UNDERSTANDING SUSTAINABLE CHEMISTRY

Sustainability presents a global challenge that must be addressed to ensure future generations prosper while using the available resources on this planet. Environmental, social, and economic factors all influence our ability to thrive, and actions aimed at addressing the sustainability challenge must be evaluated for the impacts on each of these factors.

The global chemistry enterprise is a significant economic engine that largely relies on the extraction and processing of non-renewable feedstock. The global chemical processing industry provides many of the raw materials that are used to create most of our manufactured goods. Because the global chemistry enterprise provides the material basis for society as we know it, it is critical that we take a leadership role in ensuring the future sustainability of critical environmental and human systems.

The traditional chemistry disciplines each provide tools, understanding, and technology that can be used to address 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 the sustainability of the global chemistry enterprise.

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 convert waste streams into valuable materials
- chemicals and materials that could be efficiently reused or recycled at their end-of-use
- Sustainable chemistry seeks to address issues associated with the use of potentially hazardous chemicals by, for example:
- Developing and using design rules, guidance and tools to predict and optimize new chemical entities for integrated performance, cost, and life cycle safety, health, and environmental impacts.

American Chemical Society
1155 Sixteenth Street, N.W. Washington, D.C. 20036 **T** [202] 872 6063 **F** [202] 872 6206 www.acs.org

- Diversifying the types and number of basic chemical building blocks beyond current high production volume chemical feedstock molecules provided by petrochemical extraction.
- 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 new catalysts (traditional, enzymatic, and biological) and synthetic methods including fermentation and traditional processing technologies for the transformation of biomass derived molecules into valuable products
- Creating multi-component, single pot cascade reactions, coupling and cyclization reactions, new reaction pathways
- Designing highly efficient chemistries that unite biological and chemical transformations as part of synthetic route design
- Using artificial intelligence and other emerging computation and big data tools to create efficient synthetic route design
- Developing and implementing the use of mass and 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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