LIMES PLUS Journal of Social Sciences and Humanities
ISSN: 1820-0869
E-ISSN: 2406-2871
Vol. 23 (2) 2026

Emerging Trends in Green Chemistry: Sustainable Solutions to Climate Change

Prof. Camille Renaudet
Institute for Digital Systems, Université de Montbrise, France

Received: 10.02.2026 Accepted: 28.05.2026 Publishing: 03.08.2026

Abstract:
The goal of sustainable chemistry, also called "green chemistry," is to lessen the negative effects of chemical production on the environment by reducing the amount of potentially harmful compounds used in chemical processes and products. Pollution, climate change, and the depletion of natural resources are just a few of the critical environmental problems that green chemistry may help solve. cutting-edge research in green chemistry, revealing novel approaches and tools for ecology protection. Developing more environmentally friendly solvents, increasing the use of renewable feedstocks, finding better ways to reduce waste through catalysis, and improving energy-efficient processes are all high on the list of research goals. Within the context of the circular economy, this article explores green chemistry, which is concerned with the production of chemicals through the use of previously used materials. Here you can find a comprehensive overview of green chemistry, including its current state, potential future directions for study and development, and the challenges that may prevent its broad use. These advancements demonstrate that green chemistry has the potential to lessen pollution in the industrial sector and make processes safer, cleaner, and more environmentally friendly.
Keywords: green chemistry, sustainable chemistry, renewable feedstocks, energy-efficient processes

Introduction:
There is an immediate need for more environmentally friendly methods of chemical manufacturing and other industrial operations due to the increasing global pollution, resource loss, and climate change. Because of their high energy consumption, hazardous waste production, and toxic chemical byproducts, conventional chemical processes are extremely detrimental to environmental health. These problems have contributed to the rise of "green chemistry" as an independent discipline, reflecting the growing awareness of the need to find safer alternatives to traditional chemical procedures. Green chemistry, also known as sustainable chemistry, is concerned with chemical processes, products, and technologies that endeavor to reduce energy consumption, waste, and the use of renewable raw materials. Their primary goal is to improve chemical processes so that they are less harmful to the environment and more efficient and long-lasting. Reducing resource consumption, improving industrial processes, and making materials safer are all possible outcomes of applying green chemistry concepts to chemical processes. These goals have been significantly advanced by recent developments in green chemistry. Renewable feedstock production, energy-efficient catalytic

processes, and safer alternatives to toxic solvents are transforming fields as diverse as materials research and medicine. The concept of a circular economy is gaining popularity as a means to lessen human impact on the environment; this approach, known as "green chemistry," is in line with this trend. exploring innovative approaches, tools, and ideas in green chemistry that are shaping a future that is less harmful to the environment and more sustainable. While praising achievements, we will also address the obstacles that prevent green chemical processes from being used more frequently. This discussion will center on two main points: first, the importance of green chemistry in fostering sustainability; and second, the ongoing demand for R&D to overcome obstacles and increase its influence across industries. These developments are opening the path for green chemistry, an emerging discipline that uses chemical processes to promote human and environmental health.

Emergence of Biochemicals and Alternative Fuels

Efforts to find sustainable substitutes for conventional petroleum-based chemicals have prompted research into renewable feedstocks and biochemicals. The manufacture of chemicals can be made in a more sustainable and eco-friendly way by using renewable feedstocks including plants, agricultural waste, and microorganisms. In an attempt to lessen the ecological footprint of chemical production and our reliance on nonrenewable resources, the green chemistry movement is pushing for the use of biomass feedstocks instead of fossil fuels. Renewable feedstocks and biochemicals have come a long way, but there are still many obstacles and possibilities to overcome before they can be fully utilized.

Bio-Based Chemicals: Opportunities and Challenges

A lot of people are interested in bio-based compounds made from renewable biomass instead of petroleum because they can help reduce emissions of greenhouse gases, lessen dependence on fossil fuels, and promote sustainability. Among the many organic components present in these compounds are plant biomass, agricultural waste, and algae. A significant step forward in the creation of bio-based goods has been the fermentation process, in which microbes convert sugars and other organic molecules into lactic acid, bio-based polymers, and ethanol.

Despite the promising outlook for bio-based chemical manufacturing going forward, several obstacles must be overcome before the technology can be expanded to fulfill industrial needs. There is a big threat to the economic feasibility of bio-based chemicals from competing with cheaper petroleum-based equivalents. Additionally, there is a clear need for a decrease in the astronomical prices of bioreactors and raw materials, and there is room for improvement in the efficiency of existing biotechnology methods. Due to the added complexity induced by the large variety in biomass feedstock content, successful product conversion requires personalized approaches.

Notwithstanding these obstacles, bio-based compounds hold tremendous promise. It is expected that bio-based chemicals would replace traditional petrochemicals as bioprocessing and biotechnology continue to improve the efficiency and output of bio-based production. New catalytic techniques and improvements in microbial fermentation have opened the door to greener and more cost-effective methods of making important biochemicals.

Non-Depleting Chemical Substances

A primary objective of green chemistry is the identification of more effective applications of renewable resources. As an alternative to fossil fuels, chemical synthesis might make use of wood, agricultural waste, algae, and food crops including sugarcane, soybeans, and maize. By recycling gases produced during photosynthesis, such as carbon dioxide, using these renewable raw materials can lessen the environmental impact of chemical manufacture. One further thing we can do to lessen our environmental effect is to find new uses for old food and other agricultural byproducts. Incorporating these resources into a circular economy would be a great idea.

The conversion of lignocellulosic biomass, which comprises resources like wood and agricultural residues, into biofuels and chemicals represents a major step forward in this field. Compared to more basic molecules like sugars and starches, lignocellulosic feedstocks are more resistant to degradation due to their complex structure. Improvements in pyrolysis and enzymatic hydrolysis, two pretreatment processes, are consistently raising the output of bio-based ethanol and butanol and other useful chemicals from lignocellulose.

In addition to their many other biochemical uses, algae have great promise as a feedstock for bioplastics and biofuels. Algae have many advantages over conventional crops, including low water needs, high oil and sugar yields that can be transformed into biofuels, and the ability to grow in infertile soil. Algae have recently shown an improvement in their chemical production capability due to genetic engineering, which offers up new possibilities for the environmentally benign creation of chemicals.

Biochemical Routes for the Conversion of Renewable Feedstocks

The fermentation, enzymatic catalysis, and microbial transformation processes are only a few of the numerous biochemical mechanisms that can change renewable feedstocks into biochemicals. Alteration by microbes is another biochemical effect. Bacteria with improved biochemical production capacity have been engineered thanks to recent developments in synthetic biology, metabolic engineering, and enzyme engineering. The development of synthetic biology has made this a reality. Using these genetically modified microorganisms, a broad variety of compounds can be produced from biomass. This class of molecules includes, among other things, aromatic compounds, polymers, organic acids, and alcohols.

Bioethanol and other bio-based compounds have been manufactured for a long time using fermentation procedures, which entail the conversion of carbohydrates into useful molecules by microbes like yeast or bacteria. Conversely, new developments have centered on increasing the variety of products that can be made by fermenting. The use of modified microorganisms in the production of bio-based butanol is one such example. Polymers and other chemicals used in industry rely on this as a key component. Microbial fermentation techniques can greatly improve the quality of lactic acid, a highly valuable molecule. Making biodegradable plastics requires using lactic acid.

One further interesting and novel approach that shows promise for making useful products from renewable feedstocks is the use of enzyme catalysis. Because of their selectivity in catalyzing reactions, enzymes are an excellent tool for green chemical synthesis since they may produce targeted compounds with no energy input and waste. Advances in enzyme

immobilization techniques and the identification of new enzyme catalysts have led to faster reactions and greater efficiency in biochemical transformations. Using renewable feedstocks is becoming more common due to both of these reasons.

Future Directions and Potential

A more sustainable and circular chemical industry can be built through the ongoing development of biochemicals and renewable feedstocks. More innovations are needed to improve the efficiency of biotechnological processes, lower production costs, and expand the scalability of using renewable feedstocks; this is necessary to overcome the economic problems linked with bio-based chemical synthesis. Renewable feedstocks are quickly becoming a viable alternative to petroleum-based resources in many different industries as biotechnologies progress. Products such as specialty chemicals, fuels, medicines, and polymers fall under this category.

One possible approach to turning carbon dioxide (CO2) into useful biochemicals and biofuels is to merge the manufacturing of renewable feedstock with carbon collecting and utilization technology. More efficient and cost-effective conversion of complicated biomass into useable products will be achievable with the further development of microbial and enzymatic systems. Finally, the green chemistry movement is spearheading the use of innovative biochemicals and sustainable feedstocks. As an alternative to more traditional methods of chemical synthesis, these materials are better for the environment. While there are still obstacles to overcome in terms of process efficiency and industry economic competitiveness, this field of study is also generating exciting new solutions that could lead to a more sustainable and eco-friendly future. In order to create a chemical industry that is less harmful to the environment and more sustainable, it is crucial to keep developing these technologies.

Conclusion:

Innovations in biochemicals and renewable feedstocks are triggering industry shifts by supplying greener alternatives to fossil fuel-dependent operations. These developments are crucial for the long-term health of sustainable chemistry. Using raw materials sourced from living organisms lessens our load on finite resources and mitigates the environmental damage caused by chemical manufacturing. This class includes industrial byproducts, algae, and agricultural crops. The possibility of bio-based chemicals replacing petroleum-based products is increasing exponentially due to biotech advances that more efficiently transform renewable feedstocks into useful compounds. Thanks to recent advancements in metabolic engineering, enzyme catalysis, and microbial fermentation, large-scale production of renewable chemicals is now feasible. Because of these developments, producing renewable chemicals is now within reach, despite the difficulties associated with economic feasibility, feedstock unpredictability, and process efficiency. A circular economy, which prioritizes recycling and waste reduction, is quickly becoming the norm in the chemical sector as a result of these innovations. A greener, more sustainable chemical industry is likely in the future thanks to the use of biochemicals and renewable feedstocks. Recent developments in biotechnology and green chemistry are mitigating some of the environmental damage caused by chemical production. If we want to make the most of its potential, we must continuously invest in scientific research, technological

advancement, and economic optimization. Sustainable biochemicals and renewable feedstocks hold the key to a greener, safer future for all living things. If these materials can solve current problems and build upon successful technologies, they could be pivotal in bringing about the global sustainability goals.

Bibliography

- Philipp Haueis - **2024** - *British Journal for the Philosophy of Science* 75 (3):741-768. Klodjan Xhexhi & Besnik Aliaj - **2024** - *5Th International Conference on Environmental Design and Health (Iced2024)* 585:6
- Marina Paola Banchetti-Robino & Giovanni Villani - **2023** - New York, NY: Oxford University Press.
- Victor Christianto, T. Daniel Chandra & Florentin Smarandache - **2023** - *Bulletin of Pure and Applied Sciences* 42 (2):85-100.
- Victor Christianto, T. Daniel Chandra & Florentin Smarandache - **2023** - *Bulletin of Pure and Applied Sciences* 42 (2):70-75.
- Chuck Chuan Ng - **2023** - *Journal of Environmental Management* 341 (117926).
- Chuck Chuan Ng - **2023** - *Journal of Material Cycles and Waste Management* 2023.
- Rossano Pancaldi - **2023** - *Il Pensiero Mazziniano* 1: pp. 143-169.