It Technology Essay, Research Paper

1.0 INTRODUCTION

A quote from a PC World magazine on “The Digital Future” said, “in the future,

people will live twice as long, computers will die twice as fast” 1. As computer technology

continues to accelerate at an unprecedented rate, information technology (IT) equipment

waste is becoming an increasingly significant portion of the solid waste stream.

Information Technology equipment waste is receiving increased attention for the

following reasons:

? Rapid advances in technology result in IT equipment becoming obsolete at an

increasingly rapid pace. This is resulting in an increase in the rate and quantity of IT

equipment entering the waste stream;

? A piece of IT equipment was, or is typically of high value, both in terms of its

component parts and the equipment itself;

? IT equipment commonly contains toxic materials, which are hazardous if not

managed properly.

This project provides a broad overview of how such products are

handled and to estimate the amounts of these products and materials that will enter the

waste stream in the next few years.

The specific waste streams addressed include:

? personal computers,

? monitors,

? laptop computers,

? peripherals (e.g., printers, scanners),

2.0 WASTE ESTIMATES FOR IT EQUIPMENT

This section will address the generation and flow of computer equipment waste

from both residential and IC&I sources in Canada. The types of computer equipment

addressed in this project and discussed in this section include:

- Computers (personal computers, servers);

- Monitors;

- Laptop computers;

- Printers;

- Note-pads/note-books, and;

- Peripherals (scanners, modems, keyboards etc.).

The flow of computer equipment in the solid waste stream will require increasing

attention in the future for the following reasons:

- The decreasing lifespan of IT products and their increasing annual sales,

resulting in greater discards of computer equipment waste on an annual basis;

- The mixed composition of computer equipment (i.e., metals, plastics, glass),

which makes dismantling and recycling challenging;

- The presence of hazardous materials; and,

- The life cycle ecological burden represented by waste IT equipment.

Computer equipment can become obsolete as a result of technological

advancements, for example:

- Increasing micro processing speed – from 80386 to 80486 to Pentium I, II and

now III generation systems;

- Increasing memory capacity to support faster microprocessors and expanded

storage requirements;

- Internet developments that cannot be accessed using older systems;

- New and expanding operating systems and software that cannot run on older

systems;

- Advancements in color, resolution and technology for monitors (i.e., flat panel

monitors);

- Increasing speed and color performance for laser and ink-jet printers, and

- Merging technologies such as “all-in-one” equipment, with faxing, printing and

scanning capabilities provided in one unit.

These factors have reduced both the average first life and total lifespan of

computer equipment – where first life refers to the amount of time a product is useful to

its original owner and total lifespan is the period from manufacture to disposal 2.

Computer equipment sales are projected to continue to grow as a result of

decreasing lifespan and the increased use of computers in businesses, institutions and

at home.

The largest growth in computer sales is into the residential market. In 1998 there

were 1.9 million computers installed in Canadian homes and in 2000, there were 2.2

million – an increase of 16%. In the education sector, installed computers increased by

9% in 1999, to 1.4 million. Installed computers in the business sector increased from 6.2

million in 1999 to 7.0 million in 2000 – an increase of 13% 3.

Figure 2-1 presents a simplified schematic of the lifespan of computer equipment

from point of sale, through use, to end of first life, to diversion (reuse and recycling) and

to disposal.

3.0 IT Waste Generation

Each year millions of new computers, monitors, laptops and peripherals are sold

into the Canadian marketplace. Some of these sales represent ‘new’

customers(Businesses, Institutions, Homes, Government offices) who are purchasing

computer equipment for the first time, while the majority are those that are replacing old

or out dated equipment found in residential, commercial and institutional settings. The

obsolete equipment is typically 3-5 years old 4 and, while often still usable (i.e., not

broken), it no longer meets the needs of the user. The point at which a computer

becomes obsolete is also referred to as the end of the equipment’s first life.

Obsolete computer equipment will be directed to one of four destinations/outlets:

1) Storage, 2) Reuse, 3) Recycling, 4) Disposal. (as shown in figure below)

Storage:

In many instances, discarded computer equipment is placed in storage. For

residential computers this may mean storage in basements, or for business computers

this may mean placement in storage or warehousing areas. In many cases IT

equipment is stored largely because the owner hopes that the out-dated equipment has

some potential resale value, or that they may use it in the future. In other cases,

equipment is stored simply because people do not know what to do with it and are

resistant to throwing out a piece of equipment that may have cost them thousands of

dollars a few years ago. Accurate quantification of the number of computers being

stored is not available, but estimates range from 45% to 50% of obsolete computers 5.

Eventually, stored computers will end up being disposed.

Reuse:

End of first-life computer equipment typically goes to one of two reuse

applications: 1) resold as used equipment, or 2) donated to a charity organization.

Retail outlets, both traditional and Internet-based are increasingly becoming avenues for

the sale of used computer equipment. IT manufacturers are also getting into the

business of selling used equipment.

Used IT equipment that retains some useful value will likely be resold into the

secondary computer market under the following scenarios:

- When businesses sell or auction IT equipment into the secondary market for

resale through retail outlets as used computers or for computer parts and

components (e.g., hard drives, motors/fans, CPU’s etc.), and

- End-of-lease IT equipment that is returned to the leasing company at the end of

a two or three year lease is typically sold or auctioned by the leasing company

to secondary computer companies and brokers.

A smaller percentage of used business IT equipment is often sold to employees

for personal use. With the rapid development of computer technology, this option is

diminishing. Computer equipment and dismantled components can be reused and resold

through a variety of outlets, including:

- Cascading or informal distribution of a computer within a company or within a

family;

- Through private resale companies that purchase used equipment in order to

refurbish and resell computer equipment for a profit in local or foreign markets;

- The sale of component parts that have been dismantled by primary recyclers;

- The redistribution of donated equipment (nationally or internationally) through

nonprofit organizations, sometimes in partnership with other companies that can

refurbish equipment.

Recycling:

The recycling infrastructure for computer equipment includes a mix of

primary and secondary recyclers and metal smelting facilities. Typically, primary

recyclers refurbish equipment for resale where possible and dismantle and sort the

remaining equipment into component parts, such as circuit boards, CRT’s (cathode ray

tubes), plastic housing and wires. Sorted materials are then sold to secondary

recyclers or smelters for further processing, or are sent to disposal outlets. Primary

recyclers rely mainly on manual labor for refurbishing and dismantling, although some

mechanical and automated systems are now available.

Secondary recyclers process metals, plastics and glass contained in the IT

equipment to recover raw materials. These recyclers generally use highly automated

processing equipment, requiring minimal manual disassembly.

Electronic and computer waste can also be processed at smelting facilities to

recover precious metals. The pyrometallurgical process utilized at a smelting facility

involves the melting and fusing of ores to separate metallic constituents, such as lead or

copper.

Smelters can also use the leaded glass contained in CRTs as a fluxing agent in

the production of pure lead 7. Noranda’s Horne facility in northwestern Quebec is the

largest North American copper and precious metal smelter 6.

CRTs require special processing because they can contain from 0.7 to 2.7 kg of

lead depending on the monitor size and year of manufacture. Monitors that can not be

refurbished can be recycled into new CRTs or used as fluxing agents by a secondary

lead smelter. To reuse an old CRT in the manufacture of a new CRT, the face glass is

separated from the neck and funnel glass and the frit bonding compound by sawing the

CRT at the frit bonding compound. If the CRT glass is to be used as a fluxing agent it

does not require separation. The glass can be recovered in this process as well 7.

Disposal:

IT equipment as a whole or as its dismantled component parts can be

disposed in landfills or incinerators. At this time, there is limited information available

on the percentage of the waste stream that is made up of IT equipment. A 1999 waste

composition study in the City of Calgary found that electronic equipment (including

computers, radios, televisions etc.) comprised 1.2% of the residential waste stream or

3,000 tons per year 8. This is comparable to US solid waste data that shows that

electronic waste comprises 1-2% of the solid waste stream 9. Equivalent information is

not available for IC&I waste at this time but could form the focus of future studies.

The projected trend of estimated quantities of Information technology waste disposed

from 1999 to 2005 is given below :

Projections for the flow of IT equipment and storage patterns can be further refined

as more recovery information becomes available regarding quantities of computer

equipment that are reused and recycled in Canada.

The waste flow estimates for various pieces of computer equipment are presented in the following tables:

- Table 2-2– Personal Computers

- Table 2-3– Monitors

- Table 2-4– Laptop Computers

- Table 2-5– Peripherals

Based on the Waste Flow Tool, it is estimated that in 2000, approximately 33,972

tons of IT equipment waste (including PCs monitors, laptops and peripherals) was

disposed, 15,592 tons was recycled, 24,507 tons was sent for reuse and 6,128 was

put into storage. Some pieces of IT equipment which had been stored or reused in

previous years entered the waste stream in 2000. Of the IT waste disposed, PCs and

servers accounted for an estimated 10,833 tons, monitors accounted for an estimated

10,688 tons, peripherals (scanners, printers, etc) accounted for about 11,474 tons and

laptops accounted for about 977 tons. In 2005, the Waste Flow Tools predict that

approximately 67,324 tons of IT equipment waste (including PCs monitors, laptops and

peripherals, but excluding mainframes and other large equipment) will be disposed,

47,791 tons will be reused, 11,948 tons will be stored and 43,428 tons will be recycled.

Of the total IT waste that will be disposed, PCs and servers will account for an estimated

23,349 tons, monitors will account for an estimated 24,472 tons, peripherals (scanners,

printers, etc) will account for about 17,396 tons and laptops will account for about 2,107

tons.

Note:

The quantities disposed, recycled, stored and reused do not add to the amount of

IT equipment that became obsolete in 2000 because a portion of IT equipment from

storage and reuse from earlier years enters the IT equipment waste flow in 2000.

4.0 Materials Contained in IT Equipment

The challenge encountered in diverting computers and peripherals from the

waste stream through recycling and refurbishing activity result from the diversity of

products and variety of materials contained in each product. For example, each hard

drive contains a range of metals and plastics that can be difficult to separate. It is also

difficult to identify the different plastics contained in each piece of equipment by resin

type.

The composition of personal computers and monitors are given in the Table 2 – 7

and the chart below:

? Precious metals include nickel, manganese, cobalt, barium, tin,

silver, antimony, chromium, cadmium, selenium, mercury, gold and

arsenic.

Many of the materials contained in IT equipment can be potentially hazardous if

improperly managed. For example, printed circuit boards contain heavy metals such as

antimony, silver, chromium, zinc, lead, tin and copper and a CRT in a computer monitor

can contain from 0.7 to 2.7 kg of lead depending on the monitor’s size and year of

manufacture 10.

The production of semiconductors, printed circuit boards, disk drives and

monitors use a number of hazardous materials 11. The lead oxide used in the cathode

ray tubes (CRT) of computer monitors is of particular concern and it has been estimated

that computer monitors represent approximately 15% of the lead found in the municipal

waste stream 12.

Hazardous materials found in obsolete computer equipment can be released to

the environment through the following pathways:

- Incineration of computer equipment concentrates heavy metals in ash residue;

- Landfill disposal of computer equipment, and;

- Recycling and recovery of computer equipment waste.

The estimated quantities of materials contained in disposed PC’s and monitors in

Canada in 1999 and in 2005 are shown in table and chart below:

The hazardous materials contained in computer equipment that are of greatest

concern are summarized below.

Lead

Lead is found in the CRT, in the soldering of printed circuit boards and in other

components of IT equipment. Lead represents approximately 6.3%, by weight of an

average PC 13. Based on the total number of obsolete PC’s and monitors in Canada in

2000, this translates to about 1,356 tons of lead disposed in 2000.

Based on the prediction that 47,821 tons of PCs and monitors will be disposed

in 2005 and assuming that the average composition of this equipment will not change

significantly by that year, 3,012 tons of lead will be disposed with this stream in 2005.

A CRT in a computer monitor can contain from 0.7 to 2.7 kg of lead depending on the

monitors size and year of manufacture. This lead is contained in various components of

the CRT, including: 14

? The glass funnel, which is glass that is 22-25% lead (bound into the glass). Lead

is used in the funnel to shield users from radiation produced by the electron gun.

? The faceplate, which contains 2-3% lead bound into the glass.

? The frit (a glass solder that joins the faceplate and funnel components of the

CRT), which contains 15 to 100 grams per CRT.

The lead contained in the frit is of greater concern because it is in a soluble form

(primarily lead oxide) that can leach 15, while the lead contained in the glass funnel and

in the faceplate is in an insoluble form.

Cadmium

Cadmium is present in certain components, including chip resistors, infrared

detectors, semiconductors, older CRTs and is sometimes present in plastics as a

stabilizer. Cadmium represents approximately 0.009% of a PC by weight 16. Based on

the total number of disposed PC’s in Canada in 2000, this translates to 2.0 tons of

cadmium.

Based on the prediction that 47,821 tones of PCs and monitors will be disposed

in 2005 and assuming that the average composition of this equipment will not change

significantly by that year, 4.5 tons of cadmium will be disposed with this stream in 2005.

Mercury

Mercury is used in printed circuit boards, batteries, switches and printed wiring

boards. While the percentage found in the average PC is only 0.002%, 17 based on the

total number of disposed PCs estimated in Canada in 2000, this represents 0.5 tons of

mercury. Mercury is also found in the fluorescent lamps that were previously used to

backlight laptop computer screens, but have now been replaced with xenon.

Based on the prediction that 47,821 tons of PCs and monitors will be disposed in

2005 and assuming that the average composition of this equipment will not change

significantly by that year, 1.1 tons of mercury will be disposed with this stream in

2005.

Brominated Flame Retardants

Brominated flame retardants are used to reduce the flammability of plastics in

electronic products. They are most typically used in circuit boards, connectors, plastic

covers and cables 18. There are many types of BFRs (more than 60), some of which are

more toxic than others. The European Union Waste Electrical and Electronic Equipment

(WEEE) Directive has chosen to focus its efforts on the two classes of BFRs that pose

the highest cause for concern, that is, polybrominated biphenyls (PBB) and

polybrominated diphenyl ethers (PBDE). These are the compounds that are most likely

to form dioxins and furans during the incineration process. When these compounds are

burned, brominated materials are converted into polybrominated dibenzo furans (PBDF)

and polybrominated dibenzo dioxins (PBDD) and can be released into the atmosphere.19

Therefore, when plastics containing BFRs, in particular PBB and PBDE, are

extruded during the recycling process or when they are incinerated for disposal,

hazardous compounds may be released into the environment.

Polyvinyl Chloride Plastic (PVC)

Although most computer moldings are now made using ABS plastic, PVC has

been widely used in computer cabling and housings. There is a risk that dioxins and

furans will be formed when PVC is incinerated. In addition, PVC is a difficult plastic to

recycle if mixed with styrenics and contaminates other plastics (e.g., PET) in the

recycling process.

5.0 IT Equipment Design Changes to Reduce Toxicity and Facilitate Recycling

Many manufactures are attempting to eliminate substances of concern from their

products, including, lead, arsenic, brominated flame retardants, cadmium, hexavalent

chromium, mercury and PVC. Examples are provided below.

Hewlett-Packard’s Office Jet 500 multi-purpose printer uses a metal chassis and

power supply enclosure to eliminate the need for flame retardants and light emitting

diodes (LED’s) instead of a mercury lamp for the scanner, and eliminates the need for

batteries by using flash memory technology.

The primary plastic resin used in Intel’s PCs and servers (ABS and

polycarbonate) does not use flame retardants that contain PBBs or PBDEs.

None of their products contain asbestos, or include lead or cadmium as plastic

additives. 20

Philips Consumer Electronics evaluate all of its products against their list of

banned substances (asbestos, cadmium, mercury, CFC/HCFC, PCP, PCB, PCT,

PBB/PBBE) before their introduction. 21

Motorola conducts research with their suppliers of printed wiring board laminates,

plastics, and electronic components to replace lead and BFRs. 22

Panasonic has identified 37 substances of concern in their manufacturing

process with 13 targeted for elimination and the remaining 24 for reduction. 23

Sony Corporation is developing a non-lead based solder for some products and

seeks to eliminate dioxin forming compounds through design guidelines. 24

Toshiba has introduced the Satellite 2520 notebook with a halogen-free

motherboard and plans to switch over to halogen-free boards for the entire PC

product range by the end of 2001. 25

Digital’s (now Compaq) Corporate Regulated Material Specification includes the

banning of PBBs, PBBOs and PBBEs. Numerous other halogenated compounds

are listed in this specification including the 25 halogenated dioxins and furans,

which are restricted by the German Dioxin Ordinance.

As a part of Sony’s Green Management 2002 Plan, they will eliminate the use of

halogenated flame retardants in all European models by 2001 and in all models

by 2002.

Many manufacturers are improving the recyclability of their products by

incorporating recyclable materials into products, by making their products easier to

dismantle and by marking the various materials contained in the equipment, for example:

Plastic components of Apple products that are greater than 100 grams are made

from the same type of plastic material;

Apple designs its product with latches, snap-in connections, and single screw

types requiring no specialized tools;

Hewlett Packard designs many of its products so that they are easier to take

apart; many components simply snap apart, making it easier to separate metal

from the plastic;

IBM’s DfE (Design for the Environment) guidelines encourage the use of snap fits

instead of fasteners, and where fasteners are used, they use a minimum number of

standard sizes that do not require special tools when dismantling, and Intel’s product

design checklist encourages ease of disassembly and appropriate materials choice.

6.0 Future Trends in IT Technology

The IT sectors are converging at a rapid rate and with the development of fibre-

optic networks, data, sound and video will be accessible at a rapidly expanding rate. It is

challenging to predict the extent to which the future will be different to the present. This

section will describe a number of trends identified through the literature review and survey

carried out for this study, but will not attempt to estimate the potential impacts of these

trends because of the significant uncertainty involved.

General Trends

Moore’s Law, based on a 1965 prediction by Intel cofounder Gordon Moore,

states that processing power will double every 18 months. This has been the case since

the early 1970’s and it is not expected to change even ten years from now 26. Recent

advancements in wireless phone and notepad/Palm organizers have resulted in

predictions of the demise of the PC.

Rumors of the PC’s demise may be premature, but they aren’t necessarily

exaggerated. No one can say for certain whether the PC will survive the coming

onslaught of super smart alternative computing devices ranging from wireless phones to

household appliances. Such products could make the PC less essential. In short, you

can expect PC to become smaller and more powerful, with thinner and lighter screens,

and advances in voice recognition could ultimately make your mouse and keyboard a

museum piece. But while the aging PC may undergo some cosmetic nips and tucks, it

probably won’t disappear altogether – at least not in the near future. 27

There is a new trend away from PC’s to NC’s (network computers) in the

workplace and for networks data to be contained on the Internet rather than on a

computer based network server. This approach means that the computers on people’s

desks at work will not have hard drives, which will all be located on one server. Units of

hardware, such as monitors and keypads are predicted to last at least ten years, and the

server will be upgraded only as needed. This approach will significantly reduce computer

system maintenance requirements. Also, from this study’s point of view, the size of

equipment involved – a small desktop NC – will be considerably smaller than existing

PCs, and the rate at which these units will be discarded may be slower than for current

technology, thus reducing the flow of IT waste to disposal.

7.0 Technology Changes in Computer Equipment

Flat panel displays (FPDs) such as plasma display panels and liquid crystal

displays (LCD) offer several environmental advantages over CRTs, including reduced

Weight volume, energy consumption and lead content. Lifecycle analysis and recycling

of FPDs is being researched at the University of Tennessee. It should be noted that

while FPDs do not contain leaded glass, they do contain levels of mercury that are

comparable to fluorescent lights 28. While FPDs are currently available, they are

prohibitively expensive for many users. FPDs are expected to be priced more

competitively in 2003, but will still be more expensive than CRTs. 29

Many manufacturers are also attempting to design their equipment to facilitate

upgrading. For example, IBM Printing Systems Company’s InfoPrint 3900/4000 printer

engine has been upgraded 19 times since 1990, enabling customers to upgrade their

equipment rather than dispose of it. 30

Another example of advancements in computer technology is the development of

one machine with printing, faxing, scanning and copying capabilities. The development

of these comprehensive machines will replace the need for four separate pieces of

equipment with one, at a lower or comparable price. This may result in a significantly

reduced amount of waste IT equipment at the end of its useful life.

Given the rapid technological advancements and the reducing “lag time” or

lifespan of computer equipment, it will be challenging for waste management planners

and policy makers to keep pace.

Corporate Environmental Developments

Worldwide trends in corporate environmental programs such as ISO 14001, EMS

and Extended Producer Responsibility (EPR) are beginning to impact computer

manufacturers in North America. Design for the Environment (DfE) programs at IBM,

Apple and Compaq are addressing issues such as eliminating brominated flame

retardants (BFR) in plastics, finding alternatives to lead for circuit board solder, and

labeling of plastics to aid in dismantling.

8.0 IT EQUIPMENT REUSE AND RECYCLING ACTIVITIES IN CANADA

The IT equipment reuse and recycling infrastructure in Canada is far from

uniform and has limited coverage. It is an immature business, with a relatively small

number of companies across the country, but the numbers are growing. It is expected

that the demand for this type of service will continue to grow as increasing quantities of

IT waste enter the waste stream in future years.

That said, there are already a number of IT equipment waste reuse and recycling

companies across Canada. Most companies try to refurbish viable IT equipment where

possible, as this generates the highest revenue per unit. Units which can not be

repaired, upgraded or sold, are manually dismantled by most recycling companies, who

sort the IT equipment into its various components (sometimes into 40 separate

categories) in order to get the highest market price for high quality material streams such

as wire, circuit boards, power bars, semi-precious and base metals, etc. There are also

some automated computer recycling companies that provide secure destruction services

for information contained on hard drives, that also recycle component materials. Many

companies who recycle IT equipment also handle telecom equipment.

9.0 CONCLUSIONS

This preliminary baseline study estimated that approximately 33,972 tons of IT

waste were disposed in Canada in 2000. This number is expected to rise as IT

technology continues to develop at its currently rapid pace, and IT equipment faces

continuous redesign and shorter life spans. It is assumed that a significant amount of

this waste is currently in storage, because people and businesses are unsure of what to

do with it.

Throughout Canada, both residential and commercial IT waste generators are

willing to recycle or reuse this equipment, but do not know how to go about doing this. A

directory of all the options available across the country would help considerably to

increase recovery of this waste stream, as people are reluctant to dispose of equipment

which cost a lot of money a few years ago.

The infrastructure to reuse and recycle IT waste is relatively undeveloped in

Canada at this time, but is beginning to develop at a rapid pace. As an example of this

growth, there were 4 companies in Western Canada until recently who dealt with the

recycling of IT waste, but this number has grown to about 25 this year, with increasing

need for this type of service. The Canadian infrastructure is considerably less developed

than in the US, in part due to our geography and smaller population. The capacity for

handling CRTs is particularly low, as it is globally. While processing capabilities are in

place, industry has not expressed an interest in conducting a take-back program similar

to those operating in the UK or Sweden. IT waste presents a number of challenges

because of the complex combination of materials involved (specialized plastics and

precious metals). Technologies are available to effectively refurbish and recycle this

equipment, therefore many options to disposal are available. Trends in the IT business

include a focus on designing IT equipment to facilitate easier dismantling, and a focus on

identifying options to recycle CRTs. Recycling and refurbishing of CRT’s is less

developed than for other equipment.

The IT business in Canada is characterized by numerous suppliers and agents,

but relatively little manufacturing directly in Canada. Any manufacturing by large IT

companies is carried out in the US or overseas. A number of companies were sending a

considerable amount of equipment to China. This market was closed to overseas outlets

on 1 April, 2000, which may have significant impacts on a number of the companies in

Canada who deal with this waste.

At a future date, a complete listing of all companies and organizations in Canada

who deal with IT waste should be developed, and a comprehensive survey

of all of these companies should be carried out to identify their current operations and

capacity and any barriers to increased recovery.

Leased IT equipment is easier to recover than purchased equipment, because of

the relatively limited number of suppliers involved, and the relatively easy recovery

mechanism. At this time, an estimated 75% of IT equipment in Canada is purchased

rather than leased, therefore this is the predominant pathway which needs to be

disaggregated as much as possible. Also, recovery options are different for IT equipment

generated by households, compared to businesses, therefore at a minimum, a split

between residential and commercial IT equipment owners needs to be identified.

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