

SUSTAINABLE ENGINEERING: AN INTRODUCTION

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ABSTRACT

Sustainable engineering is the process of using natural resources without compromising the environment or depleting the materials for future generations. It implies living well within the ecological limits of a finite planet. It involves the integration of social, environmental, and economic considerations into the design of product, process, and energy systems. This paper provides a brief introduction to the field of sustainable engineering.

Key Words: Sustainable Engineering, Green Engineering.

INTRODUCTION

Sustainability has been a keyword in the 21st century because it is one of the global grand challenges. For example, we hear about sustainable engineering, sustainable development, sustainable energy, sustainable software, sustainable design, sustainable living, economic sustainability, social sustainability, ecological sustainability, etc. In this same way, there has been considerable discussion about green chemistry, green engineering, green business, green manufacturing, green food, green economy, green energy, etc. The two terms (sustainability and green) are often used interchangeably. They are related as shown in Figure 2 [1]. Sustainable development has been a major driving initiative in engineering businesses throughout the world. Green engineering entails creating healthy living environments that use natural resources wisely and conservatively [2].

Engineering is the application of scientific and mathematical principles for practical purposes such as the design and operation of products and processes. It expediently utilizes resources to drive the world's economic activity, in virtually all economic sectors, e.g., military, industry, transportation, residential, commercial, agriculture, education, telecommunication, etc. Sustainable engineering (SE) is the process of designing products and systems such that they use energy and resources sustainably. It transforms existing engineering disciplines, processes, and practices to those that promote sustainability. All engineering disciplines should incorporate sustainability principles into their practice in order to improve the quality of life.

CONCEPT OF SUSTAINABLE ENGINEERING

Unlike traditional engineering approaches, sustainable engineering focuses on projects that are resource efficient, produce minimal pollution, and cause little to no damage to the natural environment. Sustainable engineering typically focuses on the following areas [3]: food production, water supply, housing and shelter, sanitation and waste management, energy conservation, transportation, industrial processing, environment, pollution prevention, materials management; medical care, and appropriate use of technology.

The four pillars of sustainability analysis are energy, efficiency, environment, and society. Sustainability analysis is multi-disciplinary in nature. It requires approaches from different disciplines such as optimization, social science, and finance. Sustainability starts with green manufacturing and extends to industrial networks and then to the ecosystem. Sustainability of a

system is its ability to survive and retain its functionality over time. A sustainable society is capable of surviving and prospering indefinitely.

The principles of sustainable engineering provide a paradigm in which engineers can design products and services to meet societal needs with minimal impact on the environment. Sustainable engineering should be based on principles that support sustainable development and should be applied early in design. The design must consider short and long-term impacts. It will be hard and expensive to turn back and redesign things. Sustainable engineering will provide ways to reduce a product's environmental effects at every stage of its lifecycle, from conception, development, and prototyping to commercialization, recycling, and disposal.

Today sustainability is seen in three-dimensions: environmental, economic, and socio-cultural, which are illustrated in Figure 3 and explained as follows [4].

- **Environmental Sustainability:** The earth resources and processes are connected with human societies. Environmental sustainability describes a possible way that human societies can sustainably develop by living within the system earth and using the resources of planet earth. It is focused on three protection goals: protection of resources, the ecosystem, and human health.
- **Economic sustainability:** This addresses effective investments, finance, job creation, and competitiveness.
- **Social sustainability:** This addresses equity, justice, security, employment, and participation

APPLICATIONS

Sustainable engineering is a practical challenge to all engineering disciplines. The following applications are practical demonstrations of sustainable engineering.

- **Sustainable Software:** Software usage has multiple direct effects. The objective of sustainable software engineering is the enhancement of software engineering which targets the direct and indirect consumption of natural resources and energy which are caused by software systems during their entire life cycle. To achieve this requires that we start off with a "cradle to grave" perspective and develop a life cycle of software products [5].
- **Construction Industry:** The construction industry has its footprints on all human efforts to control, modify, and dominate nature and natural systems. There is a growing consensus that delivering a sustainable built environment starts with incorporating sustainability thoughts at the planning and design stages of an infrastructure construction project. Geotechnical engineering can significantly influence the sustainability of infrastructure development because of its early position in the construction process [6].
- **Sustainable Engineering Education:** Higher education is now facing new challenges as it prepares future professionals. Engineers of the future will face more demanding challenges as they must design human-environment-technology systems. Engineering education is responsible for developing programs that will lead to a better, safer, and moral modern future world. Critical topics such as global warming, climate change, green practices and sustainable engineering solutions are central to recent changes to regulations and policies impacting the practice of engineering. In view of this, every engineering curricula should incorporate sustainability as an overarching theme. A degree program in sustainable engineering should be useful for engineers and non-engineers alike. Such a degree program may cover basic sciences (chemistry, biology, physics), atmospheric science, social science, economics, geography and planning, and political science. It should have great potential for hands-on multidisciplinary project-based learning [7,8].
- **Engineering Sustainable Happiness:** Everyone wants to be happy and strives to be happy. The notion of happiness is expanded to sustainable happiness. Sustainable happiness is the pursuit of happiness that does not exploit other people, the environment or future generation. By influencing decision making processes, sustainable happiness can guide individuals, communities and politicians. The key element of it is cooperation between people. Creating positive mind-sets and developing honesty and mutual trust ultimately lead towards sustainable happiness [9].

Other areas of application include sustainable hydraulic engineering, sustainable road mobility, and sustainable critical infrastructures (e.g. electric power infrastructure, transportation infrastructure, food and water infrastructures, financial infrastructure, and telecommunication infrastructures).

BENEFITS AND CHALLENGES

New residential and commercial buildings should be designed to be more environmentally friendly. This will reduce emissions, illnesses, and energy consumption.

Sustainable engineering poses a difficult set of challenges for engineers. Sustainable engineering problems are often regarded as wicked problems because they share the five most relevant characteristics of wicked problems [6]: (i) they are difficult to formulate, (ii) multiple but incompatible solutions exist, (iii) time frames are open-ended, (iv) the problems are unique, and (v)

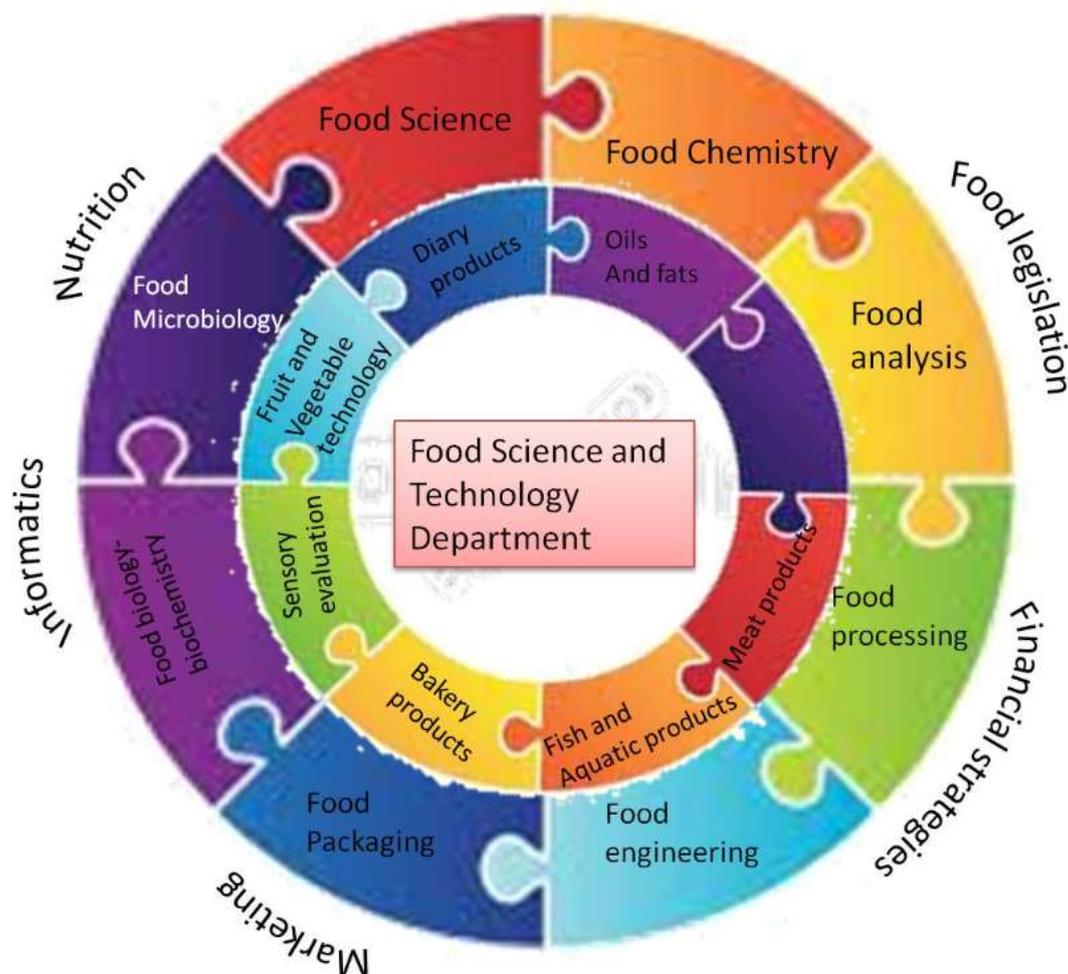


Figure 1: Green and Sustainable Food Science and Engineering

competing value systems or objectives exist in the problem. Economics is one of the most prominent barriers encountered by practitioners attempting to introduce sustainable engineering practices. Designers are often expected to follow building codes and regulations which may conflict with the principles of sustainable engineering [10].

CONCLUSION

Sustainable engineering takes environmental engineering concepts to the next level by looking at the interactions between technical, ecological, social, and economic systems. There is a great deal of interest in sustainability at the moment and a more sustainable future is ahead of us. However, sustainability is a task which cannot be addressed only by individual persons or nations. It is rather an all-embracing task including aspects of each engineering discipline, which have to be addressed on a global scale. Scientists and engineers must collaborate in international and multidisciplinary groups [11].

Engineers should cultivate the habit of making our daily engineering practice as sustainable as possible. Sustainability should be embedded into all dimensions of engineering. Every engineering curriculum should incorporate sustainability as an overarching theme. A degree program in sustainable engineering should be useful for engineers and non-engineers alike. More information about sustainable engineering can be found in the books in [12-17] and the journal exclusively devoted to it: *International Journal of Sustainable Engineering*.

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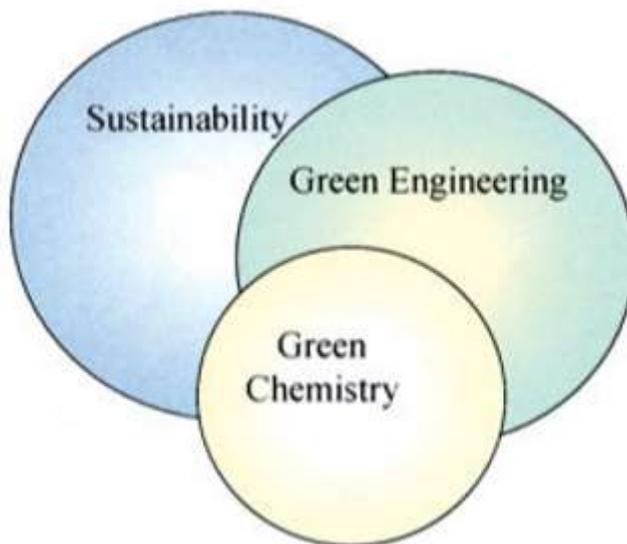


Figure 2 Relationship between green chemistry, green engineering, and sustainability [1].



Figure 3 Sustainability in the interaction of Environment, social actions, and economics [4].