THE IMPACT OF DESIGN FOR RECYCLABILITY ON THE ELECTRONICS RECYCLING PROCESS

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Abstract

The end of life processing of electronics equipment has become an issue of both scientific and political importance over the past decade. The penetration of information technology products in to seemingly every aspect of daily life does create a tremendous environmental concern. These products almost certainly contain lead-based solder on the circuit cards and may contain other hazardous heavy metals such as mercury. Legislation such as the German “Take Back” requirements target manufacturers as responsible for the proper disposition of surplus information technology products. In addition, many manufacturers have taken on the challenge of “life cycle design” as part of their design methodology. The designer is required to look at the impact of design decisions not only as they relate to a specific product attribute, but in the broader sense of environmental impact over the entire product life from procured parts to disposal. In the process of considering product disposal, the designer is required to consider final disposition processes at end of life, thus “Design for Recycling” becomes part of the over all design plan.

The incorporation of Design for Recycling (DFR) in to the design process is an extremely critical step towards the creation of more recyclable electronics products. Product design most often has the greatest impact on both the logistics and the costs of the recycling process. Constraints set forth by the design can dictate both the methodology used to recycle the product and the revenues (or costs) generated from the recycling process. This paper examines the impact of some broad DFR concepts on the electronics recycling process. The paper explores both closed loop (including reuse) and open loop recycling issues and presents some quantitative data on the impact of design for recycling on the recycling process.

Introduction

To gain an understanding of the impact the designer has on the end of life disposition of electronics products, it is important to have a clear understanding of the recycling process itself. Once an understanding of this process is reached, design considerations impacting the recyclability of a product can become quite obvious. A model for this process can be seen in figure 1.[i]

Figure 1 depicts product life beginning in the design phase and proceeding through production to the user. At some point the user determines that the product has reached the end of its technological or economic life. The IDC defines the end of its technological life as the point when the product will no longer support the latest software or user need. The end of the economic life is the point when the cost of support or maintenance is excessive. In either case, the decision is made to declare the hardware as surplus or scrap.[ii]

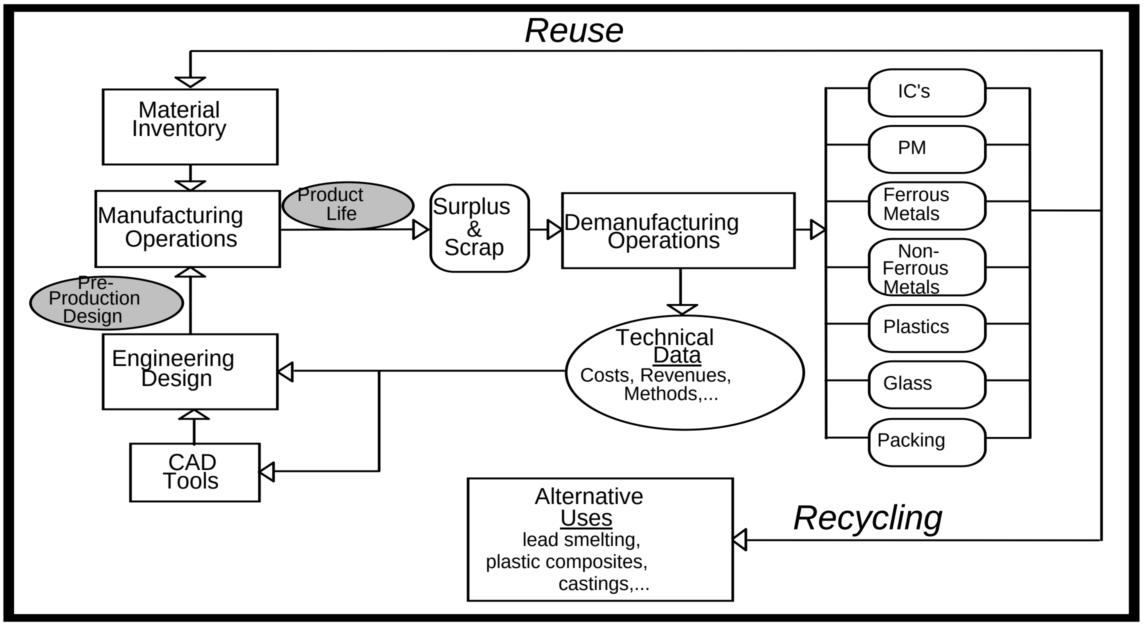


Figure 1: Closed loop reuse/recycling system

Once the hardware is declared surplus or scrap it proceeds to the recycling /demanufacturing process. The goal of this process is to liberate valuable materials such as precious metals, ferrous metals, non-ferrous metals, integrated circuits, plastics,…and hazardous materials such as lead and mercury at a minimum of cost. There are two dominant methodologies for performing this recycling process. The first is a destructive methodology using a shredder or grinder similar to that used in the automobile industry. This process minimizes labor costs, however, the liberated materials such as nonferrous metals often contain more contamination and are thus less valuable. The second and most common methodology for recycling information technology products is a non-destructive disassembly. This is typically a manual disassembly using tools common to the assembly process. This process can liberate material with little or no contamination, which not only increases the reclamation value of the material, but makes reuse of chassises, circuits, and subassemblies possible. As an example of the economic benefit gained in an open loop recycling case, clean aluminum might have 5 times the value of aluminum that is contaminated with only a small fraction of copper. As an example of the improvements in a closed loop recycling/reuse case, in for example a lease/take back situation, a manufacturer might be able to clean and reuse a plastic subassembly for a fraction of the cost it would take to produce. This paper will examine the impact of Design for Recyclability on the manual disassembly and recycling process. The economics of this process are dictated by the revenues generated through the liberation of valuable materials versus the labor costs necessary to liberate the materials. Design for recyclability concepts can impact this process in several ways possibly substantially increasing the profit that can be generated from the recycling process or increasing the percentage of recyclable content of a product.

Recycling

The electronics designer considering the end of life processing of a product can impact the recyclability of the product in a number of ways. These primarily break down in to two categories, economic impact and environmental impact. Economic improvements are of particular importance to manufacturers facing take back requirements. Design for recyclability improvements can take a mandated product recycling program from a money loser to a profit generator. Even producers that are not facing legislated product take back can benefit from economic improvements in the recycling operation. All manufacturers or electronic products face future responsibility for the products they produce. However, in a free market system, products that have a positive economic return in the recycling operation will be in demand at the end of life rather than a disposal burden. Independent recyclers will compete for the opportunity to dispose of these products

The economic and environmental improvements a designer can make by applying design for recycling concepts can be further broken down in to primary design improvement objectives. The major objectives include:

Economic Improvements

- Decrease disassembly time
- Increase liberated value
- Decrease learning curve

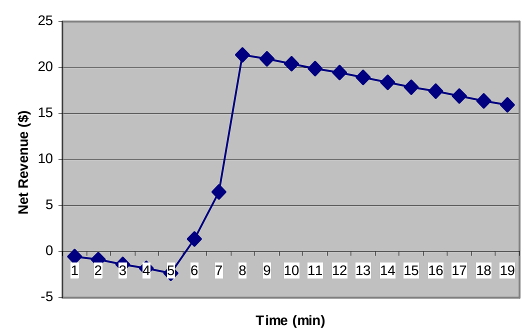
Environmental Improvements

- Increase recyclable content

Economic Improvements

A quantitative assessment of design improvements targeted at decreasing disassembly time or increasing liberated material value can be gained by an analysis of the net revenue curve that drives much of the manual disassembly recycling process. Figure 2 is an example of a net revenue curve from an actual disassembly operation.

Figure 2: Net Revenue Curve



The goal of the recycling process is to operate at the peak of the net revenue curve, thus maximizing the revenue generated in the recycling process. DFR improvements which decrease disassembly time, increase the magnitude of the peak of the net revenue curve by shifting the peak of the curve to the left (increasing net revenue generated in the process). Such improvements could include decreasing the total number of fasteners used in a design, using the same fastener type (phillips head screw as an example) throughout the entire design, or changing the fastener type from a screw to a clip. Design for recycling improvements which increase the value of the liberated materials do not move the peak of the curve, but do increase its magnitude. Such improvements could include changing from captive steel fasteners in an aluminum chassis to counter sinks, the chassis once liberated becomes clean aluminum. An additional example of improvements that can increase the value of liberated materials is labeling of plastics, this can allow the recycling of previously unidentified plastic composites. IBM realized a 40% cost savings over virgin material through the identification and recycling of pre-consumer PC/ABS scrap.[iii]

Another approach to improving the economics of the recycling process is to address the learning curve associated with the disassembly of electronic devices. In many full scale electronics recycling operations, electronic devices are disassembled in small batches of possibly 10-100 units. These small batches are dictated by the nature of material being declared surplus. The disassembler then faces the challenges of establishing the best methodology for liberating the valuable material and reaching the peak of the net revenue curve for that particular product. This process is governed by a learning curve not to dissimilar from the learning curve in the assembly process. Figure 3 represents such a curve from actual disassembly data.

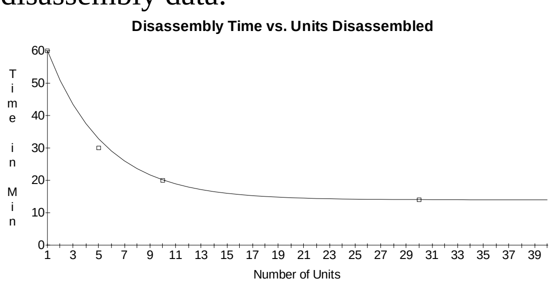


Figure 3[iv]

A design improvement for the product in figure 3 that could reduce the initial learning curve from 10 units to 5 units, could significantly improve the economics of the recycling operation. Such design improvements would include identifying the location of fasteners that may be hard to find or hidden in final assembly. Another improvement currently being considered by certain manufacturers is the inclusion of an optimum disassembly diagram within the device.

Environmental Improvements

All of these various economic improvements can have positive environmental effects as well as improving the value of the recycled materials. As an example, removing adhesive labels from a piece of ABS plastic not only allows the recycler to potential create higher liberated material value from the recycling of the ABS, but prevents the ABS from potentially being landfilled. However, some design improvements are targeted specifically at creating a more environmentally benign product. Some examples of such improvements would include packaging volume reduction or the elimination of chemical ink on a product. These types of improvements are becoming progressively more important as recyclers begin to set goals of zero landfill waste for electronic product recycling. This goal can only be reached with the cooperation of designers addressing issues of packaging waste and eliminate the use of nonrecoverable materials.

Reuse

The potential for reuse of chassises, subassemblies or piece parts provides the designer with the greatest opportunity to substantially impact the recycling operation both environmentally and economically. There are a number of industry examples of mature reuse programs, hower, none maybe as well documented as that of Xerox corporation. Xerox is in somewhat of a unique position as its product designers are creating a significant number of products that will be leased rather than purchased. This has allowed Xerox to include "used/refurbished" parts as part of "new" lease products. The only requirement is that the lease contract clearly identify that the product may contain used/recycled materials. Some estimate that Xerox products can now contain nearly 50% recycled content. This includes reground and recycled plastics but also includes actual refurbishment and reuse of major subassemblies. Reuse programs such as this can allow a recycler to generate revenue by offsetting material purchase cost for new production and for product maintenance. The importance of the economics of reuse to the recycling operation is highlighted by the fact that it is not uncommon to have only 10-20% of the product stream involved in reuse, but to generate 80-90% of recycling revenue through reuse sales. This reuse process can even be extended and used as part of maintenance of products or to sales in the secondary market.

A designer applying design for recyclability concepts is responsible for facilitating reuse potential for a product. Reuse plans developed in the early stages of product design are creating greater and greater reuse potential for the manufacturers. One necessary step is creating compatibility of subassemblies from one product generation to the next. Other examples of product attributes that are significant to reuse potential are consistency in color, architecture, and circuit technology. When considering reuse designers are often facing trade off decisions between potential new product attributes and their impact on reuse potential.

Conclusion

DFR is changing the landscape in the electronics recycling industry. Manufacturers embracing DFR concepts are creating products that will not only meet the needs of the user but will not be a disposal burden at end of life. The impact of properly considered and seemingly simple design changes on the recycling process can be enormous.

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[i] C. Boswell, "A Feedback Strategy for a Closed Loop End-of Life Process", International Conference on Clean Electronics Products and Technology, Institution of Electrical Engineers, 1995.

[ii] Kevin Hause, Lorraine Cosgrove, Bruce Stephen, Dane Anderson and Takahiko Umeyama "IDC Commentary - The Cost of PC Disposal" IDC Weekly Update, December 11, 1997

[iii] Stephen K. Ching, J. Ray Kirby, and O. Dewey Pitts, "Plastics Recycling Issues for the Computer Industry: Progress and Challenges", IEEE International Symposium on Electronics & the Environment, 1996

[iv] C. Boswell, "The Economic Impact of Design for Disassembly on the Electronics Recycling Process" ECDM, 1995