Life Cycle Analysis of Plastics in Southeast Queensland – Recycled Plastics versus Bio plastics in Electronics

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ABSTRACT

Electronic product manufacturing involves heat and chemical processing. Energy use is a major issue worldwide. Circuits in Plastic is a manufacturing technology characterised by printing conductive ink and minimal chemical and heat processing. Product disposal allows simple material recovery. Life Cycle Analysis showed that bio plastics had better environmental outcomes compared to recycled plastics; both greatly improved on PCB technology. Recycled plastic was more cost effective than bio plastic and superior to PCB. Both bio plastics and recycled plastics were excellent candidates for the CiP technology since both demonstrated equal strength in the measured criteria.

Keywords: Printed plastic circuits, Circuits in .plastic, Recycled plastic, Bioplastic, Silver ink.

1 INTRODUCTION

Printed circuit board (PCB) technology generates large quantities of hazardous electronic waste during production and product displosal, which can cause environmental and health problems. E-waste is currently increasing rapidly in Australia and electronic manufacturers are adapting environmentally sustainable techniques to reduce the problem. Technology advances has also resulted in the availability of cheaper and sophisticated electronic and electrical products. This has resulted in a reduction of the lifespan of most products rendering them obsolete in a short time [1] [2]. If the consumption rate of these products continues to increase, 'the world will be sitting on a time bomb of e-waste' [3]. The scarcity of some rare-earth elements is also a major concern. The need for effective management practices on e-waste has therefore become vitally important.

Several technologies are presently under development to replace the PCB technology while improving on the general use of plastics in electronic packaging. Among these inventions is the Circuits in Plastic (CiP) technology. The CiP technology has no copper etching and soldering in its manufacturing [4]. Electronic components are sealed in a plastic substrate, eliminating the need for an additional enclosure. Apart from its cost effectiveness, CiP products are water-proof. Encapsulating materials include recycled, biodegradable and biocompatible plastics. CiP uses less energy during production and has an effective end-of-life management strategy. Components and materials can be mechanically removed and separated for reuse and recycling. PCB products are usually incinerated for metal recovery, or disposed into the landfill [5].

Conventional plastics derived from hydrocarbon deposits are a limited resource world-wide and causes several end-of-life management issues. In addition the cost of new plastic is increasing. CiP products are designed to perform effectively in both recycled or bio plastic enclosures [5].

Mechanical and thermal tests demonstrated that CiP circuits can withstand normal product use [4, 6]. Life cycle analysis of products made using PCB and CiP has shown a reduction in resource use by 70%, (notably a 60% reduction in fossil fuel) and 95% reduction in mineral requirements. There is a 60% improvement in ecosystem quality and a 70% improvement in human health. The total energy contribution for one CiP product is 0.7 MJ and for PCB is 2.7 MJ.

This project reports a life cycle analysis (LCA) of bio plastics and recycled plastics as alternatives to new plastic for CiP. The aim was to assess the general acceptability and environmental impacts in Southeast Queensland (SEQ) through a survey and a lifecycle analysis using a life cycle tool (software).

2 AIMS AND OBJECTIVES

The authors proposed the need for further research into the possible use of an alternative source of plastic such as bio plastics or recycled plastics, which might be environmentally acceptable, readily available, support local employment and reliable [5].

In a related development, Momani [7] conducted an assessment on the impacts of bio plastics and petroleum based plastics. The assessment was based on societal impacts of the two alternatives on energy usage, fossil fuel usage, pollution, health, food supply and economic effects. He concluded that bio plastics were superior to normal plastics in most of the criteria measured and hence viable for wide scale application.

The debate on bio plastics and recycled plastics has generated several conflicting and controversial arguments. Butler's research on 'Bio-based' plastic packaging [8] included a survey by personal interviews and a conference presentation on selected plastic packaging stakeholders. He listed four essential plastic types that (Polylactic acid: PLA, Polypropylene: PP, High-density polyethylene: HDPE, Polyethylene terephthalate: PET). These plastics are commonly used in the packaging industry. The resins were measured against a set of criteria including cost, mechanical properties and environmental impact and compared them using Multi-attribute Utility Theory (MAUT). The results of the survey and the MAUT comparison revealed PET as the preferred choice in the packaging industry due to its immense strength and durability. Despite the fact that PLA has environmental benefits, it lacked some fundamental elements when compared with the other resins. When the environmental outcomes and cost were the only criteria, PLA would still not have emerged as the preferred option because HDPE has other desirable environmental characteristics such as recyclability. It was concluded that PLA may be preferred only if an environmental criteria such as greenhouse gas emissions were measured [8].

In this paper we report a life cycle analysis (LCA) and survey results in the plastic industry of Southeast Queensland comparing recycled plastics and bio plastics. It also aimed to satisfy the production and operational commitment of the CiP technology to environmental improvement by answering the research question; 'does the use of recycled plastic have better environmental outcomes compared to bio plastics in manufacturing CiP?' The objectives of the project were;

- To determine the general acceptability of recycled plastic and bio plastics in SEQ
- To assess the mechanical properties of recycled plastics and bio plastics, and
- To undertake a life cycle analysis of both recycled plastic and bio-plastics to compare their environmental outcomes

3 CIRCUITS IN PLASTIC TECHNOLOGY

CiP has fewer process steps in manufacturing. This reduces chemical usage and allows recycling and reuse of recovered raw materials. As a "cradle to cradle" technology materials can be used to manufacture new products.

Two methods are used in manufacturing CiP circuits. Method one involves creating voids in a thermoplastic sheet. The electronic components are placed in the voids and heat pressed so they are flush with the surface of the substrate. Conductive silver ink is screen printed directly on the components embossed to complete the electronic circuit. A thin film (around 100 microns) of similar material is used to heat seal the circuit to protect from the environment.

Method two involves creating voids in a thermoplastic sheet. The components are placed in the voids and heat pressed so they are flush to the substrate surface. Conductive silver ink is screen printed on a separate thin film (Figure 1). It is aligned with the components in a base substrate and heat pressed using a hot embossing machine so the connections from the printed film and components are made. It also enables the circuit to be sealed from the enviroment. The sealing process helps prevent mechancial, environmental and chemical damage of the conductive tracks during the product lifetime [6].

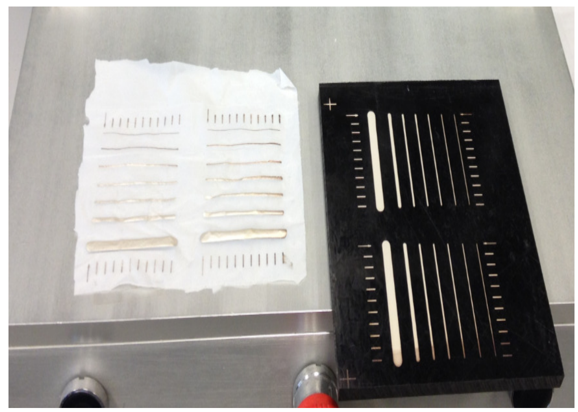

Figure 1: Conductive ink Screenprinted on bioplastic and Recycled plastic

4 SURVEY RESULTS

A summary of the overall average survey results for recycled plastics and bio plastics are outlined in Figures 2 and 3, and Tables 1 and 2.

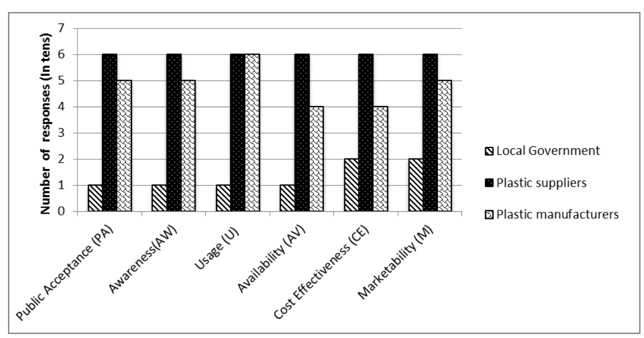

Figure 2: Survey responses to general acceptability of recycled plastics in SEQ
- Local Government: All 2 responses for CE and M, 1 response each for PA, AW, U and AV
- Plastic Suppliers: All 6 responses for PA, AW, U, AV, CE, M
- Plastic Manufacturers: 3 responses each for PA, AW and M, 1 for U and 2 responses for AV and CE

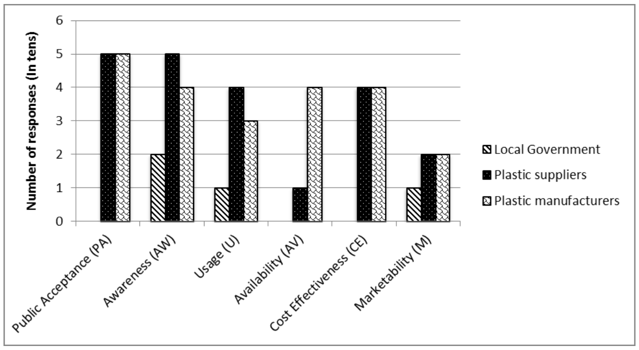

Figure 3: Survey responses to general acceptability of bio plastics in South East Queensland

- Local Government: All 2 responses for AW, 1 response each for U and M, 0 response for PA, AV and CE
- Plastic Suppliers: 5 responses each for PA and AW, 4 responses each for U and CE, 2 for M and 1 for AV
- Plastic Manufacturers: 5 responses for PA, 4 each for AW, AV and CE, 3 response for U and 2 for M

Table 1: Average survey results for recycled plastics from participants (%)

Survey Respondents	% Total for General Acceptance (GA)	% Total Mechanical Properties (MP)	Mean (%)
Local Government (2)	67	100	84
Plastic suppliers (6)	100	100	100
Plastic manufacturers (6)	80	87	84
Average for all respondents (14)	82	96	89

- *Local Government: Average number of 1.3 out of 2 for GA and 2 out of 2 for M P*
- *Plastic Suppliers: Average number of 6 out of 6 each for GA and MP*
- *Plastic Manufacturers: Average number of 4.8 out of 6 for GA and 5.2 out of 6 for MP*

Table 2: Average survey results for Bio plastics from participants (%)

Survey Respondents	% Total for General Acceptance	% Total Mechanical properties	Mean (%)
Local Government (2)	35	50	43
Plastic suppliers (6)	58	66	62
Plastic manufacturers (6)	62	47	55
Average for all respondents (14)	52	54	53

- *Local Government: Average number of 0.7 out of 2 for GA and 1 out of 2 for MP*
- *Plastic Suppliers: Average number of 3.5 out of 6 for GA and 4 out of 6 for MP*
- *Plastic Manufacturers: Average number of 3.7 out of 6 for GA and 2.8 out of 6 for MP*

From the total number of 14 people interviewed, the majority had strong views about recycled plastics (see Table 1), in contrast to Table 2 that gives values just above 50% for bio plastics. Most (82%) agreed that recycled plastics are widely accepted and used in South East Queensland compared to 52% for bio plastics. Most (96%) suggested that recycled plastics have good mechanical properties and 54% believed that bio plastics have equally high mechanical properties and can thus be used in similar applications.

Among all three respondent categories, the suppliers were very positive on the overall criteria measured for both recycled and bio plastics (100% and 62% respectively). In the case of recycled plastics, both the local government and manufacturers had equally high responses (mean value 84%). There was however a slight difference in the results for bio plastics for these two groups. The manufacturers awarded a mean value of 55% and the local government awarded the lowest mean value of 43% for all the criteria. This result might be related to the types of benefits expected and the current applications from the two alternatives.

In summary, recycled plastics were preferred to bio plastics. However for the purpose of achieving improved environmental sustainability an LCA comparison was undertaken.

5 LIFE CYCLE ANALYSIS - GOAL AND SCOPE DEFINITION

The LCA research goal was to determine the most suitable plastic materials for CiP. It compared the components, materials, energy requirement and environmental outcomes of bio-plastics and recycled plastics. The research aimed to;

- Evaluate the components and materials in manufacturing,
- Evaluate the energy requirements,
- Evaluate the environmental outcomes, and
- Determine the difference between the components, materials and environmental outcomes.

The scope involved an environmental assessment of all major life cycle phases for recycled and bio plastics for manufacturing CiP. It included the 'cradle to grave" analysis consisting of the raw materials extraction, processing, manufacturing and final end of life management of the CiP technology produced from recycled plastics and bio plastics respectively.

It excluded the specific circuit types, electrical components and uses. A lifespan of 5 years was projected for the CiP product, in that, the technology will last for 5 years irrespective of the type of plastic material used.

Two plastic materials were used: Poly lactic Acid (PLA) and recycled Acrylonitrile Butadiene Styrene (ABS) for bio plastics and recycled plastics respectively. The system boundaries were categorised into three sections:

geographical boundaries, time related boundaries and nature boundaries [9, 10].

The Eco-indicator 99 (E) V2.08 method was used for the impact assessment. The results depicted a typical end of life management scenario for the two alternatives. The comparison between recycled plastics and bio plastics were interpreted by normalization per impact category.

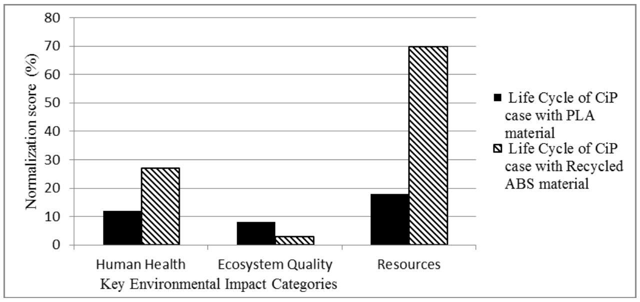

Figure 4: Normalization results for comparing 1p 'Life cycle of CiP case with PLA material' with 1p "Life cycle of CiP case with Recycled ABS material. Method: Eco-indicator 99 (E) V2.08/Europe E1 99 E/E/Normalization

HUMAN HEALTH: PLA – 12%, ABS – 27%;
ECOSYSTEM QUALITY: PLA – 8%, ABS – 3%;
RESOURCES: PLA- 18% - ABS 70%

Figure 4 shows the normalized score for the use of PLA and ABS. Normalization is a procedure that describes the extent to which an impact category contributes to environmental issues. It shows the magnitude of the impact categories relative to the reference information [9]. The result from the PLA material indicated an improvement in human health and resources while ABS had a better outcome with ecosystem quality. Although there was an overall reduction in the human health scores, PLA (12%) was less than ABS (38%). Both PLA and ABS revealed less impact on ecosystem quality (less than 10% in both scenarios). PLA values were 5% more ABS values, an indication that ABS has a smaller impact (3%) on the ecosystem quality compared to PLA (8%). There was a significant difference in electricity consumption by 52% between the two alternatives. In particular 18% was recorded for PLA compared to 70% for ABS.

6 CONCLUSIONS

The survey revealed overall mean values of 89% and 53% for recycled plastic and bio plastics respectively for general acceptability and mechanical properties. The LCA showed that bio plastics had better environmental outcomes compared to recycled plastics. Recycled plastic was more cost effective than bio plastic. A sensitivity analysis was carried out for mixed plastic (40% new plastic plus 60% of recycled plastic) and recycled plastic for the manufacturing of the CiP technology. Mixed ABS plastic, recycled ABS and PLA materials were measured against the three impact categories and higher values were recorded for mixed plastic in human health and resources.

It was concluded that both bio plastics and recycled plastics were excellent candidates for the CiP technology since they both demonstrated equal strength in the measured criteria. Further research on the adaptation and improvement of bio plastics is proposed.

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