Indicator D.5-7	H1, H3, (H4)	**12.6**
18	Number of progress or improvements documented in the year under review for suppliers already assessed in an audit follow-up / re-audit or reassessment, by region, and change compared to the previous year	A, D	Project team (TfS)	(H2), H3	**12.4** (10.3)
19	Share of chemical production based on renewable materials in relation to the global production that is based on renewable materials … [%]	D	Modification of a TWG4 Indicator	H5	**12.2**

No.	Proposed Indicator	Assignment to a SAICM (drafted) Strategic Objective	Origin of the indicator and potential data source	Criteria for sustainable chemistry (bracketed = partially applicable)	Relation to SDGs: bold = directly bracketed = indirectly
20	Reduction of the amount of hazardous chemicals used in design and manufacturing related to the total mass of chemical production by x %	A, D	Modification of IPEN Indicator D.5-2	H1, H3	**12.4** (6.3)
21	Amount of household waste generated / recycled (type…) / incinerated / landfilled per country	B, D	TWG4 (similar: IPEN Indicator D.2-15)	(H2), (H5)	**12.3., 12.5**
22	Amount of post-consumer plastic waste generated / recycled / incinerated / landfilled / not collected per country	B, C, D	Project team (based on a suggestion by the participants of Workshop #2)	(H2), (H5)	**12.5**
23	Number of countries using sustainable chemistry principles in their legal framework	D	Modification of a TWG4 Indicator	H1 - H5	**12.4** (8.2, 8.3, 9.5)
24	Material footprint, material footprint per capita, and per GDP	D	SDG Indicator 12.2.1	(H2), H5	**12.2**
25	Mortality rate attributed to unintentional poisoning … caused by chemicals	C, D	Modification of SDG Indicator 3.9.1	(H3), H4	**3.9**
26	Number of relevant instruments and collective agreements (e.g., between companies and trade unions) on occupational safety and health including the prevention of chemical risks	A, D	Modification of a TWG4 Indicator	H3	(3.9, 12.4)
27	Number of Member States whose laws and regulations and any other relevant instruments on occupational safety and health include the prevention of chemical risks	A, D	Modification of a TWG4 Indicator	H3	(3.9, 12.4)
28	Number of countries that adopt policies and instruments that implement agro-ecological strategies and practices that reduce synthetic input such as pesticides and fertilizers and are based on biodiversity and integrated soil nutrition…	D	IPEN Indicator A.1-6	H2, (H5)	**2.4, 2.5**

No.	Proposed Indicator	Assignment to a SAICM (drafted) Strategic Objective	Origin of the indicator and potential data source	Criteria for sustainable chemistry (bracketed = partially applicable)	Relation to SDGs: bold = directly bracketed = indirectly
29	Number of countries that implement circular economy without toxic chemicals recycling	D	Modification of IPEN Indicator D.2-4	H2, H3, H5	**12.5** (12.4)
30	Number of countries with EPR policies… so that the pharmaceutical industry is accountable for all pharmaceutical waste throughout the life cycle of their products	D	IPEN Indicator A.8-2	H1, H2, (H4)	(12.4, 12.5)
31	Number of PRTRs with publicly accessible data established	A, B, D	IPEN Indicator A.5-1	H1, (H4)	(12.4, 16.10)
32	Participation in educational, training and awareness programmes on chemical safety and sustainability, including # of graduates, # of participants, # of people receiving awareness programme	B	TWG4	(H2), H3, H4	**12.4** (12.8)
33	The percentage of companies with human rights (HR) due diligence procedures for toxic substances used, produced and released in their activities	D	Modification of IPEN Indicator D.6-2	H3, (H4)	(12.4, 10.3)
34	Change in water-use efficiency in the chemical industry ("water footprint")	A	Modification of SDG Indicator 6.4.1	(H2), H5	**6.4**
35	Renewable energy share in the… final energy consumption of the chemical industry	A, D	Modification of SDG Indicator 7.2.1	(H2), H5	**7.2**
36	Number of countries that have implemented pesticide legislation based on the FAO/WHO International Code of Conduct	A, B, C	TWG4 (IOMC Indicator)	H2, (H3)	**12.4**
37	Number/percentage of countries where the legal framework demands risk assessment and registration / authorization of new chemicals before putting them on the market	A, C	Project team (with reference to the IOMC Toolbox)	H1, H3	**12.4**
38	Number of (share of) countries reducing the emission of reactive N compounds (waste water, exhaust air, agriculture) by legislation	A, C	Project team	(H1), H2, H3	**2.4, 6.3,13.2**
39	Number of countries subsidising the use of synthetic fertilizers (or: not subsidising)	E	Project team	H2, (H5)	**2.4**

No.	Proposed Indicator	Assignment to a SAICM (drafted) Strategic Objective	Origin of the indicator and potential data source	Criteria for sustainable chemistry (bracketed = partially applicable)	Relation to SDGs: bold = directly bracketed = indirectly
40	Number of countries that have implemented the System of Environmental Economic Accounting (UN SEEA)	E	SDG Indicator 15.9.1b, also relation to Aichi target No. 3	H2, H4	**15.9**
41	Number of countries that phased out the manufacture, import, sale and use of Highly Hazardous Pesticides (HHP)	A, B, C	IPEN Indicator A.1-5	H1, H3	**3.9, 12.4**
42	Increase of the Environmental Protection Expenditures (%) in COFOG Reporting (COFOG = Classification of the Functions of Government)	D, E	Project team	H4	
43	Carbon pricing instruments (including fuel and carbon taxation, emissions trading systems - ETS) or: Amount of money earned from carbon pricing instruments	D, E	Project team	H2, (H5)	**13.2**
44	Number of companies conducting an environmental cost-benefit analysis	D	Project team	H4, H5	(12.6)
45	Sum of resource taxes on non-renewable natural resources and their extraction collected by countries	D, E	Project team	(H4), H5	(8.4, 9.4, 11b, 12.2)

All 45 indicators meet at least one criterion for sustainable chemistry (H). However, of these 45, only 17 indicators are already present in other sets of rules (B - established), 25 are classified as well determinable (C - determinable), and 20 as well measurable (D - measurable). When examining how many indicators meet two of the three criteria equally well, the number of suitable indicators decreases significantly to nine (B+C and C+D) and seven (B+D) respectively. Only four indicators have a very good score on all three criteria (B+C+D). That is, of the 17 established indicators, 13 are either well measurable but difficult to ascertain (e.g., too much ascertainment effort), or well ascertainable but poorly measurable (e.g., because only qualitatively ascertainable). Of the 28 indicators that are only partially established or not established at all, many are again ascertainable and/or measurable.

In the sixth and final workshop, it was recommended to revise the list of indicators, in particular to prioritize those indicators that map progress towards sustainable chemistry or trends for sustainable development in the sense of the SDGs and to map the indicators. In addition, the number of purely process indicators ("number of countries that...") should be minimized. "Key indicators" should be able to be applied by all countries, if possible, i.e., data should be available. For this purpose, the experts involved suggested the creation of a "measurability structure" (this suggestion could not be taken up in the project). After the sixth workshop, the proposed reduction was made by the contractor team and agreed with the client. This final list of 23 priority indicators can be found in Chapter 7.

In the following, an overview of available data sources (Section 6.1) is first provided. In Sections 6.2 to 6.6, individual indicators and their evaluation on the basis of the criteria are discussed by way of example, drawing on the table in the appendix.

6.1 Data generation on the global level

SAICM is a global network that also includes developing countries. Therefore, the indicators must use data that is as simple as possible to collect, especially since SAICM is not based on a binding international agreement. The IOMC has been trying for several years to raise the level of reporting with some very simple indicators that, among other things, map interrelationships between the different conventions ("data from verifiable sources for which global data are available," IOMC (2015b)). Because of the multi-stakeholder approach of SAICM, there is also the possibility to utilize reports from international organizations and other sources (e.g., from industry and environmental associations) in terms of tracking indicators. Key data sources for globally relevant indicators include the United Nations SDG Data Portal (https://unstats.un.org/sdgs/dataportal), the Open SDG Data Hub (https://unstats-undesa.opendata.arcgis.com/), the databases of organizations such as ILO (https://ilostat.ilo.org/), UNEP, UNECE, UNITAR, FAO, or WHO, or the websites of relevant multilateral environmental agreements such as the Basel Convention. Relevant sources of information from the (chemical) industry can be found at CEFIC or ICCA (Responsible Care®). However, these can only reproduce the data they receive from their member companies, so that the willingness to pass on data must be relied on here. This also applies to the world's largest database on sustainability reporting, which is operated by the Global Reporting Initiative (GRI). However, the Sustainability Disclosure Database (https://database.globalreporting.org) was decommissioned in spring 2021.

6.2 Indicators for hazards caused by chemicals

Some of the indicators refer directly or indirectly to potentially harmful substances, to their effects, or to measures to prevent or limit damage. In accordance with the procedure in the PSR or DPSIR model (see Section 5.1), they can be divided into state indicators, driving forces, impact indicators and response indicators.

In many cases, indicators of chemical hazards can build on existing reporting systems that primarily have SMCW objectives and are often only related to the process. Examples:

- No. 16: "Number of countries that have implemented a legal framework to reduce adverse impacts from chemicals throughout their lifecycle and waste" was also proposed in a similar form by the responsible working group as an indicator for the future work of SAICM (SAICM 2020b). This touches on aspects of Criteria H1, H2 and H5. The indicator is important (Criterion G) and specific (Criterion A). Information on this is available on the Internet (www.ecolex.org), so Criterion B is also fulfilled; however, the number of countries with corresponding sets of rules does not allow any conclusion on scope and enforcement. Therefore, the reliability of the indicator is rated as medium (Criterion E).
- No. 25: "Mortality rate attributed to unintentional poisoning caused by chemicals" meets Criterion H4 and, to a lesser extent, H3. It describes a condition whose change is urgently needed, and which can be tracked through regular data collection. However, the corresponding SDG indicator is more general. The addition of "caused by chemicals" is

additionally proposed to provide a more specific statement, as SDG 3.9 also refers to air pollution by particulate matter, among other things. More specific data can be collected, for example, by poisoning centers; however, completeness of data collection and reliability of diagnoses cannot be verified.

- No. 36: "Number of countries which have implemented pesticide legislation based on the FAO/WHO International Code of Conduct" is an IOMC indicator (IOMC 2015b) that meets Criteria H2 and partly H3, and is also proposed by the relevant working group as an indicator for the future work of SAICM (SAICM 2020b). It indicates how many countries are taking action ("responding") to manage pesticide use in line with SMCW. This indicator meets almost all formal criteria. However, it is not possible to record the enforcement of the relevant legislation; the measurability (Criterion D) is therefore limited.
- No. 9: "Total value inward and outward illicit financial flows related to chemicals and waste" is intended to indicate the status of the fight against illegal trade in chemicals and waste. The SDG indicator used as a source refers non-specifically to all illegal transactions. No statistical data is directly available for the addition made here, so Criteria C to E are not met. A systematic analysis of approximately 66,000 entries in the UN Comtrade database recently revealed massive violations of the Rotterdam Convention ("prior informed consent") for chemicals such as tetraethyl lead or chrysotyl asbestos as well as for pesticide trade (Zou et al. 2023).

For the transition to the broader approach of sustainable chemistry, the following indicator can serve as an example:

- No. 18: "Number of advancements or improvements documented in the year under review for suppliers already assessed in an audit follow-up / re-audit or reassessment, by region, and change compared to the previous year (TfS)" would contribute to Criteria H3 and partly also to H2. This is a suggestion by the project team that emerged from the research (see Chapter 4). EcoVadis conducts such audits on behalf of TfS[20], the results of which are of course only available to the companies directly involved. However, the data required for the indicator could be made available via anonymized statistics. These do not yet exist; therefore, measurability is not given (Criterion D). The project team addressed a corresponding request to CEFIC during the event on making the indicators usable in European policy (see Section 9.3)

Progress in the sense of sustainable chemistry is not directly related to groups of hazardous substances or the like in the indicators, but primarily to preventive or corrective measures. This can be illustrated by the following example (see also Sections 6.4 to 6.6):

- No. 23: "Number of countries using sustainable chemistry principles in their legal framework" is a proposal from TWG4 (SAICM 2020b), slightly modified by the team. The indicator is of high importance and specific (Criteria A and G). Due to the concretization of the concept of sustainable chemistry at the UNEP level in the meantime (see Chapters 1 and 2), the term "sustainable chemistry" is also clearly defined politically. However, its implementation in a set of regulations or its enforcement can hardly be measured, as already explained above with reference to indicator No. 16.

[20] Together for Sustainability (TfS) is an association of global chemical companies to conduct audits of their upstream suppliers to verify compliance with sustainability standards. TfS partners are CEFIC (the European Chemical Industry Council), VCI (the German Chemistry Council) and CPCIF (the China Petroleum and Chemistry Industry Federation), see https://www.tfs-initiative.com/.

The term "safe and sustainable by design" (SSbD) used in EU environmental policy refers to the "benign by design" principle that is part of the concept of green chemistry and sustainable chemistry. It would be beneficial to be able to track, via indicators, the extent to which this principle prevails in the synthesis of new chemical products or active pharmaceutical ingredients. This is difficult according to the experience gained in the evaluation of indicators: a conclusive, generally accepted definition is still lacking. Even if this were available (Criterion D), data would have to be collected either in relation to substitution of individual substances or groups of substances or to SSbD patent applications. In both cases, it is not expected that this will be possible with sufficient accuracy and / or reliability (see also results of ICCE 2023, Section 9.2.2).

6.3 Indicators for resources and waste

Systemic thinking is a crucial prerequisite for sustainable action. It is logical that the concept of sustainable chemistry explicitly includes the issue of resource consumption and also the interrelationships between energy and material resources (Criterion H5). The task of sustainable chemistry is to make do with fewer resources, especially non-renewable resources, and to make contributions to reducing material and energy consumption through suitable products. In addition, the waste phase ("EoL" = "end of life") is included through the specification of a "life cycle" consideration. The path to a reduction in resource consumption also leads via circular instead of linear material flows (Criterion H1). In this context, the carry-over of pollutants must be avoided (Criterion H5).

In its original version, SAICM only integrated hazardous (chemical) wastes into the work program (see Chapter 1). From TWG4, the role of waste management in SAICM was much broader (see discussion on "cross cutting high-level indicators" in (SAICM 2020b)). A stronger integration of waste management issues can now be realized with a compromise formula found in the final declaration - "the life cycle of chemicals, including products and waste" - and the preference for "circular, safer and sustainable approaches" called for in Objective D.2 under the new GFC (IISD 2023).

In the course of this study, numerous indicators were developed and discussed in the workshops as well as in interviews with individuals that are suitable for monitoring resource issues and the interface between products, materials and waste. Some examples are highlighted in more detail below:

- No. 22: "Amount of post-consumer plastic waste generated / recycled / incinerated / landfilled / not collected per country" was formulated in the context of this study and is based on a discussion at the second workshop. This indicator describes the specific status of a serious global problem and partially satisfies Criteria H2 or H5. Such detailed data on plastic waste are currently collected mainly by industrialized countries; thus, the measurability on a global scale is not given. The work on a global convention on plastic pollution (UNEA 2022a), which was initiated on the basis of UNEA Resolution 5/14, should help to provide appropriate data.
- No. 19: "Share of chemical production based on renewable materials in relation to the global production which is based on renewable materials ... [%]" was taken from the list of TWG4 ("number of companies that use natural products...") and made more precise. This indicator focuses on the necessary transformation from the use of non-renewable to renewable resources. The indicator meets Criteria H1 and H3 and clearly relates to the concept of sustainable chemistry. Global data for this is lacking so far, but could be provided by industry. Criteria C to E are therefore difficult to fulfill.

- No. 5: "Domestic material consumption, domestic material consumption per capita and per GDP" and No. 24: "Material footprint, material footprint per capita, and per GDP" were addressed at several workshops. These indicators fulfill Criterion H5 and partly also H2 and H4. However, material consumption is influenced by numerous parameters and not only by chemical production or resource-saving chemical products. Both are established as SDG indicators, but the corresponding data is missing (Material footprint) or is not up to date (Domestic material consumption).[21]

- No. 6: "Proportion of hazardous waste treated, by type of treatment, e.g., recovered, recycled, incinerated" is the version of an SDG indicator modified in the course of the project. It satisfies Criterion H3 and partly also Criteria H2 and H5. It addresses a significant problem (Criterion G) but is not specific to chemistry (Criterion A). The data are in principle available in many countries and could be assessed via the Basel Convention, if necessary, whereby the definition of hazardous waste should also be aligned with the categories of this international agreement.

- No. 29: "Number of countries that implement Circular Economy... without toxic chemicals recycling" was proposed in a similar form by IPEN. This indicator takes up the sustainability principle of recycling materials for reuse (Criteria H1, H5). However, a globally uniform definition of "circular economy" is still lacking. "Toxic chemicals" would also need to be defined in more detail. As already stated in Section 6.2 on indicators 16 and 23, the number of countries with such regulations says little about the success of the measures.

6.4 Indicators for climate and biodiversity issues

Due to the overarching approach of sustainable chemistry, interfaces to other global challenges should be considered, among others to avoid shifting problems to other sectors or between environmental media. These include planetary boundaries for greenhouse gases and the extinction of animal and plant species. Significant contributions by the chemical industry to climate protection can be made, among other things, through

- Reduction of energy consumption or use of renewable energies

- Conversion of the material basis to renewable raw materials

can be achieved. However, in view of the large demand for basic chemicals, excessive use of renewable raw materials can also lead to the destruction of species or biotopes. This issue was discussed using potentially suitable indicators in the third workshop with experts from Latin America and in the fifth workshop for Africa and the Middle East. In addition, several interviews focusing on biodiversity and production based on natural products were conducted. The link between climate gases and chemical production or products is comparatively easy to establish. The negative impact of certain products or production methods on biodiversity is known in numerous individual cases, but a general link between chemical use and species loss on a global scale is difficult to establish. Land use is considered to be the most important factor affecting biodiversity. In this respect, intensive monocultures on large areas such as sugar cane for ethanol production can result in serious damage to biodiversity, which cannot be captured in a simple indicator. For this reason, indicators were proposed that depict the framework conditions of agricultural production in connection with the use of chemicals. Here are important examples for the climate and biodiversity issues, respectively:

[21] Open SDG Data Hub www.unstats-undesa.opendata.arcigs.com (15 Sept 2022). Data up to 2017 are available for DMC, but these are only estimates.

- No. 16: "CO_2 eq. Scope 1 & 2 per unit of value added (e.g., gross output [Mg / yr]) of the chemical industry" is based on an SDG indicator, but here it is exclusively related to the chemical industry. In addition, the proposal from this study limits the carbon footprint to Scope 1 and Scope 2 in order to circumvent problems of smaller companies or of countries with low statistical possibilities when determining Scope 3. However, this reduces the informative value (Criterion G). The indicator meets Criteria H2 (holistic thinking) and H5 with reference to resource management.
- No. 35: "Renewable energy share in the... final energy consumption of the chemical industry" is, similar to the previously cited case, a more specifically formulated SDG indicator in the sense of taking sustainable chemistry into account.
- No. 38: "Number of (share of) countries reducing the emission of reactive N compounds (waste water, exhaust air, agriculture) by legislation" was developed by the project team. Various multinational agreements (e.g., OSPARCOM) address the pollution of marginal seas with nutrients, especially nitrogen compounds. Numerous countries are taking action with national initiatives against specific loads of nitrate in groundwater as a result of overfertilisation or against nitrogen oxides, ammonia, nitrous oxide from transport, agriculture and industry. With the Colombo Declaration (INMS 2021) and the subsequent UNEA resolution (UNEA 2022d), the issue is now on the global agenda. Like all "response" indicators, which only refer to the number of countries taking action, this does not allow the scope and enforcement of the measures to be represented.
- No. 41: "Number of countries that phased out the manufacture, import, sale and use of Highly Hazardous Pesticides (HHP)" was proposed by IPEN and belongs (see Section 6.3) to the indicators describing measures to protect against hazardous chemicals and fulfilling Criteria H1 and H3. However, human-toxic pesticides are also ecotoxic. In this respect, the indicator can also represent a framework condition for agriculture. In view of an unclear delimitation of HHP[22] as well as the lack of differentiation between production and consumption, measurability is problematic Criteria C to E).

Furthermore, innovations in the chemical industry, e.g., to improve the efficiency of renewable energies, to store energy, to reduce the material and energy consumption of chemical reactions, make significant contributions to climate protection. The question of the measurability of innovations is discussed in Section 6.6.

6.5 Indicators for social challenges

The data situation for measuring social issues is currently still difficult; most frameworks and reporting standards use general indicators, mostly at country level. Company indicators, on the other hand, relate to occupational safety, working hours and employee health and are not specific to the chemical industry.

Workshop participants suggested also using metrics focused on education, training, and upskilling of people entering the workforce. An indicator of the number of educational programs of this type would be useful and easy to collect. Another idea was to create a market-driven indicator that could measure behavior change from both consumers and industry.

More recent developments such as the German Supply Chain Due Diligence Act (LkSG) do not require explicit indicators, but only a general consideration and prevention of human rights

[22] IPEN refers in its proposal not only to the definition of (FAO/WHO 2016), but also to the criteria of the Pesticide Action Network of 2016 (PAN 2016). The latter have since been updated (PAN 2021).

violations and environmental risks in the supply chain. The Corporate Sustainability Due Diligence Directive (CSDDD) of the EU Commission also provides for something similar.[23]

At SAICM, there has recently been a "Community of Practice" that deals with the impact of chemicals or the chemical industry specifically on women, but there are no indicators on this yet.

Recent research indicates that women in LMICs in particular are affected by the mostly negative impacts of chemical use. They come into contact with chemicals more frequently and intensively in diverse areas of application, e.g. (Brosché 2021):

- In production: electronics manufacturing exposes workers to highly hazardous chemicals.
- During use: Women are more likely to be exposed to chemicals that have particularly harmful effects on pregnant women and developing children, such as lead in paint and chemicals in toys.
- After use and at the end of product life: e.g., when women are exposed to highly hazardous pesticides during harvesting or when cleaning used pesticide containers.

For the project, the following indicators were identified as useful and included in the list of 23 proposed indicators:

- No. 10: "Number of companies certified for Environmental Management or Health, Safety, Environment Management System... within the chemical industry... by an independent auditor". Although this indicator is primarily aimed at the environmental aspect, it would be relatively easy to collect and, assuming the principle of goodwill, reliable. In addition, environmental protection and health protection are increasingly being thought of and organized together in company and, in some cases, legal practice.
- No. 12: "Share of the world's largest chemical companies having signed on to 2014 Responsible Care Global Charter." This indicator also addresses both topics together. The problem here, however, is that the measurability of the indicator is moderate, as only the number of companies is determined, but not the degree of maturity and thus the effect of participation in the Responsible Care© initiative.
- No. 33: "The percentage of companies with human rights (HR) due diligence procedures for toxic substances used, produced and released in their activities" links human rights issues to the use of hazardous substances and is a slightly modified version of a proposal by IPEN (IPEN 2019). This is the only indicator assessed as suitable that explicitly addresses both chemical substances and human rights. It meets Criterion H3, and with limitations also H4. Undoubtedly, an important context is indexed here (Criterion G), which is also specific to production and processing of chemicals (Criterion A). However, there is no usable data basis for this so far. Regulations for the verification of supply chains by large companies (see, e.g., Spinaci 2023) may serve to collect such data in the future, but only by European companies, see the Corporate Sustainability Due Diligence Directive (CSDDD) in process above; this could provide for a corresponding database at EU level. The problems of determinability, reliability and measurability associated with this indicator are likely to be solved in the future, even beyond the borders of the EU, as it is increasingly taken into account in international reporting requirements and laws. Even if this is initially just another process

[23] At the time of writing, the CSDDD was in the trilogue process between the Commission, the EU Parliament and the Council of the European Union.

indicator, changes for the better can also be expected here under the assumption that the existence of management systems and processes leads to safer handling of toxic substances beyond pure production.

6.6 Indicators for sustainable innovations and investments

Finance plays an important role for all industries and can be a powerful lever for change towards a more sustainable economy. "Impact investing," socially responsible investing, ESG criteria, and - in Europe - the EU taxonomy are increasingly influencing investor decisions and corporate strategies. But it's not just the business environment that can help or hinder progress toward sustainability. Regulation, subsidies, taxes and other financial instruments also play an important role.

Often, latecomers receive financial support for investments in established technologies, even though these hinder the transition to sustainability. Another problem is that chemicals do not explicitly appear in the well-known ESG criteria (environmental, social, governance). Therefore, sustainable chemistry is not yet an important topic for investors. However, in the course of the public discussion about e.g., glyphosate or PFAS, this may change.

An important obstacle to the development of sustainable chemistry is an investment strategy focused on short-term profits (shareholder value orientation).

Various other approaches, such as the polluter-pays principle, influence market dynamics: companies with the best sustainability performance could benefit from price premiums, while those that are not considered sustainable or do not offer "sustainable" products face losses in market share. This is supported by the EU taxonomy and the chemicals strategy (see Section 7.3). Extended producer responsibility is increasingly becoming mandatory, e.g., in the EU and several US states. For now, this applies mainly to electronic goods, but it is expected that the concept will be extended to other industries, including the chemical sector. It should be clear that the successful implementation of EPR depends heavily on the legal and economic framework.

Regulations on taxes and penalties can be a game changer for the chemicals sector, e.g., the gradual regulation of substances classified as hazardous. This can change the portfolio of chemical manufacturers, which in turn can have an impact on the associated sales.

In many countries, prices for CO_2 emissions are being introduced or have already been established, for example via emission certificates (e.g., the EU Emissions Trading System, EU-ETS) or taxation, which could motivate energy-intensive industries and thus also chemical companies to make appropriate adjustments. GHG / CO_2 indicators are located at the interface between climate protection and finance and have already been described in Section 6.4. The appropriate indicator "Amount of fossil-fuel subsidies per unit of GDP (production and consumption) related to Chemical Industry's energy consumption" can indicate the reduction in subsidies for fossil energy that is desired in this case.

One risk lies in the, sometimes serious, differences between national and international regulations and trading systems, which may lead to companies relocating to countries with less stringent systems and lower energy prices.

Other negative incentives such as fees under climate protection agreements[24] can also be used to finance environmental protection and also make environmentally friendly production more

[24] Regulation in the United Kingdom: https://www.euki.de/en/euki-publications/factsheet-climate-change-agreements-uk/.

attractive to companies. On the other hand, subsidies and public grants could be a measure to promote innovation of products, processes and business models in the chemical sector.

One financial instrument at the state level is resource-specific taxes, which are intended to motivate people to invest in resource efficiency. A suitable indicator for this is the indicator proposed by the team

- No. 45: "Sum of Resource Taxes on non-renewable natural resources and their extraction collected by countries." The criteria of data availability and unambiguous determination as well as the application in already existing systems are not, or only partially, given. In addition, there is disagreement on the exact definition of "renewable" - e.g.: Is water renewable?[25]

Taxes can lead to changes in behavior, but are nevertheless often without a steering effect and are levied only to generate revenue. Therefore, fees, charges or other economic instruments should be included. The change also requires other business models related to the circular economy, e.g., chemical leasing, which can be supported by targeted financial assistance.

In order to measure progress in financial terms, two different types of indicators are required: at the public or governmental level and at the corporate level. As a government-level indicator, investment in environmental protection from the OECD's COFOG reporting system was discussed:

- No. 42: "Increase of the Environmental Protection Expenditures (%) in COFOG Reporting (COFOG = Classification of the Functions of Government)". The COFOG indicator is not specific enough. It would be better to have an indicator for the target group of the subsidies, i.e., whether they are directed to incumbents or to innovative solutions. COFOG is already used, but does not meet Criterion H.

At the company level, investments in research and development and "chemical alternatives assessments" (CAAs) could be taken into account, as they could indicate progress in the elimination or substitution of hazardous substances.

Innovation is seen as one of the strongest levers to support the transformation to a more sustainable and circular economy. The number of innovative "sustainable products" could thus become an indicator of the progress of the transformation. Since products cannot be sustainable per se, but only in certain applications that support sustainable development, a combination of indicators is required, e.g.:

- the materials used are based on the principles of green and sustainable chemistry (SSbD) and
- the product can be easily recycled.

The financial impact of such products could be measured by the revenue generated by these new products.

Another indicator could be the percentage of total sales accounted for by products assessed for sustainability (e.g., for companies using the Portfolio Sustainability Assessment (PSA) method of the WBCSD (2017)). The usefulness of creating a PSA in companies as an innovation indicator has been discussed on various occasions; ultimately, the problem of the very different methods is currently unresolved. A PSA indicator would not meet the criteria of traceability and also

[25] An older overview of tax revenues from nonrenewable resources is provided by (OECD 2014).

unambiguity and was therefore not included in the list of potential indicators. As the WBCSD is currently working on an update of the guideline for the PSA, this might change in the future.

The chemical industry provides numerous products and innovations for other sectors, e.g., energy from renewable sources, construction and buildings, to combat or mitigate climate change. An indicator for all these activities, i.e., the number of new patents filed in these areas, would be beneficial. However, no indicator meeting the main criteria (A to F) could be identified. Potential indicators such as subsidies for research and development or general financial incentives were also discussed, but failed due to a lack of data. The number of patents does not necessarily have to have a bearing on the contribution of the innovation to the transformation - it may also be patents for substances that ultimately involve other problems.

An SDG indicator targeting damage from catastrophic events was reviewed and modified by the team:

- No. 14: "Direct economic loss attributed to chemical disasters in relation to global GDP". In this indicator, only the direct economic loss is taken into account and all indirect costs are disregarded. Since only direct economic losses are considered, the relevance criterion is only partially met. However, it can be considered dynamic (F), reliable (E), established (B), and determinable (C). Another criticism was that it is difficult to draw the line between what is a disaster and what is an accidental release of substances. Therefore, further discussion on the definition should be considered. It was suggested that the UNISDR definition of disaster be used. Regarding the H-criteria, this indicator is lagging rather than predictive. To promote systems thinking, chemical spills caused by natural disasters should be included.

7 Suitability of indicators for international policy

7.1 Links of indicators to SDGs

The concept of sustainable chemistry has an integrative approach and, in contrast to green chemistry, includes the use phase of chemicals (Criterion H2). In addition to the further development of the production and use of chemicals, related societal issues are addressed (see Chapters 2 and 5). It would certainly be misguided to now consider the entire AGENDA 2030 from the perspective of sustainable chemistry. However, in developing the indicators, numerous interfaces with other global environmental problems and - via Criterion H3 - social problems associated with the extraction of resources, their processing and the use of the products made from them were taken into account. This integrative approach means that the indicators are applicable not only to SDG sub-goal 12.4, which is particularly relevant to SAICM, but also to other sub-goals of SDG 12, e.g.

- 12.2 - Resource consumption,
- 12.5 - Municipal waste reduction,
- 12.6 - Steps towards sustainable development and corresponding reporting in companies.

In addition, several broadly defined SDG indicators were related to the chemical industry by the project team (e.g., No. 14, 16, 34). On the other hand, indicators such as No. 38 ("...reducing the emissions of active N compounds..."), which are not addressed as a topic in SDG 12, have numerous cross-connections to SDG 2, SDG 6 and SDG 13.

The entries in the last column of Table 7 with the reference to the SDGs[26] are presented graphically in Figure 5. The indicators (circles) are each assigned to an SDG (squares) with their number (see first column of Table 6) and color-coded accordingly. Connecting lines indicate the applicability of indicators to further SDGs. The graph highlights the value of the integrative approach of sustainable chemistry for achieving the SDGs. From the graphical overview, it can be seen, among other things:

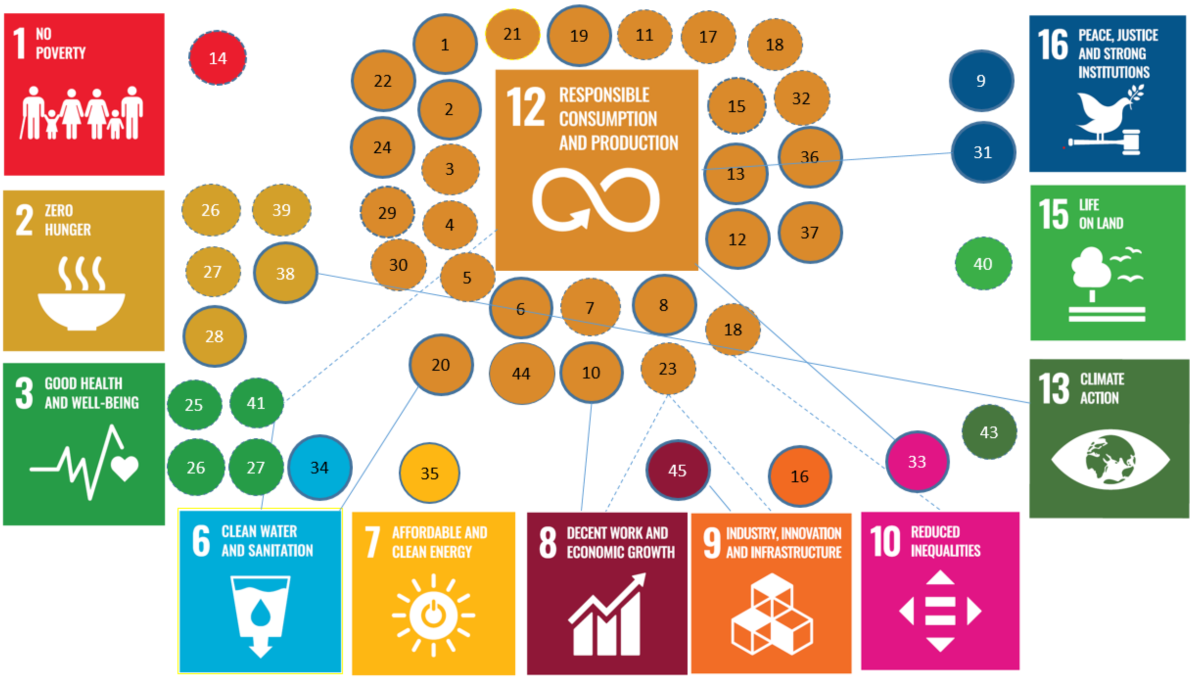
- Most of the indicators are related to SDG 12.
- Several indicators make references between SDG 12 and other SDGs (e.g., indicator #10 on SDG 8).
- Numerous indicators relate to one or more SDGs.

In addition to Figure 5, numerous indicators can also show indirect effects. An example is indicator No. 10 ("Number of companies certified for Environmental Management or Health, Safety, Environment (HSE) Management System... within the chemical industry... by an independent auditor"). It relates directly to SDG 12.4 and 12.6, respectively, and partly to SDG 8.3 ("Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation..."). Companies that are audited in terms of HSE standards will also take measures for occupational health and safety (SDG 3) and reducing emissions (SDG 13-15) to the environment, or continuously improve their standard in this regard. The overarching approach of the SDGs[27] is thus reinforced by integrative indicators.

[26] A graphical presentation with reference to individual sub-goals would no longer be presentable on a printed page.

[27] Integrative approach to implementing the SDGs in companies: www.sdgcompass.org.

Figure 5: Suggested indicators related to SDGs



The indicators (circles) are each assigned to an SDG (squares) with their number (see first column of Table 6) and color-coded accordingly. Larger circles with a closed border line indicate the most important indicators for SMCW (also in Table 7). Connecting lines indicate the applicability of indicators for further SDGs.

Source: Own illustration, N³ Thinking Ahead Dr. Friege & Partners

7.2 Suitability of indicators for SMCW

The political feasibility of the indicators, especially with reference to SMCW or for international chemicals management in general, was one of the topics of the last workshop. The following recommendations were discussed intensively:

- Limit to ten to twelve impact indicators of high relevance to the SMCW, with particular attention to the needs of developing countries, and a further maximum of ten indicators for forward-looking policies aimed at transformation towards sustainable chemistry, initially with greater relevance to G20 countries.
- Increase the proportion of indicators that reflect AGENDA 2030 goals in terms of positive, sustainable development, rather than indicators that address reduction or abatement targets. Specifically, an indicator that measures the implementation of "portfolio sustainability assessments" (PSA) was proposed.
- Refrain from using process-related indicators of the type "number of..." because of their mostly low informative value; instead, focus on impact indicators.
- Indicators should also be prioritized according to the availability of data for their measurement.
- Some indicators contain terms that are not clearly defined, such as "hazardous". These are to be provided with concrete definitions and source references.

After subsequent discussion between UBA and the project team, the following conclusions were drawn for the presentation of the results and implemented accordingly:

A limitation to about twenty indicators is useful for increasing political acceptance and has been realized (see below).

However, a split of the list in two different types of indicators (along the lines of G20 on the one hand and developing countries on the other) would contribute to widening the gap between industrialized countries and less developed nations. For this reason, such a dichotomy was not adopted.

Indicators for positively-occupied targets are included in the list (e.g., #1, #10, #11, #12). However, the focus on SMCW also requires indicators for reduction targets. The number of PSA users or the like has not yet been considered an appropriate indicator (see Section 6.6 for justification).

As part of the reduction of the list, several indicators that relate only to a certain number of countries were not included (see also the comments on this in Chapter 6). However, such easy-to-record process-related indicators often represent the beginning - but not the success - of a corrective action (e.g., No. 13).

The search for suitable indicators in existing treaties and regulations also served to make data collection for indicators as simple as possible. However, this resulted in hardly any future-oriented indicators related to the concept of sustainable chemistry. The data situation (Criteria C-E) was taken into account in the selection of around twenty indicators that could be particularly suitable for the future international management of chemicals and waste.

Difficulties due to different definitions cannot be solved within the scope of this study. Since the indicators are often based on existing regulations and treaties, practical implementation will have to rely on the definitions used there.

Based on these considerations, the list of 45 indicators presented in Chapter 6 was reduced to 23 indicators. This list is presented in Table 7; the respective numbers are identical to the order numbers in Table 6. The numbers included in the short list in Table 7 are shown in the graphic linking the indicators to the SDGs (Figure 5) and have a solid line border.

Care was taken to again include all of SAICM's "Strategic Objectives" in draft form. Five indicators relate exclusively to the particularly forward-looking objective D, 13 others to D and other objectives. The assignment of the indicators to "sound management of chemicals and waste" or to "sustainable chemistry" or to both concepts is based on an assessment by the project team, which naturally included discussions with the client and experts as well as the results of the workshops.

Table 7: List of priority indicators with respect to SMCW

No.	Proposed indicator	Assignment to a SAICM (drafted) Strategic Objective	Origin of the indicator and potential data source	Criteria for sustainable chemistry (bracketed = partially applicable)	Relation to SDGs: bold = directly bracketed = indirectly
1	Share of large/medium/small chemical enterprises of the region (Africa, Asia, Europe …) that report on their sustainability performance using GRI SRS	D, E	Project team	H2, H3, H4, H5	**12.6**
2	Number of new supplier assessments carried out in the year under review, by region, and change compared with the previous year	A, D	Project team (TfS)	(H2), H3	**12.4, 12.6**
6	Proportion of hazardous waste treated, by type of treatment, e.g., recovered, recycled, incinerated	A, D	Modification of SDG Indicator 12.4.2.	(H2), H3, (H5)	**12.4**
8	Value of fossil-fuel subsidies per unit of GDP (production and consumption) related to Chemical Industry´s energy consumption	D, E	Modification of SDG Indicator 12.c.1	H2, H5	**12.c**
9	Total value inward and outward illicit financial flows related to chemicals and waste measured per unit of product detected used for unintended application and volume of illegally disposed waste	A, C, D	Modification of SDG Indicator 16.4.1	H3, H4	**16.4**
10	Number of companies certified for Environmental Management or Health, Safety, Environment Management System... within the chemical industry... by an independent auditor	D	Modification of a TWG4 Indicator	H4, (H4), (H5)	**12.4, 12.6** (8.3)
12	Share of the world's largest chemical companies having signed on to 2014 Responsible Care Global Charter	A, D	Project team	H3	**12.4**
13	Number or share of parties that have ensured that the public has appropriate access to information on chemical handling and accident management and on alternatives that are safer for human health or the environment than the chemicals listed in Annex III of the Rotterdam Convention	B	Project team	H3, H4	**12.4**
16	CO_2eq. Scope 1 & 2 per unit of value added (e.g., gross output [Mg / yr]) of the chemical industry	C, D	Modification of SDG Indicator 9.4.1	H2, H5	**9.4**

No.	Proposed indicator	Assignment to a SAICM (drafted) Strategic Objective	Origin of the indicator and potential data source	Criteria for sustainable chemistry (bracketed = partially applicable)	Relation to SDGs: bold = directly bracketed = indirectly
19	Share of chemical production based on renewable materials in relation to the global production which is based on renewable materials … [%]	D	Modification of a TWG4 Indicator	H5	**12.2**
20	Reduction of the amount of hazardous chemicals used in design and manufacturing related to the total mass of chemical production by x %	A, D	Modification of IPEN Indicator D.5-2	H1, H3	**12.4** (6.3)
22	Amount of post-consumer plastic waste generated / recycled / incinerated / landfilled / not collected per country	B, C, D	Project team (based on a suggestion by the participants of Workshop #2)	(H2), (H5)	**12.5**
24	Material footprint, material footprint per capita, and per GDP	D	SDG Indicator 12.2.1	(H2), H5	**12.2**
28	Number of countries that adopt policies and instruments that implement agroecological strategies and practices that reduce synthetic input such as pesticides and fertilizers and are based on biodiversity and integrated soil nutrition…	D	IPEN Indicator A.1-6	H2, (H5)	**2.4, 2.5**
31	Number of PRTRs with publicly accessible data established	A, B, D	IPEN Indicator A.5-1	(H1), H4	(12.4, 16.10)
33	The percentage of companies with human rights (HR) due diligence procedures for toxic substances used, produced and released in their activities	D	Modification of IPEN Indicator D.6-2	H3, (H4)	(12.4, 10.3)
34	Change in water-use efficiency in the chemical industry ("water footprint")	A	Modification of SDG Indicator 6.4.1	(H2), H5	**6.4**
35	Renewable energy share in the… final energy consumption of the chemical industry	A, D	Modification of SDG Indicator 7.2.1	(H2), H5	**7.2**

No.	Proposed indicator	Assignment to a SAICM (drafted) Strategic Objective	Origin of the indicator and potential data source	Criteria for sustainable chemistry (bracketed = partially applicable)	Relation to SDGs: bold = directly bracketed = indirectly
36	Number of countries that have implemented pesticide legislation based on the FAO/WHO International Code of Conduct	A, B, C	TWG4 (IOMC Indicator)	(H2), H5	**12.4**
37	Number/percentage of countries where the legal framework demands risk assessment and registration / authorization of new chemicals before putting them on the market	A, C	Project team (with reference to the IOMC Toolbox)	H1, H3	**12.4**
38	Number of (share of) countries reducing the emission of reactive N compounds (waste water, exhaust air, agriculture) by legislation	A, C	Project team	(H1), H2, H3	**2.4, 6.3, 13.2**
44	Number of companies conducting an environmental cost-benefit analysis	D	Project team	H4, H5	(12.6)
45	Sum of resource taxes on non-renewable natural resources and their extraction collected by countries	D, E	Project team	(H4), H5	(8.4, 9.4, 11b, 12.2)

The numbers in the first column are linked to the complete list of indicators (see full report, Table 6, and Appendix C).
Abbreviations:
GDP: Gross domestic product
PRTR: Pollutant Release and Transfer Register
SDG Indicator: Indicator for Sustainable Development Goal No...
TWG4: Mapping exercise: existing global and regional data and indicators relevant to the Beyond 2020 Framework (SAICM 2019b).

At ICCM5, seven sub-objectives ("Targets") were formulated for "Objective D" (see box on the following page). Many of the indicators listed in Table 7 can be assigned to these sub-goals:

- To D1: indicators 6, 10, 16, 19, 35 - with these indicators primarily indicating the positive consequences expected from such investments
- To D2: indicators 8, 31, 34, 36, 37, 38, 45
- To D3: indicators 1, 12, 13
- To D4: indicators 20, 33 and partly also the indicators listed for D1
- To D5: indicators 28, 36
- To D6: There are no directly applicable indicators in Table 7. However, positive effects of such strategies can be recorded using indicators 24 and 20, among others.
- To D7: indicators 2, 12, 33

The Global Framework for Chemicals: Strategic Objective D on safer alternatives and innovative and sustainable solutions (IISD 2023)

- Target D1: By 2030, companies invest in sustainable chemistry and resource efficiency;
- Target D2: By 2035, governments implement policies encouraging circular, safer and sustainable approaches
- Target D3: By 2030, the private sector implements policies and strategies alongside reporting standards;
- Target D4: By 2030, relevant stakeholders give priority to sustainable and safer alternatives to harmful substances in research and innovation;
- Target D5: By 2030, governments implement policies supporting safer and more sustainable agricultural practices;
- Target D6: By 2030, sustainable strategies have been implemented in major economic and industry sectors to reduce their impact;
- Target D7: By 2030, stakeholders implement occupational health and safety practices and environmental protection throughout the supply chain.

IOMC supports SAICM's work in a variety of ways (including IOMC 2015a). At IP4, IOMC published a list of indicators to measure progress toward the SAICM 2020 target. An interim status of the list was discussed in a meeting between members of the responsible IOMC working group and UBA and members of the project team. The final list of IOMC indicators was not released until August 2023 as an informational submission to ICCM5 (SAICM 2023). While the IOMC continues to focus on the management of chemicals and waste (SMCW), the UBA project targets indicators that measure progress toward sustainable chemistry (SC). The lists have intersections on the following aspects (numbering refers to Table 6 and Table 7, respectively):

- Two IOMC indicators (IOMC 2015b) had already been adopted unchanged as part of this project: No. 36, 37
- There are several indicators in the revised IOMC list that are similar to the following indicators from this study: 6, 8, 31.
- Other indicators could serve to complement the list presented here, particularly on biodiversity ("Water Quality Index for Biodiversity (Trends in ecosystems affected by pollution)" and waste ("Number of parties that have developed and implemented national strategies, plans or programs for hazardous waste minimization").
- The indicators for nitrogen (No. 38, partly also No. 39) in the two lists complement each other ("Trends in nitrogen deposition", "Trends in loss of reactive nitrogen to the environment").
- The IOMC list includes other proposals for "decent work" with reference to ILO activities.

During the discussion with members of the IOMC working group, it was agreed that the lists are complementary and that both lists have gaps in terms of innovation towards sustainability, equality and financial aspects.

7.3 European Chemicals Strategy for Sustainability (EU CSS)

Globally relevant indicators often encounter problems of lack of statistical validation and lack of transparency in data collection, especially in LMICs.[28] Within Europe or the EU, on the other hand, extensive, reliable statistical documentation is available. An important impulse for the development of chemicals management comes from the Chemicals Strategy for Sustainability - CSS (EU 2020) published in 2020 as part of the so-called Green Deal of the EU Commission. As part of the CSS, among other things, a "High-Level Roundtable" was set up in 2021 to discuss the measures envisaged ("action plan"). In this action plan, in addition to numerous amendments to REACH, improvements to the framework legislation for waste, etc., topics are also addressed that are important at the UN or SAICM level, such as the implementation of the GHS (measures 80-85). Another measure is also the development of indicators ("establish ... Key Performance Indicators to measure the industrial transition towards the production of safe and sustainable chemicals"). Of course, the level of ambition of the EU here should be higher than that of SAICM, because for "sound management of chemicals and waste" there is already a corresponding legal framework in Europe with REACH, CLP, WFD, etc. The EU should also be able to develop indicators to measure the industrial transition towards the production of safe and sustainable chemicals. However, in order to take advantage of synergies, it would make sense for the indicators to be introduced in the EU and those to be introduced at SAICM to be compatible and, at best, to build on each other. Therefore, the European data base for the 45 indicators (Table 6; see Section 6.1 for data base) was reviewed with the aim of making suitable indicators usable at the EU and strengthening the link between EU chemicals policy and the work at SAICM.

First, the statistical basis of 24 indicators that are not established globally (Criterion B) and pose considerable problems with regard to Criteria C and D ("Determinable" and "Measurable", respectively) was examined at the European level. Table 8 contains a total of eight indicators for which reliable data are already available at the EU level or will be available in the foreseeable future.

Table 8: Indicators that are hardly available or measurable globally but available at EU level

No.	Existing / proposed indicator (Source)	Available data sources in the EU
1	Share of large/medium/small chemical enterprises of the region (Europe ...) that report on their sustainability performance using GRI SRS (current status: 93 % of the largest 250 corporations worldwide covering all sectors). (GRI/TEAM)	In principle available from 2025 at the latest, see CSRD (EU 2022a); electronic reporting format obligatory: European single access point (ESAP) for public corporate information (EU 2019a); tagging of relevant ESG disclosures is obligatory; European Sustainability Reporting Standards (ESRS) are under development
6	Proportion of hazardous waste treated, by type of treatment (12.4.2) e. g. recovered, recycled, incinerated. (SDG Indicator 12.4.2, Basel Convention)	EUROSTAT: Data on generation of waste available by waste category, hazardousness and NACE Rev. 2 activity[1] EUROSTAT: Data on treatment of waste available by waste category, hazardousness and waste management operations (incl. recycling) [2] EUROSTAT: No data available concerning <u>type of recycling</u> (mechanical or feedstock recycling)

[28] The World Bank speaks of frequent changes and improvements of the statistical basis already for economic data and missing data of some countries, see (World Bank 2022).

No.	Existing / proposed indicator (Source)	Available data sources in the EU
10	Number of companies (within the chemical sector) certified for Environmental Management or Health, Safety, Environment Management System by an independent auditor. (TWG4)	EU: Data available on the EMAS register, an online database hosted by the European Commission[3] Breaking down to sectors / industries by NACE-code available (e. g. NACE 20)
24	Material footprint, material footprint per capita, and per GDP. (SDG Indicator 12.2.1)	The indicator is part of the Circular Economy monitoring framework. [4] Data source: ESS[5]
27	Number of Member States whose laws and regulations and any other relevant instruments on occupational safety and health include the prevention of chemical risks. (TWG4)	National transposition measures communicated by the Member States concerning Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work, including number of and link to measures (no updates) [6]
31	Number of PRTRs with publicly accessible data established. (IPEN (Indicator A5-1))	EU: European Pollutant Release and Transfer Register (E-PRTR, see European Industrial Emissions Portal[7]), and national PRTRs[8] (→ relevant regarding "number of ...")
36	Number of countries that have implemented pesticide legislation based on the FAO/WHO International Code of Conduct. (TWG4 (IOMC Indicator))	EU: completely (n = 27= implemented, see map (status 2/2018; no data available for Greenland)[9]
42	Increase of the Environmental Protection Expenditures [%] in COFOG[10] Reporting. (Team)	OECD: Data available[11] EUROSTAT: Data available[12]

Numbering see Table 6

1 Generation of waste, by waste category, hazardousness and NACE Rev. 2 activity. https://ec.europa.eu/eurostat/databrowser/view/ENV_WASGEN/default/table?lang=en

2 https://ec.europa.eu/eurostat/databrowser/view/ENV_WASTRT/default/table?lang=en&category=env.env_was.env_wasgt

3 https://webgate.ec.europa.eu/emas2/public/registration/list: 4,143 entries: Current version: 2.1.3.202211301845 (bde6183), Version date: 30-11-2022 18:46:42, accessed 2023-01-06

4 https://ec.europa.eu/eurostat/cache/metadata/en/cei_pc020_esmsip2.htm

5 Data source: European Statistical System (ESS); Data provider: Statistical Office of the European Union (Eurostat). Material flow accounts in raw material equivalents - modelling estimates (env_ac_rme) https://ec.europa.eu/eurostat/web/products-datasets/-/env_ac_rme
Material flow accounts in raw material equivalents by final uses of products - modelling estimates (env_ac_rmefd) https://ec.europa.eu/eurostat/web/products-datasets/-/env_ac_rmefd

6 https://eur-lex.europa.eu/legal-content/EN/NIM/?uri=CELEX:31989L0391

7 EU27 plus Iceland, Liechtenstein, Norway, Serbia, Switzerland and the United Kingdom https://industry.eea.europa.eu/#/home

8 https://prtr.unece.org/prtr-global-map

9 https://www.fao.org/fileadmin/templates/agphome/documents/Pests_Pesticides/Code/World_map_2018.png

10 Classification of the Functions of Government (OECD, 2011)

11 https://stats.oecd.org/Index.aspx?DataSetCode=SNA_TABLE11

12 Government expenditure by function for European Union, 2021 (% of GDP) https://ec.europa.eu/eurostat/cache/infographs/cofog/ (10.10.2019)

For another nine indicators, data from corporate sustainability reporting should be available in the future due to the Corporate Sustainability Reporting Directive - CSRD (EU 2022a), e.g.:

- "The percentage of companies with human rights (HR) due diligence procedures for toxic substances used, produced and released in their activities" (No. 33).
- "Number of new supplier assessments carried out in the year under review, by region, and change compared with the previous year" (No. 2) or "Number of progress or improvements documented in the year under review for suppliers already assessed in an audit follow-up / re-audit or reassessment, by region, and change compared to the previous year" (No. 18).

This depends in particular on the final form of the reporting standards, the European Sustainability Reporting Standards, ESRS, and their application in practice. The first set of standards was adopted by the Commission as a Delegated Regulation on July 31, 2023 (EU 2023a) and is binding in all Member States immediately after publication in the Official Journal of the European Union.

Data from seven of the 24 indicators examined are also hardly available or not available at the EU level. Among them were the following indicators (with references to relevant databases and reasons for lack of usability):

- Change in water-use efficiency in the chemical industry (water footprint) over time (No. 34)
  - EUROSTAT: Water use in the manufacturing industry by activity and supply category available [ENV_WAT_IND__custom_4328189][29] → only direct water use (part of blue water footprint), no indirect water use
  - Needed in addition: Reference value, e.g., production volume (Mg/a etc.) or indices[30]
  - UN: SDG 6.4.1 - Change in water-use efficiency over time → Water-use efficiency (US-$/$m^3$)[31] : "Water-use efficiency measured as the ratio of dollar value added to the volume of water used. It considers water use by all economic activities, with a focus on agriculture, industry and the service sectors." → not comparable
- Number of companies publicly reporting their chemical footprint (No. 17):
  - CFP: currently 79 signatories; sixth CFP report with annual survey: 29 responders, two of them from chemical/pharmaceutical sector
  - EU: none at present
- Renewable energy share in the final energy consumption of the chemical industry (No. 35):
  - EUROSTAT: Share of renewable energy consumption available only by sector (options: transport, electricity, heating and cooling, total)[32], not by e.g., NACE code

Based on the specific objectives of the CSS and the evidence presented above on the availability of relevant data, the following indicators may be of interest for further consideration by the Commission:

[29] EUROSTAT: Water use in the manufacturing industry by activity and supply category https://ec.europa.eu/eurostat/databrowser/view/ENV_WAT_IND__custom_4328189/default/table?lang=en.

[30] EUROSTAT: Chemicals production and consumption statistics https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Chemicals_production_and_consumption_statistics#Total_production_of_chemicals.

[31] UNITED NATIONS: Progress on Water-Use Efficiency (SDG target 6.4) https://www.sdg6data.org/en/indicator/6.4.1.

[32] EUROSTAT: Share of renewable energy in gross final energy consumption by sector https://ec.europa.eu/eurostat/databrowser/view/SDG_07_40/default/table?lang=en&category=sdg.sdg_13.

- Material footprint, material footprint per capita, and per GDP (No. 24)
- Share of chemical production based on renewable materials in relation to the global production which is based on renewable materials (No. 19)
- GHG emissions of the chemical industry per value added (No. 16)
- Reduction of the amount of hazardous chemicals used in design and manufacturing related to the mass of chemical production by x % (No. 20)
- Amount of post-consumer plastic waste generated / recycled / incinerated / landfilled / not collected per country (No. 22)
- Number of companies (within the chemical sector) certified for Environmental Management or Health, Safety, Environment Management System by an independent auditor (No. 10)

7.4 Indicators for the chemical sector

In the sixth and final workshop, it was recommended to prioritize those indicators that, among other things, reflect progress in the transformation toward sustainable chemistry (see Section 7.2). These include contributions of chemistry to all areas of life (mobility, nutrition, clothing, housing), cf. Chapter 2. The 45 indicators developed in the project each fulfill at least one criterion for sustainable chemistry. The following section outlines which of the indicators can be specifically considered for monitoring progress in the chemical sector. Table 9 shows which of the indicators proposed by the team for international management of chemicals and wastes (see Chapter 6 and Appendix C) seem most appropriate for this purpose.

Table 9: Potential indicators to monitor progress in the chemical sector; "Priority" is related to the final list for SAICM (Section 6.2)

No.	Potential indicator to monitor progress in the chemical sector	Priority
1	Share of large/medium/small chemical enterprises of the region (Africa, Asia, Europe …) that report on their sustainability performance using GRI SRS	1
2	Number of new supplier assessments carried out in the year under review, by region, and change compared with the previous year [Project team (TfS)]	2
10	Number of companies certified for Environmental Management or Health, Safety, Environment Management System... within the chemical industry... by an independent auditor [TWG4]	1
12	Share of the world’s largest chemical companies having signed on to 2014 Responsible Care Global Charter.	1
20	Reduction of the amount of hazardous chemicals used in design and manufacturing related to the mass of chemical production by x % [IPEN, modified]	2
33	Percentage of companies with human rights (HR) due diligence procedures for toxic substances used, produced and released in their activities. [IPEN]	1
34	Change in water-use efficiency (SDG 6.4.1) in the chemical industry ("water footprint")	1
35	Renewable energy share in the... final energy consumption (SDG Indicator 7.2.1) of the chemical industry	1

No.	Potential indicator to monitor progress in the chemical sector	Priority
37	Number/percentage of countries where the legal framework demands risk assessment and registration / authorization of new chemicals before putting them on the market [IOMC Toolbox]	2
44	Number of companies conducting an Environmental cost-benefit Analysis	1

Numbering see Table 6

The following indicators, while deemed appropriate for monitoring progress in the chemical sector, were not included in the list of indicators most relevant to SMCW (see Section 7.1) based on the assessment against Criteria C, D, and E:

- Number of companies publicly reporting their chemical footprint
- Number of progress or improvements documented in the year under review for suppliers already assessed in an audit follow-up / re-audit or reassessment, by region, and change compared to the previous year (TfS)
- Share of companies belonging to National Associations (having implemented "Responsible Care") in the global turnover of the chemical industry or in the number of employees in the chemical industry worldwide.

Despite good evaluation with regard to Criteria C, D and E, the indicator

- Carbon pricing instruments (including fuel and carbon taxation, emissions trading systems - ETS) or: Amount of money earned from carbon pricing instruments

was not included in the final SMCW indicator list because it is not specific enough.

8 Transparency of the project

The project deals with a complex topic of international environmental policy. However, issues of safe handling of chemicals and wastes as well as the concept of sustainable chemistry are not in the center of media coverage and discussion. Rather, they are a topic for the chemical and chemical-processing industry, specially oriented non-governmental organizations, corresponding specialist departments of UNEP, OECD, EU and national governments, as well as scientific institutions and associations. Due to the project planning, the task was not only to create transparency for this specialized public, but also to interest as many experts as possible in the project and possible participation in workshops.

8.1 Selection of experts for workshops and interviews

In a first round of discussions (June - August 2020), a number of internationally renowned experts were interviewed about,

- Which aspects of sustainable chemistry should be integrated into SAICM,
- Which indicators from existing conventions, statistics of the chemical industry or the like are suitable and
- How investments in sustainable chemistry can be indexed.

In addition, the names and contact addresses of other experts important for the project were identified during the interviews. This resulted in a dynamically growing list of experts, which was used for further interview rounds or workshops.

A further round of interviews, which focused on the criteria used to evaluate indicators, was conducted from October 2020 using a detailed questionnaire. A third round of interviews (starting in May 2021) focused on the interfaces between sustainable chemistry and other global problem areas and corresponding indicators, with the questions being geared to the respective areas of expertise of the interviewees.

Efforts were made to include experts from all UN regions and to involve persons from academia, research, industry and international as well as non-governmental organizations as evenly as possible. Contacting and scheduling discussions were not always successful, especially in Africa, Asia, and the Middle East. It is likely that contacts in national administrations in particular have had to perceive other work priorities as a result of the COVID-19 pandemic. A list of the face-to-face interviews can be found in Appendix B.

8.2 Preparation, execution, and documentation of workshops

Contrary to the original planning, all workshops except the last one had to take place online. This made the discussion more difficult, as most of the participants did not know each other. In addition, concentration wanes more quickly in online meetings; therefore, the workshops were limited to about five hours. The following schedule was used for the workshops (Table 10) was used as a basis for the workshops:

Table 10: General schedule for workshops

Email No.	Messages and information	Schedule
1	Invitation to participate - description of the project with sending information	1-2 months before the workshop
2	Reminder of the invitation (in case of cancellation: request for substitution).	3 weeks before the workshop
3	Details - Outlook appointment posting, posting of the "Thought Starter" created for the particular workshop, access for the cloud (see Section 8.3); opening a channel for questions and pre-surveys, if applicable.	2 weeks before the workshop

The workshops focused on the following topics:

- Workshop No. 1, Target Region Europe and International Organizations: Criteria for the evaluation of indicators, discussion of first potential indicators.
- Workshop No. 2, target region Asia: indicators for the interfaces with climate, resource consumption as well as waste management, water management and "Chemicals of Concern" in consumer products.
- Workshop No. 3, Latin America Target Region: Biodiversity Interface Indicators.
- Workshop No. 4, Target Region North America / NAFTA: Economic Indicators, Climate Protection Interface
- Workshop No. 5, target region Africa: indicators for the use of renewable raw materials or energy sources, interfaces with biodiversity, improvement of the economic situation of developing countries.
- Workshop No. 6 served to present the complete list of indicators and to discuss a possible prioritization. It was possible to attract a circle of experts from science, international organizations and industry who had already participated in previous workshops or interviews.

The scheduling of the workshops took into account the time zones of the respective UN region. Since Asia spans numerous time zones and it was also necessary to ensure the presence of the project team, experts from Pakistan to Japan were invited for the second workshop, while experts from Africa and the Middle East were invited for the fifth workshop.

Participants of the workshops received a "thought starter" tailored to the respective topics in advance. In addition to an introduction to the project and the respective upcoming indicators, specific problems from the perspective of the respective region were presented in two to three presentations. In the workshops - see listing above - potential indicators were presented for discussion in four one-hour sessions each by working groups based on the criteria. The discussion results were recorded via "traffic lights" from the second workshop onwards (see Chapter 5), which greatly facilitated the final discussion in the workshop and the documentation.

See Appendix A for more information on the workshops.

8.3 Continuous communication with experts in the field

After the first workshop, a cloud was set up in January 2021, to which all participants of workshops and interviews as well as other interested parties were given access. In this read-only cloud, regular publications were made:

- The criteria for the selection of indicators,
- The respective current indicator lists,
- Invitations, thought starters and minutes of the workshops, as well as
- Presentations on workshop topics.

In February 2023, the cloud was replaced by an interactive platform that enabled online discussion with and between people interested in the project. Access to the platform was possible at any time upon request to the project team. The idea of the platform aimed at stimulating discussions and deepening still open topics by involving further experts.

The documents uploaded to the cloud until then (criteria, indicators and thought starters) were partly revised for better comprehensibility and published on the platform. The experts were encouraged to share their opinions on the individual indicators and the process of developing indicators by e-mails with further questions as well as publications on the platform. Individual experts got back to us by mail; these expressions of opinion were published on the platform. Despite several attempts, no interaction or discussion could be initiated on the platform itself. The reasons for this could be further time commitments on the part of the requested experts and the fact that the platform's user interface is not yet optimal. Due to the lack of interaction, the planned Delphi process could not be carried out. Nevertheless, the experts' inputs, which were submitted either in video or mail form, provided valuable clues.

On the one hand, for example, the difficulty in checking the CO_2 emissions data was pointed out. In addition to the "third party verification", the possibility of satellite-based verification was pointed out. Another contribution aimed at the anthropocentric perspectives of the indicators. The proposal suggests to complement the indicator system with simple indicators observable by the respective local population.

In connection with the EU policy event (see Section 9.3), two questions on the importance of sustainable chemistry and its potential role for CSS were posed to four key representatives of the concept and practice of sustainable chemistry:

- Prof. Dr. Dr. h. c. James Clark, University of York (United Kingdom), founder of the G2C2 network[33],
- Dr. Jonatan Kleimark, ChemSec, Gothenburg (Sweden)
- Prof. Dr. Klaus K mmerer, Leuphana University of Leb urg, and ISC_3 Science and Education Hub (Germany),
- Prof. Dr. Dr. h. c. Ferdi Schhh , Max Planck Institute for Coal Research, M heim (Germany), and former Vice-President of the Max Planck Society

The video contributions with the answers can also be found on the platform.

[33] Global Green Chemistry Centers network

9 Dissemination of the project and its results

The indicators developed in the discussion with numerous experts, as well as the approach chosen for this purpose, are not only of relevance to technical policy, but should also contribute to the continuation of the scientific and political discussion on the concept of sustainable chemistry and its benefits for society.

9.1 ISC$_3$ Stakeholder Forum

The International Sustainable Chemistry Collaborative Center (ISC$_3$)[34], funded by the German Federal Ministry for the Environment and Consumer Protection and the Federal Environmental Agency, serves primarily as a catalyst for the dissemination of the concept of sustainable chemistry. It promotes innovations, supports global entrepreneurs in their implementation, conducts summer schools for scientists, and much more. Through an Advisory Board and a Scientific Board with experts from international organizations, industry, environmental associations and science, the ISC$_3$ continuously receives information on the further development of the concept as well as on techniques that can be used for sustainable chemistry. In addition, other interested parties are involved in the work of the ISC$_3$ through a "Stakeholder Forum". It therefore made sense to present the initial findings of the project at the ISC$_3$. For this purpose, the Federal Environment Agency used the "Global Week" in 2021, in which numerous activities of the ISC$_3$, such as the Investor Forum, were bundled in terms of time.

On the occasion of the meeting on 12.11.2021 (online), the project was presented by the client and the working approach was explained by members of the project team. Both presentations were discussed in a panel discussion and also lively in the chat. The summary of the discussion was documented within the project work as follows (ISC$_3$ 2021):

"We need indicators for sustainability in chemicals management - i.e., production of chemicals, manufacturing of goods, applications, and waste phase (preferably including material recovery), but also to identify business models and financial incentives that support the sound management of chemicals in regards to systems thinking and sound management of resources.

Meet the need of the users, e.g., promoting and ensuring health and safety as well as fair, inclusive, and emancipatory labor conditions, substitution of hazardous chemicals by safe and non-regrettable alternatives, increase of material recycling without contamination throughout the entire life cycle of products. For developing countries, a sound and solid financing is of special importance.

Identify solutions towards more sustainability and communicate these as high-level messages to decision makers, to create a political momentum and call to action.

Refer to green and responsible investments and other financial incentives as opportunity to stimulate transformation."

9.2 Scientific conferences

9.2.1 7th Green and Sustainable Chemistry Conference (GREN 2023)

The series of "Green and Sustainable Chemistry Conferences" organized by Elsevier Publishing focuses on inter- and transdisciplinary aspects. In addition to important research directions in chemistry such as highly specific catalysts, inherently safe materials or materials for energy storage, alternative business models and societal developments that can be conducive to the

[34] For details, see ISC$_3$: Governance https://www.isc3.org/page/governance.

concept of sustainable chemistry are discussed. Three papers have been registered for presentation of project results at the "Green & Sustainable Chemistry Conference" (GREN 2023) in Dresden, Germany, May 22-24, 2023, and presented in a session titled "Sustainable Chemistry - A bigger picture" (presenter(s) underlined):

- How to measure sustainability in international chemicals management? Criteria for meaningful indicators (Christopher Blum[a)], Henning Friege[b)], Esther Heidbüchel[c)], Hans-Christian Stolzenberg [a)])
- An overview of appropriate indicators of waste aspects for measuring sustainability in international chemicals management (Henning Friege[b)], Barbara Zeschmar-Lahl[d)], Esther Heidbüchel[c)], Christopher Blum[a)])
- An overview of appropriate indicators of financial and economic aspects for measuring sustainability in international chemicals management (Esther Heidbüchel[c)], Henning Friege[b)], Barbara Zeschmar-Lahl[d)], Christopher Blum[a)])
  a) German Environment Agency; b) N³ Thinking Ahead Dr. Friege & Partners, / Leuphana University, Lee burg, Germany; c) Collaborating Centre for Sustainable Consumption and Production gGmbH (CSCP), Germany; d) BZL Kommunikation und Projektsteuerung GmbH, Germany.

The conference was also used to encourage comments from other scientists for publication on the interactive platform (see Section 8.3).

9.2.2 18th International Conference on Chemistry and the Environment (ICCE), 2023

The Division of Chemistry and the Environment of the European Chemical Society (EuChemS) is the organizer of the International Conference on Chemistry and the Environment (ICCE). This offers a broad spectrum of topics, especially analysis and evaluation of environmental chemicals, modeling, life cycle analysis as well as developments in "Green Chemistry". It takes place every two years. Out of the project, the topic "Opportunities of the Concept of Sustainable Chemistry to support specific SDGs" was proposed for the 18th International Conference on Chemistry and the Environment (ICCE 2023)[35] from June 11-15, 2023 in Mestre (Italy), in order to be able to discuss own results as well as findings from other projects. The ICCE 2023 Scientific Committee combined this proposal with another one on "Session 16: Green and sustainable chemistry as an enabler of circular economy: safe-by-design approaches and LCA-based assessment tools". The tasks of the "Session Chairs" were assumed by Dr. Hans-Christian Stolzenberg (German Federal Environmental Agency), Prof. Dr. Elena Semenzin (Univ. Ca' Foscari, Venice) and Prof. Dr. Henning Friege (N³ Thinking Ahead). With over 40 abstracts submitted, three sessions were designed with a total of about 25 oral and poster contributions. In the introductory lecture, Dr. Christopher Blum (Federal Environment Agency) presented results from the project under the title "How to measure sustainability in international chemicals management?". The first session was devoted exclusively to questions of implementing sustainable chemistry in society, indicators, the "safe and sustainable by design" approach, and the impact of chemicals on planetary boundaries. Two other sessions focused mainly on LCA of chemical products, syntheses from renewable resources and links between sustainable chemistry and waste management.

The presentations and discussions provided important new insights, particularly with regard to European approaches, especially since work on indicators by the Joint Research Center (JRC) was also presented. The chairpersons summarized the results as follows:

[35] https://icce2023.com/#

- Indicators for SMCW and Sustainable Chemistry vs. Indicators for "safe and sustainable by design" (SSbD): The goals of the two approaches are different and therefore the two approaches should not be compared. Rather they might complement each other to certain extents. The JRC SSbD framework should be applied to guide innovation for chemical substances and materials whereas the SMCW/SC framework focuses on macroeconomic developments. It is necessary to define SSbD properly to measure progress on national or EU level. If the implementation and application of SSbD principles will be successful since the early stages of products' development, an improvement in progress towards some pertinent targets should be measurable by the indicators proposed for the global level.
- Development of SSbD: The SSbD philosophy is challenging because of its high complexity when it goes beyond the hazard level to check different applications of substances for sustainability. On the other hand, simple assessment models for SSbD should be used with caution and can fail due to over-simplification. E.g., attempts to split SSbD (back) into separate safety and sustainability assessments would essentially thwart the integrative (innovation driving and regulation preempting) sense of the SSbD invention, including its mid-term perspective of global value beyond the immediate EU CSS context. It is meaningful, to apply the most suitable tool for each assessment level, moving from screening to more advanced assessment (according also to technology readiness level) and keeping track of data quality, assumptions made and results uncertainty.
- Chemicals and planetary boundaries: There are models and data bases for some specific chemicals (e.g., pesticides) to get a (semi-) quantitative impression of exceeding the planetary boundaries. Methodologically, this appears to be substantiated rather by local/regional data for such exceedances, however globally spread and insofar with clear global relevance. As we are approaching or exceeding the planetary boundaries worldwide adequate control and impact assessment of production and use of chemicals are desperately needed. Therefore, global cooperation and regulations for subsectors or certain pollutants are essential even if political discussions are still far away from framework conventions of this type.

This jointly prepared balance sheet of the session at ICCE 2023 also confirms findings from the project: On the one hand, it underlines the state of discussion on "chemicals and planetary boundaries" (see Chapters 1 and 2). On the other hand, the discussion at ICCE 2023 showed on the scientific level the difficulty to develop suitable indicators for the concept "safe and sustainable by design". This also corresponds to the impression gained at the EU-level event presented in the following section.

9.3 Discussion with European stakeholders

The Chemicals Strategy for Sustainability (EU 2020) has already been presented in Section 7.3. The discussion rounds initiated by the Commission and numerous stakeholders on this topic provided an important opportunity to present the indicators developed for the global discussion at the European level as well: in a short round at the SusChem Board and in an event organized by the project team.

SusChem is a European platform primarily concerned with research for sustainable chemistry topics. It integrates 17 national research agencies. The platform describes its mission as follows: "SusChem's vision is for a competitive and innovative Europe where sustainable chemistry and biotechnology together provide solutions for future generations. SusChem's mission is to initiate and inspire European chemical and biochemical innovation to respond effectively to societal challenges by providing sustainable solutions."[36] SusChem is an important provider of information on sustainable chemistry and has an impact on science, industry, but also on European politics. The Board consists mainly of members from the management of research institutes in the chemical industry and from renowned university institutes. Through the mediation of a German board member, the project team was invited to a meeting of the board. The aim and structure of the project, the criteria for the selection of indicators as well as some examples of indicators were presented at a meeting of the SusChem Board on February 22, 2023 (Dr. Christopher Blum, Federal Environment Agency, Dr. Henning Friege, N^3 Thinking Ahead). However, given the extensive agenda of the SusChem Board, no in-depth discussion was possible.

The European CSS (EU 2020) must be filled with life by the EU Commission and its implementation monitored by suitable indicators. The possible use of indicators developed in this project (see Section 7.3) was therefore discussed in a two-hour video conference on June 1, 2023, aimed at the administrative and political level of the EU and entitled "Indicators measuring progress towards sustainable chemistry". Responsible staff members from the EU Commission, the European Environmental Agency, the High-Level Roundtable on the Implementation of the Chemicals Strategy for Sustainability, and committed European experts from the project's network were invited to attend.

Michael Kuhndt (CSCP) moderated the panel, which was modest in number (about 15 participants) but of professional top-class. Short statements on the question "Do you think that the Chemicals Strategy for Sustainability is tangible enough to foster implementation of the concept of sustainable chemistry? Do you recognize gaps that should be filled?" by

- Prof. Dr. Dr. h. c. James Clark, University of York (United Kingdom), founder of the G2C2 network[37],
- Dr. Jonatan Kleimark, ChemSec, Gothenburg (Sweden)
- Prof. Dr. Klaus K mmerer, Leuphana University of Leb urg, and ISC_3 Science and Education Hub (Germany),

Project results were presented - with a focus on the criteria (see Chapter 5) and indicators suitable for the EU (see Section 7.3) - by the Federal Environment Agency (Christopher Blum) and the project team (Henning Friege), respectively. Aleksandra Malyska (EU Commission, DG ENV) described the status of the development of indicators for CSS and emphasized that these should paint as comprehensive a picture as possible. The project results would be included in the work on CSS indicators. The Commission aims to publish the indicators for CSS in 2024. Eric de Deckere (CEFIC) presented CEFIC's approach: Indicators with as good a data base as possible will be measured against the criteria developed in the project. He emphasized the need for alignment between SMCW and CSS, specifically the Commission's Transition Pathway for the Chemical Industry (EU 2023b). However, clear definitions are needed, which are lacking, e.g., for SSbD, as well as clear and realistic targets at all levels. For the discussion, the following guiding questions were focused on:

- Do the indicators foster sustainable innovation or address even additional objectives linked to the concept of sustainable chemistry?

[36] SusChem: What is SusChem? http://www.suschem.org/about.

[37] Global Green Chemistry Centers network

- Do you think that the indicators help steering investment towards the required sustainability-oriented transformations of the chemical industry as well as of allied industries?
- Do you know other indicators, which serve the same purpose, probably from other EU Directives / strategies?

The participants addressed numerous topics that had also been discussed several times in the project and introduced new aspects. Topics included the distinction between impact-related and process-related indicators, the informative value of the number of patents for innovations, the significance of "footprint" indicators for resource consumption, indicators for the possible overuse of renewable raw materials, the availability and reliability of data in connection with governance and the development of a sustainable chemical industry in Europe without loss of competitiveness. The lively and purposeful discussion is documented in Appendix D.

9.4 Homepage of the German Environment Agency

The extensive research and workshops (see Chapter 3) did not permit early publication of interim results on a generally accessible website; rather, the focus was on transparency of the project work for the expert public (see Chapter 8). It is proposed to publish the following documents on the website of the Federal Environment Agency after project completion in addition to the final report:

- List of 45 indicators (in the form available on the platform),
- Presentations given at GREN 2023 (see Section 9.2.1),
- Presentation on the occasion of ICCE 2023 (see Section 9.2.2),
- Presentations given at the EU event (see Section 9.3),
- Video contributions on the relationship between CSS and sustainable chemistry.

10 Conclusions

10.1 Criteria for indicators

Indicators must meet certain formal and substantive criteria in order to be applicable within the framework of a complex set of objectives such as the international management of chemicals and waste. The seven formal criteria selected for this study take into account not only the accuracy and significance of the indicator, but also the availability and reliability of the data required. The five substantive test criteria developed in the project relate to the concept of sustainable chemistry. The total of twelve criteria met with broad approval in the workshops and interviews. Therefore, it can be assumed that the criteria can be used by institutions dealing with political principles of chemical and waste management. For example, the criteria can be used to search for further indicators related to the development of the chemical industry and downstream production. A publication of the approach chosen here in environmental policy journals and its presentation in discussions related to sustainable chemistry (webinars, congresses) is therefore foreseen.

10.2 Indicators for global policy: future development?

The indicators selected or developed in this study are parameters that take into account aspects of sustainable chemistry in the development of the global management of chemicals and waste. On the one hand, the indicators focus on open problems and unachieved goals of the Dubai Declaration and, on the other hand, they depict developments that are conducive to sustainable chemistry or that also stand in its way. The indicators not only monitor and support (see Section 7.1) the objective of the Dubai Declaration, which is essentially formulated in SDG 12.4, but also address the achievement of numerous other SDGs. The approach of the SDGs is thus supported by the integrative concept of sustainable chemistry. Due to the interdisciplinary nature of the concept, numerous interfaces must be included, including with finance, global management of resources, health protection, climate protection or biodiversity. This diversity is difficult to represent in a few indicators. Therefore, compromises had to be made in the selection of 23 priority indicators (see Chapter 7). The focus of this list is on chemicals; due to the state of policy discussion prior to ICCM5, few indicators of waste management challenges were included. However, the results of this project underline the close link between chemicals, waste management and resource management inherent in sustainable chemistry and circular economy approaches: "benign by design" and "design for recycling" are concepts that complement each other. The compromise reached at ICCM5 (IISD 2023) on the stronger inclusion of waste in the work of the future "Global Framework on Chemicals", as well as isolated references to "resource efficiency" (Target D.1) or "circular... approaches" (Target D.2), are a good approach for further integration of the topics mentioned.

There are gaps in the economic indicators with a focus on innovations as well as investments in plants and processes that promote development in the sense of sustainable chemistry. This difficulty is also seen by other institutions and stakeholders, as the evaluation of the sixth workshop and the discussion with the IOMC showed. The concept of sustainable chemistry does not emphasize a few defined technologies such as biorefineries or reactions with highly specific catalysts. Sustainable chemistry is open to all innovations; what needs to be assessed is their impact in terms of sustainable development. How such goals can be verified by means of meaningful and measurable indicators is still unclear. There is a need for further research in this area.

Sufficient and reliable data are already available for only some of the potential indicators. In some cases, differentiation of statistical data is required in order to determine sector-specific indicators. In many cases, a compromise between data availability on the one hand and meaningfulness on the other appeared necessary. This led to the inclusion of procedural indicators such as the number of states with regulatory systems of a certain type. Since such indicators merely reflect a political trend, it makes sense to supplement or replace these indicators with ones that reflect corresponding positive consequences in the sense of impact indicators. A continuation of the discussion with the IOMC after the end of the project can contribute to the optimization of the indicators or their data basis, especially since the UN Statistics Division is represented in the Indicators Working Group of the IOMC.

Due to the multiple postponement of ICCM5 and the consequent delay in setting "targets" for further work on the SAICM successor instrument, the results achieved here could not be brought to ICCM5. The aforementioned list of the IOMC as well as further preliminary work were incorporated into a proposal for a "Measurability Structure" (SAICM 2023) at IP4.3 immediately prior to ICCM5. This distinguishes - as also discussed in this study (see Chapter 5) - between different types of targets or matching indicators:

- "headline indicators on strategic objectives",
- "process indicators on actions taken"
- "impact indicators on results"
- as well as other indicators, if required.

The criteria to be applied correspond to those of the IOMC. The indicators developed here (Table 2 and Table 6, respectively) can now be made available for the "Measurability Structure" consultation and decision-making required under the ICCM5 (IISD 2023). The scope of the approach taken here allows these indicators to be used for many of the "Targets" adopted at ICCM5, particularly in the context of "Objective D". The formal criteria are similar to those proposed by IOMC, and the substantive criteria provide the link to sustainable chemistry that is important for the GFC. However, the 23 priority indicators (Table 2) also provide a bridge between SMCW and sustainable chemistry: They serve to monitor further steps towards achieving the Dubai targets and the GFC and thus reveal how the transformation of the production and handling of chemical substances is progressing in terms of sustainable development.

10.3 Indicators for European policy: further development?

The discussion of sustainable chemistry in Europe is often reduced to the regulation of chemicals or restrictions on their use. This is also shown by many reactions from both non-governmental organizations and industry to the "Chemicals Strategy for Sustainability" (CSS). The CSS targets the opportunities offered by green and sustainable chemistry, which go far beyond improved regulation of chemicals. The criteria for indicators used here are also suitable for discussion within the CSS; they are already being used by CEFIC for internal industry discussion. Of the 45 indicators developed as part of the study, some are candidates for CSS monitoring, namely those,

- which also concern targets not yet achieved in the EU
- and for which a corresponding database is available.

The availability of data at the European level - as shown by the analysis carried out here (see Section 7.3) - is significantly better for some indicators than at the global level. Contact has already been established with the relevant departments within the European Commission; a further exchange was expressly desired by them. The members of the "High-Level Roundtable" established by the Commission for the implementation of the CSS should be informed about findings from this project.

Access to corresponding data from the chemical industry would be very helpful. Even if data - e.g., on Responsible Care® or on Together for Sustainability (TfS)/EcoVadis - are or would be available within the industry, it is not guaranteed that institutions such as UNEP can access them as long as there is no obligation to determine them according to uniform standards and to disclose them. The situation will certainly improve significantly in the EU in the next few years due to the CSRD, the EU Reporting Standards (ESRS) and the European Single Access Point for public corporate information (ESAP). This applies in particular to issues concerning the supply chain, but also, for example, the existence of certified management systems for occupational safety or the environment. These are topics for which the indicators provided by CEFIC are to be assessed as insufficient. There are particular expectations here for the creation of one or more sector-specific standards for the chemical industry.

For the discussion on the European as well as on the SAICM level, the interactive online platform established since February 2023 could be continued, if necessary. There, all the main results of the project can be viewed, downloaded, commented on and discussed with other experts. Beyond the focus on chemical processes and products, it would be useful to discuss the systematics used here with experts for other areas of industrial transformation. Possibly, this will yield further insights with regard to target control in the sense of a sustainable transformation of our industrial society.

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12 List of references

Aichi Biodiversity Targets (2010): https://www.cbd.int/sp/targets/ (10 Oct 2019).

Anastas, P.T.; Warner, J.C. (1998): Green chemistry: theory and practice. In: Oxford University press.

Anastas, P.T.; Zimmermann, J.B. (2018): The United Nations sustainability goals: How can sustainable chemistry contribute? Current Opinion in Green and Sustainable Chemistry 2018, 13, p. 150-153.

Bazzanella, A.; Friege, H.; Zeschmar-Lahl, B. (2017): Identification of Priority Topics in the Field of Sustainable Chemistry. UBA-Texte 83/2017, Dessau-Roßlau 2017. https://www.umweltbundesamt.de/sites/default/files/medien/1410/ publikationen/2017-09-08_texte_83-2017_isc3_priority-topics_0.pdf (10 Oct 2019).

Blum, C; Bunke, D.; Hungsberg, M.; Roelofs, E.; Joas, A.; Joas, R.; Blepp, M.; Stolzenberg, H.C. (2017): The concept of sustainable chemistry: key drivers for the transition towards sustainable development. Sustainable Chemistry and Pharmacy 2017, 5, p. 94-104 http://dx.doi.org/10.1016/j.scp.2017.01.001 (10 Oct 2019).

Brosché S. (2021): Women, chemicals and the SDGs. https://saicmknowledge.org/sites/default/files/publications/ipen-gender-chemicals-report-v1_6dw-en.pdf (13 Aug 2023).

BUND - Friends of the Earth Germany (2023): Challenges for a Sustainable Chemicals and Materials Policy, Position Paper. Berlin https://www.bund.net/fileadmin/user_upload_bund/publikationen/ressourcen_und_technik/challenges-for-a-sustainable-cemicals_and_Materials-Position_Paper_BUND.pdf (10 Sept 2023).

CEFIC (2023a): Responsible Care®. An ethical framework towards safe chemicals management and performance excellence https://cefic.org/responsible-care/ (14 Aug 2023).

CEFIC (2023b): Responsible Care Guidance https://cefic.org/guidance/responsible-care-guidance/ and European Responsible Care self-assessment web-tool https://self-assessment.responsible-care.com/login?returnUrl=%2F (14 Aug 2023).

Diamond, M.L.; de Wit, C.A.; Molander, S.; Scheringer, M.; Backhaus, T.; Lohmann, R.; Arvidsson, R.; Bergman, Å.; Hauschild, M.; Holoubek, I.; Persson, L.; Suzuki, N.; Vighi, M.: Zetzsch, C. (2015): Exploring the planetary boundaries for chemical pollution. Environment International 2015, 78, p. 8-15.

EEA (1999): Environmental indicators: Typology and overview. Technical report No 25, Copenhagen https://www.eea.europa.eu/publications/TEC25 (10 Oct 2019).

EU (2019a): Commission Delegated Regulation (EU) 2019/815 of 17 December 2018 supplementing Directive 2004/109/EC of the European Parliament and of the Council with regard to regulatory technical standards on the specification of a single electronic reporting format. OJ L 143, 29.5.2019, p. 1-792 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0815 (10 Sept 2023).

EU (2019b): Directive EU 2019/904 on the reduction of the impact of certain plastic products on the environment. OJ L155, p. 1-19 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019L0904 (10 Sept 2023).

EU (2020): Chemicals Strategy for Sustainability - Towards a Toxic-Free Environment, COM (2020) 667 final, 14.10.2020 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0667 (10 Sept 2023).

EU (2022a): DIRECTIVE (EU) 2022/2464 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 14 December 2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU, as regards corporate sustainability reporting. OJ L 322, 16.12.2022, p. 15-80 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32022L2464 (10 Sept 2023).

EU (2022b): COMMISSION RECOMMENDATION (EU) 2022/2510 of 8 December 2022 establishing a European assessment framework for 'safe and sustainable by design' chemicals and materials. OJ L 325, 20.12.2022, p. 179-205 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32022H2510 (10 Sept 2023).

EU (2023a): COMMISSION DELEGATED REGULATION (EU) .../... of 31.7.2023 supplementing Directive 2013/34/EU of the European Parliament and of the Council as regards sustainability reporting standards. (not in force until it is published in the Official Journal) https://finance.ec.europa.eu/regulation-and-supervision/financial-services-legislation/implementing-and-delegated-acts/corporate-sustainability-reporting-directive_en (01 Aug 2023).

EU (2023b): Transition pathway for the chemical industry. Manuscript completed in January 2023. First edition. ISBN 978-92-76-61690-0, doi: 10.2873/873037, ET-08-23-017-EN-N. https://ec.europa.eu/docsroom/documents/54595/attachments/1/translations/en/renditions/native (26 July 2023).

European Commission (2022): Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on Corporate Sustainability Due Diligence and amending Directive (EU) 2019/1937, COM(2022) 71 final. 23.02.2022 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52022PC0071 (26 July 2023).

FAO/WHO (2016): Food and Agriculture Organization of the United Nations and World Health Organization, (Guidelines on Highly Hazardous Pesticides. www.fao.org/3/i5566e/i5566e.pdf (03 June 2017).

Friege, H. (2017): Sustainable Chemistry - a Concept with Important Links to Waste Management. Sustainable Chemistry and Pharmacy 2017, 6, p. 57-60 doi.org/10.1016/j.scp.2017.08.001 (26 July 2023).

HEJ Support and Swedish Society for Nature Conservation (2021): Global minimum transparency standard; https://www.globalchemicaltransparency.org/wp-content/uploads/2021/05/presentation-White-Paper-NGO-Discussion-2021-12-03.pdf (26 July 2023).

IISD - International Institute for Sustainable Development (2023): Summary of the Fifth International Conference on Chemicals Management: 25-30 September 2023. Earth Negotiations Bulletin Vol 15, Nr. 311, 3 October 2023 https://enb.iisd.org/iccm5-saicm-intersessional-process-resumed-4-sound-management-chemicals-waste-beyond-2020 (03 Oct 2023).

INI - International Nitrogen Initiative (2021): Berlin Declaration on Sustainable Nitrogen Management for the SDGs https://ini2021.com/wp-content/uploads/2021/07/INI2021_Berlin_Declaration.pdf (25 June 2021).

INMS - International Nitrogen Management System (2021): Colombo Declaration on Sustainable Nitrogen Management. Done on 24th October 2019 in Colombo, Sri Lanka https://www.inms.international/sites/inms.international/files/Colombo%20Declaration_Final.pdf (25 June 2021).

IOMC (2015a): Activities of the Inter-Organization Programme for the Sound Management of Chemicals to support the implementation of SAICM; SAICM/ICCM.4/INF/2 https://www.saicm.org/Meetings/ICCM4/tabid/5464/language/en-US/Default.aspx (10 Aug 2023).

IOMC (2015b): Indicators of progress in implementing SAICM https://partnership.who.int/iomc/iomc-indicators-of-progress-in-implementing-saicm (24 March 2022).

IPEN (2019): Thought Starter on Beyond 2020 Indicators and Milestones: Chemical Safety Contributions to the SDGs, Sept. 17, 2019 https://ipen.org/news/thought-starter-beyond-2020-indicators-and-milestones-chemical-safety-contributions-sdgs (24 March 2022).

ISC_3 (2021): 3rd Stakeholder Forum of the International Sustainable Chemistry Collaborative Centre. Event Report https://www.isc3.org/cms/wp-content/uploads/2022/08/Report_StakeholderForum_2021.pdf (05 July 2023).

K mmerer, K.; Amsel, A. K.; Bartkowiak, D.; Blum, C.; Cinquemani, C. (2021): Key Characteristics of Sustainable Chemistry. Dialogue Paper by the International Sustainable Chemistry Collaborative Centre (ISC$_3$), Bonn, Germany https://www.isc3.org/cms/wp-content/uploads/2022/06/ISC3_Sustainable_Chemistry_key_characteristics_20210113.pdf (07 July 2023).

K mmerer, K.; Clark, J. (2016): Green and Sustainable Chemistry. In: Heinrichs, H.; Martens, P.; Michelsen, G.; Wiek, A. (Eds.): Sustainability Science. Springer. Berlin, Heidelberg. p. 43-59.

K mmerer, K.; Clark, J.; Zuin, V.G. (2020): Rethinking chemistry for a circular economy. Science 2020, 367 (6476), p. 369-370. doi:10.1126/science.aba4979.

OECD (2003): OECD Environmental Indicators - Development, Measurement, and Use. Reference Paper, Paris https://www.oecd.org/environment/indicators-modelling-outlooks/24993546.pdf (09 Sept 2023).

OECD (2011): Government at a glance, ANNEX B: Classification of the Functions of Government (COFOG) https://www.oecd.org/gov/48250728.pdf (10 Oct 2019).

OECD (2012): The Role of Government Policy in Supporting the Adoption of Green/Sustainable Chemistry Innovations. Series on Risk Management No. 26. ENV/JM/MONO(2012)3, Organisation for Economic Co-operation and Development, Paris https://one.oecd.org/document/env/jm/mono(2012)3/en/pdf (13 July 2016)

OECD (2014): Taxing the Rent of Non-Renewable Resource Sectors. OECD Economics Department Working Papers No. 1149, ECO/WKP(2014)45, Authors: Julien Daubanesi and Saraly Andrade de Sái https://dx.doi.org/10.1787/5jz0zb620vr1-en (10 Oct 2019).

OECD (2016): Sustainable Chemistry. Organisation for Economic Co-operation and Development. www.oecd.org/chemicalsafety/risk-management/sustainablechemistry.htm (29 April 2016).

PAN - Pesticide Action Network (2016): PAN International List of Highly Hazardous Pesticides (PAN List of HHPs), December 2016 https://archiv.pan-germany.org/pan-germany.org_180405/www.pan-germany.org/download/PAN_HHP_List_161212_F.pdf (28 Aug 2023).

PAN - Pesticide Action Network (2021): PAN International List of Highly Hazardous Pesticides (PAN List of HHPs), March 2021 https://pan-international.org/wp-content/uploads/PAN_HHP_List.pdf (28 Aug 2023).

Persson, L.; Almroth, B.M.C.; Collins, C.D.; Cornell, S.; de Wit, C.A.; Diamond, M.L.; Fantke, P.; Hassell , M.; MacLeod, M.; Ryberg, M.W.; Jge nsen, P.S.; Villarrubia-Gómez, P.; Wang, Z.; Hauschild, M.Z. (2022): Outside the Safe Operating Space of the Planetary Boundary for Novel Entities. Environ. Sci. Technol. 2022, 56, 3, p. 1510-1521 https://pubs.acs.org/doi/epdf/10.1021/acs.est.1c04158 (08 Sept 2022).

Rockstr m, J.; Steffen, W.; Noone, K.; Persson, A.; Chapin, F.S.; Lambin, E.F.; Lenton, T.M.; Scheffer, M.; Folke, C.; Schellnhuber, H.J.; Nykvist, B.; deWit, C.A.; Hughes, T.; van der Leeuw, S.; Rodhe, H.; Sorlin, S.; Snyder, P.K.; Costanza, R.; Svedin, U.; Falkenmark, M.; Karlberg, L.; Corell, R.W.; Fabry, V.J.; Hansen, J.; Walker, B.; Liverman, D.; Richardson, K.; Crutzen, P.; Foley, J.A. (2009): A safe operating space for humanity. Nature 2009, 461, p. 472-475 https://www.nature.com/articles/461472a.pdf (09 Sept 2022).

SAICM (2006): SAICM texts and resolutions of the International Conference on Chemicals Management, Geneva, 2006. http://www.saicm.org/Portals/12/documents/saicmtexts/SAICM-publication-EN.pdf (25 Feb 2020).

SAICM (2009): List of indicators for reporting progress in implementation of the Strategic Approach and the related basic elements of the overall orientation and guidance; SAICM/ICCM2/15, Annex III https://www.saicm.org/Portals/12/Documents/SAICM-List%20of%20indicators%20for%20reporting%20progress.pdf (15 Jan 2020).

SAICM (2018): Intersessional Process to develop recommendations on SAICM and the sound management of chemicals and waste beyond 2020. Co-chairs' Paper - Draft for consideration of the ICCM5 Bureau. 10 December 2018 (REV 1) - final unedited version for ICCM5 Bureau input. https://www.saicm.org/Portals/12/Documents/meetings/Bureau/ICCM5B6/SAICM-ICCM-5-Bureau-6-3-Co-Chairs-paper.pdf (02 Oct 2019).

SAICM (2019a): First e-meeting of the Technical Working Group, 10 January 2020. Meeting Reference Documents, TWG/Document/3 - Proposal by TWG Co-chairs: Suggested framework to support the development of targets & indicators. http://www.saicm.org/Portals/12/Documents/meetings/TGW/TWG-Doc-3_Suggested_framework.pdf (10 Oct 2019).

SAICM (2019b): First e-meeting of the Technical Working Group, 10 January 2020. Meeting Reference Documents, TWG/Document/4 - Mapping exercise: existing global and regional data and indicators relevant to the Beyond 2020 Framework https://www.saicm.org/Portals/12/Documents/meetings/TGW/TWG-Doc-4_Mapping_Exercise.docx (10 Oct 2019).

SAICM (2019c): Sixth meeting of the Bureau of the International Conference on Chemicals Management for its fifth session. Meeting Report http://www.saicm.org/About/Bureau/Bureaumeetings/tabid/5949/language/en-US/Default.aspx and https://www.saicm.org/Portals/12/Documents/meetings/Bureau/ICCM5B6/ICCM5-Bureau-Sixth-meeting-Jan-2019-Report.pdf (10 Sept 2023).

SAICM (2020a): Proposed targets prepared by the Technical Working Group on targets, indicators and milestones for SAICM and the sound management of chemicals and waste beyond 2020, SAICM/IP.4/3, 21-02-2020. https://www.saicm.org/Portals/12/documents/meetings/IP4/old/(old)SAICM_IP4_3_Proposed-targets-TWG-SAICM-smcw-beyond-2020.pdf (10 Sept 2023).

SAICM (2020b): Supplementary information on proposed targets prepared by the Technical Working Group on targets, indicators and milestones for SAICM and the sound management of chemicals and waste beyond 2020; SAICM/IP.4/INF/15, 16 March 2020 https://www.saicm.org/Portals/12/documents/meetings/IP4/old/(old)SAICM_IP4_INF_15_TWG_FINAL.pdf (10 Sept 2023).

SAICM (2021): Virtual Working Group on targets, indicators and milestones. Co-facilitators' final report of the outcomes of the Virtual Working Group, SAICM/ICCM.5/VWG1/Final report, 16 February 2021. https://www.saicm.org/Portals/12/documents/meetings/VirtualWG/Target/VWG1_Co-facilitators-final-report_16FEB2021_FINAL.pdf (29 March 2021).

SAICM (2022a): Outcome of the Virtual Working Group on targets, indicators and milestones, SAICM/IP.4/2/Rev.1/Add.1, 15 July 2022 https://www.saicm.org/Portals/12/documents/meetings/IP4/2022/SAICM_IP.4_2_Rev.1_Add.1_Outcome%20of%20VWG1%20on%20targets,%20indicators%20and%20milestones.pdf (06 Sept 2023).

SAICM (2022b): Strengthening integrated chemicals and waste management: An IOMC contribution to the intersessional process on the "Strategic Approach and sound management of chemicals and waste beyond 2020", SAICM/IP.4/INF/18, 27 July 2022 https://www.saicm.org/Portals/12/documents/meetings/IP4/2022/SAICM_IP4_INF_18_IOMC%20Integrated%20chemicals%20and%20waste%20management__.pdf (15 Sept 2022).

SAICM (2023): Inventory and analysis report: existing indicators on chemicals and waste management. SAICM/IP.4/INF/39/Rev.1, 08/08/2023, Annex: IOMC Indicators Project Working Group: IOMC: Update to the Inventory and analysis report: existing indicators on chemicals and waste management. 17/07/2023. https://www.saicm.org/Portals/12/documents/meetings/IP4_3/SAICM_IP.4_INF_39_Rev.1.pdf (09 June 2023).

SAICM Secretariat (2018): Independent Evaluation of the Strategic Approach from 2006-2015. Draft Report (Author: Robert Nurick, Atlantic Council) http://www.saicm.org/Portals/12/documents/meetings/IP2/IP_2_4_Independent_Evaluation.pdf (20 Feb 2020).

Spinaci, S. (2023): Corporate sustainability due diligence: How to integrate human rights and environmental concerns in value chains. European Parliament, BRIEFING - EU Legislation in Progress, 2nd edition https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/729424/EPRS_BRI(2022)729424_EN.pdf (10 Sept 2023).

Statista (2023): Distribution of global chemical and pharmaceutical industry investment by region from 2000 to 2030. Published by Statista Research Department, 04/14/2023 https://de.statista.com/statistik/daten/studie/726729/umfrage/anteil-an-weltweiten-investitionen-der-chemie-und-pharmaindustrie-nach-regionen/ (09 Sept 2023).

Steffen, W.; Richardson, K.; Rockstr m, J.; Cornell, S. E.; Fetzer, I.; Bennett, E. M.; Biggs, R.; Carpenter, S. R.; de Vries, W.; de Wit, C. A.; Folke, C.; Gerten, D.; Heinke, J.; Mace, G. M.; Persson, L. M.; Ramanathan, V.; Reyers, B.; Sorlin, S. (2015): Planetary Boundaries: guiding human development on a changing planet. Science 2015, 347 (6223), p. 1259855. https://www.science.org/doi/10.1126/science.1259855 (09 Sept 2023).

Steinhäuser, K.G.; von Gleich, A.; Große-Ophoff, M.; Kn er, W. (2022): The Necessity of a Global Binding Framework for Sustainable Management of Chemicals and Materials - Interactions with Climate and Biodiversity. Sustainable Chemistry 2022, 3(2), p. 205-237 https://doi.org/10.3390/suschem3020014 (03 July 2023).

UBA (2009): Sustainable Chemistry. Positions and Criteria of the Federal Environment Agency. Background paper, Federal Environment Agency, Dessau-Roßlau https://www.umweltbundesamt.de/sites/default/files/medien/publikation/long/3798.pdf (10 Sept 2023).

UBA (2011): Guide on sustainable chemicals. A decision tool for substance manufacturers, formulators and end users of chemicals. Federal Environment Agency, Dessau-Roßlau https://www.umweltbundesamt.de/sites/default/files/medien/479/publikationen/161221_uba_fb_chemikalien_engl_bf.pdf (10 Sept 2023).

UN - United Nations (2002): Report of the World Summit on Sustainable Development. Johannesburg, South Africa, 26 August - 4 September 2002, A/CONF.199/20* (* Reissued for technical reasons.) https://digitallibrary.un.org/nanna/record/478154/files/A_CONF.199_20-EN.pdf (03 July 2023).

UNCED (1992): United Nations Conference on Environment & Development, Rio de Janeiro, Brazil, 3 to 14 June 1992, Agenda 21 https://sustainabledevelopment.un.org/content/documents/Agenda21.pdf (03 July 2023).

UNEA - United Nations Environment Assembly (2016): Sound Management of Chemicals and Waste, UNEP/EA.2/Res.7 https://wedocs.unep.org/bitstream/handle/20.500.11822/11183/K1607167_UNEPEA2_RES7E.pdf?sequence=1 &isAllowed=y (15 Jan 2020).

UNEA - United Nations Environment Assembly (2019): Sound Management of Chemicals and Waste, UNEP/EA.4/Res.8 https://wedocs.unep.org/bitstream/handle/20.500.11822/28518/English.pdf?sequence=3&isAllowed=y (15 Jan 2020).

UNEA - United Nations Environment Assembly (2022a): End Plastic Pollution: Towards an International Legally Binding Instrument - Resolution adopted by the United Nations Environment Assembly on 2 March 2022, UNEP/EA.5/Res.14 https://wedocs.unep.org/handle/20.500.11822/40597 (04 July 2023).

UNEA - United Nations Environment Assembly (2022b): Science-policy panel to contribute further to the sound management of chemicals and waste and to prevent pollution, UNEP/EA.5/Res. 8 https://wedocs.unep.org/handle/20.500.11822/40653 (03 July 2023)

UNEA - United Nations Environment Assembly (2022c): Sound management of chemicals and waste, UNEP/EA.5/Res.7 https://wedocs.unep.org/bitstream/handle/20.500.11822/39846/SOUND%20MANAGEMENT%20OF%20CHEMI CALS%20AND%20WASTE.%20English.pdf?sequence=1&isAllowed=y (03 July 2023).

UNEA - United Nations Environment Assembly (2022d): Sustainable nitrogen management, UNEP/EA.5/Res. 2 https://wedocs.unep.org/bitstream/handle/20.500.11822/39816/SUSTAINABLE%20NITROGEN%20MANAGEM ENT.%20English.pdf?sequence=1&isAllowed=y (04 July 2023).

UNEP (2019): Global Chemicals Outlook (GCO) II - From Legacies to Innovative Solutions: Implementing the 2030 Agenda for Sustainable Development. https://www.unep.org/resources/report/global-chemicals-outlook-ii-legacies-innovative-solutions (23 Aug 2019).

UNEP (2020): Green and Sustainable Chemistry: Framework Manual (Lead author: Achim Halpaap), ISBN No: 978-92-807-3839-1 https://www.unep.org/resources/toolkits-manuals-and-guides/green-and-sustainable-chemistry-framework-manual (21 July 2021).

UNIDO - United Nations Industrial Development Organisation (2016): Global promotion and implementation of chemical leasing business models in industry, Ten years outlook, Vienna. https://www.recpnet.org/wp-content/uploads/2016/08/10-Years-Chemical-Leasing-Report.pdf (07 July 2023).

WBCSD - World Business Council for Sustainable Development (2017): Framework for portfolio sustainability assessments (PSA). https://www.wbcsd.org/Projects/Chemicals/Resources/Framework-for-portfolio-sustainability-assessments and https://www.wbcsd.org/contentwbc/download/3944/52805/1 (30 March 2023).

WBCSD - World Business Council for Sustainable Development (2018): Chemical Sector SDG Roadmap; https://www.wbcsd.org/Programs/People-and-Society/Sustainable-Development-Goals/Resources/Chemical-Sector-SDG-Roadmap and https://www.wbcsd.org/contentwbc/download/5187/69414/1 (30 March 2023).

World Bank (2022): New World Bank country classifications by income level: 2022-2023, Nada Hamadeh, Catherine Van Rompaey, Eric Metreau, Shwetha Grace Eapen, July 01, 2022 https://blogs.worldbank.org/opendata/new-world-bank-country-classifications-income-level-2022-2023 (10 Sept 2023).

Zou, H.; Wang, T.; Wang Z.-L.; Wang, Z. (2023): Continuing large-scale global trade and illegal trade of highly hazardous chemicals. Nature Sustainability, online preprint, published 10.07.2023. https://doi.org/10.1038/s41893-023-01158-w and https://www.nature.com/articles/s41893-023-01158-w (09 Sept 2023).

A Appendix: Short documentation of workshops

Workshop No. and Date, Target Group	Affiliation of Participants	Invited Talks	Indicators under Discussion
No. 1, 17th Nov 2020 Europe and international organizations	- Dr. Hans-Christian Stolzenberg and Dr. Christopher Blum from UBA, (Federal Environment Agency), along with members from the project team were present. UBA was the organizer of the workshop. - Representatives from the Austrian Environment Ministry contributed to the workshop discussions. - Representatives from Verbraucherzentrale NRW, a German consumer protection organization, also attended. - ISC_3, an international organization focused on sustainable chemistry, had participants in the workshop. - BASF, a large German multinational chemical company, and Evonik, a specialized German chemical company were represented. - The United Nations Environment Programme (UNEP) and Organization for Economic Co-operation and Development (OECD) were international organizations present at the workshop. - Universities such as University of Cambridge and Leuphana University were represented at the workshop. - IPEN, a global network working towards the elimination of toxic substances, was also represented. - Other participants were from the project team (UBA, N^3, ADO, CSCP, BZL).	- "Common understanding of sustainable chemistry" (Prof. Dr. Klaus K mmerer) - "Green and sustainable chemistry framework manual" (Dr. Achim Halpaap).	- The workshop aimed to discuss the adequacy and proposal of indicators for anchoring sustainable chemistry in chemicals management. - The participants engaged in expert discussions on the suitability of criteria for the selection of such indicators and reviewed the proposals made by project members. - The participants also considered the current state of strategic objectives for Strategic Approach to International Chemicals Management (SAICM) and Sound Management of Chemicals and Waste (SMCW). - The group discussed and determined the most important indicators, such as green list indicators, and their significance. - The workshop also focused on the development and application of new indicators to measure the contribution of sustainable chemistry. - Some of the major indicators discussed were CO_2 emissions, "benign by design", and the use of natural products as a source of a percentage of chemical production. - Two working groups were formed to critically evaluate the selection of criteria for a useful indicator and formed a consensus on their suitability. - The working groups also discussed potential indicators from both the "white" and "green" lists, assessing their suitability based on predefined criteria. - The collaborative effort provided opportunities for dialogue on challenges, ideas, and potential gaps in the world of sustainable chemistry.

Workshop No. and Date, Target Group	Affiliation of Participants	Invited Talks	Indicators under Discussion
No. 2, 9th March 2021 Asia	- The participants in the workshop on sustainable chemistry in chemical management and its development included individuals from various industries, research and education institutions, government agencies, and non-governmental organizations (NGOs). - There were representatives from Tsinhua University School of Environment, PR China; NimkarTek Technical Services, India; S.N. Arts, D.J.M. Commerce & B.N.S. Science College, India; Jalan University, Malaysia; Department of Chemistry, Immanuel College, India; COMSAT, University Islamabad Lahore Campus, Pakistan; ISC$_3$, Germany; Safety and Health Technology Center (SAHTECH), Taiwan; WAYY Consulting, Singapore; BASF Asia Pacific, Malaysia; Abasaheb Garware College, India; Asian Center for Environmental Health &. IPEN, Bangladesh; Environment and Security Centre of Mongolia (ESCM), Mongolia; National Metal and Materials Technology Center (MTEC), Thailand; UNEP Chemicals and Waste Branch; European Environmental Agency; EPA, Division of Pollution Control, Vietnam; Environmental and Social Development Organization, Bangladesh; and POPs Environmental Consulting, Germany.	- "Sustainable chemistry and the textile industry - a personal view". (Ullhas Nimkar (NimkarTek)) - "Plastics in construction - opportunities, resources, and waste: results of the ISC3 workflow 2019-2020" (Dr. Claudio Cinquemani, ISC$_3$).	- The development of indicators for sustainable chemistry and chemical management was a key focus of the workshop, considering its growing importance for achieving at least 14 Sustainable Development Goals (SDGs). - Strategic objectives and targets for international chemicals management beyond 2020 were discussed, and the need for indicators to measure contributions of sustainable chemistry in chemicals management to sustainable development was highlighted. - Two examples of potential indicators were presented for assessment: "CO2 emission per unit of value added (SDG9.4.1) for products of the chemical industry" and "Number of countries which have adopted regulations aiming at disclosing chemicals of concern in consumer products (IPEN indicator A.2-5)". - Other examples discussed included "Number of countries ending fossil fuel subsidies" and "Change in water-use efficiency over time (SDG6.4.1) in the chemical industry (water footprint)". - The participants recognized that indicators require clear definitions, precise units for measurement, and validated calculation methods to be effective. - There was a proposal to establish indicators at different levels, such as regions, individual countries, and companies in the chemical industry, along with the development of sub-indicators. - There was a call for focusing on environmental and health safety, resource conservation in a circular economy, and reduction of greenhouse gases when industrial transition to safe-and-sustainable-by-design chemicals is being considered. - Discussion highlighted the need for leadership initiatives in the strategic approach to international chemicals management (SAICM) process to develop sound indicators as soon as possible. - Participants agreed on the importance of further developing the process and methodology of indicator assessment and

Workshop No. and Date, Target Group	Affiliation of Participants	Invited Talks	Indicators under Discussion
	- The project team included 9 persons from UBA, N^3, ADO, CSCP, BZL. - The discussion was led, and presentations offered by a range of individuals including Dr. Hans-Christian Stolzenberg from UBA, Dr. Christopher Blum from UBA, Ullhas Nimkar from NimkarTek, Dr. Henning Friege from N^3, Dr. Esther Heidbüchel from CSCP, and Dr. Claudio Cinquemani from ISC_3. - The participants introduced themselves and their affiliations at the beginning of the workshop.		expressed interest in debriefing on criteria guidance. - It was acknowledged that the lack of in-person meetings due to the pandemic could potentially affect the course and the depth of expert discussions on such matters. - Results from the discussion were due for further discussion with the SAICM secretariat, United Nations Environment Programme (UNEP), and the European Commission, amongst others.
No. 3, 29th June 2021 Latin America	- The participants at the workshop were from a variety of affiliations that included a range of academic institutions, industry representatives, environmental organizations, and governmental bodies. The affiliations were spread across different regions, particularly Latin America. - Participating organizations included BASF South America (Brazil), UNEP Chemicals and Waste Branch, Ministry of the Environment (Peru), University Mayor de Chile, Santiago (Chile), Universidad de Concepci (Chile), Organization for Women in Science for the Development World - OWSD (Peru), Federal University of Sao Carlos (Brazil). - Other participants were from World Biogas	- "Green and sustainable chemistry, agriculture and biodiversity: an overview from Latin America" (Prof. Dr. Dr. Vania Zuin (VZ), Universidade Federal de Sao Carlos, Brazil; Visiting Professor, Leuphana University, Germany). - Sustainability approaches of Braskem (Dr. Jorge Soto (JS), Braskem, Sustainable Development Director) - Threats to soil biodiversity linked to chemicals (Prof. Dr. Sergio Peña-	- Participants discussed the difficulties of globally accepted targets and indicators for sustainable chemistry and chemicals management. This ongoing discussion is being taken place under the framework of SAICM (Strategic Approach to International Chemicals Management). - The concept of developing indicators that measure the contributions of sustainable chemistry elements, particularly in chemicals management towards overall sustainable development, was also discussed. The progress of this project is to be presented at the ICCM5 event. - The workshop focused on the relations between sustainable chemistry and biodiversity, agriculture, soil, and water management. - Examples of indicators discussed included: the number of companies utilizing natural products as a source, share of chemical production based on renewable materials, and specific indicators focusing on sustainable chemistry's interaction with biodiversity, agriculture, and nutrition. - Several proposed indicators were discussed by the working groups, including number or share of countries having goals on pesticides under their

Workshop No. and Date, Target Group	Affiliation of Participants	Invited Talks	Indicators under Discussion
	Association (UK), INI Latin America (Chile), Camara del la industria Quimica Y Petroquimica (Argentina), Dow Chemical (Argentina), Nouryon Chemicals (Brazil), CSCP (Costa Rica), Givaudan Argentina SA (Argentina), and Braskem (Brazil). - Apart from these individuals, there were 7 more participants from the project team (UBA, N³, ADO, CSCP, BZL).	Neira (SPN), Universidad Mayor de Chile)	National Biodiversity Strategy and Action Plan (NBSAP), the number of countries subsidizing the use of synthetic fertilizers, number of countries with positive incentives or subsidies for conservation and sustainable use of biodiversity, and number or share of countries regulating the emission of reactive nitrogen compounds. - The selection and effectiveness of these indicators were discussed in detail in the workshop, with consideration to their specificity, accuracy, potential impacts, and the feasibility of collecting reliable data. - Other considerations included the need for regulation and monitoring systems, the correlation between prevention and promotion in legislation, the application of the precautionary principle in environmental law, and the need to take a systemic approach to avoid negative trade-offs or unintended consequences.
No. 4, 4th November 2021 North America / NAFTA	- 14 participants from various organizations including UNEP Economy Division, UNEP Chemicals and Waste, Lowell Center for Sustainable Production (USA), Environment and Climate Change Canada, Scientific and Technical Advisory Panel to Global Environment Facility, Health Canada, The Chemours Company (USA), Washington State Department of Ecology (USA), American Chemical Society Green Chemistry Institute (USA), and State Ministry for Social Affairs, Health, and Integration (Germany) - 10 members from the project team (UBA, N³, ADO, CSCP, BZL. - Opening remarks and introduction of the participants by Dr. Hans-Christian Stolzenberg from UBA	"Mainstreaming sustainability indicators in chemicals and wastes across supply chains" (Professor Saleem H. Ali, Scientific and Technical Advisory Panel of the GEF, and University of Delaware, USA). - "Informing decisions for holistic chemical management and sustainable portfolios" (Dr. Andrew Liu, Global Product Sustainability Strategy Leader, Chemours). - "Financing and sustainable investments as	- Discussions centered on indicators related to climate protection and finances regarding sustainable chemistry. - The workshop focused on the development of indicators for sustainable chemistry elements in chemicals management for sustainable development. - Insights were shared regarding the difficulties in arriving at globally accepted targets and indicators. The project aims to contribute to the International Conference on Chemicals Management's technical work required for monitoring chemicals management progress worldwide. - Participants discussed developing indicators based on existing conventions. - The application of "sound management of chemicals and waste beyond 2020" was suggested to cover future-oriented targets focusing on the safe handling of chemicals and waste. - Considerations were made for indicators mirroring the contributions of sustainable chemistry elements in chemicals management to general, sustainable development.

Workshop No. and Date, Target Group	Affiliation of Participants	Invited Talks	Indicators under Discussion
	- Presentation by Dr. Christopher Blum from UBA on the project's key aims and its concept - Contribution from Professor Saleem H. Ali from the Scientific and Technical Advisory Panel to Global Environment Facility and University of Delaware USA - Dr. Henning Friege from N^3 and Dr. Esther Heidbüchel from CSCP explained the project's methodology and presented several indicators. - Contributions from Dr. Andrew Liu from Chemours and Professor Dr. Joel Tickner from University of Massachusetts, Lowell Center for Sustainable Production, and Director of Green Chemistry and Commerce Council.	a key factor in driving sustainable chemistry" (Prof. Dr. Joel Tickner, Univ. of Massachusetts, Lowell Center for Sustainable Production, and Director of Green Chemistry and Commerce Council, GC3).	- Workshops discussed the indicator "Direct economic loss attributed to disasters related to the production, transport, storage, application of chemicals in relation to global gross domestic product (GDP)." It was noted that the indicator only looks at direct economic loss and excludes indirect costs. - The indicator "CO2eq. scope 1 & 2 per unit of value added of the chemical industry" was introduced for consideration. Discussions focused on the specificity of the indicator, established and determinable for larger companies, but challenging for small and medium enterprises. - There was a discussion on the potential indicators for financial issues related to chemistry, such as "Increase in % of the Environmental Protection Expenditures in COFOG4 Reporting" and "Number of countries collecting Resource Taxes on non-renewable natural resources and their extraction". - Discussions also included the idea of creating a market driven indicator to reflect behaviors change from both consumers and industry.
No. 5, 3rd March 2022 Africa and Middle East	- Participants of the workshop came from a variety of international organizations and educational institutions. - The affiliations include Action Planète Bio from Cameroon, Univ. de Sousse from Tunisia, Pan African Vision for the Environment - PAVE from Nigeria. - Univ. of Addis Ababa from Ethiopia, and European Chemical Industry Council - Cefic from Belgium also participated. - Other participants came from Chemonics Egypt, OECD Chemicals Division, University of Cape Town from the Republic of South Africa, and Federal	- "The role of renewable raw materials and waste for the sustainable design of plastics" (Dr. Eeva Leinala, OECD, Principal Administrator of the Risk Reduction Programme and the Good Laboratory Practices and Mutual Acceptance of Data Programmes). - "Development of Bio-Based Economy in Egypt:	- The participants discussed different indicators focusing on sustainable chemistry with bioeconomy and the transition from fossil to regenerative raw materials. - Indicator: "The number of companies using natural products as a source, and the percentage share of chemical production based on renewable materials" was discussed, noting the complexity of defining renewable materials and the challenge of making comparable system connections for data collection. - Indicator: "Countries that implement pesticide legislation based on the FAO/WHO International Code of Conduct (CoC)" was debated, focusing on dynamicity, specificity, and measurable elements. - The indicator regarding renewable energy share in the final energy consumption of the chemical industry was considered. It was established that the

Workshop No. and Date, Target Group	Affiliation of Participants	Invited Talks	Indicators under Discussion
	Institute of Industrial Research from Nigeria. - University of Port Harcourt in Nigeria, Stockholm University in Sweden, Environmental Health and Safety Consultancy and Analytical Laboratories in Kenya were also represented. - There were participants from Bahir Dar University - EiTEX in Ethiopia, Environment Section, One Stop Service Center - OSSC in Myanmar, and Kyushu University in Japan. - TÜV Rheinland Group from Hong Kong and SABIC from the Netherlands were also part of the pool of participants. - In addition, there were 8 persons from the project team (UBA, N³, CSCP, ADO, BZL).	Constraints and Challenges" (Prof. Dr. Ahmed Gaber. Cairo University, and CEO of Chemonics Egypt). - "Coffee and plastics recycling - a joint business model" (Dr. Kalie-Martin Cheng).	chemical industry needs to differentiate their energy consumption between renewable and fossil origin. - The group also highlighted the importance of developing countries and least developed countries' share of global exports of chemical products, focusing on the relevancy of data and sustainability aspects. - Indicator pertaining to developing countries and least developed countries' share of global exports of chemical products. Discussions revolved around the specificity of 'chemical products'. - The possible linkage of the FAO/WHO International Code of Conduct (CoC) with sustainability and the implementation and enforcement of the CoC was analyzed. - Number of companies that use natural products as a source as a share of chemicals production was discussed, with the group agreeing that the indicator was not very specific, and it would be challenging to measure and determine it. - Indicator: "Renewable energy share in the final energy consumption of the chemical industry" was questioned by the group especially regarding what "final" means, the non-availability of specific energy consumption data in the chemical industry and the questionable reliability of energy consumption data from different sources. Other aspects such as the dependency on other regions, the need for technology innovation and transparency issues were also discussed. - Indicator: "Developing countries and least developed countries share of global exports of chemical products" was discussed weighing its specificity, reliability, and transparency. The group also highlighted the possibility of discarding unlinked sustainability aspects with respect to this indicator. Furthermore, the potential of renewable energy to strengthen the position of developing countries was put forward. - The group also highlighted the importance of developing countries and least developed countries' share of global exports of chemical products, focusing on

Workshop No. and Date, Target Group	Affiliation of Participants	Invited Talks	Indicators under Discussion
			the relevancy of data and sustainability aspects. - The indicator "Number of companies that use natural products as a source as a share of chemicals production" was discussed extensively in terms of its current specificity, measurability, sustainability criteria, and potential contribution to innovation.
No. 6, 29th March 2023 Experts from science, international organisations and industry who had already participated in previous work-shops or interviews	- Participants comprised of individuals from various national and international organizations representing different sectors related to chemicals management and sustainable chemistry. - The recorded participants were affiliates of various environmental consulting groups, chemical companies, government agencies, and academic institutions with a focus on chemistry. - The participants represented diverse geographical regions including Germany, the USA, OECD member countries, Chile, the UK, Denmark, Austria, Kenya, and Belgium. - It was a hybrid meeting that had both online video participation and physical on-site attendance, thus participants affiliated with different regions were able to attend. - The external expert participants who commented on the project results were affiliates of UNEP, Technical University of Denmark, Sustainable Strategy Development Branch, Global Alliance on Health and Pollution, and Centre for Science and Technology Innovations. - The project team members were affiliates of	Comments on the project results with focus on the analysis of the identified indicators and consequences for international policy by - Sandra Averous-Monnery (UNEP). - Dr. Eric de Deckere (CEFIC), - Peter Fantke (Technical University of Denmark), - Dr. Wibke L lsberg (BASF), - Jill Hanna, MA (Senior Advisor to Global Alliance on Health and Pollution, tbc), - Cecilia Wandiga (CSTI, Kenya)	- Discussions during the workshop revolved around the development of indicators to measure progress towards sustainable chemistry. - Certain indicators were identified that are related to objective D, targets of which go beyond the sound management of chemicals and waste. These include measuring the share of chemical production based on renewable materials and the number of documented improvements in sustainable practices among suppliers. - Participants suggested that indicators should be feasible to measure and document by companies and national statistics offices. They also suggested that indicators should capture emerging policy issues. - Some participants expressed the need for clearer definitions and formulations of indicators. - Potential indicators proposed include the share of companies reporting their sustainability performance, investment in the sustainable chemical industry, and the percentage of companies with human rights due diligence procedures for toxic substances used in their operations. - There were diverse views on the effectiveness of sustainability reporting, with some suggesting it could be an incentive for action in companies, while others believed it needed to be more detailed to show the impact of sustainability actions and reports. - Some participants emphasized the need for indicators to consider region-specific factors. For instance, greenhouse gas emissions are not limited to a specific location, while chemical pollution is a local problem.

Workshop No. and Date, Target Group	Affiliation of Participants	Invited Talks	Indicators under Discussion
	the German Environment Agency (UBA), the Sustainable Development Strategy Branch at BASF SE, Technical University of Denmark, and UNEP Chemicals and Health Branch. - The Sustainable Challenge Platform project team consisted of representatives from UBA, N³, CSCP, and ADO - who contributed on-site at the meeting and remotely via video. - A participant representing Sustainable Strategy Development Branch, BASF (Germany) was also present at the site. - The IOMC (Inter-Organization Programme for the Sound Management of Chemicals) members who provided comments were affiliated with United Nations Environment Programme (UNEP) and European Chemical Industry Council (CEFIC).		- Banks and financial institutions were highlighted as key stakeholders that could play a role in driving innovations in the chemical industry through their investment choices. - On biodiversity, participants discussed the use of existing indicators such as the water quality index and assessing bodies of water with good ambiance, as well as monitoring air pollution. - The discussions revealed a need for a balance between 'negative' indicators focusing on avoiding and reducing impacts, and 'good' indicators that show impact and trigger innovative approaches. - Participants suggested linking the development of the proposed indicators to the Sustainable Development Goals (SDGs) to highlight their significance in policy discussions. - Stakeholders agreed on the need to develop lists of indicators according to criteria such as impact, relevance to industry, scientific credibility, and the ability to generate action. These indicators should also align with ongoing initiatives and industry practices for consistency and ease of implementation. - Participants agreed on the importance of enhancing the political importance of these indicators by demonstrating links between them and the SDGs. - Finally, the indicators should consider cultural variations and the different approaches to chemistry across regions, with the G20 perspective offering a starting point for analysis.

B Appendix: List of interview partners

B.1 Interviews, first round (June - August, 2020)

Title	Name	Surname	Affiliation	Subjects, focus questions	Discussion partner
Dr.	James	Constable	Am. Chem. Society, USA	Concept of Sustainable Chemistry complementing SMCW? Targets and indicators from conventions, treaties, frameworks, approaches etc. Investment in sustainable chemical management Recommendation for further experts to be involved	H. Friege
	Bob	Diderich	OECD		H. Friege
Dr.	Joe	DiGangi	IPEN senior science and technical advisor, USA		H. Friege
Prof. Dr.	Vania	Gomez Zuyn	Univ. of Sao Paulo, Brazil		H. Friege
Prof. Dr.	Klaus	K mmerer	Leuphana University, Germany		H. Friege
Dr.	Achim	Halpaap	Independent Consultant, former UNEP	Status of UNEP's work on sustainable chemistry	H. Friege

B.2 Interviews, second round (October - December, 2020)

Title	Name	Surname	Affiliation	Subjects, focus questions	Discussion partner
	Simon	Buckle	OECD	See round 1, especially indicators from conventions, treaties, frameworks, approaches etc.: Which have proven to be useful, what effort for measuring and controlling, recommended modifications Indicators for monitoring progress in shifting investments to sustainable chemicals management; existing reporting or monitoring systems? Basic and additional sustainability criteria	H. Friege
	Achim	Ilzhöfer	Covestro, Germany		E. Heidbüchel
Dr.	Thomas	Jakl	Ministry for Environment, Austria		B. Zeschmar-Lahl
	Pierre	Quiblier	UNEP Chemicals and Health Branch		E. Heidbüchel
	Jorge	Soto	Braskem, Brazil		C. Fedato
Dr.	Joel	Tickner	Lowell Center for Sustainable Production, GC3, USA		B. Zeschmar-Lahl

B.3 Interviews, third round (May, 2021 - March, 2022)

Title	Name	Surname	Affiliation	Subjects, focus questions	Discussion partner
Prof. Dr.	Pariatamby	Agamuthu	Jalan University, Malaysia	Interfaces between (sustainable) chemistry, resources and waste and suitable indicators	H. Friege
Prof. Dr.	Ricardo	Barra	Universidad de Concepcion, Chile	See round 1, especially indicators from conventions, treaties, frameworks, approaches etc.: Which have proven to be useful, why? Topics important for SMCW, not covered by existing conventions etc. Indicators for monitoring progress in shifting investments to sustainable chemicals management; existing reporting or monitoring systems? Cross-cutting issues linked to the chemical sector requiring more or better indicators to measure progress towards Sustainable Chemistry? Recommendation of experts from other sectors (climate, health, labor, biodiversity, agriculture, investments, reinsurance ...).	H. Friege
Dr.	Alexis	Bazzanella	DECHEMA, Germany	See round 1, especially indicators from conventions, treaties, frameworks, approaches etc.: Which have proven to be useful, why? Indicators for monitoring progress in shifting investments to sustainable chemicals management; existing reporting or monitoring systems? Cross-cutting issues linked to the chemical sector requiring more or better indicators to measure progress towards Sustainable Chemistry? Recommendation of experts from other sectors (climate, health, labor, biodiversity, agriculture, investments, reinsurance ...).	H. Friege
Dr.	Gero	Leson	Dr. Bronner's, USA	Use of renewable materials in the chemical industry, protection of biodiversity Indicators for bioeconomy	H. Friege
Prof. Dr.	Martin	Scheringer	ETH Zurich, Switzerland, Chairman IPCP (International Panel on Chemical Pollution)	Science-Policy-Interface (SPI) Indicators for sustainable chemistry	H. Friege

Title	Name	Surname	Affiliation	Subjects, focus questions	Discussion partner
Prof. Dr.	Josef	Settele	UFZ Helmholtz, Germany, IPBES Vice-Chair	Indicators for biodiversity Role of pesticides and toxic chemicals for biodiversity	H. Friege
Prof. Dr.	Mark	Sutton	UK Centre for Ecology and Hydrology, UK	Global Partnership for Nutrient Management (GPNM) Indicators for overfertilization	H. Friege
Dr.	Xenia	Trier	University of Copenhagen, Section for Environmental Chemistry and Physics, Denmark	See round 1, especially indicators from conventions, treaties, frameworks, approaches etc.: Which have proven to be useful, why? Topics important for SMCW, not covered by existing conventions etc. Indicators for monitoring progress in shifting investments to sustainable chemicals management; existing reporting or monitoring systems? Cross-cutting issues linked to the chemical sector requiring more or better indicators to measure progress towards Sustainable Chemistry? Recommendation of experts from other sectors (climate, health, labor, biodiversity, agriculture, investments, reinsurance ...).	E. Heidbüchel
	Berthold	Welling	VCI / Chemie³, Germany	See round 1, especially indicators from conventions, treaties, frameworks, approaches etc.: Which have proven to be useful, why? Topics important for SMCW, not covered by existing conventions etc. Indicators for monitoring progress in shifting investments to sustainable chemicals management; existing reporting or monitoring systems? Cross-cutting issues linked to the chemical sector requiring more or better indicators to measure progress towards Sustainable Chemistry? Recommendation of experts from other sectors (climate, health, labor, biodiversity, agriculture, investments, reinsurance ...).	H. Friege

B.4 Interviews, fourth round (March - June, 2023)

Title	Name	Surname	Affiliation	Subjects, focus questions	Discussion partner
	Jill	Hanna	Global Alliance on Health and Pollution, UK	How to enforce the application of indicators in the SAICM process? Waste and its potential links to sustainable chemistry	H. Friege
Dr. Dr.	Christoph Wibke	Jaekel L Isberg	BASF, Germany	Use of indicators by (KPI's) BASF Indicators for progress in the field of sustainable chemistry Further development of portfolio sustainability assessments (PSA) How can we measure / assess investments in innovative processes and products in terms of sustainable chemistry?	H.C. Stolzenberg, C. Blum, H. Friege

C Appendix: Complete list of indicators

- Column B: Objective (cf. SAICM/document/4.3)
- Column C: Original version of the indicator; the bold part of the text refers to the indicator proposed in this study.
- Column D: Modification of the original version of the indicator (if necessary) in bold or recommendations for modification (no bold).
- Column E: Referred source (e.g., convention).
- Columns G-L: Classification of the respective indicator according to Criteria A-G (see Chapter 5).
- Column M: Classification of the respective indicator according to the H-criteria, the Criteria H1...H5 for which the indicator is relevant (in brackets: relevant, if applicable) are mentioned in each case.

No.	Objective (cf. SAICM / document/ 4.3)	Existing / proposed indicator	Alternative or add-on by the team	Source	A) Specific ?	B) Esta-blished?	C) Deter-minable?	D) Mea-surable?	E) Reliable & trans-parent?	F) Dynamic ?	G) Perti-nent?	H) Sustain-ability:
1	D, E	**Share of large / medium / small chemical enterprises of the region (Africa, Asia, Europe ...) that report on their sustainability performance using GRI SRS (current status: 93 % of the largest 250 corporations worldwide covering all sectors).**		GRI	3: Yes	3: Yes	0: No	0: No	3: Yes	3: Yes	3: Yes	H2, H3, H4, H5
2	D, A	**Number of new supplier assessments carried out in the year under review, by region, and change compared with the previous year.**		TfS	3: Yes	3: Yes	2: Difficult	1: Very Difficult	2: Difficult	3: Yes	3: Yes	(H2), H3: ESG criteria have to be met, e.g., environment, safety at work, human rights,

No.	Objective (cf. SAICM / document/ 4.3)	Existing / proposed indicator	Alternative or add-on by the team	Source	A) Specific ?	B) Esta-blished?	C) Deter-minable?	D) Mea-surable?	E) Reliable & trans-parent?	F) Dynamic ?	G) Perti-nent?	H) Sustain-ability:
												ethics and sustainable procurement
3	D, A	Number of inspections undertaken/inspectors by the number of relevant industries.	**Number of Inspections (by authorities or independent auditors) undertaken to prove compliance with existing regulation in the relevant industries**	TWG4, based on ILO	3: Yes	3: Yes	2: Difficult	2: Partly	2: Difficult	0: No	2: Medium	H3
4	D	Number of governments and the private sector applying EPR.	**Share of product categories (in relation to all product categories) for which extended producer responsibility applies**	TWG4	3: Yes	0: No	2: Medium	2: Medium	2: Medium	3: Yes	3: Yes	H4, H5 (H1)
5	D	**Domestic material consumption, domestic material consumption per capita and per GDP.**		SDG Ind. 12.2.2	0: No	3: Yes	2: Medium	3: Yes	2: Medium	3: Yes	0: No	H5, (H4)
6	D, A	a) Hazardous waste generated per capita; and b) proportion of hazardous waste treated, by type of treatment.	**Proportion of hazardous waste treated, by type of treatment (12.4.2), e.g.,**	SDG Ind. 12.4.2 Basel Conv.	0: No	2: Partly	2: Medium	3: Yes	2: Difficult	3: Yes	3: Yes	(H2), H3, (H5)

No.	Objective (cf. SAICM / document/ 4.3)	Existing / proposed indicator	Alternative or add-on by the team	Source	A) Specific?	B) Esta-blished?	C) Deter-minable?	D) Mea-surable?	E) Reliable & trans-parent?	F) Dynamic?	G) Perti-nent?	H) Sustain-ability:
			recovered, recycled, incinerated									
7	B, E	**Number of countries that have adopted…regulations aiming at disclosing chemicals of concern (CoC) in consumer products.**		IPEN (indicator A.2-5)	2: Difficult	0: No	3: Yes	1: Very difficult	2: Medium	3: Yes	3: Yes	(H1), H3
8	D, E	**Amount of fossil-fuel subsidies per unit of GDP (production and consumption).**	**Replace "Amount" with "Value". Add "per unit of GDP related to Chemical Industry´s energy consumption"**	SDG Ind. 12.c.1	3: Yes	3: Yes	3: Yes	3: Yes	2: Difficult	3: Yes	3: Yes	H2, H5
9	A, C, D	**Total value of inward and outward illicit financial flows (in current US-$).**	**Add "related to chemical products and waste" measured per unit of product detected used for unintended application and volume of illegally disposed waste**	SDG Ind. 16.4.1	3: Yes	0: No	2: Difficult	3: Yes	2: Difficult	0: No	0: No	H3, H4
10	D	**Number of companies certified for Environmental Management or Health,**	**… (within sector) … by an independent auditor**	TWG4	3: Yes	3: Yes	2: Partly	3: Yes	3: Yes	3: Yes	3: Yes	H3, (H4), (H5)

No.	Objective (cf. SAICM / document/ 4.3)	Existing / proposed indicator	Alternative or add-on by the team	Source	A) Specific?	B) Esta-blished?	C) Deter-minable?	D) Mea-surable?	E) Reliable & trans-parent?	F) Dynamic?	G) Perti-nent?	H) Sustain-ability:
		Safety, Environment Management System.										
11	A, D	**Share of companies belonging to National Associations (having implemented RC) in the global turnover of the chemical industry or in the number of employees in the chemical industry worldwide.**		Respon-sible Care	3: Yes	3: Yes	3: Yes	2: Medium	2: Medium	3: Yes	3: Yes	H3,(H4)
12	A, D	**Share of the world's largest chemical companies having signed on to 2014 RC Global Charter.**		Respon-sible Care	3: Yes	3: Yes	3: Yes	2: Medium	3: Yes	3: Yes	3: Yes	H3
13	B	**Number or share of parties that have ensured that the public has appropriate access to information on chemical handling and accident management and on alternatives that are safer for human health or the environment than the chemicals listed in Annex III.**		Rotterdam Conven-tion	3: Yes	3: Yes	3: Yes	3: Yes	2: Medium	3: Yes	3: Yes	H3, H4
14	B	**Direct economic loss attributed to disasters in relation to global GDP.**	**"...chemical disasters"; UNISDR definition of accidents should be used**	SDG Ind. 1.5.2	2: Partly	3: Yes	3: Yes	3: Yes	2: Medium	3: Yes	2: Medi-um	H3

No.	Objective (cf. SAICM / document/ 4.3)	Existing / proposed indicator	Alternative or add-on by the team	Source	A) Specific?	B) Esta-blished?	C) Deter-minable?	D) Mea-surable?	E) Reliable & trans-parent?	F) Dynamic?	G) Perti-nent?	H) Sustain-ability:
15	A	Number of legal frameworks implemented by countries **to reduce adverse impacts from chemicals throughout their lifecycle and waste.**	**Number of countries that have implemented a legal framework to reduce …**	TWG4	3: Yes	3: Yes	3: Yes	3: Yes	2: Medium	3: Yes	3: Yes	H1, H2, H5
16	D, C	CO_2 emission per unit of value added.	**CO_2eq. Scope 1 & 2 per unit of value added (e.g., gross output [Mg / yr]) of the chemical industry**	SDG Ind. 9.4.1	2: Medium	3: Yes	2: Difficult	3: Yes	3: Yes	3: Yes	2: Medium	H2, H5
17	D	**Number of companies publicly reporting their chemical footprint.**		IPEN (indicator D.5-7)	0: No	2: Medium	2: Medium	3: Yes	2: Medium	3: Yes	3: Yes	H1, H3, (H4)
18	D, A	Number of progress or improvements documented in the year under review for suppliers already assessed in a reassessment, by region, and change compared to the previous year.	**Number of progress or improvements documented in the year under review for suppliers already assessed in an audit follow-up / re-audit or reassessment, by region, and change compared to the previous year**	TfS	3: Yes	3: Yes	2: Medium	1: Very Difficult	2: Difficult	3: Yes	3: Yes	(H2), H3

No.	Objective (cf. SAICM / document/ 4.3)	Existing / proposed indicator	Alternative or add-on by the team	Source	A) Specific?	B) Established?	C) Determinable?	D) Measurable?	E) Reliable & transparent?	F) Dynamic?	G) Pertinent?	H) Sustainability:
19	D	Number of companies that use natural products as a source…	**Share of chemical production based on renewable materials in relation to the global production which is based on renewable materials … [%]**	TWG4	3: Yes	0: No	2: Medium	2: Medium	2: Difficult	3: Yes	3: Yes	H5
20	A, D	Number of companies that eliminate or reduce the use of hazardous chemicals in design and manufacturing by 70% and publicly reports progress periodically.	**Reduction of the amount of hazardous chemicals used in design and manufacturing related to the mass of chemical production by xx%**	IPEN (indicator D.5-2)	3: Yes	0: No	2: Difficult	2: Difficult	2: Difficult	3: Yes	3: Yes	H1, H3
21	D, B	**Amount of household waste generated / recycled (type…) / incinerated / landfilled per country.**		TWG4 (similar: IPEN Ind. D.2-15)	3: Yes	2: Partly	3: Yes	3: Yes	2: Difficult	3: Yes	3: Yes	(H2), (H5)
22	D, B, C	**Amount of post-consumer plastic waste generated / recycled / incinerated / landfilled / not collected per country.**		Team (based on a suggestion by the participants of Workshop #2)	3: Yes	2: Partly	3: Yes	3: Yes	2: Difficult	3: Yes	3: Yes	(H2), (H5)

No.	Objective (cf. SAICM / document/ 4.3)	Existing / proposed indicator	Alternative or add-on by the team	Source	A) Specific?	B) Esta-blished?	C) Deter-minable?	D) Mea-surable?	E) Reliable & trans-parent?	F) Dynamic?	G) Perti-nent?	H) Sustain-ability:
23	D	**Number of countries using sustainable chemistry principles.**	**… principles <u>in their legal framework</u>**	TWG4	3: Yes	2: Partly	3: Yes	1: Very difficult	2: Medium	3: Yes	3: Yes	H1-H5
24	D	**Material footprint, material footprint per capita, and per GDP.**		SDG Ind. 12.2.1	0: No	3: Yes	3: High	2: Medium	2: Medium	3: Yes	0: No	(H2), H5
25	C. D	**Mortality rate attributed to unintentional poisoning.**	**… caused by chemicals**	SDG Ind. 3.9.1	0: No	3: Yes	2: Medium	3: Yes	2: Difficult	3: Yes	2: Mediu m	H4, (H3)
26	A, D	Number of Member States whose laws and regulations, collective agreements where appropriate, and any other relevant instruments on occupational safety and health include the prevention of chemical risks.	**Number of relevant instruments and collective agreements (e.g., between companies and trade unions) on occupational safety and health including the prevention of chemical risks**	TWG4	3: Yes	2: Partly	3: Yes	1: Very difficult	3: Yes	3: Yes	3: Yes	H3
27	A, D	Number of Member States whose laws and regulations, collective agreements where appropriate, and any other relevant instruments on occupational safety and health include the prevention of chemical risks.	**Number of Member States whose laws and regulations and any other relevant instruments on occupational safety and health include the**	TWG4	3: Yes	2: Partly	3: Yes	2: Difficult	3: Yes	3: Yes	3: Yes	H3

No.	Objective (cf. SAICM / document/ 4.3)	Existing / proposed indicator	Alternative or add-on by the team	Source	A) Specific?	B) Established?	C) Determinable?	D) Measurable?	E) Reliable & transparent?	F) Dynamic?	G) Pertinent?	H) Sustainability:
			prevention of chemical risks.									
28	D	**Number of countries that adopt policies and instruments that implement agroecological strategies and practices that reduce synthetic input such as pesticides and fertilizers and are based on biodiversity and integrated soil nutrition…**		IPEN (Ind. A.1-6)	3: Yes	0: No	3: Yes	2: Difficult	2: Difficult	3: Yes	3: Yes	H2, (H5)
29	D	**Number of countries that implement Circular Economy** / cradle to cradle **systems without toxic chemicals recycling.**		IPEN (Ind. D.2-4)	3: Yes	0: No	3: Yes	2: Difficult	2: Difficult	3: Yes	0: No	H2, H3, H5
30	D	**Number of countries with EPR policies… so that the pharmaceutical industry is accountable for all pharmaceutical waste throughout the life cycle of their products.**	Similar: IPEN indicator D.2-1	IPEN Ind. A.8-2	3: Yes	0: No	2: Difficult	2: Difficult	2: Difficult	3: Yes	3: Yes	H1, H2, (H4)
31	D, B, A	**Number of PRTRs with publicly accessible data established.**		IPEN (Ind. A5-1)	3: Yes	3: Yes	3: Yes	2: Difficult	3: Yes	3: Yes	2: Partly	(H1), H4
32	B	**Participation in educational, training and awareness programmes on chemical safety and sustainability,**		TWG4	3: Yes	0: No	1: Very difficult	2: Difficult	2: Difficult	3: Yes	0: No	(H2), H3, H4

No.	Objective (cf. SAICM / document/ 4.3)	Existing / proposed indicator	Alternative or add-on by the team	Source	A) Specific?	B) Established?	C) Determinable?	D) Measurable?	E) Reliable & transparent?	F) Dynamic?	G) Pertinent?	H) Sustainability:
		including # of graduates, # of participants, # of people receiving awareness programme.										
33	D	**The** number and **percentage of companies with human rights (HR) due diligence procedures for toxic substances used, produced and released in their activities.**	**The percentage of companies…**	IPEN Ind. D.6-2	3: Yes	2: Partly	2: Difficult	2: Partly	2: Difficult	3: Yes	3: Yes	H3, (H4)
34	A	Change in water-use efficiency over time.	**Change in water-use efficiency (SDG 6.4.1) in the chemical industry (water footprint)**	SDG Ind. 6.4.1	3: Yes	2: Partly	2: Medium	3: Yes	3: Yes	3: Yes	3: Yes	(H2), H5
35	A, D	**Renewable energy share in the… final energy consumption.**	**… of the chemical industry**	SDG Ind. 7.2.1	3: Yes	2: Partly	2: Medium	3: Yes	3: Yes	3: Yes	3: Yes	(H2), H5
36	A, B, C	**Number of countries which have implemented pesticide legislation based on the FAO/WHO International Code of Conduct.**		TWG4 (IOMC indicator)	3: Yes	3: Yes	3: Yes	2: Difficult	3: Yes	3: Yes	3: Yes	H2,(H3)
37	A, C	**Number/percentage of countries where the legal framework demands risk assessment and registration / authorization of new chemicals before putting them on the market.**		IOMC Toolbox	3: Yes	0: No	3: Yes	2: Difficult	0: No	3: Yes	3: Yes	H1, H3

No.	Objective (cf. SAICM / document/ 4.3)	Existing / proposed indicator	Alternative or add-on by the team	Source	A) Specific ?	B) Esta-blished?	C) Deter-minable?	D) Mea-surable?	E) Reliable & trans-parent?	F) Dynamic ?	G) Perti-nent?	H) Sustain-ability:
38	**A, C**	**Number of (share of) countries reducing the emission of reactive N compounds (waste water, exhaust air, agriculture) by legislation.**		OSPAR-COM, HELCOM, see also Berlin Decl.	3: Yes	0: No	3: Yes	2: Partly	3: Yes	3: Yes	3: Yes	(H1), H2, H3
39	**E**	**Number of countries subsidising the use of synthetic fertilizers (Or: not subsidising).**		Berlin Decl.	3: Yes	0: No	3: Yes	2: Difficult	3: Yes	3: Yes	3: Yes	H2, (H5)
40	E	**Number of countries that have implemented the System of Environmental Economic Accounting[38].**		SDG 15.9.1.b Aichi Target No.3	3: Yes	0: No	3: Yes	3: Yes	3: Yes	3: Yes	3: Yes	H2, H4
41	B, A, C	**Number of countries that phased out the manufacture, import, sale and use of HHP.**		IPEN indicator A1.5	3: Yes	0: No	2: Partly	2: Medium	2: Medium	3: Yes	3: Yes	H1, H3
42	D, E	**Increase of the Environmental Protection Expenditures [%] in COFOG Reporting.**	Participants of Workshop #4 discussed this indicator controversially	Team	0: No	2: Partly	3: Yes	3: Yes	3: Yes	3: Yes	3: Yes	H4
43	E, D	**Number of countries applying carbon pricing instruments (including fuel and carbon taxation, emissions trading systems).**	Decrease of Carbon Certificates in ETS. Better to replace "Number of …" with	Project team	0: No	0: No	3: High	3: Yes	3: Yes	3: Yes	3: Yes	H2, (H5)

[38] UN SEEA, cf. https://seea.un.org/ecosystem-accounting

No.	Objective (cf. SAICM / document/ 4.3)	Existing / proposed indicator	Alternative or add-on by the team	Source	A) Specific?	B) Established?	C) Determinable?	D) Measurable?	E) Reliable & transparent?	F) Dynamic?	G) Pertinent?	H) Sustainability:
			"Amount of money earned from Carbon Taxation and / or ETS."									
44	D	**Number of companies conducting an Environmental cost-benefit Analysis.**		Project team	3: Yes	0: No	3: Yes	3: Yes	3: Yes	2: Partly	3: Yes	H4, H5
45	D, E	**Sum of resource taxes on non-renewable natural resources and their extraction collected by countries.**		Project team	0: No	0: No	3: Yes	3: Yes	3: Yes	2: Partly	3: Yes	H5 (H4)

Abbreviations:

CoC	Chemicals of Concern
COFOG	Classification of the Functions of Government
ETS	Emission trading system
GDP	Gross domestic product
HHP	Highly hazardous pesticides
ILO	International Labour Organisation
PRTR	Pollutant Release and Transfer Register
SDG Ind.	Indicator for Sustainable Development Goal No…
TWG4	SAICM TWG.document.4 Mapping Exercise (SAICM 2019b)

D Appendix: Minutes of "Indicators measuring progress towards sustainable chemistry"

External participants from UNEP Chemicals and Waste Branch, University of Stockholm (Sweden), CEFIC, EU Commission, DG ENV EU Commission, DG RTD, RIVM (The Netherlands), Austrian Ministry for the Environment, University of York, SusChem, Dutch National Institute for Public Health and the Environment, University of Copenhagen (Denmark), BASF SE

Host: Hans-Christian Stolzenberg, Christopher Blum, Anja Klauk (German Environment Agency)

Project team: Barbara Zeschmar-Lahl, Henning Friege, Cristina Fedato, Michael Kuhndt, Vladislav Sedov, Simon Obladen.

All presentations from this workshop are available to the participants on the interactive platform or from the project team (on demand). The event was moderated by Michael Kuhndt, Managing Director of CSCP. Technical support was provided by Vladislav Sedov.

Opening

The moderator - Michael Kuhndt - opened the meeting and introduced himself. He asked if there were any objections to recording of the meeting. The records will be cleared after evaluation of the discussion. As there were no objections, recording was started.

HCS welcomed the participants on behalf of the UBA and gave a short introduction into the subject: final preparatory phase on global level for the World Chemicals Conference ICCM5 in Bonn from September 25-29 2023, decision on a system of strategic objectives and targets expected for the SAICM successor and Sound Management of Chemicals and Waste (SMCW) beyond 2020. He stressed the point that corresponding indicators are under development as contribution to technical work after ICCM5. Many of these global activities advance mostly parallel to the discussion of the Chemicals Strategy for Sustainability (CSS) in Europe, yet; therefore, the event serves to foster closer linkages of both "discussion and working communities".

Relation between sustainable chemistry and Chemicals Strategy for Sustainability (CSS): Views of prominent experts in the field

MK introduced two questions to three well-known experts of sustainable chemistry:

- Do you think that the Chemicals Strategy for Sustainability is tangible enough to foster implementation of the concept of sustainable chemistry?
- Do you recognize gaps that should be filled?

The pre-recorded interviews were conducted with

- Prof. Dr. Dr. h. c. James Clark, University of York (United Kingdom), founder of the G2C2 network[39],
- Dr. Jonatan Kleimark, ChemSec, Gothenburg (Sweden)
- Prof. Dr. Klaus K mmerer, Leuphana University of Leb urg, and ISC_3 Science and Education Hub (Germany),

[39] Global Green Chemistry Centers network

Anchoring Sustainable Chemistry in policy - from a global to a European perspective

The moderator introduced Christopher Blum and asked him for his presentation "Indicators measuring progress towards sustainable chemistry: Criteria for meaningful indicators".

CB explained the background and objectives of SAICM and introduced the indicator project. In particular, he explained the criteria for the selection and the assessment of indicators. These criteria can also be useful for EU policy.

Then, the moderator introduced Henning Friege and gave him the floor for his contribution "Global indicators for monitoring the Chemicals Strategy for Sustainability (CSS)?"

HF positioned the CSS initiative within the global attempts towards sound management of chemicals and waste and sustainable chemistry. European companies run production facilities all over the world. The global trade with chemicals forces a synopsis of both perspectives of chemicals policy. He presented some indicators that might also be useful in the European context.

The moderator thanked the speakers for structuring the frame of the following discussion. He asked for urgent matters of understanding. As there were no spontaneous questions from the plenary, he illuminated the background of the discussion: The CSS aims to "better protect citizens and the environment" and also "boost innovation for safe and sustainable chemicals". Therefore, the following questions should be discussed:

- Will the indicators presented in excerpts meet at least one of the two objectives of the CSS? Do they foster sustainable innovation or address even additional objectives linked to the concept of sustainable chemistry?
- Are there other indicators that serve the same purpose, probably from other EU Directives / Strategies?

Flash comments

The moderator gave the floor to Aleksandra Malyska (EU, DG ENV, AM) and Eric de Deckere (CEFIC, EdD) for flash comments.

AM introduced the work of the Commission on the CSS and her special responsibilities in this field. Work on indicators for CSS started in spring 2021, aiming at successful monitoring of drivers and impacts. At the beginning, about 150 indicators were developed but reduced to 29 indicators that are still under investigation. Many potential indicators were dropped as no data were available. The Commission is looking for stewards (European and national agencies, but also public private partnerships with associations) that are able to measure and to collect the data needed for monitoring. This work shall be finalized in 2024; a dashboard of indicators will then be available on the EEA website. Currently, DG GROW works on a legislation proposal for data. She recognized the necessity for more indicators to get a broader picture. Thus, possibilities for co-operation with the project, e.g., on occasion of PARC[40] meetings, would be welcome.

EdD highly appreciated the system of criteria developed in the project. CEFIC adopted these criteria to check potential indicators, part of which have already been published on the website of the association; other indicators will be published in short term. The industry needs support for their decisions on investments. Therefore, the portfolio sustainability assessment (PSA)

[40] European Partnership for the Assessment of Risks from Chemicals (PARC) https://www.eu-parc.eu/.

becomes a widely used instrument in the chemical industry. He underlined that indicators are just a tool to evaluate distance to target - reasonable targets must be at the start. They should be discussed with all stakeholders. He welcomed the alignment of sound management of chemicals and waste (SMCW) and CSS (and here especially the European Commission's Transition Pathway for the Chemical Industry (EU 2023b) because of very different targets to be met. He stressed the necessity for reliable data. Data collection is still challenging; even European statistics would include mistakes. Moreover, clear definitions for some important targets, e.g., "safe and sustainable by design" (SSbD) are lacking; therefore, indicators for targets like this would be very challenging. He recommended to re-formulate some indicators thus using positive connotations, e.g., relation of recycled, incinerated, dumped post-consumer plastics in relation to the amount of available used material instead in relation to the amount of waste.

Plenary discussion

MK thanked both speakers for their clear and concise comments and opened the plenary discussion. He launched the second part of the discussion by raising two questions related to the indicators identified within this project:

- Do they foster sustainable innovation or address even additional objectives linked to the concept of sustainable chemistry?
- Do you know other indicators which serve the same purpose, probably from other EU Directives / Strategies?

The following subjects were discussed in detail:

- Sociological aspects as mentioned by Clark and Kümmerer are very important for measuring the chemicals industry's progress on the transformation pathway, as they represent a key hurdle.
- Indicators to reflect the transition to more sustainable production and consumption are e.g., number of patents, number of start-up's busy in sustainable chemistry, percent of eco-labeled products increasing relevance of green procurement.
- Many indicators are relative (% of ...). There is a need for indicators that also describe the absolute quantities in order to monitor the reduction in material flows, even for renewable resources.
- Indicators on research and innovation are needed, e.g., number of companies using or participating in SSbD (Safe and Sustainable by Design[41]), or funding (EU) or international investment programs.
- Indicators should not only focus on minimizing harm, but also measure and express positive developments and benefits.
- It is necessary to build up confidence in the monitoring. Meaningful indicators and reliable data are key.
- Material footprint indicators are most important to monitor consumers' behavior.
- Would it be possible to have indicators proposed, that 1) can be filled now 2) that could/should be filled in the future if new data are being gathered? Indicators for "SSbD"

[41] The "safe and sustainable by design" (SSbD) framework is a voluntary approach to guide the innovation process for chemicals and materials, announced on 8 December 2022 in a Commission Recommendation (EU 2022b).

should be developed in the sense of a long-term perspective, e.g., monitoring certain investments for bio-refineries etc. It was proposed to check this question in the framework of PARC.

- The Commission has to integrate quite different targets to monitor the transition of the chemical industry towards sustainability including competitiveness, social aspects, development of infrastructure etc. To measure different aspects of this twin transition requires both existing indicators and new ones developed from scratch. Thus, indicators that reflect the whole picture would be of value, but this is an extremely difficult task.
- How to create market dynamics in sustainable chemistry? Which indicators are suitable to measure this development?
- Are there indicators for the potential overexploitation of land and natural resources when we try to synthesize most chemicals from natural feedstock?
- Indicators related to more efficiency (e.g., the amount of resources used for 1 Mio € value creation) can hide increasing mass flows of resources etc. - be careful!

MK asked for interim comments by the hosts.

CB stressed the opportunity to introduce indicators developed in the project because of the good database in Europe.

HCS agreed that qualified and reliable data are key; therefore, it is necessary to identify custodians (= "stewards / data holder") that are willing to validate and share their data. MK mentioned that the CSS shall boost the investment and innovative capacity for production and use of chemicals that are safe and sustainable by design, and throughout their life cycle. He opened the second part of the discussion and asked for answers to the following questions:

- Do you think that the indicators help steering investment towards the required sustainability-oriented transformations of the chemical industry as well as of allied industries?
- Do you know other indicators which serve the same purpose, probably from other EU Directives / strategies?

The following subjects were discussed in detail:

- There should be more information about the direction of investments, not only in commercial production capacities but also for public research. It is necessary to check former research funding to learn about its effects for the present production and consumption and then to align funding activities for the transition.
- Are there opportunities to establish companies - also from abroad - in Europe that are based on new and more sustainable production techniques and natural resources? Investments of this type would be very welcome. There is a lot of funding of startups and SMEs by the Commission in cases of appropriate research projects and investments in facilities.
- The European industry should remain competitive. Thus, (re-)location of companies to Europe which focus on sustainable chemistry research and application would have merits.
- HF referred to discussions in former workshops on process indicators. The project team dropped many of these (often easy to measure) indicators because of low significance, e.g., the number of parties of a convention: It is not clear if and how a convention is enforced in a

specific country. He underlined that there will be far more data available due to CSR reporting, but there is no plan how to use these data for monitoring CSS. Participants agreed, but stressed the need to create indicators or at least indications for the direction of the transition. It was recommended to use indicators for impacts on the ecosystem, e.g., the amount of pesticides. CEFIC agreed that "number of..." indicators, e.g., mapping the companies that have committed to "Responsible Care" or have installed environmental management systems, is interesting but does not reflect progress in sustainable performance. Research and innovation are extremely difficult to monitor with regard to the assessment of innovations and their importance with respect to the complete research budget of international companies.

- Which economic / financial indicators are suitable to measure innovations towards more sustainable chemicals (SSbD) and products? In Europe, many more data will be available in future due to the extended obligation for sustainability reporting following the CSR directive in combination with the technical criteria of the Taxonomy regulation. If these data are collected in a format that can be queried by artificial intelligence (AI) we will get an impression on expenses and investments in green and sustainable chemistry.
- HF agreed that the taxonomy and related directives will increase reporting activities with many data. Unfortunately, the European Sustainability Reporting Standards (ESRS) pose many questions and are often not precise, e.g., ESRS "Circular Economy": What are the reporting obligations?
- It would be useful first to have a solid set of indicators, and then secondly to consider how data for the indicators can be standardized. The establishment and funding of technical support centers (which are already involved in producing standardized data for e.g., sustainable products, eco-labelling etc.) could perhaps be of interest.
- Ideas for funding technical support for standards: taxation on uses of SVHCs in case of derogations from restrictions.
- With respect to SAICM and multilateral Conventions it is necessary to get an impression about governance structures that are indispensable to implement the targets and to monitor progress. Good governance should also be a target for sustainability, not only a tool to ensure reliability of the data provided.
- Who will be responsible to generate data on social development?
- HF referenced to a contribution from the audience and deplored the ambiguities and lack of definitions in many ESRS, e.g., ESRS E5 on circular economy or ESRS E2 on pollution. He agreed with a recommendation from the audience to look for standardization of this reporting to get comparable and meaningful data that can also be used for monitoring of the transition. The Commission should check and modify the ESRS to make them useful also for monitoring the CSS. CEFIC announced the start of a "learning network" aiming at a concise reporting and deplored that most of the indicators in the ESRS reflect discussions of the last decade without considering recent developments.
- Indicators can be distinguished according to their function either for monitoring a process or an impact. It is necessary to have indications for the distance to the targets.

MK remarked similarities between this debate on sustainable chemistry and discussions on digitalization: How to monitor progress, how to detect non-desirable developments? This sector is of special interest as data collection depends on the progress of digitalization all over the world. He briefly summarized the lively discussion and thanked all participants for their contributions.

Final comments by the host

HCS appreciated the commitment and the ideas of the participants in this meeting. Many contributions were in line with considerations of recent work on the project. The way to find suitable indicators on a good database is stony and uphill. He underlined the necessary convergence of similar discussions in different sectors as well as in different parts of the globe to come to common solutions. Data and their custodians are always a big point. HCS further mentioned the World Chemicals Conference (ICCM5) that is anticipated to adopt the targets for "SAICM 2.0" and SMCW beyond 2020. After the ICCM5, "deep diving for indicators" will become even more dynamic. He mentioned the opportunity for further discussion on the interactive platform, probably to be continued and intensified after ICCM5.

Closing

MK added that the platform can be accessed by a code that is provided by the project team. It is sufficient to send an email to the project manager. He again thanked all participants and closed the meeting at 12:00.

E Appendix: List of documents checked for potential indicators and milestones

Name of the document	Source
Aichi Targets	Convention on Biological Diversity: Aichi Biodiversity Targets https://www.cbd.int/sp/targets/
Basel Convention	Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal. © Published by the Secretariat of the Basel Convention (SBC) in May 2018. https://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW-IMPL-CONVTEXT.English.pdf (revised version, 2020).
Carbon Disclosure Project (CDP)	CDP (2015): Back to the laboratory. Are global chemical companies innovating for a low-carbon future? By James Magness (Head of Investor Research), Chloe Chan and Charles Fruitiere. Executive Summary, August 2015 https://6fefcbb86e61af1b2fc4-c70d8ead6ced550b4d987d7c03fcdd1d.ssl.cf3.rackcdn.com/cms/reports/documents/000/000/619/original/chemicals-report-exec-summary-2015.pdf?1470225121 CDP (2017): Catalyst for change. Which chemical companies are prepared for the low carbon transition? Authors: Carole Ferguson, Tom Crocker and James Smyth. Executive Summary, October 2017 https://6fefcbb86e61af1b2fc4-c70d8ead6ced550b4d987d7c03fcdd1d.ssl.cf3.rackcdn.com/cms/reports/documents/000/002/683/original/CDP_Chemicals_2017.pdf?1507139412 Sector-specific questions for the Chemicals sector, based on https://guidance.cdp.net/en/guidance?cid=8&ctype=theme&idtype=ThemeID&incchild=1&microsite=0&otype=Questionnaire&tags=TAG-592%2CTAG-605%2CTAG-600
Cefic: Responsible Care©	ICCA (2014): Responsible Care® Global Charter https://cefic.org/app/uploads/2008/02/ICCA-RC-Global-Charter.pdf ICCA (2019): Responsible Care® Status Report 2018 https://www.icca-chem.org/wp-content/uploads/2019/01/Responsible-Care-Status-Report-2018.pdf Responsible Care Self-assessment tool https://cefic.org/app/uploads/2019/06/Responsible-Care-Self-assessment-tool.xlsm
Chemie³	www.chemiehoch3.de/leitbild-nachhaltigkeit/
COFOG Reporting	EU: https://ec.europa.eu/eurostat/cache/infographs/cofog/ EUROSTAT: Government expenditure by function https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Government_expenditure_by_function EUROSTAT: CLASSIFICATION OF THE FUNCTIONS OF GOVERNMENT (COFOG). Manual on sources and methods for the compilation of COFOG statistics. 2019 edition https://ec.europa.eu/eurostat/documents/3859598/10142242/KS-GQ-19-010-EN-N.pdf/ed64a194-81db-112b-074b-b7a9eb946c32?t=1569418084000
DJSI Dow Jones Sustainability Index	SAM (2019): Industry Leader Report 2019, Chemicals CHM. https://portal.csa.spglobal.com/survey/documents/DJSI_IndustryLeader_CHM.pdf SAM (2020a): Measuring Intangibles. SAM's Corporate Sustainability Assessment Methodology. https://portal.csa.spglobal.com/survey/documents/DJSI_CSA_Measuring_Intangibles.pdf SAM (2020b): CSA Companion 2020. SAM Corporate Sustainability Assessment (CSA). https://portal.csa.spglobal.com/survey/documents/SAM_CSA_Companion.pdf

Name of the document	Source
	SAM (2020c): SAM 2020 - Methodology Updates. https://portal.csa.spglobal.com/survey/documents/SAM_CSA_MethodologyChanges.pdf SAM (2020d): CSA Weights Overview 2020. SAM Corporate Sustainability Assessment (CSA). https://portal.csa.spglobal.com/survey/documents/SAM_CSA_Weights.pdf
Dubai Declaration	UNEP: Strategic Approach to International Chemicals Management. SAICM texts and resolutions of the International Conference on Chemicals Management, 2006
EU Chemicals Strategy for Sustainability Strategy (EU CSS)	Chemicals Strategy for Sustainability - Towards a Toxic-Free Environment, COM (2020) 667 final, 14.10.2020 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0667
EU Circular Economy Action Plan (EU CEAP)	European Commission: COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS: A new Circular Economy Action Plan. For a cleaner and more competitive Europe. Brussels, 11.3.2020, COM(2020) 98 final https://eur-lex.europa.eu/resource.html?uri=cellar:9903b325-6388-11ea-b735-01aa75ed71a1.0017.02/DOC_1&format=PDF Annex: https://eur-lex.europa.eu/resource.html?uri=cellar:9903b325-6388-11ea-b735-01aa75ed71a1.0017.02/DOC_2&format=PDF
EU: Corporate Social Responsibility Directive (CSRD)	EU (2022a): DIRECTIVE (EU) 2022/2464 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 14 December 2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU, as regards corporate sustainability reporting https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32022L2464
EU Safe and Sustainable by Design SSbBD	EU (2022b): COMMISSION RECOMMENDATION (EU) 2022/2510 of 8 December 2022 establishing a European assessment framework for 'safe and sustainable by design' chemicals and materials. OJ L 325, 20.12.2022, p. 179-205 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32022H2510
EcoVadis	EcoVadis CSR Methodology - Overview and Principles EcoVadis 360° Watch - A Key Component of the Assessment Methodology EcoVadis Scorecard sampleEcoVadis (2016): Vergleich der CSR-Leistung Deutscher Unternehmen mit Unternehmen aus BRICS -, OECD Staaten, den USA und China (Comparison of the CSR performance of German companies with companies from BRICS, OECD countries, the USA and China). White Paper, available only in German; *text excerpt translated using deepl.com*. https://content.cdntwrk.com/files/aT0xMTAxMTk5JnY9MSZpc3N1ZU5hbWU9Z2VybWFuLXN0dWR5LW9uLXN1cHBsaWVyLXBlcmZvcm1hbmNlJmNtZD1kJnNpZz0zZmQ5MzM5MzUxNTY0MDhiODkyNTA3NTRlN2M3MTEyZA%253D%253D EcoVadis (2018): EcoVadis CSR Methodology. Overview and Principles. EcoVadis Public EcoVadis 2018 V2.2 EN https://content.cdntwrk.com/files/aT0xMTAwNjk4JnY9MSZpc3N1ZU5hbWU9ZWNvdmFkaXMtY3NyLW1ldGhvZG9sb2d5LW92ZXJ2aWV3LWFuZC1wcmluY2lwbGVzJmNtZD1kJnNpZz01YzA3MWI1MGZhMDgxODMwMTI0MzE1ZWQzMzVjYjZlNQ%253D%253D EcoVadis 360° Watch - A Key Component of the Assessment Methodology EcoVadis Scorecard sample
FTSE 4 Good	Mackenzie, Craig and Rees, William and Rodionova, Tatiana, The FTSE4Good Effect: The Impact of Responsible Investment Indices on Environmental Management (March

Name of the document	Source
	8, 2012). Available at SSRN: https://ssrn.com/abstract=1966474 or http://dx.doi.org/10.2139/ssrn.1966474 London Exchange Group. 2012. Revealing the full picture: Your Guide to ESG Reporting. https://www.lseg.com/sites/default/files/content/images/Green_Finance/ESG/2018/February/LSEG_ESG_report_January_2018.pdf https://www.ftserussell.com/analytics/factsheets/home/search FTSE Russell: FTSE4Good Index Series https://research.ftserussell.com/products/downloads/ftse4good-brochure.pdf
Global Compact	United Nations Global Compact; https://unglobalcompact.org/
Global Product Stewardship (GPS)	ICCA: Product Stewardship Guidelines ICCA: Guidance on Chemical Risk Assessment ICCA: Regulatory Toolbox: Guidance on the Introduction or Revision of Legislation on Chemicals Management for Developing Countries
Global Reporting Initiative (GRI)	GRI Sustainability Reporting Standards 2016/2020 https://www.globalreporting.org/standards/gri-standards-download-center/ Sustainability disclosure database https://database.globalreporting.org (no longer available)
Globally Harmonised System of classification and labelling of chemicals	UNEP GUIDANCE ON THE DEVELOPMENT OF LEGAL AND INSTITUTIONAL INFRASTRUCTURES AND MEASURES FOR RECOVERING COSTS OF NATIONAL ADMINISTRATION FOR SOUND MANAGEMENT OF CHEMICALS (2015). http://wedocs.unep.org/bitstream/handle/20.500.11822/12224/LIRA_Guidance%20Report_PRESS.pdf Persson, L., Karlsson-Vinkhuyzen, S., Lai, A., Persson, Å. and Fick, S. (2017). The globally harmonized system of classification and labeling of chemicals: explaining the legal implementation gap. Sustainability 9 (12), 2176. https://doi.org/10.3390/su9122176.
Human Biomonitoring	WHO Regional Office for Europe - Human biomonitoring: facts and figures - http://www.euro.who.int/en/media-centre/events/events/2015/04/ehp-mid-term-review/publications/human-biomonitoring-facts-and-figures Umweltbundesamt - https://www.umweltbundesamt.de/en/topics/health/assessing-environmentally-related-health-risks/human-biomonitoring Project on Human Biomonitoring HBM4Europe https://www.hbm4eu.eu/
IEA: Future of Hydrogen	IEA: The Future of Hydrogen. Seizing today's opportunities Report prepared by the IEA for the G20, Japan. https://www.iea.org/reports/the-future-of-hydrogen
ILO Chemicals Convention No. 170, 1990	ILO: All You Need to Know: Convention No. 170. https://www.ilo.org/wcmsp5/groups/public/---ed_protect/---protrav/---safework/documents/publication/wcms_731982.pdf
ILO Prevention of Major Industrial Accidents Convention No. 174, 1993	Convention Text: https://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO:12100:P12100_INSTRUMENT_ID:312319:NO
International Panel on Climate Change IPCC	IPCC websites IPCC Special Report "Global warming of 1.5°C" Umweltbundesamt website

Name of the document	Source
Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services	IPBES website Global Assessment Report on Biodiversity and Ecosystem Services https://ipbes.net/sites/default/files/ipbes_7_10_add.1_en_1.pdf Bundesamt für Naturschutz (BfN) Wissenschaftsplattform Erde und Umwelt IPBES (2018): The regional assessment report on BIODIVERSITY AND ECOSYSTEM SERVICES FOR AFRICA https://www.ipbes.net/assessment-reports/africa https://www.ipbes.net/sites/default/files/africa_assessment_report_20181219_0.pdf
IOMC Toolbox	IOMC (2020): Overview of the IOMC. Stakeholder workshop on strengthening governance for the sound management of chemicals and waste beyond 2020. Frankfurt, 14-16 January 2020. https://www.unitar.org/sites/default/files/media/file/IOMC%20presentation_Jan%202020.pdf UNEP (2015): UNEP GUIDANCE ON THE DEVELOPMENT OF LEGAL AND INSTITUTIONAL INFRASTRUCTURES AND MEASURES FOR RECOVERING COSTS OF NATIONAL ADMINISTRATION FOR SOUND MANAGEMENT OF CHEMICALS. http://wedocs.unep.org/bitstream/handle/20.500.11822/12224/LIRA_Guidance%20Report_PRESS.pdf UNITAR (2017): Final Evaluation of the IOMC Toolbox for Decision Making in Chemicals Management - Phase II. October 2017. https://unitar.org/sites/default/files/uploads/pprs/iomc-evaluation-finalreport_rc2.pdf
Kunming-Montreal Global Biodiversity Framework	CBD: https://www.cbd.int/gbf/ UNEP: https://www.unep.org/resources/kunming-montreal-global-biodiversity-framework
LkSG Supply Chain Due Diligence Act	Lieferkettensorgfaltspflichtengesetz https://www.bmas.de/DE/Service/Gesetze-und-Gesetzesvorhaben/Gesetz-Unternehmerische-Sorgfaltspflichten-Lieferketten/gesetz-unternehmerische-sorgfaltspflichten-lieferketten.html IHK NRW: Informationen & Hinweise zu nachhaltigen Lieferketten und zum Lieferkettensorgfaltspflichtengesetz https://www.ostwestfalen.ihk.de/unternehmen-entwickeln/international/das-deutsche-lieferkettengesetz-mehr-schutz-fuer-mensch-und-umwelt/ https://www.ostwestfalen.ihk.de/fileadmin/Dokumente/International/News/Linkliste_Lieferketten_Sorgfaltspflichten.pdf
LIRA Guidance	UNEP: LIRA Guidance https://www.unenvironment.org/resources/report/lira-guidance UNEP (2015): UNEP GUIDANCE ON THE DEVELOPMENT OF LEGAL AND INSTITUTIONAL INFRASTRUCTURES AND MEASURES FOR RECOVERING COSTS OF NATIONAL ADMINISTRATION FOR SOUND MANAGEMENT OF CHEMICALS https://wedocs.unep.org/bitstream/handle/20.500.11822/12224/LIRA_Guidance%20Report_PRESS.pdf?sequence=1&isAllowed=y
Malaysia Biotechnology	Bioeconomy Corporation Malaysia http://www.bioeconomycorporation.my/ Bioeconomy Transformation Programme. Annual Report 2015 http://www.bioeconomycorporation.my/wp-content/uploads/2011/11/publications/BTP_AR_2015.pdf

Name of the document	Source
Minamata Convention	Minamata Convention on Mercury. https://mercuryconvention.org/sites/default/files/2021-06/Minamata-Convention-booklet-Sep2019-EN.pdf
Montreal Protocol	UNEP: Handbook for the Montreal Protocol on Substances that Deplete the Ozone Layer. Fourteenth edition (2020). https://ozone.unep.org/sites/default/files/Handbooks/MP-Handbook-2020-English.pdf
MSCI ACWI Sustainable Impact Index	MSCI (2020a): MSCI ACWI Sustainable Impact Index (USD). MAR 31, 2020. https://www.msci.com/documents/10199/6d2b3e68-90e0-448e-bd52-eaf0397539d1 MSCI (2020b): MSCI ACWI Sustainable Impact Index Methodology. February 2020. https://www.msci.com/eqb/methodology/meth_docs/MSCI_ACWI_Sustainable_Impact_Index_Feb2020.pdf
MSCI ESG Indexes	MSCI: ESG RATINGS METHODOLOGY. Executive Summary. MSCI ESG Research, May 2015 https://www.msci.com/documents/10199/123a2b2b-1395-4aa2-a121-ea14de6d708a MSCI (2019): MSCI ESG Ratings. https://www.msci.com/documents/1296102/15233886/MSCI-ESG-Ratings-Brochure-cbr-en.pdf/7fb1ae78-6825-63cd-5b84-f4a411171d34?t=1572865945980
Nagoya Protocol	Secretariat of the Convention on Biological Diversity (2011): NAGOYA PROTOCOL ON ACCESS TO GENETIC RESOURCES AND THE FAIR AND EQUITABLE SHARING OF BENEFITS ARISING FROM THEIR UTILIZATION TO THE CONVENTION ON BIOLOGICAL DIVERSITY. Text and Annex. https://www.cbd.int/abs/doc/protocol/nagoya-protocol-en.pdf
National Hazardous Waste Management Plan (NHWMP) (2014-2020) of Ireland	National Hazardous Waste Management Plan. https://www.epa.ie/waste/hazardous/ Progress Report on the implementation of the National Hazardous Waste Management Plan https://www.epa.ie/pubs/reports/waste/haz/EPA_NationalHazardousWasteManagementPlan_web.pdf
OECD Sustainability Reporting	OECD Due Diligence Guidance for Responsible Business Conduct https://www.oecd.org/corporate/mne/due-diligence-guidance-for-responsible-business-conduct.htm Implementing the OECD Due Diligence Guidance http://www.oecd.org/corporate/mne/implementingtheguidance.htm
OSPARCOM	CONVENTION FOR THE PROTECTION OF THE MARINE ENVIRONMENT OF THE NORTH-EAST ATLANTIC; https://www.ospar.org/site/assets/files/1290/ospar_convention_e_updated_text_in_2007_no_revs.pdf OSPAR Commission (2010): The North East Atlantic Environment Strategy. Strategy of the OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic 2010–2020, OSPAR Agreement 2010-3 OSPAR Commission (2018): Work priorities for OSPAR Secretariat 2018-2020, OSPAR 18/10/2 Rev.1 OSPAR Commission (2019): The OSPAR list of chemicals for priority action. Suggestions for future actions. Report prepared by the Uppsala University, ISBN: 978-1-911458-79-1
PRTR (div.)	UNECE (2008): Guidance on Implementation of the Protocol on Pollutant Release and Transfer Registers.

Name of the document	Source
	https://www.unece.org/fileadmin/DAM/env/pp/prtr/guidance/PRTR_May_2008_for_CD.pdf EEA (2020): European Pollutant Release and Transfer Register (E-PRTR); https://www.eea.europa.eu/themes/air/links/data-sources/european-pollutant-release-and-transfer https://www.oecd.org/env_prtr_data/
Rotterdam Convention	Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade. https://www.pic.int/Portals/5/download.aspx?d=UNEP-FAO-RC-CONVTEXT-2019.English.pdf (revised in 2019).
SAICM Indicators	SAICM (2009): List of indicators for reporting progress in implementation of the Strategic Approach and the related basic elements of the overall orientation and guidance; SAICM/ICCM2/15, Annex III https://www.saicm.org/Portals/12/Documents/SAICM-List%20of%20indicators%20for%20reporting%20progress.pdf
Science Based Targets for Nature (SBTN)	https://sciencebasedtargetsnetwork.org https://sciencebasedtargetsnetwork.org/resources/
SDG Indicators (e.g., for goal #12) / SDG Compass	https://unstats.un.org/sdgs/indicators/indicators-list/ https://sdgcompass.org https://sdgcompass.org/wp-content/uploads/2015/12/019104_SDG_Compass_Guide_2015.pdf
South African Bioeconomy Strategy	Department of Science and Technology, South Africa (2013): The Bio-economy Strategy. https://www.gov.za/documents/bio-economy-strategy https://www.gov.za/sites/default/files/gcis_document/201409/bioeconomy-strategya.pdf
Stockholm Convention	Stockholm Convention on persistent organic pollutants (POPs). https://chm.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP-CONVTEXT-2021.English.pdf (revised in 2019).
Sustainability Accounting Standards Board (SASB)	SASB (2018a): CHEMICALS. Sustainability Accounting Standard. Version 2018-10; October 2018. https://www.sasb.org/wp-content/uploads/2018/11/Chemicals_Standard_2018.pdf SASB (2018b): CHEMICALS. Basis for Conclusions. October 2018. https://www.sasb.org/wp-content/uploads/2018/11/Chemicals_BFC_2018.pdf
Sustainability Framework, d. World Bank	2016. "World Bank Environmental and Social Framework." World Bank, Washington, DC. https://projects.worldbank.org/en/projects-operations/environmental-and-social-framework/brief/esf-training Environmental & Social Framework for IPF Operations, Guidance Note for Borrowers, ESS3: Resource Efficiency and Pollution Prevention and Management http://documents.worldbank.org/curated/en/112401530216856982/ESF-Guidance-Note-3-Resource-Efficiency-and-Pollution-Prevention-and-Management-English.pdf
Together for Sustainability	TfS Together for Sustainability (2019a): 2018 ANNUAL ACTIVITY REPORT. https://tfs-initiative.com/audit-process/#1472630050074-10b9365f-40ca TfS Together for Sustainability (2019b): Third Party Audit Program, Version 3.1, 28.08.2019 https://tfs-initiative.com/dl/TfS_Audit_Program_V3-0.pdf

Name of the document	Source
	TfS Together for Sustainability (2020): Audit Preparation Document https://tfs-initiative.com/dl/Audit-Preparation-Document-V3-0.xlsx
TWG4: New proposals	SAICM (2019b): Sixth meeting of the Bureau of the International Conference on Chemicals Management for its fifth session. Meeting Report http://www.saicm.org/About/Bureau/Bureaumeetings/tabid/5949/language/en-US/Default.aspx and https://www.saicm.org/Portals/12/Documents/meetings/Bureau/ICCM5B6/ICCM5-Bureau-Sixth-meeting-Jan-2019-Report.pdf SAICM (2020b): Supplementary information on proposed targets prepared by the Technical Working Group on targets, indicators and milestones for SAICM and the sound management of chemicals and waste beyond 2020; SAICM/IP.4/INF/15, 16 March 2020 https://www.saicm.org/Portals/12/documents/meetings/IP4/old/(old)SAICM_IP4_INF_15_TWG_FINAL.pdf
UN Global Compact	https://www.unglobalcompact.org https://www.globalreporting.org/information/about-gri/alliances-and-synergies/Pages/UNGC-and-GRI.aspx 2019 Progress report: https://www.unglobalcompact.org/library/5716
UN SDG Compass	https://sdgcompass.org https://sdgcompass.org/wp-content/uploads/2015/12/019104_SDG_Compass_Guide_2015.pdf
UN System of Environmental Accounting - SEEA	Secretariat of the Convention on Biological Diversity (2020): Global Biodiversity Outlook 5. Montreal. https://www.cbd.int/gbo5 UNECE: Conference of European Statisticians'. Set of Core Climate Change-related Indicators and Statistics Using the System of Environmental-Economic Accounting https://unece.org/sites/default/files/2021-08/CES_Set_Core_CCR_Indicators-Report.pdf
UNITAR National Profiles	http://cwm.unitar.org/national-profiles/nphomepage/np3_region.aspx National Profile examples: Costa Rica: http://cwm.unitar.org/national-profiles/publications/cw/np/np_pdf/Costa_Rica_National_Profile_2008.pdf Germany: http://cwm.unitar.org/national-profiles/publications/cw/np/np_pdf/Germany_National_Profile_ENG.pdf Mali: http://cwm.unitar.org/national-profiles/publications/cw/np/np_pdf/Mali_National_Profile_2010.pdf
WBCSD PSA Guideline	WBCSD - World Business Council for Sustainable Development (2017): Framework for portfolio sustainability assessments (PSA). https://www.wbcsd.org/Projects/Chemicals/Resources/Framework-for-portfolio-sustainability-assessments and https://www.wbcsd.org/contentwbc/download/3944/52805/1
WHO Internat. Health Regulations	www.euro.who.int/en/health-topics/health-emergencies/international-health-regulations/a-framework-to-protect-people-from-health-emergencies https://apps.who.int/iris/bitstream/handle/10665/84933/WHO_HSE_GCR_2013.2_eng.pdf?sequence=1
Circular Economy Approaches	See: National Hazardous Waste Management Plan (NHWMP) (2014-2020) of Ireland

Name of the document	Source
(national programs, Ellen Mac Arthur)	Ellen MacArthur Foundation et al. (2015): GROWTH WITHIN: A CIRCULAR ECONOMY VISION FOR A COMPETITIVE EUROPE
Economy for the Common Good (former GWÖ approach)	https://www.ecogood.org/apply-ecg/
Management approaches for sustainable corporate governance (e.g., Total Impact Measurement & Management (TIMM))	https://www.pwc.com/gx/en/services/sustainability/total-impact-measurement-management.html
Sustainable Public Procurement (SPP) approaches (e.g., Sustainable Leadership Council, Kompass Nachhaltigkeit NRW, national approaches)	https://circabc.europa.eu/ui/group/44278090-3fae-4515-bcc2-44fd57c1d0d1/library/f69e60f9-9dc6-4345-aa18-b9a4b6dfdbf0?p=1&n=10&sort=name_ASC