BACKGROUND DOCUMENT ON

RECYCLING

WASTE FROM COMPUTERS

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1 BACKGROUND

Consumer electronic products that have reached their "end-of-life" are heading for landfills in ever increasing volumes. End-of-life electronics, or EEEs, represent a wide array of products that range from small transistor radios to large televisions and computer systems. Rapid advancements in technology over the last twenty five years has provided a global society where information exchange now occurs at the touch of a button in one's own home. Where modern civilizations of the late fifties boasted that sixty percent of homes had a television, homes today have on average 2.6 televisions and over fifty percent of North American homes have at least one personal computer.

While this revolution of high tech communications has unquestionably served to enhance everyday life, it has also created some environmental challenges that, if not solved now, will escalate into a situation that will cause irreversible damage to the environment and ultimately human health.

1.1 The Problems:

a) Toxic Components:

Many electronic products, in particular personal computers (PCs), have complicated assemblies comprised of more than 1,000 materials, many of which are highly toxic if released to the environment.

b) Increasing Amount of EEE Waste:

Product obsolescence is becoming more rapid since the speed of innovation and the dynamism of product manufacturing / marketing has resulted in a short life span (less than two years) for many computer products. Shorted product life span coupled with computer sales that are increasing at an average 15% per year will result in a doubling in the volume of obsolete computers over the next five to six years. To compound the problem, the switch from analogue to digital transmission will require everyone who owns a television to switch to high definition television (HDTV) receivers. The problem with televisions is the same as computer monitors – cathode ray tubes (CRTs) and the associated lead content contained within. With television penetration approaching 100% of households and PC penetration over 50%, the need for consumer participation in recycling will be paramount over the next decade.

c) Recycling Infrastructure is Not in Place:

While many jurisdictions have developed effective reuse and recycling programs, many are not equipped to handle the increasing amounts of computers and TVs that are entering the waste stream. Others have no programs in place.

d) North America, Cradle to Grave Legislation is Slow to Develop:

Although many European countries have enacted legislation to ban the land filling of Electronic Waste, including requirements of manufacturers to take back and safely recycle or dispose of electronic trash, governments in North America are more prone to develop non-legislated alternatives. In fact, the US Trade representative, at the request of the American electronic associations, is currently lobbying against European Union Initiatives for fear that “take back” legislation will negatively affect trade in electronic parts and products.

Similarly, while some manufacturers are moving to reduce or replace toxic elements and, as well, insure that component parts are recyclable, manufacturing protocol is not mandatory.

1.2 Alberta’s Situation:

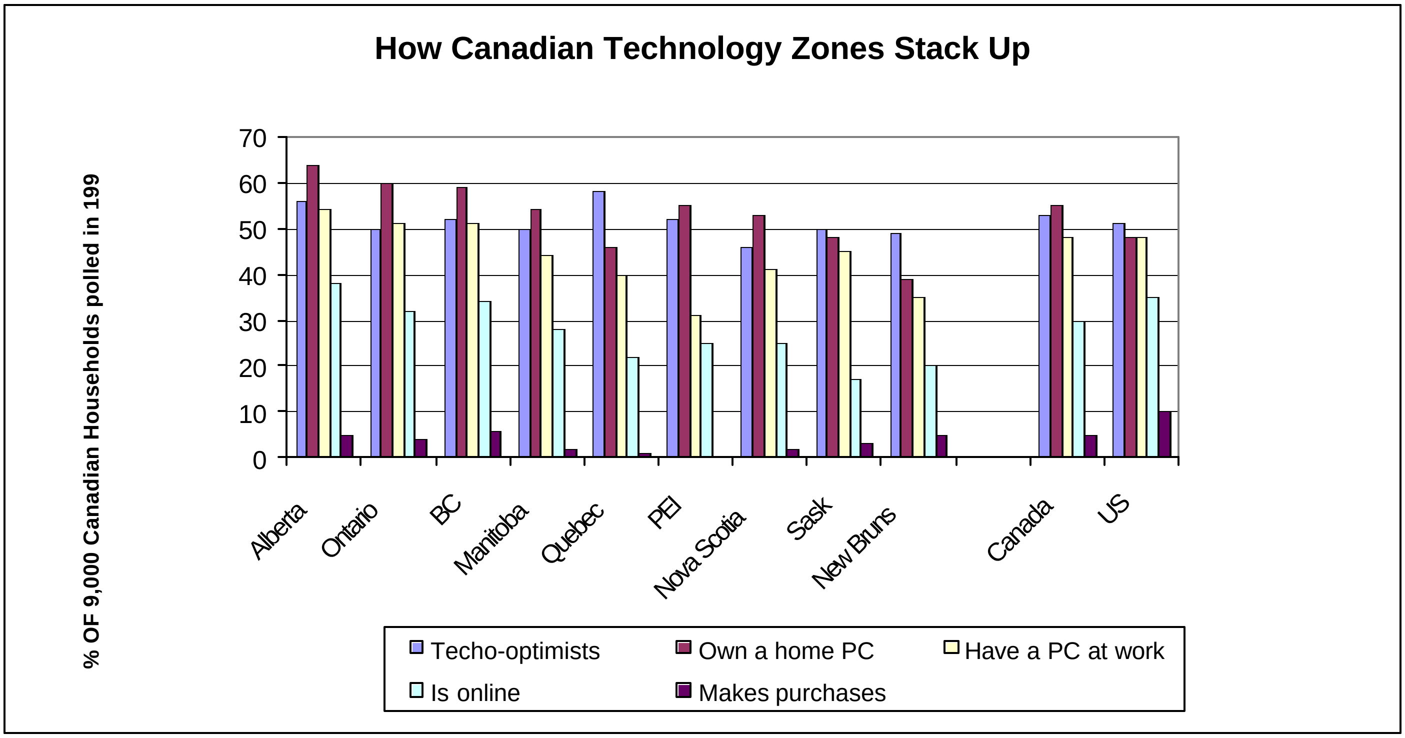
The problems associated with electronic waste are universal. However, these problems are more pronounced in Alberta due to a higher than average ownership of personal computers (on a per household basis) than any other Province in Canada (63% compared to a national average of 55%). While there are some organizations who are active in rebuilding old computers for reuse and others who dismantle parts for the purpose of recycling, there are no formalized province-wide programs in place, nor is there any pending legislation regarding the land filling or recycling of computer, television and electronic waste.

In the past, not-for-profits societies, schools and charities served as an excellent reuse alternative; however, these groups no longer have the in-house support needed to get donated equipment up and running. Furthermore, they too require systems with the capacity to run updated software programs. As a result, anything more than two years old is graciously refused.

Reuse programs will always remain as a beneficial use for obsolete PCs; however, the degree of impact they have in solving the computer waste problem will be minimal and, in fact, will only tend to postpone the “cradle to grave” cycle through retention.

Graph 1.1 outlines ownership of PCs in Alberta and across Canada. The rates in Alberta at approximately 63% for home PCs and 54% for at work PCs are the highest of any Province in Canada.

Graph 1.1


How Canadian Technology Zones Stack Up
% OF 9,000 Canadian Households polled in 199
70
60
50
40
30
20
10
0
Alberta
Ontario
BC
Manitoba
Quebec
PEI
Nova Scotia
Sask
New Bruns
Canada
US
Techo-optimists
Own a home PC
Have a PC at work
Is online
Makes purchases

1.3 Time for Action:

In recognizing the emerging problems associated with computer waste and electronic waste in general, the Capital Region Waste Minimization Committee (representing 20 Edmonton and region municipalities) requested that background work be done to:

- confirm the number of computers and accessories being land filled in Alberta;
- complete a search for successful recycling programs occurring in other jurisdictions;
- identify partnerships in the development of computer recycling; and,
- recommend a strategy for a voluntary recycling program.

The Alberta Plastics Recycling Association (APRA), in cooperation with Alberta Action on Waste, agreed to undertake this work as part of the ongoing Alberta Plastics Recycling Strategy (plastics make up 6.2 kgs per computer on average). Work began in May of 2000 and was completed in August of 2000.

It is believed that the results of this work, contained herein, will set the stage for growth in Alberta's computer waste recycling infrastructure and hopefully pave the way for a volunteer, non-legislated approach to averting the major environmental problems associated with this rapidly growing waste stream. If all those responsible including: manufacturers, consumers and governments, do not respond voluntarily, a legislated approach that includes non-compliance penalties will be necessary in the near future.

2 VOLUMES OF PERSONAL COMPUTERS (PCs) IN THE ALBERTA WASTE STREAM (2000)

Annual waste stream volume estimates for personal computers are derived from rates of ownership, frequency of discard and retention / storage of PCs. Growth in population, coupled with increased use rates will no doubt increase the waste volumes over time. Unless consumers are given choices about what to do with obsolete equipment and also, products that are manufactured to last longer, it is not likely a solution to computer waste will be found.

Consumers are reluctant to dispose of older working personal computers because there is a widespread belief that even older systems have value if passed on to those in need. Reuse, therefore has been the most popular alternative, where and when accepting users can be found. There is a perceived value to retaining outdated equipment. Of interest is that passed on computers usually have a shorter life span because they cannot run new software products.

It has been estimated that seventy percent of electronic waste is stored in attics, garages and company storerooms for an average three years (Recycling Council of British Columbia). The equipment loses much of its value during that time.

Central Mortgage and Housing reports that there were 979,175 dwelling units in Alberta in 1996, with an average 2.7 people per unit. With a current population of close to 2.9 million, there are an estimated 1.07 Million households; 764,000 of which have working PCs at home and 578,000 at the workplace. That's 1,252,000 PCs and doesn't include schools and libraries. Furthermore, due to upgrading of systems, 70% of residences are likely to have close to 472,000 obsolete systems stored.

The Alberta School System, as of August 31, 1999, had over 71,000 modern computers (less than five years old) in their system (Bonnie Brooks, Mgr., Stakeholder Technology, Alberta Learning) and universities and colleges are estimated to have 54,000 computers (extrapolated to be three times that reported at the U of A campus by Terry Mitchell, Materials Mgt, July 2000).

There are also 256 library Boards in Alberta and some 308 library service points. This system is interconnected by computers and there is an average of 2.7 computer terminals at library service points representing close to 830 computer terminals across the Province.

Table 2.1
Estimated Volumes of PCs in Alberta (2000)

Home based PC systems	674,000
Home based stored PC systems	472,000
Work based PC systems (Inc. private & municipal)	578,000
Alberta schools	71,000
Colleges and universities	54,000
Libraries	830
Total stored and in use	**1,849,830**

The annual waste stream volumes today represent that volume which has not been diverted from landfill through dismantling and recycling. The majority of PCs stored for potential reuse or resale are included as waste since they will ultimately (within 3 years) have no value on the resale / reuse market. The only exception to this would be if a major recycler (not a dismantler) were to establish in Alberta and offer large scale automated recycling processes that mechanically separate recyclable components.

At the present time in Alberta, there are three companies (two in Calgary and one in Edmonton) that provide electronics recycling services. Both companies accept a wide range of electronic products, including computer systems. They dismantle parts and broker component parts to other end users locally, in the US and in Asia. Major clients of these two companies include Petro-Canada, Mobile Oil and the “Computers for Schools” Program, which accept donations from Telus, CIBC and Government agencies and, in turn, send off unusable equipment.

Annual quantities of personal computers recycled / dismantled from these companies approach 124,000 PCs per year (3400 tonnes).

In addition to these dismantlers, some companies accept old computers for the purpose of rebuilding and reselling (examples include: C+L Computers and ARC Computer Solutions – both in Edmonton). Also, the Alberta Government resells or auctions off approximately 4500 computers at surplus stores located in Edmonton and Calgary. These quantities are not calculated into the diversion estimate since they too will enter the waste stream within three years.

Table 2.3 provides an estimate of annual computer waste in the Province. The volumes are based upon today’s average computer life span of 3.5 years. The 124,000 PCs that are recycled represents a recycle rate of close to 23%. In comparison, the recycle rate for large appliances (white goods) is 70%. Table 2.4 outlines what might be expected in the future and is based upon industry trends that show that the average life span of computers by 2005 will be two years. Predictions also account for an expected 15% per year increase in retail purchases (note: this reflects population increase as well as increased use).

Table 2.2
Computer Waste in Alberta Today

Existing PCs in use or stored	1.85 M
Average Turnover (obsolescence) @ 3.5 yrs	529,000 per year
Less current numbers recycled / dismantled	-124,000 (based on 60 lbs per PC system)
Year 2000 WASTE ESTIMATE	**405,000 PCs or 11,045 tonnes**

Table 2.3
Expected Computer Waste in Alberta 2005
(Based upon 15% increase sales per year)

Estimate of PCs in use or stored 2005	3.7 M
Average Turnover (obsolescence) @ 2yrs	1.85 M
Less recycle amounts at year 2000 levels	-124,000
Year 2005 WASTE ESTIMATE (without recycling intervention)	**1.73 M PCs or 47,000 tonnes**

3 "E-TOXICS" – WHAT'S IN A TYPICAL DESKTOP COMPUTER?

The general public will relate personal computer systems with a Central Processing Unit (CPU), a monitor, keyboard and printer. However, computer systems are a complicated assembly of more than 1,000 materials, many of which are highly toxic, such as chlorinated and brominated substances, toxic gases, toxic metals, biologically active materials, acids, plastics and plastic additives. For some computer components like monitors, it takes several thousand years to decompose in a landfill (Human Hitec Assist – Computer Recycling web site).

The health impacts of some of the mixtures and material combinations are not known; however, constituents such as lead, cadmium and mercury are well documented as extreme health risks under certain conditions, particularly when released into the environment. Polyvinyl chloride (PVC), mainly used in cabling and in older computer housings is a major cause of dioxin formation in open burning and garbage incinerators. Newer computer housings are now using other forms of resins (like ABS and polycarbonates); however, the mixtures of plastics used is seldom detected or stamped on the housings.

How computers are handled during manufacturing, disposal and in recycling is of paramount concern. The production of semi-conductors, printer circuit boards, disk drives uses hazardous chemicals, and workers involved in chip manufacturing are now beginning to come forward and report cancer clusters. In addition, new evidence is emerging that computer recyclers have levels of dangerous chemicals in their blood (Silicon Valley, Toxics Coalition web site).

Table 3.1 outlines some of the materials that are contained within a typical desktop computer. Also provided are percentages outlining the efficiency rates for recycling as presented in 1996. In some cases, the recycleability of some components may have improved over the last four-year period. As an example, one manufacturer (IBM) is replacing polyvinyl / casings, which is a toxic plastic when incinerated, with 100% recycled resin (PC / ABS). Others are reducing the lead content by using lead free solder.

Table 3.1

Materials used in a desktop computer and the efficiency of current recycling processes

Composition of a Desktop Personal Computer Based on a typical desktop computer, weighing – 60 lbs.				
Table presented in: Microelectronics and Computer Technology Corporation (MCC), 1996 Electronics Industry Environmental Roadmap, Austin, TX MCC				
Name	**Content (% of total weight)**	**Weight of material in computer (lbs)**	**Recycling Efficiency (current recycleability)**	**Use / Location**
Plastics	22.9907	13.8	20%	Includes organics, oxides
Lead	6.2988	3.8	5%	Metal joining, radiation shield
Aluminum	14.1723	8.5	80%	Structural, conductivity / housing connectors
Germanium	0.0016	<0.1	0%	Semiconductor/PWB
Gallium	0.0013	<0.1	0%	Semiconductor/PWB
Iron	20.4712	12.3	80%	Structural, magnetivity (steel) PWB
Tin	1.0078	0.6	70%	Metal joining/PWB, CRT
Copper	6.9287	4.2	90%	Conductivity/CRT, PWB
Barium	0.0315	<0.1	0%	In vacuum tube/CRT
Nickel	0.8503	0.51	80%	Structural, magnetivity/ (steel) PWB
Zinc	2.2046	1.32	60%	Battery, phosphor emitter / PWB
Tantalum	0.0157	<0.1	0%	Capacitors / PWB power supply
Indium	0.0016	<0.1	60%	Transistor, rectifiers / PWB
Vanadium	0.0002	<0.1	0%	Red phosphor activator
Terbium	0	0	0%	Green phosphor activator
Beryllium	0.0157	<0.1	0%	Thermal conductivity / PWB
Gold	0.0016	<0.1	99%	Connectivity, conductivity
Europium	0.0002	<0.1	0%	Phosphor activator / PWB
Titanium	0.0157	<0.1	0%	Pigment, alloying agent
Ruthenium	0.0016	<0.1	80%	Resistive circuit / PWB
Cobalt	0.0157	<0.1	85%	Structural, magnetivity /(steel) PWB
Palladium	0.0003	<0.1	95%	Connectivity, conductivity
Manganese	0.0315	<0.1	0%	Structural, magnetivity /(steel) PWB
Silver	0.0189	<0.1	98%	Conductivity / PWB connectors
Antinomy	0.0094	<0.1	0%	Diodes / housing PWB, CRT
Bismuth	0.0063	<0.1	0%	Wetting agent in thick film
Chromium	0.0063	<0.1	0%	Decorative, hardener, steel
Cadmium	0.0094	<0.1	0%	Battery, glu-green phosphor, PWB, CRT
Selenium	0.0016	0.00096	70%	Rectifiers / PWB
Niobium	0.0002	<0.1	0%	Welding, allow/housing
Yttrium	0.0002	<0.1	0%	Red phosphor emitter / CRT
Rhodium	0		50%	Thick film conductor / PWB
Platinum	0		95%	Thick film conductor / PWB
Mercury	0.0022	<0.1	0%	Batteries, switches / housing
Arsenic	0.0013	<0.1	0%	Doping agents in transistors
Silica	24.8803	15	0%	Glass, solid state devices / CRT

Note: plastics contain polybrominated flame-retardants and hundreds of additives and stabilizers not listed separately.

3.1 Risks related to some e-toxics found in computers

(Taken from the Silicon Valley Toxics Coalition web site Note: data refers to U.S. statistics)

Lead

Lead can cause damage to the central and peripheral nervous systems, blood system and kidneys in humans. Effects on the endocrine system have also been observed and their serious negative effect on children's brain development has been well documented. Lead accumulates in the environment and has high acute and chronic toxic effects on plants, animals and microorganisms.

Consumer electronics constitute 40% of the lead found in landfills. The main concern in regard to the presence of lead in landfills is the potential for the lead to leach and contaminate drinking water supplies.

The main applications of lead in computers are:

1. soldering of printed circuit boards and other electronic components
2. glass panels in computer monitors (cathode ray tubes or CRTs)

Between 1997 and 2004, over 315 million computers will become obsolete is the USA. This adds up to about 1.2 billion pounds of lead! In Alberta, this could represent close to 7 million computers and 20 million lbs. of lead, most of which comes from CRTs.

Cadmium

Cadmium compounds are classified as toxic with a possible risk of irreversible effects on human health. Cadmium and cadmium compounds accumulate in the human body, in particular in kidneys. Cadmium is absorbed through respiration, but is also taken up with food. Due to the long life (30 years), cadmium can easily be accumulated in amounts that cause symptoms of poisoning. Cadmium shows a danger of cumulative effects in the environment due to its acute and chronic toxicity.

In electrical and electronic equipment, cadmium occurs in certain components such as SMD chip resistors, infrared detectors and semiconductors. Older types of cathode ray tubes contain cadmium. Furthermore, cadmium is used as a plastic stabilizer.

Between 1997 and 2004, over 315 million computers will become obsolete and this represents almost 2 million pounds of cadmium content.

Mercury

When inorganic mercury spreads out in the water, it is transformed to methylated mercury in the bottom sediments. Methy1ated mercury easily accumulates in living organisms and concentrates through the food chain particularly via fish. Methylated mercury causes chronic damage to the brain.

It is estimated that 22% of the yearly world consumption of mercury is used in electrical and electronic equipment. It is basically used in thermostats, (position) sensors, relays and switches (e.g. on printed circuit boards and in measuring equipment) and discharge lamps. Furthermore, it is used in medical equipment, data transmission, telecommunications, and mobile phones.

Mercury is also used in batteries, switches/housing, and printed wiring boards. Although this amount is small for any single component, 315 million obsolete computers by the year 2004 represent more than 400,000 pounds of mercury in total in the U.S. (8800 lbs. in Alberta).

Hexavalent Chromium (Chromium VI)

Some manufactures still apply this substance as corrosion protection of untreated and galvanized steel plates and as a decorative and hardener for steel housing

Chromium VI can easily pass through membranes of cells and is easily absorbed producing various toxic effects within the cells. It causes strong allergic reactions even in small concentrations. Asthmatic bronchitis is another allergic reaction linked to chromium VI. Chromium VI may also cause DNA damage

In addition hexavalent chromium compounds are toxic for the environment. It is well documented that contaminated wastes can leach from landfills. Incineration results in the generation of fly ash from which chromium is leachable, and there is widespread agreement among scientists that wastes containing chromium should not be incinerated.

Of the more than 315 million computers destined to become obsolete between 1997 and 2004, about 1.2 million pounds of hexavalent chromium will be present

Plastics

Based on the calculation that more than 315 million computers will become obsolete between 1997 and 2004 and that plastics make up 13.8 pounds per computer on average (U.S. calculations), there will be more than 4 billion pounds of plastic present in this computer waste. In Alberta, this could represent over 43,000 tonnes or 25% of the total annual plastic waste stream. An analysis commissioned by the Microelectronics and Computer Technology Corporation (MCC) estimated that the total electronics plastic scrap amounted to more than 1 billion pounds per year in the U.S. (580,000 tons per year). This same study estimated that the largest volume of plastics used in electronics manufacturing (at 26%) was polyvinyl chloride (PVC), which creates more environmental and health hazards than most other type of plastic (see below). While many computer companies have recently reduced or phased out the use of PVC, there is still a growing volume of PVC contained in the computer scrap cabling - potentially up to 250 million pounds per year in the U.S.

PVC

The use of PVC in computers has been mainly used in cabling and computer housings, although most computer moldings are now being made of ABS plastic and polycarbonates. PVC cabling is used for its fire retardant properties, but there are concerns that once alight, fumes from PVC cabling can be a major contributor to fatalities and hence there are pressures to switch to alternatives for safety reasons. Such alternatives are low-density polyethylene and thermoplastic olefins.

PVC is a difficult plastic to recycle and it contaminates other plastics in the recycling process. Of more importance, however, the production and burning of PVC products generates dioxins and furans. This plastic commonly used in packaging and household products is a major cause of dioxin formation in open burning and garbage incinerators. Hospitals are now beginning to phase out the use of PVC products such as disposal gloves and IV bags because of the dangers of incinerating these products.

Many local authorities in Europe have PVC-free policies for municipal buildings, pipes, wallpaper, flooring windows and packaging. Recent concerns about the use of softeners in PVC plastic toys leaching out into children's mouths have lead to further restrictions on PVC.

Brominated Flame Retardants

Brominated flame-retardants are a class of brominated chemicals commonly used in electronic products as a means for reducing flammability. In computers, they are used mainly in four applications: in printed circuit boards, in components such as connectors, in plastic covers and in cables. They are also used in plastic covers of TV sets and in domestic kitchen appliances

Various scientific observations indicate that Polybrominated Diphenylethers (PBDE) might act as endocrine disrupters. Research has revealed that levels of PBDEs in human breast milk are doubling every five years and this has prompted concern because of the effect of these chemicals in young animals.

A recent study found that newborn mice fed PBDEs show abnormal behavior when placed in new surroundings. Normal mice become very active when first transferred to a new environment but gradually slow down as they complete their explorations. However, treated mice were less active at first but became more active after being in new surroundings for an hour. Researchers concluded that exposure to the chemicals in early life could induce neurotoxic effects similar to those caused by other toxic substances such as PCBs and some pesticides.

Other studies have shown PBD, like many halogenated organics, reduces levels of the hormone thyroxin in exposed animals and have been shown to cross the blood brain barrier in the developing fetus. Thyroid is an essential hormone needed to regulate the normal development of all animal species, including humans.

Researchers in the US found exposure to Polybrominated Biphenyls (PBBs} may cause an increased risk of cancer of the digestive and lymph systems. The study looked at cancer incidence in individuals exposed to PBBs after a 1973 food contamination incident in Michigan. About a ton of PBB fire retardant was added to cattle feed in error and contamination spread through the animal and human food chain. Some-nine million people were affected. A study published in 1998 found that the group with the highest exposure was 23 times more likely to develop digestive cancers, including-stomach, pancreas and liver cancers. Preliminary results also found a 49-fo1d increase in lymph cancers.

The presence of PBBs in Arctic seal samples indicates a wide geographical distribution. The principal known routes of PBBs from point sources into the aquatic environment are PBBs plant areas and waste dumps. PBBs are almost insoluble in water and are primarily found in sediments of polluted lakes and rivers. PBBs have been found to be 200 times more soluble in a landfill leachate than in distilled water, which may result in a wider distribution in the environment. Once they have been released into the environment, they can reach the food chain, where they are concentrated. PBBs have been detected in fish from several regions. Ingestion of fish is a source of PBB transfer to mammals and birds. Neither uptake nor degradation of PBBs by plants has been recorded. In contrast, PBBs are easily absorbed by animals.

These chemicals make computer recycling particularly hazardous to workers.

The presence of polybrominated flame-retardants in plastic makes recycling dangerous and difficult. It has been shown that Polybrominated Diphenylethers(PBDEs) form the toxic polybrominated dibenzo furans (PBDF) and polybrominated dibenzo dioxins (PBDD) during the extruding process, which is part of the plastic recycling process. As a consequence, the German chemical industry stopped the production of chemicals in 1986.

In addition, high concentrations of PBDEs have been found in the blood of workers in recycling plants. A recent Swedish study found that when fax machines or other electronic equipment are recycled, dust containing toxic flame-retardants is spread in the air. Workers at dismantling facilities had 70 times the level of one form of flame retardant than are found in hospital cleaners. Because of their common presence in air, clerks working full-time at computer screens also had levels of flame-retardants in their blood - slightly higher than for cleaners. Humans may directly absorb PBDEs when they are emitted from electronic circuit boards and plastic computer and TV cabinets

In May 1998, Sweden's National Chemicals Inspectorate called for a ban on PBB and PBDE while urging their government to work for a European wide ban and for controls on the international trade in these chemicals.

As a consequence, PBBs should no longer be used commercially.

- Between 1997 and 2004 over 315 million computers will become obsolete in the U.S.
- Calculations for the amount of brominated flame retardants present in monitors total over 350 million pounds

This is an underestimate because it does not take into account the amount present in the computer tower or printed wiring boards.

3.2 Disposing of Computers Can Be Hazardous

In addition to the recent evidence of worker exposure to flame retardants, the environmental risks posed by landfilling and burning are also significant. In particular, when computer waste is landfilled or incinerated, it poses contamination problems in leachate to water sources and toxic air emissions.

The Hazards of Incinerating Computer Junk

The stream of Waste from Electronic and Electrical Equipment (WEEE) contributes significantly to the heavy metals and halogenated substances contained in the municipal waste stream. Because of the variety of different substances found together in electroscrap, incineration is particularly dangerous. For instance, copper is a catalyst for dioxin formation when flame-retardants are incinerated. This is of particular concern as the incineration of brominated flame retardants at a low temperature (600-800^{o}C) may lead to the generation of extremely toxic polybrominated dioxins (PBDDs) and furans (PBDFs).

Significant quantities of PVC are contained in WEEE, which makes the flue gas residues and air emissions particularly dangerous.

The introduction of WEEE into incinerators results in high concentrations of metals, including heavy metals, in the slag, in the fly ash, the flue gas and in the filter cake. In this context, more than 90% of the cadmium put to an incinerator is found in the fly ash and more than 70% of the mercury in the filter cake.

Municipal incineration is the largest point source of dioxins into the US and Canadian environments and among the largest point source of heavy metal contamination of the atmosphere.

Some producers send their electroscrap to cement kilns for use as an alternative to fuel. Smelting also presents the same dangers as incineration. Indeed, there is growing concern that the Noranda Smelter in Quebec, where much of the. North

American electroscrap is sent, is producing dioxins due to the residual presence of PVC or other plastics in the scrap.

The Hazards of Landfilling Computer Junk

It has become common knowledge that all landfills leak. Even the best 'state of the art" landfills are not completely tight throughout their lifetimes and a certain amount of chemical and metal leaching will occur. The situation is far worse for older or less stringent dump sites

Mercury will leach when certain electronic devices, such as circuit breakers are destroyed. The same is true for PCBs from condensers. When brominated flame retarded plastic or cadmium-containing plastics are landfilled, both PBDE and the cadmium may leach into the soil and groundwater. It has been found that significant amounts of lead ions are dissolved from broken lead containing glass, such as the cone glass of cathode ray tubes, when mixed with acid waters which commonly occur in landfills.

Not only the leaching of mercury poses specific problems. The vaporization of metallic mercury and dimethylene mercury, both part of WEEE, is also of concern. In addition, uncontrolled fires may arise at the landfills and this could be a frequent occurrence in many countries. When exposed to fire, metals and other chemical substances, such as the extremely toxic dioxins and furans (TCDD – Tetrachloro-dibenzo-dioxin, PCDDs, PBDDs and PCDFs - polychlorinated and polybrominated dioxins and furans) from halogenated flame retardant products and PCB containing condensers can be emitted.

The Hazards of Recycling Computer Junk

Recycling of hazardous products has little environmental benefit- it simply moves the hazards into secondary products that eventually have to be disposed of. Unless the goal is to redesign the product to use non-hazardous material, such recycling is a false solution.

The list of e-toxic components in computers include:

- computer circuit boards containing heavy metals like lead & cadmium
- computer batteries containing cadmium
- cathode ray tubes with lead oxide & barium
- brominated flame-retardants used on printed circuit boards, cables and plastic casing
- Poly Vinyl Chloride (PVC) coated copper cables and plastic computer casings that release highly toxic dioxins & furans when burnt to recover valuable metals
- mercury switches
- mercury in flat screens

- Poly Chlorinated Biphenyl's (PCBs) present in older capacitors and transformers

Due to the halogenated substances found in plastics, both dioxins and furans are generated as a consequence of recycling the metal content of WEEE. Halogenated substances contained in WEEE, in particular brominated flame-retardants, are also of concern during the extrusion of plastics, which is part of plastic recycling. Due to the risk of generating dioxins and furans, recyclers usually abstain from recycling flame-retarded plastics from WEE. However, due to the lack of proper identification of plastic containing flame-retardants, most recyclers do not process any plastic from WEEE.

Environmental problems during the recycling of WEEE are not only linked to halogenated substances. Hazardous emissions to the air also result from the recycling of WEEE containing heavy metals such as lead and cadmium. (39) These emissions could be significantly reduced by means of pre-treatment operations. Another problem with heavy metals and halogenated substances in untreated WEEE occurs during the shredding process. Since most WEEE is shredded without proper disassembly, hazardous substances, such as PCB contained in capacitors, may be dispersed into the recovered metals and the shredder waste.

4 COMPUTER RECYCLING IN ALBERTA AND OTHER JURISDICTIONS

As mentioned previously in this report, the outlets for recycling computers in Alberta include two electronic waste dismantlers and brokers located in Calgary. Some major centers have localized not-for-profit groups and privates who receive and refurbish computers for re-use and often re-sale; however, the volumes handled are estimated to be insignificant (30 to 500 per year).

The three major dismantlers have estimated that they receive and dismantle close to 125,000 computer systems per year combined. Equipment is dismantled by hand, component parts of value are separated and very little is reportedly landfilled. Plastics are reported to go to a local Calgary or Edmonton recyclers, metals and cables to the U.S. and circuit boards to Asia. Some parts are re-sold to local computer reclaimers. The remaining un-valuable metals are sent to smelters.

These companies combined suggest that they have a throughput capacity to handle / dismantle all of the computer waste volume predicted by 2005. However, they are not set up to handle monitors (CRTs).

The export of electronic scrap to places like China and Taiwan has proven to be profitable in the past because labor costs are cheaper and regulations concerning toxic components were lax.

It was ten times cheaper to ship Cathode Ray Tube (CRT) monitors to China than it was to recycle them here in North America (mostly U.S.).

However, in 1994, the Basel Convention, which involved 60 countries, agreed to an immediate ban on the exports of hazardous waste destined for non-OECD countries. By 1997, the effectively ended the export of toxic wastes from rich OECD countries to poor non)ECD countries. This included China and, while some exporting still takes place for recycling purposes, Asia has closed the door on electronic scrap, thus forcing North Americans to seek a “home grown” solution to handling an ever increasing volume of computer and electronic waste.

Many jurisdictions in the U.S. have responded to this challenge. For example, Pasco County Florida developed a permanent site for EEE waste and HHW (Household Hazardous Waste). The 3.5 month pilot project resulted in the collection of 45 tonnes of EEE (which included computers) and 30 tonnes of CRT (TV and computer monitors).

With a population of approximately 350,000, this represented an average .24 lbs per capita and a cost of $44 (U.S.) per CRT collected. All waste was distributed to electronic recyclers for de-manufacturing (dismantling) and ultimate re-sale or disposal.

Other communities in the U.S. have ongoing programs to collect electronic equipment from residents.

- Massachusetts Department of Environmental Protection has five permanent regional collection facilities that accept electronic equipment at no cost.

- Hennepin County Environmental Services, Minnesota, on ongoing collection program for electronic equipment and appliances. Contact Cheryl Lofrano-Zaske at (612) 348-8992 for more information.

- The State of Minnesota has begun a collection and management development pilot project for used electronic appliances. The Minnesota Office of Environmental Assistance is collaborating with Sony Electronics, the Asset Recovery Group of Waste Management, Panasonic and the American Plastics Council to evaluate various collection strategies and market development opportunities for recycling scrap from used and component parts.

- Wisconsin Department of Corrections manages a computer-recycling project at two correctional facilities. The project accepts used computers from state agencies and the public, produces refurbished computer system for sale to schools and nonprofits and demanufacture rest. The prisoners employed on this project work toward certification as technicians. For information on this project, contact Steve Kronzer at (608) 246-5649.

NCR maintains a list of reuse and recycling organizations throughout the United States. To obtain the list, send an e-mail (Electronics Recycling Initiative at eri@nrc-recycle.org).

These programs run parallel with U.S. based state legislation in at least twelve states where regulatory frameworks for the disposition of computers and electronic equipment are unfolding. Vermont already has a law prohibiting the disposal of products containing mercury. Here in Canada, Ontario has also regulated the disposal of mercury containing products in concentrated amounts.

In Alberta, government is more prone to enact mandatory regulations or legislation only as a last alternative and has placed significant emphasis in solving recycling issues through voluntary approaches involving consumers, manufacturers and governments in a collaborative approach.

5 STRATEGIES FOR MANAGING USED COMPUTERS

There are a number of approaches to managing the increased volume of computer waste in the Province of Alberta and while recycling will likely have the greatest impact in diverting this problematic waste from the landfill, reduction, reuse and recovery will also play important roles. The following information includes extracts from ***Reiterate***, the newsletter of the Recycling Council of British Columbia.

Reduce:
With an expected 15% increase in sales per year, increased obsolescence and growth in population, reductions in the use of computers is highly unlikely. However, there are measures being taken and current initiatives by some companies to reduce obsolescence. For example, Toshiba is working on a modular upgradeable and customizable computer, which will allow low cost upgrades through rewritten cartridges thus eliminating high cost computer chip upgrades.

Efforts to reduce material are also mirrored in some new computer designs that are flatter, lighter and more integrated. Other companies propose centralized networks similar to the telephone system. Here consumers would have only a simple screen and keyboard at home or in the office and we would pay a monthly fee based on the level of software complexity we would want to access. Some think this could lead to information control and lack of privacy. Others think this would make access to the Internet cheaper, less materials intensive, and more accessible to everyone, while achieving comparable privacy as is found with the current use of PCs anyway. Increased public education about reduction alternatives is a step in the right direction. Environmental groups and agencies could play a vital role in this cause by encouraging “smart purchasing” for consumers and advocate changes to purchasing policies and overall systems management of large computer users such as municipal governments, institutions and schools.

Reuse:
Entrepreneurs have taken advantage of the opportunity to repair and reuse old equipment to create profitable businesses. But the recycled computer industry is still subject to the challenges faced by new hardware ... obsoletism!

Creative inroads have been made in the reuse option for computers. One of the most promising is the work of New Deal – ‘bringing leading edge software to lagging edge hardware’! This company recognizes that one of the key frustrations to computer users is old hardware that doesn’t have the power to run new software. An estimated 80 million 286/386/486 based PCs worldwide are fully functional, yet unable to meet the excessive processor, storage and memory requirements of the latest software used by major corporations.

New Deal provides a unique solution to this challenge by providing a comprehensive package of windows environment software that can run on any PC, from a 286 to a Pentium – breathing a new life into old equipment. New Deal is also a sponsor of New Deal Foundation, which provides royalty-free software to educational, religious and non-profit organizations around the world. Check out New Deal at http://www.new-deal.com.

Don't procrastinate! Nearly 70% of electronic waste is stored in attics, company storerooms and garages because of perceived value … encourage your residents and co-workers to find reuse or recycling options as soon as the system turns over - they're more likely to find higher value solutions.

Donations make up a small percentage of computer reuse applications. The social benefits of donating used computer equipment to schools, non-profit organizations, staff, etc. are high. Donating used electronic equipment to worthwhile causes increases computer literacy and enables organizations to be more effective and efficient in the work they do.

But managing donations is difficult. Many businesses don't know where to find good homes for the equipment, and both the time it takes to make the 'matches' and storage needs are sometimes underestimated. Some organizations take equipment exclusively for distributing to the non-profit sector.

ReBOOT Canada is the country's leading provider of computer hardware to charitable organizations across Canada. More than 4,000 units of computer hardware have been given to over 400 organizations. reBOOT Canada is the first full service non-profit organization dedicated to helping charitable organizations increase their computer equipment from corporations and individuals, then re-distributes those machines to charities and non-profit organizations across the country.

ReBOOT Canada accepts any computer system (486 DX2-66mhz processor or higher, Macintosh LCIII or higher), or any parts or peripherals, which work with those machines. Monitors and printers are always needed. Reboot Canada will:

Pick up the equipment at your location (minimum 5 units); and,

Issue a tax receipt for the market value of the computer equipment donated.

You will receive a thank you letter from the recipients of the equipment so you are aware of where the donated computer equipment is going.

Contact reBOOT Canada @ tel: (604) 215-7772

e-mail: rgilson@tradeworks. bc.ca

website: http://www.reboot.on.ca

While donations are an important component of an overall strategy, the volumes are low, and other barriers, such as lack of support and knowledge on the part of the receiver to effectively use the equipment, pose challenges. If you live in a populated area such as the Lower Mainland of BC or Central Okanogan, chances are that you will have a choice of computer refurbishers and recyclers to take your old machines. In more rural areas, the volumes don't always warrant a recycling enterprise. In some cases, opportunities exist at local schools and community centers to donate equipment for use in computer classes (for taking apart and rebuilding) or even art classes.

Used computer parts can be reused in different applications. Many valuable parts of computers can be salvaged for reuse, but careful disassembly is essential. Reclaimed parts are used for making toys and servicing and repairing older computers.

A good market for used parts exists in other parts of the world where older equipment is the norm. Last year, a technology upgrade at the HSBC (formerly Hong Kong Bank of Canada) left 800 bank terminal workstations obsolete and destined for disposal. One of the bank's purchasing staff set out to reuse and recycle the equipment. Within months, thousands of pounds of computer hardware and software were sent to Indonesia and Oman where the older banking terminals were still in sue and in need of parts. (from R.C.B.C. newsletter, December issue).

Recycling:
Many of the resulting commodities, particularly ferrous and nonferrous metals, are easy to handle and have ready markets. Others, such as CRT glass, are more difficult. Monitor glass contains about 20 percent lead by weight (on average 2.5 lbs of lead per screen) and has few markets. The most reliable market is to lead smelters, where the lead is captured and refined and the glass silica fraction is used as a flux. This market is available to generators that can produce a high volume of glass that has been broken or pulverized to sizes ranging from ½" minus to 6" minus and from which all ferrous and nonferrous materials have been removed.

Glass-to-glass recycling remains an undeveloped market, which is limited by the requirement that CRTs be physically broken apart and sorted into two or three glass fractions, each with a different lead content. One example is the combination of Envirocycle (Hallstead, Pennsylvania), which saws CRTs apart and sorts the glass, and Techneglass (Columbus, Ohio), which uses the glass to produce new CRTs. This market is limited further by the fact that nearly all of the monitors sold in the U.S. are produced offshore. Little demand for leaded, or even unleaded, monitor glass exists in the U.S.

Plastics always have been the most difficult nuts for electronics processors to crack. Typical electronic equipment can contain a half-dozen or more different and incompatible types of plastic. Until recently, colors involved were generally beige and black. Now a broad spectrum of colored plastics is appearing in electronic equipment. This adds the burden of sorting by color as well as type if the plastic is to have any value. Properly sorted and prepared, some plastics can be worth $0.20 to $0.30 per pound, but more sorting means significantly more overhead. Since the markets for mixed engineered plastics historically are weak, some processors and demanufacturers find it more cost effective to landfill or incinerate the plastic. Often, the market drives the decision.

Recovery:
Energy recovery through incineration will not qualify as reasonable alternative in Alberta because of the toxic elements contained within computer systems. However, the encouraged replacement of PVC plastic with less toxic resins may well lead the way to an excellent energy source for those plastics that are not recycled. Plastic, by weight, constitutes 20% of computer systems. In Alberta, plastic scrap from computers alone is estimated to reach over 9,000 tonnes per year by the middle of the next decade and plastics contain similar BTU values as high-grade coal.

Improvements in manufacturing protocol and reuse of PCs (and parts) will always remain as socially accepted and beneficial approaches in the quest to keep computer waste out of the landfill. However, increases in use and continued obsolescence will no doubt require an aggressive campaign to recycle the vast amounts of computer scrap in the future.

The current handling capacity (predominantly dismantlers) to dismantle and recycle computer parts and components metals and plastics is quire favorable according to current operators. They have markets for most components and can collectively handle the expected volumes. However, there will be a need for the development of public education, a collection infrastructure and ideally a local recycler capable of handling the vast quantities of CRT monitors from both computers and televisions. To date, those CRTs that are not landfilled are sent to the U.S. for recycling at a cost of $3.00 to $5.00 per monitor.

1. PROVINCE WIDE RECYCLERS WITH THE CAPACITY TO HANDLE NOT ONLY THE EXPECTED VOLUMES OF EEE WASTE, BUT CRT MONITORS AS WELL.

2. WIDESPREAD PUBLIC EDUCATION REGARDING THE DISPOSAL OF EEE WASTE AND SELECTIVE PURCHASING.

3. A COLLECTION SYSTEM CAPABLE OF HANDLING VOLUMES AND CONTAINMENT.

4. THE NECESSARY DOLLARS TO MAKE THE SYSTEM WORK inc:
   - COOPERATIVE EFFORTS OF MANUFACTURERS TO SHARE THE COST AND RESPONSIBILITY OF COLLECTION AND RECYCLING
   - THE EFFORTS OF MANUFACTURERS TO USE RENEWABLE MATERIALS AND ENERGY AND; NON-RENEWABLE MATERIALS THAT ARE SAFER.

Bio-based plastics are plastics made with plant-based chemicals or plant-produced polymers rather than from petro-chemicals. Bio-based plastics exist but they do not see common use because of lack of market demand and the low price of petroleum-based plastics. Bio-based toners, glues and inks also exist and are used more frequently. Solar computers also exist but they are currently very expensive.

Because many of the materials used are non-renewable, designers could ensure the product is built for re-use, repair and/or upgradability. Some computer manufacturers such as Dell and Gateway lease out their products thereby ensuring they get them back to further upgrade and lease out again.

Many companies have shown they can design cleaner products. Industry is making some progress to design cleaner products, but we need to move beyond pilot products and ensure all products are upgradeable and non-toxic.

- Hewlett Packard Company has developed a safe cleaning method for chips using carbon dioxide cleaning as a substitute for hazardous solvents
- Printed circuit boards can be redesigned to use a different base material, which is self-extinguishing thereby eliminating the need for flame-retardants.
- Matsushita is "accelerating efforts to eliminate toxic substances and develop more environmentally benign materials such as lead free solder, non-halogenated lead wires and non-halogenated plastics. Matsushita also developed "the first ever lead-free solder for flow soldering applications and have recently launched, in Japan, their first totally-recyclable television sets." Sony Corp has developed a lead-free solder alloy, which is usable in conventional soldering equipment. There is a range of lead -free solders now available. Obviously, substitutes need to be proven for safety.
- Pressures to eliminate halogenated flame-retardants and design products for recycling have led to the use of metal shielding in computer housings.
- In 1998 IBM introduced the first computer that uses 100% recycled resin (PC/ABS) in all major plastic parts for a total of 3.5 pounds of resin per product.
- Researchers at Delft University in Holland are investigating the design of a wind up laptop similar to the wind-up radio that plays one hour for every 20 seconds of hand winding.

6 A RECOMMENDED SOLUTION FOR ALBERTA

Alberta based electronics recyclers claim to have the capacity to dismantle, separate and salvage the expected volume of computer systems to enter Alberta's waste stream over the next five-year period. While this is encouraging, it is not known just how much of the actual components are recycled / re-sold and how much is landfilled. It is also not known how safe the dismantling process is since there is no accounting of the toxic elements and their actual end destination. A comprehensive, safe and well-monitored solution will be essential if the potential environmental and health problems associated with EEE waste are to be dealt with and if CRT monitors are safely disposed or recycled.

Since the problem is universal, rapid advances in technology are occurring. Concurrent Technologies Corp., a large non-profit under contract with the Department of Defense (Washington), is developing a demonstration facility in Largo, Florida to showcase new technologies and processes for demanufacturing EOL electronic equipment. Scheduled to open in the fall of 2000, this facility and its research efforts will provide an opportunity for both private sector recyclers and governments to examine the latest options before entering into comprehensive collection and recycling programs.

Also emerging in Alberta, has been an interest from a German based recycling company, GLOBUS CONSULTING AND CONTRACTING. This company has been active in Germany collecting and recycling a wide array of recyclable waste stream products ranging from batteries and car parts to aluminum bottle caps. The recycling of electronics scrap is of interest to them because of the value of recovered metals: gold, copper, aluminum, and lead. They utilize large-scale mechanical shredders and various technologies to separate component parts. PC boards, as an example, are pre-shredded, delaminated then separated through electrostatic and fluid bed processes to isolate aluminum, plastic and copper.

With the volumes of personal computers, and for that matter televisions, that will be entering the waste stream, the Province will require at least one major electronics scrap recycler / processor capable of handling annual volumes in excess of 50,000 tonnes. It is responsible for government to encourage such development, but not at the expense of the environment. In this regard, interested companies should be forced to demonstrate the ability to safely recycle, maximize the recovery of recycled components and safely dispose of non-recyclable elements including toxic waste.

Alberta's current recycling infrastructure, which includes markets for plastics, metals and glass is well positioned to support major electronics scrap recycling. Also, Albertans have a strong recycling mentality and, where opportunities exist, response to programs will occur at a quick pace. Whether program development is legislated or voluntary, the cost of collection will likely be borne indirectly by the consumer at local municipal levels and the cost for recycling (based on discussions with electronic scrap dismantlers) is adequately covered through the value of recovered gold, copper and aluminum. Successful program development in a voluntary, non-legislated approach will require that the responsibility for the problem and the cost to collect and recycle be shared amongst all stakeholders including:

1. Manufacturers and retailers to:
    - manufacture electronics with recyclable components and non-toxic components and processes.
    - sell equipment that has a longer life and take back / collect obsolete equipment as part of recycling management.
    - assist in educating consumers about e-toxics and “right choice purchasing”.
    - work together in establishing in house recycling programs for consumers.

2. Recyclers to:
    - seek markets and maximize the recycling of all components.
    - remain aware and increase education in the handling of e-toxics and the ultimate disposal of hazardous waste.
    - work with retailers and manufacturers to develop recycle programs.
    - pay for the cost of pick-up from collection depots.

3. Consumers to:
    - make wise purchases and encourage others to recycle electronics including computer systems.

4. Governments (Provincial and Municipal) to:
    - undertake more selective purchasing through purchasing policies that encourage proper selection of longer lasting systems with greater recycling content.
    - develop localized public education and awareness programs outlining the problems with e-waste and the opportunities available for reduction, reuse and recycle.
    - set recovery targets and identify the consequences of not meeting targets
    - monitor and record that recycling recovery rates and provide an appropriate regulatory framework for the smelting, incineration or landfilling of e-toxics (predominately lead and mercury and toxic plastics).
    - cooperate in establishing computer waste collection depots and/or waste round ups.
    - encourage and attract growth in the e-scrap recycling industry, particularly CRTs.

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