ACS Chemistry for Life®

Committee on Environment and Sustainability

Fact Sheet

UNDERSTANDING SUSTAINABLE CHEMISTRY

Sustainability presents a global challenge that must be addressed to preserve natural resources for future generations. Environmental, social, and economic factors all influence our ability to thrive, and actions aimed at achieving sustainability must be evaluated for their impacts on each of these factors. Challenges to achieving sustainability include population growth and the increasing standard of living in developing counties. The United States Department of agriculture expects that this planet's human population will reach 9 billion by 2050, vastly increasing the pressure on food production from limited land and water. Energy consumption continues to grow, driven primarily by increased per capita consumption in India and the developing world.

The global chemistry enterprise is a significant economic engine that largely relies on the extraction and processing of non-renewable feedstocks. The chemical processing industry provides many of the raw materials that serve as building blocks for most of our manufactured goods, which influence the quality of society as we know it. In less-developed regions, the availability of such goods is limited, leading to large global disparities in standards of living. Our goal should be to ensure the future sustainability of critical environmental and human systems for everyone.

The traditional chemistry and engineering disciplines provide tools, understanding, and technology for addressing many sustainability challenges. For example, Environmental Chemistry can inform the creation of fate, transport, and effects models and can help provide and evaluate remediation technologies. Organic and materials chemistry provide new materials for energy generation, energy storage, and water purification. The terms Green Chemistry, and more recently Sustainable Chemistry, have been coined in order to organize and identify chemistry research, development, and implementation where the explicit end goal is improving sustainability. Engineering underlies the transformation of green chemistry research into practice.

Principles of Green Chemistry and engineering were formulated specifically to address waste, pollution, and toxicity associated with chemical synthesis and the chemical industry. The term Sustainable Chemistry includes the practice of Green Chemistry while also being used to classify any chemistry research and application that seeks to simultaneously improve the economic, social and environmental performance of any goods or service.

Using many of the tools and metrics developed by Green Chemistry practitioners, Sustainable Chemistry practices and research can improve the overall sustainability of the chemical enterprise through changes to feedstocks, chemicals, chemical transformations, and industrial processes.

Sustainable chemistry seeks to address the adverse impacts associated with the continuing use of fossil carbon and elementally scarce substances in chemical manufacturing and energy applications by, for example, designing and developing:

- Chemistry that converts renewable carbon sources into simple molecules that are subsequently transformed into valuable chemicals.
- Catalysts and materials that do not rely on scarce minerals or metals
- Methods and technology to reduce waste generation and convert waste streams into valuable materials
- Chemicals and materials that could be efficiently reused or recycled at their end-of-use
- Technology for collecting and processing recyclable chemicals and materials, such as used motor oil, expired batteries, solvents, plastics, etc.

Sustainable chemistry seeks to address issues associated with the use of potentially hazardous chemicals by, for example:

- Finding alternatives to toxic chemicals
- Developing and using design rules, guidance and tools to predict and optimize new chemical entities for integrated performance, cost, life-cycle safety, health, and environmental impacts.
- Finding alternatives to current petrochemical feedstocks.
- Ensuring that chemicals do not persist in the environment or accumulate in biological systems

Sustainable chemistry seeks to improve the efficiency and efficacy of the chemical transformations by, for example:

- Developing technology for transformation of biomass into valuable products. Such technology may include catalysts (traditional, enzymatic, and biological) and synthetic methods (fermentation and traditional processing technologies).
- Creating new reaction pathways, including multi-component, cascade reactions as well as coupling and cyclization reactions.
- Designing highly efficient processes that combine biological and chemical transformations
- Using artificial intelligence and other emerging computation and big data tools to create efficient synthetic route design
- Developing and implementing the use of energy-efficient metrics and reactions

Sustainable chemistry seeks to improve the efficiency and efficacy of industrial processes by, for example:

- Developing new separation and purification technologies that improve the energy and mass efficiency while reducing the use of solvents
- Developing new continuous flow, micro- and mini-reactors, heat exchangers, mixers, etc. numbered-up to meet volume requirements while improving industry flexibility and capital efficiency
- Developing state-of-the-art metrics and methodologies for assessing process efficiency, hazard, risk, and sustainability trade-offs throughout the life cycle of a product

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