UBC Social, Ecological Economic Development Studies (SEEDS) Student Reports

An Investigation into Sustainable Computer Hardware For the New SUB

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APSC 261 Project Report
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ABSTRACT

The Alma Mater Society is currently in the process of building a new Student Union Building at UBC. One of the goals of this project is to make the new SUB as sustainable as possible. As part of completing this objective, the AMS is looking into sustainable computer hardware. The goal of this project report is to advise the AMS on the various types of computer hardware available, analyse each of their strengths and weaknesses and then recommend solutions based on a triple-bottom-line assessment that encompasses the social, economic and environmental aspects of sustainability.

The assessment is broken down into three sections: System Units, Displays and Waste Disposal. The System Unit section deals with the parts that comprise the processing elements of the computer (conventionally known as the tower). Three systems were compared: Desktops, Nettops and Thin Clients. Thin Clients are what is being recommended due to their low power consumption, low maintenance cost and low requirement of materials to manufacture them. Three types of displays were analyzed: CCFL-LCDs, LED-LCDs and OLEDs. OLEDs are chosen for their long-life, low-power consumption and the lack of toxic chemicals.

For Disposal of old computers, various aspects are analyzed: Stewardship program items, non-stewardship program items, and reuse items. It recommended that the best approach would be to reuse the old computers as part of the thin client hardware and send physically damaged ones to recycling companies such as E-Cycle.

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GLOSSARY

Basel Act Network Convention: The Basel Convention came into force in 1992, and is a global environmental agreement on the control of trans-boundary movements of hazardous wastes and their disposal (About the Convention, 2009).

Cold Cathode Fluorescent Lighting: Backlighting technology used in LCD Screens.

Gigabyte: Unit of information storage

Hardware: Physical, material parts of a computer system.

Light Emitting Diode: A device that converts electrical energy into light energy of a specific color

Liquid Crystal Display (LCD): A display technology used in TVs and computer monitors.

Nettop: A nettop is a very small form factor, inexpensive, low-wattage desktop computer designed for basic tasks such as surfing the Internet, accessing web-based applications, document processing, and audio/video playback (Mann, 2009).

Software: Abstract informational parts of a computer system.

System Unit: This is the processing center for a computer. Conventionally known as a tower, it contains most of the information processing hardware of a computer such as the CPU, RAM, motherboard and the hard drive

Total Ownership Cost: The total cost of owning a computer system. This includes the initial cost of buying the computer itself and the costs incurred during the operational lifetime of the computer.

Watt: Unit of power consumption

LIST OF ABBREVIATIONS

AMS: Alma Mater Society

CCFL: Cold Cathode Fluorescent Lighting

CRT: Cathode Ray Tube

GB: Gigabyte

GEEP: Global Electric Electronic Processing

LCD: Liquid Crystal Display

LED: Light Emitting Diode

SUB: Student Union Building

UBC: University of British Columbia

TOC: Total Ownership Cost

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1.0 Introduction

The Alma Mater Society of the University of British Columbia will be building a new Student Union Building (SUB) by 2014. UBC has always strived to maintain high levels of sustainability in all its operations. UBC would like the new SUB to be highly sustainable in every aspect. One of the major components of the new SUB will be the computer hardware, specifically the student access terminal computers. These computers provide students access to the internet and other computer facilities of the SUB.

The AMS would like to have the latest and most sustainable computer systems implemented in the new SUB. This report will analyze the types of hardware available and make a recommendation to the AMS on which hardware to purchase. The analysis will follow a triple-bottom-line assessment of the two main components of a computer: System unit and the display and the various methods of recycling and reusing computers.

Due to the rapidly advancing technology in this field, product specific recommendations cannot be made as they would definitely be obsolete by 2014. Instead, whole classes of hardware will be assessed and then recommendations will be made upon these assessments.

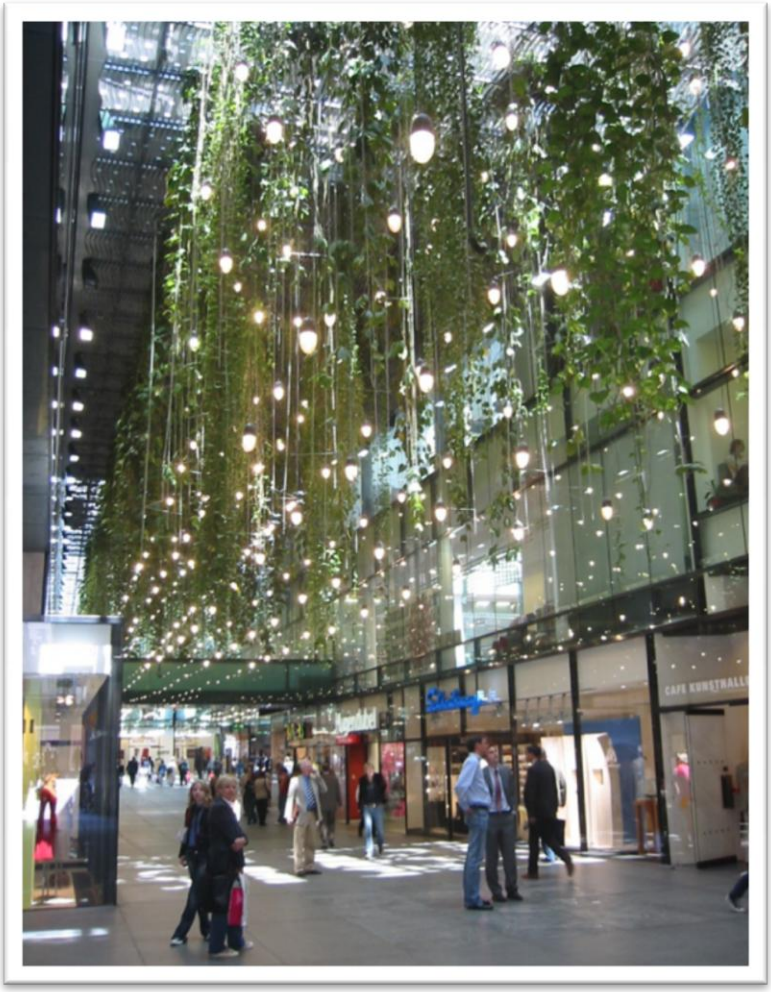

Figure 1: Ideas for a Future Green Sub

Source: UBC AMS http://www2.ams.ubc.ca/index.php/ams/subpage/category/new_sub_timeline/

2.0 System Units

System Units (SU) are the brains of any computer system. They contain all the processing hardware such as the CPU, GPU, memory, hard drive, optical drive and the motherboard. They are conventionally known as the "tower".

This section discusses the system units that will be implemented into the new SUB. It identifies the factors to consider and then compares the various system unit types available and analyses their strengths and weaknesses with respect to these factors. There are three main system unit types available in the market: Desktops, Nettops and Thin Clients. These three systems will be analyzed. Specific product recommendations cannot be made as in the computing-world, the technologies change very rapidly, and one cannot anticipate these changes. Hence, entire classes of system units will be analyzed as one and recommendations would be made to one of these classes.

2.1 Factors Considered

Environmental

Power Consumption

Computers can consume a large amount of power. Having lower power consumption ratings is beneficial to the environment, especially when a large number of computers are present.

Lifetime

Hardware needs to last long (at least 5-6 years) before being obsolete. This not only saves money but also keeps the environment cleaner as there will not be a need to dispose of computers often.

Size

Computers vary a lot in size. A larger computer typically uses much more material-plastics, metals, cardboard packaging composites, etc. A large computer is also more expensive to transport, causing more emissions. A large computer also has a reduced aesthetic value.

Economic

Initial Cost

This is the primary cost of the computers themselves. Cost needs to be minimized so that many more computers can be purchased for the same capital. This will allow many more students to use them at the same time.

Maintenance Costs

Computers also incur secondary maintenance costs. Hardware failures are common in large installations. When used in a public environment such as the SUB, the computers are subject to vandalism, both physically and through software. Having mechanisms that can easily and quickly reset the computer back to its original state would be preferable.

RELIABILITY

The computers at the SUB need to be highly reliable to allow students to use them whenever they need them. Frequent intermittent failures will only cause students to lose trust in the computer systems at the SUB. If students do not use the computers, then they will be running for no reason, defeating the purpose of having computers in the SUB.

SOCIAL

EASE OF USE

The computers need to be easy to use in order to allow access to everyone, regardless of their level of technical expertise.

2.2 DESKTOP COMPUTERS

These computers are the standard ones found in most people's homes, offices, etc. They are single stand-alone units with a complete set of hardware. They are configured with midrange CPUs (Intel Core 2, i7, Phenom X4), generous amounts of memory (4GB), large hard drives (250GB), optical drives and graphics processing units. They are powerful computers and are able to run almost any software without a hitch. They also tend to last quite long before becoming obsolete. They do tend to consume large amounts of power, cost more and need more maintenance. They also occupy a lot of physical space. Due to the large size, they also take a large amount of materials to make them. Transporting them also costs a lot. The advantages and disadvantages of this computer system are listed in the table below:

TABLE 1: ANALYSIS OF DESKTOP COMPUTERS

Advantages	Disadvantages
• **High performance** • **Good device support** • **No need for special Software/Operating Systems to run** • **People already know how to use them** • **Reliable** • **Medium life (5 Years at least)** • **Can run most Programs**	• High Power Consumption (500w[1]) • Needs maintenance and support • The computer itself is heavy and large, difficult to transport • Somewhat expensive($800 for mid range) • Can be upgraded fairly easily

[1] Wattages and prices are not for specific products, but they are representative of products available in the market in November 2009.

2.3 Low-Power Net-tops

A nettop is a very small form factor, low-wattage computer designed for basic tasks such as surfing the Internet, document processing (Casiraya, 2008). These are computers with reduced hardware. They run low-power processors (Intel Atom/AMD Sempron) with small hard drives, low memory, no GPU, no optical drive. They may run special Linux based operating systems or older versions of Windows. They are inexpensive, consume very little power and are physically small and light. They also do not take much material to make and are inexpensive.

Refer to Table 2 for an analysis of nettop computers' strengths and weaknesses.

Figure 2: Linutop Nettop and a CFL Bulb for comparison of size and power usage (8w)

Source: http://www.linutop.com/linutop2/index.en.html

Table 2: Nettops

Advantages	Disadvantages
• **Low power consumption (~60W)** • **Compact(Figure 2), easy to transport** • **Inexpensive (~$400)**	• Short life. (3 years) Since these computers have low performance, they get obsolete very quickly. • If a special Linux OS is used, then people may not know how to use it. • Needs maintenance and support. • Will not run all programs. Limited by low performance. • Not easy to upgrade. Most of the time, it is not upgradable.

2.4 Networked Thin Client Systems

These computers are based on a server-client system. The computers themselves are very low power and low performance hardware. They are mostly only to receive input from the user and forward it to the central server. The central server then processes the input and forwards back the output to the client and to the user. The server is a high performance computer with fast hardware. However, since this computing power is shared across the clients, most demanding applications cannot be run. However, this setup will do fine for web browsing and office applications. A powerful centralized server will need to be setup.

Due to the networked nature of the thin client systems, most maintenance operations need to be done only on the central server. Vandalized computers can be easily reset regularly, or even after a user logs off.

Table 3: Thin Clients

Advantages	Disadvantages
• **Very low power consumption (~20W)** • **Total ownership cost is lower than desktops (30% lower)** • **Performance is scalable (more servers means more performance)** • **Very easy to manage and maintain (only the server needs maintenance)** • **Compact systems** • **Easy to upgrade** • **Has long life (Only the server needs to be upgraded or replaced)** • **Could even use existing/older hardware as clients at no cost.**	• Low performance (a single server cannot handle very intensive tasks) • Device support is limited. • Failure of the server can bring down all the systems in the system

2.5 Bottom Line

Considering all the environmental, social and economic factors, Thin Client systems seem to be the best choice for the SUB computers.

They offer many advantages over the other types of computer systems because of the following reasons:

- Superior energy savings through low power consumption.
- Low Total Cost of Ownership (TCO) and running costs.
- Centralized remote management systems reduce maintenance costs.
- Can reuse the existing computers as clients.
- Long Life.
- High Reliability.

3.0 Display

This section discusses the display that will be used with the new computer hardware in the new SUB. The approach to selecting a display is to first identify the factors that need to be considered, then assess available technologies, and finally select a technology based on the assessment. There are three predominant display types available: CCFL-LCD, LED-LCD and OLED. These three will be analyzed. Only a specification guideline of the final product will be recommended at the conclusion of this section, the specific model shall be carefully selected according to the guideline when the time comes.

3.1 Factors Considered

Environmental

Material

Displays can contain chemicals that are harmful to the environment especially when disposed of. Dangerous materials can be released into the environment during the manufacturing process of the display. The display should contain if possible, none of such materials.

Power Consumption

Display consumes a significant portion of power in a computer system. The display is expected to consume zero power on standby, and very little power on active. The power rating should be well below Energy Star standard.

Economic

Unit Cost

The unit cost for a standard size display should be within a reasonable range given the limited budget for the new SUB.

Operating Cost

This is the economic benefit of low power consumption. The cost of electricity for running the displays is proportional to the power rating.

Lifetime

Displays do not go obsolete as fast as the processing hardware does. Thus, a good display should last quite long if properly maintained. Long life means fewer replacements are required and less money would be required.

Social

Privacy

The display needs to have a reasonable viewing angle so that the students can have privacy. Students would not be comfortable using the computers if the person next to them can see their screen clearly.

3.2 Liquid Crystal Display, Cold Cathode Fluorescent Lamp backlight (CCFL backlit LCD)

LCDs display images by letting light from a source pass through a combination of crystals and polarized glass. CCFL LCDs use cold cathode fluorescent lamps as the light source. LCDs are the most common computer display due to its low cost and low power consumption. The CCFL LCDs are used in the SUB now alongside with the older CRTs. According to the assessment factors, CCFL backlit LCD can be characterized as follows.

Table 4: CCFL Backlit LCDs

Material	Glass, mercury
Power Consumption	Relatively high due to energy loss from heat generated by CCFL
Unit Cost	Current market price: CAD 200+
Operating Cost	CAD 6.04 per unit per year[2]
Lifetime	Long, typically lifetime of a LCD display is about 60,000 hours
Privacy	High, viewing angle could be very small if needed.

3.3 Liquid Crystal Display, Light-Emitting Diode backlight (LED backlit LCD)

The LED backlight LCD uses the same technology as the regular LCD except the light source is from an LED matrix. The LED backlight LCD is a relatively new technology compared to CCFL LCD. Currently it is present mostly in the high-end display market, but it is gradually becoming mainstream technology.

Table 5: LED Backlit LCDs

Material	Glass
Power Consumption	Relatively low due to the efficiency of LED backlight
Unit Cost	Current market price: CAD 300+
Operating Cost	At least 30% reduction from CCFL LCD: < CAD4.23
Lifetime	Same as the 60,000 hour CCFL lifetime
Privacy	Same as CCFL

[2]Typical Energy Star rated LCD has power rating of 25 watts, assume 8 hours per day usage, annual power consumption equal to 73kWh, BC Hydro residential rate is 8.27 cents per kWh, thus each LCD cost 6.04 dollars per year.

3.4 Organic Light Emitting Diode (OLED)

OLED is a solid state device that generates light with thin films of organic molecules. This technology is currently under intensive research and development around the world. Although it has been used in consumer electronics, for display the size needed for computers the technology is still immature. There are still some problems like high cost and low lifetime. These issues are expected to be ironed out by 2014.

Table 6: OLED

Material	Organic materials
Power Consumption	Very low since it does not require backlighting
Unit Cost	Very high but expected to follow Moore's Law[3]
Operating Cost	Very low because of its low power consumption
Lifetime	30,000 hours currently, but expected to increase to 60,000 in the future
Privacy	Low. Since light emits directly off the surface, viewing angle is huge

3.5 Bottom Line

The old displays should only be replaced if the new ones can show a significant improvement amount on all the factors. The new SUB should definitely acquire new displays because current technologies used by SUB consume much more power than the future technologies available for the new SUB. Considering all that, OLED monitors seem to be the best solution for the new SUB, assuming the technology is mature in 2014. The reasons are as follows:

- Non-hazardous, bio-degradable materials
- Very low power consumption
- Very low operating cost
- Long lifetime (60,000 hours)

[3] Price halves every 18 months.

4.0 Computer Equipment Disposal

This section will look at the current practices for disposing of computer hardware and other electronics at UBC. Although it will mainly focus on the environmental implications, it will also address certain economical and social aspects. An assessment will then be made of the current situation, and a solution for improved practices will be recommended.

4.1 Stewardship Program items

The approved items for the Stewardship Program are desktop and laptop computers, monitors (LCD and CRT), televisions, computer peripherals (mice, keyboards, and cables), printers and fax machines (UBC, 2008). UBC Waste Management currently takes these items to be recycled at Encorp Pacific, a federally incorporated, non-profit product stewardship corporation. Encorp Pacific develops, manages and improves systems that recover used packaging and end-of-life products from consumers. They ensure that these items are properly recycled and not land-filled, illegally dumped, shipped overseas to developing countries, incinerated or handled by workers unsafely or unhealthily. To ensure that this is implemented, all processes are audited according to the Electronic Product Stewardship Canada's Environmental Recycling Standard. This standard is considered to be the minimum environmental, health and safety requirement for recycling electronics and strictly prohibits land-filling, improper handling and disposal of hazardous materials, and dumping of any equipment or parts in developing nations.

After the audit, all items are sent to one of the following:

- -E-Cycle Solutions
- -GEEP Alberta
- -Genesis Recycling
- -Sims Recycling
- -Teck Cominco

Once sent to one of these facilities, all electronics are either processed to recover raw materials, such as metals, glass and plastics, or sold to be re-used (refer to Table 7 to see where all the recovered materials go). Each of the above-mentioned organizations has a separation process with a recovery rate ranging from between 98% to 100%. Out of all five companies, E-Cycle Solutions is the only one that is regularly audited by the government. It also has a strict Operational, Health and Safety Program for the wellness of the employees and guarantees to render all electronics completely inoperable and all data to be completely destroyed (E-Cycle Solutions, 2007).Genesis Recycling also offers data destruction services, but for a fee of $3.50 / lb (Genesis Recycling Ltd, 2006). GEEP Alberta also re-sells some of the electronics for re-use, although it is not specified to whom the electronics are sold to (GEEP, 2009).

4.2 Non-Stewardship Program items

The Non-Stewardship program items include microwaves, stereo-systems, video cameras, DVD/CD players, large printers, scanners, hand-held electronics and other electronic items (UBC, 2008). UBC Waste Management currently sends their Non-Stewardship Program items to E-Cycle Solutions (above-mentioned).

4.3 Re-use items

UBC Waste Management currently sends their computer equipment that could potentially be re-used or refurbished to Free Geek Vancouver. Free Geek is a volunteer-based, non-profit, computer re-use and recycling centre that accepts all computer equipment, functioning or not and in any condition, free of charge. Free Geek is entirely locally owned and operated, and they give priority to re-use before recycling the equipment donated to them, because it involves less energy expenditure and potential pollutants that arise during manufacturing and transport. If they do need to recycle certain items, it is done locally rather than sending them overseas to developing countries, in accordance with the Basel Action Network Convention (Free Geek, 2009).

Computers for Schools BC, another non-profit organization, collects used computer equipment, refurbishes it, then sends it to schools, libraries, Community Access sites and learning focused organizations in BC. Computers for Schools operates in cooperation with federal, provincial and territorial governments, as well as the public school system, and it is directed and funded by Industry Canada. This organization provides over 1000 young people in Canada each year with technical work experience, and helps to increase the ratio of computers to students in Canada (Industry Canada, 2008).

4.4 Broken or smashed items

Broken televisions or computer screens refer to those items where the screens are physically damaged, which includes bare television tubes. It does not refer to the operability of the items due to other problems. Televisions and computers which are broken in this way are considered as hazardous materials as defined by provincial regulations and are not handled by any of the above-mentioned companies.

Table 7: Where Do The Materials Go?
Source: Encorp Pacific Canada. http://www.encorp.ca/cfm/index.cfm?It=939&Id=12&Se=40

Material/Component	Process	Result	Process Location
Leaded Glass	Hand Dismantle/Crushed/ Smelted	Metal Recovery	Canada
Glass	Grind	Material Recovery	Canada
Plastic	Regrind / Smelted	Plastic / Energy Recovery	Canada
Plastic	Bailed / Ground	Plastic Commodity	US
Metal (non-ferrous)	Ground / Smelted	Metal Recovery	Canada / US
Metal (ferrous)	Ground / Smelted	Metal Recovery	Canada / US
Other Metals (Brass, Bronze & Fine particles)	Smelter	Metal Recovery	Canada
Cables and Wires	Regrind	Metal Recovery	Canada
High Grade Printed Wire Boards (Circuit Boards)	Smelted	Metal Recovery	Canada / Belgium
Low Grade Printed Wire Boards (Circuit Boards)	Smelted	Metal Recovery	Canada / Belgium
Mercury Bulb	Distilled	Mercury	US
Mercury Bulb	Distilled	Phosphorus Recovery (Powder Reuse)	US
Batteries (non rechargeable)	Smelted	Metal Recovery	Canada
Batteries (rechargeable)	Smelted	Metal Recovery (Lithium, Nickel, Cadmium)	Canada / US

4.5 Triple Bottom-Line

The current computer disposal practices at UBC are acceptable. The current choice of recyclers all practice in accordance to the Basel Action Network Convention, which works to prevent globalization of the toxic chemical crisis. The current organizations recycle the received electronic items locally, and they handle and dispose of toxic materials in ways that are adequately safe and healthy for the workers and the environment. By keeping these current organizations as UBC's recyclers, we are taking active steps in preventing more electronic waste from being dumped onto the grounds of developing countries, where they build up on landfills allowing mercury and lead to leak into the ground, and where they are also often incinerated allowing flame retardants such as PCBs to be released, which is very harmful to the residents.

There could however be a few changes done to the current disposal scheme. It seems needless to send UBC's electronic waste to Encorp Pacific, since it is subsequently sent to E-Cycle Solutions, GEEP Alberta, Genesis Recycling, SIMS Recycling Solutions or Teck Cominco. Since all the Non-Stewardship Program items are sent to E-Cycle Solutions anyway, it is recommended that the Stewardship Program items be sent there directly as well, as this would eliminate unnecessary intermediates and be more cost efficient. Also, this would ensure the protection of privacy for the AMS staff and the UBC students and faculty, as E-Cycle Solutions guarantees the destruction of all electronic data.

Encorp Pacific would however be useful for the collection of UBC's broken electronics, as most other companies do not accept them because they are hazardous as such. Encorp Pacific has two locations in the lower mainland of B.C. which does accepts such items: Ralph's on Mitchell in Richmond, B.C. and Ralph's Scott Road Japanese in Surrey, B.C.

In terms of the computer equipment at the former SUB, it is recommended that the computers be used as clients for the new networked thin client systems proposed in Section 2. This way, UBC would avoid increasing plastic consumption and expending as much money as it would for either purchasing new computers or having them completely refurbished. However, if some are considered to be too old (this includes the displays and other equipment) to be re-used at the University, then it is recommended that they be sent to Free Geek, or also to Computers for Schools BC.

5.0 Conclusion

After assessing the available options and taking into consideration environmental, social and economic implications, a bottom line has been devised regarding computer hardware, displays, and the purchase and disposal practices of computer equipment for the new SUB. In terms of new computer hardware, Thin-Client Systems would be the optimal choice due to low energy consumption, Low Total Cost of Ownership, low maintenance cost, long life, high reliability, and reusability of old computers as clients. The recommended choice of display is the OLED monitor, because of its low operating cost, low power consumption, long lifetime, and it is composed of non-hazard and biodegradable material.

Finally, in terms of the old computers and displays, it is recommended that they be re-used, if possible, for the new networked Thin-Client Systems. If this is not possible then they should be sent for re-use to either Free Geek Vancouver or Computers for Schools BC. If this option is also not possible, then they should be sent directly to E-Cycle Solutions, and if any equipment at the old SUB is physically damaged, they should be sent to Encorp Pacific's Ralph on Mitchell in Richmond or Ralph's Scott Road Japanese in Surrey.

BIBLIOGRAPHY

About the Convention. (2009). Retrieved November 17, 2009, from Secretariat of the Basel Convention: http://www.basel.int/

Casiraya, L. (2008, April 4). *'Netbooks,' 'Nettops' target secondary PC users*. Retrieved November 17, 2009, from Inquirer.Net: http://technology.inquirer.net/infotech/infotech/view/20080404-128374/Netbooks-Nettops-target-secondary-PC-users

E-Cycle Solutions. (2007). *Secure Recycling Process*. Retrieved November 17, 2009, from E-Cycle Solutions: http://www.ecyclesolutions.com/index.php?option=com_content&view=frontpage&Itemid=1

Encorp Pacific. (2008). *Broken End-of-Life Electronics*. Retrieved November 17, 2009, from Encorp Pacific, Canada: http://www.encorp.ca/cfm/index.cfm?It=939&Id=19&Se=40

Encorp Pacific. (2008). *The Electronics Recycling Process*. Retrieved November 17, 2009, from Encorp Pacific Canada: http://www.encorp.ca/cfm/index.cfm?It=939&Id=12&Se=40

Free Geek. (2009). *Out Principles*. Retrieved November 2009, 2009, from Free Geek Vancouver, Canada: http://freegeekvancouver.org/en/computer_recycling_principles

GEEP. (2009). *E-Waste Product Resale*. Retrieved November 17, 2009, from Global Electirc Electronic Processing (GEEP): http://www.geepinc.com/productsresale.php

Genesis Recycling Ltd. (2006). *The Process*. Retrieved November 17, 2009, from Genesis Recycling Ltd. Aldergrove B.C. Website: http://www.genesisrecycling.ca

Industry Canada. (2008). *History of CFS*. Retrieved November 17, 2009, from Computers for Schools British Columbia: http://www.cfsbc.ca/bctechhistory.html

Mann, P. (2009, February 12). *A Glimpse of Computers to Come?* Retrieved November 17, 2009, from Hexus.net: http://www.hexus.net/content/item.php?item=17078

UBC. (2008). *What Items Does UBC Accept as E-Waste?* Retrieved November 17, 2009, from University Of British Columbia Recycling: http://www.recycle.ubc.ca/ewaste.htm