Sustainable Green Product Design: A Review

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***Abstract*—** With the rapid advancement of technology, increasing scarcity of resources and increasing demand of product it become necessary to consider sustainability aspects of product design. In response to increasing scarcity of resource, users are adopting a sustainable development of green products. Green Production is introduce to address wasted resources or fewer resources, in production to increase productivity, drive down costs and deducts impact on environment and socio-economy. The main objective of sustainable green design are as follows: consider recycling fully, reduce the waste, increase product durability, the material's fitness, environment friendly, be easy to decompose and assemble, save energy source and select the least polluting material, guarantee' staff safety and so on. Hence, this paper gives an overview of the concept of Sustainable Green Product Design.

***Keywords*—** Sustainable Development, Product Conceptual Design, Methods and Techniques, Green Engineering, Green Awareness Affects, Green Initiatives.

I. INTRODUCTION

With the advancement of technology, people begin to pay more attention to the adverse effects of resources and energy on social environment. So there should be the requirement of Sustainable product design which depends on its social, economic and environmental conditions. The idea of sustainable design evolves from sustainable development and it requires the process of product design and impact on environment. Sustainable green product design is focused on continuous improvement, recognizing that reducing environmental and social impact is a circular process that begins and ends and begins again with the inquiry into how to make products of better quality, using fewer resources, and creating less or no waste in the process [1-2].

II. SUSTAINABLE DEVELOPMENT

The most common definition of Sustainable Development: "development that meets the requirement of the present without compromising the ability of future generations to meet their own needs [3-4]. There are three critical components for sustainable developments are economic growth, social equity and environmental sustainability. The concept of sustainable development discusses the issue of whether present life-styles are acceptable and whether there is any reason to pass them on to the next meeting needs of present generation, for the purpose of achieving the balance of environment, society and economy and maintaining sustained and coordinated development of human society.

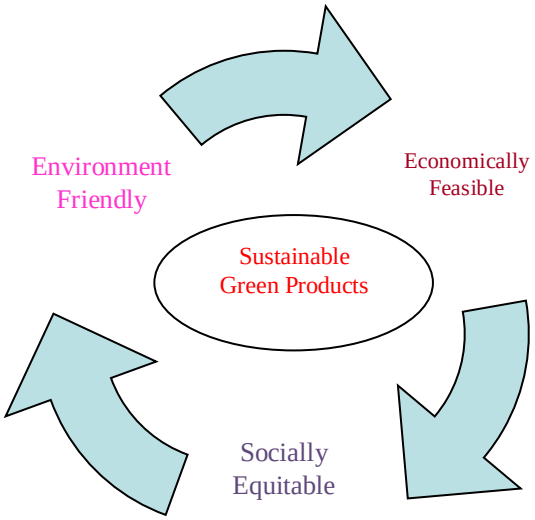

Fig. 1: Sustainability

The advantages of sustainable product is that they use less energy, fewer limited resources, increase production, do not deplete natural resources, do not pollute the environment and can be reduced, reused, recovered or recycled at the end of their useful life [5].

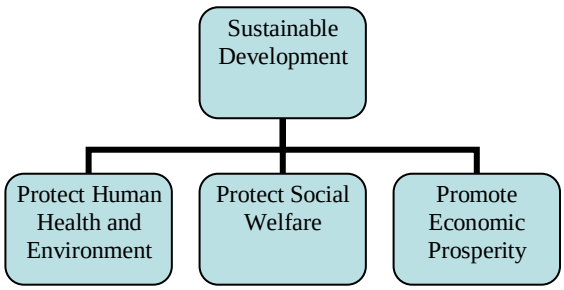

Fig. 2: Sustainable Development

III. PRODUCT CONCEPTUAL DESIGN

Product conceptual design is the core of product innovation. It is not only the most important and complicated but also the most active and innovative design stage, indicating the development trend of products. Conceptual design is a series of orderly, organized and targeted design activities from analyzing needs of users to generate conceptual products, and expressing a continuously evolving process

from crude to refined, from fuzzy to clear and from abstract to concrete. Therefore, the design of putting conceptual products as a goal is defined as product conceptual design [6]. Design process of product conceptual design completes in three steps.

A. *Design Connotations of Product Conceptual Design*

There are three aspects of design connotations, which are given as following-

1) Describing design requirements clearly and abstractly.

*2)*Seeking principles and solving ways, obtaining solutions.

3) Making a decision-making.

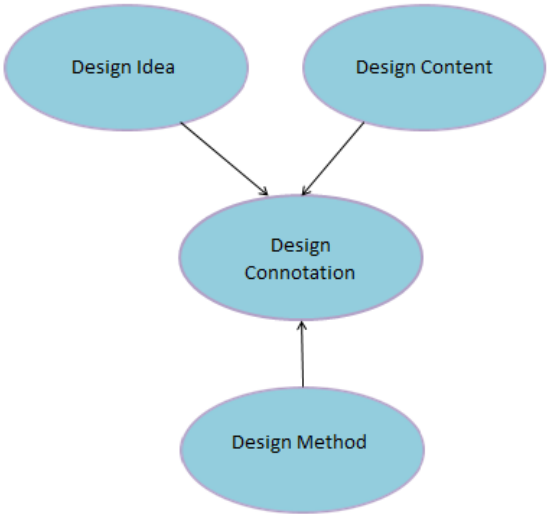

Fig. 3: Three steps of Design Connotations

B. *Design Principles of Product Conceptual Design*

In order to provide the successful rate of product design, product conceptual design must follow the following design principles: principles of demand, adaptation, economic efficiency, ecology, structural design and material selection and humanization.

1) Ecological principle

Eco-design mainly consist of two aspects-

- Reducing consumption of resources and achieving sustainable development strategy from the perspective of protecting environment.
- Lowering costs, reducing potential responsibility and risk.

2) Principles of structural design and material selection

It should be able to determine structural shape of product functional carrier and disassembly and recoverability of connecting parts, reducing using quantities of parts, raw materials for manufacturing and the types of materials for using so as to conveniently recycle and re-use [7].

C. *Design Purposes of Product Conceptual Design*

Its design purposes are to make a reasonable forecast to future development of science and technology and people's life style and break the old traditional mode of thinking.

IV. METHODS AND TECHNIQUES OF SUSTAINABLE DESIGN

There are several methods and techniques of sustainable product design [13], which are given as following-

- Establishing the Aims and the Scope of Sustainable Design.
- Appropriate Technology (AT) analysis.
- Life Cycle Assessment of Products.
- Design with Place
- Design with Prudence
- Design with Nature
- Make Nature Visible
- Service Substitution

These methods and techniques are used to achieve a goal of sustainable design, which is reducing and minimizing the use of resources [8].

V. INTERGRATED SUSTAINABLE GREEN DESIGN

It includes the simulation methods, sustainability statistical analysis method to capture processes before they go out of control, to stay compliant, to maintain IP rights, to experiments, to communicate, collaborate using web based knowledge management methods.

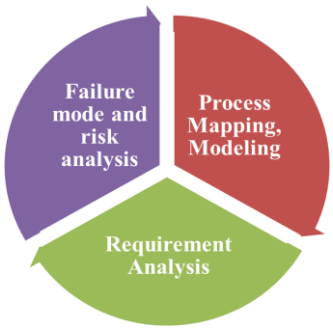

Fig 4: Integrated Architecture of Green Engineering

Green product design evolves generic "Monozukuri Principles". It includes eco-friendly, sustainable design, manufacturing and assembly for the purpose of reducing waste, helping the environment, the communities and in the long term increasing profits, customer satisfaction, and product quality [9]. The basic criteria of green deign are as follows:

- 4R's concept (reduce, recycle, recover, reuse) for E-waste management [15].

- Increase Product Durability.
- Material Fitness
- Easy to decompose and assemble.
- Save energy source and select the least polluting material.

VI. GREEN AWARENESS EFFECTS

The increasing scarcity of resources has raised green sustainability awareness. So it will tend to the development of green products [14]. The main aim of green awareness affects are:

- Resource Utilization.
- Total Resource Conservation.
- Manufacturer's profitability.

The development of green products provides dual Excellency in both profitability and sustainability [10].

VII. GREEN INITIATIVES TOWARDS SUSTAINABLE PRODUCT DESIGN

Due to the rapid development of the technology, the green aspects of the products are being neglected. Therefore many green initiatives should be taken for environmental sustainability with the aim of protecting the natural environment [11]. The objectives of green initiatives towards sustainable product design are as follows:

- To select suitable criteria for designing sustainable engineering product.
- To present the green initiative awareness based on the finished engineering technological product design.

Program Learning Outcome (PLO) is used for protecting the natural environment. The goal of this study is to look into the initiative towards the protection of the environment through the engineering products that have been designed and produced by students of Kolej Kemahiran Tinggi MARA Balik Pulau, Pulau Pinang (KKTMBP). It is important to achieve sustainable engineered processes, services, technologies and products in designing. Green engineering design is an approach to product and process design that reduces environmental impact without compromising the quality of products or the commercial viability. There are two models for the evaluation of green initiatives.

A. Design for Environment (DFE) Model

This model is based on "Life Cycle Assessment of Product" [12], which has given the idea of optimization of raw material stage's strategy for global warming impact consisting of seven criteria namely (1) raw material, (2) manufacturing, (3) product use, (4) distribution, (5) end of life, (6) internal driver, (7) external driver.

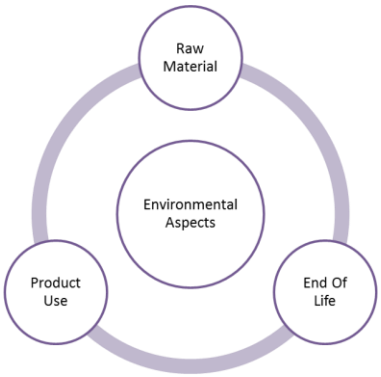

Fig 5: Environment Aspects of Product system

The frequency distribution and percentage of Green Initiatives of the products that should be taken for sustainable design are as follows.

Table 1: Frequency Distribution and Percentage of Green Initiatives

Main Criteria	Sub Criteria	Frequency (N=20)	Percent (%)
Raw Material	Reduce Material	11	55
	Renewable	2	10
	Energy Content	11	55
	Recycled	10	50
	Non Toxic	20	100
Product Use	Energy Efficiency	12	60
	Durability	17	85
	Low Waste	17	85
	Low Consumables	19	95
	Clean Energy Sources	18	90
End Of Life	Reuse	6	30
	Remanufacture	12	60
	Disassembly	19	95
	Recycling	15	75
	Safe Proposal	16	80

1) Raw Material

It consist of reduction of material use, use renewable material, use recycled and recyclable material, avoid toxic or hazardous substances, use of lower energy contents material.

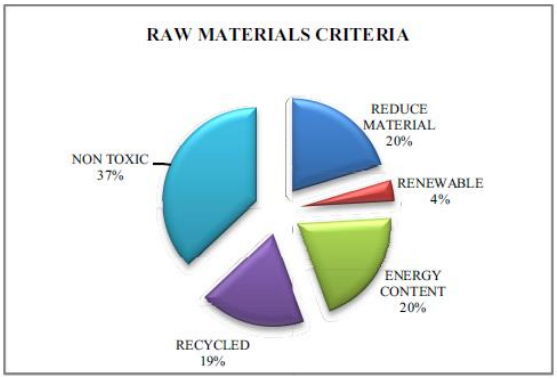

Fig 6: Raw Material Criteria

2) Product use

It is use to design for energy efficiency, design for material conservation, design for minimal consumption, avoidance of waste, design for low-impact operation, and design for durability.

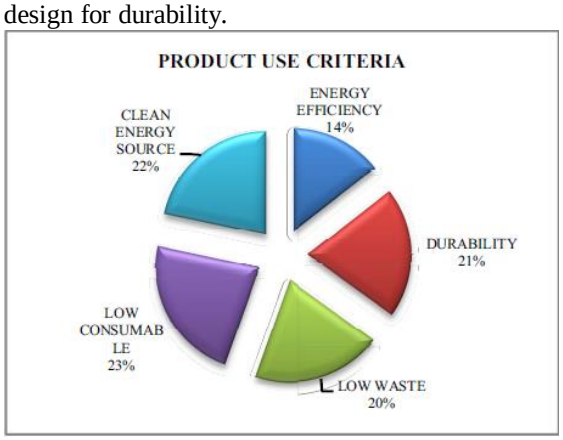

Fig 7: Product Use Criteria

3) End of life

It is use to design for re-use, design for remanufacturing, design for disassembly, design for recycling, and design for safe disposal [11].

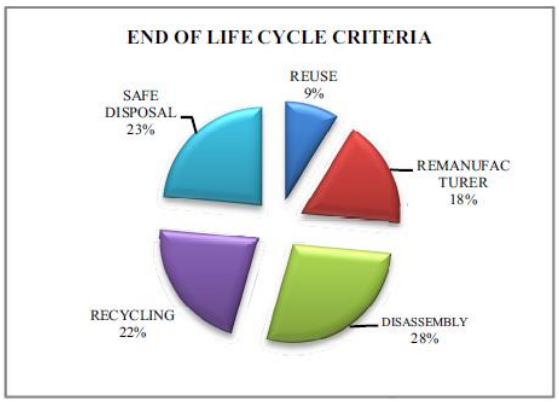

Fig 8: End of Life Criteria

B. Adaptation Model

It is use to determine the existence of environment aspects of product system and results are recorded in a tabular form. Therefore products are identified for the existence of green initiatives.

VIII. CONCLUSION

Finally we concluded that green product as the product that will not pollute the earth or deplore natural resources, and can be recycled or conserved and also has more environmentally sound content or packaging to reduce the impact on the environment . Green product also defines as the product that incorporates the strategies in recycling or with recycled content, reduced packaging or using less toxic materials to reduce the impact on the natural environment. There are various methods and techniques for the sustainable product design and we discussed the necessity of Integrated Sustainable Green Engineering. Here, we also discussed that what are the green initiatives and which is essential for environmental sustainability.

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