

# A CASE STUDY ON SUSTAINABLE DESIGN THROUGH THE TWELVE PRINCIPLES OF GREEN ENGINEERING

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## ABSTRACT:

Sustainable design is an essential aspect of mitigating environmental impacts, and green engineering offers a framework for incorporating sustainable design practices. The twelve principles of green engineering provide a guideline for designing sustainable products and systems, emphasizing reducing waste and pollution, minimizing resource depletion, and prioritizing sustainability over short-term gains. This case study focuses on sustainable design through the twelve principles of green engineering. Through case studies and analysis, this case study examines the application of the twelve principles to sustainable design and explores the benefits and challenges of sustainable design practices. The study referred to in the paragraph focuses on the "Twelve Principles of Green Engineering," which are intended to guide the use of science and technology in achieving sustainability. The conclusions drawn from the study relate to how these principles can be used to optimize the use of resources and reduce environmental impact in the short term. The principles are seen as an essential strategy for achieving sustainability through green engineering. However, the study also highlights the potential for even greater sustainability gains through the reengineering of entire systems, such as personal transportation networks. By considering the principles of green engineering in the design of these systems, it becomes possible to create more flexible and sustainable solutions. Therefore, the study emphasizes the continued importance of the principles of green engineering, both in optimizing current technologies and in creating more sustainable systems for the future. The case study concludes by highlighting the importance of sustainable design in mitigating environmental impacts and providing direction for future research and practice in the field of green engineering.

**KEYWORDS:** *Sustainable Design; Green Engineering; Environmental Impacts*

## 1.0 INTRODUCTION

The concept of sustainable design and green engineering has gained significant attention in recent years as the environmental impact of human activities has become increasingly apparent. The depletion of natural resources, pollution, and climate change are some of the significant environmental problems caused by human activities. As such, sustainable design and green engineering have emerged as essential fields of study for engineers, designers, and policymakers who seek to mitigate the environmental impact of human activities.

Sustainable design and green engineering aim to create products and systems that are environmentally friendly, socially responsible, and economically viable. These fields promote the use of renewable resources, the reduction of waste and pollution, and the development of products and systems that have a minimal environmental impact. Sustainable design and green engineering consider the entire lifecycle of a product or system, from the sourcing of raw materials to the end-of-life disposal or recycling.

Since then, sustainable design and green engineering have become increasingly important in various fields, including architecture, product design, and manufacturing. Governments, businesses, and individuals have also recognized the importance of sustainable design and green engineering and have

taken steps to incorporate these principles into their practices.

## **2.0 LITERATURE REVIEWS**

Sustainable design is an essential aspect of mitigating environmental impacts and ensuring a sustainable future for our planet. With the increasing awareness of the environmental impact of human activities, the field of green engineering has emerged as a framework for incorporating sustainable design practices. Green engineering emphasizes the need to design products and systems that prioritize the well-being of the environment and society over short-term gains.

The twelve principles of green engineering provide a comprehensive guide for designing sustainable products and systems. These principles were developed to guide engineers in creating products and systems that are environmentally friendly and sustainable. The principles emphasize reducing waste and pollution, minimizing resource depletion, and prioritizing sustainability in the design process. Each principle is interconnected and works together to create a holistic approach to sustainable design.

The application of the twelve principles of green engineering to sustainable design is crucial in mitigating environmental impacts. By case studies, this paper explores how these principles can be utilized in designing sustainable products and systems. The case studies highlight the importance of integrating the twelve principles into the design process to create products and systems that are sustainable and environmentally friendly. This paper also examines the benefits and challenges of sustainable design practices. While sustainable design has numerous benefits for the environment and society, there are also challenges to implementing these practices. The challenges include technological and financial barriers, as well as a lack of awareness and education on sustainable design practices. In conclusion, this case study emphasizes the importance of sustainable design through green engineering principles. Sustainable design is critical for mitigating the environmental impact of human activities and creating a more sustainable future. The twelve principles of green engineering provide a valuable guide for incorporating sustainable design practices, and their application can result in sustainable products and systems that benefit society and the environment.

## **3.0 METHODOLOGY**

One research method that could be used to study sustainable design through the twelve principles of green engineering is a case study analysis. This method involves analyzing real-world cases of sustainable design projects and evaluating them against the principles of green engineering. To conduct a case study analysis, the researcher would select several sustainable design projects that align with the principles of green engineering. These could include projects in a variety of fields, such as renewable energy, sustainable transportation, or green building design.

Once the projects have been selected, the researcher would collect data on each project, including information on the design process, materials used, energy consumption, and environmental impact. This data could be collected through a combination of interviews with project stakeholders, review of project documentation, and on-site observations. Next, the researcher would evaluate each project against the principles of green engineering. This would involve comparing the design choices made in each project to the principles, and assessing the extent to which the project aligns with each principle.

Finally, the researcher would draw conclusions based on the analysis of the case studies. This could include identifying best practices for sustainable design, highlighting areas for improvement in existing projects, and making recommendations for future sustainable design projects. One advantage of the case study analysis method is that it allows for a detailed examination of real-world examples of sustainable design. This can provide insights into the challenges and opportunities associated with implementing sustainable design principles in practice. Additionally, the method allows for a comparison of different projects, which can help identify patterns and trends across different fields of sustainable design.

However, one potential limitation of this method is that the findings may not be generalizable to other contexts or projects. Additionally, the analysis may be subjective to some degree, as the researcher's interpretation of the principles of green engineering may differ from others. To address these limitations, it may be necessary to supplement the case study analysis with other research methods, such as surveys or focus groups, to obtain a more comprehensive understanding of sustainable design practices and principles.

### 3.0 RESULTS AND DISCUSSIONS

Green engineering is a field that seeks to create environmentally responsible and sustainable products, processes, and technologies. The objective of green engineering is to reduce the negative impact that human activities have on the environment by promoting the use of renewable resources, minimizing waste and pollution, and prioritizing prevention over treatment. The principles of green engineering provide a framework for achieving these objectives and can be applied to a wide range of industries and applications as simplified in Table 1.

Table 1: Twelve (12) Principles of Green Engineering – Problems & Solutions

| No. | Principle                                                                                                                                                                                            | Problem                                                                                                                                                                                                                                                                                                                              | Solution                                                                                                                                                                                                                                                                                                                                |
|-----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | <b>Inherently Risk-Free</b><br>-refers to the concept that a product or process is designed in a way that eliminates or minimizes the risk of harm or adverse effects to humans and the environment. | <i>Many products and processes in various industries have inherent risks that can harm humans and the environment such as, chemicals used in manufacturing processes can be hazardous to human health and the environment if not properly managed. This poses a significant challenge to promote sustainable and safe practices.</i> | <i>Green engineering and sustainable design provide a framework for developing products and processes that are inherently risk-free or have a minimal environmental impact using renewable resources, reducing waste and pollution, and designing products and processes that eliminate or minimize the use of hazardous chemicals.</i> |
| 2   | <b>Instead of Therapy use Prevention</b><br>-preferable to prevent waste than to treat or clean up after it has already been created.                                                                | <i>Waste is not just some unfortunate byproduct of a process but is deliberately included in it without much thought. Even though it seems obvious that should be minimized or avoid producing waste whenever possible.</i>                                                                                                          | <i>All technologies aimed at achieving waste-free design.</i>                                                                                                                                                                                                                                                                           |
| 3   | <b>Create a Separation Plan</b><br>-separation and purification processes should be planned to use the least amount of energy and resources possible.                                                | <i>The initial design decisions made in the early stages of a project can have a significant impact on how easy it is to separate and purify products, enabling their subsequent reuse and recycling.</i>                                                                                                                            | <i>Simplify the process of recovering, recycling, and reusing materials.</i>                                                                                                                                                                                                                                                            |
| 4   | <b>Maximize Efficiency in terms of Mass, Energy and Time</b><br>-states that the efficiency of mass, energy, space, and time should be maximized in the design of products, processes, and systems.  | <i>This approach can also be applied in the water and wastewater industries, where treatment systems are controlled.</i>                                                                                                                                                                                                             | <i>Effectively control complex water and wastewater treatment processes, advanced control algorithms should be considered.</i>                                                                                                                                                                                                          |

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|----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 5  | <b>Input-Pushed vs Output-pulled</b><br><i>-by the use of energy and resources, processes and systems should be "output pulled" rather than "input pushed".</i>                                                         | <i>Increasing the output generation of a system can alleviate the stress caused by an increase in input.</i>                                                                                                     | <i>This approach involves recycling and reusing materials instead of disposing of them, which conserves energy and resources while reducing environmental harm.</i>                            |
| 6  | <b>Maximize Complexity</b><br><i>-design decisions on recycling, reuse, or good disposition, inherent entropy and complexity must be seen as an investment.</i>                                                         | <i>Separating the different components for recycling would be a challenging and time-consuming process with little financial benefit, thus a poor choice for these extremely complicated items or processes.</i> | <i>By improving recycling, it can help to reduce waste and promote sustainability.</i>                                                                                                         |
| 7  | <b>Instead of immortality, Choose Durability</b><br><i>-targeted durability, not immortality.</i>                                                                                                                       | <i>Products that have a lifespan that extends far beyond their effective economic use are often the root cause of environmental issues</i>                                                                       | <i>It is important to design products with sustainability in mind and consider their entire lifecycle.</i>                                                                                     |
| 8  | <b>Fulfil Need while Reducing Excess</b><br><i>-design for unneeded capacity or capability solutions should be viewed as a design mistake.</i>                                                                          | <i>The water and wastewater sectors after the individual household has its own set of restrictions as well as a variety of inputs and outputs.</i>                                                               | <i>To improve water safety and minimize disinfection byproducts, exploring alternative disinfection methods is crucial.</i>                                                                    |
| 9  | <b>Minimize the Variety of Materials</b><br><i>-to encourage disassembly and value retention, material diversity in multi-component items should be reduced.</i>                                                        | <i>By limiting the range of materials used, it may be more challenging to incorporate sustainable or eco- friendly options, which could have negative environmental impacts.</i>                                 | <i>Creating sustainable products involves considering the environmental impact of the materials used and the product's end-of-life management.</i>                                             |
| 10 | <b>Integrate Regional Energy and Materials Flows</b><br><i>-the integration and interconnection with accessible energy and material flows must be incorporated into the design of products, processes, and systems.</i> | <i>Integrating regional energy and material flows can create social and political challenges.</i>                                                                                                                | <i>Develop mechanisms that can prevent conflicts from disrupting progress, promote cooperation and collaboration, and create a more cohesive and sustainable regional integration process.</i> |
| 11 | <b>Design for Future Commence</b><br><i>-systems, processes, and products should be created to function in an "afterlife" of commerce.</i>                                                                              | <i>The future is inherently unpredictable, and designing for it requires making assumptions and projections that may not come to fruition.</i>                                                                   | <i>Adaptive management approaches involve continuously monitoring and adjusting plans based on new information and changing circumstances should be considered.</i>                            |
| 12 | <b>Instead of Decreasing, Renewable</b><br><i>-emphasizes that energy and material inputs should be replenish</i>                                                                                                       | <i>The continued exploitation of diminishing resources only serves to exacerbate environmental harm as virgin</i>                                                                                                | <i>Encouraging consumers to adopt more sustainable consumption patterns can help to reduce demand for virgin</i>                                                                               |

|  |                                 |                                                          |                                                                                |
|--|---------------------------------|----------------------------------------------------------|--------------------------------------------------------------------------------|
|  | <i>able rather than finite.</i> | <i>compounds require repeated extraction procedures.</i> | <i>resources and minimize the environmental impact of resource extraction.</i> |
|--|---------------------------------|----------------------------------------------------------|--------------------------------------------------------------------------------|

In conclusion, the review paper methodology provides researchers with a comprehensive and systematic approach to analyzing and synthesizing existing literature on a specific topic. This methodology involves several key steps, including defining the research question, conducting a literature search, screening, and selecting studies, extracting data, synthesizing findings, and writing the review paper. By following this methodology, researchers can ensure that their review is thorough, accurate, and informative.

One of the main advantages of the review paper methodology is that it provides a structured and rigorous approach to reviewing the literature. By defining clear research questions and conducting a systematic literature search, researchers can ensure that they capture all relevant studies on a particular topic. This can help to identify gaps in knowledge, highlight areas for future research, and provide evidence-based recommendations for practice.

Moreover, the review paper methodology is particularly useful for synthesizing findings across multiple studies. By extracting key data from each publication and synthesizing the findings across the literature, researchers can identify patterns, trends, and themes that may not be apparent from individual studies. This can provide a more comprehensive and nuanced understanding of a particular topic and can help to inform evidence-based practice.

### **3.1 AN EXAMPLE OF CONVERTING FOUNDRY WASTE MATERIALS INTO BRICKS (PRINCIPLES 6, 9 & 12)**

Recycling foundry waste into bricks is a project that aims to produce high mechanical compressive properties and to reduce the cost of the production of the building bricks. Nowadays, foundry waste of CO<sub>2</sub> sand is abundant because after used the foundry waste CO<sub>2</sub> sand, the factory or the others party will just throw away them into the disposal site. In addition, the use of foundry waste CO<sub>2</sub> sand can help to reduce the cost of production of building bricks and utilize residual waste aware garbage, most of which is highly regarded by some. With the success of this project, foundry waste CO<sub>2</sub> sand can be used to produce a composition of new brick ornaments (Refer to Figure 1). The aim is to change the waste foundry sand with the original sand to make a cement brick. From that, it can help Malaysia to decrease the discharge of the waste. Current use of cement brick in the growing economic situation got more request from many companies in development. The production of cement brick by industry also increased based on increasing the usage of cement brick. Addition in waste of foundry sand can reduce the absorption and porosity in structure.





**Figure 1:** Experimental Study on Recycling Foundry Waste into Bricks

#### 4.0 CONCLUSIONS

In recent years, there has been growing recognition of the importance of sustainable design through the twelve principles of green engineering. As we face an increasingly urgent need to address the environmental challenges that we are currently experiencing, traditional approaches to design and engineering are no longer sufficient. Instead, we need to adopt a more sustainable approach that prioritizes environmental sustainability and social responsibility.

The twelve principles of green engineering provide a comprehensive framework for sustainable design, covering a wide range of areas, including waste reduction, renewable materials, energy efficiency, and pollution prevention. By incorporating these principles into our design processes and practices, we can create products and systems that minimize waste, reduce energy consumption, and promote environmental sustainability.

Ongoing research and development in this area are crucial to advance sustainable design practices and drive innovation in various fields, including construction, product design, renewable energy, and sustainable agriculture. This research is exploring new ways to design and construct buildings that reduce energy consumption, developing new materials and manufacturing processes that minimize waste, and investigating new technologies for generating renewable energy. It is also exploring new methods for

sustainable agriculture that can reduce soil erosion, promote biodiversity, and improve the sustainability of our food systems.

The benefits of sustainable design through the twelve principles of green engineering are clear. It can help us to reduce our environmental impact, promote social responsibility, and create a more sustainable, equitable, and just society. By implementing these principles, we can build a future that is resilient, inclusive, and environmentally sustainable.

However, there are also challenges that must be overcome to achieve these goals. One of the most significant challenges is to ensure that sustainable design practices are widely adopted and implemented across all industries and sectors. This will require significant changes in the way we approach design and engineering, as well as a shift in mindset and culture towards sustainability.

In conclusion, sustainable design through the twelve principles of green engineering is essential for addressing the environmental challenges we face today. Ongoing research and development in this area are crucial to advance sustainable design practices and drive innovation. By implementing these principles, we can build a more sustainable future and create a world that is resilient, inclusive, and environmentally sustainable. However, achieving these goals will require significant changes in the way we approach design and engineering, as well as a cultural shift towards sustainability. We must continue to invest in research and development and work collaboratively across industries and sectors to ensure that sustainable design becomes the norm rather than the exception.

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