A green design chain collaboration model for TFT-LCD industry

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Abstract

Global warming has triggered public concern for environmental protection. Given this trend, carbon emission evaluation and improvement become a critical management in many companies. However, the developing of such kind of a model is very complicated, considering regulations, process, and platform to register and many other problems managers have to deal with. The complex process makes carbon emission management a very difficult issue. This research is to integrate green design and life cycle assessment (LCA) and builds up a feasible model- low carbon value chain model (LCVCM)- for assessing and improving carbon emission on a case product. The implementation method involves four steps: "Scoping the process of product", "Analyzing carbon emission on each process", "Simulating carbon Impact", and " Targeting and Improving the Product". From the result, the carbon footprints are significantly reduced. LCVCM drives an original product from a less green into a greener and more eco-efficient product. After years of efforts, the standard quantity of carbon emission will be clearly taken into consideration by green product development. This model is created which enabling many organizations to improve their carbon emissions. It also supports organizations to find the balance between environment and economics thereafter.

Keywords: Carbon footprint, Green design, Life Cycle Assessment, Global Warming.

I. Introduction

The modern acceleration of global warming, attributed primarily to anthropogenic greenhouse gas emissions and blamed for extreme weather patterns and weather-induced natural disasters, draws prodigious attention of both governments and scientists the world over [1]. From intensifying focus upon global warming, two interlocking sources of pressure have evolved which now bind the world economy. First, the limits of the natural world could constrain business operations, realign markets, and perhaps even threaten the planet's well-being. Second, enterprises face a growing spectrum of stakeholders who are concerned about the environment. Those who best meet and find solutions to these challenges will lead the competitive pack [2]. Green designs in reducing carbon emissions are generally efficient when life cycle assessment (LCA) is employed during the design stage since all possible carbon emissions factors from inputs, manufacturing processes, distribution, use, and disposal are calculated and optimized during design. Materials selection and carbon management are two core principles of green design strategies in developing low carbon supply chains, because prevention is better than cure. During the design stage, careful selection of raw materials and ecological manufacture has advanced impacts and therefore also has the potential to significantly reduce an environmental shock [3]. By employing green design strategy, companies produce less scrap and less pollution. In short, green products are efficient, easy to assemble, easy to manufacture, and, above all, superior designs. In recent years, LCA has been utilized in a variety of applications, such as automotive design, manufacturing systems, and consumer product design.

Our research integrates green design strategies and LCA principle to develop a low carbon value chain methodology. Such an analysis can provide valuable information related to complete processes and also provide information about how to reduce the carbon emissions of a product. The paper is organized into five sections. Section 2 reviews green design strategy. Section 3 presents the low carbon value chain model for integrating green design

strategy and LCA. A detailed case study is presented in Section 4, which presents the mass customized product's bill-of-materials (BOM), value chain hierarchy and the model for reducing the overall carbon footprint structure. Finally, conclusions are drawn in Section 5.

II. Ease Green design for carbon footprint management

Carbon reduction and carbon management are two broad green design principles (Figure1). Materials are major contributors of environmental degradation. Carbon reduction strategy eliminates carbon pollution at the source level by using less material to perform the same operation. Therefore, any reduction in material consumption yields a corresponding reduction in carbon emissions and prevents environmental damage. Raw materials and waste reduction, material substitution, and product life extensions are all goals of carbon reduction. Better carbon management techniques include green design for 3R (reduce, reuse, recycle), green design for manufacturing processes, and green design for incineration. Green design strategy in this phase is aimed at making products easy to manufacture, remanufacture, recycle, compost, and incinerate. This principle can also be applied to outsourcing. Green design strategies to minimize and eliminate environmental problems can be found by working with suppliers to develop win-win solutions [4]. All the above actions take a co-work and control approach to greening value chains.

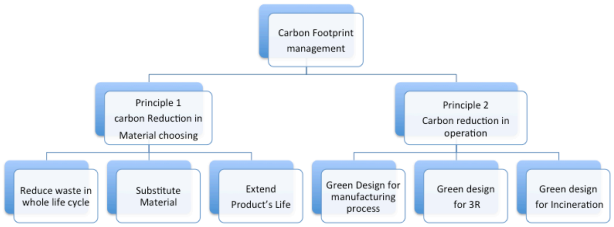


Figure1. Green design strategy in managing carbon footprint.

III. Conceptualizing low carbon value chain

"Carbon footprint" has become a widely used term and concept in the public debate on responsibility and abatement action against the threat of global climate change. It is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product [5].

A significant portion in establishing low carbon life-cycle impacts is determined by decisions made in the green design stages [6]. Building on this early stage design work, this paper presents a low carbon supply chain model developed through the integration of SimaPro software with LCA methodology and green design optimization techniques in order to minimize carbon footprint impacts during the early design stage. LCA, as a useful tool for developing low carbon value chain involving environmental criteria, has been used by environmental consumer groups to help consumers decide what to buy, by manufacturers to identify areas for improvement, and by legislators to develop criteria for environmental labeling schemes. The LCA is also an integrated approach for low carbon value chain that includes all components: inputs and emissions from the system; inputs and emissions over the entire life cycle of a value chain; facilities, raw material acquisition methods; distribution and disposal methods; and issues including recycle, reuse, and so on.

This paper presents a four-phase framework: the initiation phase, consisting of the problem and objective definition; the second phase defines all inputs and solid, liquid, and gaseous wastes; the third phase is impact analysis, connecting inputs and outputs to real-world environmental problems; and, finally, the improvement phase, focusing on the overall green performance, as shown in extent (Figure 2).

3.1. Scoping the process of product

The first step in performing a life-cycle assessment is to identify the purpose of analysis. The work may be done to review materials, products, or processes; evaluate resource use; train employees in waste reduction; and set up policy. The studies could be product specific. The next step is to define the product boundaries. The product definition should include precisely where the life-cycle begins and where the initial life-cycle attains completion and a new cycle begins. It should begin with material extraction and end with final disposal of the product. The system definition should also take into account the depth of analysis.

3.2. Analyzing carbon emission on each process

The purpose of life-cycle inventory analysis is to develop a model to account for carbon emissions of all inputs and outputs during each stage of the life cycle. Typically, the analysis is broken down into multiple stages such as raw materials extraction, raw materials processing, manufacture, assembly, filling and packaging, distribution, use and maintenance, reuse, recycling and disposal.

3.3. Simulating carbon Impact

The carbon impact analysis use simulation to evaluate the effects of resources and carbon emissions identified in the life-cycle inventory analysis. One major problem during this step is deciding how to account for recycling and by-products. Once the data are collected and inventory of inputs and outputs prepared, the next step is to quantify the effect of the inventory in the environment. Impact analysis is still in the early stages of development. LCA takes into account specific, pre-determined impacts

such as environmental and human health impacts, resource depletion, social welfare, or carbon emissions in this model.

3.4. Targeting and Improving the Product

The purpose of this phase is to figure out all possible causes resulted in carbon emissions on the entire life cycle. We begin with an analysis of each individual product component. Each product component has its own unique and specific physical features. Managing these features and synergy is the key performance process of green design. Therefore, this principle consists of improving functional characteristics, enhancing 3R ratio, pollution evaluation, and extending product life. We begin by reviewing the product BOM and analyzing the following aspects of each component:

1. Manufacturing process
2. Features and functionality of materials
3. Potential for materials reduction
4. Potential for improvements in materials re-usage
5. Potential for carbon reduction through recycling mechanisms

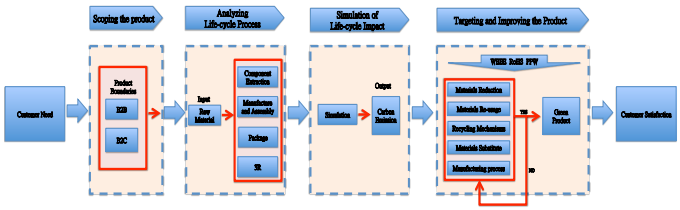


Figure 2. Low carbon value chain model.

IV. Simulation Result

The case study uses thin film transistor liquid crystal displays (TFT LCD) as an example (Table 1). The paper focuses on assessing the effects of green design in reducing carbon emissions during the manufacturing, transport, use, and disposal of TFT LCDs in relation to emissions throughout the comparable cycle with traditional design. In order to evaluate the carbon footprints across the value chain, Figure 3 shows the entire value chain of a TFT LCD. Simultaneously, this paper selects the Global Warming Potential indicators for investigating carbon footprints. Results of the analysis are presented in this section. The all nodes represent product components of a TFT LCD during the production process. The system includes key parts such as: LED light bar, thermal pad, back, and special optical engine system components. The prime manufacturer (i.e. the end-product producer) assembles the parts and components to produce the final product, which often has several configurations required for mass customization. Figure 4 is the TFT LCD structure tree which is used to calculate the various product configuration carbon footprints and which displays the BOM of a modularized TFT LCD. A common TFT LCD structure contains nine parts.

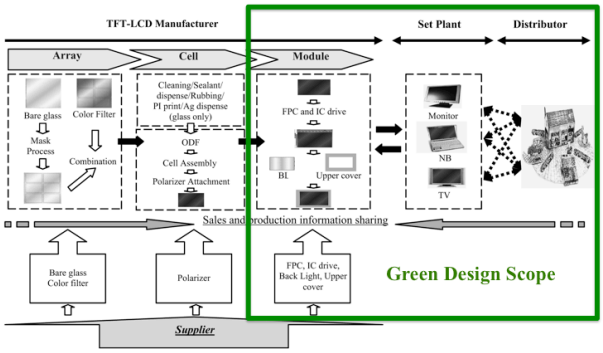
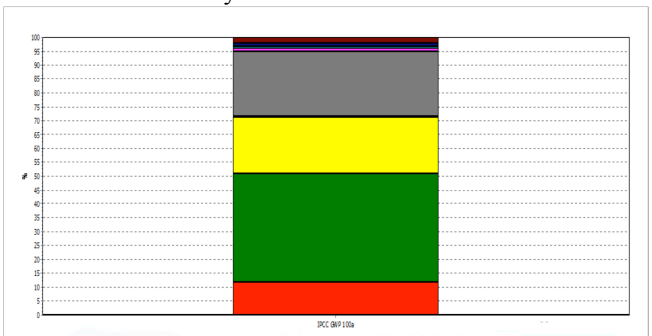


Figure 3: The value chain for TFT LCD product.

4.1. Carbon footprint analysis for original product

The first review is to determine which contributors to the total carbon footprint are significant and which ones are negligible from a global warming impacts point of view. The carbon footprint impacts are calculated separately for the raw materials, the production, and the logistics (by sea and by road). The carbon dioxide emission coefficients for each industry are obtained from the report "Update and Maintenance of the Resource Utilization Model and Policy Analysis" (Lin and Huang 2006) to evaluate TFT LCDs. The TFT LCD carbon footprint analysis reveals that approximately 71.29% of the overall carbon footprint is from raw materials, 15.9% is from production, and 12.81% is from logistics. Obviously, materials are major contributors of environmental degradation. Even though extraction, processing, and manufacturing add value to products, these processes also damage the environment. The following Table 2 presents the simulation for each part of a TFT LCD, broken down by these LCA stages. The values shown in the table indicate that the backplane will result in 34.65471 kg more carbon emission than other components.

Table 2. Carbon analysis of TFT-LCD.

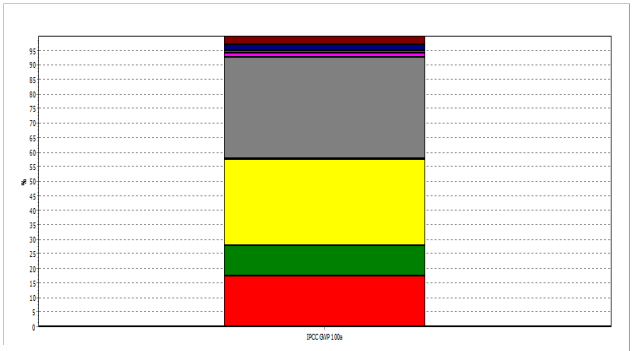


Impact	Strategy	TOTAL (Kg CO2 eq)	LCD Panel	Backlight Modular	LED Lightbar Modular	Source Cover Modular	Optical membrane Modular	Metal frame Modular	Plastic frame Modular	Packaging Material	T-CON Modular
Carbon Emission	Tradition way	87.87934	10.22054	34.65471	17.56049	0.387971	20.61751	0.937256	0.512048	1.200463	1.788352

4.2.Green design strategy for this case

The backplane results in a major portion of the overall carbon footprint. Therefore, substitution of polluting materials with less polluting ones is a sensible strategy to reduce pollution and remain competitive. According to green design strategy, this case substitutes an alternate material for the backplane modular component.

Table 3. Green design strategy for TFT-LCD.



Impact	Strategy	TOTAL (Kg CO2 eq)	LCD Panel	Backlight Modular	LED Lightbar Modular	Source Cover Modular	Optical membrane Modular	Metal frame Modular	Plastic frame Modular	Packaging Material	T-CON Modular
Carbon Emission	Green Dedign	59.62819	10.22054	6.403563	17.56049	0.387971	20.61751	0.937256	0.512048	1.200463	1.788352

As observed in table 3, the measure of emissions resulting with green design (6.403563 kg) is less than that without green design (34.6547 kg). This green design method can reduce carbon emissions by 28 kg. Fig 5 highlights the differences between the two approaches.

Global manufacturers face the challenge of reducing carbon emissions and protecting our earth. If a consumer has to make a choice between a polluting and a nonpolluting product, assuming the two products are equal in all other regards such as features, quality, cost, functionality, cosmetic appeal, etc., he is likely to choose a nonpolluting one. Hence a manufacturer of a polluting product is likely to lose market share in the long run. All product producers are responsible for designing and manufacturing green products with minimized carbon footprints. When manufacturers are dedicated to the reduction of carbon footprints, the sale of green products enhances their competitiveness and brand reputation. The low carbon value chain model based on green strategy presents a significant correlation between materials chosen and carbon reduction.

Using the above strategies, this study divides the reduction of carbon footprints into two scenarios. The first scenario uses traditional materials, but the carbon footprint is higher. The second scenario replaces traditional materials with alternate materials and produces a low carbon footprint. According to the result, the methods used for reducing the carbon footprint of the TFT LCD include enhancing ecological efficiency and lowering the carbon footprints attributed to specific materials. Simultaneously, as demonstrated by the research result and review of relevant literature and technical reports, Figure 5 shows that a green design strategy is effective in reducing the carbon footprint of a TFT LCD.

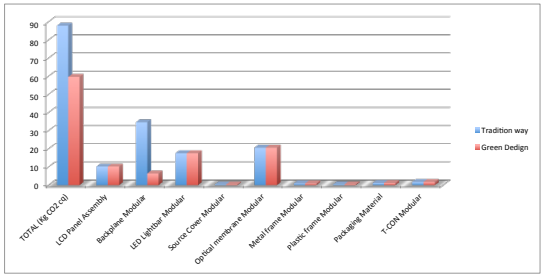


Figure 5. The differences between the two approaches.

V. Conclusion

Global warming has prompted nations to pay more attention to ecological protection, resource integration, and laws dedicated to carbon emissions regulation. If companies can develop innovative approaches to provide low carbon products, the performance will reflect significantly on reputation and market share. Therefore, low carbon value design is an innovative perspective for manufacturers to maximize core competitiveness and minimize environmental shocks. This paper constructs a low carbon design model (LCVCM) based on green design strategy. LCA is used to define and estimate all product components resulting in carbon footprints. Simultaneously, the simulation tool has been applied to test product components and clarify the optimal low carbon improvement, calculating for the various interacting factors.

This paper provides a preliminary study to help corporations accurately assess and reduce the carbon footprints of mass customized green products. It drives an original product from a less green into a greener and more eco-efficient product. The implementation method involves four steps: “Scoping the process of product”, “Analyzing carbon emission on each process of whole life cycle ”, “Simulating carbon Impact”, and “ Targeting and Improving the Product”. A model is created accordingly to support the carbon reduction. From the result of this case study, the carbon footprints are significantly reduced. In addition, this model also presents simulations with two scenarios and explores how the design-effective method can reduce the carbon footprint. The result of the analysis demonstrates that the connection between carbon footprints and the green component life-cycle design is interrelated.

According to the results, the green design strategy is appropriate for the carbon emission issues and the proposed model serves as an adequate base for analyzing carbon emissions of similar products in a larger context. This paper expects that the industry understands clearly

the global effects related to its decisions and encourages companies to realize that pollution-prevention activities must be initiated. Further work will extend to green production system application and consider the issue of multi-objective optimization under a green design mechanism.

After years of efforts, the standard quantity of carbon emission can now be clearly considered in the green product development. It is clear that many organizations were willing to adapt green design, green life cycle analysis and 3R (recycle, reuse, and reduction) under this new trend. A more active carbon model is created which enabling many organizations to improve their processes and to reduce carbon emissions thereafter.

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