UN environment programme

Green and sustainable chemistry: Conceptual Framework manual

Prepared by United Nations Environment Programme
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About the Outline of the Conceptual Framework Manual

This annotated outline features the proposed flow, chapters and sections of a conceptual framework manual on green and sustainable chemistry which will be developed by UNEP during the course of 2020, pursuant to the mandate received from the United Nations Environment Assembly (UNEA) in 2019 through Resolution 4/8. The framework manual will be complemented by specific manuals, with specific topics to be determined once the framework manual has taken shape. This outline aims to bring together a wide range of perspectives on green and sustainable chemistry to be featured in the framework manual. It is hoped that these diverse perspectives are organized in a way that they provide a better understanding of relevant concepts and help stimulate action at various levels and in different settings. While the document does not seek to create a global definition (or definitions), criteria and reference points are offered to help guide action in a direction that chemistry can become fully compatible with, and contribute to, implementing the 2030 Agenda for Sustainable Development.

An initial outline of the conceptual framework manual (which is expected to be 30-40 pp. in length) was be reviewed at an informal workshop on 5-6 December 2019 in Geneva, Switzerland. This revised version seeks to take into account comments and perspectives provided by participants of the workshop. It is not meant to be circulated at this early stage to a wider audience. In reviewing the outline, reviewers are encouraged to:

- provide feedback on the flow of the document and its chapters and sections;
- consider suitability of the identified dimensions and topics;
- topics identify meriting further elaboration in annexes/specific manuals; and
- propose key references to be used and cited in drafting the document.

A broader consultative process to provide further input on this outlines and manuals is planned to take place during the course of 2020.

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1 Introduction

Background

Over the past decades, the concepts of green and sustainable chemistry have gained significant momentum and attention in light of their potential to advance safer chemistry and contribute towards achieving the Sustainable Development Goals (SDGs). While the concept of "green chemistry" is elaborated through the well-known 12 principles that focus on safer and less resource intensive chemistry, "sustainable chemistry" is evolving as a more holistic complementary concept. This creates opportunities to foster a better common understanding, including on the relationship between green and sustainable chemistry.

In 2019, the United Nations Environment Programme (UNEP) prepared the 'Analysis of Stakeholder Submissions on Sustainable Chemistry Pursuant to UNEA Resolution 2/7'3, which was made available as an information document for the fourth session of the United Nations Environment Assembly (UNEA-4) (Nairobi, Kenya, 11-15 March 2019). The report finds that:

- the concept of sustainable chemistry is widely used by stakeholders around the world;
- sustainable chemistry cases submitted address various stages of the chemicals and waste life cycle and illustrate the role of sustainable chemistry in achieving the SDGs;
- stakeholders have a broad understanding and interpretation of sustainable chemistry and welcome further work to facilitate a common understanding; and
- further steps in the context of the intersessional process to prepare recommendations regarding the Strategic Approach and the sound management of chemicals and waste beyond 2020 could include development of practical guidance on sustainable chemistry.

The Global Chemicals Outlook II (GCO-II), published by UNEP in 2019, lists among the implementation of actions up to and beyond 2020 to integrate green and sustainable chemistry in education, research, and innovation policies and programmes. It finds that:

- "green chemistry" focuses on reducing or eliminating the use or generation of hazardous substances in the design, manufacturing and application of chemical products, guided by the well-known 12 green chemistry principle;
- "sustainable chemistry" is evolving as a more holistic complementary concept which embraces green chemistry;
- recent discussions have expanded the sustainable chemistry concept in a direction where chemistry is contributing to sustainable development across its three dimensions, i.e. environmental, social and economic;

Mandate

In 2019, Resolution 4/8[6], adopted by UNEA-4, welcomed the analysis of best practices in sustainable chemistry and recognized the value of developing a better understanding of sustainable chemistry opportunities globally. The resolution further requested the Executive Director, subject to the availability of resources and, where appropriate, in cooperation with the member organizations

of the Inter-Organization Programme for the Sound Management of Chemicals (IOMC), to synthetize UNEP's analysis of best practices in sustainable chemistry into manuals on green and sustainable chemistry, in consultation with relevant stakeholders, by UNEA5, and to continue the work on a holistic approach for the sound management of chemicals and waste in the long term, taking into account both the importance of the sound management of chemicals and the potential benefits of chemicals for sustainable development.

Purpose and target audiences of the framework manual

- The framework manual targets a wide range of audiences and stakeholders concerned with the sound management of chemicals and waste. This includes decision-makers and managers in the public and private sectors, academia and research, other civil society organizations and the public at large.

- Various chapter may be of different interest to different groups which will be mentioned within each chapter. In chapter references will be included to indicate relevance for specific targets audiences. Furthermore the planned specialized manuals could address more specific target audiences.

- The main purpose of the framework manual therefore is to introduce, in a structured way the various facets of green and sustainable chemistry, with the intention to generate a common understanding, foster reflection and action.

Methodology and approach

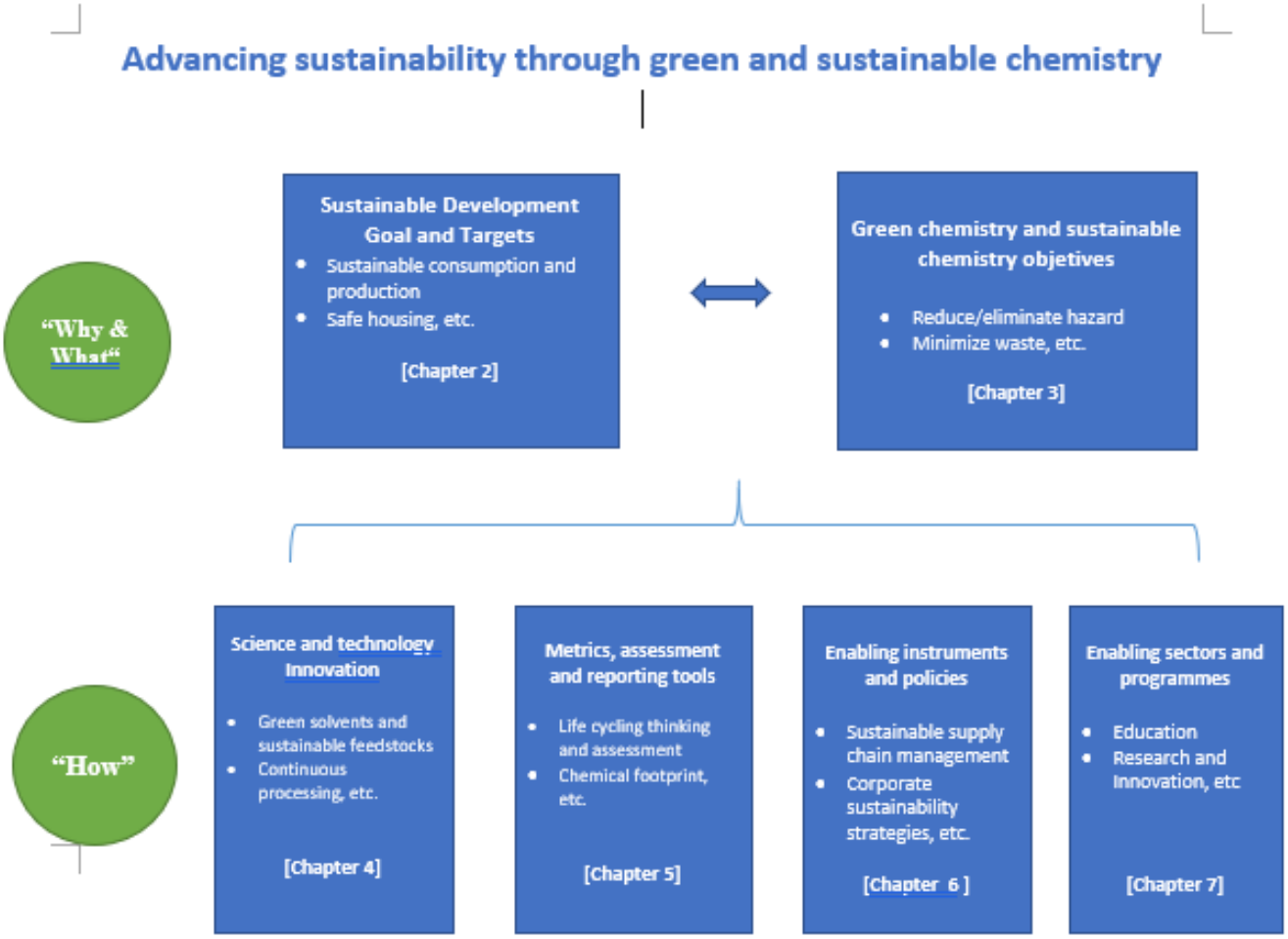
The use of the term "manuals" in the UNEA-4 mandate suggests an interest to produce deliverables and outputs which can be of practical value for actors engaged in green and sustainable chemistry and seeking to contribute towards sustainable development. Equally relevant, by using a plural in the mandate ("manuals"), more than one manual may be prepared. Ideally, and in line with the mandate, the synthesis of the analysis of best practices in sustainable chemistry into manuals on green and sustainable chemistry could be used to derive common elements and characteristics of green and sustainable chemistry.

Stakeholder engagement

- Summary of the consultative process, key milestones and stakeholder engagement

Overview of the framework manual

- Brief summary of the structure of the framework manual which is organized around five major elements of a "green and sustainable chemistry framework" including: objectives; design and innovation areas; relevant SDGs; metrics, assessment and reporting tools; and enabling instruments, policies and sectors. The various elements are addressed in specific chapters/sections.



2 Chemistry and sustainable development: challenges and opportunities

2.1 Why is enhanced systemic action on green and sustainable chemistry needed?

Global trends cause significant concerns, calling for new commitments and action

- Releases of hazardous chemicals during production and product life cycles have created (and continue to create) a range of challenges for human health, the environment, and sustainable development.

- Reference to some important trend data featured in GCO-II

- The global goal to minimize adverse effects of chemicals and waste will not be achieved by 2020. "Business as usual is not an option" (UNEP 2019).

- There is a growing quest to ensure that (a) adverse impacts from chemicals are minimized and (b) innovations that safely contribute to achieving sustainable development objectives are advanced.

- Various stakeholder communities as well as various international reports, such as GCO-II have called for transformative action to these two ends.

Green and sustainable chemistry innovations are needed to implement SDG 12 on Sustainable Consumption and Production

- Innovations in chemistry, if sustainability criteria are met, can contribute to reducing pollution resulting from chemicals production and use, enhancing resource efficiency and advancing circularity
- Green and sustainable chemistry innovations will also support a shift towards sustainable consumption and production patterns.

Green and sustainable chemistry innovations can help achieve broader sustainable development objectives

- While innovation is desirable and needs to be scaled up, legacies associated with chemistries of the past centuries point to the value of robust criteria for guiding research and innovation that is fully compatible with the 2030 Sustainable Development Agenda.

- Innovations in chemistry, if sustainability criteria are met, can contribute to the implementation of many SDGs, including those addressing climate change, zero hunger, energy, housing, etc.

SDGs and targets relevant for green and sustainable chemistry

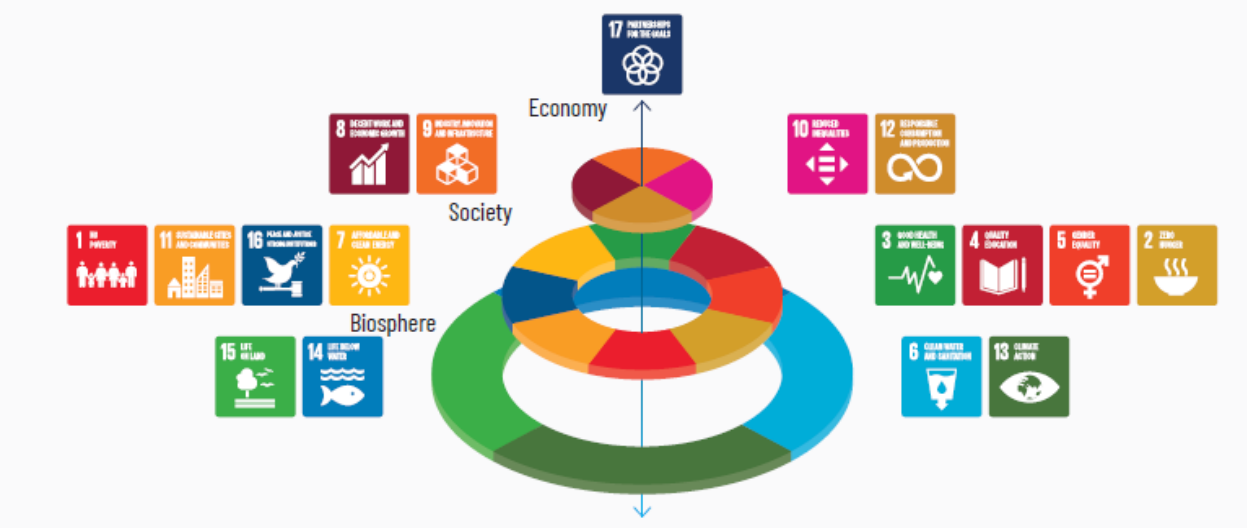
Sectors	SDG targets	Green and sustainable chemistry applications and opportunities
Agriculture and food	Target 2.4: sustainable food production	
Health	Target 3.8: safe medicines and vaccines	
Energy	Target 7.a: clean energy research and technologies	
Infrastructure	Target 9.1: sustainable infrastructures	
Industry	Target 9.2: sustainable industrialization	
Housing	Target 11.1: safe housing	
Transport	Target 11.2: sustainable transport systems	
Tourism	Target 8.9: sustainable tourism	
Mining	Target 12.2: Sustainable use of natural resources	

Recognizing the three dimensions of sustainable development in advancing chemistry innovation

- Environmental [1]
- Social
- Economic

The three dimensions of sustainability (adapted from SRC 2016) – source . GCO II

[1] (i) natural resources should be used at rates that do not unacceptably deplete supplies over the long term and (ii) residues should be generated at rates no higher than can be assimilated readily by the natural environment (Graedel, 2002)

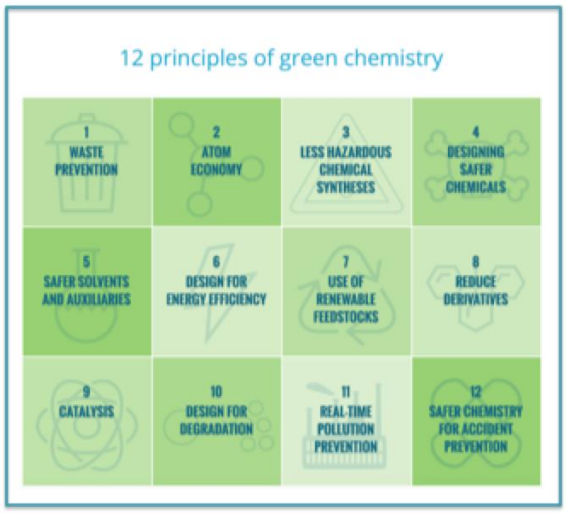


2.2 The evolving understanding of green and sustainable chemistry

Key developments over the past decades

Green chemistry as a foundation to advance sustainability

- *Brief introduction to the 12 principle of green chemistry and how they focus on molecular design and process engineering considerations.*

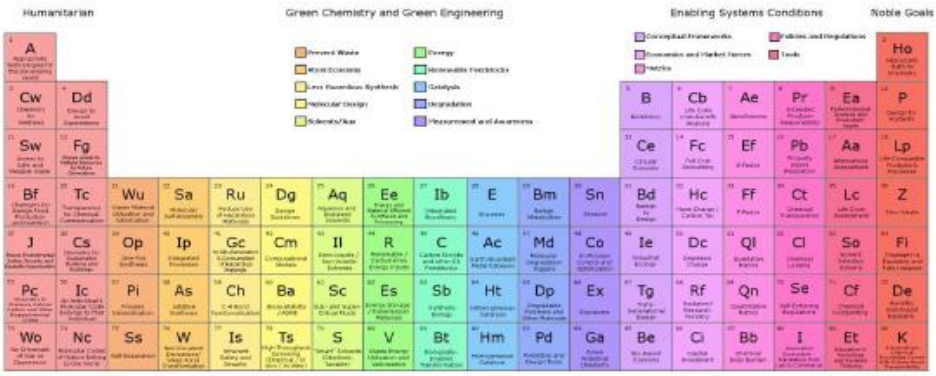


"Twelve Principles of Green Chemistry" - Image from Beyond Benign website

Towards a broader and holistic perspective: sustainable chemistry

- Brief summary of the literature on sustainable chemistry (e.g. UBA 2017, ISC3 2019) suggesting a holistic approach which links sustainable chemistry to the implementation of the 2030 Sustainable Development Agenda, including SGD 12 on Sustainable Consumption and Production.
- Reference to recent work placing green chemistry elements with a broader system of sustainable chemistry

The Periodic Table of the Elements of Green and Sustainable Chemistry (Anastas and Zimmermann, 2019)

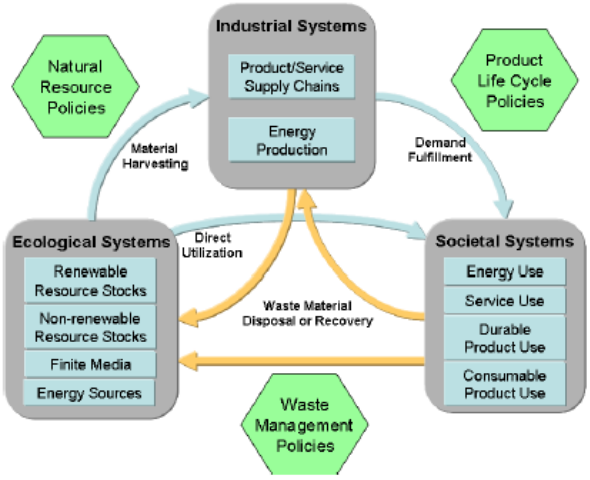


Interface green and sustainable chemistry with sound management of chemicals and waste

2.3 Chemistry in the broader system of materials and products flow : a lifecycle approach

Chemicals, material and product flow cycles

- According to the International Resources Panel's Global Resources Outlook 2019 (Oberle et al. 2019), approximately 92 billion tonnes of materials are estimated to have been extracted globally in 2017. The Outlook assumes that under a historical trend scenario, this will reach 190 billion tonnes, by 2060.



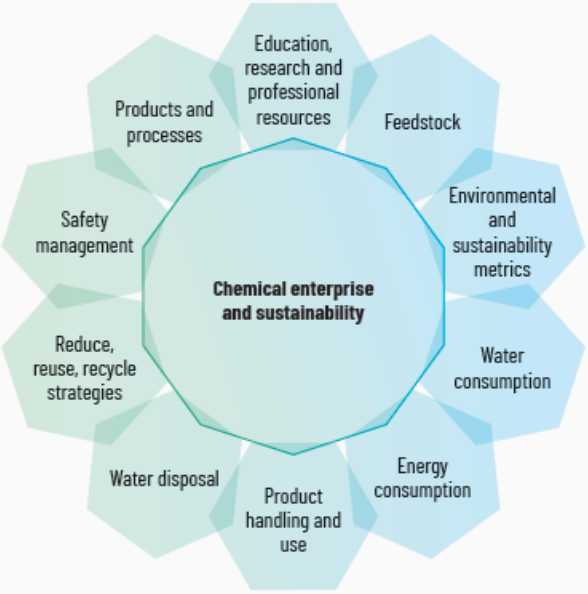
Systems View of Material Flow Cycles (OECD 2010))

- Chemical releases and pollution may occur and needs to be minimized throughout the entire life cycle of materials and products

Sustainability dimensions of the chemical enterprise

- Brief description of the many dimensions which need to be addressed in advancing sustainability of the chemical industry, guided by the diagram below

Figure 1.2 **Dimensions of a chemical enterprise: towards sustainability (adapted from Hill, Kumar and Verma 2013, p. 27)**



2.4 Sustainable materials and product design as a driver for innovation

Sustainable materials management and product design

- Driven by a range of factors (e.g. regulation, consumer demand, commitments) a number of downstream industries, brands and retailers have scales up efforts to sell products free of hazardous substance, which is becoming a driver for green and sustainable chemistry innovation.

- The importance of regulations to drive chemistry innovations

Design approaches to foster sustainability

- Cradle-to-cradle design
- Functional substitution
- Collaboration of actors across the value and supply chains
- Etc.

2.5 Green and sustainable chemistry in a developing country context

- Consideration of related challenges and opportunities to implement green and sustainable chemistry in a developing country context. Include a discussion on how green and sustainable chemistry could help developing countries towards the environmentally sound management of chemicals and waste while at the same time promoting economic development.
- Contribution of traditional knowledge.

3 A deeper dive: what does green and sustainable chemistry aim to achieve? Objectives and guiding considerations

The vision of green and sustainable chemistry is to make tangible contributions to the implementation of the 2030 Agenda for Sustainable Development, by shifting chemistry in a direction which is fully compatible with sustainability criteria. SDGs which green and sustainable chemistry can directly contribute to include, but are not limited to, zero hunger (SDG2), good health and well-being (SGD 3), clean water and sanitation (SDG 6), affordable and clean energy (SDG 7), sustainable consumption and production (SDG 12), and climate action (SGD 13). By reducing chemical hazards and pollution, green and sustainable chemistry also contributes more indirectly to other SDGs, such as decent work and economic growth (SDG 8), life below water (SGD 14) or life on land (SGD 15)

Green and sustainable chemistry objectives and guiding considerations

The vision of green and sustainable chemistry can be achieved through innovations in chemistry that provide desirable functions of chemicals, materials, products, and production processes without causing harm to human health and the environment, while meeting broader development objectives. "Chemistry innovation", in this context, includes both innovation in chemistry and chemical engineering sciences. The following objectives and guiding considerations are offered to chemists, chemical engineers, managers in the private and public sectors, policy makers and other stakeholders to shift chemistry innovations towards green and sustainable chemistry. They range from molecular design based on green chemistry principles, to addressing societal needs. While being distinctive, overlaps occur across objectives, given the diverse yet distinctive entry points. Ideally, chemistry innovations should consider and be compatible with all of the 10 objectives, although in practice, this may not always be possible.

3.1 Minimizing chemical hazards: Design of chemicals with minimized (or no) hazard potential for use in materials, products and production processes ("benign by design")

The objective is relevant for chemists, chemical engineers, and product designers engaged in chemistry and chemical engineering innovation. It encourages the design and use of chemical molecules (or groups of molecules) with minimized (or no) hazard potential, in order to advance safe and sustainable materials, and develop sustainable products and production processes in which chemicals are used.

3.2 Avoiding regrettable substitutions: Develop safe alternatives for chemicals of concern without creating negative trade-offs

The objective is relevant for chemists and product designers and encourages chemistry innovation to develop alternatives for chemicals (or groups of chemicals) that cause significant concern for human health and the environment. Such alternatives should avoid any negative impact on human health or the environment, nor compromise other broader development objectives (e.g. mitigating climate change). Otherwise they could be considered "regrettable". Alternatives may also include providing desired functions without using any hazardous chemicals.

3.3 Using sustainable feedstocks: Use of sustainably sourced resources and feedstocks without creating negative trade-offs

The objective is relevant for chemists, and supply chain managers in the chemical industry. It encourages the use of renewable resources as feedstocks for the chemical industry, while ensuring that the production and use of bio-based feedstocks meets broader sustainability criteria. Relevant considerations include but are not limited to replacing agricultural land for food production, expanding agriculture at the detriment of forest, and broader land use questions.

3.4 Advancing sustainability of production: Use green and sustainable chemistry innovation to improve resource efficiency, pollution prevention and waste minimization in industrial processes

The objective is relevant for chemists, as well as chemical and industrial engineers engaged in developing chemistry and chemical engineering solutions that can improve industrial production processes. It encourages chemistry innovation to enhance resource efficiency, minimize industrial waste, and foster reuse and recycling of chemicals and materials during production processes.

3.5 Advancing sustainability of products. Use green and sustainable chemistry innovation to create sustainable products with minimized (or no) chemical hazard potential

The objective is relevant for brand managers, product designers, chemists and chemical engineers engaged in product design and production. It encourages chemistry innovations to design and produce sustainable products which are non-toxic, have longevity (i.e. duration of shelf and service-life, repairability), are safe, and can be reused or recycled within a circular economy.

3.6 Minimizing chemical releases and pollution: Reduce chemical releases throughout the life cycle of chemicals and products

The objective is relevant for production managers, chemical engineers and chemists engaged in industrial processes and product development. It encourages chemistry innovations to minimize releases of chemicals to indoor and outdoor environments during production processes and from products. That can be achieved by maximizing the use of closed systems, minimizing or eliminating hazardous chemicals in products, and ensuring reuse and recycling of materials throughout the life cycle of products.

3.7 Enabling non-toxic circularity: Use of chemistry innovations to enable circular material flows and sustainable supply chains throughout the life cycle

The objective is relevant for all managers and scientists engaged in product development and industrial processes. It encourages green and sustainable chemistry innovation to foster sustainable material management, including maintaining the highest possible value of materials during the life cycle of a product. It also encourages eliminating hazardous chemicals in products which would prevent product recycling.

3.8 **Maximizing social benefits:** Consider social considerations and high standards of ethics, education and justice in advancing chemistry innovation

The objective is relevant for all policy makers, managers and scientists engaged in the sound management of chemicals and waste. It encourages development of policies and management approaches to ensure that chemistry innovation is fully compatible with broader social sustainability considerations, including, but not limited to ethics, socio-economic aspects and justice considerations.

3.9 **Protecting workers, consumers and vulnerable populations**: Safeguard the health of workers, consumers and vulnerable groups in formal and informal sectors

The objective is relevant for all policy makers, managers and scientists engaged the sound management of chemicals and waste. It encourages green and sustainable chemistry innovation to go hand-in-hand with other measures to protect workers, consumers and vulnerable groups, given that hazardous chemicals will continue to be in use and need to be managed properly.

3.10 **Developing solutions for sustainability challenges:** Focus chemistry innovation to help address societal and sustainability challenges

The objective is relevant for all managers and scientists engaged in a broader discussion in society about the role of green and sustainable chemistry, and the related chemical industry to meet societal needs and foster sustainable development. It encourages to focus chemistry innovation on developing solutions for major sustainability challenges, including, but not limited to food security, human wellbeing, or mobility.

Text Box: Leap-frogging technologies through green and sustainable chemistry

4 Science and technology innovations to advance green and sustainable chemistry

Table: Chemicals with sustainability challenges and innovation opportunities

Groups of Chemicals / Sectors	Environment and Human Health Concerns	Innovation Opportunities
Plastics		
Agrochemicals		
Pharmaceuticals		
Flame-retardants		
Etc..		

[The sections below will be adjusted, as per suggestion of the meeting on 5-6 December, taking into account the green chemistry cells in the green and sustainable chemistry periodic table The objective is to ensure the elements below are exhaustive and covering well all information from the green and sustainable chemistry periodic table

4.1 Resources and feedstocks

- Renewable biomass as feedstocks
- Carbon dioxide chemistry

4.2 Catalysis

- Earth abundant metal catalysis
- Organo-catalysts
- Bio-catalysis
- Photo-catalysis

4.3 Solvents

- Organic solvents
- Water
- Alcohol

4.4 Process and engineering innovations

- Continuous processing vs. batch processing
- Use of renewable energy

4.5 Using traditional knowledge

5 Assessment tools, metrics and reporting to advance green and sustainable chemistry

5.1 Sustainability assessment and life-cycle metrics

Life cycle assessment and thinking

- Brief discussion how life cycle approaches can help to ensure that all stages in a product cycle are taking into account in green and sustainable chemistry innovations and sustainability assessments, and that all impact areas are considered.

Chemical footprint metrics

- Brief discussion how chemicals footprint approaches can help to understand making progress in advancing green and sustainable chemistry

5.2 Green chemistry and engineering metrics

Hazard screening

E-factor and Process Mass Intensity (PMI)

Text Box: ACS Greener Chemical Products & Processes Standards

5.3 Sustainable chemistry metrics

- Brief review of the literature concerning challenges to define and measure sustainable chemistry

5.4 Sustainability performance reporting and their chemistry dimension

6 Enabling instruments and policies to advance green and sustainable chemistry

6.1 Regulatory action and standards

6.2 Labeling, certification and transparency

6.3 Sustainable procurement (public and private)

6.4 Sustainable supply chain management

6.5 Sustainable and circular business models

6.6 Knowledge-sharing and award programs

6.7 Supporting policy principles and approaches

Precautionary approach

Polluter pays principle

Product stewardship and extended producer responsibility

Corporate and social responsibility

Gender equity

Human rights and the rule of law

Transparency

6.8 Public-private partnerships

7 Enabling sector policies and programs to advance green and sustainable chemistry

7.1 Green and sustainable chemistry education

- Important sub-section to be developed drawing attention to a wealth of resources available

7.2 Green and sustainable chemistry research, innovation and digitilization

- Important sub-section to be developed drawing attention to a wealth of resources available

Ensuring that chemistry innovations meet sustainability criteria

7.3 Green and sustainable chemistry financing

- Important sub-section to be developed drawing attention to a wealth of resources available

8 Developing a green and sustainable chemistry road map

- Drawing upon examples in the public and private sector, this concluding chapter will make practical suggestion for actors to integrate green and sustainable chemistry consideration in their planning processes.

9 Annex A: Conceptual framework: Advancing the sustainability of chemistry through green and sustainable chemistry

[Revised conception framework with details will be added, once the specific chapters have been further developed]