



Chemicals Innovation Action Agenda: Transition to Safer Chemicals and Technologies

Final Report

Contract No 07.0201/2018/776820/ETU/ENV.B2

EU Study and Workshop on innovation, design for sustainability and hazardous chemicals: practical experiences and policy implications.

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Chemicals Innovation Action Agenda:

Transitioning to Safer Chemicals and Technologies

Final Report

Report for

European Commission

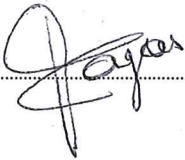
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Chemicals Innovation Action Agenda

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Document revisions

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1	Draft final report	13/03/2019
2	Final report (pending logo agreements)	18/04/2019
3	Final report (with logo)	19/06/2019

Executive Summary

What is the Chemicals Innovation Action Agenda?

The transition to chemicals that are safer for human health and the environment is a prerequisite for a globally competitive, low carbon, resource efficient and sustainable Europe as well as for a circular economy. This rests on safer chemical material flows, from product design to end of life. It requires new ways of producing and consuming, and new products, markets and business opportunities. Policy makers, businesses, and consumers all have roles to play.

Whilst regulatory and market forces are driving a transition away from substances of concern, many substitution efforts have fallen short in effectively providing safer, high performing and cost-effective alternatives. This is in part due to the complexity of the substitution process. Without careful assessment of alternatives, “regrettable” substitutions, whereby the alternative selected poses similar or worse hazards/risks or results in lower performance than the substance of concern, can occur.

In this context, the European Commission (DG ENV) commissioned a study, led by a partnership between Wood and the Lowell Center for Sustainable Production (University of Massachusetts), to understand how frontrunner companies have substituted substances of concern¹ from their supply chains, products and portfolios; what lessons can be drawn from their experience; and how best practice can be scaled to expand opportunities for innovation.

This Agenda sets out a series of actions designed to scale investment and innovation in safer chemicals and technologies to accelerate their adoption. It has been shaped with organisations from a range of industry sectors that have invested in chemicals, processes, and product innovations – often before and beyond the demands of regulatory compliance - to prevent, identify and eliminate the use of substances of concern across the life cycle of their products.

A Task Force of 12 representatives from these companies along with NGO representation was convened. Broader stakeholder input was gathered through a workshop of 70 participants in January 2019.

What does the Action Agenda involve?

This Agenda focusses on three specific objectives:

- **improving information and knowledge sharing;**
- **enhancing supply chain collaborations and partnerships; and**
- **establishing a policy mix to de-risk innovation.**

To achieve these objectives, four priority action areas are proposed. They require the concerted effort of a variety of actors: Government and the public sector, businesses (including SMEs), investors, academic and private/public research institutions.

¹ For the purpose of this report, the project team uses the following definition: substances of concern are defined as substances with scientific evidence of detrimental effects to human health and/or the environment (e.g., carcinogenicity, mutagenicity, endocrine disruption, aquatic toxicity, etc.).

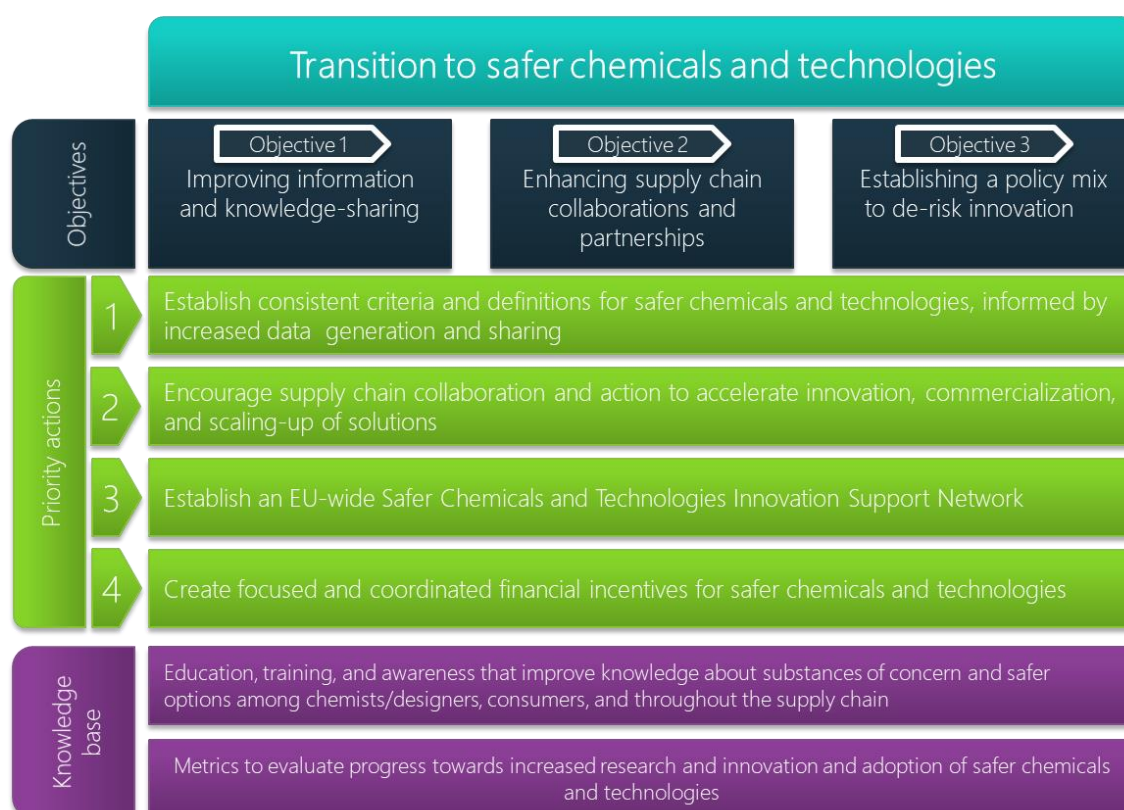
Priority Action 1: Establish consistent criteria and definitions for safer chemicals and technologies, informed by increased data generation and sharing. This includes developing harmonised criteria for safer chemicals and creating an inventory of such chemicals, considering environmental and human health end points and based on the full product lifecycle. These will require increased data generation and sharing.

Priority Action 2: Encourage supply chain collaboration and action to accelerate innovation, commercialisation, and scaling-up of solutions. This includes the organisation and facilitation of supply chain collaborations that support substitution, based on chemical *functions*. These must engage the entire supply chain as well those with potential technology solutions, establishing partnerships to drive commercialisation of safer chemicals and technologies.

Priority Action 3: Establish an EU-wide Safer Chemicals and Technologies Innovation Support Network. Coordinated by an impartial central entity, companies could consult this network for information on safer alternative chemicals that are commercially available or under development as well as technical expertise and training related to the evaluation and adoption of alternatives.

Priority Action 4: Create focused and coordinated financial incentives for safer chemicals and technologies. This entails de-risking and accelerating research and innovation activities, by more effectively focusing and coordinating funding and financing initiatives.

These objectives and priority actions areas are outlined in the graphic below.



In addition to the Priority Actions identified, this Agenda highlights a need for an **improved knowledge base** for driving the design, commercialisation, and scale of safer chemicals and technologies. These include: education, training, and awareness options throughout the supply chain and among chemists/designers, consumers. New metrics to evaluate progress will also be required.

Among other actors, the **European Commission** can play a key role in the successful implementation of this Action Agenda. Potential roles include:

- Supporting and providing direction for the design and adoption of safer chemicals and technologies
- Facilitating stakeholder and supply chain dialogues, collaboration and action.
- Enabling new infrastructure/resources to support the Agenda.
- Recognising and rewarding frontrunners.
- Delivering efficiency, by mapping out clear roles and connections between the Commission and Member States authorities, avoiding duplication of efforts and focusing resources on activities with the maximum impact.

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1. Introduction



1. Introduction

The transition to innovative, safer chemicals and technologies (for human health and the environment), from product design to end of life is a prerequisite for a globally competitive, sustainable Europe, and for a circular economy. It requires new ways of producing and consuming, and new products and business opportunities. Policy makers, businesses, and consumers all have roles to play.

Global scientific research has revealed the large externalities that result from chemical exposure. The WHO has estimated the burden of disease from (selected) chemicals at around 1.6 million lives and around 45 million disability-adjusted life years in 2016.^{iv} The UNEP's Global Chemicals Outlook II (GCO II)^v, published in March 2019 called for more ambitious action at all levels, whilst recognising the challenge chemical intensive products and complex global supply chains pose to the realisation of a circular economy built on safer chemicals and technologies. The GCO II also notes the role of informed substitution with safer alternatives as a driver for solutions and innovation.

A far-reaching European legislative framework for chemicals management is in place. It is designed to protect human health, the environment, and support the efficient functioning of the internal market while contributing to enhanced competitiveness and innovation. An extensive evaluation of this framework is now being finalised. This will inform the actions of a new Commission and its decision makers in 2019.

Effective and targeted support of innovation toward safer chemicals and technologies for human health and the environment, whilst continuing to reduce the impact of substances of concern, will be key to achieving the Commission's goals. In this context, the European Commission (DG ENV) commissioned a study, led by a partnership between Wood and the Lowell Center for Sustainable Production (University of Massachusetts), to understand how frontrunner companies have substituted substances of concern – often ahead of regulatory requirement – from their supply chains, products and portfolios; what lessons can be drawn from their experience of wider relevance; and how best practice can be scaled and opportunities for innovation expanded.

This report outlines a “Chemicals Innovation Action Agenda” with actions required to scale investment and innovation in safer chemicals and technologies to accelerate their adoption.

The Chemicals Innovation Action Agenda has been shaped by leading organisations from a number of industry sectors that have made efforts to go over and above regulatory compliance by investing in chemical, process, and in product innovation that reduces or eliminates the use of substances of concern across the life cycle of their products. To create the Agenda, the Commission convened a Task Force of representatives from twelve companies. The companies involved were deliberately selected based on their activities in a range of sectors and positions in the supply chain. These included, but were not limited to, sectors which sell their products directly to the consumer. The Task Force also included representatives from NGOs/civil society

Substances of concern and safer chemicals and technologies defined

For the purposes of this report, the project team uses the definitions below.

Substances of concern are defined as substances with scientific evidence of detrimental effects to human health and/or the environment (e.g., carcinogenicity, mutagenicity, endocrine disruption, aquatic toxicity, etc.). Lists of such chemicals have been issued by government authorities, NGOs and enterprises, e.g., ECHA's Candidate List of Substances of Very High Concernⁱ, ChemSec's SIN Listⁱⁱ, or the Danish retailer Coop'sⁱⁱⁱ list of substances in its chemical's strategy. *Note that, in the context of the interface between the EU's chemical, product and waste legislation, the Commission (DG ENV) is running a consultation to help define 'substances of concern'.*

Safer chemicals and technologies are defined as being safer for human health, environmentally benign, and effective chemical products, processes, and technologies. This includes chemical, material, or technology alternatives – including the option of not continuing an activity where it is non-essential. Safer chemicals and technologies due to their inherent chemical, physical and mechanical properties deliver the functional performance required and exhibit a lower propensity to induce adverse effects in humans or animals and in the case of chemicals, to persist in the environment.

– Adapted from OECD and the Lowell Center for Sustainable Production

actively involved in the development of safer chemicals and technologies. The objective was to facilitate valuable dialogue and constructive exchange both within the industry and between it and policy makers.

Broader stakeholder input was gathered through a workshop convened by the Commission in January 2019 with approximately 70 participants involved in discussions based on an initial Thought Starter. Case examples in this Action Agenda, developed based on interviews, literature, and presentations at the Commission workshop, are intended to provide practical examples of efforts that might be explored further in new sectors and with new companies.

Note that all views expressed in this report are those of the authors, based on research and discussion with Task Force members. They do not necessarily represent the official policy or position of any of the Task Force organisations.

Task Force members



AkzoNobel



INDITEX





This report outlines a novel “Chemicals Innovation Action Agenda” with actions required to scale investment and innovation in safer chemicals and technologies to accelerate their adoption.

2. Convergence of need and opportunity



2. Convergence of need and opportunity

Drivers for safer chemicals and technologies

Regulatory and market forces, in conjunction with consumer activism, are driving a transition away from substances of concern in production processes and products. The REACH restriction and authorisation processes^{vi} and European Union directives, such as the Chemical Agents Directive^{vii} and the Carcinogens and Mutagens Directive^{viii}, for example, encourage substitution as a strategy for managing the risks of substances of concern, to protect workers, consumers and the environment.^{ix,x} Non-governmental organisation (NGO) initiatives such as Greenpeace's "Detox" campaign^{xi,xii} and the activities of ChemSec^{xiii} such as the MarketPlace or the SIN List, among others, channel public concerns about the health and environmental risks of substances of concern in consumer products, workplaces, and communities. These translate into specific retailer and brand demands to avoid the use of such chemicals in their raw materials, production processes and products. Frontrunner companies placing safer chemicals and technologies on the market, often before regulatory mandates, can benefit from an advantage over competitors reacting later. When certain preconditions are met, this can incentivise action among upstream chemical suppliers that can create new market opportunities, enhance corporate reputation, engender customer trust, and expand market share.^{xiv}

But many substitution efforts have fallen short in effecting a broad transition to safer, effective alternatives. This is in part due to the complexity of the substitution process and global supply chains. So-called "regrettable" substitutions, where alternatives selected are subsequently found to pose similar or worse hazard profiles or performance trade-offs, can occur. The replacement of the endocrine disrupting chemical, bisphenol A (BPA) with "drop-in" replacements bisphenol S or F is one example. A recent review of 32 studies^{xv} found that these structurally similar, but less scrutinised (by policy makers or the market), alternatives have similar estrogenic potency as BPA.^{xvi} Valspar's (a subsidiary of Sherman Williams) alternative metal food-contact can coating,^{xvii,xviii} and Dow Chemical and Koehler's alternatives for thermal printing paper^{xix} demonstrate that novel, commercially viable alternatives can be developed.



Frontrunner companies – Nouryon's Imagine Chemistry Programme: Innovation through Collaboration

Working with start-ups, scale-ups, universities and other research groups, Nouryon (formerly AkzoNobel Specialty Chemicals) is reaping the benefits of collaboration to innovate in safer and more sustainable chemical products. Since 2017, Nouryon has issued annual "challenges" to solicit innovations in a number of areas – from sustainable bio-based surfactants to chlorate manufacturing processes that no longer use hexavalent chromium. The result: 20 new formal collaborations that have taken the form of joint development agreements, sourcing agreements, research agreements and other support to move ideas towards commercialisation. Key to the success of the collaborative process is establishing trust, transparency and respect for intellectual property.

Source: van Heiningen, R. Imagine Chemistry – Collaborative Innovation. Workshop on Chemicals Innovation and Design for Sustainability. Brussels, 16 Jan 2019; see also: <https://imaginechemistry.nouryon.com/about/>

Reframing substitution as an innovation opportunity

To date, much of the emphasis on chemical substitution has focused primarily on *avoiding* a specific substance of concern (or chemical class of concern), rather than considering the *function* that chemical provides and safer alternatives that may meet that function. By identifying how a specific function can be met in a less impactful way ("functional substitution") new opportunities emerge and substitution can be reframed from being primarily a regulatory compliance activity to an **innovation opportunity**.^{xx} A focus on

function opens up opportunities for the design and adoption of safer chemicals and technologies to meet growing demands from downstream users (e.g., consumer facing businesses), with economic, environmental, and health benefits. A functional approach to substitution also comes with some limitations. Often function and hazard interlink and removing a specific substance of concern can undermine the necessary function. In this context, entirely new, non-chemical solutions to meet that function may need to be considered. This may involve changing the material used, re-designing the process, the product (chain) and/or the service.

The European Chemicals Agency (ECHA) launched its substitution strategy in 2018 with a focus on explicitly connecting substitution to innovation in safer chemicals, materials and technologies and advocating a wider change in industry practice and in outlook to address the risks associated with substances of concern. A goal of the strategy is to ensure that regulatory priorities are more closely linked to funding and incentives that support innovation activities.^{xxi} At the Member State level, in 2018 the Dutch Government released its Safe Chemicals Innovation Agenda. This identified seven areas where further research is needed to stimulate the safe design of chemicals, materials and products.^{xxii} In October 2018, this was followed by a supply chain workshop – also organised by the Dutch Government - on Safer and Sustainable Anti-Fouling for Recreational Watercraft to discuss needs for innovation and increased adoption of safer and sustainable anti-fouling technologies. Member States such as Sweden^{xxiii} are also expanding efforts to support substitution, for example by establishing a substitution centre.^{xxiv}

Despite many drivers and efforts by stakeholders to accelerate the substitution of substances of concern, this process is often costly, challenging, and takes time. As a result, there is an important role for actions and initiatives that overcome these barriers (see the box below).

Barrier / challenge	Brief Description
Recent reports by T. Fennelly and Associates Inc., and Tickner and Jacobs identify a number of key barriers to the development and adoption of safer chemicals and technologies ^{xxv} :	
Incumbency	It is difficult for new entrants to compete with existing lower cost / price, well-performing chemicals and technologies that are part of complex and established supply chains or product lines with long life cycles.
Demand signals not getting through to relevant actors in global supply chains	Because of complex supply chains, chemical manufacturers often cannot observe the strong demand signals from retailers, brands, and their customers on the need for safer substitutes.
Confusion about safer/sustainable chemistry/eco-innovation products and definitions	Conflicting information from studies and lack of consistent definitions for “safer”, “sustainable,” “eco innovation,” or “safe by design” cause confusion among end-users and can result in the continued use of incumbent chemicals.
Concern about “switching risk”	Companies are concerned about implementing alternatives that may have inferior performance or other costs such as process or equipment changes, material incompatibility, workforce training, customer education, and regulatory impacts, among others.
Lack of a connection between regulatory priorities and research and innovation activity	Despite a number of European Commission and Member State parallel innovation research and support programmes that could be leveraged, specific funding programmes supporting both early- and later-stage innovation research for solutions addressing substances of concern do not currently exist.
Limited technical capacity to evaluate or adopt substitutes	Small and medium sized enterprises frequently lack the resources and technical expertise to test the performance of potential alternatives, evaluate their toxicity and risks, or conduct validation assessments related to customer specifications.
Lack of transparency in the supply chain.	Information on chemical ingredients is often missing or protected by confidential business information claims, making it difficult for companies to make informed decisions about substitution.

The chemical life cycle in a circular economy

The Circular Economy and the Bioeconomy are growing priorities for the European Commission and for businesses. However, there are concerns about potential trade-offs between circularity and bio-economy goals and chemicals priorities outlined in the 7th Environment Action Programme.^{xxvi} Some of these trade-offs may be addressed through greater attention to upfront design and innovation of chemicals, materials, processes and products.

In a circular economy, recycled materials feed back into the economy as 'secondary' raw materials. The EU Circular Economy Action Plan^{xxvii} notes that better design increases product durability, facilitates repair, upgrade or remanufacture and saves resources by recovering valuable materials and components.

In its communication addressing the interface between chemical, product and waste legislation^{xxviii}, the Commission indicates that all 'materials should be safe, fit-for-purpose and designed for durability, recyclability and low environmental impact'. It concludes that **the best way to prevent substances of concern in waste is by avoiding their use in products in the first place**. Thereby, it encourages the elimination of substances of concern, the substitution of substances of concern with safer ones, and where not possible, the reduction of their presence through minimisation of the use of substances of concern and improvements in their tracking, thereby tackling potential future challenges from legacy substances. It is important to note that in some cases there may be trade-offs between circular economy goals of longevity and recyclability of a product and safer chemicals; an example of such trade-off is the use of biocides in formulated products to extend the life of those formulations. In these cases, innovation to optimise both goals will be required.



Frontrunner companies - Coop Denmark: Steering Safer Solutions into the Supply Chain through Education and Policy Change.

As a result of growing consumer concern about chemicals in products, Coop, the largest retail enterprise in Denmark, has implemented an ambitious chemicals policy, often acting ahead of legislation, to eliminate hazardous chemicals from the products sold in its supermarkets. Since 1999, Coop has banned numerous substances of concern in products sold at its stores, including chemical groups such as fluorinated substances and phthalates and a ban on all endocrine disrupting chemicals in cosmetics

and toys in 2004. In 2017, Coop sought broader policy changes to restrict substances of concern in consumer products and launched a campaign aimed at the Danish Parliament to enact more protective chemicals legislation. The campaign succeeded through its use of social media and other outreach efforts to raise awareness and understanding of consumers and government officials about the health threats posed by these chemicals. As a result, the Parliament agreed to launch a 2018-2021 Joint Chemistry Initiative. This includes an Innovation in Chemistry project that will support Danish companies with innovative ideas to reduce hazardous substances of concern in products and to find safer alternatives, including advancing green chemistry solutions.

Sources: Teller Blume, M. A Retailers Experience. Workshop on Chemicals Innovation and Design for Sustainability. Brussels, 16 Jan 2019; see also: <https://mst.dk/media/143466/kemiindsats-engelsk.pdf>



Frontrunner companies - Clariant: Integrating Product Sustainability and Innovation through its Portfolio Value Program.

In 2013, Clariant, a specialty chemicals company, launched its Portfolio Value Program (PVP). It began by soliciting input from all of the Clariant business units, to determine how to imbed sustainability innovation throughout the company. Over 260 innovation project leaders are now trained in the PVP process. Clariant then engaged with its customers, suppliers, industry leaders, academia, and policy makers in an open dialogue on product sustainability. The EcoTain® label launched in 2015, was a result of this process and is designed as a "best-in-class" sustainability label. There are 36 criteria used to screen products in the following areas: planet - raw materials and sustainable sourcing and environmental protection; people - safer use, transparency and information and addressing mega trends and societal needs; and performance - integrated sustainable business and performance advantages. These criteria support the business case for innovation in sustainable chemistry and support healthy competition within the company to create more sustainable products. To date more than 150 products have achieved the EcoTain® label.

Sources: Chung, Lynette. A Forward-looking Approach to Sustainable Chemistry Innovation. Presented at the project workshop on 16 January 2019.



By identifying how a specific function can be met in a less impactful way, substitution can be reframed from being primarily a regulatory compliance activity to an innovation opportunity.

3. The Chemicals Innovation Action Agenda



3. The Chemicals Innovation Action Agenda

The goal of this Chemicals Innovation Action Agenda is to identify new business opportunities that accelerate investment, innovation, and adoption of safer chemicals and technologies, supporting the transition towards a circular economy.

The transition to a circular economy and to safer chemicals and technologies requires systemic change, in which innovation will play a key role. This Chemicals Innovation Action Agenda outlines key enablers and specific actions to advance the availability and adoption of safer chemicals and technologies. Note that this is not an exhaustive collection of possible actions, but rather a set of priorities identified by the Task Force and workshop participants, supplemented by extensive research.

Each of the priority actions elaborated here requires the concerted effort of a variety of societal actors, playing important roles in accelerating investment and innovation in and adoption of safer chemicals and technologies over time. These actors include:

Relevant actors

- **Government and the public sector** have the capacity to provide clear, early signals of policy direction and decisions on specific chemicals; gather, analyse and disseminate actionable data to support the evaluation and adoption of alternatives; and provide funding, infrastructure, and incentives to drive research and innovation in safer chemicals and technologies.
- **Businesses** have the capacity to share knowledge and information on chemical uses and risks, technology needs, costs, and innovations that can overcome substitution challenges; invest in new research; and to collaborate and partner with innovators in their value chain and with innovative start-ups.
- **Investors** can take a longer-term view on the innovation investment environment, working not only to directly finance projects but by supporting partnerships to help move innovations from chemical manufacturers and technology developers into the market. They can also channel investment to viable products and help investment in upscaling and accelerating industry learning rates for new technologies.
- **Academic and private/public research institutions** can assist with focusing innovation research on functional/application/product needs of the market, and by better integrating the concepts from sustainable chemistry and engineering, toxicology and ecotoxicology in the compulsory curriculum.

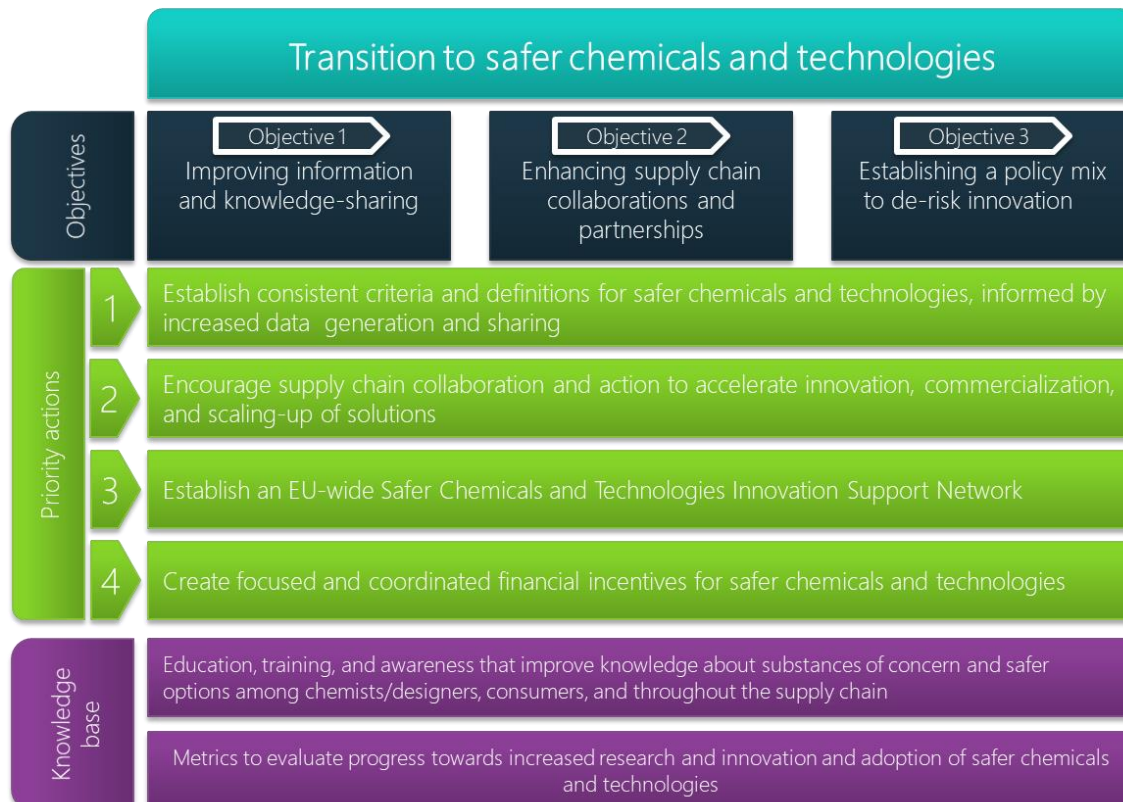
Objectives and Priority Actions

The Priority Actions outlined in this Agenda fall under three underlying broad categories of objectives to drive the innovation and adoption of safer chemicals and technologies. These objectives are outlined in the graphic and described further below.

Objective 1: Improving information and knowledge-sharing is a key element in closing gaps between supply chain actors regarding their understanding of chemical uses and functions, hazard properties and risks, and available alternatives. To make informed decisions on safer chemicals and technologies, companies throughout the supply chain need enhanced information on chemical ingredients in both formulated products and articles, beyond information provided in Safety Data Sheets, as well as availability, costs, and performance, and potential trade-offs of alternatives. Increased access to actionable data and tools is necessary to support such information sharing. With this information, companies can both innovate and improve the internal business case for substitution. In addition, this information can help focus Research and Innovation (R&I) needs. Improving information transparency throughout the supply chain must be coupled with adequate protections for confidential information.

Objective 2: Enhancing supply chain collaborations and partnerships can serve as a critical accelerator of development of safer chemistry and technology solutions.^{xxix} Enhancing relationships among chemical producers, suppliers, retailers, and customers and establishing financial and other mechanisms to support such partnerships can address the barriers identified in section 2. Such collaborations can facilitate cost sharing and help support the business case for investment, innovation, and adoption.

Objective 3: Establishing a policy mix to de-risk innovation can also improve the business case for safer chemicals and technologies. Research indicates innovation requires both willingness (which market and regulatory forces can augment) as well as capacity and the opportunity to innovate.^{xxx} Government plays an important role in all aspects. There is strong evidence of the value of regulation and enforcement as drivers for substitution, by providing clear signals to the market^{xxxi}. Government support, recognition, and funding for innovation and adoption of safer chemicals and technologies, including clear criteria and metrics as well as support for collaboration and partnership, can address many of the identified barriers to innovation.



Four **specific priority actions** have been identified during the study. The intention is to improve the capacity of the EU to scale investment, innovation and adoption in safer chemicals and technologies. These are summarised below. The remainder of the report provides detail on each.

Specific priority actions identified are:

1. Establish consistent criteria and definitions for safer chemicals and technologies, informed by increased data generation and sharing.
2. Encourage supply chain collaboration and action to accelerate innovation, commercialization, and scaling-up of solutions.
3. Establish an EU-wide Safer Chemicals and Technologies Innovation Support Network.
4. Create focused and coordinated financial incentives for safer chemicals and technologies.

Priority Action 1: Establish consistent criteria and definitions for safer chemicals and technologies, informed by increased data generation and sharing

Priority Action 1 seeks to address the lack of clear definitions and criteria about which alternatives are safer, including through their lifecycles. This action will require developing guidance to improve data sharing on ingredients, hazards and safer alternatives for functions and applications. A recent report published by OECD^{xxxii} prioritised needs for both data generation and sharing, e.g. data on availability of alternatives and alternatives assessments, product ingredient, life cycle inventory data, use data, etc.

Information on chemical ingredients and associated hazards are often missing, e.g. for articles and mixtures, or protected by confidential business information claims, making it difficult for companies to make informed decisions about substitution. While legitimate confidential business information must be protected, the Strategic Approach to International Chemicals Management (SAICM) notes that “information on chemicals relating to the health and safety of humans and the environment should not be regarded as confidential”^{xxxiii}. More generally, data exchange has improved in recent years (in part via REACH) but additional information is required throughout the supply, including on alternatives. Conflicting information and lack of consistent definitions for “safer”, “sustainable”, “eco innovation”, or “safe by design” can cause confusion among along the value chain and can result in the continued use of incumbent chemicals. Currently, regulation is focused more on avoiding or managing substances of concern rather than driving innovation specifically towards safer alternatives.

Sought outcomes and expected impacts	• Provision of clear and harmonised criteria and definitions of what is ‘safer’ and ‘sustainable’ chemicals, products and processes • Reduction of transparency barriers and increased knowledge about ingredient and hazard information while protecting intellectual property • Reframing of chemical priorities as functional challenges, linked to R&I priorities • Effective integration of transition to safer products and processes into public procurement
Existing models (that can be scaled up)	• The US EPA’s Safer Chemicals Ingredient List^{xxxiv}, a list of chemical ingredients that the US EPA’s Safer Choice Program has evaluated and determined to be safer than traditional chemical ingredients • ZDHC gateway^{xxxv}, a search engine for formulations conforming to ZDHC’s Manufacturing Restricted Substance List helping textile and leather manufacturer to find safer alternatives and drive substitution. • International Material Data System (IMDS), in which all materials used for automobile manufacturing are collected, maintained, analysed and archived • The Chemical Hazard Data Commons^{xxxvi}, which provides hazard data for over 100,000 chemicals, to help scientists, researchers, and product innovators identify substances of concern and collaborate to find safer alternatives.
Starting point	• Conduct a landscape analysis that addresses what information is needed (chemical ingredients, hazards, alternatives) by whom and in what form to support safer substitutions/safer by design strategies • Establish a set of agreed guiding principles that inform initial criteria for defining safer chemicals and technologies. The criteria should include both environmental and health end points. Ideally, these would include consideration of the full product lifecycle and highlight trade-offs with incumbent chemicals/technologies.
Key actions that can be taken	• Develop specific, harmonised criteria for safer chemicals and create an inventory of such chemicals. Positive criteria can help guide businesses in making better choices, rather than focusing on what to avoid. Diverse “positive lists” are needed by supply chain stage. These may be substance or formulation based or focus on specific brands application and/or function. In turn these positive lists could be graded standards (i.e. Bronze, Silver and Gold) linked to levels of ambition and/or periods over which attainment is achievable.^{xxxvii} • Establish new data sharing platforms that are designed around the need for actionable information to support the use of safer chemicals and technologies across varied users in the supply chain
Key questions and considerations	• How can incentives for data sharing (and collection) be created, while protecting intellectual property? • What are key learnings (pros and cons) from past efforts to develop criteria for safer chemicals/innovations (or from positive lists for safer/approved chemicals) i.e., from the US EPA Safer Choice program^{xxxviii}? • Could criteria be connected to ISO standards given that standardisation could facilitate investment?

Priority Action 2: Encourage supply chain collaboration and action to accelerate innovation, commercialisation, and scaling-up of solutions

Priority Action 2 addresses the challenges of incumbency, lack of clear demand signals and transparency in the supply chain that can hinder investment in safer chemicals and technologies. In complex, global supply chains, chemical manufacturers often do not receive strong demand signals from retailers, brands, and their customers on preferences for safer substitutes. Retailers and brands also may not fully appreciate the time and upstream costs involved in bringing new solutions to market and to scale. Industry collaborations within a sector or value chain can serve as critical accelerators for development of safer chemistry and technology solutions. Collaboration efforts can reduce transparency barriers –increasing knowledge about needs for innovation in safer chemicals - while protecting intellectual property (IP). Dialogues on safer alternatives can provide an open forum for understanding demands, performance needs, costs, and other issues related to adoption. Such dialogues are essential to kick off the substitution process.

Sought outcomes and expected impacts	- Enhanced supply chain dialogue on safer alternative innovations that improve understanding of demand, performance needs, costs, and other issues related to adoption. - Increased supply chain collaboration/partnerships for priority chemicals and functions that then drive development (including evaluation and joint testing), commercialisation, and scaling-up of safer substitutes, as well as improve trust and transparency along the supply chain.
Existing models (that can be scaled up)	- Forum on environmentally friendly chrome plating in Finland (including industry, end-users, regulators, academia, funding actors)^{xxxix}; - Dutch initiative on sustainable anti-fouling for recreational boats (including testing of alternatives)^{xl} - Guidelines and best practices for substitution in the textile sector by the Nordic Council^{xli} - The Zero Discharge of Hazardous Chemicals initiative^{xlii}, includes a collaboration of 28 brands, 81 supply chain affiliates, and 17 associates to support the implementation of safer chemical management practices in the textile, leather and footwear value chains. - GC3 Collaborative Innovation project on Preservatives^{xliii} aimed to identify and support innovators developing preservative technologies with improved environmental, health and safety profiles for use in cosmetics, personal care and household products.
Starting point	Develop criteria and prioritise chemical functions for supply chain dialogue and collaboration, using existing information (e.g. Commission studies, SVHC and restriction priorities, sectoral or NGO priority lists) as well as the pre-competitive nature of technology. Implement a pilot project to demonstrate how such collaborations can lead to improvements in communication about and action on safer chemicals and technologies and establish a model/best practices for additional collaborations/partnerships, including dissemination of findings. Such a pilot project could be focused on a substance with evidence of potential risks, market or regulatory pressures, and where there are likely alternatives but challenges in practice.
Key actions that can be taken	Organise and facilitate supply chain collaborations for priority chemical functions, convened by a Member State, the Commission or industry that engages the entire supply chain as well as innovators (such as start-ups) that have potential technology solutions. Establish partnerships to drive commercialisation of safer chemicals and technologies where costs of research, evaluation, and performance and pilot testing are shared among participants and co-financing or support is offered by government authorities. Undertake additional actions to enhance trust while protecting IP. These parallel actions will be essential to facilitate supply chain collaborations, for instance: utilising credible third party service providers, which can collect and analyse ingredient data for chemical hazards and identify safer alternatives, providing needed information to retailers and others while protecting IP; using ecolabels/certifications where ingredient data are interpreted and determined as safer by a legitimate authority; engaging in pre-articulated shared IP arrangements among parties in a collaboration. Finally, new technologies, such as Blockchain may enable enhanced supply chain transparency.

Key questions and considerations

- What neutral entity or entities is in the best position to organise and facilitate such collaborations, how can best practices and findings from collaborations be most effectively developed and disseminated, and how can efforts across Member States be best coordinated?
 - How should priorities for such collaborations be established?
 - How can the impacts of such collaborations be best documented?
 - How can intellectual property and legitimate confidential information best be protected while ensuring transparency and information flow along the supply chain. For example, independent third parties?
-

Priority Action 3: Establish an EU-wide Safer Chemicals and Technologies Innovation Support Network

Priority Action 3 addresses the complex process of substitution which requires information on chemical hazards and alternatives, technical support, market access, and collaboration along the supply chain. Given the multi-faceted nature of the substitution process and the disparate work being undertaken by various actors across Europe, the need for one single driving entity to coordinate these efforts was recognised.

Moreover, small and medium sized enterprises frequently lack the resources, capacity, and technical expertise to identify or evaluate the potential the toxicity and performance of alternatives, conduct validation assessments related to customer specifications, or adopt safer chemicals and technologies. Companies are concerned about “switching risk” i.e. implementing alternatives that may have inferior performance or other costs such as process or equipment changes along the supply chain, among others. The example of the Massachusetts Toxics Use Reduction Institute demonstrates that dedicated technical support can accelerate substitution efforts by collecting and disseminating information^{xliii} identifying technology needs, demonstrating success stories, and convening stakeholders^{xliiv}.

Sought outcomes and expected impacts	- A trusted entity or network that companies can consult for clear information on safer alternative chemicals that are commercially available or under development as well as technical expertise related to evaluation and adoption of alternatives. - A holistic approach that addresses Europe’s goal to create a sustainable environment and circular economy; that is EU-wide with MS “nodes” to be far-reaching across all MS; and that establishes coordinated platform(s) for sharing information from Member States and industry, providing a “one stop shop” for information on alternatives, connections, and case examples.
Existing models (that can be scaled up)	- The Swedish Substitution Centre which aims to help SME’s identify alternatives to substances of concern.^{xlii} - Denmark’s Eco-Innovation funding programme and its recently launched Innovation in Chemistry project which offers models to support R&I on safer chemicals and technologies^{xlii} - The Massachusetts Toxics Use Reduction Institute^{xliii}
Starting point	Identify the best structure (e.g. a single institution that can disseminate relevant information, and/or a network of “help desks” that can reach smaller MS and companies regarding safer chemicals and technologies and most appropriate host and/or sources of funding as well as priorities, involving pre-existing institutions as well as front-runner companies and SMEs. Identify partner institutions for such a network, including research institutions, academia, authorities, and companies to identify and leverage case examples, knowledge, capacities and expertise.
Key actions that can be taken	Implement Priority Activities for a Network. Activities may differ by region or sector but could include: - Undertaking industrial training - Compiling data needed to make the business case for safer chemicals and technologies - Supporting research on new technologies or adoption challenges - Providing direct technical assistance to firms (e.g. helpdesks) - Facilitating supply chain dialogues, partnerships, and market access - Development of methods and tools for evaluation of safer alternatives - Dissemination of relevant information to different stakeholders to raise awareness, such as information on alternatives and case studies
Key questions and considerations	- What are the most relevant cross-European models for industry technical assistance, including ones established for other purposes? - What are potential sustainable funding models for such a network of centres? - What are the most effective means to understand the technical assistance needs of industry, to prioritise activities, and amplify impact at an EU level?

Priority Action 4: Create focused and coordinated financial incentives for safer chemicals and technologies

Priority Action 4 supports newer, safer chemicals and technologies to compete with incumbent chemicals/technologies that are part of complex and established supply chains, especially for products with long life cycles. Specific, coordinated funding programmes that specifically support both early-stage and later-stage innovation research for safer chemicals and technologies do not currently exist, despite a number of European Commission and Member State wider innovation support programmes that could be leveraged. To direct innovation toward a desired area, it was recognised that additional financial support needs to be considered. Further financial incentives are needed for investment in safer chemicals to offset some of the costs for the manufacturer or adopter of those new technologies, which can help to de-risk the business environment for first movers.

Sought outcomes and expected impacts	• Understand the different business hurdles to innovation and adoption in order to establish appropriate incentives across the value chain (e.g. tax breaks, research and development credits). • De-risk and accelerate research and innovation as well as the adoption and commercialisation of safer chemicals and technologies. • Reduce the overall costs associated with commercialising new safer chemicals (including their registration) via R&I and investment tax credits. • Establish public-private partnerships where costs of investment (i.e. among government, private investors, industry) are shared • Create new financial accounting mechanisms that help investors and firms more effectively make the financial case for adopting safer chemicals
Existing models (that can be scaled up)	• Member State Innovation Funds such as Danish <i>Kemi Kredsløb</i>^{xviii}, German Environmental Innovation Programme^{xlix} and Tekes (now Business Finland)ⁱ in Finland. • European Investment Bank's "InnovFin – EU Finance for Innovators"ⁱⁱ funding efforts on the Circular Economy and Bioeconomy • Canadian initiatives including: Green Centre Canada^{lii}, Bio-industrial Innovation Canada^{liii} (BIC), National Research Council of Canada^{liv} (NRC), and Sustainable Development Technology Canada^{lv} (SDTC)
Starting point	• Undertake a landscape assessment. to understand what financial mechanisms are needed for supporting innovation and substitution (R&D, commercialisation, adoption and scale), what current mechanisms exist and how these current mechanisms could be coordinated and improved, and gaps in policy highlighted from the current reviews of legislation (i.e. Fitness Checks) to identify where further incentives may be necessary. • Initiate a dialogue with frontrunner companies to better understand the incentive needs for development and commercialisation of safer chemicals and technologies.
Key actions that can be taken	• Develop an EU wide safe chemicals innovation research agenda, like the Dutch Safe Chemicals Innovation Agenda^{lvi} that outlines key functional substitution priorities and needs, drives incentives and innovation and prioritises activities of the EU-network of substitution support centres. • Facilitate entry to market and recognition for demonstrated safer chemicals and technologies through the regulatory review process. • Develop a dedicated Safer Chemicals and Technologies Funding Program, much like existing programmes for renewable energy technologies, to coordinate and prioritise safer chemistry and technologies for various types of funding from R&D to adoption and scale. • Coordinate a 'safer chemicals and technologies' pillar under FP9 (Horizon Europe), to provide financial support for SME's and start-ups and establishing loan guarantees, grants or credits to take on or partially share the burden of the risk for innovation and adoption of safer chemicals. • Develop preferential procurement programmes for companies that are commercialising safer solutions, modelled from programmes that have leveraged sustainable solutions in the bio-fuels area. • Engage investment funds (such as venture funds and other investment organisations) and sustainability standards organisations (such as Dow Jones Sustainability Index) in helping to create incentives for safer chemicals and technologies as well as the long-term funding horizons necessary for investment.
Key questions and considerations	• How can approaches be developed to ensure full costs and benefits are considered across the whole supply chain – especially in products with longer lifecycles and higher circularity? • How can more effective SEA techniques which reflect the benefits of safer chemicals and technologies and internalise externalities of substances of concern be developed, such as those employed in air quality and pollution assessment in the UK? • What criteria for safer chemistry are being used for giving financial incentives or preferential procurement and how can those goals/standards be defined?

4. Uptake: bringing the actions to implementation



4. Uptake: bringing the actions to implementation

The proposed Chemicals Innovation Action Agenda is ambitious. Implementing the priority actions outlined in this Agenda will not be simple given the challenges of the substitution process in complex supply chains. Implementing the Agenda will require reframing chemicals challenges as functional challenges and innovation opportunities, establishing new collaborations and partnerships along the value chain and among stakeholders, and ultimately new roles for government. It will also require the engagement of an expanded and more diverse set of stakeholders, beyond those typically involved in chemicals management discussions, including: downstream chemical users and retailers; academic and research institutions; financial institutions; and a broader range of Commission and Member State authorities. Importantly, such an Agenda would need to be implemented broadly throughout the European Union, beyond those Member States that have typically exerted leadership in chemicals management policies and eco-innovation programmes. Given that a large percentage of European manufacturing and chemicals use occurs in Small and Medium Sized Enterprises, the actions envisioned in this Agenda must also reach all types of businesses, not just larger, multinational or frontrunner firms.

In addition to the Priority Actions identified, there is a need for an improved knowledge base that can enhance the impacts of the Action Agenda in driving the design, commercialisation, and scale of safer chemicals and technologies as well as clarification of the potential roles of the Commission and Member States in implementing the agenda. These are outlined below.

4.1 Improving the knowledge base to support implementation of the Agenda

Improving knowledge about substances of concern and safer alternatives can play a critical role in driving demand for safer chemicals and technologies, embedding considerations of safer chemicals and technologies at the design phase, and supporting a mind-set change in education, industry, and government. There are two particular aspects of improving knowledge that can help shape a more effective implementation of the Action Agenda:

- Education, training, and awareness that improves knowledge about substances of concern and safer options among chemists/designers, consumers, and throughout the supply chain.
- Metrics to evaluate progress towards increased research and innovation and adoption of safer chemicals and technologies.

Education and awareness raising that improves knowledge about substances of concern and safer options among chemists/designers, consumers, and throughout the supply chain

The mindset change required to implement this Action Agenda will require education and awareness building at multiple levels: consumers; those studying chemical design, engineering, toxicology; business; and professionals. Such education and awareness can fundamentally shift purchasing behaviours as well as design, marketing, and sourcing of chemicals and products over the long term. The needs for education, awareness raising, and information differ depending on whether it is knowledge conveyed to a new chemist, designer, or professional, information to consumers to make more informed choices, or information on options through the supply chain. While the Commission can play an important role in enhancing knowledge

and awareness to different stakeholders, educational curriculum competencies tend to rest at the Member State level.

- **University education.** Chemistry and engineering students designing the chemicals, processes, and products of the future generally receive little education or training on chemical toxicity, life cycle impacts, or sustainability. Yet, companies are increasingly seeking chemists, engineers and designers who already have an understanding of sustainability. Institutions of higher education have been slow to respond in adapting curricula to meet these needs^{lvii, lviii}. Moreover, the training of those who study the health effects of chemicals, such as toxicologists, has not focused on the design of safer chemicals and materials. While health, safety and environment and lifecycle considerations are increasingly integrated into the product development process in industry, this is not generally the case in academic training. Such education on safer chemicals and technologies can be extended to students in business and finance who will be the corporate decision-makers of the future. New educational programmes and curricula that integrate the study of chemistry and engineering with environmental health sciences and other disciplines is an essential step towards ensuring that the new generation of practitioners is ready to implement the goals of this Chemicals Innovation Action Agenda.
- **Consumer awareness.** Market forces are often not strong enough to encourage the use or development of safer chemicals. When customers do demand safer chemicals, they may not be willing to pay increased costs for safer options. A number of companies, for example COOP in Denmark, have undertaken education campaigns with their customers to raise awareness about substances of concern in specific products and demand policy changes and other actions to drive the substitution of safer chemicals in products. NGOs such as Greenpeace and ChemSec have been successful in educating consumers about substances of concern in products and providing resources that focus consumer demand for safer chemicals. New projects such as Ask REACH^{lix} are providing tools for consumers to raise awareness about what substances concern are present in products, allowing them to ask questions of brands and retailers and make more informed purchasing decisions. Additional information outreach is needed for consumers so that they can better understand the hazards of chemicals; ask appropriate questions of retailers and brands on product ingredients, hazards and safer options; select and understand the benefits of safer options; and be more willing to adapt to cost, performance and functional changes (such as electronic receipts instead of paper ones) that might accompany safer options.
- **Supply chain awareness and training.** While frontrunner manufacturing companies are increasingly integrating their R&I and environmental, health, safety and sustainability functions, this is not universally the case. There is a need for additional information dissemination and training along the supply chain on safer chemicals and technologies that helps different functions in firms understand the value of safer options; supports the design, evaluation and adoption of safer options, overcoming potential cost and performance barriers; builds cross-functional collaboration in companies; and ultimately makes a strong business case for investment. Training throughout the supply chain can help to build understanding of challenges to adoption of safer alternatives at different steps of the product life cycle and in different regions as well as dialogue and action that can help overcome those challenges. Some particular job functions where training or information dissemination could be helpful, in addition to chemists and engineers include financial officers, and those in purchasing, sales, and marketing. In addition to education of business leaders, there is a need for those who are providing technical advice to business to have a strong understanding of safer chemicals and technologies.
- **Government authorities and legislator awareness.** Professionals evaluating risk, determining incentives, enforcing laws, and developing and implementing policies, also must have the information and training to understand the value of supporting innovation in safer chemicals and technologies as key to meeting policy goals.

Metrics to evaluate progress towards investment and innovation in and adoption of safer chemistry and technologies

Metrics provide both accountability and information to understand whether investments and actions are leading towards increased innovation in and adoption of safer chemicals. Such metrics can also help with recognising and rewarding frontrunners and providing information to expand impact of the Action Agenda. There is a need for metrics at both the government and firm levels. While REACH provides data to understand whether substances of concern are being reduced, without clear criteria for safer chemicals, it is difficult to understand whether the supply and adoption of safer chemicals is increasing. Additional ways to measure the impacts of research funding, investment, and other incentives in supporting safer chemicals and technologies are needed. At the firm level, a number of sustainability indices exist that could be expanded to include consideration of innovation in safer chemistry, such as the Dow Jones Sustainability Index. These provide important knowledge to financial institutions making investment choices. Existing efforts to measure corporate chemicals management systems and provide recognition to frontrunner companies, such as the Chemical Footprint Project^{ix}, could be expanded to explicitly measure investment in safer chemicals and technologies. These types of metrics can provide knowledge that helps drive investors and large purchasers towards frontrunner firms.

4.2 The potential role of the Commission

While all stakeholders have key roles to play in supporting the transition to safer chemicals and technologies, governments, particularly the Commission, have a particularly important role in establishing policy frameworks, leadership, and direction to the Action Agenda. Policy improvements are needed that enhance information flow along the supply chain, particularly for chemicals in products, that incentivise companies using substances of concern to internalise the costs of using such chemicals and to evaluate safer options at an earlier stage, and ultimately, consistently restrict substances of highest concern. Such policies need to be applied equally to chemicals used and manufactured in Europe as well as those in imported articles. But policies are also needed that facilitate innovation in new, safer chemicals and technologies and provide high level recognition of frontrunners. Such policies need to be linked with funding mechanisms for R&I and clear financial incentives. Importantly, the success of a Chemicals Innovation Action Agenda depends on adequate, sustained, long-term resources to effectively implement policies and programmes.

During the 2014-2019 period, the Commission has undertaken a significant number of chemicals-related reviews such as the 2nd REACH Review, the Chemicals-Waste-Products Interface Communication, and the Fitness Check of the most relevant chemicals legislation (other than REACH). These together provide a comprehensive assessment of the current situation with regards to chemicals regulation. Along with analysis undertaken as part of the formative work for a Non-toxic Environment strategy these could serve as a starting point to help understand gaps and needs in the ability of the Commission's and Member State regulatory and non-regulatory policies and programmes to effectively drive innovation in safer chemicals and technologies. It is important that these policies/programmes remain coherent yet be better connected to effectively address substances of concern while supporting progress towards safer chemistry and technologies. Additionally, a Chemicals Innovation Action Agenda needs to be highly integrated with circular economy and bio-economy policy and research frameworks, given their connections and priority status within the European Union.

As a credible and trusted voice with an ability to establish broad policy agendas that mobilise stakeholders, the potential role of the Commission was identified by stakeholders. Some of these roles are explored below. But these can only go so far. Such a transition requires sustained commitment, based on clear goals and milestones from policymakers at all levels alongside industry, academia NGOs and, not least, consumers.

Potential roles for the Commission

- Supporting and providing direction for the design and adoption of safer chemicals and technologies.** The Commission can play a unique role in adapting existing knowledge, resources, and infrastructure to support safer chemicals and technologies, including: establishing actionable data on chemical ingredients to design, evaluate, and adopt safer chemicals; providing tools for companies to identify and assess safer substitutes; and establish clear criteria and definitions to guide adoption of safer chemicals and technologies (Priority Action 1). In particular, the Commission could develop an action plan to establish data sharing platforms based around agreed criteria.
- Facilitating stakeholder and supply chain dialogues, collaboration and action.** The Commission can use its position to serve as a connector and convenor, initialising collaborative discussions along the supply chain (Priority Action 2) and connecting stakeholders as a starting point for future action. In particular, Member States can: disseminate guidelines and/or best practices for supply chain collaborations (the Dutch government published 'lessons learnt' on their supply chain workshop on sustainable anti-fouling technologies); prioritise areas where supply chain dialogues are needed through existing studies and/or REACH processes (e.g. the Safe Chemicals Innovation Agenda); coordinate supply chain dialogues and collaborations (by bringing actors together and providing a forum for the initiative or initiation of the dialogue); coordinate initiatives between Member States (e.g. avoiding non-coordinated initiatives for similar technologies/sectors); take stock of progress and findings across and within sectors; disseminate findings and; provide funding and/or organise co-funding with Member States.
- Enabling new infrastructure/resources to support the Agenda.** The Commission can take a leadership role in establishing the infrastructure necessary to implement the agenda (Priority Actions 3 and 4). For example, the Commission and Member States could provide resources and coordination support to establish the European-wide Safer Chemicals and Technologies Innovation Support Network noted in Priority Action 3.
- Rewarding and recognizing frontrunners.** Beyond the traditional role of focusing on those lagging behind through restrictions and enforcement, the Commission can position itself to as part of the solution, supporting frontrunners and those companies trying to catch up with them. For example, based on a research agenda for safer chemistry and technology innovation that outlines key priorities and needs the Commission could coordinate a green chemistry pillar under FP9 (Horizon Europe) to provide financial support for SME's and start-ups. The Commission could also provide financial help by taking on - or partially sharing the burden of risk - for innovation and adoption of safer chemicals. The Commission could also use preferential procurement for companies that are commercialising safer solutions. This model of effective procurement utilisation has previously leveraged sustainable solutions in the bio-fuels area.
- Delivering efficiency.** It is important for the Commission to map out clear roles and connections between Commission and Member State authorities that ensures more effective communication and coordination of activities envisioned under this Agenda, avoids duplication, and focuses resources on activities that will have maximum impact in driving innovation and adoption of safer chemicals and technologies.

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- ⁱⁱⁱ Chemical Watch, <https://chemicalwatch.com/37216/coop-denmark-publishes-chemicals-strategy>
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- ^v https://wedocs.unep.org/bitstream/handle/20.500.11822/27651/GCOII_synth.pdf?sequence=1&isAllowed=y
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- ^{xxxvi} <https://commons.healthymaterials.net/>
- ^{xxxvii} It should be noted that positive lists should consider the use of other technologies, not only chemicals. They should not be mandatory, but rather must show potential solutions in terms of functional substitution (i.e. the use of e-receipts rather than paper receipts due to BPA concerns). Negative lists were considered a first step in the transition to safer chemistry, by raising awareness, in particular for smaller companies, on what should be phased out. Positive lists might be more useful for larger companies with larger

resources, to prioritise solutions. Positive lists can also serve as a reward as solutions which may be endorsed by NGOs, society, and governments, which can be seen as an incentive for industry.

^{xxxviii} <https://www.epa.gov/saferchoice/safer-ingredients>

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^{xli} <https://www.rivm.nl/en/news/alternatives-available-for-environmentally-detrimental-antifouling-paints>

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^{xlii} <https://www.roadmapzero.com/gateway/>

^{xliii} <https://greenchemistryandcommerce.org/projects/innovation/preservatives-project>

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^{lviii} <https://greenchemistryandcommerce.org/projects/education>

^{lix} <https://www.askreach.eu/>

^{lx} <https://www.chemicalfootprint.org/>

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