ADVANCING THE 10 OBJECTIVES AND GUIDING CONSIDERATIONS FOR GREEN AND SUSTAINABLE CHEMISTRY

Ranging from green molecular design to ensuring that chemistry works to address societal needs, the 10 objectives and guiding considerations for green and sustainable chemistry, presented in UNEPs Green and Sustainable Chemistry: Framework Manual, seek to inspire and guide relevant stakeholders to shift their chemistry innovations towards sustainability.

This document includes the following elements to provide further context for each objective and support action towards the green and sustainable chemistry transformation.

- Illustrative examples directly extracted from the framework manual that demonstrate how stakeholders are taking action to advance or support each objective/guiding consideration.
- Questions to encourage key actors and change-makers to reflect on the role they can play to advance the corresponding objective/guiding consideration.
- Resources in the form of tools, reports and initiatives to promote further learning relevant to the achievement of each objective/guiding consideration.

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1 Minimizing Chemical Hazards

Design of chemicals with minimized (or no) hazard properties for use in materials, products and production processes ("benign by design").

Digital technologies are contributing to the effort to design alternative functional chemicals with minimized hazard properties. Advanced software combined with powerful computing capability can facilitate and accelerate the design process by rapidly screening the chemical space to select non-hazardous candidates for substitution that provide the desired functionality (see Chapter 4, pg 50).

? What are the key considerations when developing a functional chemical or chemical product which is benign-by-design? Are you taking into account its entire lifecycle from manufacturing to disposal?

Have a look at these *e-courses developed by The Lifecycle Initiative* for an introduction to lifecycle thinking. To learn more about computational tools which can support the development of safe and sustainable chemicals check out *OECD's QSAR toolbox*.

2 Avoiding regrettable substitutions and alternatives

Develop safe and sustainable alternatives for chemicals of concern through material and product innovations that do not create negative trade-offs.

One way that innovators are utilizing green and sustainable chemistry concepts to design sustainable alternative products and processes is through biomimicry. By mirroring processes found in nature, alternative products, materials and processes without negative tradeoffs can be developed. One relevant technique is to design products with "triggered instability" to harmlessly decompose after use, just as in the natural world (see chapter 2, pg 19).

? Are you familiar with an ability of a living organism or a natural phenomenon which could provide a desired functionality to a product or material? Can you think of an innovation in the market which uses concepts from nature?

Check out the short film "*The Promise of Biomimicry (2020)*" to find out about nature inspired design. For further information on the selection of alternative chemicals see *OECD's Guidance on Key Considerations for the Identification and Selection of Safer Chemical Alternatives (2021)*.

3 Sustainable sourcing of resources and feedstocks

Use of sustainably sourced resources, materials and feedstocks without creating negative trade-offs.

One possible renewable feedstock or resource is the potent greenhouse gas, carbon dioxide. Green and sustainable chemistry innovators are developing and scaling-up technologies that exploit the available chemical pathways to convert the abundant gas into fuels or chemical products (see chapter 4, pg 38).

? Are renewable feedstocks currently being discussed or implemented in your region? What are some important factors and trade-offs to account for when evaluating the sustainability of an alternative feedstock? Consider the sourcing of the feedstock and the nature of the final products.

Check out this report from the International Energy Agency titled "*Putting CO_2 to Use – Creating value from emissions (2019)*" on the possibilities and implications of utilizing carbon dioxide feedstocks.

4 Advancing Sustainability of Production Processes

Use green and sustainable chemistry innovation to improve resource efficiency, pollution prevention, and waste minimization in industrial processes.

New developments in catalysis are advancing the sustainability of chemical processes. One such case is the use of small organic molecules to perform what is called Organocatalysis. These materials can be sourced from waste and often require milder and less hazardous reaction conditions than traditional metal catalysts (see chapter 4, pg 47).

? Think about a common material or product with which you are familiar, are you aware of the production process to make it and the corresponding environmental impacts (e.g. energy/resource consumption, pollution release, waste generation)? How could green and sustainable chemistry innovations and practices reduce these impacts?

For more on how green and sustainable chemistry can advance the sustainability of production processes see *how Amgen re-designed their peptide manufacturing process* to win the United States Green Chemistry Challenge or check out this *toolkit on Green Chemistry and chemical process improvement* developed by UNIDO.

5 Advancing Sustainability of Products

Use green and sustainable chemistry innovation to create sustainable products and consumption with minimized (or no) chemical hazard potential.

Through the development of alternative functional chemicals for use as plasticizers, surfactants, flame retardants and more, green and sustainable chemistry innovation can help design products that are less hazardous to human and environmental health. One line of research is seeking to develop non-hazardous bio-surfactants based on algae for use in household soaps and detergents (see chapter 4, pg 40).

? What aspects of the products you use, or sell are unsustainable? Do you know how they are made and what happens to their contents after disposal?

Read this report by UNEP, "*The Business Case for Knowing Chemicals in Products and Supply Chains (2014)*", for an overview on why you should know what chemicals are in the products you sell. Also, see the *work being done around the world by the International Pollutants Elimination Network* to generate and share knowledge on hazardous chemicals in products.

6 Minimize chemical release and pollution

Reduce chemical releases throughout the life cycle of chemicals and products.

Pollutant Release and Transfer Registries (PRTRs) are powerful data-collection systems that track the release of hazardous substances from industrial zones and other sources. They can be used to identify hotspots for the deployment of green and sustainable chemistry solutions and to subsequently evaluate their effectiveness after implementation (see chapter 7, pg 80).

? Can you access your region's PRTR to see the pollution landscape in your region? How could green and sustainable chemistry practices and innovations contribute to mitigating these pollution sources?

PRTR.NET, developed by UNECE and OECD, is a global portal to PRTR information and activities from around the world. Also check out the *UNITAR PRTR Platform* or the *E-PRTR* page for EU related pollution data.

7 Enabling non-toxic circularity and minimizing waste

Use of chemistry innovations to enable non-toxic circular material flows and sustainable supply and value chains throughout the life cycle.

Green and sustainable chemistry innovation can play an important role in advancing the circular economy through the design of recyclable products, novel waste conversion technologies and reducing resource use (see chapter 2, pg 23). One such example is the green and sustainable chemistry enabled conversion of agricultural residues into renewable feedstocks for industry (see chapter 4, pg 37).

? Are you aware of some barriers which prevent easy recycling and recovery of certain products and how green and sustainable chemistry innovations can help overcome them? Have you considered how to promote the manufacture and consumption of products from post-consumer sources?

To find out what it takes to design a product that advances the circular economy, check out the *European Environment Agency's approach for safe and sustainable product design*. Also, visit the *circulars accelerator webpage* to see how innovators are utilizing green and sustainable chemistry concepts to advance circularity.

8 Maximizing Social Benefits

Consider social factors, high standards of ethics, education and justice in chemistry innovation.

Right-to-know policies that promote public engagement in chemistry activities empower workers to become drivers of green and sustainable chemistry and ensures that they benefit from the relevant innovations. Examples of such frameworks include the UNECE Convention on Access to Information or the Regional Agreement on Access to Information and Public Participation and Justice in Environmental Matters in Latin America and the Caribbean (see Chapter 5, pg 58).

? Are there any initiatives in your region which encourage public participation in decisions related to chemistry activities? Can you think of any specific entry-points for engaging with citizens such as social media or community organizations?

See how accessible digital technology is contributing to public empowerment with *The Scan4Chem app developed by AskREACH* that allows consumers to request information on toxic chemicals by scanning the product barcode. Also, for some examples of how developing countries are accelerating the transformation to green and sustainable chemistry through research, check out *these case studies compiled by UNEP, UNIDO and ISC3*.

9 Protecting workers, consumers, and vulnerable populations

Safeguard the health of workers, consumers and vulnerable groups in formal and informal sectors.

Factory operators can use green and sustainable chemistry innovations and concepts to modify processes such that they run at lower temperatures and pressures and use fewer toxic reagents. Milder reaction conditions reduce energy consumption while lowering the risk of dangerous accidents, resulting in improved safety for workers and surrounding communities (see chapter 4, pg 50).

? Are you aware of the hazards associated with manufacturing the products you use? Which aspects of those processes could be modified to protect employees and surrounding populations?

Check out this *UNEP's Ecoinnovation manual success story* from Malaysia and ILO's report "*Exposure to hazardous chemicals at work and resulting health impacts: A global review (2021)*" to see what opportunities exist for green and sustainable chemistry to improve working conditions.

10 Developing solutions for sustainability challenges

Focus chemistry innovation to help address societal and sustainability challenges.

Green and sustainable chemistry technologies are playing a role in the effort to end fossil fuel reliance through innovations related to solar fuels, energy storage materials and improved photo-voltaic energy generation (see chapter 4, page 52).

? How can green and sustainable chemistry be used to address the three planetary crises of climate change, biodiversity and pollution?

See how working to better manage chemicals and waste can also contribute to other environmental areas of concern in this UNEP report titled, "*Assessment on linkages with other clusters related to chemicals and waste management and options to coordinate and cooperate on areas of common interest (2020)*".