



ADDRESSING END-OF-LIFE ELECTRONICS THROUGH DESIGN:

A Compendium of
DESIGN-FOR-ENVIRONMENT EFFORTS
OF EIA MEMBERS

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OF THE
ELECTRONICS INDUSTRIES**

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FOREWORD

The members of the Electronic Industries Alliance (EIA) are leaders in the technological revolution that has increased prosperity and improved our overall quality of life. The proliferation of electronics in our homes and offices has changed the way we communicate, conduct business, educate, and enjoy our leisure time. These changes are well-publicized, but the record of achievement of EIA member companies in meeting environmental challenges is less well known. This publication summarizes the leadership of the high technology industry in meeting one of these environmental challenges: the management of electronic products at the end of their useful life.

As the use of electronic products becomes increasingly widespread, the disposition of these products after their use is an emerging environmental issue that needs to be addressed. EIA members have responded to this challenge with technological creativity and innovation. Even as the electronics industry has experienced significant growth, competition, and consumer demand for improved products, EIA members have recognized the need to continuously improve its environmental performance through Design for the Environment (DfE) initiatives to minimize or eliminate adverse environmental impacts throughout the product's life-cycle. EIA members have improved the overall environmental performance of their products and processes by minimizing or reducing wastes at their manufacturing facilities and improving the energy efficiency of their products. To address the challenge of end-of-life electronics, EIA members have worked to design products to facilitate opportunities for reuse and recycling when the products reach the end of their useful life.

The following pages demonstrate the commitment of electronics manufacturers to innovative design that results in environmentally sound management of end-of-life electronic products. These DfE success stories provide only a snapshot of the efforts undertaken voluntarily by electronics companies to minimize the environmental impacts of their products. The achievements by EIA members highlighted in this publication result in significant benefits to the environment by saving raw materials and natural resources used in new product manufacturing and diverting substantial quantities of materials from the waste stream. EIA members can be proud of the strides they have made to address environmental concerns associated with electronic products. We will continue working on these and other efforts to improve protection of our global environment in pursuit of the goal of sustainable development.

*Dave McCurdy
EIA PRESIDENT*

*Diana Bendz
IBM, Chair, EIA DfE Committee*

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INTRODUCTION

Manufacturers of high-tech products face daunting challenges in the design and manufacture of products to meet the increasing demands and expectations of users and provide superior performance and cost-effectiveness, while also minimizing potentially adverse environmental impacts. EIA members have addressed these demands by proactively taking environmental considerations into account at the earliest stages of product design and development. The discipline of designing products to minimize environmental impacts throughout the life-cycle of the product is known as Design for the Environment (DfE).

Design for Environment (DfE)

The systematic and proactive consideration during design and development of a product's effect on the environment over its entire life cycle from conception through disposition. This consideration includes all processes associated with the creation, use, and ultimate disposition of the product.

*D.T. Allen, UCLA, and Joseph Fiksel, Decision Focus, Inc.
"Terminology Used in Design for the Environment"*

An engineering perspective in which the environmentally related characteristics of a product, process, or facility are optimized.

T. E. Graedel and B. R. Allenby, Industrial Ecology

EIA members are leaders in using DfE to improve the environmental attributes of their products and processes. The high-tech industry has employed creative, innovative design approaches that eliminate or minimize adverse environmental impacts throughout the product life cycle -- from the manufacturing, distribution, and use of a product, to its reuse, disassembly, recycling, and disposition.

While EIA members have a demonstrated record of achievement in using DfE to reduce pollution in their production processes, improve the energy efficiency of their products, and other initiatives, this publication focuses on the design efforts of member companies in protecting the environment at the final stage in the product life-cycle - after the product has reached the end of its useful life.

Design advances improve the management of used electronics by:

- ✓ Eliminating or minimizing the use of substances that may impede environmentally safe recycling or disposal;
- ✓ Using recycled content when such materials are available and cost effective, and do not interfere with manufacturing requirements or product quality;
- ✓ Improving the ability for products to be reused, refurbished, or repaired where possible, thereby extending the useful life of the product and delaying the need for disposal;
- ✓ Facilitating disassembly by employing techniques such as snap-fit assembly;
- ✓ Minimizing the diversity of materials and the number of parts within a product;
- ✓ Providing for the coding or identification of materials; and
- ✓ Promoting the recyclability of materials by avoiding the use of coatings and paints on parts.

The following pages summarize just some of the innovative design initiatives of EIA members that help promote the environmentally sound, economically efficient management of end-of-life electronics. By employing life-cycle thinking to initial product design, EIA members have undertaken a series of steps that will reduce environmental impacts and increase opportunities for the recycling of electronic products at the end of their useful life.



MATERIALS SELECTION

Electronic products and components are complex assemblies, comprised of many materials and substances. The nature and number of materials found in high-tech products can have significant implications for the management of these products at the end-of-life stage.

Questions have been raised concerning whether some materials may be safely disposed. The diversity of materials found in some products can impede recycling opportunities because it can be difficult to identify, separate, and recycle many of these materials.

To address these challenges, EIA members have employed DfE techniques to the materials selection process. Our member companies have reduced or eliminated the use of substances of concern, evaluated alternatives to these materials, reduced the volume of materials found in electronics, and increased the use of recycled materials or materials that can be readily recycled.

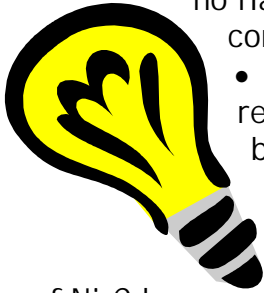
Reduction/elimination of the use of constituents of concern

Where certain materials have been shown to pose a significant risk of environmental harm, EIA members have acted as the global leaders in taking action. Perhaps the most prominent example of this leadership is the action to eliminate the use of ozone depleting substances (such as chlorofluorocarbons or "CFCs"). EIA members led the way in phasing-out the use of these chemicals years ahead of the deadlines established under the Montreal Protocol. Similarly, as concerns have arisen over the presence of cadmium in batteries, EIA members have shifted to other battery chemistries. For example, lithium-ion batteries provide superior performance for some products and can be smaller and lighter than other battery chemistries, while having lower toxicity.

To the extent technically feasible, EIA members have eliminated many substances of concern from their products, including: arsenic, asbestos, brominated flame retardants, cadmium, hexavalent chromium, mercury, and PCBs.

- **Apple's** Macintosh PowerBooks have used longer-life, less toxic rechargeable lithium-ion batteries for the last three product generations, in place of nickel-cadmium batteries.
- **Compaq** has generated a listing of hazardous materials that are banned or restricted from use in Compaq products.
- **Corning-Asahi** has eliminated arsenic in cathode ray tube (CRT) glass and the use of lead in the panel glass of CRTs.

- The design of **Hewlett-Packard's** OfficeJet 500 multi-purpose printer has eliminated the need for plastic flame retardants by using a metal chassis and power supply enclosure, utilizes light-emitting diodes (LEDs) instead of a mercury lamp for the scanner, and eliminates the need for batteries by using flash memory technology.
- The primary plastic resin used in **Intel's** PCs and servers (ABS + polycarbonate) have no flame retardants containing PBBs or PBDEs. None of their products contain asbestos, or include lead or cadmium as plastic additives.
 - **Kodak's** new digital cameras (DC 240, DC 265) incorporate rechargeable Ni-MH batteries instead of traditional Ni-Cd batteries. Light-emitting diodes have replaced mercury lamps in film-scanner products.
 - **Lucent's** Wireless Customer Adaptor was designed to incorporate new environmental constraints, such as elimination of Ni-Cd batteries and 85% reduction in usage of lead solder.
- **Panasonic** has been a leader in the development of non-lead-based solders. Panasonic was the first company to apply reflow type lead-free soldering to compact portable mini-disc player PC boards. Its video equipment division has been developing a low-cost tin-copper base solder, which will be introduced into the marketplace in 2000.
- **Philips Consumer Electronics** has a list of banned substances (asbestos, cadmium, mercury, CFC/HCFC, PCP, PCB, PCT, PBB/PBBE), and all products are evaluated against this list before introduction.
- **Sharp** has eliminated the use of lead acid batteries in the design of camcorder products, replacing them with new battery technologies.
- **Thomson Consumer Electronics** eliminated the use of arsenic in CRT glass manufacturing and eliminated the use of cadmium in CRT assembly. Thomson has also replaced VOC based paints with water-based paints within the wood cabinet and plastic finishing operations.



Research into alternatives to substances of concern

Many materials of potential concern are used in electronic products because of their unique properties and the absence of suitable alternatives. EIA members are continuously engaged in the search for substitutes that satisfy performance and cost specifications while also protecting the environment. For example, a significant amount of effort has focused on alternatives to the use of lead in electronic assemblies. EIA member companies conducted a major research project with the National Center for Manufacturing Sciences (NCMS) to evaluate lead-free solder substitutes. This four-year, \$19 million collaborative research program concluded that substitutes for tin-lead solder that met necessary performance requirements were not readily available. NCMS, "Lead-Free Solder Project Final Report" (August 1997).

EIA and member companies are currently working with the National Electronics Manufacturing Initiative (NEMI) to explore alternatives to lead-based solder. In addition, companies are taking the initiative to reduce or eliminate substances of concern:

- **Motorola** is conducting on-going research with their suppliers of printed wiring board laminates, plastics, and electronic components to replace lead and brominated flame retardants.
- **Panasonic** has identified 37 substances with 13 targeted for elimination and the remaining 24 for reduction.
- **Sony Corporation** is developing a non-lead based solder for some products and seeks to eliminate dioxin forming compounds through design guidelines.

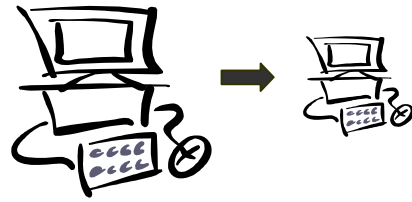
Standardization of material types

New generation electronic products are now being made from plastics comprised of uniform resin blends or polymers, as opposed to varying types of plastics. Companies indicate that there is a dual benefit to standardizing material types and reducing the diversity of materials in products. Not only does standardization help to make the product easier to recycle by minimizing the different types of plastic or parts used, but standardizing materials is also makes economic sense by reducing manufacturing costs.

- At **Motorola**, housings are made of standard engineering plastics. Several Motorola phone models have eliminated the use of brass inserts in their plastic housings.
- **Panasonic's** High Vision television model now offered in Japan utilizes a screwless locking structure to achieve an 80% reduction in the number of parts compared with previous models. This reduction is largely accomplished by implementing parts standardization measures. Furthermore, the number of polystyrene resin grades used in Panasonic televisions has been reduced from 20 to 4, greatly increasing the recyclability of parts.
- Through **Pitney Bowes'** DfE program, engineers are periodically trained to reduce the volume of materials in products and minimize the use of fillers, colors and toxic chemicals in their design of products whenever possible.
- Efforts to reduce material usage has been incorporated into the design of **Sharp** televisions, where they are reducing the types of plastic used by 50% and the number of parts by 33%. Similarly, Sharp has reduced the product weight of its VCRs by 27% and the number of parts by 15%.

Reduction in the volume of materials, product miniaturization

EIA members are pursuing design initiatives to reduce the size of products or minimize the volume of material used in their products, without compromising the functionality, integrity, and durability of the product. In addition to the benefits that these efforts provide product users, reducing the amount of material in a product can conserve raw materials, reduce the amount of energy needed to transport lighter products, and facilitate recycling at the end-of-life.



One example of this initiative involves thin wall plastic design, which helps to conserve the amount of material needed while maintaining strength requirements. **Panasonic** is utilizing one-piece molding as a new design feature for its televisions. Gas-assisted molding, which involves making the walls hollow by injecting high-pressure gas, makes it possible to vary wall thickness. Instead of using adhesive glues to mold vital parts together, the gas-assist process allows for a better fit among components while reducing the weight and thickness of the cabinets. It also allows

Component Example - Hot Line Clamp AMP Incorporated

Problem

Traditional hot-line clamps that connect transformers to power distribution networks use a high volume of raw material and a copper-alloy casting process. Some components also must be machined. These products can have performance limitations. In addition, installation quality depends on the skill of the installer and disconnection in highly corrosive environments (such as coastal installations) is often possible only by destroying the connector.

Solution and Benefits

Using drawn wire for the main connector body, the new design uses less raw material and fewer components than traditional products, and creates less scrap during production. The connector also improves electrical performance and installation quality. Other benefits include reduced copper use by 28,000 pounds per year and reduced energy loss.

for a reduction in the number of component parts used. **Thomson Consumer Electronics** and **Toshiba** have also implemented gas assisted molding allowing for the capability of varying wall thickness and more efficient use of plastic resin material. Prior to the use of this process, a front and bottom of a TV consisted of a front panel, bottom panel, four CRT brackets, and ten metal screws; under the new process, the entire assembly is molded as one piece. There are several other benefits to gas assisted molding, including reduced labor for assembly (and later, disassembly), a 30 percent reduction in the amount of material required (e.g., no need for screw bosses and the reinforced areas around them), and a higher quality cabinet. Other examples include:

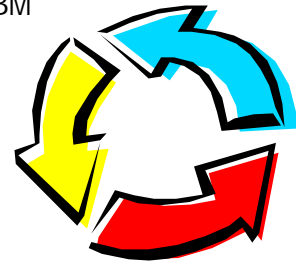
- The smaller size of **Kodak's** new APS and Single-Use Cameras not only reduces construction materials but also reduces the number and/or size of batteries required for flash photography.
- **Motorola's** Eagle i1000 combines the capabilities of a digital cellular phone, two-way radio, and pager in a light-weight, palm-size handset, thus eliminating materials that would otherwise be used in producing multiple products.

- The product volume of **Philips Consumer Electronics** audio and communication products has been substantially reduced (30-50% compared with same functionality some five to ten years ago).

Use of recycled materials (recycled content)

EIA members actively promote increased recycling by challenging engineers and designers to incorporate recycled content resins in products where technically and economically feasible, and by working with raw materials suppliers to provide recycled materials. These activities support and further stimulate the market for recycled commodities and help develop the recycling infrastructure.

- Since 1992, **Hewlett Packard** has replaced expanded polystyrene endcaps with recycled pulp endcaps in virtually all of their LaserJet toner cartridges.
- The eight major plastic parts of **IBM's** 6893 IntelliStation E Pro system unit are now made with 100% recycled content plastic resin. IBM has used over 1.7 million pounds of recycled plastics in its products over the last 6 years.
- On average 77% (by weight) of **Kodak's** Single Use Cameras may be recycled/reused.
- The recycled content of the sheet and rolled steel that **Pitney Bowes** purchases domestically for use in their products ranges between 50 - 90%. The company's plastic injection operations incorporate an average of 5 percent pre-consumer plastic into components produced by Pitney Bowes, and purchases of components from outside vendors contain up to 3 percent recycled content.
- **Sharp** has been utilizing post consumer recycled plastic in the toner bottles that supply copier products since 1996.
- At **Thomson Consumer Electronics**, internal plastic scrap has been reduced to less than 1% by blending regrind materials with virgin plastic resin within their molding processes.



The undeveloped nature of the existing recycling infrastructure and the resulting lack of available recycled materials has limited the ability of many companies to incorporate greater volumes of recycled plastic content. Regulatory requirements that impede the collection, storage, or transport of discarded electronic equipment creates additional barriers to greater recycling.

Selection of materials that are easily recycled

EIA member companies have sought to incorporate materials that are themselves recyclable, thereby encouraging future recycling and the development of an efficient recycling infrastructure.

- ⇒ Plastic components of **Apple** products that are greater than 100 grams are made from the same type of plastic material to facilitate recycling.
- ⇒ **Kodak's** One-Time-Use-Camera parts are made from polystyrene that have enabled reuse/recycling of over 200 million cameras to date with over a 60 % return rate worldwide.
- ⇒ **Panasonic** has developed the industry's first television with a magnesium alloy cabinet, of which about 90% can be recycled to basic materials.
- ⇒ **Sony** has a camcorder model in which they have replaced plastic with magnesium housing, which greatly increases the recyclability.

UPGRADABILITY, MAINTENANCE, REPAIR



Today's high-tech products are often designed with future upgrades in mind to prevent the premature retirement of equipment and protect the customer's investment. This design feature also avoids the generation of waste. For example, many computer components such as circuit boards, memory, and disk drives can accommodate memory expansions and upgrades, thereby providing the consumer with the latest technological improvements and extending the useful life of the product. In addition, products are designed so that components and subassemblies are easily accessible and separately repairable and replaceable.

- **Apple's** easy access door and modular product designs in the Power Macintosh G3 computers allow for rapid accessibility for easy installation and service of hardware, and upgrades to expansion cards, memory, and storage devices.
- Many of **Compaq's** products are designed with ease of upgradability in mind, including: system memory, mother boards, processors, video, drives, etc. Some desktop PCs are designed to disassemble and re-assemble without tools. The power supplies in many systems are rated high enough to accommodate many generations of technology. Compaq's rack server designs have had the same basic rack design unchanged for many years, allowing new technology modules to fit in server racks manufactured many years ago. A number of Compaq's notebook computer designs incorporate modular drive designs so that a user can interchange different hard drives, floppy drives and CD-Rom drives in the same drive bays. This allows for easy upgrade of the drives.
- All **Intel** motherboards, PCs, workstations, and server major subassemblies can be disassembled and then upgraded with only a screwdriver.

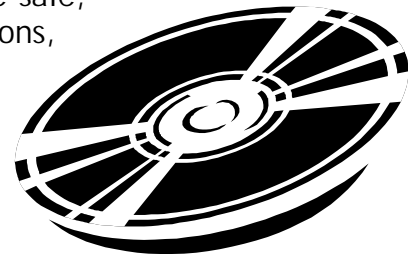
A number of **IBM** products showcase DfE attributes that relate specifically to product upgrades.

- In **IBM**'s server product lines, the AS/400e series along with the RS/6000 Enterprise Server Model S70 and the 43P Models 140 and 240 are designed to be upgradeable. Features such as processors, memory, internal storage and other subsystems can be upgraded by the customer to aid in extending the life of the computer system.
- By electronically distributing software upgrades, trial or subscription-based software and support documentation that has traditionally been hardcopy material, **IBM**'s software manufacturing group avoids the generation of product-related wastes through "dematerialization." In 1997, electronically distributed software upgrades exceed 1.9 million diskettes-worth of data sent to over 60 countries.
- **IBM** Printing Systems Company's InfoPrint 4000 printer models are designed for upgradeability; the 3900/4000 printer engine has been upgraded 19 times since 1990, enabling customers to upgrade their equipment rather than dispose of it.

While designing a product to permit upgrades and repairs can help extend its useful life, the opportunity to upgrade older products in a manner that retains the features desired by users may be limited by the fast pace of technological change and new product development.

REUSE AND REFURBISHMENT

EIA members have worked aggressively to expand and improve the efficiency and availability of electronic product reuse and refurbishment. Many EIA companies have established programs to recondition used products for re-sale, donate products to educational and nonprofit organizations, or reuse spare parts or materials. EIA and our members also cooperate with nationally-recognized organizations to promote the reuse of computers in schools, and we support Executive Order 12999 (April 17, 1996) as a means of making computers no longer used by the federal government available to schools and nonprofit organizations. To promote the ability of technicians to repair, maintain, and upgrade electronic products, EIA's consumer electronics sector has established a certification program for electronics technicians.



Use of refurbished/reconditioned parts

Substantial quantities of used electronic products are already managed in an environmentally beneficial, cost-effective manner through manufacturers' voluntary asset recovery programs. Many EIA members offer services to their customers, either through in-house programs or through the use of outside contractors, resulting in the reuse, refurbishment, and reclamation of selected electronic products and materials. The equipment may no longer serve the needs of the original customer, but it still retains value and may be continue to be beneficial to other users. These programs

are voluntary company efforts that serve a business purpose by providing a service to customers, while also enhancing the environment.

One example of a comprehensive reuse program is that of **Sun Microsystems**. Once the used systems are received from the customer, Sun's product reuse system commences. Armed with a "save list" and aided by barcodes on key components, the company's partners carefully separate out these components. When returned systems are unsuitable for remanufacture, these systems (plus parts not on the original "save list") continue to circulate and fulfill other useful functions. Even grayscale monitors can be reused in industrial applications -- for example, for an inventory display system on a loading dock. And a too-loud disk drive can find new life in a noisy computer-game arcade. Companies also recondition used machines for resale on the commercial market.

The electronics industry has also been responsible for creating cooperative environments that provide dual benefits - refurbishment of older equipment and valuable job training. **Intel Corporation** has provided a refurbishing service for some customers of PC and server products. Used PCs from Intel internal use are refurbished and reassigned throughout the company. There is also an extensive donation program for used PCs to local communities and schools. "Students Recycling Used Technology (StRUT)" was founded by Intel and the Northwest Regional Education Service District to teach high school students technical computer skills and give schools free, refurbished computers. Since 1995, over 15,000 computers have been donated by Intel and 70 other companies. 10,000 of these computers have been refurbished by students and placed in classrooms. One of the more novel StRUT programs is now running at Arizona's Mesa Community College, which supports the Welfare to Work program. Thanks to StRUT donations, welfare recipients in the Network Academy are now learning skills to take into the workplace.

Pitney Bowes operates a substantial asset recovery program for mailing systems and office equipment that has been returned because of an upgrade or the expiration of a service term. In 1998, the company remanufactured over 270,000 units and over 1.2 million parts were reused.

Other examples of asset recovery programs by EIA members include the following:

- **Hewlett Packard** operates product-refurbishing centers in the United States, Germany and Australia, in which used Hewlett Packard products -- mainly computers, peripherals and test and measurement systems - are refurbished for resale. Some products are resold at the Hewlett Packard Shopping Village -- an online store that sells new and lower-priced, refurbished consumer products to U.S. customers.
- **Sun** extends the life of its older equipment by refurbishing the product and selling it as re-marketed equipment. Remarketed systems, sold as used, generate more income than would recycling the parts. And, compared to building from scratch, fewer resources are needed to rebuild systems or to test unused systems that are classified as "used".

- **Toshiba's** service parts division is co-located at the same site as the TV plant. Excess or obsolete TV parts from the plant are turned over to the parts division for reuse.

REMANUFACTURING

Several EIA members look upon the return of used equipment as a valuable raw material for use in new products. This practice helps to minimize costs to the manufacturer, but also serves to preserve natural resources and minimize the generation of wastes.

- **Intel Corporation** reclaims about half of the 200mm test wafers used in its manufacturing quality assurance system. Each batch of initial wafers takes several days and high-energy inputs to produce. Supporting EHS policy promoting resource reuse, the materials organization has initiated a program to reclaim these wafers for further reuse, avoiding the resource inputs required to manufacture new wafers.
- As part of **Kodak's** remanufacturing efforts, valuable electronics parts such as circuit boards, power supplies, CRTs, and print heads are returned from the field for repair and remanufacturing. These reconditioned products are quality tested and returned to the supply chain reducing raw material consumption.
- In 1997, **Xerox** remanufactured equipment from more than 30,000 tons of returned machines, diverting them from landfills and effectively reducing raw material and energy consumption. In recent years, Xerox has more than doubled the percentage of machines that are remanufactured, and all of these products meet the same quality standards as newly-built equipment.

Remanufacturing of Leased Application Tooling

AMP Incorporated

Problem

AMP leases application tooling such as applicators, terminators and leadmakers to customers. At the end of the leases, the equipment was returned to AMP and all machines and component parts were scrapped and sent out with solid waste. For each new order, the tooling was manufactured using all new components.

Solution and Benefits

This equipment and its machined components are now recycled, freeing 74,000 hours of production capacity, shortening customer lead times, and reducing material use and energy consumption. AMP now recycles 128,028 machined components annually. In addition, the cleaning process has been transformed from one based on a petroleum naphtha solvent to a totally aqueous process. Benefits include reduced steel usage of 334,000 per year, reduction in electricity usage of approximately 700,000 kilowatts/hour per year and elimination of 238,000 pounds of solid waste per year.

DISASSEMBLY

Ease of dismantling (product configuration/modular design)

The use of modular product designs and "snap" fasteners has been adopted in new products to shorten assembly times (thereby driving down production costs), extend the serviceability and life of the product, and aid in end-of-life disassembly opportunities. These features allow for the quick removal of components and materials for servicing, and can speed disassembly of products for sorting operations. This results in reduced service time and operational costs. Companies have also redesigned equipment so it can easily be disassembled with simple tools such as a screwdriver, or have eliminated the need for tools all together by employing the use of clip or snap fasteners.

- **Apple** designs its product for ease of assembly and disassembly utilizing latches, snap-in connections, and single screw-types requiring no specialized tools.
- A growing number of **Hewlett Packard** products are designed to be easier to take apart and recycle. Many components simply snap apart, making it easier to separate metal from the plastic.
- **IBM's** DfE guidelines encourage the use of snap fits over fasteners, and where fasteners are necessary, the use of industry-standard fasteners with a minimum number of head sizes and types and which do not require special tools when dismantling.
- The ultrasonic welds of **Kodak's** Single Use Cameras have been replaced with snap-fit technology enabling a faster disassembly and a lower scrap rate.

A review of **Lucent's** Business Communications Systems 8403 Terminal (office phone) identified opportunities for improvement of the environmental profile of the terminal by:

- Changing rubber feet to a snap on configuration instead of a glued in place application;
- Acoustic foam piece press fit over speaker instead of being glued to housing;
- A transparent poly-carbonate sheet previously used as a light diffuser glued to the phone housing was eliminated totally with new design not needing diffuser; and
- Bosses (for screws) were added into design for re-assembly should snap fits break, thus aiding disassembly and reuse.

- **Panasonic's** new television designs incorporate a modular structure that allows for modules to be easily disassembled and sorted according to materials composition for greater recycling. Previously, power switches and terminals were fixed at the chassis from the front and rear sides using a large number of machine screws, but now these switches and terminals are on printed circuit boards and in cassettes to eliminate electric wires. The company has also employed a joint structure switch terminal for one-touch removal, thereby further improving the ease of disassembly.
- Disassembly time of **Philips Consumer Electronics** has been generally reduced, in particular for relevant products like TVs and monitors, by reducing the number of screws and introducing the use of clips/snaps instead.

- Instead of using permanent methods such as ultrasonic welding or spray coatings to unite electromagnetic shields, **Sun** engineers have designed the shields with the minimum number of heatstake (bonding points). In this way, the metal shields and plastic housings are easy to separate and recycle.
- **United Technologies Corporation's** Carrier Air Conditioner has separate outdoor fan, an indoor compressor, and air distribution units. The embedded electronics in the Carrier unit have been consolidated into three separate modules designed for snap fit installation and removal.
- For **Xerox's** new generation of digital products, disassembly is possible within minutes. For purposes of conserving valuable natural resources, these machines are built with fewer parts -- particularly fewer replacement parts -- than would have been required for an earlier, comparable product.

RECYCLABILITY



Because some electronic products or components will not be suitable for reuse or refurbishment, an important priority of DfE efforts is to increasing the opportunities for these materials to be recycled. To achieve this result, EIA members have implemented design guidelines to minimize hard to remove labels and foams, the plating and painting of parts, the number of different materials used in an individual product or component, and the avoidance incompatible materials. One important example of the effort by electronics manufacturers to promote greater recyclability of their products involves CRT glass. In the early 1990s, American CRT manufacturers agreed to standardize funnel glass across the industry in an effort to facilitate and achieve 100% recyclability of CRT glass in the United States.

Application of Design Guideline

Lucent's 5ESS Switch Access Interface Unit

This project integrated DfE criteria into the redesign of the 5ESS - Access Interface Unit, a main component of the telecommunications central office switch. A DfE evaluation of the switch was conducted including analyses of the material content and recyclability of the current design. Results included:

- Changeover of many of the manufacturing lines from wave soldering to surface mount, reducing the amount of lead in the finished product;
- Elimination of mercury relays from the design;
- Changes to more recyclable plastics when available; and
- Avoidance of coatings when feasible that increases recyclability.

Minimization of material types and number of parts

EIA members have significantly reduced the different types of materials and minimized the number of parts used in products to further increase recyclability. By minimizing the diversity of materials used and increasing the simplicity of products, it makes it easier to identify material types and separate parts for recycling.

- **Hewlett Packard** has reduced the number of toner cartridge parts by 21%, thereby reducing the amount of material used and increasing recycling capability. HP also uses an innovative foam chassis to reduce the number of parts needed to build some of its products and to make them easier to disassemble for recycling.
- **Panasonic** has developed solid molding of micro sound-pores in the speaker openings of its televisions, which enabled the company to abolish speaker panels comprised of different materials, successfully reducing the time and cost of material separation after the disassembly.
- **Xerox's** Document Centre 265 incorporates many DfE innovations, including the reduction down to 250 replacement parts instead of 2000, and an ergonomically designed and returnable print cartridge that is more than 60% recyclable and 90% remanufacturable.

Use of material identification (coding) for batching and sorting and the ability to separate components into similar/dissimilar materials

Several EIA members have begun the practice of embedding identification codes of plastic type on products and components. This makes it easier for recyclers to sort and reuse materials that are in demand. If the plastic type is known, the chances of reuse or recycling are greater. Frequently, these plastic parts are identified with plastic resin identification codes, such as those established under the International Standards Organization (ISO).



- **Hewlett Packard** helps facilitate recycling by marking all plastic parts according to ISO 11469 and by molding user instructions into the plastic instead of using a paper label. HP also puts material identification codes on plastic parts.
- Plastic parts used in **Intel** products more than 25 g are marked in accordance with the requirements of ISO 11469.

Avoidance of paper or foil labels, adhesives, coatings, and finishes

When feasible, EIA members have avoided the use of paper or foil labels on plastic parts, seeking instead to imprint or mold product codes or instructions into the plastic, thereby increasing the ability to recycle the products. Similar practices have been employed regarding the use of glue adhesives, decorative coating and finishes. In 1998, a relational study of DfE practices and end-of-life performance was completed at **IBM's** largest recovery center to gauge the effectiveness of DfE design implementation over a 15 year period. Reduction in the use of metallized coatings on plastic parts and reduction in painted decorative finishes were two of the DfE initiatives that realized measurable benefits at the end of life. By avoiding the use of these surface contaminants, it makes it easier to recycle by removing the necessity to remove labels or adhesives prior to recycling.

Elimination or reduction of special paints or finishes also helps to make electronic products more recyclable. Paint on **Toshiba** televisions was reduced to one fourth of the amount used on previous models. The surface quality of the back cover was improved to the point where no paint was required. The front cover paint was reduced to a thin semi-transparent level that blends with the black polystyrene used in the TV cabinet. **Thomson Consumer Electronics** implemented "as molded" plastic processes, which eliminates the need for painting altogether.



Partnerships among manufacturers, suppliers, and recyclers

Electronics companies have partnered with other entities to increase electronics recycling. For example, CRT manufacturers -- seeking to increase the recyclability of CRT glass -- partnered with third-parties to establish recycling companies to develop recycling technologies to process CRTs.

- **Advanced Micro Devices** provides a cost free recycling option for semiconductor products that require shipment in anti-static plastic trays. They provide customers with a listing by geographical region of worldwide tray recyclers and they provide free freight and duty costs for the return of trays. Static coating is reapplied to the trays and the trays are reused.
- **IBM's** Environmentally Conscious Products program supports a network of Materials Recovery Centers (MRCs) around the globe that process surplus and scrap electronic equipment from within the corporation, local communities, and customers. Ten of IBM's major MRCs processed more than 55,000 metric tons of end-of-life equipment in 1998, of which more than 90% was recycled and less than 4.3% sent to landfill.
- **Kodak** developed an industry-level exchange program with other Single-Use Camera manufacturer's in France, UK, Japan, Canada and the United States in which non-Kodak manufactured cameras are not scrapped but returned to the original manufacturer for reuse/recycling.
- **Motorola** has initiated the recycling of cellular base stations for industrial customers in Europe, and is cooperating with a customer on a product life-cycle assessment study.
- **Pitney Bowes'** business infrastructure is designed to ensure the recovery of leased products. There are programs in place to increase the efficiency of product/parts returns and to maximize asset recovery operations. In 1998, 465,000 units were returned and over 50% of them were remanufactured as marketable products. From those returned products that could not be remanufactured, 67,000 components were reclaimed for reuse.
- For years, **Xerox** has accepted the return of leased machines and trade-ins from customers. Although these xerographic machines could no longer achieve the fine balance required to produce acceptable copies, many of the components still performed to original specifications. Xerox created a systematic, worldwide

process to remanufacture these assets, which marked the beginning of the Xerox Environmental Leadership Program.

Participation in demonstration programs

EIA and our members have been instrumental in initiating and supporting electronics recycling pilot programs around the country. EIA and individual companies have participated in select pilots, including projects operated under the auspices of the EPA Common Sense Initiative (CSI) Computer and Electronics Sector, to collect data and assess possible solutions for the collection and recycling of discarded electronics. These pilots have occurred in Minnesota, Massachusetts, New York, California, Illinois, and elsewhere. Several companies have also participated in international initiatives aimed at electronics recycling demonstration projects.



- **Motorola** is a participant and leader in the ECTEL cellular phone recycling pilot in the United Kingdom and Sweden. An upcoming pilot will be held in a Southern European country.
- **Panasonic** has participated in recycling research and has led the development of a large home electronics recycling facility just outside of Tokyo. The facility is perhaps Japan's largest and most advanced pilot home electronics recycling facility.
- **Philips Consumer Electronics** has been the main driver behind a pilot project in Eindhoven, the Netherlands, in which more than 500 tons of discarded brown goods have been collected and recycled. Valuable lessons have been learned about environmental gain, cost, and about design for recycling. The project has been carried out in partnership with other manufacturers. Valuable lessons learned from these pilots will help guide the establishment of an infrastructure and encourage research and development of new recycling technologies to better manage these materials.

Research and Information Sharing

EIA members are working with other interested parties to identify and address technical and regulatory concerns, support academic studies, and disseminate additional information on electronics recycling. For example, EIA and



members are working with the **New Jersey Institute of Technology** (NJIT) on markets for recycled CRT glass, such as using re-engineered CRT glass as x-ray shielding materials for wall coverings in hospitals, medical centers, and industrial radiological departments, or in portable applications for mobile x-ray barriers. EIA and its members have also been working with the **Department of Energy** to conduct research in glass and plastics recycling and separation, and to establish a national electronics recycling center in Oak Ridge, Tennessee. Several major consumer electronics manufacturers, including **Hitachi, Mitsubishi, Panasonic, Sanyo, Sharp, Sony, Toshiba**, have worked together in Japan to develop a CRT recycling process for post-consumer TV sets.

Supply Chain Management

Companies often demand the same level of environmental commitment and product innovation from suppliers and vendors, which can have a significant multiplier effect on the environmental attributes of a product. For example, basic components and packaging materials are important considerations in assessing the overall environmental impact of the finished product. Additional environmental benefit can be achieved by specifying to suppliers and vendors that components comprise recycled content or be recyclable themselves.

- **Apple** has taken an integrated approach to bringing environmental considerations into its business practices. Apple has focused on establishing environmental criteria into its vendor contracts and agreements during product concept, design, and development through the use of its Apple Product Environmental Specification (APES) database. Through the incorporation of APES in both product design specifications and vendor contracts, environmental considerations become another element in the supplier evaluation and qualification process.
- **Compaq** evaluates environmental practices of suppliers as part of the supplier selection process, such as CFC use and hazardous waste management. Compaq does environmental audits on suppliers that do specific processes that can be environmentally unfriendly if not handled properly. Compaq manages sources of materials, such as plastics, so that suppliers do not substitute environmentally unfriendly materials in place of known good materials.
- **Hewlett-Packard** expects product material suppliers to act as responsible corporate citizens and take a positive, proactive stance regarding environmental issues. As part of their environmental improvement policies, Hewlett Packard suggests suppliers scrutinize their manufacturing processes to identify and reduce the use of potential environmental hazards and to design products that facilitate disassembly and recycling by using compatible materials and adhesives.

- **Xerox** suppliers of products, parts, commodities, materials, chemicals, packaging, and services are expected to operate in a manner consistent with and fully supportive of the company's EH&S policies and principles. The objective is to maintain regulatory compliance, develop waste-free products and facilities, fulfill customer environmental preferences, and satisfy environmental ecolabel criteria.

RECYCLING

The use of materials obtained from recycling electronic products -- glass, metals, and plastics -- is conducted by a developing network of recyclers and raw material suppliers who have extensive expertise in the unique properties and uses of these materials. While these recyclers and raw material suppliers are in the best position to market recycled materials, EIA member companies has been supporting this effort.

For example, **Hewlett Packard** operates a recycling center in California that processes 3 million pounds of obsolete equipment each month. **IBM** operates materials recycling centers around the world, and these operations processed more than 55,000 metric tons of materials in 1998, of which more than 90 percent was recycled and less than 4.2 percent was sent to landfills.

Cathode Ray Tube (CRT) Glass

In an effort to avoid waste generation, EIA members have been engaged in efforts to recycle CRTs and find useful applications for this glass, either in new CRTs or other products.

- **Corning-Asahi** has established process technology and installed materials handling systems that can accommodate end-of-life recycled glass and currently recycles CRT glass recovered by recyclers into new CRT glass.
- **IBM** has initiated projects that turn scrapped CRT glass into works of art--literally. CRT glass from IBM end-of-life operations is transformed by local artists and companies into attractive and functional glassware, such as carafes, bowls, paperweights, and vases.
- **JVC** assists Service Centers by incurring the cost of recycling defective CRTs that are replaced within the JVC warranty period. JVC has contracted with Envirocycle, Inc. to recycle JVC defective CRTs and provides Authorized Service Centers with a pre-paid UPS shipping label to return defective CRTs.
- In March of 1998, **Panasonic** began commercial recycling trials for used TVs. During the trials, Panasonic aimed to improve the efficiency and cost-effectiveness of recycling and the development of optimal disposal methods, particularly for CRT glass.
- **Philips Electronics** has developed a process to recycle CRT glass from both screens and cones in a glass-to-glass process. This process is now put into practice in a Philips Glass factory in Germany on full operational scale.
- **Thomson Consumer Electronics** developed a process and support system, which used mixed origin recycled TV glass as a raw material for the manufacturing of

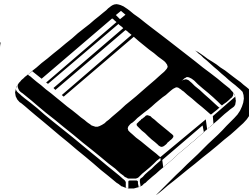
CRT glass. This process has resulted in a greater than 99% recovery and recycling of scrap TV glass within its Americas Operations. Dust from electrostatic precipitators, glass fines and sludge's from the CRT glass operations are also recycled into CRT glass.

- **Toshiba's** TV engineering and refurbishing departments are located on the same site as the U.S. TV plant. As a result, there are excess CRTs from returned sets, engineering prototypes, and plant rejects. These CRTs are sent to Retail Display Corporation, which attempts to refurbish them and sell them to TV servicers. The tubes that are not serviceable are sent from Retail Display to Envirocycle for recycling into basic materials. For quality reasons, CRT glass manufacturers actually prefer recycled CRT glass to virgin material.

Regulations that classify some CRTs as hazardous waste can serve to discourage the recycling of these materials by increasing the costs and burdens of collecting, storing and recycling. EIA has been working with federal and state officials to streamline the regulations applicable to CRT recycling.

Chips and Precious Metals

Electronic components, such as semiconductor and circuit boards, contain precious metals which can be easily be recovered and recycled. Often, this involves recovery and shredding of products and the use of magnetized equipment to extract the metals from the scrap plastic.



- **Advanced Micro Devices** sends scrap semiconductors and metal bearing product wastes to a recycler where lead, copper and precious metals are reclaimed.
- **Intel** recycles all scrap semiconductors for precious metals recovery. Most scrap wafers are reprocessed or recycled for reuse.
- **Philips** utilizes a tailor-made mechanical shredding and separation process to extract precious metals from electronics.
- After proprietary parts such as EPROM (erasable, programmable, read-only memory) chips are destroyed or erased, **Sun's** partner company extracts them from the circuit boards, straightens their leads, tests and repackages them, then sells them for reuse. After recovering chips, what is left of the circuit board is shredded and processed to extract the precious metals (gold, platinum, palladium, copper, and silver).

Batteries

As stated above (see "Reduction/Elimination of Substances of Concern"), many EIA members have shifted away from using nickel-cadmium (Ni-Cd) batteries in their products to using other battery chemistries. The electronics industry continues to work to improve the recyclability of battery technologies and transition to alternative battery chemistry that pose less risk to the environment.

- **IBM's** DfE guidelines address the challenges presented by batteries at end of life, and discourage the use of batteries containing lead, cadmium, and other materials that may require special handling at end of life.
- **Sony** has engineered, developed and operates a recycling operation for Lithium-ion (Li-ion) batteries, which has no EPA regulated "toxic" materials that are of concern at product end-of-life.
- Some of **Sun's** server products have back-up power systems built in powered by rechargeable batteries. Because many countries restrict the disposal of Ni-Cd batteries, recycling facilities for these batteries are not widespread nor easily accessible. Sun's design team noted that an alternative technology to nickel-cadmium -- lead-acid batteries -- had more extensive recycling options available, so from an environmental standpoint, that technology was favored.

Because the risks associated with the disposal of Ni-Cd batteries were established, battery manufacturers and manufacturers of products using these batteries established a comprehensive recycling program. These companies established the Rechargeable Battery Recycling Corporation (RBRC) and worked to enact federal legislation (P.L. 104-142) that removes regulatory barriers to the efficient collection and recycling of batteries.



Returnable and Refillable Toner Cartridges

In response to consumer requests, EIA members have voluntarily instituted toner cartridge return and recycling programs. The overwhelming success of these programs has served as a model for other collection and recycling programs. Through these efforts alone, the industry has diverted substantial volumes of material from the waste stream. The toner cartridges are primarily reused, but may also be recycled into other products.

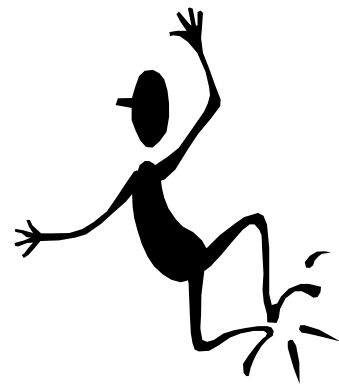
- Under **Hewlett Packard's** Gold Standard Program, up to 95% of each returned LaserJet toner cartridge is recycled, which has diverted over 18 million pounds of material from landfills. Products made from the recycled materials consist of clothing buttons, plastic trays, tractor parts, and a host of other useful products.
- **Sharp** has instituted a toner cartridge-recycling program for its small home office line of copiers. Under this program the customer can return the cartridge using a prepaid mailing label and receive a small rebate. Sharp cleans, repairs, and refills

the cartridges for resale. During 1997, an average of more than 5,000 cartridges were returned each month.

- **Xerox's** Design-for-Remanufacturing program was first piloted on print and copy cartridges because of customer concerns with the disposal of old cartridges. Xerox provides customers with prepaid return labels so they can reuse the packaging from the new cartridge and ship the used cartridge for remanufacturing, adhering to the same quality standards as new ones. In 1997, Xerox's print and copy cartridge return rate reached 65%. A similar initiative was implemented for toner containers -- over 4.4 million toner containers have been returned for reuse and recycling and over 2 million pounds of plastic has been diverted from landfills

CONCLUSION

This compendium provides a mere sampling of some of the efforts undertaken by the EIA members to design electronic products for environmentally sound and economically viable management at the end of their useful life. The industry continues to expand these efforts and explore new ways in which to improve the environmental attributes of electronic products and maximize the preservation of important natural resources through greater product recovery and recycling.



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