Toxic and Hazardous Materials in Electronics

An Environmental Scan of Toxic and Hazardous Materials in IT and Telecom Products and Waste

Final Report

For Environment Canada, National Office of Pollution Prevention and Industry Canada, Computers for Schools Program

By Five Winds International, LP

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1. Introduction

In October 2000 Environment Canada released a report called *Information Technology (IT) and Telecommunications (Telecom) Waste in Canada.* The report identified significant quantities of IT and Telecom waste going to disposal and projected that the amount of computers, monitors, laptops, cell phones and other related equipment disposed will double from 36,900 tonnes in 1999 to an estimated 71,650 tonnes in 2005.

The *IT and Telecom Waste in Canada* report also described toxic or hazardous materials present in computer and telecom equipment and estimated the aggregate tonnage of such substances being disposed annually, primarily in landfills. Lead, mercury, cadmium, brominated flame-retardants and other substances present in this equipment could pose hazards if they are released when the equipment is recycled, incinerated or disposed in landfills.

Building upon the *IT and Telecom Waste in Canada* report, this study documents the literature about selected toxic or hazardous materials used in computer and telecom equipment. It focuses on toxic or hazardous materials contained in personal computers, monitors, laptop computers, peripherals (e.g. printers, scanners), telephones, mobile telephones and facsimile machines. It does not address toxic or hazardous materials used in the manufacturing processes. The scope of products addressed is the same as those covered by the *IT and Telecom Waste in Canada* report.

Specifically, this study addresses three questions:

1. What toxic or hazardous materials are contained in these products?
2. What happens to these toxic or hazardous materials at the products' end-of-life when they are recycled, landfilled or incinerated?
3. What are product manufacturers doing to reduce toxic or hazardous materials in products and/or their potential for release to the environment at the products' end-of-life?

This study examined nine toxic or hazardous materials that are, or were used in IT and telecom equipment: mercury (or it compounds), lead (or its compounds), cadmium (or its compounds), beryllium (or its compounds), hexavalent chromium, brominated flame-retardants, polyvinyl chlorides (PVC) and polychlorinated biphenyls (PCBs).

The information gained through this study will contribute to building the knowledge and expertise of parties responsible for government policies, laws, regulations and other initiatives concerning toxic and hazardous materials in Canada. This study will also be useful to identify areas of potential concern for IT and telecom recycling and disposal activities carried out by the Government of Canada (e.g. Computers for Schools program). Finally, this study will help the Government of Canada determine the relative importance of the IT and telecom sectors compared to other sources of toxic and hazardous materials released to the environment in Canada.

This study identifies and summarizes what is currently known in the areas of interest identified above. The information documented in this study is drawn from available literature including published reports, proceedings of conferences and articles – original, previously unpublished research is not included. The report is organized as follows:

- Chapter 2 documents the uses and quantities of mercury, lead, cadmium, beryllium, hexavalent chromium, antimony, brominated flame-retardants, polyvinyl chloride (PVC) and polychlorinated biphenyls (PCBs) in IT and telecom equipment.

- Chapter 3 documents releases to the workplace and to the environment of the above nine toxic or hazardous materials when the equipment is recycled (by hand or machine), disposed in landfills, or incinerated.

- Chapter 4 examines examples of polices, management systems, programs and tools to reduce or eliminate toxic or hazardous materials from products by ten IT and Telecom OEMs. Brief case study examples of several products demonstrating reduction or elimination of toxic or hazardous materials are also included.

- Chapter 5 presents some concluding remarks about this study and makes four recommendations to improve the quality and reach of this study and to further the goals of this study.

- A **Glossary** is included to help the reader become familiar with specialized electronics terminology used in this report.

- A complete list of sources consulted is included in **References** at the end of the report.

- Appendix 1 presents environmental profiles of the toxic or hazardous materials referred to in this study, summarizing their potential toxicity and environmental effects.

- Appendix 2 is a copy of Ericsson's Lists of Banned and Restricted Materials

- Appendix 3 is a copy of Motorola's Eco-Design Substances List

2. Toxic and Hazardous Materials in IT and Telecom Products

Information on nine toxic or hazardous materials and substances is presented in the following tables. Highlights summarizing each table are also briefly discussed. The tables are organized into 5 columns of information. The "Where Found" column indicates where each potentially toxic or hazardous substance is located in the IT and telecom equipment. The second column, "Use", signifies the reason(s) that the substance is used in the product. Column three, "Quantity" shows how much of the substance is found in each component part. The "Status" column communicates general information regarding how a substance in a specific product is being managed, what the recent trends are (i.e. is use decreasing or increasing), relevant legislation, and other comments. Finally column five "For More Information" gives the source of the information and indicates where to go if more information is required.

Toxic or hazardous substances found in similar components that were identified in different resources are grouped together in the tables for easy comparison of use and quantity. In cases where different references disagree on quantities it is important to note the “vintage” of the source. For example, in the case of mercury in fluorescent lamps used to back light LCD displays, lamp manufacturers have made significant progress in the past decade reducing the amount of mercury used. In some cases (e.g. for recyclers) it may be important to consult older references to determine the types and quantities of toxic or hazardous materials used in older IT and telecom equipment that is now being disposed. In other cases where references disagree, no simple explanation exists and the underlying assumptions and methodology must be consulted.

It is important to note that most of the information found on potentially toxic or hazardous substances in electronic equipment was focused on personal computers, laptop computers and monitors. There is a distinct lack of information and studies on toxic or hazardous substances in other IT and telecom equipment such as peripherals (scanners and printers), fax machines, telephones and mobile phones. This is understandable given the recent developments and focus on end-of-life management programs for many consumer products.

Mercury

The main concern for managing mercury at its end-of-life in IT and telecom equipment is backlight bulbs or lamps that illuminate laptop and other flat panel display screens. The amount of mercury per screen is relatively small, averaging 0.12mg-50mg per screen, but if everyone were to dispose of their old laptops at once the amount released to landfill or through incineration would be significant. Mercury-containing lamps and bulbs are quite energy-efficient and cost-effective and no practical substitute exists. Lamp manufacturers continue working to reduce the mercury content in each bulb or lamp, but it is expected that this use will increase because of the lack of alternatives. The EU's Waste Electrical and Electronic Equipment (WEEE) Directive[1] requires that substitutes for mercury be found for all uses in electronic equipment (for example, switches and lamps) with the exception of mercury lamps containing less than 5mg/lamp.

Mercury in IT and Telecom Equipment				
Where Found	**Use**	**Quantity**	**Status**	**For more info**
Fluorescent lamps - flat screen laptop displays	Back light for LCD	0.12-5 mg/laptop		US EPA as cited in EIA, 2000.
Fluorescent lamps - flat screen laptop displays	Back light for LCD	Manufacturers must report any intentionally added mercury	Banned in all uses except lamps (EU).	EIA, 2001.
Fluorescent lamps - flat screen laptop displays	Illumination light			Tonetti (EPA), 2000.
Fluorescent tubes - flat screen laptop displays	Transforms UV light in the gas discharge to visible light	Avg. 3-20 mg/laptop	No practical substitute for mercury in fluorescent tubes has been found.	Nordic Council of Ministers [a], 1995.
Fluorescent lamps - flat laptop displays	Transforms UV light in the gas discharge to visible light	20-50 mg/tube depending on size of tube	Increased use is expected because of energy efficiency.	U.S. EPA, 1994.
Fluorescent lamps - flat laptop displays	Transforms UV light in the gas discharge to visible light	4 g/100 fluorescent tubes		Bender and Williams, 1998.
Fluorescent lamps - flat laptop displays	Transforms UV light in the gas discharge to visible light		Substitute for mercury required under WEEE by 2008. Exceptions: compact lamps < 5 mg/lamp, straight lamps < 10 mg/lamp.	WEEE Directive, 2000.

[1] The original WEEE Directive has been divided into three separate Directives: WEEE, RoHS (Restrictions on Hazardous Substances) and EEE (Electrical and Electronic Equipment). For the purpose of simplicity, these will be referred to collectively as " the WEEE Directive".

Mercury in IT and Telecom Equipment				
Where Found	**Use**	**Quantity**	**Status**	**For more info**
Batteries		0.0022% of total weight		MCC, 1996.
Batteries				Nordic Council of Ministers [a], 1995.
Batteries			Minimal use of mercury recommended, substance under special attention, several current affairs.	C4E Guidance Document, 2000.
Monitor - CRTs	Highly efficient at transforming UV-light to visible light		Mercury use in this application has not been openly published.	Nordic Council of Ministers [a], 1995.
Mobile phones			Substitute for mercury required under WEEE.	WEEE Directive, 2000.

Lead

Lead as a hazardous substance in electrical and electronic equipment has been well documented in published material. Given the amount of historical research on the toxicity of lead on human health and the environment, it is understandable why many studies have been conducted on lead as a hazardous component of electronic equipment. The major uses for lead in electronic components include tin-lead solder, cathode ray tubes in monitors, cabling, earlier batteries, printed circuit boards and fluorescent tubes. Large quantities of lead-acid batteries are used in emergency power supplies for larger telecom network infrastructure (e.g. central office switches), but these products are outside the scope of this study.

The most significant and increasing use of lead in electronic equipment is in cathode ray tube (CRT) displays and monitors. Lead in CRTs acts as a radiation shield and lowers the melting temperature of the glass. CRTs are made up of three main components - the funnel, the neck and the frit. Estimates for lead amounts in these three components amount to between 0.4 kg and 3 kg per monitor. CRTs have recently been banned from landfills in Massachusetts and the trend will probably continue in other jurisdictions.[2] For consumer safety, the WEEE Directive exempts the use of lead in CRTs as a radiation shield but will require substitution for lead used in solder, batteries, and stabilizers.

The second largest source of lead in electronics is found in tin-lead solder (usually in the ratio 60/40 tin-lead), which connects many component parts together. Lead is used in this capacity because of its good conductivity, high corrosion resistance, cost-effectiveness and low melting point. Quantified, the amount of lead used as connecting materials is about 50 g/m^2 of printed circuit board. Alternatives to tin-lead solder have been developed and many OEMs are actively involved in implementing lead-free solders (see Chapter 4 for details).

Lead in IT and Telecom Equipment				
Where Found	**Use**	**Quantity**	**Status**	**For More Info**
Tin-lead solder	Interconnection materials	0.7% total weight of circuit board		International Council on Metals and the Environment as cited in EIA, 2000.
Tin-lead solder	Interconnection materials	Most common solder is 63% tin and 37% lead Surface mount -0.2mg lead Through hole joints-2mg lead		Nordic Council of Ministers [a], 1995.
Tin-lead solder	Interconnection materials	Threshold reporting level 1000 ppm	Considered "material of interest".	EIA, 2001.

[2] University of Tennessee, as cited in EIA, 2000.

Lead in IT and Telecom Equipment				
Where Found	**Use**	**Quantity**	**Status**	**For More Info**
Tin-lead solder	Interconnection materials, good conductivity	50 g/m^2 of printed circuit board	Substitute required for lead under WEEE by 2008.	WEEE Directive, 2000.
Tin-lead solder	Interconnection materials, good conductivity		Substance under special attention, several current affairs.	C4E Guidance Document, 2000.
Tin-lead solder (60/40 tin-lead)	Interconnection materials, good conductivity		WEEE Directive bans lead by 2004.	IPC Roadmap, 2000.
Monitor - CRTs (65-75% lead in frit, 22-25% lead in funnel glass and 30% lead in neck)	Radiation shield	0.5 kg/17 inch monitor	Massachusetts bans CRTs from landfills, April 2000.	University of Tennessee as cited in EIA, 2000.
Monitor - CRTs (70% lead in frit, 22% in funnel glass, 30% in neck, 29% in stem, 2.5% in panel)	Radiation shield			University of Massachusetts, 1998.
Monitor - CRTs	Radiation shield	743 g		Young, 1999.
Monitor - CRTs (most significant quantities found in funnel portion, 75.3 mg/L)	Radiation shield	avg. 18.5 mg/L	Regulatory limit in U.S. is 5 mg/L.	University of Florida, 1999.
Monitor - CRTs (neck, funnel and faceplate)	Radiation shield, deflector, lowers melting temperature of the glass locally	0.4 kg/monitor		Nordic Council of Ministers [a], 1995.
Monitor - CRTs	Leaded glass, radiation shield	Threshold reporting level 1000 ppm	Considered "material of interest".	EIA, 2001.
Monitor - CRTs	Leaded glass, radiation shield	0.4 kg/monitor	WEEE Directive exempts lead phase out as radiation protection.	WEEE Directive, 2000.
Monitor - CRTs	Leaded glass, radiation shield		Substance under special attention, several current affairs.	C4E Guidance Document, 2000.
Monitor - CRTs	Leaded glass, radiation shield	2-3 kg/monitor		Tonetti (EPA), 2000.
PCs & Monitors		6.3% total weight		MCC, 1996.
PCs & Monitors	Molding agent in plastic manufacture	Threshold reporting level 1000 ppm	Considered "material of interest".	EIA, 2001.

Lead in IT and Telecom Equipment				
Where Found	**Use**	**Quantity**	**Status**	**For More Info**
PCs & Monitors	Packaging/packaging inks		Banned in EU Packaging Directive, 1994.	EIA, 2001.
Monitors	Components	6.2 g		Young, 1999.
Cabling	Used as stabilizer in PVC cabling	0.0016 lbs/10 ft of computer cable		Plastics Industry as cited in EIA, 2000.
Cabling	Stabilizer, combined with PVC			Young, 1999.
Cabling	Surface treatment for copper alloy	60% tin, 40% lead		Nordic Council of Ministers [a], 1995.
Cabling	Stabilizer			Nordic Council of Ministers [a], 1995.
Cabling	Used as stabilizer in PVC cabling	Threshold reporting level 1000 ppm	Considered "material of interest".	EIA, 2001.
Cabling	Low melting point, good conductivity, high corrosion resistance		WEEE Directive bans lead in this application by 2004.	IPC Roadmap, 2000.
Batteries in earlier laptops	Power supply		No longer used. Replaced with nickel cadmium or lithium ion batteries.	EIA, 2000.
Batteries in earlier laptops	Power supply, sealed lead-acid battery			Tonetti (EPA), 2000.
Printed circuit boards	Connects computer chips to printed circuit boards	1.36-18.4 g		Young, 1999.
Printed circuit boards	Low melting point, good conductivity, high corrosion resistance		Substance under special attention, several current affairs.	C4E Guidance Document, 2000.
Printed circuit boards	Final surface finish		WEEE Directive bans lead in this application by 2008.	IPC Roadmap, 2000.
Printed circuit boards	Connects computer chips to printed circuit boards			Tonetti (EPA), 2000.
Motherboards	Components	9.5 g		Young, 1999.

Lead in IT and Telecom Equipment				
Where Found	**Use**	**Quantity**	**Status**	**For More Info**
Fluorescent tubes	Lowers melting point of the glass locally, makes it easier to get an air-tight connection	1.5 g/fluorescent tube		Nordic Council of Ministers [a], 1995.
Fluorescent tubes	Lowers melting point of the glass locally, makes it easier to get an air-tight connection		Substitute for lead required under WEEE by 2008. Some exemptions apply.	WEEE Directive, 2000.
Printers	Connecting material in form of solder			Tonetti (EPA), 2000.
Capacitors	Tin-lead solder, connecting agent			Nordic Council of Ministers [a], 1995.

Cadmium

A number of sources reviewed during this study reference the use of cadmium metal in IT and telecom equipment. Cadmium's use in electronic products is varied because of its attractive properties, including excellent corrosion resistance, low electrical resistance, good soldering characteristics, and solubility in strong acids (which facilitates the preparation of red, orange and yellow cadmium pigments for plastics). The most familiar use of cadmium is in nickel-cadmium (Ni-Cd) batteries; extensively used in earlier laptops, cell phones, etc. Ni-Cd batteries have since been replaced in most jurisdictions with either lithium-ion or metal-hydride batteries. Even though Ni-Cd batteries are being phased-out, older equipment containing Ni-Cd batteries still needs to be appropriately managed.

Current uses of cadmium ranges from acting as a stabilizer in plastic components to being added to components as a colour pigment. Cadmium sulphide is used as a phosphorescent coating on the inside of fluorescent monitor screens in amounts between 5 and 10 grams per screen. Colour in a monitor screen is achieved using three electron guns, a shadow mask and the cadmium phosphorescent coating. Cadmium is also added to PVC plastic insulation of wires and cables as a plastic stabilizer and flame-retardant. Specific quantities of cadmium used in each component are difficult to find in the existing literature. The American Electronic Industry Association (EIA) considers cadmium a substance of concern and the WEEE Directive requires a substitute for cadmium in all uses by 2008.

Cadmium in IT and Telecom Equipment				
Where Found	**Use**	**Quantity**	**Status**	**For More Info**
PCs	Plating applications	(<0.01%)		MCC as cited in EIA, 2000.
PCs	Plating applications in contacts and switches			Tonetti (EPA), 2000.
PCs	Battery, emitter, housing, PWB, CRT	0.0063% of total weight		MCC, 1996.
Batteries - laptop computers	Power supply			EIA, 2000.
Batteries - laptop computers	Power supply			Nordic Council of Ministers [a], 1995.
Batteries - laptop computers	Power supply		Substance under special attention, several current affairs.	C4E Guidance Document, 2000.
Batteries - laptop computers	Power supply (NiCd battery)			Tonetti (EPA), 2000.
Monitors - CRTs	Phosphorescent coating on inside of screen	5-10 g/screen		Young, 1999.

Cadmium in IT and Telecom Equipment				
Where Found	**Use**	**Quantity**	**Status**	**For More Info**
Monitor - CRTs		<0.1% total use		Nordic Council of Ministers [a], 1995.
Monitors - CRTs	Phosphorescent coating on inside of screen		Substitute for cadmium required under WEEE by 2008.	WEEE Directive, 2000.
Monitors - CRTs	Phosphorescent coating on inside of screen		Substance under special attention, several current affairs.	C4E Guidance Document, 2000.
Monitors - CRTs	Phosphorescent coating on inside of screen			Tonetti (EPA), 2000.
Cabling	Plasticizer, stabilizer, flame-retardants and colouring in PVC cabling			Young, 1999.
Cabling	Colour pigment and stabilizer		Forbidden in Sweden.	Nordic Council of Ministers [a], 1995.
Cabling	Plastic stabilizer, colour pigment		Restrictions in Austria, Switzerland, Denmark, Netherlands and Sweden.	EIA, 2001.
Cabling	Plastic stabilizer			Tonetti (EPA), 2000.
Motherboards	Components	0.004 g		Young, 1999.
Plastic computer housings	Plastic stabilizer, colour pigment	>25 g	Banned in Sweden.	EIA, 2001.
Plastic computer housings	Colour pigment		Substance under special attention, several current affairs.	C4E Guidance Document, 2000.
Printed circuit boards	Surface finish	Threshold reporting level 1000 ppm	Considered "material of interest".	EIA, 2001.
Printed circuit boards	Chip resistors, semiconductors		Substitute for cadmium required under WEEE by 2008.	WEEE Directive, 2000.

Beryllium

Beryllium metal offers a unique and incomparable combination of properties. It is one of the lightest structural materials available but is several times stronger than steel. It has excellent thermal conductivity, high electrical conductivity, good corrosion resistance, good fatigue resistance, high strength and good formability. Traditionally, copper-beryllium alloys were used in motherboards on personal computers. Beryllium is rarely used in this form anymore, but its use in combination with copper as an alloy is increasing. Beryllium improves the properties of copper contact springs because of its high strength, high conductivity and high elastic quality. Between 2-4% of these copper alloys is beryllium metal. Beryllium metal is sometimes overlooked as one of the components of concern in end-of-life electronic equipment. Not a great deal of information is available on beryllium, as it has only recently been recognized as a potentially toxic or hazardous component in IT and telecom equipment.

Beryllium in IT and Telecom Equipment				
Where Found	**Use**	**Quantity**	**Status**	**For More Info**
Motherboards			No longer used in motherboards.	EIA, 2000.
Motherboards	Components	0.08 g		Young, 1999.
Motherboards	Copper-beryllium alloy	2% beryllium		Tonetti, (EPA) 2000.
Connectors				EIA, 2000.
PBA (Printed Board Assembly) connectors	Contact springs, improve elasticity of copper alloy	Contain 2-4% beryllium	Use is slowly increasing.	Nordic Council of Ministers [a], 1995.
PBA (Printed Board Assembly) connectors	Contact springs, improve elasticity of copper alloy	Threshold reporting level 1000 ppm	Considered "material of interest".	EIA, 2001.
Finger clips	Maintain electrical conductivity in metal housings			EIA, 2000.
PCs		0.0157% total weight		MCC, 1996.
Monitors	Components	0.05 g		Young, 1999.
Relays	Improve properties of copper contact springs			Young, 1999.
Relays	Improve properties of copper contact springs			Nordic Council of Ministers [a], 1995.
Relays	High strength, high conductivity		Substance under special attention, several current affairs.	C4E Guidance Document, 2000.

Beryllium in IT and Telecom Equipment				
Where Found	**Use**	**Quantity**	**Status**	**For More Info**
Switches				Nordic Council of Ministers [a], 1995.
Switches	High strength, high conductivity		Substance under special attention, several current affairs.	C4E Guidance Document, 2000.
Laser printers	Rotating mirror, lightweight rigidity for precision instrumentation		Substance under special attention.	C4E Guidance Document, 2000.

Hexavalent Chromium (Cr VI)

Very little information on the uses of hexavalent chromium in IT and telecom equipment exists in the literature that was reviewed. There is some consensus that chromium VI is typically used as a hardener or stabilizer for plastic housings and as a colorant in pigments. References to quantities of chromium VI in these components were poor. The use that is occurring seems to be in trace amounts, between 0.2 and 0.3 grams per component. As a colour pigment, the European Union is moving to restrict the use of chromium VI. Hexavalent chromium may also be present on the surface of metal parts that have been protected from corrosion with chromate conversion coatings – no references to quantities of Cr VI present in this application were found.

Chromium VI in IT and Telecom Equipment				
Where Found	**Use**	**Quantity**	**Status**	**For More Info**
PCs	Decorative, hardener, housing, PWB	0.0094% of total weight		MCC, 1996.
PCs	Anti-corrosion treatment	Threshold reporting level 1000 ppm	Considered "material of interest".	EIA, 2001.
Monitors	Components	0.2 g		Young, 1999.
PCs & Monitors	Packaging and packaging inks, colorant		Banned in EU Packaging Directive (1994).	EIA, 2001.
PCs & Monitors	Colorant in pigments		Substance under special attention, RoHS Directive.	C4E Guidance Document.
Cabling	Stabilizer, combined with PVC			Young, 1999.
Motherboards	Components	0.3 g		Young, 1999.
Hard discs	Hard disc plate, hardener			Young, 1999.

Antimony

Information on antimony use and quantities in electronic equipment is sparse. It is used in IT and telecom products as a flame-retardant, as a melting agent in CRT glass, and as a solder alloy in cabling. Antimony appears to be present in these products as a trace element, contributing less than 0.2% of the total weight. However, European Industry Groups are currently preparing a guidance document for antimony and the American Electronics Industry Alliance (EIA) has labelled antimony as a "material of interest" because it is a known carcinogen. The EIA has set a threshold reporting level for antimony of 1000 ppm when it is used in the manufacture of electronic products.

Antimony in IT and Telecom Equipment				
Where Found	**Use**	**Quantity**	**Status**	**For More Info**
PCs	Flame retardant	0.01%		MCC as cited in EIA, 2000.
Monitors	Melting agent in CRT glass	0.2% in funnel and 0.24% in the panel		Personal conversation with Steve Wood, Techneglas as cited in EIA, 2000.
Monitors	Melting agent in CRT glass	Threshold reporting level 1000 ppm	Considered "material of interest".	EIA, 2001.
Cabling	Stabilizer, flame retardant, combined with PVC			Young, 1999.
Cabling	Solder material (antimony-tin)			Nordic Council of Ministers [a], 1995.
Cabling	Solder alloy	Threshold reporting level 1000 ppm	Considered "material of interest".	EIA, 2001.
Integrated circuits	Added to semiconductor chip to help with conductivity	< Amount naturally found in soil		Nordic Council of Ministers [a], 1995.
Plastic computer housings	Flame retardant synergist (used in combination with flame retardant and PVC)	Threshold reporting level 1000 ppm	Considered "material of interest".	EIA, 2001.
			In preparation, substance under special attention.	C4E Guidance Document.

Brominated Flame-Retardants

Flame-retardants are found in the majority of IT and telecom products for fire safety requirements. They are incorporated into printed circuit boards, plastic computer housings, motherboards, keyboards and cables among other things to prevent the development or spread of fires. PBBs (or polybrominated biphenyls) and PBDEs (polybrominated diphenyl ethers), two types of brominated flame-retardants, have been largely eliminated in several countries and replaced with TBBP-A (tetrabromobisphenol), a flame-retardant considered by some to be slightly less hazardous. TBBP-A is slated for full risk assessment as part of the EU's Fourth Priority Substances List process. Again the issue of proper management is still critical considering these flame-retardants will be present in many end-of-life products. The WEEE Directive requires substitution for both PBBs and PBDEs by 2008. Alternative flame-retardants without bromine as an additive and designs with no flame-retardants are being implemented by several OEMs (see Chapter 5 for details). In terms of quantities of flame-retardants found in IT and telecom equipment, published research is quite poor. Some sources attempt to quantify the amounts but the numbers vary significantly from one to another.

Brominated Flame-Retardants in IT and Telecom Equipment				
Where Found	**Use**	**Quantity**	**Status**	**For More Info**
Printed circuit boards (PBBs)	Flame retardant		Largely eliminated 7-10 years ago.	EIA, 2000.
Printed circuit boards (TBBPAs)	Flame retardant, additive or reactive		Has partially replaced PBB and PBDE.	Simon, 1999.
Printed circuit boards (TBBPAs)	Flame retardant	28.6 g	Replacing PBDE although hasn't thoroughly been researched.	Young, 1999.
Printed circuit boards (TBBPA)	Flame retardant, additive or reactive	0.4kg/m2 of laminate, 17% TBBA	Replacing PBDE.	Nordic Council of Ministers [a], 1995.
Printed circuit boards (TBBPAs)	Flame retardant, additive or reactive			EIA, 2000.
Printed circuit boards (PBBs)	Flame retardant		Only one PBB made in recent history, and production ceased in 2000. All others stopped in 1980's.	EIA, 2001.
Printed circuit boards (TBBPAs)	Flame retardant, additive or reactive	Threshold reporting level 1000 ppm in any plastic part > 25 g		EIA, 2001.
Printed circuit boards (PBBs & PBDEs)	Flame retardant, additive or reactive		Substitute required for PBBs and PBDEs under WEEE by 2008.	WEEE Directive, 2000.

Brominated Flame-Retardants in IT and Telecom Equipment				
Where Found	**Use**	**Quantity**	**Status**	**For More Info**
Printed circuit boards	Flame retardant			Tonetti (EPA), 2000.
Plastic computer housings (PBDOs)	Flame retardant			EIA, 2000.
Plastic computer housings (PBDEs)	Flame retardant	500 g	Use has declined in recent years.	Young, 1999.
Plastic computer housings (PBBs)	Flame retardant, additive			Simon, 1999.
Plastic computer housings (PBDEs)	Flame retardant, additive			Simon, 1999.
Plastic computer housings - ABS (PBDEs)	Flame retardant	Contains 25% PBDE	After 1985, successive shift over to PVC which a good retardant due to high concentration of chlorine.	Nordic Council of Ministers [a], 1995.
Plastic computer housings (PBBs & PBDEs)	Flame retardant, additive or reactive		Substitute required for PBBs and PBDEs under WEEE by 2008.	WEEE Directive, 2000.
Motherboards (TBBPAs)	Flame retardant	107 g	Replacing PBDE.	Young, 1999.
Keyboard buttons (PBBs)	Flame retardant, additive			Simon, 1999.
Connectors	Flame retardant, additive or reactive		Substitute required for flame retardant under WEEE by 2008.	WEEE Directive, 2000.
Cabling (PBBs & PBDEs)	Flame retardant, additive or reactive		Substitute required for PBBs and PBDEs under WEEE by 2008.	WEEE Directive, 2000.

PolyVinyl Chloride – PVC

Many different types of plastics are used in the manufacture of electronic equipment. PVC, one of the major plastic polymers, appears to draw the most attention in literature focusing on potentially hazardous materials in electronics. This is probably because of the well-documented risks of dioxin formation during the incineration of PVC material. The predominant use of PVC plastic in electronics is as a structural feature in plastic computer housings, keyboards and cables. PVC has good chemical resistance that original electronic equipment manufactures look for when designing durable products. Estimated quantities of PVC in different products range from 37.1 grams in a keyboard to a total of 314 grams in all of the cables connecting different component pieces together (for example the cables connecting the monitor, mouse and keyboard to the CPU). There are other factors that contribute to the potentially hazardous nature of PVC as a substance that needs to be managed with precaution at a product's end-of-life. Both chlorine and flame-retardants are often additives in the plastic manufacturing process and are added to cables and housings. It is extremely difficult to identify which types of plastics or flame-retardants are found in each component. This creates considerable difficulty when attempting to manage waste IT and telecom equipment.

PVC in IT and Telecom Equipment				
Where Found	**Use**	**Quantity**	**Status**	**For More Info**
Monitors				EIA, 2000.
Keyboards				EIA, 2000.
Keyboards	Cable and plug	37.1 g		Young, 1999.
Cabling				EIA, 2000.
Cabling		216-314 g		Young, 1999.
Cabling	Good chemical resistance, used in protection mantle			Nordic Council of Ministers [a], 1995.
Cabling	Good chemical resistance, used in protection mantle	Threshold reporting level 1000 ppm		EIA, 2001.
Plastic computer housings	Structural, cosmetic	23% by weight of PCs		Young, 1999.
Choking coils		22-48 g		Young, 1999.
Cellular phone windows	Good chemical resistance, used in protection mantle	Threshold reporting level 1000 ppm		EIA, 2001.
Plastic computer housings	Structural, cosmetic	Threshold reporting level 1000 ppm		EIA, 2001.
			In preparation, substance under special attention.	C4E Guidance Document, 2000.

PolyChlorinated Biphenyls – PCBs

There is some uncertainty about where and when PCBs have been used in IT and telecom equipment. Some sources state that PCBs have never been used in PCs. Others refer to PCB use in old capacitors, while others cite PCB use as a possible flame-retardant in PVC plastic cables. Although no PCB quantities were located in the literature, it should still be regarded as a substance to manage with precaution at its end-of-life. It is likely that products containing PCBs are now obsolete, have already been disposed of or are currently being stored.

PCBs in IT and Telecom Equipment				
Where Found	**Use**	**Quantity**	**Status**	**For More Info**
Have never been used in PCs			Banned in U.S. and Sweden in 1977.	MCC as cited in EIA, 2000.
Capacitors (special)	Used for mains voltages and higher		Forbidden in early 70s.	Nordic Council of Ministers [a], 1995.
Capacitors	Phase compensation of fluorescent tubes		Not expected but historically used, "Controlled material" in the U.S.	EIA, 2001.
Cabling	Flame retardant combined with PVC plastics			Nordic Council of Ministers [a], 1995.

3. Releases of Toxic and Hazardous Materials

Many of the hazards associated with substances and materials in IT and Telecom equipment arise when the equipment reaches its end-of-life and is disassembled, recycled, incinerated or deposited in a landfill.

This chapter presents information on the potential hazards from recycling, incinerating or landfilling wastes that contain toxic or hazardous substances and materials. Where possible, the information is specific to the IT and telecom components described in chapter 2 and these components are highlighted with boldface type. Other information is less specific and refers to releases from electrical and electronics waste in general.

The information is organized in tables according to the substance of concern and the waste management option. Each table describes how a particular substance is released from the equipment at its end-of-life, provides relevant comments and directs the reader to sources for further information. This is similar to the organization of the data in chapter 2 of this study.

As each substance behaves differently, it is necessary to consider for each type of equipment whether it is preferable to recycle, incinerate or deposit it to landfill.[3] When making this decision, it is important to recognize that both recycling and incineration still require that some fraction be deposited in a landfill and it is within these fractions that toxic or hazardous substances may be most concentrated.[4]

Recycling
Recycling in a broad sense is perceived as the preferable option for waste management. Recycling IT and telecom products to recover valuable components include manual disassembly, shredding, grinding, burning and melting (to reclaim plastics), solder melting, and metals processing. The substances examined in this study are reported as not being released from IT and telecom equipment during manual disassembly. During other recycling processes, toxic or hazardous substances are released and adverse impacts may be realized and even increased. One example is the formation of dioxins and furans when plastics containing bromine- or chlorine-compounds are heated for recycling.

Recycling IT and telecom equipment appears to predominantly pose hazards in the occupational environment. Most well documented, are toxic or hazardous releases from cathode ray tubes and printed circuit boards. Metals and organics are released as fine particulate dusts and fumes during recycling when CRTs are crushed, PCBs are shredded, and when the residues are heated.

In many cases, proper handling and controlled pre-treatment of IT and telecom wastes can minimize the hazards associated with these substances. For example, controlled breakage of waste fluorescent lamps and collection of mercury emissions will avoid uncontrolled breakage and emissions during transport to waste management facilities. Such precautionary measures help to ensure that recycling is actually the best option in terms of the product's life cycle impact.

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[3] Nordic Council of Ministers [b] 1995.
[4] Nordic Council of Ministers [b] 1995.

Incineration

IT and telecom wastes, together with remnant fractions from recycling processes, may be incinerated to recover energy from the waste or to reduce the volume.[5] Incineration is paradoxical in nature. Incineration reduces the toxic or hazardous potential of some substances while increasing the toxic or hazardous potential of others, such as PVC. Incinerating IT and telecom waste concentrates substances, such as lead, in residues for value recovery or further management, yet incineration disperses other toxic or hazardous substances in the environment.[6] Toxic or hazardous air emissions are often attributed to incinerated electrical and electronic equipment. The most well referenced examples include historical air emissions of mercury and the more recently documented problem of dioxin and furan emissions when plastics containing halogens are incinerated (bromine and chlorine are two of the most common halogens incorporated into plastic).

Compared with standard household wastes, electrical and electronic equipment contains significantly higher concentrations of bromine, lead and other metals. In one study, small white and brown goods[7] were responsible for 90 per cent of bromine in the bottom ash and fly ash residues.[8]

Certain OECD countries have banned the incineration of electrical and electronic waste,[9] therefore making recycling a more favourable waste management option. If it is possible to use existing capacity, incineration appears economically preferable to landfilling because of the increased potential to recover rare metals and other materials of value.

Plastics and CRTs from IT and telecom equipment appear to be the most well documented components releasing toxic or hazardous substances during incineration. Metals from CRTs and the dioxins and furans formed when plastics (PVC or BFR-treated plastic) are burned are the reasons for concern. Generally speaking, there are hazards associated with the incineration of IT and telecom wastes that stem from not understanding substance interactions or the effects of low dose exposure to many substances over time. Thus, calculating the risks associated with widely dispersing substances from IT and telecom wastes into the environment becomes laden with uncertainties.

Deposition in a Landfill – Landfilling

Waste electrical and electronic equipment in general contribute "significantly" to the amount of heavy metals and halogenated substances in municipal waste streams. In landfills, negative environmental effects are associated both with deposited IT and telecom waste and with residues

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[5] The advantages and disadvantages of waste incineration are widely debated – Incineration reduces the environmental hazards associated with some organic compounds, while increasing the hazardous nature of other compounds and dispersing them to air, water and soil. See Nordic Council of Ministers [b] 1995, p.21 for further discussion.

[6] Incineration residues include: fly ash, bottom ash or slag and wastewater from acid flue gas cleaning, in addition to air emissions from the incineration stack.

[7] In the Dutch Decree (1998) brown goods include sound equipment, image receiving equipment, computers, paper printing equipment, telecommunications equipment and electric and electronic charging equipment.

[8] Dutch Decree 1998.

[9] These countries include Sweden, the Netherlands, and Switzerland. An incineration ban is also part of the WEEE Directive of the European Union (as cited in OECD, 2000).

deposited from the incineration of these wastes. Leaching and evaporation of heavy metals and other toxic or hazardous substances from the waste products pose significant problems. In addition, the variety of substances used in IT and telecom equipment will interact to exert synergistic effects, potentially increasing their release and magnifying their negative effects.[10]

Metals from lamps in IT and telecom equipment are a well-referenced route for release of toxic or hazardous substances in landfills, namely lead and mercury. Plastics in cables and other components will also release cadmium, brominated flame-retardants and phthalates into landfill leachate.

Research conducted to substantiate Europe's WEEE Directive indicates that this equipment is deposited in uncontrolled landfills to a "significant" extent in certain Member States. Even in controlled landfills, leaching of metals and other toxic or hazardous substances must be expected.

[10] Nordic Council of Ministers [b] 1995.

Mercury

The main concern with mercury during recycling of IT and telecom wastes appear to be emissions of the metal to air. In this form, it poses health hazards to workers. Of particular concern is the release of mercury when lamps are broken for recycling, though hazards can be minimised with proper controls. The incineration of IT and telecom wastes release mercury to the air. In Europe, an estimated 36 tonnes of mercury are emitted to the air each year from all waste incineration processes.[11] For mercury and all other toxic or hazardous substances, it is important to consider their interaction and the potential synergistic effects of the many substances in IT and telecom equipment. In landfills, it is well documented that mercury leaches from products into soil and groundwater and emits to air, where it transforms and is transported from the source.

No information on the behaviour of mercury, from IT and telecom batteries, during waste management operations was collected during the course of this study.

Recycling - Mercury in IT and Telecom Equipment		
Release	**Comment**	**For more info**
Mercury may be released from **glass** when it is reclaimed and processed to make new products.		NEMA, 2001.
Crushing **lamps** releases mercury to the air.	With controls, mercury emitted to air during crushing operations can be collected.	NEMA, 2001.
	Lighting and electrical equipment contributed an estimated 11% to the total anthropogenic emissions of mercury to air in Europe in the mid 1990's.	KemI Report no 10/97.
Mercury from products may be released to air during the recycling of products.		KemI, 1997.
Recycling the metal content of waste electrical & electronic equipment may generate dioxins and furans.		WEEE DIRECTIVE, 2000. Riss, 1990. C4E. 2000.

[11] WEEE Directive 2000.

Incineration - Mercury in IT and Telecom Equipment		
Release	**Comment**	**For more info**
Without controls, incineration of **lamps** released 90% of the contained mercury to the air in USA.	NEMA states lamps should not be incinerated. Most incinerators should have controls in place by 2000.	NEMA, 2001.
When incinerated, nearly all mercury in the waste leaves the furnace in the uncleaned flue gas (92%). For dry incineration plants, nearly all mercury in the waste is emitted to the air (75%).		Nordic Council of Ministers [b] 1995 pp.41
Mercury contained in products may be emitted when they are incinerated.		KemI, 1997.

Landfilling - Mercury in IT and Telecom Equipment		
Release	**Comment**	**For more info**
Mercury contained in products may volatilize from landfills.		KemI, 1997.
In landfills, metallic mercury and dimethylene mercury can vapourize (e.g. 1kg per year from a landfill in Sweden).		Nordic Council of Ministers [b] 1995. WEEE DIRECTIVE, 2000.
Mercury will leach from devices, such as **lamps** and circuit breakers, when they are destroyed.		WEEE DIRECTIVE, 2000.
Mercury is transported from landfills in soil and water, given its strong affinity for organic material.		Nordic Council of Ministers [b] 1995 pp48.
Uncontrolled landfill fires may emit metals.		WEEE DIRECTIVE, 2000.

Lead

Recycling Printed Circuit Boards and Cathode Ray Tubes from IT and telecom equipment pose the most well documented hazards. Lead is released from these components when heated as part of various recycling processes. Lead is released to air as dust or fumes, posing hazards to health and the environment. When IT and telecom wastes are incinerated, most of the lead they contain will be transferred to the slag (bottom ash) fraction. This fraction must then be treated as special waste and its use is governed by costly controls and regulations. A Dutch study determined that if “small white and brown goods” were not incinerated with the main waste stream the concentration of lead (and other metals) in the bottom ash would fall below the Dutch leaching requirements for lead and not need stringent control on its management. In landfills, lead will leach from CRTs and lead-solder. The acidic nature of landfill leachate may enhance the release of lead from components and the subsequent availability of lead for uptake to the environment.

Recycling - Lead in IT and Telecom Equipment		
Release	**Comment**	**For more info**
Lead is released as fumes from **Printed Circuit Boards** when they are heated to harvest components.	PCBs are heated to soften the lead solder and remove chips.	OECD, 2000.
Lead is released as fine particulate dusts from **Printed Circuit Boards** if the board is burned or shredded.	Burning and shredding are common prior to smelting processes for reclaiming metal.	OECD, 2000.
Melting **lead solder** in dismantling & recycling operations poses an array of potentially serious concerns.	Lead fumes are a danger to workers and the environment.	OECD, 2000.
Leaded **glass** components, such as **CRT** televisions and **monitors,** may be separated and recycled to recover either the leaded glass (closed loop) or the lead metal (open loop).		C4E, 2000.
Dust containing lead is produced when workers break **CRTs**.	While workers need protection from this dust, the glass need be broken into relatively small pieces before significant amounts of lead are released to the environment.	OECD, 2000.
If lead from **CRTs** is placed in a smelting process, most of the lead will remain in the slag from the process.		OECD, 2000.
	To minimize the production of any dust, fume or vapour separation and recycling facilities should operate in accordance with relevant occupational and environmental legislation.	C4E, 2000.

Recycling - Lead in IT and Telecom Equipment		
Release	**Comment**	**For more info**
Lead is released in furnace exhaust emissions when **Printed Circuit Boards** are burned, prior to smelting for metal recovery.	For details on control technologies, see OECD, 2000.	OECD, 2000.
Lead is released as lead oxide dust or fumes from **CRTs** and **Printed Circuit Boards** when processed at high temperatures.		OECD, 2000.
Risk from exposure to lead oxide is unlikely when working with leaded **glass**.	Risk to the general public through air emissions and water discharges is low and 'no further action' is recommended ('Preliminary Life Cycle Analysis for Pollution Prevention Assessment for Lead Solder', USEPA, 1992).	C4E, 2000.

Incineration - Lead in IT and Telecom Equipment		
Release	**Comment**	**For more info**
Lead from **CRTs** or **Printed Circuit Boards** is released to air and ash fractions when incinerated.	This ash must then be landfilled or may be used as a raw material (e.g. building & construction industry) depending on the lead concentration.	OECD, 2000
	Lead is more volatile in the presence of chlorine during incineration	Nordic Council of Ministers [b] 1995.
	Lead should be phased out of use as a stabilizer in PVC by 2005.	ENDS, March 2001.
When waste that contains lead is incinerated, ca. 65% of the lead will end up in the incineration slag - 35% in the fly ash and flue gas and less than 1% will be released to air.		Nordic Council of Ministers [b] 1995.

Landfilling - Lead in IT and Telecom Equipment		
Release	**Comment**	**For more info**
Lead from **lead-solder** leaches from electronics in landfills.	4.4% of lead in landfill is from consumer electronics (not including TV picture tubes).	NEMA, 2001. C4E, 2000.
In the acidic groundwater of landfills, significant amounts of lead ions are dissolved from broken glass containing lead, e.g. cone glass from **CRTs**.	Pollution from cone glass in landfills is "likely".	Fleischer, *et al.*, 1992 WEEE DIRECTIVE, 2000 Nordic Council of Ministers [b] 1995.
In leaded **glass,** lead oxide is tightly bound in a glass matrix and is unavailable for uptake by the environment.	Equipment containing leaded glass may be recycled or deposited to landfill.	C4E, 2000.
Lead in PVC "is not readily liberated during degradation".	Lead is a standard stabiliser in PVC.	EIA, 2000.
Lead stabilisers are released from certain types of PVC cables that contain a combination of plasticizers.		European Commission [b], 2000.
	In landfills, lead leaches from incineration ash.	OECD, 2000.
	Leachate from landfills across the United States had lead concentrations below the maximum allowed limit (AWD Technologies Inc.).	C4E, 2000.

Cadmium

Recycling components that contain cadmium will release the cadmium to the air, where it becomes available for inhalation. Cadmium and cadmium oxide dust and fumes are emitted when plastics are burned, when metals are heated and when Printed Circuit Boards are shredded during metal recovery operations. In Europe, 16 tonnes of cadmium per year are emitted to air from incineration processes. In landfills, cadmium leaches from the plastics and batteries in IT and telecom equipment. Similar to other metals, cadmium also leaches from incineration residues that are landfilled.

Recycling - Cadmium in IT and Telecom Equipment		
Release	**Comment**	**For more info**
Cadmium oxide dust is released from plastic when it is burned.	Plastic is burned prior to, or during, metal reclamation.	OECD, 2000.
Cadmium oxide dust or fume is released from Cd-plated metal contacts and switches, when processed at high temperatures.	e.g. in metal processing steps.	OECD, 2000.
Breaking CRT screens, cadmium in phosphor coatings could pose inhalation hazards to workers in the breaking operations.		OECD, 2000.
Cadmium is released in fine particulate dusts from **Printed Circuit Boards** when they are burned or shredded.	Burning and shredding are common prior to metal recovery processes.	EC Directive 91/338/EEC.
	In some countries, certain products containing cadmium are restricted under regulations.[12]	EC Directive 91/338/EEC.
	The Directive on Batteries and Accumulators (91/157/EEC) includes a ban on all batteries containing more than 0.0005% Cd, beginning in 2008. This prohibition could eliminate NiCd batteries (in favour of NiMH and Li-ion batteries).	C4E, 2000.

[12] Sweden, Denmark, Netherlands, Switzerland, Austria and Norway restricted certain cadmium products before the EC product restrictions on pigments, stabilizers and coatings. Now, cadmium and certain cadmium products are regulated under EC Directives 76/769/EEC, 91/338/EEC, 91/157/EEC and under The 1989 European Commission Action Programme on Cadmium.

Incineration - Cadmium in IT and Telecom Equipment		
Release	**Comment**	**For more info**
Cadmium is emitted to air when computer **monitors** are incinerated.		OECD, 2000.
When incinerated, 79% of cadmium in the waste will be released to fly ash and flue gas cleaning residue, while 20% will be transferred to slag and 1% to air.		Nordic Council of Ministers [b] 1995.

Landfilling - Cadmium in IT and Telecom Equipment		
Release	**Comment**	**For more info**
In landfills, cadmium is released from **plastics,** NiCd-**batteries** and from fly ash and slag incineration residues. Cadmium leaches from these sources.	Leaching from deposited fly ash is higher than that from slag (bottom ash).	Nordic Council of Ministers [b] 1995.
Cadmium will tend to leach from incineration slag (bottom ash) into water at levels less than the maximum admissible concentrations for drinking water.	Cadmium may leach into soil and groundwater.	Resource Recovery Forum. Online WEEE Directive, 2000.
In an OECD study, 90% of leachate samples from municipal solid waste landfills pass the WHO recommended cadmium drinking water standard of, even samples from 50-year old unlined landfill sites.		C4E, 2000.

Beryllium

Most recent studies on beryllium focus on its behaviour during recycling. This is partly because beryllium is not known to be toxic to the environment and because it has only recently been identified as a health hazard in IT and telecom equipment due to trends for recycling. Beryllium is most hazardous when inhaled as a dust or fume. Forms of beryllium are released when components are shredded and from copper-beryllium alloys when metals are heated. If an organization is aware of the risks of beryllium and manages or controls those risks appropriately, the risk to human health is small. However, if an organization is unaware of the risks, and takes no measures to control or manage the risks, the risk to human health can be quite serious[13]. Noranda Inc. is currently in the process of documenting the risks of beryllium for its employees working at electronic recycling facilities. No information was found on the behaviour of beryllium in IT and telecom waste during incineration or landfilling processes. To some extent, it can be inferred that it behaves in a similar manner to other metals – concentrating in incineration residues and mobilizing from products in landfill leachates.

Recycling - Beryllium in IT and Telecom Equipment		
Release	**Comment**	**For more info**
Operations generating airborne material, e.g. grinding or welding, require suitable air extraction and filtration (under existing workplace regulations).	Beryllium metal components should be segregated from equipment at end-of-life and returned to the supplier for recycling.	C4E, 2000.
Beryllia components should not be passed through crushing and shredding operations without proper controls, due to the risk of dust generation.		C4E, 2000.
The greatest exposures to **beryllium** occur in the workplace (i.e., where it is mined, processed, or converted into alloys and Chemicals).		USEPA, 2000.
Risk can only arise from airborne Be dust or fumes generated from the material.		C4E, 2000.
Beryllium from copper-beryllium alloys is released as beryllium oxide dust or fume during high temperature metal processing.		OECD, 2000.
Beryllium metal scrap should not be re-melted without appropriate controls		
Beryllia ceramic components should be separated from equipment at end-of-life and returned to the supplier for recycling		C4E, 2000.

[13] Thomas, Cindy, 2001: Personal Communication, Noranda Inc. May 3rd, 2001.

Recycling - Beryllium in IT and Telecom Equipment		
Release	**Comment**	**For more info**
Any operation (involving BeO), which could generate airborne material, e.g. grinding and polishing, laser cutting, high temperature heat treatment in moist atmospheres or handling of powder forms, requires suitable air extraction and ventilation		C4E, 2000.
Recycling of beryllium poses "small" health and human safety concerns if beryllium is airborne and inhaled.		EIA, 2000.
	Beryllium was identified in 1995 by the Nordic Council of Ministers (1995 [b]) as requiring further assessment to determine the associated environmental impacts.	
	Beryllium metal does not give off dust or fumes during application in electrical or electronic equipment.	C4E, 2000.

Incineration - Beryllium in IT and Telecom Equipment		
Release	**Comment**	**For More Info**
Once products containing beryllium are incinerated, the Be (as an oxide or sulphur) is mainly transferred to the slag from incineration processes.	Beryllium probably does not volatilize in incineration plants with grate furnace technologies.[14]	Tillman, 1994.

During the course of this study, no information was gathered on the release of beryllium from IT and telecom equipment in landfills.

[14] These technologies are described further in *Environmental Consequences of Incineration and Landfilling of Waste from Electr(on)ic Equipment,* a document by the Nordic Council of Ministers [b] 1995, p.19.

Hexavalent Chromium (Cr VI)

Studies show hexavalent chromium (Cr VI) is transferred to incineration residues. In landfills, chromium VI leaches from incineration residues and directly from products. Chapter 2 documents that the hexavalent form of chromium is used in the plastics of personal computers, cabling and packaging for IT and telecom equipment. Thus, these sources contribute to the chromium VI that is released to air, soil and water from incineration and landfill reactions.

No specific information was found on the release of hexavalent chromium during recycling of IT and telecom equipment during the course of this study.

Incineration - Chromium VI in IT and Telecom Equipment		
Release	**Comment**	**For more info**
When incinerated, 90% of chromium in the waste will be contained in the final slag - less than 1% will be released to air and 10% to fly ash and flue gas cleaning residue.		Nordic Council of Ministers [b] 1995.
Chromium VI will evaporate from fly ash.		WEEE DIRECTIVE, 2000.
Soil contaminated with fly ash from incinerated hexavalent chromium, is highly toxic.		Recycling Council of Ontario, 2000.

Landfilling - Chromium VI in IT and Telecom Equipment		
Release	**Comment**	**For more info**
Chromium easily leaches from landfills that are not "appropriately" sealed.		WEEE DIRECTIVE, 2000.
Chromium VI is easily soluble in fly ash that is deposited in landfills.		WEEE DIRECTIVE, 2000.
	Chromium and chlorine together exhibit increased toxicity – synergistic effects.	Nordic Council of Ministers [b] 1995.

Antimony

There appears to be little documentation on the behaviour of antimony during recycling, incineration and landfilling of IT and telecom equipment. A study by Tillman (1994) as cited in a report by the Nordic Council of Ministers (1995 [b]), measures the antimony transferred from incinerated products to incineration residues. However, the ratio of various product types in the waste composition is not stated.

Recycling - Antimony in IT and Telecom Equipment		
Release	**Comment**	**For more info**
Occupational exposure to antimony dust or contact with skin may occur when processing antimony metal.		USEPA, 2000.

Incineration - Antimony in IT and Telecom Equipment		
Release	**Comment**	**For more info**
Without acid flue gas cleaning, 40% of Antimony from the waste is released in incineration slag, 58% in the fly ash and 2% is released in the incinerator shaft.		Tillman, 1994.
	Antimony trioxide is a combustion product of Antimony	Nordic Council of Ministers [b] 1995.

No information was gathered on how antimony behaves, or is released from, IT and telecom equipment in landfills.

Brominated Flame-Retardants

Specific information on releases of brominated flame-retardants from printed circuit boards and connectors was not available. Measurements in the table indicate that brominated flame-retardants are released from waste, from plastic and more specifically in some cases, from electrical and electronics waste. Brominated flame-retardants will release from plastics differently, depending on whether they are additives or are reacted into the plastic. In IT and telecom equipment, additive flame-retardants in printed circuit boards (PBDEs and TBBP-A), computer housings (PBBs), keyboard buttons, connectors and cabling pose the most significant hazard to workers during recycling processes.

Bromine from incinerated, flame-retarded plastic will be present in incineration residues. Better documented is the evidence that incineration of plastics including brominated flame-retardants will produce toxic or hazardous dibenzo-dioxins and –furans. The brominated flame-retardant groups PBDE and PBB are soluble in landfill leachate, particularly when used as additive flame-retardants in products. They will also volatilize from waste in landfills (e.g. PBDEs).

Recycling - Brominated Flame-Retardants in IT and Telecom Equipment		
Release	**Comment**	**For more info**
Bromine is released from **plastic** treated with brominated flame-retardant during plastics extrusion to produce dibenzo-dioxins and -furans.	This is due to the heating involved in the extrusion processes.	OECD, 2000.
Extrusion processes during recycling of plastics treated with BFR lead to the formation of polybrominated dibenzo-dioxins and -furans.	Partly for this reason, the German chemical industry stopped producing PBDEs in 1986.	WEEE DIRECTIVE, 2000. Brenner, 1986. Sellström, 1996.
Dust containing PBDE is released from electrical and electronic equipment into the air during recycling. This has led to high concentrations of PBDE measured in the blood of recycling plant employees	This has lead to high concentrations of PBDE measured in the blood of recycling plant employees. Recyclers usually do not recycle flame-retarded plastics, given the risks of generating dioxins and furans. Most recyclers do not process any plastic from waste ELECTRICAL & ELECTRONIC equipment because it is hard to properly distinguish flame-retarded plastic. Penta-, octa- or deca-brominated diphenylether are used in combination with antimony trioxide	WEEE DIRECTIVE, 2000. Brenner, 1986. Danish EPA, 1999. Sjödin *et. al*. 1999. ENDS Report, 1998.

Recycling - Brominated Flame-Retardants in IT and Telecom Equipment		
Release	**Comment**	**For more info**
When recycled, **plastic** is shredded and ground into flakes. These processes produce dust-containing plastics, which can damage lungs when inhaled.		Taberman *et.al.* 1995.
Certain monomers in the plastic will evaporate during the shredding and grinding of plastics, posing ecotoxicity and human toxicity risks.		Taberman et.al. 1995.
Plastic is burned during metal recovery - dibenzo-dioxins and -furans are produced when BFR treated plastic is burned.		OECD, 2000.
Wastewater from plastics recycling processes is often discharged directly to sewers.		Taberman et.al. 1995.
Waste dumps are one of two principle point sources of PBB to the aquatic environment.		WEEE Directive, 2000.
Release from factory adding TBBP-A to products = 50 ng/g measured upstream and 430 ng/g measured downstream		KemI. 1995. PM nr 10/95.

Incineration - Brominated Flame-Retardants in IT and Telecom Equipment		
Release	**Comment**	**For more info**
When incinerated, bromine from brominated flame-retarded plastics will occur in the fly ash (as HBr and as bromide).		Nordic Council of Ministers [b] 1995 pp.42
Incineration of products A18at 600-800 °C may generate polybrominated dibenzodioxins and dibenzofurans (at 800 °C, 0.16% dibenzo- dioxins and furans are formed).	Copper acts as a catalyst when flame-retardants are incinerated, increasing the risk of formation of dioxins.	KemI. 1995. PM nr 10/95. Schacht, SweEPA.
During combustion, bromine from flame-retarded plastics forms dibenzo-dioxins and -furans.	Bromine combines with carbon and hydrogen.	OECD, 2000.

Incineration - Brominated Flame-Retardants in IT and Telecom Equipment		
Release	**Comment**	**For more info**
	TBBP-A has partially replaced PBB and PBDE. TBBP-A is slated for full risk assessment by the EU in the EU's Fourth Priority Substances List.	Simon. A. 1999.
	KemI state a need to identify hazards of waste deposits and burning of products treated with TBBP-A or products with TBBP-A incorporated.[15]	KemI. 1995. PM nr 10/95.
	TBBP-A is "not considered hazardous" when used as a reactive intermediate in plastic.[16]	EIA, 2000.

Landfilling - Brominated Flame-Retardants in IT and Telecom Equipment		
Release	**Comment**	**For more info**
	PBBs have measured 200 times more soluble in landfill leachate than in distilled water.[17]	WEEE DIRECTIVE, 2000.
In landfills, brominated flame-retardants leach from plastics and other materials and can spread. BFRs are also spread by volatilization from landfills.	PBDEs may leach into the soil and groundwater.	Nordic Council of Ministers [b] 1995. WEEE DIRECTIVE, 2000.
As a reactive flame-retardant, TBBP-A is unlikely to leach from products – thus production facilities are greatest source of exposure		KemI. 1995. PM nr 10/95.
Uncontrolled burning in landfills can emit dioxins, furans such as tetrachlorodibenzodioxin and polychlorinated and polybrominated dioxins and furans due to halogenated materials in the waste.		WEEE DIRECTIVE, 2000.

[15] TBBP-A has partially replaced PBB and PBDE (Simon, 1999). TBBP-A is slated for full risk assessment by the European Union.

[16] TBBP-A is used in acrylonitrile butadiene styrene plastic (ABS) as an additive flame-retardant. ABS makes ca. 57-59% of the plastic in a personal computer, according to EIA, 2000.

[17] PBBs are no longer produced, though they are a potential problem in equipment made prior to 2000 (Simon, 1999).

PolyVinyl Chloride – PVC

PVC plastics will release dioxins and furans during recycling processes and will generate dusts and fumes hazardous to workers when heated and shredded. For these reasons, very little PVC is recycled. In fact, only a small fraction of any plastic from electrical and electronic equipment is properly recycled. This is because different types of plastic are not clearly marked and recyclers want to avoid the risk of handling PVC. In certain applications, PVC will contain chloro-paraffins, poly-chlorinated biphenyl and other phthalates that are released during shredding and heating and pose potential hazards to recycling workers and the environment.

The most well referenced information on PVCs document the production of dioxins and furans when it is incinerated. Within certain temperature ranges, the production of these compounds can be reduced. Incinerating PVC will also release chlorine to the air and in incineration residues. Specific to IT and telecom equipment, phthalates from PVC cabling will migrate from landfills.

Recycling - PVC in IT and Telecom Equipment		
Release	**Comment**	**For more info**
Chlorine from PVC will form dibenzo-dioxins and furans during plastics extrusion processes.		OECD, 2000.
PVC insulation on **power cords** has been removed by burning, sometimes in uncontrolled combustion. Incomplete burning will emit particles and dibenzo-dioxins and -furans in exhaust emissions.	PVC insulated **electrical wire** should be separated from personal computers during dismantling, when accessible.	OECD, 2000.
	PVC in **cable insulation** contains chloro-paraffins. PVC can also contain polychlorinated biphenyl, a softener. PVC may also contain PCBs, as well as lead and cadmium as pigments or stabilizers	Nordic Council of Ministers [b] 1995.
Recycling PVC containing heavy metals can lead to dilution of heavy metals into new products.	Plastics recycling is limited because 1) many different resins are used in each type of equipment, 2) plastics are not clearly labelled by type, and 3) halogens in the plastic require protection measures for humans and the environment if plastics are shredded or heated.	OECD, 2000. European Commission [b], 2000.
	Very little PVC waste, in particular waste electrical & electronic equipment is currently recycled. (approx. 20% of plastic in electrical & electronic equipment is PVC)	WEEE DIRECTIVE, 2000. DG XI, 2000. Rohr, 1992.

Incineration - PVC in IT and Telecom Equipment		
Release	**Comment**	**For more info**
Substantial evidence indicates PVC is not suitable for incineration.	In particular, the quantity and toxic or hazardous nature of flue gas residues generated from incineration of PVC.	WEEE DIRECTIVE, 2000. Danish EPA, 1996.
Residues from incineration of PVC contain heavy metals and dioxins.	End-of-pipe solutions to address this residue are less preferable than preventive measures that reduce the quantities of residues generated.	European Commission [b], 2000.
Chlorine is released from PVC **insulation** during waste incineration and will form dibenzo-dioxins and furans.		OECD, 2000.
Combustion of **plastics** is not 100% effective – small amounts of polycyclic aromatic hydrocarbons, dioxins and other decomposition products will be emitted		Nordic Council of Ministers [b] 1995.
Concerns about dioxin formation from PVC due to incineration of obsolete personal computers "appear to be unfounded".		EIA, 2000.
Chlorine from waste in a wet incineration process is emitted mainly in wastewater (50%) and fly ash and sludge (38%)		Nordic Council of Ministers [b] 1995.
In dry incineration, chlorine from waste is released in fly ash and acid flue gas cleaning residue (60%), to air (30%) and in slag (10%)		Nordic Council of Ministers [b] 1995.

Landfilling - PVC in IT and Telecom Equipment		
Release	**Comment**	**For more info**
Phthalates in landfilled **cables** migrate and are emitted.		KemI Report no 4/97, 1997. DG ENV, 1999.
PVC should be marked and separated out of the waste stream.	This is stated in a recent draft resolution from the European Parliament Environment Committee	ENDS, March 2001.

PolyChlorinated Biphenlys – PCBs

PCBs have been well recognized as a hazard to human health and to the environment for more than two decades. As IT and telecom equipment included in this study are relatively recent technologies, sources indicate that PCBs are not found in this equipment. During this study, one reference documents PCBs in capacitors and cites it as a risk for contamination of recycling residues. Given the chemical nature of PCBs, shredding and heating components that contain PCBs likely pose hazards to recycling workers in the occupational environment.

When incinerated, PCBs will potentially form dioxins and furans. In landfills, PCBs will leach from products, such as circuit breakers. Components that contain PCBs will also be a source of dioxins and furans in unintentional, uncontrolled landfill fires.

Recycling - PCBs in IT and Telecom Equipment		
Release	**Comment**	**For more info**
PCBs, e.g. from **capacitors**, may remain in recovered materials and in shredder waste.[18]	This will contain contaminated shredder wastes and must be handled as dangerous (i.e. hazardous) waste that is more costly to process.	WEEE DIRECTIVE, 2000.

Incineration - PCBs in IT and Telecom Equipment		
Release	**Comment**	**For more info**
PCBs may be released to the air from incineration of wastes containing PCBs.		USEPA, 2000.
Uncontrolled incineration of PCBs produces dioxins and furans (polychlorinated and polybrominated dioxins and furans).		WEEE DIRECTIVE, 2000.

[18] PCBs were historically used in capacitors. According to an EIA publication (2000), capacitors are not part of personal computers and thus, risk from PCBs are not an issue when the PCs become waste. Alternatively, an OECD document states capacitors, that may contain PCBs, are components of personal computers (OECD, 2000).

Landfilling - PCBs in IT and Telecom Equipment		
Release	**Comment**	**For more info**
PCBs may leach when devices containing them, e.g. circuit breakers, are destroyed		WEEE DIRECTIVE, 2000.
PCBs may be released to the air from disposal sites containing capacitors (and other PCB wastes).		USEPA, 2000.
Uncontrolled landfill fires may emit dioxins, furans such as tetrachlorodibenzodioxin and polychlorinated and polybrominated dioxins and furans		WEEE DIRECTIVE, 2000.

Substances in IT and telecom equipment may not exert negative environmental effects until their end-of-life stage, when the equipment is disassembled, recycled, incinerated or deposited in a landfill. At this stage, the potential toxic or hazardous effects of substances must be addressed. This will involve detailed studies, risk assessments, control technologies, containment facilities and monitoring and reporting activities. The opportunity to avoid these hazards and the associated costs arises at a much earlier stage – at the stage of equipment design, when materials and technologies are developed and chosen. Investing research efforts and resources at the product development stage will have the greatest influence and offer the widest scope to identify improvements.

A waste management strategy should aim to avoid waste and the costs associated with it. Given the accumulation of obsolete IT and telecom waste, choices must be made about recycling, incinerating and landfilling the various components. However, investing in an infrastructure based on this backlog may create a system that relies on a steady flow of waste. A management scheme dealing with the accumulated IT and telecom waste should be linked to a scheme that provides continuous incentive for waste avoidance.

4. OEM Initiatives to Reduce Toxic or Hazardous Materials

Many Original Equipment Manufacturers ("OEMs") in the IT and Telecom sector have initiated policies, management systems, programs and tools to reduce or eliminate toxic or hazardous materials from their products – some examples of these initiatives are shown in Table 1. Details of these initiatives are discussed below, in sections organized alphabetically by OEM.

Table 1: Example OEM Initiatives to Manage or Eliminate Toxic or Hazardous Substances from Products

Type of Initiative	Examples of Use	Example OEMs
Strategy or Policy	Policy to eliminate Lead by 2002	Fujitsu
Management System	Integrating product objectives into Environmental Management Systems	IBM
Program	Product Stewardship Organization	HP
	Design for Environment (DfE)	Apple, Compaq, IBM, Motorola, Philips, Sony
	Supply Chain Management	Ericsson, Motorola, Sony
Tool	DfE Tools (e.g. Green Design Advisor)	Motorola
	Product Declarations, Product Environmental Profiles	Apple, HP, IBM
	Banned & Restricted Materials Lists[19]	Ericsson, Motorola, Sony
	Supplier Self Assessments	Ericsson

As a result of these initiatives and other factors, several toxic or hazardous materials are banned or restricted by IT and Telecom OEMs. Table 2 shows the status of the toxic or hazardous materials examined in this study at ten OEMs. A "blank" entry in Table 2 should not be interpreted as indicating a particular OEM is not concerned about that specific substance – only that no data concerning how that OEM treats the substance was available for this study.

Table 2: Status of Some Toxic or Hazardous Materials at Selected OEMs

Legend **X = Banned or Scheduled Ban** **R = Restricted or Reportable** **S = Suspected or Watched** **Substance**	**Apple**	**Compaq**	**Ericsson**	**Fujitsu**	**Hewlett-Packard**	**IBM**	**Matsushita (Panasonic)**	**Motorola**	**Philips**	**Sony**
Mercury or its compounds			X	R		R		R	X	X
Lead or its compounds	S	S	X	X	S	R	X	R	S	X
Cadmium or its compounds			X	R		R		R	X	X
Beryllium or its compounds			X			R		R		
Hexavalent Chromium			R	R		R		R		
Antimony or its compounds			R			R		R		
Brominated Flame Retardants	R	R	X	R	R	S	R	S	R	R
Polyvinyl Chloride (PVC)					R	S	R	R		X
Polychlorinated Biphenyls (PCBs)				X				X	X	X

Source: Company publications; Five Winds International

[19] These lists are sometimes known as "black" and "grey" lists, particularly in the automotive sector. This report uses the terminology "banned" and "restricted," which is more common in the electronics sector.

This chapter examines examples of initiatives to reduce or eliminate toxic or hazardous materials from products by ten IT and telecom OEMs. Brief case study examples for several products are also included. The information presented in this chapter represents some examples of these initiatives – it is not an exhaustive list of all such initiatives by the ten OEMs included, nor does it include all OEMs active in this area. Unless otherwise referenced, information comes from published company sources (e.g. web sites, environmental reports).

The "priority focus" concerning toxic or hazardous materials by OEMs examined in this study is the elimination of lead solder and brominated flame-retardants. The EU WEEE Directive targets both of these substances for elimination (with certain exceptions) and significant progress has been made identifying and implementing alternatives. For example, the results of a major international study on halogen-free flame-retardants are shown below and the status of lead-free solder at selected Japanese OEMs is shown in Table 3.

The International Project on Flame-Retardancy in Electronics – Conceptual Study

Between 1997 and 1999, The Swedish Institute of Production Engineering Research (IVF), in cooperation with twelve major European and Japanese product manufacturers and material suppliers, carried out a comprehensive study of state-of-the-art halogen-free flame-retardants and design for flame-retardancy. The conclusions of the study are shown below.

1. There is a trend towards halogen-free alternatives. An increasing number of actions are being taken by companies as well as society.
2. The issue of going halogen-free was first raised in Europe, but Japanese companies are responding to this issue faster than European companies.
3. Corporate initiatives are becoming a major driving force.
4. A wide range of bromine-free materials is available on the market meeting the UL94V-O[1] requirement. These materials look promising but there is a lack of data enabling a full assessment particularly concerning environmental performance.
5. Halogen-free materials are available for all levels of a product, from enclosures down to printed circuit board laminates and integrated circuit (IC) encapsulants. However, the supply of halogen-free laminates and in particular IC encapsulants is limited.
6. There are great opportunities in "design for halogen-free", i.e. to reduce or eliminate the need for halogenated and other flame retardants by design measures.[2]
7. The shift towards "halogen-free" creates market and business opportunities. The key issue is probably to choose the right timing and corporate procedure (i.e. what to do with whom).
8. There are no liability hindrances to a shift to halogen-free as long as flame-retardancy requirements are met.
9. "Halogen-free" or "bromine-free" may come to be perceived as an added value by the market in the future.

Source: IVF, 1999, as cited in Bergendahl, 2000.

[1] A commonly used industry flammability standard.
[2] For example, see the Apple Computer Power Mac G4 example discussed below.

Table 3: Status of Lead-Free Solder at Selected Japanese OEMs

OEM	Products using Lead-Free Solder	Timing
Fujitsu	High End Servers	Oct. 1999
	All new products	Dec. 2002
Hitachi	Video cameras, Vacuum cleaners, Washing machines	Spring 1999
	All new products	Mar. 2002
Matsushita (Panasonic)	Optical disk drivers	Nov. 1996
	Mini Disks	Sept. 1998
	All new products	Mar. 2002
NEC	Pagers	Dec. 1998
	Notebook PCs	Oct. 1999
	All new products	Dec. 2002
Sony	Video cameras	Mar. 2000
	All new products	Mar. 2002

Source: Suga, University of Tokyo, 2000

Apple Computer

Apple Computer recognizes the importance of environmental attributes in electronic products, and considers their products' environmental performance to be a customer, market-driven issue. Environmental attributes (including the use of **hazardous materials**) are considered to be integral parts of the product's attributes during its design and development. For example, the design of the Power Mac G4 desktop computer released in the fall of 1999 incorporated a number of environmental innovations.

In the Power Mac G4, the use of an inner sheet metal chassis design ensured that product safety fire enclosure requirements were met, and therefore the polycarbonate resin panels did not need to contain any flame retardant chemicals (such as **halogenated flame retardants**).[20]

Apple publishes environmental profiles for several of its products using Apple's Product Environmental Specifications (APES). APES is a "work-in-progress" compilation of environmental attributes from various regional, country, and industry association product environmental criteria. It includes legislative and voluntary criteria from ECMA (European Computer Manufacturers Association), SITO (Swedish IT and Telecom Organization), Blue Angel (the German eco label), ENERGY STAR (U.S. energy efficiency eco label), and TCO (Swedish Confederation of Professional Employees). Section 3 of APES addresses hazardous materials used in products and includes declarations concerning mercury, lead, cadmium, brominated flame retardants and other materials that have been banned or restricted by legislation or eco labels.

Apple has compiled the APES list of environmental attributes to guide product development and for use as environmental metrics. In addition to its use by product development teams, Apple uses APES to provide environmental specifications for their customers who have specific questions, needs, or concerns.

[20] Sweatman et al., 2000.

Compaq

Compaq focuses on environmental stewardship during every phase of the product life cycle. When Compaq engineers begin the design of a computer, they consider the environmental impact of component parts and their readiness to be recycled when the computer is no longer useful. Formalized in 1994, DfE Guidelines have been developed for use across Compaq product lines on a worldwide scale. They emphasize several key principles:

- Energy Conservation,
- Disassembly,
- Reuse and Recyclability,
- Low Impact Packaging, and
- Upgradeability.

Compaq integrates numerous features into the design and manufacture of its products in an effort to reduce environmental impact over the life cycle. In Europe, two eco-labels recognize the company's production of environmentally sound products. In Germany, Compaq has received the Blue Angel eco-label and in Sweden the TCO '95 designation. These programs identify products that are environmentally friendly, recyclable and easily serviced. Compaq's commercial desktop product families are certified with the German Blue Angel eco-label.

In the area of SCM, Compaq has developed a supplier development process to manage their supply chain. The suppliers are given a questionnaire to fill in information about their policy and commitment, compliance history, processes and assessment, their suppliers, CFCs and other **hazardous materials**, and their waste minimization initiatives. In terms of material specification, the suppliers' policies must meet or exceed regulations. Compaq's environment health and safety criteria are used to track compliance on parts and purchasing contracts.

Compaq monitors banned or restricted chemicals, materials, and substances globally and maintains a restricted material specification enabling them to meet at a minimum the strictest regulation in the countries where they do business. They have eliminated the use of **brominated and chlorinated flame-retardants** from the housing plastics in their products. Compaq uses purchasing and product specifications to control the types of materials used to manufacture their products.

Ericsson

In their 2000 Environmental report, Ericsson states eight environmental goals; three concern toxic or hazardous materials in products:

- Use **lead-free solder** in 80 percent of new products from 2002,
- Eliminate **halogenated flame-retardants** in printed circuit boards in 80 percent of new products from 2002, and
- Eliminate the use of **beryllium oxide** in new products from 2002.

Concerns about toxicity and health hazards have led Ericsson to commit to using **lead-free solder** in 80 percent of their new products by 2002. In March 2000, a lead-free solder project was started to develop and release a production process for lead-free solder on printed circuit board assemblies, and to ensure the reliability of lead-free interconnections. The alternative currently being tested is an alloy of tin, silver and copper. This has a higher melting temperature than the current tin/lead solder alloy, and requires modifications to components and the production process. Ericsson has been running lead-free tests since 1998 and high-volume verification tests are scheduled for June 2001. In partnership with universities and other institutions, Ericsson is investigating the metallurgic effects of different types of solder and surface finishes on components and printed boards.

The high-temperature soldering process required for Ericsson's lead-free solder places new requirements on components, and hence on their suppliers. Ericsson has conducted seminars with suppliers and their own purchasing organization to highlight the new requirements. They have also surveyed 100 of their suppliers regarding their ability to deliver these components (see box "Ericsson's Green Component Letter to Suppliers"), and several have been selected for future cooperation on this issue. The ability of suppliers to supply components that can withstand the higher temperature profile of the lead-free soldering system will help determine if Ericsson can meet its lead-free goal.

Ericsson believes that **brominated flame-retardants** constitute an ecological threat serious enough to initiate a project to replace them with nitrogen-phosphorous compounds or inorganic compounds. Ten suppliers of halogen-free materials for printed circuit boards have been evaluated. Working closely with suppliers, Ericsson is carrying out beta testing on halogen-free printed circuit board materials. For many of the halogen-free alternatives, the production yield has actually been increased compared with using traditional materials. Ericsson claims to be on target to meet their stated goal of eliminating halogenated flame-retardants in printed circuit boards in 80 percent of new products from 2002. According to Ericsson, fulfilling this goal is dependent on the availability and price of halogen-free materials.

Ericsson states **"beryllium oxide** is known to constitute a health hazard similar to that of asbestos". Although most Ericsson products have never used beryllium oxide, a few products have components containing beryllium oxide. These will be replaced in all new products with alternative techniques or components. For example, the RBS 2401 GSM radio base station (part of the telecom network infrastructure for mobile telephones) is beryllium oxide-free. Prototypes of other beryllium oxide-free products are being manufactured and will soon be undergoing tests, in preparation for Ericsson's goal of eliminating beryllium oxide in new products from 2001 onwards.

In addition to the above initiatives, Ericsson has developed lists of banned and restricted substances (see Appendix 2) to meet laws and legislation or anticipated laws and legislation in the countries they operate in. These lists specify the chemical substances that are generally banned from Ericsson's products and operations. Ericsson's product managers, product design functions, purchasing functions and suppliers are responsible for compliance with these lists.

The banned and restricted substances apply to all Ericsson products, and to products that Ericsson purchases from its suppliers; hence they apply to everything ranging from electronics to office furniture. Additional lists cover the production processes used to make Ericsson's products. According to Ericsson, "banned substances shall under no circumstances be present, not even in low concentrations, [whereas] restricted substances shall be phased out as soon as possible and replaced with technically and economically acceptable alternatives."

The focus of Ericsson's ban and the restriction are on the deliberate use of the listed substances. The ban or restriction does not apply in cases where a substance is present, in very small concentrations, from natural contamination.

Ericsson's "Green Component" Letter to Suppliers

May 04, 2000

Dear Ericsson Supplier,

The development and commercialization of environmentally responsible products continues to be a key emphasis for the telecommunication industry, driving the need for environmentally friendly materials such as bromine free laminates and non-lead solders in printed circuit boards. This industry demand has been driven by several factors. Proposed legislation in the EU as well as public sentiment and concerns over the risks associated with these types of materials continues to fuel the need for solutions, and has generated a market need to provide consumers with "green" alternatives. Because of increasing market demands and the impending environmental legislation, there are new Ericsson directives, stating:

- Use lead-free solder in 80 % of our new products by the end of 2001
- Eliminate by the end of 2001 the use of the following substances:
    - Halogenated flame retardants, in 80 % or our new printed boards
    - Beryllium oxide, in 100 % of our new products

The chosen lead-free soldering processes under consideration by Ericsson will significantly increase the temperature requirements of components. This letter in turn is an attempt to initially determine where you as a key supplier to Ericsson are in relation to this directive. In order to help determine this, there are three areas we would like for you to review and report on concerning the make up of the components you supply to Ericsson.

- Can your components be used with the required solder paste/process year 2001?
- What is the "temperature profile" of your components (Initial)?
- What is the repair process "temperature profile" of your components (Rework)?
- Do the components you supply to Ericsson contain lead, halogens or beryllium oxide? If so, are there any plans to eliminate these materials?

Please find attached a technical requirement specification, which explains in more detail the type of information we require. We appreciate your cooperation and would be grateful for a reply before June 9th. If you have any questions, please contact Gunnar Löfquist, project manager, +46 8 7193489, gunnar.lofquist@edt.ericsson.se.

Best regards,
Telefonaktiebolaget LM Ericsson
Corporate Sourcing

Bo Westerberg
Vice President

Fujitsu

Adoption of Internal Hazardous Materials Standard
Fujitsu has a voluntary internal standard banning or restricting the use of a variety of **hazardous materials** in its products. Examples of banned and restricted materials are shown below.

Banned materials:	PCB, asbestos, Polychlorinated Naphthalene, CFCs, specified halons, carbon tetrachloride, etc. (30 substances in total)
Restricted materials:	Cadmium, hexavalent chromium, arsenic, mercury, selenium, lead, HCFCs, HFCs, halogenated compounds, etc. (155 substances in total)

Since 1996, Fujitsu has applied an internal design standard to assess the environmental attributes of all new products. This "product environmental assessment" covers 40 criteria, including the use of banned or restricted materials. To comply with Fujitsu's internal "green products" standard, the product or packaging materials must not contain internally restricted hazardous materials. Between 1996 and 1999, 1294 products were assessed, and 141 passed the standard. In 1999, 96 models passed the standard, including:

• Desktop PCs	33 models
• Notebook computers	22 models
• Cathode-ray tube/liquid crystal displays	12 models
• Page printers	5 models
• Point-of-sale terminals	4 models
• Network equipment	2 models
• ATMs	4 models
• IA servers	4 models
• Scanners	3 models
• Mobile telephones	2 models
• Small magnetic disks	2 models
• Opto-magnetic disks	2 models
• Workstations	1 models
Total	*96 models*

Fujitsu has a policy (see below) and targets to reduce and eventually eliminate the use of lead:

- Starting October 2000, the entire LSI [semiconductor] products will be made lead-free.
- Starting December 2001, lead-free solder will be adopted for ½ of the entire printed circuit board production.
- Starting December 2002, the complete elimination of lead will be targeted.

Fujitsu's Policy to Reduce the Use of Lead

Mar 21,2000
FUJITSU LIMITED
Environmental Engineering Center

With a view to eliminating completely the use of lead, a polluting substance of environment, from our products, we have decided our policy to reduce the use of lead step by step. Now, we are going to promote our activities for the reduction of lead in line with this policy.

Background
Lead is a toxic substance that may cause serious anemia or mental disorder and is therefore regarded as polluting substance of our environment. The soldering material used for electronic equipment is in most cases an alloy of tin and lead. When this alloy comes into contact with water, the lead dissolves away and if this water is acidic (pH is 3 or less), the amount of such dissolution increases extremely. If the acid rain, which is of great problem in recent years, gets into contact with disposed electronic equipment, the contamination might be aggravated further.

At the present moment, the use of lead is not regulated actually because too urgent restriction of the use of tin-lead soldering material could cause a great impact to the entire economic activities. However, the reduction of lead in the electronic equipment is certainly an issue we cannot avoid from the viewpoint of protecting global environment. We have so far developed, jointly with Fujitsu Laboratories Ltd., 2 kinds of lead-free soldering material for assembly of printed circuit board and for assembly of parts. This material was adopted as the soldering material for the assembly of Global Server [GS8900] (released on October 18, 1999). As shown in this example, we are making effort for the reduction of the use of lead in manufacturing.

Our policy for the reduction of lead
We are planning to reduce step by step the use of lead in the products produced by us as shown below. The use of lead has to be eliminated also in the process of manufacturing parts and components by outside companies other than Fujitsu. Accordingly, we are planning to specify in future the use of lead-free soldering material as our standard to request our parts suppliers their understanding and cooperation.

(1) Starting October 2000, the entire LSI products will be made lead-free.
For entire LSI products produced by electronic devices sector, the use of the solder material containing lead will be reduced completely by plating lead-free solder.
(2) Starting December 2001, lead-free solder will be adopted for one half of the entire printed circuit boards production.
In the manufacture of printed circuit board used for set products such as computers [including personal computers], hard-disks, displays, routers, mobile phones, we are planning to use lead-free solder for one half of the total production.
(3) Starting December 2002, complete elimination of lead will be targeted
We aim at eliminating the use of lead completely from our products.

Contact
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Hewlett-Packard (HP)

HP's environmental policy is shown below. The product stewardship section of the policy states that HP will "Design our products and services … to minimize use of hazardous materials…"

Hewlett-Packard Environmental Policy

Product Stewardship
- Design our products and services to be safe to use, to minimize use of **hazardous materials**, energy and other resources, and to enable recycling or reuse.

Pollution Prevention
- Conduct our operations in a manner that prevents pollution, conserves resources, and proactively addresses past environmental contamination.

Continual Improvement
- Integrate environmental management into our business and decision-making processes, regularly measure our performance, and practice continual improvement.

Legal Compliance
- Ensure our products and operations comply with applicable environmental regulations and requirements.

Stakeholder Involvement
- Provide clear and candid environmental information about our products, services and operations to customers, shareholders, employees, government agencies and the public.
- Inform suppliers of our environmental requirements and encourage them to adopt sound environmental management practices.
- Foster environmental responsibility among our employees.
- Contribute constructively to environmental public policy.

7 March 2000
(signed)
Carly Fiorina
President and Chief Executive Officer
Hewlett-Packard Company

HP's product stewardship organization has the responsibility to recommend design changes to reduce the environmental impact of their products. Its responsibility extends to providing information about the environmental aspects of products and documentation for eco-labels. In addition, the organization is charged with staying current with the latest technological developments and end-of-life solutions – such as product take-back programs – affecting the environmental attributes of HP's products and services.

HP's DfE guidelines recommend that its product designers consider the following:

- Place environmental stewards on every design team to identify design changes that may reduce environmental impact throughout the product's life cycle.

- Eliminate the use of polybrominated biphenyl (PBB) and polybrominated diphenyl ether (PBDE) **flame-retardants** where applicable.
- Reduce the number and types of materials used, and standardize the types of plastic resins used.
- Use moulded-in colours and finishes instead of paint, coatings or plating whenever possible.
- Help customers use resources responsibly by minimizing the energy consumption of HP's printing, imaging and computing products.
- Increase the use of pre-and post-consumer recycled materials in product packaging.
- Minimize customer waste burdens by using fewer product or packaging materials overall.
- Design for disassembly and recyclability by implementing solutions such as the ISO 11469 plastics labelling standard, minimizing the number of fasteners and the number of tools necessary for disassembly.

Although these DfE guidelines are not mandatory, it is apparent that they do have some influence on HP designers. Environmental profiles of several HP products (see below) indicate that **halogenated flame-retardants** have been eliminated from housing plastics for several models.

Environmental profiles for seven HP desktops and workstations, seven printers, three scanners and eight classes of UNIX servers are available on the HP web site.[21] In addition to other product related environmental information, these profiles address toxic or hazardous materials. For example, the environmental profile for the Brio desktop PC includes the following information about "voluntary restricted materials":

- **Halogenated flame-retardants** are not used in the housing plastics.
- Halogenated polymers (e.g. **PVC**) are not used in the housing plastics.
- Antimony trioxide is not used in the product

The UNIX server environmental profile includes a statement that the following "may require special handling at end-of-life":

- **Lead** in solder and/or cathode ray tube
- Lithium ion battery(s) are on the system board

IBM

IBM's Environmentally Conscious Products (ECP) program was established in 1992. The program has established five environmental design objectives for IBM products:

1. Develop products with consideration for their upgradeability to extend product life.
2. Develop products with consideration for their reuse and recyclability at the end of product life.
3. Develop products that can safely be disposed of at the end of product life.
4. Develop and manufacture products that use recycled materials where they are technically and economically justifiable.

[21] http://www.hp.com/hpinfo/community/environment/pr_prodsafe.htm

5. Develop products that will provide improvements in energy efficiency and/or reduced consumption of energy.

All of IBM 's product development groups have implemented IBM 's Environmental Management System (EMS) with a focus on these objectives. Additionally, product development groups may establish more specific objectives and targets applicable to their product set. The second and third objectives address **hazardous materials** present in IBM products.

ECP requirements have been incorporated into IBM's Integrated Product Development (IPD) process. The IPD process is a tool used by product and process development engineers, among others, to ensure a consistent, efficient end-to-end process for designing IBM's products.

IBM's ECP program is supported by a dedicated group at IBM's Research Triangle Park, North Carolina, facility. The Engineering Center for Environmentally Conscious Products (ECECP) is IBM’s centre of competence for DFE activities and serves as a resource for division environmental specialists, product development and procurement engineers, suppliers, and product recycling centres.

The Center manages the PEP (Product Environmental Profiles) process. An important element of IBM 's EMS, the PEP process is used to monitor and document the environmental characteristics of products. It also provides a tool for measuring ECP progress as part of the EMS and is a means for evaluating IBM products for compliance with worldwide environmental standards and legal requirements.

In 1999, the PEP database was enhanced to include DfE assessments. DfE assessments are performed by all product development groups and provide a simple and convenient methodology for evaluating a product’s design versus preferred environmental design characteristics.

In 1999, IBM’s target was to complete DfE assessments on a minimum of 80 percent of box-type products released during the year. Several product areas completed assessments on 100 percent of their new products, including servers, printing systems, retail store solutions and storage products. Personal Systems Group (responsible for desktop PCs and laptops) completed DfE assessments on 75 percent of product types released in 1999.

ECECP activities also included a major focus on IBM 's materials and component suppliers. In 1999, the Center worked with IBM 's major plastics suppliers to promote IBM 's objectives and targets for use of recycled plastics and development of more environmentally preferable **flame-retardants**. Because of this focus, the ECECP was able to qualify four new plastics resins containing recycled materials, and has initiated evaluations of new plastics with **non-halogenated flame-retardants**.

The ECECP also conducted initial environmental evaluations of sheet metal surface treatments in 1999. Sheet metal used in IBM products is typically treated through a number of processes to prevent corrosion and rust. Some of these processes include the use of **hexavalent chromium**. Based on these evaluations, IBM has initiated a more extensive analysis of sheet metal alternatives through its Global Mechanical Commodity Council. This evaluation will examine other important factors such as performance, worldwide availability, and cost, in addition to environmental factors, to determine the best sheet metal purchasing strategy for IBM.

IBM's AS/400e series 600, S10, 620 and S20 of servers received a 1997 Edison Award for Environmental Achievement, sponsored by the American Marketing Association. The seventh annual Edison Award recognized IBM's comprehensive approach to environmental attributes throughout the product line, from energy efficiency and design for product end-of-life, to the reduction in use of hazardous materials.

Matsushita/Panasonic

The Matsushita Electric Group operates under the Panasonic brand in North America.

Matsushita's policy is to "reduce use of chemical substances that may be harmful to the human body and ecosystem." Their targets include using **lead-free solder** for all products by the end of 2002, and reducing the use of halogen compounds such as **brominated flame retardants** and polyvinyl chloride (**PVC**) resin in plastics.

According to Matsushita, "We are accelerating our efforts to eliminate recognized toxic substances and develop more environmentally benign materials, such as **lead-free solder**, non-halogenated lead wires, and non-halogenated plastics. To control lead solder's possible impact on the environment at the time of its disposal, we successfully developed the first ever lead-free solder for flow soldering applications. The new development has been put to use in the television manufacture process since last December [1999]."[22]

Matsushita/Panasonic uses **lead-free solder** in a portable mini-disk player. The solder contains tin, silver and bismuth and the company claims that the solder has the same temperature and agglutinating[23] qualities as lead solder. They also produce **halogen-free**[24] circuit boards and **PVC**-free wiring.

Motorola

Motorola has defined the long-term objectives shown below that reflect their ultimate ideals and vision of a sustainable world. Time is not specified in these objectives, as they may currently have financial and technological limitations.

Motorola's Long Term Environmental Objectives

- Zero waste - Reuse or recycle all our waste materials.
- Benign emissions - Eliminate all emissions from our plants that adversely impact the environment.
- Closed loop - Conserve natural resources by fully integrating our products and processes in the recycling loop.

[22] Nitta, T. and Thompson, D., 1999.
[23] Refers to the ability to form a mechanical bond, i.e. the adhesive properties of the solder.
[24] Does not contain brominated flame-retardants or other halogens.

- Green energy - Use energy in highly efficient ways at our sites and use renewable energy where practical.
- All products designed for the environment and safety - Design our products to reduce environmental impact and improve safety in our world.

Motorola has also defined short-term goals that are considered "stepping-stones toward achieving our long-term objectives." Their short-term goals are divided into three categories: Business, Process and Product. One of the short-term product goals shown below address **hazardous materials** present in products.

Motorola's Short Term Environmental Product Design and Content Goals

- Design our products to be highly recyclable.
- Reduce the use of **hazardous materials**.
- Reduce energy use in our products.
- Increase the use of recycled materials in our products.
- Minimize the ratio of packaging material to product volume.
- Label all plastic parts weighing more than four grams to aid future recycling.

To help engineers achieve these Design for Environment goals, Motorola partnered with the University of Erlangen in Germany to develop a software tool called the Green Design Advisor (GDA). The GDA enables Motorola's product designers to compare different materials and processes that could be used to create a product. This gives design engineers the ability to choose and compare different materials and processes based on their potential environmental impact. For example, the figure below, generated by the GDA, compares the environmental impact of two competing designs for a test product, illustrating that design B has a lower overall environmental impact.

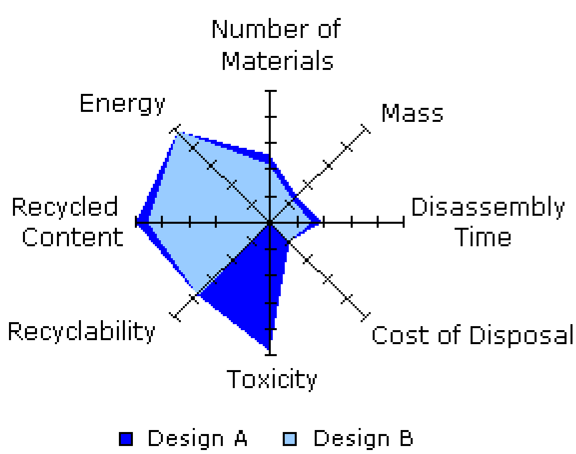

Figure 1: Motorola Green Design Advisor Allows Comparison of Competing Designs

Source: Motorola

Another tool Motorola has developed to assist their design engineers is the product environmental template (PET). The PET contains product goals for packaging reduction, recyclability, energy reduction and material content. The PET also requires a documented end-of-life strategy for new products.

Motorola encourages their suppliers to provide them with environmentally preferred products. Suppliers are encouraged to create products that are energy efficient, highly recyclable and contain significant amounts of recycled materials and low amounts of **hazardous materials**.

To evaluate supplier components and products for environmental performance, Motorola created an "Eco Design Criteria Substances List" (see Appendix 3). This list defines what substances need to be reported if they are in suppliers' components and products. Motorola plans to revise this list as necessary to address regulatory developments and to better define life cycle impacts or stakeholder needs.

According to Motorola, the Concorde cellular phone, scheduled to be released in the first quarter of 2001, contains "significantly" less **lead solder** and **brominated flame-retardants** than its predecessor.

In 1999, the Illinois Engineering Council recognized Motorola's Advanced Technology Center in Schaumburg, IL by awarding it their "Project of the Year" award. The award cited Motorola's "environmentally sensitive product design program, which demonstrated interdisciplinary engineering, social benefit and creativity."

Philips

Recognizing that good environmental policy makes for good economic policy, Philips has integrated its environmental policy into its products and processes.

Within Philips' environmental policy, product development objectives include:
- Evaluating the environmental impact over the total life cycle of a product,
- Taking steps toward more efficient use of materials, including packaging,
- Reducing or eliminating **hazardous substances**,
- Reducing energy consumption, and
- Contributing to improving recycling and disposal.

Philips' environmental objectives are detailed in its Global Environmental Policy. Additional targets are defined in their EcoVision program, focusing on green product development and manufacturing.

Philips EcoVision Program (1998-2002)
Marketing Drive
- Green as part of Philips' brand positioning
- Product development (EcoDesign) and marketing and sales shall be focused on one or more of the following Green Focal Areas:
  - Weight
  - **Hazardous substances**
  - Recycling and disposal

    - Energy consumption
    - Packaging
- Every Line of Business will come up with a "Green Flagship" in 1998 (benchmarked and improved on the five Green Focal Areas)
- Every division will be asked in 1998 to define increasing percentages of its product portfolio that will be EcoDesigned in the period 1999 through 2001
- 15% packaging reduction (weight, bench marked to predecessor)

Under the EcoVision program, Green Flagship products must be developed. These are defined as products with a better environmental performance than their predecessors or competitors in one or more of five Green Focal Areas (weight, **hazardous substances**, recycling and disposal, energy consumption, and packaging) and which do not under-perform in the others. In 2000, 64 Philips products were selected as Green Flagships, and 44 of these were marketed as such.

According to Philips' President Cor Boonstra, "we know from our market research that there is a demand for products that are ecologically sound. Our Green Flagship products respond to people's concerns about the environmental impact of the products they use. This enhances the emotional bond we have with our consumers, enhancing the Philips brand. This, in turn, enhances shareholder value."

To support the EcoVision program and Green Flagship products, Philips has a list of banned substances (including asbestos, cadmium, mercury, CFC/HCFC, PCP, PCB, PCT, PBB/PBBE) and all products are evaluated against this list before introduction.[25]

Sony

Strategy for Harmful Chemical Substances in Purchased Components and Materials
Sony has designated 56 chemicals as "Sony Specified Environmental Substances Used in Components and Materials." In 1999, Sony started the process of supervising the amounts of these chemicals contained in the parts and materials used to make each Sony product.

When selecting the 56 chemicals, Sony consulted relevant laws and the voluntary initiatives of industrial associations. Substances that had the potential to be used in electronics and electrical equipment were identified. From these, Sony determined that 56 substances required management. Working with its suppliers, Sony has assembled a database on the quantity of these substances found in the components and materials that it purchases. Sony is currently developing a system to calculate the total amount of specified substances in its products by using this database and information about the composition of each product.

Sony kicked off its procurement management activities in fiscal 1997 with the goal of starting full-scale management in fiscal 2000. The company's efforts are progressing in three stages.
- Fiscal 1998: Establishment of a framework for the entire management system.
- Fiscal 1999: Data survey – Sony surveyed suppliers to gather information on the quantity of specified substances contained in components that it purchases.

[25] EIA, 1999.

- Fiscal 2000 onwards: Evaluation of the environmental impact of products and implementation of actions to reduce their environmental impact. Sony's goal is to systematically reduce the environmental impact of specified substances based on measurements of their content in each Sony product.

Sony has made progress in eliminating high environmental impact materials from its products. The company recently developed an external housing and FR-1 printed circuit board made of **halogen-free flame-retardant** plastics. According to Sony "these plastics take advantage of technology to prevent the formation of toxic dioxin and furan compounds." In Europe, the housing and circuit board were first introduced in a colour TV set in 1995, followed by a computer display in 1996. In 1998, they were introduced into home VCRs and audio equipment in Europe.

In 1998, Sony developed **halogen-free** CEM-3 circuit boards and FR-4 multi-layer circuit boards for high-performance products like DVD players. Sony started selling these products in April 1999. Sony's halogen-free external housing and printed circuit boards meet the EU's WEEE regulation banning halogenated flame-retardants, a regulation that is scheduled to take effect in 2004. These items also comply with German Blue Angel and Swedish TCO 95 eco label standards. Sony plans to progressively introduce products incorporating halogen-free external housings, circuit boards and similar components to other markets around the world.

Sony has developed a **lead-free** solder made from tin, silver, bismuth, copper and germanium (Sn-2.0Ag-4.0Bi-0.5Cu-0.1Ge).[26] Sony claims that the small amount of germanium in the alloy drastically improves the solderability and the reliability of the Sn-Ag-Bi system. This new solder can be used with conventional soldering equipment, eliminating the need for extensive new capital expenditures.[27]

Sony has pledged to phase-out use of PVC.[28]

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[26] The numbers before each element represent their percentage weight in the alloy. The balance (not shown) is tin (Sn).
[27] Habu, K. et al., 1999.
[28] Tomorrow, 2001.

5. Conclusions and Recommendations

Table 4 summarizes the availability and quality of data for various toxic or hazardous materials found in IT and Telecom equipment. The summary is based on a 3-point scale. Data availability and data quality are rated as Good, Fair or Poor.

Table 4: Summary of Data Quality and Availability

Material	Toxic or Hazardous Substances in Electronics	Releases of Toxic or Hazardous Substances
Mercury	Data availability - Fair Data quality - Fair	Data availability – Good Data quality – Good
Lead and its compounds	Data availability - Good Data quality - Fair	Data availability – Good Data quality – Good
Cadmium and its compounds	Data availability - Fair Data quality - Fair	Data availability – Good Data quality – Good
Brominated Flame-Retardants	Data availability - Good for PBDE & PBB groups, Good also for TBBP-A: Poor for other halogenated flame-retardants Data quality - Fair	Data availability – Good for PBDE & PBB groups, Good also for TBBP-A: Poor for other halogenated flame-retardants Data quality – Fair
Beryllium and its compounds	Data availability - Fair Data quality- Poor	Data availability – Fair Data quality – Good
Hexavalent Chromium (Cr VI)	Data availability - Poor Data quality - Poor	Data availability – Poor Data quality – Good
PVC	Data availability- Fair Data quality- Poor	Data availability – Fair Data quality – Good
PCBs	Data availability - Poor Data quality - Poor	Data availability – Fair Data quality – Good
Antimony	Data availability - Poor Data quality - Poor	Data availability – Poor Data quality – Poor

There is a notable lack of published information available on potentially toxic or hazardous substances in telephones, mobile phones, fax machines and peripherals such as printers and scanners. This is especially apparent compared to the detailed information available for laptops, personal computers and monitors.

The key results of this study can be summarized as follows:

1. Toxic and hazardous materials are present in IT and telecom products. The use of some toxic or hazardous materials is declining, but this is being offset by growth in these sectors and the introduction of new uses for toxic or hazardous materials (e.g. beryllium).
2. There is a risk that toxic or hazardous materials present in IT and telecom products will be released to the environment during recycling, landfilling or incineration.
3. The substances examined in this study are reported as not being released from IT and telecom equipment during manual disassembly.
4. The main occupational health concerns for recycling workers appear to be associated with mechanical or thermal recycling processes such as shredding, grinding, burning and melting (to reclaim plastics), solder melting, and metals processing.

5. Many major OEMs are making progress in reducing and eliminating toxic or hazardous materials from their products. The key drivers are actual or anticipated regulations by governments and customers (especially in Europe and Japan), and their own environmental policies.
6. The focus of OEM initiatives appears to be on eliminating lead solder and brominated flame-retardants from their products. This is driven, at least in part, by the EU WEEE Directive.
7. Supply Chain Management (SCM) is critical for OEMs to control and manage toxic or hazardous materials in their products. This has become even more important in recent years as the trend towards outsourcing electronics manufacturing continues.
8. Japanese OEMs are leading in eliminating lead-containing solder from their products.

Based on this study, several recommendations can be made.

Recommendation #1: Initiate a more extensive review process for this study.
One way to improve the quality and potential impact of this study would be to implement a more extensive review process involving experts from industry, academia, and governments to take advantage of their knowledge and networks. This would be useful to identify gaps in the information and to improve the study.

Recommendation #2: Collect primary information from OEMs
Due to time and resource constraints, the review of OEM initiatives to reduce or eliminate toxic or hazardous materials was based mainly on published company sources (e.g. web sites, environmental reports, conference documents). A richer, more current and more complete understanding of OEM initiatives in this area (including drivers, barriers, opportunities and future plans) would require interviews with OEM staff, using close ended and open ended questions to verify the information collected and to collect new information.

Recommendation #3: Collaborate with others for further work
During the research for this study, there was a high degree of interest expressed by other parties (e.g. U.S. EPA, industry associations, OEMs) about obtaining a copy of this study when it is complete. It appears that many parties are interested in this topic and are looking for similar information. If further work is contemplated, there are many opportunities for collaboration.

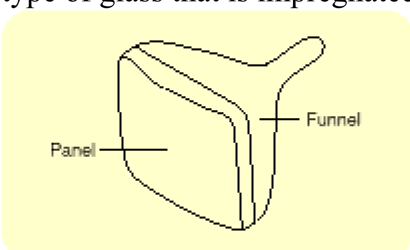
Recommendation #4: Start implementing solutions now
It is clear from reviewing the literature that significant resources have already been devoted to understanding what toxic or hazardous materials are present in IT and telecom equipment and what happens to those materials when the equipment is recycled, landfilled or incinerated. Although there may be some gaps in the data, there is more than enough data and information available now to justify proceeding with solutions. It is clear from the actions of leading OEMs that, at least in some cases, technically and economically viable solutions do exist.

Glossary of Electronics Terms

Acknowledgement
There are several good glossaries of electronics terms available on the Internet. Most of the following definitions are taken from:
Electronics Circuit Repair and Technology Center at http://www.ensil.com/glossary.htm and
CNET glossary at http://www.cnet.com/Resources/Info/Glossary/

Card
A printed circuit board of smaller dimensions is commonly referred to as a card. A card is generally one level lower than the printed circuit board in the hierarchy of electronic packaging. A card is also referred to as a "daughter board".

Cathode Ray Tube (CRT)
The active component of monitors and TVs, the cathode ray tube is a big bell of glass with electron guns at one end and a viewing screen at the other. The panel of the CRT is the front surface where the image is generated. The funnel-shaped rear section is enclosed with a special type of glass that is impregnated with lead.



Source: Sony

CEM-3
A printed circuit board substrate material composed of nonwoven glass fibres and a woven fabric that is copper plated on both sides. CEM-3 is lower cost than FR-4, another popular substrate with higher performance ratings.

Chip-on-Board (COB)
A configuration in which an integrated circuit or "chip," is directly attached to a printed circuit board or substrate by solder or conductive adhesives.

Electronic Packaging
The technology of interconnecting semiconductor and other electronic devices to provide an electronic function.

Encapsulant
The material used to cover COB devices to provide mechanical protection and to ensure reliability, typically an epoxy.

Encapsulation
The sealing or covering of an element or circuit for the purpose of mechanical and environmental protection.

Eutectic
The minimum melting point of a combination of two or more materials. The eutectic temperature of an alloy is always lower than the melting point of any of its individual constituents. The eutectic temperature is the particular temperature at which the eutectic occurs. Eutectic alloys, when heated, transform directly from a solid to a liquid and do not show any pasty regions. For example, eutectic solder paste has a composition of 63% tin (Sn) and 37% lead (Pb), and has a eutectic temperature of 183ºC.

FR-1
An entry-level flame retardant ("FR") printed circuit board substrate material based on a paper substrate with a phenolic resin binder.

FR-4
A high performance flame retardant ("FR") printed circuit board substrate material composed of woven glass fibre fabric with epoxy binder that is copper plated on both sides.

Integrated Circuit
A microcircuit that consists of interconnected elements inseparably associated and formed in-situ on or within a single substrate, usually silicon, to perform an electronic circuit function.

Liquid Crystal Display (LCD)
Created by sandwiching an electrically reactive substance between two electrodes, LCDs can be darkened or lightened by applying and removing current. Large numbers of LCDs grouped closely together can act as pixels in a flat-panel display.

Mother Board
The main printed circuit board of computers and other electronic devices is commonly referred to as a "mother board". Smaller cards or "daughter boards" are often attached to mother boards.

Plated Through Hole (PTH)
A plated hole in a PCB is used as an interconnection between the top and bottom sides or the inner layers of a PCB. PTH is intended to mount component leads in through hole technology.

Printed Circuit Board (PCB) or Printed Wiring Board (PWB)
The term generally used for printed circuit configurations such as rigid or flexible, single, double, or multilayered boards that are completely processed. A PCB or PWB is a substrate of a glass fabric impregnated with a resin (usually epoxy) and cured and clad metal (almost always copper) upon which a pattern of conductive traces is formed to interconnect components.

Printed Wiring Assembly
Also called printed circuit assembly, this term is used for a printed wiring board in which all the individual components have been completely attached. Also know as a "populated board".

Reflow Soldering
The process of joining two metallic surfaces (without the melting of base metals) attained through the heating of predeposited solder paste to subsequently form solder fillets at the metallized areas.

Solder Paste
A homogenous and kinetically stable mixture of minute spherical solder particles, flux, and a vehicle system.

Solder
A low melting point alloy, usually of lead (Pb) and tin (Sn), that can wet copper, conduct current, and mechanically join conductors.

Solderability
The ability of a conductor to be wetted by solder and to form a strong bond with the solder.

Soldering
A process of joining metallic surfaces with solder, without melting the base material.

Surface Mount Technology (SMT)
A method of assembling printed circuit boards where the components are mounted onto the surface of the board rather than being inserted into holes in the board.

Through Hole
A hole connecting the two surfaces of a printed circuit structure.

Wave Soldering
A process in which many potential solder joints are brought in contact with a wave of molten solder for a short period of time and are soldered simultaneously.

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Ericsson: http://www.ericsson.com/about/environment.shtml
Fujitsu: http://www.fujitsu.co.jp/hypertext/About_fujitsu/environment/index-e.html
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IBM: http://www.ibm.com/ibm/environment/
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Motorola: http://www.motorola.com/EHS/environment/
Philips: http://www.philips.com/environment/
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Appendix 1: Environmental Profiles of Selected Toxic or Hazardous Materials

Environmental Profile of Selected Toxic or Hazardous Materials	
Toxic or Hazardous Substance	**Information on potential toxicity & environmental effect**
Mercury	Elemental mercury is classified as dangerous (i.e. hazardous) substance, toxic by inhalation with danger of cumulative effects. Organic mercury has increased toxic properties. In the body, mercury affects the central nervous system and kidneys in humans. Mercury is classified as very toxic to aquatic organisms and is suspected to cause long-term effects in the aquatic environment. Mercury will bioaccumulate and biomagnify in the environment. It is easily transported long distances in the atmosphere.
Lead	Lead compounds are all classified as dangerous (i.e. hazardous) substances.[29] Lead affects the central nervous system and kidney of humans, and toxicity varies depending on exposure and amount of lead in the blood. Lead is toxic to organisms in the environment when it is soluble (i.e. bioavailable). Lead will not biomagnify in food chains.

[29] C4E Guidance Document, 2000.

Environmental Profile of Selected Toxic or Hazardous Materials	
Toxic or Hazardous Substance	**Information on potential toxicity & environmental effect**
Cadmium	Cadmium is classified as highly toxic.[30] The USEPA classifies cadmium as a probable human carcinogen of medium carcinogenic hazard.[31] Cadmium affects the renal and respiratory system in humans. Workers exposed to high levels of cadmium fume and dusts show the "most pronounced" effects of cadmium exposure.[32] Occupational studies indicate a risk of lung cancer from exposure to inhaled cadmium (USEPA, 2000). Small amounts of dissolved cadmium are toxic to aquatic and terrestrial organisms, when soluble cadmium species are available in the environment. Cadmium is persistent in the environment, has potential to bioaccumulate, and is toxic in the environment.
Beryllium	Beryllium metal, beryllium oxide and beryllium-copper alloys[33] are considered very toxic by inhalation.[34] USEPA classifies beryllium as a probable human carcinogen of medium carcinogenic hazard. Occupational inhalation exposure to high levels of beryllium may cause inflammation of the lungs and acute pneumonitis, in the short term. Long-term inhalation exposure may cause chronic beryllium disease (berylliosis) – the onset of which may be delayed up to 20 years. Chronic beryllium disease may cause death (USEPA, 2000). Beryllium compounds are classified as non-toxic to the environment.

[30] C4E Guidance Document, 2000.
[31] USEPA, 2000: "Polychlorinated Biphenyls (PCBs)" *Unified Air Toxics Website, Office of Air Quality, Planning and Standards*. September 21, 2000. Online. http://www.epa.gov/ttn/uatw/hlthef/polychlo.html
[32] C4E Guidance Document, 2000.
[33] It has been recognised by the EC and the OECD that alloys in general may be inappropriately hazard-classified under the present system, which uses arbitrary concentration limits more appropriate for simple mixtures. Discussion is underway, between the EC; the OECD and industry, to determine how alloys might be better classified by direct assessment of their own properties. Once this procedure is established, existing data will be presented to argue that copper beryllium alloys are in fact non-carcinogenic (2).
[34] C4E Guidance Document, 2000.

Environmental Profile of Selected Toxic or Hazardous Materials	
Toxic or Hazardous Substance	**Information on potential toxicity & environmental effect**
Hexavalent Chromium	Inhaled hexavalent chromium is a potential carcinogen and genotoxin.[35] Studies of workers have clearly established that inhaled hexavalent chromium is a human carcinogen (USEPA, 2000), with the respiratory tract as the major target organ. Exposure to hexavalent chromium can affect the gastrointestinal and neurological systems and may cause sensitization or burns upon contact with skin. Chromium and chlorine together exhibit increased toxicity – synergistic effects.[36] Hexavalent chromium is persistent and toxic to the environment.
Antimony	Antimony is considered to have high acute toxicity (USEPA, 2000). The USEPA has not classified antimony for carcinogenicity.
Brominated Flame Retardants *PBDEs (poly brominated diphenyl ethers).*	 PBDEs are suspected endocrine disruptors.[37,38] The behaviour of PBDEs resembles the well studied PCB's and DDT.[39] PBDEs are stable, persistent and will bio-accumulate.
PBBs (poly brominated biphenyls)	PBBs are stable, persistent and will bio-accumulate. Their behaviour resembles that of PCB's and DDT.
TBBP-A (tetrabromo bisphenol-a)	TBBP-A is highly toxic to aquatic organisms. It is less toxic than PBDEs and PBB when used reactively in plastics.[40] TBBP-A is persistent and suspected to bio-accumulate.

[35] C4E Guidance Document, 2000.
[36] Nordic Council of Ministers, 1995 p.50
[37] Suspected effects of endocrine disruption include: abnormalities to reproductive systems, reduce and damaged sperm, immune suppression and reduction in cognitive abilities (http://www.greenpeace.org/~toxics/, 2001)
[38] WEEE Directive, 2000.
[39] Simon, 1999.
[40] Simon, 1999.

Environmental Profile of Selected Toxic or Hazardous Materials	
Toxic or Hazardous Substance	**Information on potential toxicity & environmental effect**
PVC (polyvinyl chloride)	Much of the concern over PVC plastics surrounds the use of additives. Stabilizers and plasticizers are additives that need to be assessed for toxic or hazardous characteristics and risks to human health and the environment. In particular, stabilizers containing heavy metals such as lead and cadmium, and the phthalate group of plasticizers (EU, 2000 [b]).
PCBs (polychlorinated biphenyls)	PCBs are a group of chemicals containing 209 individual compounds (congeners) with varying harmful effects. The USEPA has classified all PCBs as probable human carcinogens of medium carcinogenic hazard. No information is available on the short-term effects of PCBs in humans. Long-term inhalation exposure to PCBs can affect the respiratory tract, gastrointestinal system, liver, skin and eyes. Occupational exposure to PCBs has been associated with low sperm counts and elevated blood concentrations of PCBs. PCBs are persistent in the environment and have potential to bioaccumulate. PCBs found in the environment will have varied composition because of biotransformation or bioaccumulation.[41]

[41] USEPA, 2000: "Polychlorinated Biphenyls (PCBs)" *Unified Air Toxics Website, Office of Air Quality, Planning and Standards*. September 21, 2000. Online. http://www.epa.gov/ttn/uatw/hlthef/polychlo.html

Appendix 2: Ericsson Lists of Banned and Restricted Substances

Appendix 3: Motorola Eco-Design Substances List