Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2018, 5(7):20-23**

Review Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Green Engineering: A Primer

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Abstract Green engineering is the design of processes and products that minimize pollution, promote sustainability, and protect human health without sacrificing economic viability and efficiency. It is the process of using hardware and software technologies to reduce our impact on the environment. It also involves designing materials, processes, and devices over the entire life cycle of a product. This paper provides a brief introduction to green engineering.

Keywords Green engineering, green technology, environmental engineering, green chemistry

Introduction

Concerns about global climate change, shortages of water, depletion of materials, degradation of the environment, and soaring energy prices are driving new priorities and expectations. There has also been serious demand for green and renewable chemicals around the globe. To meet these demands, engineers and scientists worldwide are leading the charge and crafting strategies to address them. Engineering is a profession that solves problems confronting our civilization. Green engineering (GE) is the discipline that promotes the idea of making things better for the environment right from the start. Every manufacturer is now under scrutiny for how environmental friendly its processes and products are.

All engineers can employ green engineering principles regardless of the specific area of engineering. Green engineering encompasses common measurements such as power quality and consumption and emissions from vehicles and factories. Factors that are motivating companies to go green include environmental legislation, rising waste-disposal costs, and corporate image.

Green engineering financially and technologically designs products and processes in a manner that simultaneously decreases the amount of pollution and minimizes exposures to potential hazards. Green engineering is not actually an engineering discipline, but an overarching engineering framework for all design disciplines. It is closely related to environmental engineering.

Green Engineering Principles

Anastas and Zimmerman [1] organized an overview of developments in green engineering into 12 principles. Their 12 Principles of GE have been proposed as a framework for examining existing products as well as to evaluate new product designs. Green engineering may be regarded as the incorporation of these 12 principles into engineering practices. The principles are stated as follows [1,2].

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 recycle, 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.

It is evident from these principles that green engineering is extremely complex. However, the principles have been put to use in fostering sustainability. The abbreviated principles of green engineering and green chemistry are illustrated in Figure 1 [3].

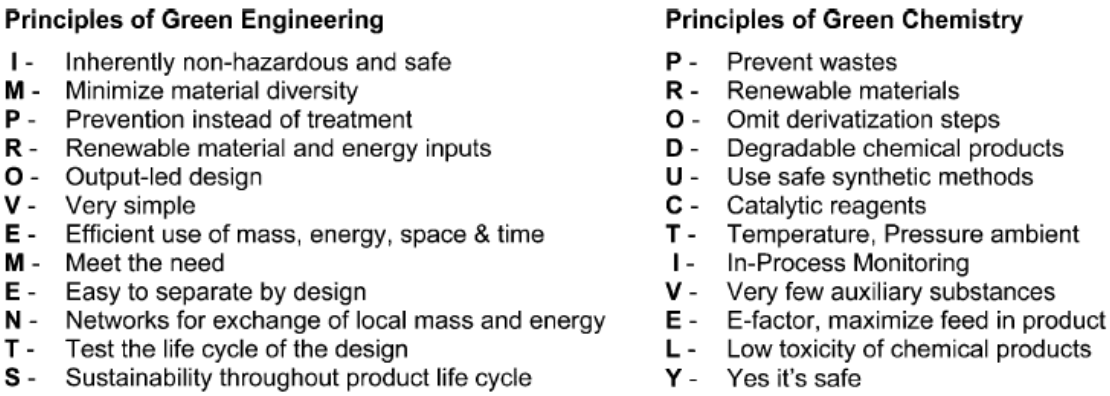

Figure 1: Abbreviated principles of green engineering and green chemistry [3].

Applications

The main goal of GE is meeting the needs of society in ways without depleting natural resources on the planet. GE is a way to make many of the things people use in everyday life more efficient, safe, and long-lasting. Thus, GE is an environmentally friendly engineering. Engineers who want to lower the emissions of their products and develop devices that consume less energy need green engineering.

Green engineering is all around you. Examples include solar cells, reusable water bottles, green buildings, and newer cars that run more cleanly. More detailed examples are presented as follows.

- *Green Chemistry*: Green chemistry is an integral part of green engineering since it provides the foundation on which to build green engineering. The relationship between green chemistry, green engineering, and sustainability is shown in Figure 2 [4]. Combining green chemistry with green engineering at the earliest design stages will maximize efficiency, minimize waste, and increase profitability [5]. From design to disposal, green engineering is finding ways to balance environmental compatibility with economic profitability. Chemical innovations have largely contributed to improving the quality of life for people around the world.

- *Pharmaceutical Manufacturing*: The pharmaceutical industry produces medicines that allow patients to be healthy and live long. It is committed to producing medicines with minimal environmental impact. There are opportunities to reduce the environmental footprint and economic cost of pharmaceutical manufacturing. GE represents a practical transformation of the industry.
- *Green Nanotechnology:* In the context of nanotechnology, green innovation is aimed at processes for the production of products that are safe, energy efficient, and minimize greenhouse emissions. Green nanotechnology is about manufacturing processes that are environmentally sustainable [6]. It has the goal of producing nanomaterials and products without harming the environment. For example, nanoscale catalysts can cause chemical reactions more efficient and less wasteful.

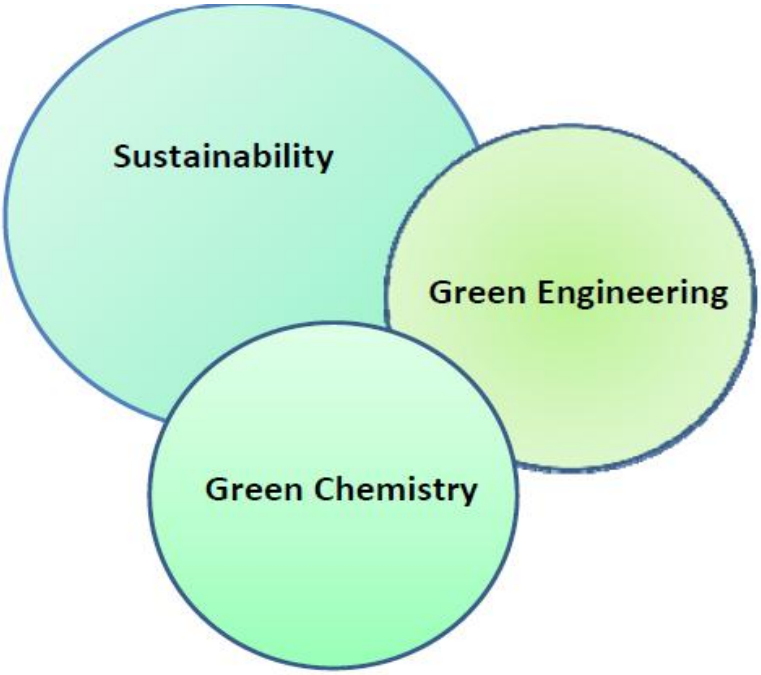

Figure 2: Relationship between green chemistry, green engineering, and sustainability [4].

Other applications include green energy, green employment, and green products.

Challenges

The cost of implementing green engineering over traditional solutions can be a deterrent. The disadvantages of GE include high implementation costs, lack of information, uncertainty about performance impacts, and lack of human resources and skills [7].

As mentioned earlier, green engineering is complex by nature. Although engineers have learned to design systems with a modest degree of complexity, the need for increased complexity is growing.

In China, for example, the major impediments to implementing GE seem to be competing priorities between economic growth and environmental protection. It still needs to train and educate its scientists and engineers [8].

Integrating green engineering into a non-green curriculum can be challenging. Since GE is unique, teaching it must be carefully implemented in order to effectively present the material to students [9].

Conclusion

Green engineering involves creating healthy living environments that use natural resources wisely and conservatively. It is the framework for an eco-friendly business. It makes more sense to start designing for sustainability right from the start.

Education is a crucial tool for realizing the new concept of green engineering. GE principles are gaining attention in engineering education. It is being introduced to students at both the undergraduate and graduate

levels in the US and around the world. The inclusion of GE tools and principles in engineering education will grow over the years [10,11]. More information about GE can be found in [12].

References

[1] P. T. Anastas and J. B. Zimmerman, "12 principles of green engineering," *Environmental Science & Technology*, vol 37, no. 3, 2003, pp. 94A-101A.

[2] "12 Principles of Green Engineering," https://www.acs.org/content/acs/en/greenchemistry/what-is-green-chemistry/principles/12-principles-of-green-engineering.html

[3] N. Asfaw et al., "The 13 principles of green chemistry and engineering for a greener Africa," *Green Chemistry*, vol. 13, 2011, pp. 1059-1060.

[4] "Is sustainable energy development possible?", unknown website

[5] M. Kirchhoff, "Promoting green engineering through green chemistry," *Environmental Science & Technology*, vol. 37, October 2003, pp. 5349-5353.

[6] K. V. Katti, "Realms of green nanotechnology," *International Journal of Green Nanotechnology*, vol. 1, no. 1, 2013.

[7] M. Bhardwaj and Neelam, "The advantages and disadvantages of green technology," *Journal of Basic and Applied Engineering Research*, vol. 2, no. 22, October-December, 2015, pp. 1957-1960.

[8] K. J. M. Matus, X. Xiao, and J. B. Zimmerman, "Green chemistry and green engineering in China: drivers, policies and barriers in innovation," *Journal of Cleaner Production*, vol. 32, 2012, pp. 193-203.

[9] A. M. Flynn et al., "Teaching teachers to teach green engineering," *Journal of STEM Education*, vol. 7, no. 3&4, July-December 2006, pp. 13-24.

[10] D. R. Shonnard et al., "Green education through as U.S. EPA/academia collaboration," *Environmental Science & Technology*, vol. 37, no. 23, 2003, pp. 5453-5462.

[11] D. T. Allen et al., "Green engineering education in chemical engineering curricula: A quarter century of progress and prospects for future transformations." *ACS Sustainable Chemistry & Engineering*, vol. 4, 2016, pp. 5850-5854.

[12] D. T. Allen and D. R. Shonnard, *Green Engineering: Environmentally Conscious Design of Chemical Processes*. Upper Saddle River, NJ: Prentice Hall, 2002.

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