

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal) | Impact Factor: 7.512|

Visit: www.ijirset.com

Vol. 9, Issue 2, February 2020

A Study on the Role of Green Chemistry in Daily Life

¹Dr. Varsha Srivastava, ²Dr. Nidhi Vinod Singh, ³Dr. Udai Pratap Singh

^{1,2}Assistant Professor, Dept. of Chemistry, DAV College, Kanpur, Uttar Pradesh, India

³Assistant Professor (Corresponding Author), Dept. of Chemistry, DAV College, Kanpur, Uttar Pradesh, India

ABSTRACT: Green chemistry, similar to sustainable chemistry or circular chemistry,^[1] is an area of chemistry and chemical engineering focused on the design of products and processes that minimize or eliminate the use and generation of hazardous substances.^[2] While environmental chemistry focuses on the effects of polluting chemicals on nature, green chemistry focuses on the environmental impact of chemistry, including lowering consumption of nonrenewable resources and technological approaches for preventing pollution.^{[3][4][5][6][7][8]}

The overarching goals of green chemistry—namely, more resource-efficient and inherently safer design of molecules, materials, products, and processes—can be pursued in a wide range of contexts.

Green chemistry emerged from a variety of existing ideas and research efforts (such as atom economy and catalysis) in the period leading up to the 1990s, in the context of increasing attention to problems of chemical pollution and resource depletion. The development of green chemistry in Europe and the United States was linked to a shift in environmental problem-solving strategies: a movement from command and control regulation and mandated lowering of industrial emissions at the "end of the pipe," toward the active prevention of pollution through the innovative design of production technologies themselves. The set of concepts now recognized as green chemistry coalesced in the mid- to late-1990s, along with broader adoption of the term (which prevailed over competing terms such as "clean" and "sustainable" chemistry).^{[11][12]}

In the United States, the Environmental Protection Agency played a significant early role in fostering green chemistry through its pollution prevention programs, funding, and professional coordination. At the same time in the United Kingdom, researchers at the University of York contributed to the establishment of the Green Chemistry Network within the Royal Society of Chemistry, and the launch of the journal *Green Chemistry*.^[12]

KEYWORDS: Green, Chemistry, Sustainable, Environmental, Pollution, Regulation, EPA, Clean, Resources

I. INTRODUCTION

In 1998, Paul Anastas (who then directed the Green Chemistry Program at the US EPA) and John C. Warner (then of Polaroid Corporation) published a set of principles to guide the practice of green chemistry.^[13] The twelve principles address a range of ways to lower the environmental and health impacts of chemical production, and also indicate research priorities for the development of green chemistry technologies.

The principles cover such concepts as:

- the design of processes to maximize the amount of raw material that ends up in the product;
- the use of renewable material feedstocks and energy sources;
- the use of safe, environmentally benign substances, including solvents, whenever possible;
- the design of energy efficient processes;

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal) | Impact Factor: 7.512|

Visit: www.ijirset.com

Vol. 9, Issue 2, February 2020

- avoiding the production of waste, which is viewed as the ideal form of waste management.

The twelve principles of green chemistry are:^[14]

1. Prevention. Preventing waste is better than treating or cleaning up waste after it is created.
2. Atom economy. Synthetic methods should try to maximize the incorporation of all materials used in the process into the final product. This means that less waste will be generated as a result.
3. Less hazardous chemical syntheses. Synthetic methods should avoid using or generating substances toxic to humans and/or the environment.
4. Designing safer chemicals. Chemical products should be designed to achieve their desired function while being as non-toxic as possible.
5. Safer solvents and auxiliaries. Auxiliary substances should be avoided wherever possible, and as non-hazardous as possible when they must be used.
6. Design for energy efficiency. Energy requirements should be minimized, and processes should be conducted at ambient temperature and pressure whenever possible.
7. Use of renewable feedstocks. Whenever it is practical to do so, renewable feedstocks or raw materials are preferable to non-renewable ones.
8. Reduce derivatives. Unnecessary generation of derivatives—such as the use of protecting groups—should be minimized or avoided if possible; such steps require additional reagents and may generate additional waste.
9. Catalysis. Catalytic reagents that can be used in small quantities to repeat a reaction are superior to stoichiometric reagents (ones that are consumed in a reaction).
10. Design for degradation. Chemical products should be designed so that they do not pollute the environment; when their function is complete, they should break down into non-harmful products.
11. Real-time analysis for pollution prevention. Analytical methodologies need to be further developed to permit real-time, in-process monitoring and control before hazardous substances form.
12. Inherently safer chemistry for accident prevention. Whenever possible, the substances in a process, and the forms of those substances, should be chosen to minimize risks such as explosions, fires, and accidental releases.

Trends

Attempts are being made not only to quantify the greenness of a chemical process but also to factor in other variables such as chemical yield, the price of reaction components, safety in handling chemicals, hardware demands, energy profile and ease of product workup and purification. In one quantitative study,^[15] the reduction of nitrobenzene to aniline receives 64 points out of 100 marking it as an acceptable synthesis overall whereas a synthesis of an amide using HMDS is only described as adequate with a combined 32 points.

Green chemistry is increasingly seen as a powerful tool that researchers must use to evaluate the environmental impact of nanotechnology.^[16] As nano materials are developed, the environmental and human health impacts of both the products themselves and the processes to make them must be considered to ensure their long-term economic viability. There is a trend of nano material technology in the practice, however, people ignored the potential nanotoxicity. Therefore, people need to address further consideration on legal, ethical, safety, and regulatory issues associated with nanomaterials,^[17]

Examples

Green solvents

The major application of solvents in human activities is in paints and coatings (46% of usage). Smaller volume applications include cleaning, de-greasing, adhesives, and in chemical synthesis.^[18] Traditional solvents are often toxic

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal) | Impact Factor: 7.512|

Visit: www.ijirset.com

Vol. 9, Issue 2, February 2020

or are chlorinated. Green solvents, on the other hand, are generally less harmful to health and the environment and preferably more sustainable. Ideally, solvents would be derived from renewable resources and biodegrade to innocuous, often a naturally occurring product.^{[19][20]} However, the manufacture of solvents from biomass can be more harmful to the environment than making the same solvents from fossil fuels.^[21] Thus the environmental impact of solvent manufacture must be considered when a solvent is being selected for a product or process.^[22] Another factor to consider is the fate of the solvent after use. If the solvent is being used in an enclosed situation where solvent collection and recycling is feasible, then the energy cost and environmental harm associated with recycling should be considered; in such a situation water, which is energy-intensive to purify, may not be the greenest choice. On the other hand, a solvent contained in a consumer product is likely to be released into the environment upon use, and therefore the environmental impact of the solvent itself is more important than the energy cost and impact of solvent recycling; in such a case water is very likely to be a green choice. In short, the impact of the entire lifetime of the solvent, from cradle to grave (or cradle to cradle if recycled) must be considered. Thus the most comprehensive definition of a green solvent is the following: "a green solvent is the solvent that makes a product or process have the least environmental impact over its entire life cycle."^[23]

By definition, then, a solvent might be green for one application (because it results in less environmental harm than any other solvent that could be used for that application) and yet not be a green solvent for a different application. A classic example is water, which is a very green solvent for consumer products such as toilet bowl cleaner but is not a green solvent for the manufacture of polytetrafluoroethylene. For the production of that polymer, the use of water as solvent requires the addition of perfluorinated surfactants which are highly persistent. Instead, supercritical carbon dioxide seems to be the greenest solvent for that application because it performs well without any surfactant.^[23] In summary, no solvent can be declared to be a "green solvent" unless the declaration is limited to a specific application.

Synthetic techniques

Novel or enhanced synthetic techniques can often provide improved environmental performance or enable better adherence to the principles of green chemistry. For example, the 2005 Nobel Prize for Chemistry was awarded to Yves Chauvin, Robert H. Grubbs and Richard R. Schrock, for the development of the metathesis method in organic synthesis, with explicit reference to its contribution to green chemistry and "smarter production."^[24] A 2005 review identified three key developments in green chemistry in the field of organic synthesis: use of supercritical carbon dioxide as green solvent, aqueous hydrogen peroxide for clean oxidations and the use of hydrogen in asymmetric synthesis.^[25] Some further examples of applied green chemistry are supercritical water oxidation, on water reactions, and dry media reactions.¹

Bioengineering is also seen as a promising technique for achieving green chemistry goals. A number of important process chemicals can be synthesized in engineered organisms, such as shikimate, a Tamiflu precursor which is fermented by Roche in bacteria. Click chemistry is often cited⁴ as a style of chemical synthesis that is consistent with the goals of green chemistry. The concept of 'green pharmacy' has recently been articulated based on similar principles.^[26]

Carbon dioxide as blowing agent

In 1996, Dow Chemical won the 1996 Greener Reaction Conditions award for their 100% carbon dioxide blowing agent for polystyrene foam production. Polystyrene foam is a common material used in packing and food transportation. Seven hundred million pounds are produced each year in the United States alone. Traditionally, CFC and other ozone-depleting chemicals were used in the production process of the foam sheets, presenting a serious environmental hazard. Flammable, explosive, and, in some cases toxic hydrocarbons have also been used as CFC replacements, but they present their own problems. Dow Chemical discovered that supercritical carbon dioxide works equally as well as a blowing agent, without the need for hazardous substances, allowing the polystyrene to be more easily recycled. The CO₂ used in the process is reused from other industries, so the net carbon released from the process is zero.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal) | Impact Factor: 7.512|

Visit: www.ijirset.com

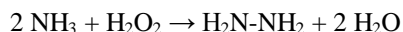
Vol. 9, Issue 2, February 2020

Hydrazine

Addressing principle #2 is the peroxide process for producing hydrazine without cogenerating salt. Hydrazine is traditionally produced by the Olin Raschig process from sodium hypochlorite (the active ingredient in many bleaches) and ammonia. The net reaction produces one equivalent of sodium chloride for every equivalent of the targeted product hydrazine:^[27]



In the greener peroxide process hydrogen peroxide is employed as the oxidant and the side product is water. The net conversion follows:

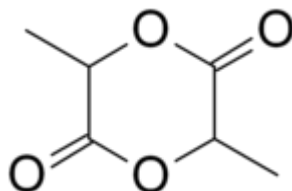


Addressing principle #4, this process does not require auxiliary extracting solvents. Methyl ethyl ketone is used as a carrier for the hydrazine, the intermediate ketazine phase separates from the reaction mixture, facilitating workup without the need of an extracting solvent.

1,3-Propanediol

Addressing principle #7 is a green route to 1,3-propanediol, which is traditionally generated from petrochemical precursors. It can be produced from renewable precursors via the bioseparation of 1,3-propanediol using a genetically modified strain of *E. coli*.^[28] This diol is used to make new polyesters for the manufacture of carpets.

Lactide



Lactide

In 2002, Cargill Dow (now NatureWorks) won the Greener Reaction Conditions Award for their improved method for polymerization of polylactic acid. Unfortunately, lactide-base polymers do not perform well and the project was discontinued by Dow soon after the award. Lactic acid is produced by fermenting corn and converted to lactide, the cyclic dimer ester of lactic acid using an efficient, tin-catalyzed cyclization. The L,L-lactide enantiomer is isolated by distillation and polymerized in the melt to make a crystallizable polymer, which has some applications including textiles and apparel, cutlery, and food packaging. Wal-Mart has announced that it is using/will use PLA for its produce packaging. The NatureWorks PLA process substitutes renewable materials for petroleum feedstocks, doesn't require the use of hazardous organic solvents typical in other PLA processes, and results in a high-quality polymer that is recyclable and compostable.

Carpet tile backings

In 2003 Shaw Industries selected a combination of polyolefin resins as the base polymer of choice for EcoWorx due to the low toxicity of its feedstocks, superior adhesion properties, dimensional stability, and its ability to be recycled. The EcoWorx compound also had to be designed to be compatible with nylon carpet fiber. Although EcoWorx may be recovered from any fiber type, nylon-6 provides a significant advantage. Polyolefins are compatible with known nylon-6 depolymerization methods. PVC interferes with those processes. Nylon-6 chemistry is well-known and not addressed in first-generation production. From its inception, EcoWorx met all of the design criteria necessary to satisfy the needs of the marketplace from a performance, health, and environmental standpoint. Research indicated that separation of the fiber and backing through elutriation, grinding, and air separation proved to be the best way to recover the face and backing components, but an infrastructure for returning postconsumer EcoWorx to the elutriation process was

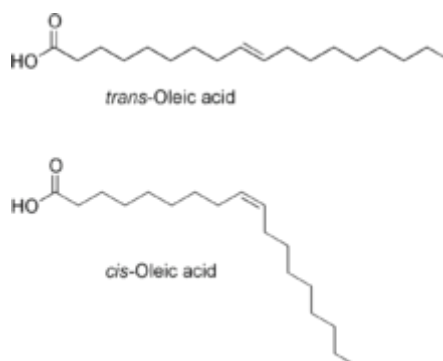
International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal) | Impact Factor: 7.512|

Visit: www.ijirset.com

Vol. 9, Issue 2, February 2020

necessary. Research also indicated that the postconsumer carpet tile had a positive economic value at the end of its useful life. EcoWorx is recognized by MBDC as a certified cradle-to-cradle design.



Trans and cis fatty acids

Transesterification of fats

In 2005, Archer Daniels Midland (ADM) and Novozymes won the Greener Synthetic Pathways Award for their enzyme interesterification process. In response to the U.S. Food and Drug Administration (FDA) mandated labeling of trans-fats on nutritional information by January 1, 2006, Novozymes and ADM worked together to develop a clean, enzymatic process for the interesterification of oils and fats by interchanging saturated and unsaturated fatty acids. The result is commercially viable products without trans-fats. In addition to the human health benefits of eliminating trans-fats, the process has reduced the use of toxic chemicals and water, prevents vast amounts of byproducts, and reduces the amount of fats and oils wasted.

Bio-succinic acid

In 2011, the Outstanding Green Chemistry Accomplishments by a Small Business Award went to BioAmber Inc. for integrated production and downstream applications of bio-based succinic acid. Succinic acid is a platform chemical that is an important starting material in the formulations of everyday products. Traditionally, succinic acid is produced from petroleum-based feedstocks. BioAmber has developed process and technology that produces succinic acid from the fermentation of renewable feedstocks at a lower cost and lower energy expenditure than the petroleum equivalent while sequestering CO₂ rather than emitting it.^[29] However, lower prices of oil precipitated the company into bankruptcy^[30] and bio-sourced succinic acid is now barely made.^[31]

Laboratory chemicals

Several laboratory chemicals are controversial from the perspective of Green chemistry. The Massachusetts Institute of Technology created a "Green" Alternatives Wizard [2] to help identify alternatives. Ethidium bromide, xylene, mercury, and formaldehyde have been identified as "worst offenders" which have alternatives.^[32] Solvents in particular make a large contribution to the environmental impact of chemical manufacturing and there is a growing focus on introducing Greener solvents into the earliest stage of development of these processes: laboratory-scale reaction and purification methods.^[33] In the Pharmaceutical Industry, both GSK^[34] and Pfizer^[35] have published Solvent Selection Guides for their Drug Discovery chemists.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal) | Impact Factor: 7.512|

Visit: www.ijirset.com

Vol. 9, Issue 2, February 2020

II. DISCUSSION

Legislation

The EU

In 2007, The EU put into place the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) program, which requires companies to provide data showing that their products are safe. This regulation (1907/2006) ensures not only the assessment of the chemicals' hazards as well as risks during their uses but also includes measures for banning or restricting/authorising uses of specific substances. ECHA, the EU Chemicals Agency in Helsinki, is implementing the regulation whereas the enforcement lies with the EU member states.

United States

The United States formed the Environmental Protection Agency (EPA) in 1970 to protect human and environmental health by creating and enforcing environmental regulation. Green chemistry builds on the EPA's goals by encouraging chemists and engineers to design chemicals, processes, and products that avoid the creation of toxins and waste.^[36]

The U.S. law that governs the majority of industrial chemicals (excluding pesticides, foods, and pharmaceuticals) is the Toxic Substances Control Act (TSCA) of 1976. Examining the role of regulatory programs in shaping the development of green chemistry in the United States, analysts have revealed structural flaws and long-standing weaknesses in TSCA; for example, a 2006 report to the California Legislature concludes that TSCA has produced a domestic chemicals market that discounts the hazardous properties of chemicals relative to their function, price, and performance.^[37] Scholars have argued that such market conditions represent a key barrier to the scientific, technical, and commercial success of green chemistry in the U.S., and fundamental policy changes are needed to correct these weaknesses.^[38]

Passed in 1990, the Pollution Prevention Act helped foster new approaches for dealing with pollution by preventing environmental problems before they happen.

Green chemistry grew in popularity in the United States after the Pollution Prevention Act of 1990 was passed. This Act declared that pollution should be lowered by improving designs and products rather than treatment and disposal. These regulations encouraged chemists to reimagine pollution and research ways to limit the toxins in the atmosphere. In 1991, the EPA Office of Pollution Prevention and Toxics created a research grant program encouraging the research and recreation of chemical products and processes to limit the impact on the environment and human health.^[39] The EPA hosts The Green Chemistry Challenge each year to incentivize the economic and environmental benefits of developing and utilizing green chemistry.^[40]

In 2008, the State of California approved two laws aiming to encourage green chemistry, launching the California Green Chemistry Initiative. One of these statutes required California's Department of Toxic Substances Control (DTSC) to develop new regulations to prioritize "chemicals of concern" and promote the substitution of hazardous chemicals with safer alternatives. The resulting regulations took effect in 2013, initiating DTSC's Safer Consumer Products Program.^[41]

Education

Many institutions offer courses^[42] and degrees on Green Chemistry. Examples from across the globe are Denmark's Technical University,^[43] and several in the US, e.g. at the Universities of Massachusetts-Boston,^[44] Michigan,^[45] and Oregon.^[46] Masters and doctoral level courses in Green Technology has been introduced by the Institute of Chemical Technology, India.^[47] In the UK at the University of York^[48] University of Leicester, Department of Chemistry and MRes in Green Chemistry at Imperial College London. In Spain different universities like the Universitat Jaume I^[49] or the Universidad de Navarra,^[50] offer Green Chemistry master courses. There are also websites focusing on green chemistry, such as the Michigan Green Chemistry Clearinghouse.^[51]

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal) | Impact Factor: 7.512|

Visit: www.ijirset.com

Vol. 9, Issue 2, February 2020

Apart from its Green Chemistry Master courses the Zurich University of Applied Sciences ZHAW presents an exposition and web page "Making chemistry green" for a broader public, illustrating the 12 principles.^[52]

Scientific journals specialized in green chemistry

- Green Chemistry (RSC)
- Green Chemistry Letters and Reviews (Open Access) (Taylor & Francis)
- ChemSusChem (Wiley)
- ACS Sustainable Chemistry & Engineering (ACS)

Contested definition

There are ambiguities in the definition of green chemistry, and in how it is understood among broader science, policy, and business communities. Even within chemistry, researchers have used the term "green chemistry" to describe a range of work independently of the framework put forward by Anastas and Warner (i.e., the 12 principles).^[12] While not all uses of the term are legitimate (see greenwashing), many are, and the authoritative status of any single definition is uncertain. More broadly, the idea of green chemistry can easily be linked (or confused) with related concepts like green engineering, environmental design, or sustainability in general. The complexity and multifaceted nature of green chemistry makes it difficult to devise clear and simple metrics. As a result, "what is green" is often open to debate.^[53]

Awards

Several scientific societies have created awards to encourage research in green chemistry.

- Australia's Green Chemistry Challenge Awards overseen by The Royal Australian Chemical Institute (RACI).
- The Canadian Green Chemistry Medal.^[54]
- In Italy, Green Chemistry activities center around an inter-university consortium known as INCA.^[55]
- In Japan, The Green & Sustainable Chemistry Network oversees the GSC awards program.^[56]
- In the United Kingdom, the Green Chemical Technology Awards are given by Crystal Faraday.^[57]
- In the US, the Presidential Green Chemistry Challenge Awards recognize individuals and businesses.^{[58][59]}

Green engineering not the design of products and processes by applying financially and technologically feasible principles to achieve one or more of the following goals: (1) decrease in the amount of pollution that is generated by a construction or operation of a facility, (2) minimization of human population exposure to potential hazards (including reducing toxicity), (3) improved uses of matter and energy throughout the life cycle of the product and processes, and (4) maintaining economic efficiency and viability.^[1] Green engineering can an overarching framework for all design disciplines.

Principles

Green engineering follows nine guiding principles:

1. Engineer processes and products holistically, use systems analysis and integrate environmental impact assessment tools.
2. Conserve and improve natural ecosystems while protecting human health and well-being.
3. Use life-cycle thinking in all engineering activities.
4. Ensure that all material and energy inputs and outputs are as inherently safe and benign as possible.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal) | Impact Factor: 7.512|

Visit: www.ijirset.com

Vol. 9, Issue 2, February 2020

5. Minimize the depletion of natural resources.
6. Prevent waste.
7. Develop and apply engineering solutions while being cognizant of local geography, aspirations, and cultures.
8. Create engineering solutions beyond current or dominant technologies; improve, innovate, and invent (technologies) to achieve sustainability.
9. Actively engage communities and stakeholders in development of engineering solutions.^{[2][3]}

In 2003, The American Chemical Society introduced a new list of twelve principles:

1. Inherent Rather Than Circumstantial – Designers need to strive to ensure that all materials and energy inputs and outputs are as inherently nonhazardous as possible.
2. Prevention Instead of Treatment – It is better to prevent waste than to treat or clean up waste after it is formed.
3. Design for Separation – Separation and purification operations should be designed to minimize energy consumption and materials use.
4. Maximize Efficiency – Products, processes, and systems should be designed to maximize mass, energy, space, and time efficiency.
5. Output-Pulled Versus Input-Pushed – Products, processes, and systems should be "output pulled" rather than "input pushed" through the use of energy and materials.
6. Conserve Complexity – Embedded entropy and complexity must be viewed as an investment when making design choices on recycling, reuse, or beneficial disposition.
7. Durability Rather Than Immortality – Targeted durability, not immortality, should be a design goal.
8. Meet Need, Minimize Excess – Design for unnecessary capacity or capability (e.g., "one size fits all") solutions should be considered a design flaw.
9. Minimize Material Diversity – Material diversity in multicomponent products should be minimized to promote disassembly and value retention.
10. Integrate Material and Energy Flows – Design of products, processes, and systems must include integration and interconnectivity with available energy and materials flows.
11. Design for Commercial "Afterlife" – Products, processes, and systems should be designed for performance in a commercial "afterlife."
12. Renewable Rather Than Depleting – Material and energy inputs should be renewable rather than depleting.^[4]

Systems approach

Many engineering disciplines engage in green engineering. This includes sustainable design, life cycle analysis (LCA), pollution prevention, design for the environment (DfE), design for disassembly (DfD), and design for recycling (DfR). As such, green engineering is a subset of sustainable engineering.^[5] Green engineering involves four basic approaches to improve processes and products to make them more efficient from an environmental standpoint.^[6]

1. Waste reduction;
2. Materials management;
3. Pollution prevention; and,
4. Product enhancement.

Green engineering approaches design from a systematic perspective which integrates numerous professional disciplines. In addition to all engineering disciplines, green engineering includes land use planning, architecture, landscape architecture, and other design fields, as well as the social sciences (e.g. to determine how various groups of people use products and services). Green engineers are concerned with space, the sense of place, viewing the site map as a set of fluxes across the boundary, and considering the combinations of these systems over larger regions, e.g. urban

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal) | Impact Factor: 7.512|

Visit: www.ijirset.com

Vol. 9, Issue 2, February 2020

areas. The life cycle analysis is an important green engineering tool, which provides a holistic view of the entirety of a product, process or activity, encompassing raw materials, manufacturing, transportation, distribution, use, maintenance, recycling, and final disposal. Assessing its life cycle should yield a complete picture of the product. The first step in a life cycle assessment is to gather data on the flow of a material through an identifiable society. Once the quantities of various components of such a flow are known, the important functions and impacts of each step in the production, manufacture, use, and recovery/disposal are estimated. In sustainable design, engineers must optimize for variables that give the best performance in temporal frames.^[7]

The system approach employed in green engineering is similar to value engineering (VE). Daniel A. Vallero has compared green engineering to be a form of VE because both systems require that all elements and linkages within the overall project be considered to enhance the value of the project. Every component and step of the system must be challenged. Ascertaining overall value is determined not only by a project's cost-effectiveness, but other values, including environmental and public health factors. Thus, the broader sense of VE is compatible with and can be identical to green engineering, since VE is aimed at effectiveness, not just efficiency, i.e. a project is designed to achieve multiple objectives, without sacrificing any important values. Efficiency is an engineering and thermodynamic term for the ratio of an input to an output of energy and mass within a system. As the ratio approaches 100%, the system becomes more efficient. Effectiveness requires that efficiencies be met for each component, but also that the integration of components lead to an effective, multiple value-based design.^[8] Green engineering is also a type of concurrent engineering, since tasks must be parallelized to achieve multiple design objectives.

III. RESULTS

Green building (also known as green construction or sustainable building) refers to both a structure and the application of processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: from planning to design, construction, operation, maintenance, renovation, and demolition.^[1] This requires close cooperation of the contractor, the architects, the engineers, and the client at all project stages.^[2] The Green Building practice expands and complements the classical building design concerns of economy, utility, durability, and comfort.^[1] Green building also refers to saving resources to the maximum extent, including energy saving, land saving, water saving, material saving, etc., during the whole life cycle of the building, protecting the environment and reducing pollution, providing people with healthy, comfortable and efficient use of space, and being in harmony with nature Buildings that live in harmony. Green building technology focuses on low consumption, high efficiency, economy, environmental protection, integration and optimization.^[3]

Although new technologies are constantly being developed to complement current practices in creating greener structures, the common objective of green buildings is to reduce the overall impact of the built environment on human health and the natural environment by:

- Efficiently using energy, water, and other resources
- Protecting occupant health and improving employee productivity (see healthy building)
- Reducing waste, pollution, and environmental degradation^[1]

Natural building is a similar concept, usually on a smaller scale and focusing on the use of locally available natural materials.^[5] Other related topics include sustainable design and green architecture. Sustainability may be defined as meeting the needs of present generations without compromising the ability of future generations to meet their needs.^[6] Although some green building programs don't address the issue of retrofitting existing homes, others do, especially through public schemes for energy efficient refurbishment. Green construction principles can easily be applied to retrofit work as well as new construction.

A 2009 report by the U.S. General Services Administration found 12 sustainably-designed buildings that cost less to operate and have excellent energy performance. In addition, occupants were overall more satisfied with the building than those in typical commercial buildings. These are eco-friendly buildings.^[7]

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal) | Impact Factor: 7.512|

Visit: www.ijirset.com

Vol. 9, Issue 2, February 2020

Reducing environmental impact

Buildings represent a large part of energy, electricity, water and materials consumption. As of 2019, they account for 37% of global energy use and energy-related CO₂ emissions, which the United Nations estimate contributed to 33% of overall worldwide emissions.^{[8][9]} Including the manufacturing of building materials, the global CO₂ emissions were 39%.^[10] If new technologies in construction are not adopted during this time of rapid growth, emissions could double by 2050, according to the United Nations Environment Program.

Buildings account for a large amount of land. According to the National Resources Inventory, approximately 107 million acres (430,000 km²) of land in the United States are developed. The International Energy Agency released a publication that estimated that existing buildings are responsible for more than 40% of the world's total primary energy consumption and for 24% of global carbon dioxide emissions.^{[11][12]}

According to Global status report from the year 2016, buildings consume more than 30% of all produced energy. The report states that "Under a below 2°C trajectory, effective action to improve building energy efficiency could limit building final energy demand to just above current levels, meaning that the average energy intensity of the global building stock would decrease by more than 80% by 2050".^[13]



Hanging gardens of One Central Park, Sydney

Green building practices aim to reduce the environmental impact of building as the building sector has the greatest potential to deliver significant cuts in emissions at little or no cost. General guidelines can be summarized as follows: Every building should be as small as possible. Avoid contributing to sprawl, even if the most energy-efficient, environmentally sound methods are used in design and construction. Bioclimatic design principles are able to reduce energy expenditure and by extension, carbon emissions. Bioclimatic design is a method of building design that takes local climate into account to create comfortable conditions within the structure.^{[14][15]} This could be as simple as constructing a different shape for the building envelope or facing the building towards the south to maximize solar exposure for energy or lighting purposes. Given the limitations of city planned construction, bioclimatic principles may be employed on a lesser scale, however it is still an effective passive method to reduce environmental impact.

The concept of sustainable development can be traced to the energy (especially fossil oil) crisis and environmental pollution concerns of the 1960s and 1970s.^[17] The Rachel Carson book, "Silent Spring",^[18] published in 1962, is considered to be one of the first initial efforts to describe sustainable development as related to green building.^[17] The green building movement in the U.S. originated from the need and desire for more energy efficient and environmentally friendly construction practices. There are a number of motives for building green, including environmental, economic, and social benefits.^[1] However, modern sustainability initiatives call for an integrated and synergistic design to both new construction and in the retrofitting of existing structures. Also known as sustainable design, this approach integrates the building life-cycle with each green practice employed with a design-purpose to create a synergy among the practices used.

Green building brings together a vast array of practices, techniques, and skills to reduce and ultimately eliminate the impacts of buildings on the environment and human health. It often emphasizes taking advantage of renewable resources, e.g., using sunlight through passive solar, active solar, and photovoltaic equipment, and using plants and trees through green roofs, rain gardens, and reduction of rainwater run-off. Many other techniques are used, such as

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal) | Impact Factor: 7.512|

Visit: www.ijirset.com

Vol. 9, Issue 2, February 2020

using low-impact building materials or using packed gravel or permeable concrete instead of conventional concrete or asphalt to enhance replenishment of groundwater.

While the practices or technologies employed in green building are constantly evolving and may differ from region to region, fundamental principles persist from which the method is derived: siting and structure design efficiency, energy efficiency, water efficiency, materials efficiency, indoor environmental quality enhancement, operations and maintenance optimization and waste and toxics reduction.^{[19][20]} The essence of green building is an optimization of one or more of these principles. Also, with the proper synergistic design, individual green building technologies may work together to produce a greater cumulative effect.

On the aesthetic side of green architecture or sustainable design is the philosophy of designing a building that is in harmony with the natural features and resources surrounding the site. There are several key steps in designing sustainable buildings: specify 'green' building materials from local sources, reduce loads, optimize systems, and generate on-site renewable energy.

Life cycle assessment

A life cycle assessment (LCA) can help avoid a narrow outlook on environmental, social and economic concerns^[21] by assessing a full range of impacts associated with all cradle-to-grave stages of a process: from extraction of raw materials through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling. Impacts taken into account include (among others) embodied energy, global warming potential, resource use, air pollution, water pollution, and waste.

In terms of green building, the last few years have seen a shift away from a prescriptive approach, which assumes that certain prescribed practices are better for the environment, toward the scientific evaluation of actual performance through LCA.

Siting and structure design efficiency

The foundation of any construction project is rooted in the concept and design stages. The concept stage, in fact, is one of the major steps in a project life cycle, as it has the largest impact on cost and performance.^[24] In designing environmentally optimal buildings, the objective is to minimize the total environmental impact associated with all life-cycle stages of the building project.



Exterior Light Shelves - Green Office Building, Denver, Colorado

However, building as a process is not as streamlined as an industrial process, and varies from one building to the other, never repeating itself identically. In addition, buildings are much more complex products, composed of a multitude of materials and components each constituting various design variables to be decided at the design stage. A variation of every design variable may affect the environment during all the building's relevant life-cycle stages.^[25]

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal) | Impact Factor: 7.512|

Visit: www.ijirset.com

Vol. 9, Issue 2, February 2020

Energy efficiency



An eco-house at Findhorn Ecovillage with a turf roof and solar panels

Green buildings often include measures to reduce energy consumption – both the embodied energy required to extract, process, transport and install building materials and operating energy to provide services such as heating and power for equipment.

As high-performance buildings use less operating energy, embodied energy has assumed much greater importance – and may make up as much as 30% of the overall life cycle energy consumption. Studies such as the U.S. LCI Database Project^[26] show buildings built primarily with wood will have a lower embodied energy than those built primarily with brick, concrete, or steel.^[27]

To reduce operating energy use, designers use details that reduce air leakage through the building envelope (the barrier between conditioned and unconditioned space). They also specify high-performance windows and extra insulation in walls, ceilings, and floors. Another strategy, passive solar building design, is often implemented in low-energy homes. Designers orient windows and walls and place awnings, porches, and trees^[28] to shade windows and roofs during the summer while maximizing solar gain in the winter. In addition, effective window placement (daylighting) can provide more natural light and lessen the need for electric lighting during the day. Solar water heating further reduces energy costs.

Onsite generation of renewable energy through solar power, wind power, hydro power, or biomass can significantly reduce the environmental impact of the building. Power generation is generally the most expensive feature to add to a building.

Energy efficiency for green buildings can be evaluated from either numerical or non-numerical methods. These include use of simulation modelling, analytical or statistical tools.^[29]

Water efficiency

Reducing water consumption and protecting water quality are key objectives in sustainable building. One critical issue of water consumption is that in many areas, the demands on the supplying aquifer exceed its ability to replenish itself. To the maximum extent feasible, facilities should increase their dependence on water that is collected, used, purified, and reused on-site. The protection and conservation of water throughout the life of a building may be accomplished by designing for dual plumbing that recycles water in toilet flushing or by using water for washing of the cars. Wastewater may be minimized by utilizing water conserving fixtures such as ultra-low flush toilets and low-flow shower heads.^[30] Bidets help eliminate the use of toilet paper, reducing sewer traffic and increasing possibilities of re-using water on-site. Point of use water treatment and heating improves both water quality and energy efficiency while reducing the amount of water in circulation. The use of non-sewage and greywater for on-site use such as site-irrigation will minimize demands on the local aquifer.^[31]

Large commercial buildings with water and energy efficiency can qualify for an LEED Certification. Philadelphia's Comcast Center is the tallest building in Philadelphia. It's also one of the tallest buildings in the USA that

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal) | Impact Factor: 7.512|

Visit: www.ijirset.com

Vol. 9, Issue 2, February 2020

is LEED Certified. Their environmental engineering consists of a hybrid central chilled water system which cools floor-by-floor with steam instead of water. Burn's Mechanical set-up the entire renovation of the 58 story, 1.4 million square foot sky scraper.

Materials efficiency

Building materials typically considered 'green' include lumber(that has been certified to a third-party standard), rapidly renewable plant materials (like bamboo and straw), dimension stone, recycled stone, hempcrete, recycled metal (see: copper sustainability and recyclability), and other non-toxic, reusable, renewable, and/or recyclable products. Materials with lower embodied energy can be used in substitution to common building materials with high degrees of energy consumption and carbon/harmful emissions. For concrete a high performance self-healing version is available,^{[32][33]} however options with lower yields of pollutive waste entertain ideas of upcycling and congregate supplementing; replacing traditional concrete mixes with slag, production waste, and aggregates.^[34] Insulation also sees multiple angles for substitution. Commonly used fiberglass has competition from other eco-friendly, low energy embodying insulators with similar or higher R-values (per inch of thickness) at a competitive price. Sheep wool, cellulose, and ThermaCork perform more efficiently, however, use may be limited by transportation or installation costs.

Furthermore, embodied energy comparisons can help deduce the selection of building material and its efficiency. Wood production emits less CO₂ than concrete and steel if produced in a sustainable way just as steel can be produced more sustainably through improvements in technology (e.g. EAF) and energy recycling/carbon capture(an underutilized potential for systematically storing carbon in the built environment).^{[35][36][37]}

The EPA (Environmental Protection Agency) also suggests using recycled industrial goods, such as coal combustion products, foundry sand, and demolition debris in construction projects.^[19] Energy efficient building materials and appliances are promoted in the United States through energy rebate programs.

A 2017 report from the Boston Consulting Group found that, investments in developing greener forms of cement, iron, and steel lead to bigger greenhouse gas reductions compared with investments in electricity and aviation.^[38] In addition, the process of making cement without producing CO₂ is unavoidable. However, using pozzolans clinkers can reduce CO₂ emission while in the process of making cement.^[39]

Indoor environmental quality enhancement

The Indoor Environmental Quality (IEQ) category in LEED standards, one of the five environmental categories, was created to provide comfort, well-being, and productivity of occupants. The LEED IEQ category addresses design and construction guidelines especially: indoor air quality (IAQ), thermal quality, and lighting quality.^{[40][41][42]}

Indoor Air Quality seeks to reduce volatile organic compounds, or VOCs, and other air impurities such as microbial contaminants. Buildings rely on a properly designed ventilation system (passively/naturally or mechanically powered) to provide adequate ventilation of cleaner air from outdoors or recirculated, filtered air as well as isolated operations (kitchens, dry cleaners, etc.) from other occupancies. During the design and construction process choosing construction materials and interior finish products with zero or low VOC emissions will improve IAQ. Most building materials and cleaning/maintenance products emit gases, some of them toxic, such as many VOCs including formaldehyde. These gases can have a detrimental impact on occupants' health, comfort, and productivity. Avoiding these products will increase a building's IEQ. LEED,^[43] HQE^[44] and Green Star contain specifications on use of low-emitting interior. Draft LEED 2012^[45] is about to expand the scope of the involved products. BREEAM^[46] limits formaldehyde emissions, no other VOCs. MAS Certified Green is a registered trademark to delineate low VOC-emitting products in the marketplace.^[47] The MAS Certified Green Program ensures that any potentially hazardous chemicals released from manufactured products have been thoroughly tested and meet rigorous standards established by independent toxicologists to address recognized long-term health concerns. These IAQ standards have been adopted by and incorporated into the following programs:

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal) | Impact Factor: 7.512|

Visit: www.ijirset.com

Vol. 9, Issue 2, February 2020

- The United States Green Building Council (USGBC) in their LEED rating system^[48]
- The California Department of Public Health (CDPH) in their section 01350 standards^[49]
- The Collaborative for High Performance Schools (CHPS) in their Best Practices Manual^[50]
- The Business and Institutional Furniture Manufacturers Association (BIFMA) in their level® sustainability standard.^[51]

Also important to indoor air quality is the control of moisture accumulation (dampness) leading to mold growth and the presence of bacteria and viruses as well as dust mites and other organisms and microbiological concerns. Water intrusion through a building's envelope or water condensing on cold surfaces on the building's interior can enhance and sustain microbial growth. A well-insulated and tightly sealed envelope will reduce moisture problems but adequate ventilation is also necessary to eliminate moisture from sources indoors including human metabolic processes, cooking, bathing, cleaning, and other activities.^[52]

Personal temperature and airflow control over the HVAC system coupled with a properly designed building envelope will also aid in increasing a building's thermal quality. Creating a high performance luminous environment through the careful integration of daylight and electrical light sources will improve on the lighting quality and energy performance of a structure.^{[31][53]}

Solid wood products, particularly flooring, are often specified in environments where occupants are known to have allergies to dust or other particulates. Wood itself is considered to be hypo-allergenic and its smooth surfaces prevent the buildup of particles common in soft finishes like carpet. The Asthma and Allergy Foundation of America recommends hardwood, vinyl, linoleum tile or slate flooring instead of carpet.^[54] The use of wood products can also improve air quality by absorbing or releasing moisture in the air to moderate humidity.^[55]

Interactions among all the indoor components and the occupants together form the processes that determine the indoor air quality. Extensive investigation of such processes is the subject of indoor air scientific research and is well documented in the journal *Indoor Air*.^[56]

Operations and maintenance optimization

No matter how sustainable a building may have been in its design and construction, it can only remain so if it is operated responsibly and maintained properly. Ensuring operations and maintenance (O&M) personnel are part of the project's planning and development process will help retain the green criteria designed at the onset of the project.^[57] Every aspect of green building is integrated into the O&M phase of a building's life. The addition of new green technologies also falls on the O&M staff. Although the goal of waste reduction may be applied during the design, construction and demolition phases of a building's life-cycle, it is in the O&M phase that green practices such as recycling and air quality enhancement take place. O&M staff should aim to establish best practices in energy efficiency, resource conservation, ecologically sensitive products and other sustainable practices. Education of building operators and occupants is key to effective implementation of sustainable strategies in O&M services.^[58]

Waste reduction

Green architecture also seeks to reduce waste of energy, water and materials used during construction. For example, in California nearly 60% of the state's waste comes from commercial buildings^[59] During the construction phase, one goal should be to reduce the amount of material going to landfills. Well-designed buildings also help reduce the amount of waste generated by the occupants as well, by providing on-site solutions such as compost bins to reduce matter going to landfills.

To reduce the amount of wood that goes to landfill, Neutral Alliance (a coalition of government, NGOs and the forest industry) created the website dontwastewood.com. The site includes a variety of resources for regulators, municipalities, developers, contractors, owner/operators and individuals/homeowners looking for information on wood recycling.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal) | Impact Factor: 7.512|

Visit: www.ijirset.com

Vol. 9, Issue 2, February 2020

When buildings reach the end of their useful life, they are typically demolished and hauled to landfills. Deconstruction is a method of harvesting what is commonly considered "waste" and reclaiming it into useful building material.^[60] Extending the useful life of a structure also reduces waste – building materials such as wood that are light and easy to work with make renovations easier.^[61]

To reduce the impact on wells or water treatment plants, several options exist. "Greywater", wastewater from sources such as dishwashing or washing machines, can be used for subsurface irrigation, or if treated, for non-potable purposes, e.g., to flush toilets and wash cars. Rainwater collectors are used for similar purposes.

Centralized wastewater treatment systems can be costly and use a lot of energy. An alternative to this process is converting waste and wastewater into fertilizer, which avoids these costs and shows other benefits. By collecting human waste at the source and running it to a semi-centralized biogas plant with other biological waste, liquid fertilizer can be produced. This concept was demonstrated by a settlement in Lübeck Germany in the late 1990s. Practices like these provide soil with organic nutrients and create carbon sinks that remove carbon dioxide from the atmosphere, offsetting greenhouse gas emission. Producing artificial fertilizer is also more costly in energy than this process.^[62]

Reduce impact onto electricity network

Electricity networks are built based on peak demand (another name is peak load). Peak demand is measured in the units of watts (W). It shows how fast electrical energy is consumed. Residential electricity is often charged on electrical energy (kilowatt hour, kWh). Green buildings or sustainable buildings are often capable of saving electrical energy but not necessarily reducing peak demand.

When sustainable building features are designed, constructed and operated efficiently, peak demand can be reduced so that there is less desire for electricity network expansion and there is less impact onto carbon emission and climate change.^[63] These sustainable features can be good orientation, sufficient indoor thermal mass, good insulation, photovoltaic panels, thermal or electrical energy storage systems, smart building (home) energy management systems.^[64]

Regulation and operation

As a result of the increased interest in green building concepts and practices, a number of organizations have developed standards, codes and rating systems for use by government regulators, building professionals and consumers. In some cases, codes are written so local governments can adopt them as bylaws to reduce the local environmental impact of buildings.

Green building rating systems such as BREEAM (United Kingdom), LEED (United States and Canada), DGNB (Germany), CASBEE (Japan), and VERDE^{GBCe} (Spain), GRIHA (India) help consumers determine a structure's level of environmental performance. They award credits for optional building features that support green design in categories such as location and maintenance of building site, conservation of water, energy, and building materials, and occupant comfort and health. The number of credits generally determines the level of achievement.^[75]

Green building codes and standards, such as the International Code Council's draft International Green Construction Code,^[76] are sets of rules created by standards development organizations that establish minimum requirements for elements of green building such as materials or heating and cooling.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal) | Impact Factor: 7.512|

Visit: www.ijirset.com

Vol. 9, Issue 2, February 2020

Some of the major building environmental assessment tools currently in use include:

- United States: International Green Construction Code (IGCC)

Green neighborhoods and villages

At the beginning of the 21st century, efforts were made to implement the principles of green building, not only for individual buildings, but also for neighborhoods and villages. The intent is to create zero energy neighborhoods and villages, which means they're going to create all the energy on their own. They will also reuse waste, implement sustainable transportation, and produce their own food.^{[77][78]} Green villages have been identified as a way to decentralize sustainable climate practices, which may prove key in areas with high rural or scattered village populations, such as India, where 74% of the population lives in over 600,000 different villages.^[79]

IV. CONCLUSIONS

International frameworks and assessment tools

IPCC Fourth Assessment Report

Climate Change 2007, the Fourth Assessment Report (AR4) of the United Nations Intergovernmental Panel on Climate Change (IPCC), is the fourth in a series of such reports. The IPCC was established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) to assess scientific, technical and socio-economic information concerning climate change, its potential effects and options for adaptation and mitigation.^[80]

UNEP and Climate change

United Nations Environment Program UNEP works to facilitate the transition to low-carbon societies, support climate proofing efforts, improve understanding of climate change science, and raise public awareness about this global challenge.

REFERENCES

1. Mutlu, Hatice; Barner, Leonie (2017-06-03). "Getting the Terms Right: Green, Sustainable, or Circular Chemistry?". *Macromolecular Chemistry and Physics*. 223 (13): 2200111. doi:10.1002/macp.201700111. ISSN 1022-1352. S2CID 249357642.
2. ^ "Green Chemistry". United States Environmental Protection Agency. 2006-06-28. Retrieved 2011-03-23.
3. ^ Sheldon, R. A.; Arends, I. W. C. E.; Hanefeld, U. (2007). *Green Chemistry and Catalysis* (PDF). doi:10.1002/9783527611003. ISBN 9783527611003. S2CID 92947071.
4. ^ Clark, J. H.; Luque, R.; Matharu, A. S. (2012). "Green Chemistry, Biofuels, and Biorefinery". *Annual Review of Chemical and Biomolecular Engineering*. 3: 183–207. doi:10.1146/annurev-chembioeng-062011-081014. PMID 22468603.
5. ^ Cernansky, R. (2015). "Chemistry: Green refill". *Nature*. 519 (7543): 379–380. doi:10.1038/nj7543-379a. PMID 25793239.
6. ^ Sanderson, K. (2011). "Chemistry: It's not easy being green". *Nature*. 469 (7328): 18–20. Bibcode:2011Natur.469...18S. doi:10.1038/469018a. PMID 21209638.
7. ^ Poliakov, M.; Licence, P. (2007). "Sustainable technology: Green chemistry". *Nature*. 450 (7171): 810–812. Bibcode:2007Natur.450..810P. doi:10.1038/450810a. PMID 18064000. S2CID 12340643.
8. ^ Clark, J. H. (1999). "Green chemistry: Challenges and opportunities". *Green Chemistry*. 1: 1–8. doi:10.1039/A807961G.



ISSN(Online): 2319-8753
ISSN(Print): 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal) | Impact Factor: 7.512|

Visit: www.ijirset.com

Vol. 9, Issue 2, February 2020

9. ^ Marteel, Anne E.; Davies, Julian A.; Olson, Walter W.; Abraham, Martin A. (2003). "GREEN CHEMISTRY AND ENGINEERING: Drivers, Metrics, and Reduction to Practice". Annual Review of Environment and Resources. 28: 401–428. doi:10.1146/annurev.energy.28.011503.163459.
10. ^ Vert, Michel; Doi, Yoshiharu; Hellwich, Karl-Heinz; Hess, Michael; Hodge, Philip; Kubisa, Przemyslaw; Rinaudo, Marguerite; Schué, François (2012). "Terminology for biorelated polymers and applications (IUPAC Recommendations 2012)" (PDF). Pure and Applied Chemistry. 84 (2): 377–410. doi:10.1351/PAC-REC-10-12-04. S2CID 98107080.
11. ^ Woodhouse, E. J.; Breyman, S. (2005). "Green chemistry as social movement?". Science, Technology, & Human Values. 30 (2): 199–222. doi:10.1177/0162243904271726. S2CID 146774456.