Efficient E-waste Managment in Costa Rica

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CXP-CR24

Project Number: CXP CR24 -41

Efficient E-waste Management in Costa Rica

An Interactive Qualifying Project

submitted to the Faculty

of the

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the
Bachelor of Science degree

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Date: June 28, 2002

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Abstract

Intel Costa Rica seeks to develop a system to manage computer scrap and its disposal in Costa Rica effectively. Through interviews and surveys of individuals and organizations that potentially may become involved with E-waste management, we researched Costa Rica's current situation concerning computer waste. We developed two recycling models as part of a comprehensive implementation plan. The long-term objective of this plan is to develop local recycling capabilities to manage the E-waste generated by Costa Rica and possibly neighboring countries.

Authorship Page

"Efficient E-waste Management in Costa Rica" was a combined effort, equally shared by Joseph Havelick, Antti Koski, and Daniel Wallance both in conducting field research and in writing the text. Individual sections were written first by either an individual or a collective endeavor as indicated below; however, each student reviewed the final report. Suggestions and comments were made by Professors Creighton Peet and Bland Addison.

The following outline illustrates who wrote each section before editing. JH corresponds to Joseph Havelick; AK corresponds to Antti Koski; DW corresponds to Daniel Wallance. Appendix F was created by Intel Arizona / Arizona StRUT. This was included as a reference document for Intel Costa Rica.

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Acknowledgements

Upon completion of this Interactive Qualifying Project, we would like to thank our generous and hospitable sponsor, Intel Costa Rica for initiating this project, and our supportive liaisons, Mary Helen Bialas and Anibal Alterno. Other Intel employees we want to recognize are Nacira Otoya, Todd Brady and Scott O'connell, the later two of Intel, Arizona. Also, we would like to thank our patient and supportive advisors from Worcester Polytechnic Institute, Professors Bland Addison and Creighton Peet.

In addition, we appreciate the informative contributions of the interviewees; Fernando Burgantes, Elizabeth Carazo, Jorge Cardoza, Adolfo Cordoba, Arturo Lopez, Ismael Mazón, Emilia Mora, Sergio Musmanni, Ana Gabriel Perez, David Portilla, Rosendo Pujol, Licda. Katia Rodríguez, Juan Carlos Salas, Henry Salazar, and Patricio Solis.

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Executive Summary

There is growing concern over the issue of E-waste disposal in Costa Rica. While the country is becoming more industrialized and computer usage is increasing, Costa Rica still lacks the facilities to efficiently dispose of these products once they become obsolete or broken. This issue has caught the eye of Intel Costa Rica, which is determined to create a solution before it becomes a serious problem.

Currently, most of Costa Rica's computer scrap is simply sent to local landfills, since this is the only feasible disposal method. Although at this time, this is not a vast amount of E-waste, the future promises greater numbers of computers that will need to be disposed of since computer usage is growing in the country. This is a problem with two dimensions. First, there are many toxic and potentially harmful substances that are found inside computers. Disposing of them in a landfill or dump could expose the surrounding environment and humans to the adverse effects of these substances. Granted, landfills are meant to isolate the trash and the leakage is supposed to be treated, but no system is entirely effective. In addition, they take up a large amount of space, and if the numbers of computers continue to rise as predicted, they will consume a significant amount of space in Costa Rica's landfills.

The second problem is that we are wasting resources. Old computers could be an excellent source of parts, precious metals, and plastics. Our initial concern before disposing of a system should be whether or not it could be reused in some way. Many times, an old system might not need more than a motherboard and CPU upgrade, saving all the other parts from disposal. In addition, it is always possible to donate an old system to someone with lesser needs. Ultimately, if a system has been deemed unusable,

it can be mined for individual materials, such as silver and gold. This brings us to our proposed alternative.

Ideally, Costa Rica would have a local mining facility that would take computer scrap and mine it for materials that could be sold on a materials exchange market. The problem is that currently, the closest facilities are in the US. In order to attract any mining company to Costa Rica, one would have to know first how much computer scrap would be generated per year in order to determine whether it would be a profitable operation. We, therefore, generated two recycling models, one which ships the material internationally to be processed, and the other which does the recycling locally. Both models include a function of refurbishment and recirculation of computers in order to make the most out of a system before it is sent to be mined.

Since shipping the material to the United States would cost more than the anticipated returns, it is not the ideal solution. Thus, we recommend implementing this model temporarily to raise awareness about computer scrap issues and the alternatives to landfills. Furthermore, the initial system would allow Costa Rica to gather statistical data that might be used to pursue the development of a recycling industry in Costa Rica.

In addition, we recommend two collection methods. First, a continuous collection cycle by which people could drop off their computer scrap at any time at a designated collection area. This would benefit corporations and organizations with large amounts of computer scrap, since they could dispose of them year-round. Second, we recommend the creation of a computer recycling day. Focusing publicity around this date, individual computer owners will be more likely to become informed and involved in E-environmentalism. Also, to help cover the costs associated with shipping scrap to the

US, local companies could be encouraged to get involved and help sponsor the event. Companies will be more likely to sponsor an environmentally friendly event such as a computer recycling day than a year-round initiative.

In the long run, statistical data will be generated which could be used to attract a mining business to Costa Rica. This will not only reduce disposal costs, but strengthen the local economy. In addition, this business might well become more profitable, as it will be the first in Latin America and other countries may choose to send some of their computer scrap to be processed, thus increasing the customer base of people willing to contribute computer scrap to the recycling system.

We believe these recommendations are for the good of Costa Rica, its people, and the environment. A reduction in E-waste will not only reduce the risk of harm from pollution, but also prevent the depletion of the resource pool. In addition, Intel Costa Rica has a chance to gain from a recycling industry as well. If a recycling industry were to develop, it would no longer have to ship its HVI to the US for processing, reducing its costs. Additionally, having Intel's name associated with the creating of a recycling initiative would make the public more aware of Intel's commitment to protecting the environment and people of Costa Rica.

"Efficient E-waste Management in Costa Rica" was prepared by members of Worcester Polytechnic Institute Costa Rica Project Center. The relationship of the Center to Intel Costa Rica and the relevance of the topic to Intel Costa Rica are presented in Appendix A.

Chapter 1 Introduction

American consumers desire novelty and speed. The chip-making company Intel realizes that there is a pride just shy of an obsession associated with being the owner of the newest, most attractive, or the fastest product on the market. Technological advancement in the capitalist economic system is driven by this phenomenon. In order to gain profits, industries such as Intel must develop their products to be newer and better. In turn, consumers have repeatedly sought these changes, purchased the newest products, and awaited eagerly the next best thing.

Although this system leads to incredible technological evolution, it does have shortcomings. The rapid paced purchasing and disposal of outdated technology leads to excess waste. Without a system in place to recycle old products into resources that are valuable, we are slowly depleting our total resource pool. Such is the case with the computer industry. Today, microelectronics symbolizes the core of modern technology, and the consumer market is continually creating large amounts of waste. With prices of personal computers dropping and the increasing desire to do things better, faster and more effectively, consumers repeatedly upgrade and replace their old computer systems. This creates an ever-growing amount of electronics waste, or E-waste.

E-waste is a problem with two dimensions. First, we have the issue of E-waste disposal. What is commonly considered waste actually consists of valuable materials. Printed circuit boards (PCBs) often carry several types of precious metals including gold and silver. It is sometimes thought that it is acceptable to just dispose of old electronics hardware, but in reality, you are throwing away valuable resources. Second, is the issue of environmental effects. Many electronics contain chemicals or compounds that are potentially dangerous to the environment and humans. For example, computer monitors alone contain a substantial amount of lead. Large scale disposal of such products could prove devastating to the earth and its inhabitants.

With computer usage increasing and lacking a recycling industry to process excess E-waste, many Costa Rican companies and individuals are starting to realize the potential harm that comes from the short life cycles of PCs. As it stands now, there is no effective, environmentally sound system in place for the recycling or disposal of locally produced computer scrap in Costa Rica. Intel, which built an assembly plant in Costa Rica in 1998, is also aware of this issue. They wish to research the possibilities of a system to manage out-dated PCs found in Costa Rica before these computers become an environmental problem.

Our goal has been to present to Intel Costa Rica a management system that provides the basis for a recycling program for E-waste. In addition, we have provided recommendations for including a student-run refurbishing center, which would re-circulate usable computer scrap. Such management systems have already been implemented elsewhere, and we believe they can be successful in Costa Rica. We have analyzed the processes and components that are part of computer scrap recycling and have provided recommendations for a customized scrap management system that meets the needs of Intel Costa Rica and Costa Rica as a whole.

Our research required us to use multiple methodologies. We carried out interviews with several people representing landfills, non-government organizations concerned with E-waste disposal, as well as organizations that would potentially become involved in the E-waste recycling process. Furthermore, we researched case studies of previously implemented waste management systems and their successes and failures. We also surveyed several recyclers internationally to determine which would be most suited for the needs of Costa Rica. In addition, we analyzed the possibility of implementing several E-waste recycling models in Costa Rica based on economics, feasibility, and probability of success. Finally, we recognized that our recommendations will not be implemented without considering possible adverse effects upon the society and economy of Costa Rica. As part of our methodology, we attempted to predict these consequences and factor them into our recommendations.

On a larger scale, we hope that our recommendations and research will be able to help others, as E-waste is a global problem. The solutions we have recommended may prove to be applicable to Intel Corporation and other countries or organizations in the future, helping them find solutions to their own specific problems. They are bound to encounter similar issues with E-waste we encountered in Costa Rica, in which case we hope our report might serve as a reference for information and ideas.

Chapter 2. Background Information

2.1 Introduction

This section provides the essential information to understand what E-waste is and what is occurring on a global scale. It includes information on what computer scrap is, why it is a problem, what is done internationally to deal with the problem, general recycling information, and social issues involved with recycling E-waste in Costa Rica.

2.2 Overview of Computer Scrap

2.2.1 Definition

The phrase 'computer scrap' encapsulates a broad spectrum of electronic products produced worldwide. When an electronic product becomes obsolete and no longer has any value for the user, the product is downgraded from being considered a useful electronic asset to computer scrap. Increasingly, many such downgraded transitions are taking place each year because of increased manufacturing of new and improved electronic equipment. In many cases, it is cheaper for the consumer to purchase new equipment than to take a broken product to a repair facility. Also in many cases, for a cheaper or comparable price, the user will get a faster, better, and more technologically advanced device. These incentives leave average consumers with little choice but to treat broken electronic devices as computer scrap. In this study, the term 'computer scrap' will include any and all obsolete electronic products and individual components used by or related to computers.

2.2.2 Producers of Computer Scrap

The generators of computer scrap in the United States are classified into three sectors, individuals and small businesses, large businesses and institutions, and original equipment manufacturers. For individuals and small businesses that need to dispose of computer scrap, the only viable (and preferred) method seems to be throwing it in the trash. Most landfills and incinerators in the United States still accept this type of computer scrap for a fee, except in California and Massachusetts where law prohibits such disposal. Large corporations generally use the re-use/recycle/export market or lease their computers from leasing companies who take back working and non-working computers at the end of a contract. In the latter case, the leasing company has to deal with large quantities of computer scrap while large corporations get the use of the technology without the hassle of disposal. Original equipment manufacturers generally recycle their computer scrap either through a contract or at their own recycling facilities if a substandard piece of equipment comes off the production line (Byster et al., 2002, p. 6).

A standard desktop computer is made of a cathode ray tube (CRT) monitor, a computer chassis, and several densely packed cables providing the control for the system. The chassis and CRT monitor both house printed circuit boards with a multitude of resistors, capacitors, integrated circuits, plastic connectors, etc. All three components contain chemical elements, many of which are potentially hazardous to the environment if disposed of improperly, such as chlorinated and brominated substances, toxic gases and metals, biologically active materials, acids, plastics, and plastic additives (Brodersen, 1994, p. 175).

Anyone buying electronic devices is adding to the growing amount of computer scrap. Every day in the United States thousands of durable goods come to the end of their lives and enter the solid waste stream. It is estimated that 150 million discarded personal computers will have been deposited in a landfill by the year 2005 (Navin-Chandra, Prinz, Wei Chen, 1993, p. 178). The ever-increasing rate of manufacturing electronic devices drastically expands the amount of computer scrap each year that requires management.

2.2.3 Chemical Content of Computer Scrap

Several analytical methods exist to identify the chemical makeup of printed circuit boards. One such method discussed by Dr. K. Brodersen, B. Danzer, and D. Tartler (1994) results in both qualitative and quantitative information about the evaluated material. X-Ray-Fluorescence spectroscopy applied to the sample material after preparation using cutting mills and ultra-centrifugal mills results in large amounts of qualitative data that depict the chemical makeup of the sample (Brodersen, 1994, p. 174). The presence of flame retardants (brominated substances), precious metals (such as silver or gold), or potentially polluting elements (such as lead or tin) is easily determined using this particular method (Brodersen, 1994, p. 174). Quantitative results of printed circuit board scrap show that it contains 49% glass, ceramics, and metal oxides, 4% bromine, 19% plastics, and 28% metals. The 28% metals consist of 7% copper, 2% zinc, 6% iron, 3% nickel, 1% tin, and 9% other metals. The glass fiber that acts as reinforcement to the circuit board contains mostly flame retardant epoxy resin, which was classified as plastic (Brodersen, 1994, p. 175).

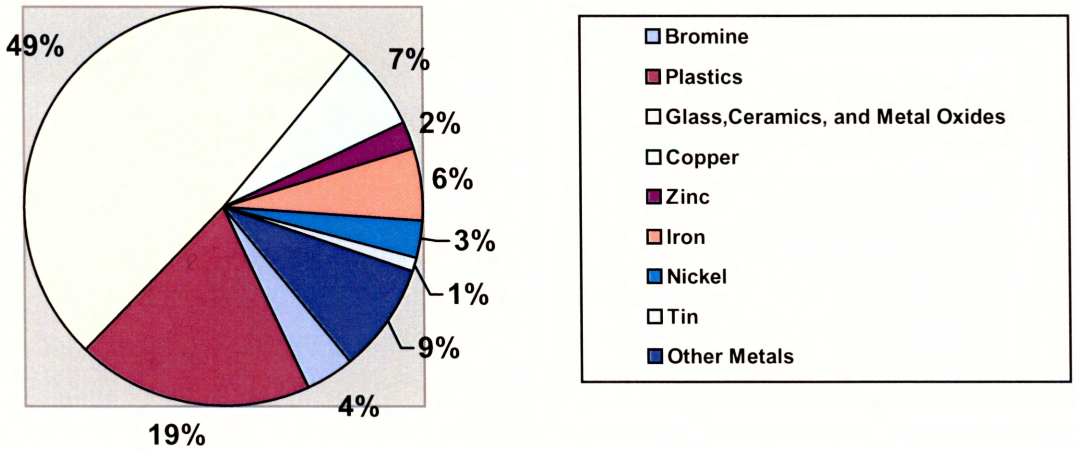

Figure 1: Chemical makeup of printed circuit boards (Brodersen, 1994, p. 176)

Another main portion of computer scrap is the CRT monitor. It is a commonly known fact that the management of CRT monitor disposal has become the most difficult problem due to its adverse environmental hazards when discarded in a landfill and its 'bulky' size. There are two hazardous materials of concern that are found in monitors: lead and polybrominated flame retardants. The lead, which is used to shield the user from x-rays generated in the CRT, is found in the screen, funnel, neck and frit (a solder glass used in color monitors). If discarded in an acidic environment, such as a landfill, the lead could become mobilized and eventually enter the environment (Smith, et al., 1995, p. 124). In older monitors, polybrominated flame retardant was used as an additive to plastic monitor coverings and circuit boards to limit the spreading of flames if the computer caught on fire. The problem with this type of flame retardant material is if it were incinerated at a low temperature, dioxin would be formed and released into the atmosphere (U.S. EPA, 2001b).

Byster et al. (2002, p. 44) claim a slightly different chemical makeup can be found in a whole personal desktop computer. Through unidentified methods, the authors list the chemical components of a 70 pound computer by weight as listed in Table 1. Each of these elements impacts the environment in different ways.

Table 1: Elements contained within computer components (Byster et al., 2002, p. 44)

Material	Weight	Found in and Comments
Plastics	22.9907 lbs	Includes organics and oxides other than silica
Lead	6.2988 lbs	Metal joining, radiation shield of CRT and in printed wire boards (PWBs)
Aluminum	14.1723 lbs	The casing, conductivity/housing, CRTs, PWBs, and connectors
Germanium	0.0016 lbs	Some semiconductors/PWBs
Gallium	0.0013 lbs	Some semiconductor/PWBs
Iron	20.4712 lbs	Structural casing, steel housing, CRTs, and PWBs
Tin	1.0078 lb	Metal joinings, PWBs, and CRTs
Copper	6.9287 lbs	CRTs, PWBs, and connectors
Barium	0.0315 lbs	Vacuum tubes and CRTs
Nickel	0.8503 lbs	Structural portion, steel housing, CRTs, and PWBs
Zinc	2.2046 lbs	The battery, PWBs, and CRTs
Tantalum	0.0157 lbs	Capacitors and power supplies
Indium	0.0016 lbs	Transistors and rectifiers
Vanadium	0.0002 lbs	The red phosphor emitter of the CRT
Terbium	Trace amounts	Green phosphor activator, CRTs, and PWBs
Beryllium	0.0157 lbs	Connectors
Gold	0.0016 lbs	PWBs, connectors
Europium	0.0002 lbs	PWBs
Titanium	0.0157 lbs	Aluminum housings
Ruthenium	0.0016 lbs	Resistors
Cobalt	0.0157 lbs	Steel housing, CRTs, and PWBs
Palladium	0.0003 lbs	PWBs and connectors
Manganese	0.0315 lbs	Steel housing, CRTs, and PWBs
Silver	0.0189 lbs	PWBs and connectors
Antinomy	0.0094 lbs	The housing of diodes, PWBs, and CRTs
Bismuth	0.0063 lbs	PWBs
Chromium	0.0063 lbs	Steel housing
Cadmium	0.0094 lbs	Batteries, PWBs, and CRTs
Selenium	0.0016 lbs	PWBs
Niobium	0.0002 lbs	Housing
Yttrium	0.0002 lbs	CRTs
Rhodium	Trace amounts	PWBs
Platinum	Trace amounts	PWBs
Mercury	0.0022 lbs	Batteries, switches, the housing, and PWBs
Arsenic	0.0013 lbs	Transistors
Silica	24.8803 lbs	Glass, solid state devices, and PWBs

2.2.4 Environmental Impact

The Basel Convention, the primary mechanism for control of international movement of hazardous waste defines a waste as 'hazardous' if, under virtually any circumstances, its disposal may have an adverse environmental effect (Bullock, 1995, p. 192). Therefore, under this definition, completely obsolete computers and computer scrap are considered hazardous waste in almost every case. Nonetheless, just recently, the U.S. EPA has classified computers and electronics as recyclables rather than hazardous waste to encourage the recycling of computers and electronic components (U.S. EPA, 2002c).

Metal and dioxin emissions from improper disposal of hazardous material, such as incineration in an improper manner, can pose potential human and ecological risks. Lead has been shown, in a number of DNA structure and function assays, to affect the molecular processes associated with the regulation of gene expression (U.S. EPA, 1986). Lead can either be properly disposed of or reused. According to a study done by Sony Electronics (Smith, et al., 1995, p.125), a 17-inch monitor has 1.6 kg of lead and a 20-inch monitor usually has 2.2 kg of lead. Under long-term exposure to lead and similar heavy metal hazardous waste, serious consequences could result, including cancer and other health risks in humans. Exposure can also cause high toxic effects on plants, animals, and microorganisms in the environment, which could eventually reach humans though biological transfer methods. Exposure to dioxin is known to promote cancer and other harmful health effects in humans and other receptors of dioxin (U.S. EPA, 2001b). Over time, mercury, another of the above-mentioned toxic metals found in computer scrap, can become aqueous as it separates from the computer scrap in a landfill. This form of inorganic mercury causes chronic damage to the brain (Silicon Valley Toxics Coalition, 2002b).

The United States Environmental Protection Agency (U.S. EPA) has identified ten metals that may pose human health risks by inhalation or direct exposure (U.S. EPA, 2001b). These metals are antimony, arsenic, barium, beryllium, cadmium, chromium, lead, mercury, silver, and thallium. Mercury, in particular, has significant potential to transfer up the food chain through water and sediments to fish and humans. The U.S. EPA has also identified eight additional chemicals that form compounds of potential concern when evaluating human and ecological risks. These eight additional metals are aluminum, copper, cobalt, manganese, nickel, selenium, vanadium, and zinc (U.S EPA, 2001b). Not surprisingly, many of these metals can be detected in most landfills in the United States (U.S. EPA, 1999b).

The Silicon Valley Toxics Coalition and The Basel Action Network have researched and identified the hazards computer scrap contains, documented in Exporting Harm by L. Byster, et al (2002, p. 9). Recycling computers has serious side effects for workers and the environment, especially when the recycling industry cannot afford to take the necessary precautions to protect the environment and the workers (Byster et al., 2002, p. 9). The most common toxic materials found in computer scrap are lead, cadmium, mercury, hexavalent chromium/chromium VI, plastics including polyvinyl chloride (PVC), brominated flame retardants (BFRs), barium, beryllium, powdered forms of carbon (found in printer cartridges), and phosphor with additives (Byster et al, 2002, 9). Table 2 displays the use of each item along with the environmental impact.

Table 2: Impact of hazardous substances found in computer scrap (Byster et al, 2002, p. 9)

	Environmental Impact	Use in Electronics Parts
Lead	Causes damage to central and peripheral nervous system, blood systems, kidney, and reproductive system in humans. Inhibits children's brain development. Well documented averse effects on plant, animal, and microorganism life	Computer monitors to shield the user from harmful x-rays, printed circuit boards, and components
Cadmium	Accumulates in the human body and causes adverse effects, especially to the kidney	Many components, such as surface mount resistors, IR detectors, and other semiconductors. Some older monitors also contain cadmium
Mercury	Causes damage to brain, organs, developing fetus, along with other organs	Thermostats, sensors, relays, switches, medical equipment, lamps, cellular phones, flat panel displays, and batteries
Chromium VI	Damages DNA and is extremely toxic to the environment. It easily passes through cell membranes and is absorbed	Protection that prevents corrosion of steel
Plastics with PVC and BFRs	Dioxins can form when burning these plastics, causing adverse health effects in plant and animal life	Cabling and computer housings
Barium	Short term exposure may cause brain swelling, muscle weakness, damage to heart, liver, and spleen	Front panel of CRT monitor to protect user from radiation
Beryllium	Exposure may cause lung cancer, chronic beryllium disease (beryllicosis), a disease that effects the lungs, or some form of skin disease	It is a good conductor of electricity
Carbon	It may be slightly cancerous and can cause respiratory tract irritation	Powdered carbon is used for black toner in a printer cartridge
Phosphor with additives	Not well documented, but is hazardous and it is recommended to seek medical attention immediately if exposed	Coated on the interior of CRT monitor faceplate for resolution purposes

2.2.5 Human Risk Assessment of Elements in Computer Scrap

The risk assessment of human exposure to chemicals found in computer scrap is difficult to determine in many cases. The U.S. EPA has encouraged and/or sponsored a multitude of studies on the exposure to many different elements, including those found in computer scrap. This section will briefly summarize the foreseen risks due to exposure of some of the better known elements in computer scrap, as dictated by the U.S. EPA. For more complete and detailed information on each element, see Appendix G.

Exposure to polychlorinated biphenyls (PCBs), a common element of capacitors, is known to cause cancer. The U.S. EPA (1997) lists the human carcinogenicity data as inadequate. However, several studies were discovered that evaluated cancer mortality among workers exposed to PCBs in capacitor manufacturing plants in New York and Massachusetts. The study indicated that a statistically significant increase in death from cancer was reported in the area of the study, indicating a possible connection to exposure to PCBs and cancer.

The most well known element found in computer scrap is lead. As stated before, exposure to inorganic lead and lead compounds causes damage to central and peripheral nervous system, blood systems, kidney, and reproductive system in humans. Although the U.S. EPA (1993) describes the human carcinogenicity data as inadequate, some research has found that there is a connection between lead exposure and cancer in humans. Of four studies, two found no connection, one found a decrease in cancer, and one found an increase in cancer.

The presence of nickel in computer scrap has also led to many wondering how this element impacts humans. The U.S. EPA (1991a) considers the human carcinogenicity data of nickel refinery dust sufficient. The evidence discovered throughout the years from pyrometallurgical sulfide nickel refineries around the world all show similar results. All studies have reported high risk lung and nasal cancer among men ever exposed to dustier areas of the refinery. Other types of nickel, such as nickel carbonyl, have been classified as a probable human carcinogen with inadequate human carcinogenicity data (U.S. EPA, 1987). Nickel in the form of soluble salts has been shown to significantly decrease organ and body weight in lab rats in a two year study. Even at 6 weeks females rats showed a reduction of weight and after 52 weeks the male rats showed a reduction (U.S. EPA, 1996).

Two and one fifth pounds of a 70 pound computer is made of Zinc (Byster et al., 2002, p. 44). The U.S. EPA lists the human carcinogenicity data as inadequate (U.S. EPA, 1992). However, case studies have been conducted on workers exposed to zinc. In one case, a 59 year old female and a 26 year old male received 100-150 mg/day of zinc sulfate (female) and zinc acetate (male). The study concluded saying that a profound anemia is associated with hypoceruloplasminemia and hypocupremia. The conditions were corrected by copper supplementation and, in one case, withdrawal of zinc (U.S. EPA, 1992).

Small amounts of Beryllium can be found in computer scrap. Beryllium is know to promote cancer, but is used since it is a good conductor (Byster et al, 2002, p. 9). The U.S. EPA (1998) classifies the human carcinogenicity data of the effects of beryllium and beryllium compounds as limited. One study concluded that humans exposure to beryllium did not have significantly different from the number of deaths than expected on the basis of age and calendar time period for the general white U.S. male population. However, significant cases of malignant neoplasm of trachea, bronchus, lung and heart disease, and nonneoplastic respiratory disease were observed in the study participants (U.S. EPA, 1998).

Documents explain that exposure to cadmium, another element found in computer scrap, can cause significant proteinuria (U.S. EPA, 1987a). The U.S. EPA (1987a) classifies the human carcinogenicity data as limited for cadmium and labels it as a probable human carcinogen. In one documented case there was twice the risk of lung cancer among smelter workers who were exposed to cadmium. Six hundred and two workers who worked at least 6 months in a potentially exposed environment between 1940 and 1969 were studied. The researchers were able to ascertain that the increased risk of lung cancer was probably not due to the presence of arsenic or to smoking in workers exposed to both arsenic and cadmium in the workplace (U.S. EPA, 1987a).

Another commonly known element in computer scrap is mercury. The U.S. EPA (1988c) lists the critical effects of mercury: hand tremors, increase in memory disturbance, and slightly subjective and objective evidence of autonomic dysfunction. In one study, male workers exposed to low level of mercury vapor in various occupations showed the measure of tremor was significantly increased (U.S. EPA, 1988c). Due to inadequate human and animal data, the U.S. EPA (1988c) has classified the evidence for human carcinogenicy of mercury as 'not classifiable'. One study done on exposed workers showed no significant increases in mortality from exposed workers compared to the general population in the same area (U.S. EPA, 1988c).

Very little or no information is available about the human risk of exposure to many elements found in computer scrap. This list includes tin, iron, tantalum, indium, terbium, gold, europium, titanium, ruthenium, cobalt, palladium, bismuth, niobium, yttrium, rhodium, and platinum. No other additional information on the effects of these elements on humans was discovered. Additional elements not mentioned in this section are detailed in Appendix G.

2.2.6 Facts about Computer Scrap

- Americans are buying more computers than people from any other nation with over 50% of U.S. households having computers (U.S. Department of Labor, 1999).
- Data from single-day recycling collection events in the United States have shown that 50% of computers turned in are in good working order and have only been discarded to acquire the latest technology (Byster et al., 2002, p. 5).
- About 90,000 metric tons of lead were introduced into commerce through computer monitor production in the year 1998 (Smith, Small, Dodds, Amagai, Strong, 1995, p. 125).
- The incentive for the United States industries to export computer scrap is due to non-existent environmental standards and low wages in other countries, making it cheaper to ship computer scrap abroad for disassembly than to disassemble at home, so millions of pounds of computer scrap generated in the United States is being exported, mostly for recycling (Byster et al., 2002, p. 4).
- It is estimated that 150 million discarded personal computers will have ended up in landfills in the United States by the year 2005 (Navin-Chandra, Prinz, Wei Chen, 1993, p. 178).
- In the United States, it was estimated that 20 million computers became obsolete, and needed disposal, in the year 1998, and it is expected that this figure will rise much higher in the future (Byster et al., 2002, p. 5).

2.3 Recycling

2.3.1 Definition

Recycling is the process of using waste and used materials in an effective manner to conserve resources. This process is generally implemented by individuals and organizations who are conscious of the growing waste problem and wish to reduce their individual waste disposal, and often, to cut costs in manufacturing by reusing material. As the U.S. EPA (2001a) has stated, recycling turns materials that would otherwise become waste into valuable resources and generates a host of environmental, financial, and social benefits.

The Basel Convention recognizes the hierarchy of waste management as follows: waste avoidance/minimization, recovery, reuse, and recycling, and finally as the last option, disposal (Bullock, 1995, p. 194).

2.3.2 Waste Avoidance/Reduction

Avoiding and reducing waste production is a necessary consideration in the manufacturing and design of electrical devices. This first step of waste management reduces the total amount of waste that may potentially enter the hazardous waste stream from the beginning. Since source reduction prevents the generation of waste, it is the most preferable method of waste management (U.S. EPA, 2001a). Once the product has been manufactured, the decisions made regarding its environmental management do not include avoidance or modifications of its design. The only other solutions for this situation include recycling or disposal (Bullock, 1995, p. 194).

2.3.3 Recycle: Recovery and Reuse

The most common recycling terms in the recycling industry are recovery, reuse, and recycle – known as the 3Rs. C. Haas, P. Kodukula, K. Noll, and C. Schmidt (1985, p. 1) suggest the choice between recovery, reuse, and/or recycling of valuable materials from waste seems to depend on two main factors: technology and economic gain. The high cost of recovering a low valued material seems to prevent many industries from adopting a recycling or reclaiming program. Now, with much advancement in technology and cheaper recycling costs, the idea of recycling has changed in many industries. T. Duston (1993, p. 128) claims that there has been a movement among environmental groups to take a more global view of economizing on resources provided by recycling alone. This would involve at least two of the three components: recycling and reusing. The goal to this second step in the hierarchy of waste management of computer scrap is to avoid the disposal of the product and focus on reclaiming and reusing (Bullock, 1995, p. 194).

The recovery of waste typically involves reusing the item either with or without modification. The product can generally be disassembled down into the lowest reusable form without damaging the original components' functions. For example, a working or partially working computer chassis with a hard drive, motherboard, and other internal components can be broken down into each usable component. From the computer itself and also from the casing of a monitor, metals and plastics can be removed. This would include all the cards plugged into the motherboard, the central processing unit (CPU), all hard and floppy drives, power supply, memory sticks, etc. If these components are of no use, they can be broken down even further into other reusable components. For example, the chips can be removed, the sockets can be unsoldered, the wires can be clipped and reclaimed, etc. Once these components become a problem, the material can be broken into basic elements. To implement this process and remove materials such as these, large devices are often used to scrap computers into small shards of metal similar to disposing of soda cans at supermarkets (Hewlett Packard, 2002). This makes it easier to melt down and separate individual components.

Reusing material from unwanted waste and used materials to conserve resources is the main element in effective recycling. The reuse of material simply consists of taking the recovered assets and creating a useable asset. Reusing refers to using the material again without significant processing (Duston, 1993, p. 129). For example, the materials recovered in the first stage of de-manufacturing can be organized to refurbish a computer or they can be sold or donated. As for individual elements, copper can be reused for wiring and precious metals such as gold can also be extracted. The recycling program's effectiveness can be measured by reuse yield: the amount of material coming in versus the amount of material being reused.

This recovery and reusing cycle is known as recycling, as described above. Figure 2 illustrates the recovery and reuse process of recycling. Once it is determined that

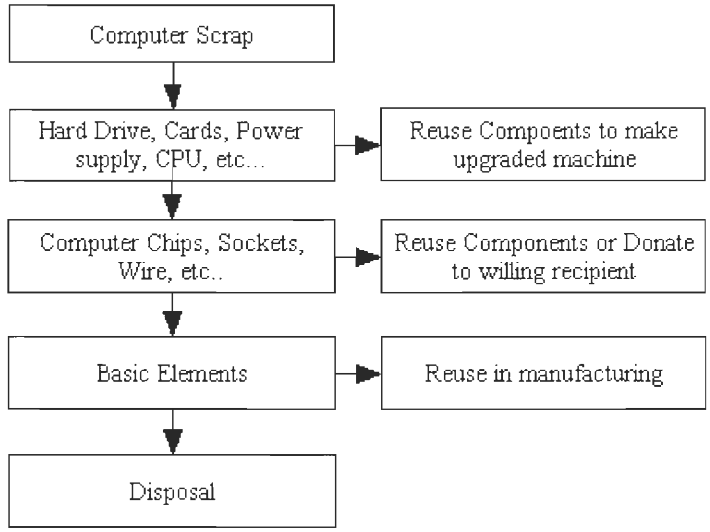

Figure 2: Basic computer scrap recover and reuse recycling approach (Bullock, 1995, p. 194)

the recovered item is not usable, saleable, or able to be donated, it can be broken into even smaller and smaller components until the basic elements of the waste are reached. At each stage the recovered item can be evaluated as an asset. If the basic element cannot be used, it must be disposed of properly.

T. Porada (1994, p. 171) introduces a method similar to the recover and reuse method, but calls it the 6R method: reuse, resale, refurbish, remanufacture, reclaim, and recycle. All of these methodologies combined are essentially the same as the recover and reuse method.

2.3.4 Waste Disposal

Once the waste is deemed unusable, passing through the recover and reuse phase, it must be disposed of using one of several common methods: land disposal, waterborne disposal, or evaporation disposal (Higgins, 1989, p. 213). Since up to twenty percent of waste presents significant problems for any of the conventional trash disposal methods, it is crucial to evaluate the method suitable for the type of waste being disposed and to prepare the waste in a manner suitable for the selected disposable method (Duston, 1993, p. 125).

Incineration of waste can be used to prepare waste for final disposal. Although the incineration process unavoidably releases toxic gases into the atmosphere, causing harm to the environment, it is unfortunately commonly used. Generally, the incineration process can reduce the volume and weight of the material, but it has environmental drawbacks. Higgins (1989, p. 213) claims that incineration can be used to reduce volume, toxicity, and mobility. When waste is burned, its chemical makeup is altered and its toxicity is generally reduced. Volume is reduced by evaporation of water and simple organics. Mobility is reduced since only inorganic metals and silicates remain in the ash, which is a solid with minimal volume.

2.3.5 Planning and Implementing Recycling Management

Many issues of concern arise when attempting to plan a successful recycling program. T. Duston (1993, p. 76) explains that an important consideration in planning is whether the management initially supports recycling. This can also be extended to include the donors of computer scrap and those who process the computer scrap. Motivation for recycling and carrying out the program is an ingredient for success. Duston also points out that a key issue to take into consideration is to know the value in recycled material, how to break it down, and how long it takes to break it down. This also includes knowing the local, state, and federal laws that govern such a process and ensuring compliance in devices and methods used while recycling.

Education plays a key role in the ongoing success of a recycling plan. Informing the population covered by the recycling efforts and including them in decision-making allows for continuous product flow and product reuse. Methods for educating the public could include public meetings, press coverage, demonstrations at recycling centers, schools and community meetings (Duston, 1993, p. 82). Encouragement could be given to motivate the public into recycling by advertising environmental progress through the means discussed above or using brochures.

The final part in implementing a recycling plan includes the training of employees. The employees involved in recycling need to know what the recycled material is, where it goes, and how to break it down. Volunteers could be used in this area to cut the costs of the recycling program.

2.3.6 Recycling Economics

Although companies such as Roteb in the Netherlands and Hewlett Packard in the United States are entering the recycling market, the benefits of entry must be examined to determine the recycling markets' economic potential. Regardless of whether a company is entering the electronic and computer scrap recycling market as a part of company strategy, such as Hewlett Packard, or entering the recycling market under new government mandate, it is a common belief that the issue of whether a company can turn a profit on recycling, break even, or lose money has a large impact on the recycling programs.

The main goal of recycling electronic devices is to have as little of the device end up in landfills as possible, thereby protecting the environment. Regardless of whether the recycling is done voluntarily such as the case of Hewlett Packard or under government regulations such as the WEEE European directive, costs are still involved. In 1999 a study was done by Philips electronics based in the Netherlands, which places the cost of recycling a TV between 10 and 15 US dollars (Stevels, Ram, Deckers, 1999, p. 384). At the same time they also ambitiously estimated that as recycling becomes more efficient and cost goes down, in the year 2010 there will be no difference in cost between recycling electronic scrap or simply placing the scrap into a landfill.

Smith, Small, Dodds, Amagai, and Strong (1995, p. 125) suggest that for any recycling process to be viable, the cost to recycle must be less than the value recovered. To maximize this ratio, the production costs for recycling the material must be avoided, while the value of the new asset should be as high as possible. This includes breaking the computer scrap into the most valuable pieces using the least amount of time and money.

Each ton of computer scrap removed from the solid waste stream that is recycled includes several costs: collection, processing, and resale/disposal fees. Collection of computer scrap consists of locating and collecting the computer scrap at one final disposal location. Most standard city garbage collectors have garbage trucks that gather the waste and deliver it to the final collecting location (Duston, 1993, p. 42). Similarly, a computer recycling facility incurs costs by collection. Cost savings in this area might include eliminating collection service, renting dumpsters, locating computer scrap donors on the Internet, and reducing collection transportation costs in a variety of ways. By creating an Internet web site for scrap collection, you could locate potential donors of computer scrap. This would increase your waste input, and you could even charge for scrap pick up. Processing cost includes the cost of breaking the computer scrap into reusable, re-saleable, or disposable material. In order to evaluate cost avoidance in this area, the specific methods would have to be analyzed. The last induced cost includes resale/disposal fees. If the final yield of the recycling facility was not 100% and some waste was generated, the final product would need to be disposed of elsewhere. If the product were reusable or re-saleable, this cost would include marketing costs and any other cost incurred while removing the asset from the processing facility. These costs, in the resale/disposal area, are directly related to the processing costs. For example, if the processing costs allow for high yield of product, the disposal fees would be reduced.

2.3.7 Recovery and Reuse Management

When examining different aspects of recycling computer scrap, it must be understood that there are different types of recycling. As the term implies, reusing computers is simply where the product is actually to be used again. Giving the recovered product to secondary corporations is often the immediate solution to the recycling problem. Computers that can still be used are given to schools or other smaller corporations. Even when the devices can no longer be used for their designated purpose, they still may have very large value when sold to secondary users. For example, corporations could sell their computers to schools or home users who might not want to spend the money to buy a high-end system that they do not need. This method is beneficial to both the seller and the buyer. The seller of the old computer is able to make a decent sum of money from a product that no longer has value to the corporation or individual. The buyer then is able to get a fairly decent system for his or her purposes at a good cost. For example, with computer monitors, they would be in the hands of the primary user for up to a period of four years, but they are still in good condition and can be used by other parties who do not need the latest technology up to a period of 12 years (Smith, et al., 1995, p. 126).

It may not be possible to reuse computers in their entirety. A computer may be in a condition where certain components are not working but others are in decent shape. For example, a motherboard might be broken, but the hard drive and RAM would still be usable. These components could be removed and resold as used products. They would still need to be checked and possibly some refurbishing would need to be done. The other option is if computer components are damaged beyond the point of direct reuse, then only sub-components can be reused. For example, a motherboard might have lots of chips and memory devices that are still in good condition. In this case the board itself is damaged, but the chips can be removed and sold to computer manufactures or other groups seeking these components.

If a computer is beyond use either as a complete operating system or even the individual chips from the circuit boards, then the computer will have to be scrapped for its individual metals. This might happen if the components are out of date and beyond use even by secondary users. Or it could be necessary if the components are damaged beyond repair. The computer would have to have all batteries removed before individual materials can be separated and scrapped. For example, the glass in a monitor from the cathode ray tube would be separated from the plastic casing. Careful attention would be needed to insure that the lead is removed from the glass. The glass can then be reused in other monitors or different products.

To minimize computer scrap in the future, electronic devices need to be created where the parts can be easily removed and identified. Therefore, the removal of individual components for either reuse in secondary markets or the recycling of components can be done more rapidly, saving time and money (Ron & Penev, 1995, p.366).

2.4 International E-waste Management Systems

Computer producers over the last decade have reaped great benefits from sales of computer systems. High technology countries prospered greatly from the massive computer development over the past two decades. Also, individual groups of people have benefited from the same computer development. One such group that of students have and are in the midst of exploring information and acquiring new knowledge through the medium of computers. While governments, computer producers, and students have all seen the benefits of the technological revolution, all of us will bear some heavy negative consequences if nothing is done to address the increasing E-waste arising from the computer revolution. Already countries are faced with the mounting challenge of computer scrap plaguing landfills. Computer producers are feeling these negative effects, both from value being lost in discarded systems and from government pressure to mend the problem. Just as countries and computer producers are starting to experience the negative effects, unsuspecting groups of individuals such as students will inevitably face similar issues in their careers. Currently there are three main methods found throughout the world for implementing computer scrap management programs.

Outside the United States, governments are imposing and have imposed regulations such as the European WEEE directive to force electronics and computer producers to be answerable for discarded products. Regardless of whether corporations support these initiatives or not, they are being forced to take back previously manufactured computer scrap discarded by consumers.

A second method can be found in countries such as the United States where currently there are no direct regulations affecting take-back of computer scrap. In this case, corporations are finding value in implementing computer scrap recycling programs on their own initiative, such as in the programs set up by Hewlett Packard and IBM.

The third factor encouraging recycling is driven by the educational system's need to provide students with a technical education based upon building refurbished computer systems. To enable such programs, corporate and private donations provide the necessary resources to support various student-run refurbishing programs found in US high schools. As a by-product, refurbished computers are created to fulfill the needs of the school districts.

The beneficial effects of regulations and/or independent initiatives can be seen through successful management programs across the world.

Corporate Initiatives

Corporations are initiating their own computer recycling programs for economic benefit and/or for improvement of community relationships. Two such companies with recycling programs are IBM and Hewlett Packard. IBM had started their computer recycling program to recover lost value from their discarded computer systems (Grenchus, Keene, & Nobs, 1997, p. 157). On the other hand, Hewlett Packad started their computer recycling program in a partial effort to improve community relations (Levine, 2001, p. 22).

2.4.1 IBM

Overview:

In the United States, corporations have been implementing computer recycling and/or management programs without government pressure. For example, in 1994 International Business Machines (IBM) began a program in New York State to manage / reuse internally used computer systems. The purpose of the system was to recover value from discarded computer systems owned by IBM (Grenchus, et al., 1997, p. 157). Today, in the year 2002, IBM is actively engaged in recycling all computer parts from any origin (IBM, 2002e). The start of both recycling programs came internally from IBM and not because of any government regulation.

IBM Programs:

Arising from a desire to salvage as discarded value and/or equipment from company computer scrap, IBM implemented a scrap management center in upstate New York for internal use only. Three years after the plant opened, IBM was able to analyze and manage about 70 million pounds of electronic devices (Grenchus, et al., 1997, p.157). According to Grenchus et al. (1997, p. 157) the plant was used to manage only electronic scrap originating from IBM facilities. At the plant computer parts are disassembled and analyzed to determine potential value. Afterwards the scrap and usable computer parts are brought to recycling centers where various organizations purchase the usable components. The plant was so successful that 65 million dollars were saved in just three years after the plant was opened (Grenchus et al., 1997, p. 157). Although the plant was designed for recycling equipment directly owned by IBM, today anyone can send any computer part ranging from computer mice to whole systems. Currently the parts sent by consumers, who pay $29.99 for this service, partly to cover shipping expenses, do not go to this specific plant but instead to a separate computer recycling company called Envirocycle, Inc. (IBM, 2002e). Corporations, however, send their computer scrap to IBM, which then uses their New York facility to recycle the computer scrap. Envirocycle, Inc. has been recycling computer scrap for 15 years and has over 500 customers in the United States (Envirocycle, 2001).

Upon the arrival of the components at the Envirocycle facility, they are analyzed for potential value. If the system does not have any value, then it is recycled. However, many times the systems are still usable. In that case the computer or parts are repaired and given to charitable, not-for-profit organizations. If the parts are given to such an organization, then the person who originally shipped the parts receives a notification stating what was received, which can be used as a tax deduction (IBM, 2002b).

IBM still receives computer equipment that is repaired and resold, such as is done at the facility in New York. As long as the devices are in decent shape, reusable equipment includes whole computer systems and individual components such as hard drives, mice, and motherboards. The components can be resold to various secondary markets or even resold as used parts. In addition to the recycling center in New York, other recycling programs have been formed in Europe, North America, and Asia (IBM, 2002d). In these countries a recycling center might not be under the direct control of IBM, but IBM does maintain relationships with recycling organizations there. The larger centers are located in Europe and Japan (IBM, 2002c). Also IBM provides computer recycling services to corporations where they can make money from the computers they recycle (IBM, 2002e). In the year 2000, IBM collected 51,304 metric tons of computer scrap of which only 3.22 percent went to landfills (Lyon and Balta, 2001, p. 19).

2.4.2 Hewlett Packard

Overview:

Other corporations have also initiated programs similar to the one created by IBM. Hewlett Packard recognized the need to have a computer related scrap management system. They implemented and are currently running recycling centers both in the United States and abroad. Even though they maintain recycling centers in countries under the European Union, their recycling plant in France which opened in 1989 (Ferrer, 1997, p. 87) was not in response to the European waste initiative, because the initiative is not estimated to be implemented until the end of 2002 (Hieronymi, 2001, p. 217). In addition to Hewlett Packard's own initiative in running recycling programs around the world, they have a similar consumer product take-back program as IBM.

Hewlett Packard Programs:

Similar to the IBM recycling facilities and programs, Hewlett Packard also maintains recycling facilities. Since 1989 Hewlett Packard has maintained a recycling center in Grenoble, France. The center's main purpose is to reuse and turn computer scrap into new products including computer components and ink and toner cartridges for printers. When devices can no longer be reused, they are recycled. According to Geraldo Ferrer (1997, p. 87), only three percent of all the components that arrive in the recycling center are placed in landfills. More recently in 1997 Hewlett Packard opened a recycling plant in San Jose, California for computer systems (Hewlett Packard, 2002).

According to Hewlett Packard (2002), each month 3.5 to 4 million pounds of computer scrap are dealt with at the plant. When computer items arrive, they are examined for any potential use in their current state. Every single component that can be removed for further use is saved. If a product as a whole still can be used, then it is saved. Assuming the product is not of use, then every component including hard drives are saved. The remainder is brought to large shredding devices, which grind down the computers to shards of scrap material the size of a square centimeter. From there, metals and plastics are extracted from the ground scrap (Hewlett Packard, 2002).

Hewlett Packard (2002) has a fairly high success rate with recycling computer scrap. Their older plant in France, with a success rate of 97 percent in either reusing or recycling computer scrap, complements the newer plant in California that claims to have a hundred percent success rate.

In addition to the recycling plants, Hewlett Packard offers consumers a program in which, for a small fee, individuals can send to HP almost any computer related product for recycling or reuse. As with IBM the primary goal is to be able to reuse the computer parts. However, if the parts cannot be reused, then they are recycled. The reusable parts are donated to charities, but the consumer does not receive a tax deduction form. The remaining scrap that cannot be reused is recycled without any portion ending up in landfills (Hewlett Packard, 2001). According to Levine from TechBiz (2001, p. 22), the purpose of the consumer take-back program is to improve community relations. Hewlett Packard's ability to reuse 100 percent of the computer scrap retrieved by their consumer take-back program is the same as it is at their plant in California.

Government Regulatory Directives

Unlike the United States federal government, governments in other nations have and are imposing tight waste management regulations on electronic and computer producers. The main principle behind the take-back programs is that producers of computer and electronic equipment are responsible for what happens to their products and that no responsibility should fall on consumers. Producers, under government laws of extended producer responsibility, are required to take back computer and electronic scrap no matter how long ago the scrapped product was originally produced. The corporations are responsible for paying all the associated recycling fees. Two examples where producer responsibility programs are mandated by law are in Taiwan and a directive by the European Union that, according to Bette Fishbein (Fishbein, 2002), will be completed by the end of the year 2002. Each case is unique because the laws are not the same, and the exact producer requirements are not identical. However, the underlying concept of producer responsibility is the same in Taiwan as it is under the European Union directive.

2.4.3 Taiwan

Overview:

Around the same time as the opening of Hewlett Packard's recycling plant in California, the EPA of Taiwan began an initiative of producer responsibility. Under the act that became effective in 1998, producers of computer scrap have to pay the fees for consumer recycling of any of their products (Lee, Chang, Wang, & Wen, 1999, p. 209). Unlike other directives such as that of the European Union, the consumers who initially recycled the product obtain a monetary reward for service (Lee, et al., 1999, p. 214). A reward given to consumers for recycling their computers is unique to Taiwan, and can be contrasted to Hewlett Packard and IBM charging consumers a fee to process their old electronic equipment. Unlike Hewlett Packard and IBM's recycling plants, the program in Taiwan was created under government regulations and not as a corporate strategy.

Taiwan's Government Regulations:

Just as Hewlett Packard recycles computer scrap, companies in Taiwan producing computer products are required by the government to take back old computer parts, which they manufactured at some point, and recycle them. Also in 1998 a program was implemented in Taiwan whereby people return old scrap computer equipment and receive cash in exchange. According to Lee et al. (1999, p. 212) thirteen percent of all global computer production occurs in Taiwan. Even though there is a large amount of computer production, there is no one organization that is responsible for computer recycling. Unlike Hewlett Packard in the United States, which is able to recycle 100 percent of its products that enter the recycling facility, (according to Lee et al., 1999, p. 213) many computer parts in Taiwan end up at ordinary scrap landfills where they are taken apart and often dumped illegally. The government of Taiwan created the Scrap Computer Management Foundation in 1998 in response to an increasingly large demand from the government to make products that are currently considered scrap the responsibility of the company who created them, that is, the original equipment manufacturer (OEM). The initial company is responsible for insuring successful collection of computer scrap and insuring that the scrap is brought to designated storage sites. Because the problem of dealing with computer scrap is new in relation to ordinary scrap such as cars, there is no current method (as of 1998) to deal with the computer scrap being stored. Standard computer sellers, who have the expertise to determine the value of the computer scrap, collect it at various locations throughout Taiwan. (Lee et al., 1999, p. 214). According to Lee et al. (1999, p. 220), four hundred collection locations where people can bring their scrap computers in exchange for money existed by the end of 1998. From these locations, the scrap is collected and brought to three large storage locations (Lee et al., 1999, p. 214).

The three large storage locations now contain computer scrap that would otherwise be thrown into landfills mixed with other garbage. The separate piles only contain computer scrap, which could be easily managed when methods of recycling computers are put into place. Fees are charged for each piece of computer scrap given to a storage facility as part of the government initiative to make corporations responsible for their scrapped products. Depending on the type of scrap, for example, whether it is a notebook or a computer hard drive, different processing fees have to be paid by the OEM. In addition, as an incentive to encourage recycling, the consumers who bring their old computers to the storage locations receive money in exchange for each computer part they bring. The reward varies depending on which computer part was given. Also, the collection points where computer resellers obtain the computer parts from consumers before they are brought to scrap yards are given compensation money in addition to the consumers. After the parts are brought to scrap yards, the government of Taiwan provides continuing efforts to insure computer scrap remains at the final delivery location (Lee et al., 1999, p. 218). Unlike the recycling program of Hewlett Packard where they can directly sell usable computer scrap or obtain value from the scrapped metals or plastic, in Taiwan there is not much value in the scrap for the scrap yards. To solve this problem an independent verifying agency is responsible for determining the quantity of computer scrap at the storage sites. The sites are then paid depending on the quantity of scrap they have (Lee et al., 1999, p. 215). Therefore, as Hewlett Packard receives money directly from the computer scrap, the scrap yards in Taiwan receive money in a similar way, but from the government. According to Lee et al. (1999, p. 218) in the first five months of the mandatory computer recycling program, 91,829 computers and monitors were collected. For comparison, each year in Taiwan it is estimated that 300,000 personal computers become scrap (Lee et al., 1999, p. 209). In the first month of the recycling program a total of 14,220 components were collected, which increased to 23,962 components five months later (Lee et al., 1999, p. 218).

The second phase of the recycling program as of 1998 was to implement a system where the vast amounts of computers stored at collection sites would be recycled. A possible means of implementation would be to try and induce existing companies doing recycling into taking part in recycling computer scrap (Lee et al., 1999, p. 218).

The Hewlett Packard system and that of Taiwan show two different approaches to recycling. Hewlett Packard has already started a successful program in which they are able to recycle 100 percent of the computer scrap (Hewlett Packard, 2002). This impressive record is comparable to the success of Taiwan in being able to implement a collection program even though there is no recycling at this point. Although Hewlett Packard is able to recycle 100 percent of the material coming into the California recycling plant, Ron and Penev from the Eindhoven University of Technology in the Netherlands (1995, p. 365) claim that it is not possible to recover 100 percent of the materials used in a computer. They also say that each type of material in a computer cannot be recovered in a pure state, but they don't specify that recovering 100 percent of the materials that make up a computer includes recovering materials in their pure state (Ron & Penev, 1995, p. 365). Perhaps this discrepancy is explained by the fact that Ron and Penev made their claim in 1995, and the Hewlett Packard plant, with its greater success, was not created for recycling computer components until 1997.

2.4.4 European Union

Overview:

Around the same time that government regulations in Taiwan came out requiring computer corporations to take back previously produced computer systems for recycling, the European Union was developing a similar program. The European directive also requires corporations located under the control of the European Union to be responsible for recycling previously produced computer or electronic systems. As with the Taiwan regulations, producers under the European directive must take back discarded devices regardless of how long ago they were manufactured. Unlike the voluntary actions by Hewlett Packard and IBM in the United States, once implemented, the European directive will be required regulation.

European Regulation:

Taiwan's approach of making the producer of electronic equipment responsible for disposal is not unique to Taiwan. According to Hieronymi (2001, p. 217), the European Union, in response to the increasing amount of electronic scrap filling landfills has created an initiative to deal with computer scrap. The Waste from Electric and Electronic Equipment directive or WEEE will insure that all corporations in the European Union that have created electronic equipment such as computers are responsible for implementing recycling and collection programs to manage electronic and/or computer scrap. Under the new initiative, even if a corporation is no longer producing a certain product, it is still responsible for its proper recycling (Hieronymi, 2001, p. 217). Similar to Taiwan, the WEEE also requires electronic or computer manufactures to be responsible for paying all associated fees of the recycling program without any being placed on the consumer. Another source confirms this by stating that consumers bringing computers or electronic equipment for recycling will not be charged (Fishbein, 2002, p.55). Although in both cases consumers will not be directly responsible for paying the recycling fees, they will probably still be affected. According to Snowdon, Whitaker, and Ford (2000, p. 46), since the expense of the recycling falls on the producer of the equipment, the consumer might see an increase in the cost of new electronic goods. Because the producer of the equipment is responsible for waste no matter how long ago it was produced, the corporation will have to incur the resulting fees. If the producer decides to pass the resulting recycling or management fees on to the consumer through an increase in the price of future products, the resulting price increase could be quite large. Snowdown, Whitaker, and Ford (2000, p. 46) believe that a large increase in price might be needed to pay for the recycling of all old electronic products while insuring a satisfactory amount of resources to support future required recycling. Unlike Taiwan, however, the European Union directive does not provide consumers with incentives for recycling. In Taiwan and Europe, there are no direct means to insure that consumers will not simply place their scrap computers and electronic components into the trash. However, there is still a provision in the WEEE directive which does specify that electronic waste must be collected independently (Fishbein, 2002, p. 55). The information presented makes it clear that the European initiative and Hewlett Packard use different methods to avoid scraping hazardous components. Hewlett Packard removes all batteries from a device that cannot be further used before it is reduced to scrap metal shards (Hewlett Packard, 2002). The European directive, however, insists that components in computers containing toxins be removed to insure environmentally safe disposal (Snowdon, Whitaker, & Ford, 2002, p. 45). Taiwan imposes a similar tactic. Although Taiwan did not have recycling facilities to deal with their computer scrap as of 1998, they did give instructions on recycling computer scrap to recycling facilities that might want to recycle the scrap. The instructions are specific in relation to environmental hazards posed by different parts (Lee et al., 1999 pp. 218-219). At the same time, the European WEEE directive as of 2002 has not been implemented by law into the European Union. In comparison, Hewlett Packard has so far had 6 years of operation from the start of their recent recycling center in 1997 in California, and Taiwan has been in operation for 5 years (Fishbein, 2002, p. 54).

2.4.5 European Organizations

Overview:

Although, different environmental tactics can be seen in voluntary corporate computer recycling as apposed to required government regulations of such recycling, a combination of both approaches does exist. Roteb a recycling company in the Netherlands saw a potential benefit in becoming involved in a possible future high demand for recycling arising from the new WEEE directive (Kirkke, Harten, & Schuur, 1999, p. 745). Since Roteb is not a producer of computer scrap, they are not under the regulations of the European law, but because they are a recycling center, they will be able to take advantage of a large amount of computer scrap the directive will anticipate being recycled. Therefore, they still see themselves as a potential player under the WEEE directive, even though they are not under its authority as a computer producer would be.

Roteb's Operations:

Even before the European Union directive was to be implemented, waste management organizations have been looking at ways to recycle electronic scrap, including computer products. One such company is Roteb in the Netherlands. The company, primarily located in Rotterdam in the Netherlands, has been looking at the problem of governments making producers responsible for the waste management of their produced goods (Krikke, et al., 1999, p. 745). As greater responsibility falls on the producers of goods primarily through extended producer responsibility, more recycling facilities will need to be created. Roteb began to examine the entry into recycling electronic scrap through a case study done in 1998 by Krikke from the Rotterdam School of Management and A. van Harten along with P.C. Schuur from the Twente University in the Netherlands (Krikke et al., 1999, p. 739). The study takes the proposal of Roteb to enter computer scrap recycling and examines various aspects of their entry. The importance of the study, which was done before there was any requirement, shows that individual waste companies that have not focused previously on recycling consumer goods are now looking into recycling of electronic equipment. In addition to the case study, Ferrer (1997, p. 86) from the University of North Carolina, also makes a similar diagnosis that most of the recycling in Europe is done in response to possible government regulations demanding that producers take back their used equipment for recycling. Companies such as Roteb feel that the amount of recycling will become large enough that there is potential value in entering the recycling market. Also by taking the position that there will be a large requirement in the future under European laws for producers to be responsible for their waste, they are preparing for a time when a large demand will be placed on waste management companies to deal with recycling (Krikke, et al., 1999, p. 745).

According to Ron and Penev (1995, p. 72) another company with an excellent history of recycling is Siemens-Nixdorf in Germany. They have been recycling computer products since 1988. In 1995, and as early as 1992, they were able to recycle up to 80 percent of the computer scrap they received. They were also able to recycle computer monitor glass into use in new screens and distributed separated metals and other components to third parties for further recycling and use. Although Siemens-Nixdorf has been able to recycle computer monitor glass into other new monitors, a case study on computer monitor recycling done by Sony Electronics in the United States indicated that they were not able to find any companies that could recycle cathode ray tube monitor glass because of its lead content (Smith, et al., 1995, p. 126). In addition to Siemens-Nixdorf there are numerous other recycling companies in the Netherlands and Germany that also deal with various types of computer scrap (Ron & Penev, 1995, p. 373).

Education Based Recycling

Every type of initiative for computer recycling originated from a program designed to fit the needs of or to benefit a particular sponsor. IBM originally developed a recycling program to reuse their computer scrap in order to generate revenue (Grenchus, et al., 1997, p. 157). Hewlett Packard developed its recycling program on its own initiative partly to further community relations (Levine, 2001, p. 22). The government of Taiwan and the European Union have implemented programs to manage the increasing amount of computer scrap which engulfs their landfills. In addition, on the other end of the spectrum, educational programs in computer technology benefit by managing computer scrap.

2.4.6 Students Recycling Used Technology

A program called StRUT, which stands for students recycling used technology, was formed in 1995 in Oregon through a partnership by Intel and a school district (StRUT, 2002d). The purpose of the program is to get students below college level involved in exploring technology through refurbishing computer systems. Students participating in the program are taught technical skills and obtain valuable experience in analyzing, refurbishing and building computers from components donated to the program. Donations are received from over 800 companies, including 14 million dollars worth of equipment from Intel in one year (StRUT, 2002d). StRUT primarily receives donations from businesses and private organizations. The types of computer scrap that can be donated are similar to what can be donated in the programs by Hewlett Packard and IBM. However, the purpose of the donation programs is entirely different. HP and IBM both charge money to give them computer scrap (IBM, 2002e; Hewlett Packard, 2001).

The main goal of both programs is to recycle computer scrap. Recycling is primarily in the form of refurbishing the computer scrap for charities and then melting or shredding the remaining components. Unlike IBM and HP, StRUT's primary focus is not computer recycling or environmental protection, but instead education (StRUT, 2002a). In each of the 136 schools participating in the StRUT location in Oregon, students can learn technical skills, possibly earn hardware certification, and also gain valuable management experience (StRUT, 2002b).

The secondary goal of StRUT is in recycling computers (StRUT, 2002a). Just like HP and IBM, StRUT's focus in recycling is to try and reuse as much of the computer scrap as possible. Donated computer parts are used by students in StRUT to create workable computer systems. The working systems are then donated to schools chosen by the StRUT program. This is similar to IBM and HP donating reusable computer systems to their chosen charities. To insure that the computers donated by StRUT are used for their intended purpose strict regulations are placed on their use. This includes StRUT retaining ownership of the systems unless special permission has been given.

Regardless of how much effort is put into refurbishing computer systems by the participating schools, there is always computer scrap left over. HP and IBM also find this problem in their programs. Part of the agreement that StRUT has with participating schools is that all unusable parts will be recycled through designated recycling companies. Also, all parts received by StRUT directly, which are unusable, will be recycled (StRUT, 2002c). The success of recycling through the StRUT program can be compared to HP's plant in California. In nine months from September 2000, StRUT was able to recycle about 1.3 million pounds of computer scrap or approximately 0.14 million pounds a month (StRUT, 2002c).

On the other hand, HP estimates that they are able to recycle 3.5 to 4 million pounds of computer scrap each month at their center in California (Hewlett Packard, 2002). Although there is a significant difference in the amounts recycled by HP and StRUT, the 1.3 million pounds recycled by StRUT does not take into account the computers at the participating schools. Also Hewlett Packard is a worldwide corporation that has a donation program where people can ship their computer scrap to their recycling facility. StRUT, on the other hand, can only receive donations by hand delivery or large quantities can be picked up by truck, but only locally (StRUT, 2002b). Regardless of the success of HP's recycling program, immeasurable success can be seen in the Oregon StRUT program. With 3,600 students creating 22,000 computers since the start of the program, which then entered schools, the success is incomparable (StRUT, 2002d).

The success of StRUT can also be seen through its expansion and achievements in other states. Two years after the start of StRUT in Oregon, the program was expanded to include Arizona where currently over 100 companies are donating equipment (AZStRUT, 2001). A year later in Texas a StRUT program was also started (Texas StRUT, 2002b). Although continued success can be seen through legislation allowing state owned computers to be donated in Oregon, barriers have arisen (Texas StRUT, 2002a). In April of this year, Oregon's environmental division put a ban on computer monitors that caused StRUT to refuse acceptance of any Cathode Ray Tubes (StRUT, 2002c).

2.4.7 International Recycling Approaches

Companies that either maintain recycling programs as part of corporate policy or are forced to be responsible for recycling by government initiatives approach recycling through three techniques. The first technique is where the company obtains computer scrap and only provides disassembly or preprocessing services. For example, the plant created by IBM in New York is designed as a demanufacturing plant where computer scrap is disassembled and the individual components are then shipped to other organizations for recycling (Grenchus, et al., 1997, p. 159). Roteb in the Netherlands also desires to take the same course of action as IBM (Krikke, et al., 1999, p. 745). They wish to provide disassembly or preprocessing services on site while letting outside groups be responsible for recycling and disposal in landfills, if any.

Hewlett Packard implements an alternative tactic where all recycling takes place onsite. In their plant in California, HP has machines that provide onsite shredding of computer equipment. Unlike other companies such as Roteb and IBM, Hewlett Packard is able to recycle and analyze portions for reuse without the aid of any outside organizations (HP, 2002).

At the opposite end, and unlike Hewlett Packard, IBM's take-back program for consumers does not rely on any facility maintained by IBM. Instead, IBM only maintains the service, offering consumers an easy method to ship computer scrap to an independent computer recycling service (IBM, 2002a).

As government regulations increase, continued outsourcing of recycling programs will become necessary. Roteb is one of the companies that recognizes this increasing necessity. (Krikke, et al., 1999, p. 745). Therefore, to minimize future costs, a possible solution is to develop computer parts that can easily be dismantled for recycling.

2.4.8 Product Ecology or Design for Recyclability

A common method for reducing recycling costs is to design the product in a form that allows for easy disposability and disassembly. A successful recycling program is beneficial to managing existing computer scrap as shown by previous programs such as those by IBM and HP. However, the recycling can be enhanced by focusing the development of new computers and electronic equipment on design for recyclability.

Since the materials in the product affect the cost of product recycling, it is useful to create a product that is easy to recycle. D. Navin-Chandra, F. Prinz, and R. Wei Chen (1993, p. 181) describe some crucial elements of product design while considering recycling benefits. The authors introduce two categories while considering a design for recycling: selecting suitable materials and designing for ease of disassembly.

Selecting suitable materials includes considerations for the materials mix, toxicity of the materials, the recyclability of the materials, using recycled materials, and materials compatibility. The mix of materials used in a product should be reduced to as few elements as possible since the task of separation will be more difficult with a variety of elements. Toxicity of materials refers to awareness of the environmental impact of toxic materials, such as heavy metals and polybrominated plastics used in flame retardants. The use of such materials will add complications and costs to manufacturing, separation, recovery, and disposal. Just as the European WEEE directive protects against disposal of computer scrap, a second European directive, the RoHS or Restriction of Hazardous Substances is designed to enhance recyclablity by phasing out the use of toxic substances, as mentioned above (Fishbein, 2002, p. 55).

Material recyclability refers to design considerations to use materials that can be easily recycled once separated. The cost of recycling easily recyclable materials far outweighs the cost of purchasing the new raw material. Materials compatibility suggests using pieces that fit together easily. If compatible materials are used in assembly, then reduced costs are guaranteed at disassembly. It is also suggested to use recyclable or recycled materials if the engineering requirements are satisfied.

The second category discussed by the authors was design for ease of disassembly (Navin-Chandra, Prinz, Wei Chen, 1993, p. 181). The suggested rules for design include: choosing joints that are easy to disassemble if the material is not recyclable, simplify and standardize component fits and interfaces, identify separation joints, use water soluble adhesives where possible, label all materials for identification, design for ease of handling and cleaning of components, choose easy separating joints for parts which have reuse value, consider environmental changes such as rust in design, use same size joints for adjacent parts, and provide access for hand tools or power tools.

2.5 Intel's Presence in Costa Rica

2.5.1 Intel's Arrival

Since 1874, Costa Rica's economy depended heavily upon the production and export of bananas and coffee. The advent of high tech corporations is only a recent development. Stone (2000, p.42) expressed that previously there has been a great difference in the country's production potential and its actual output. For example, the citizens of Costa Rica boast a 95 percent literacy rate, which is higher than any of its neighboring countries. In general, Costa Ricans are highly educated as compared to other Latin Americans. With a surplus of skilled labor, Costa Rica has a relatively high potential for high-quality skilled production, but the problem has been that it has lacked significant industries.

In 1996, Intel hoped to reduce risks based on concentration of capital through expansion internationally and reduce the cost of goods sold by erecting another plant for assembly and testing of its products (Carl, 2000). They recognized the potential of the Costa Rican workforce and its stable government and studied its San José region for the site of their new facility. Intel had not initially considered Costa Rica as a front runner, but when the Costa Rican government offered 400,000 square feet to Intel in a tax free industrial zone, Intel made the move. Furthermore, Intel Costa Rica receives a 50 percent bulk rate on utilities (Vogel, 1998). This is, however, the standard incentive package given to any large industry that chooses to set up shop in Costa Rica.

In addition to other benefits, the Costa Rican government agreed to emphasize English in their schools, creating mandatory English courses. They also began work on creating a national network of computer labs throughout all schools and universities (Vogel, 1998, p. A18). Costa Rica has always placed a large emphasis on the development of its educational system. The proposition to expand the education requirements and capabilities serves to further exemplify this.

Swayed by Costa Rica's strategic geographic position, the governmental benefits and the potential of the workforce, Intel chose Costa Rica for the site of the new plant. Breaking ground in 1997, the facility was completed and opened in 1998 (Carl, 2000, p.1). It consists of two assembly and testing plants, CR1 and CR3, and a center of distribution, CR2.

2.5.2 Opposition to Intel Costa Rica

There was a minority of people opposed to the construction of the Intel Costa Rica plant, fearing it would have negative consequences upon the environment and local populations (Byster, 1997, p.2). The residents of Belen, the area chosen for the site of the facility, expressed concern on the following topics. First, the plant was to be built directly on top of a main aquifer for Costa Rican central valley. The issue of water usage was a primary concern, since Intel Costa Rica was predicted to use over 1 million gallons a day as part of the manufacturing process. Second, the plant was also placed near artesian springs and a river. Third, there were questions regarding the water conservation system Intel Costa Rica agreed to install and whether or not the plant would use a closed loop system. Fourth, Intel had failed to disclose what sorts of chemicals and hazardous materials would need to be disposed of, as there was no governmental regulation compelling them to do so. And fifth, residents were concerned with the health effects of the high voltage power lines that were to be constructed to support the needs of the new plant. (Campaign for Responsible Technology, 1998, p.2).

2.5.3 Intel Costa Rica's Actual Effects

This opposition proved to be a hindrance in the actual construction of the plant, as many local residents took action. There were several protest incidents, most of which were resolved (Campaign for Responsible Technology, 1998, p.1). The facility was completed, and operation began in 1998. Today, there are few Costa Ricans who are still in opposition to Intel Costa Rica. Many of the problems of misinformation or lack of information have been cleared up. First, the town of Belen is built almost directly on top of the aquifer that people were concerned about. No matter where Intel built in Belen, they would have been on top or near it. Therefore, Intel Costa Rica periodically tests the water in the aquifer through 4 test points, both upstream and downstream, in order to ensure the plant has no effect on the water itself. On the issue of water consumption, they consume a fraction of the 1 million gallons of water per day which was predicted, most of which is for personal use rather than in manufacturing. In addition, they use water that they pay for from the town of Belen. They have no well to draw from the aquifer.

Second, the issue of pollution in local springs and rivers is nonexistent according to Intel Costa Rica. They use a biological treatment plant on site that treats the water to be crystal clear. Although it is not a closed loop system, where the treated water is recycled back into the plant, the capabilities exist, and they plan on doing it in the future.

Lastly, the chemicals and hazardous wastes are disposed of properly. Intel Costa Rica prides itself on adhering not only to all Costa Rican laws and regulations, but those of the US also. This creates environmental standards that are higher than those any company in Costa Rica is expected to follow. Furthermore, all hazardous material is handled in a proper manor, ensuring no leakage into the environment. Finally, the material that cannot be treated locally is then shipped internationally to be processed. Overall, Intel Costa Rica sees itself as very environmentally responsible, thus their interest in further means to reduce E-waste.

2.6 Economics

2.6.1 Economic Growth

Opposition to the construction of the Intel plant was a minority voice. For the most part, the country supported the construction of the new plant. Costa Rica's government offered their standard incentives to encourage Intel to build there in order to boost the economy and encourage future investments. The 300 million dollar complex created over 2,000 jobs for the highly literate Costa Ricans, often paying well above the average salary (Informatica International Clayton S.A., 2000). Costa Rica's shrewd political and business decisions, in general, are reflected in the country's current success.

Today, it does not show the signs of poverty that are evident in neighboring countries, a success which some feel Intel has played a part in (Carl, 2000, p.198).

Overall, the arrival of Intel in Costa Rica has been positive, representing a new economic era forged with high-tech industries. Bananas and coffee, which used to be the primary exports, grossed 10 and 5 percent of exports, respectively, in 1999. During the same period, computer products represented 37 percent of exports (Carl, 2000, p.196). This boosted the GDP by 8% and resulted in a trade surplus, which has not existed in Costa Rica since 1986 (Johnson, 2000, p.1).

The benefits to the Costa Rican economy were predicted to go beyond the boost to the GDP and trade profits. The country has geared up to become the next high-tech growth center. The capital has acquired the nickname "San Jose South," in its resemblance to the San Jose at the heart of Silicon Valley (Vogel, 1998, P. A18). The flexibility and minimal bureaucracy that drew Intel into Costa Rica and the success story that followed began to attract other high tech industries to the small country. Acer set up shop with a customer support center employing 350 people. AETEC, an Arizona-based technological services company, also decided to build in Costa Rica, employing many skilled Costa Ricans in its 25,833 ft^2 facility (Informatica International Clayton S.A., 2000).

New industries are predicted to develop to supplement the new high-tech economy. As Intel basically represents the entire semiconductor industry currently in Costa Rica, they are forced to import 90% of their supplies. The development of a more expansive electronics industry would not only cut costs for Intel, but would bring more money into the local economy (Stone, 2000, p. 43).

In addition, the potential for the development of a waste management industry seems logical. As of now, there are no waste treatment facilities available for many of the specific chemical wastes produced by Intel Costa Rica. Thus, the company is forced to export all of its chemical wastes to the US for treatment. With Costa Rica's interest in environmental conservation, and the probability of cutting shipping costs by doing recycling in the country, the potential for a waste disposal/recycling industry is worth considering.

2.6.2 Potentially Harmful Dependency

There is a fear, however, that Costa Rica's economy is too closely linked with the economics of Intel. Stone (2000, p. 43) states that "economists worry the nation is becoming too dependent on Intel, and that the company is getting [inexpensive] labor while [Costa Rica is] getting little in return [working out of a tax free industrial zone]. But others portray Intel's success as a can't-lose proposition." The ties between the Costa Rican government and the production facility are tight. This currently serves to benefit the economy since as Intel profits, so does the country. The concern was what would happen if Intel's economic state declines. When more than a third of a country's exports are coming from a single source, fluctuations of the source are likely to be reflected in the national economy.

In the year 2000, due to the overall condition of the industry, Intel's production began to decline. It was predicted that this would lead to a drop of the national GDP growth from 8 percent to 4 percent (Stone, 2000, p. 43). What Costa Rica actually saw was a drop to 2 percent, which continued down below 1 percent in 2001 (Australian

Department of Foreign Affairs and Trade, 2001, p.1). Although one cannot definitively say that Intel's shift in production was the cause of the diminished growth of the GDP, it certainly played some part. This is indicative of the close links between the profits of Intel and the Costa Rican economy.

Intel Costa Rica plays a pivotal role in the economy of Costa Rica. For this reason, they hold a lot of public responsibility. If a change in production means a significant drop in the GDP growth, what would a large scale failure of Intel produce for the small country? In addition, there is a lot of pressure put on Intel Costa Rica in the realm of environmental concerns. As mentioned before, there were Costa Ricans who were in opposition to the construction of the facility, and some still feel negatively towards Intel Costa Rica, mostly in regards to environmental concerns. This pressure along with the economic links have put Intel Costa Rica in a pivotal and significant position.

2.7 Legal and Political Framework

2.7.1 Environmental Conservationism and Laws

Intel Costa Rica acknowledges the powerful position it accepts these good public responsibilities. Currently, there is little regulation governing many of the electronic production operations that exist in Costa Rica, since it is a relatively new industry. Intel Costa Rica, nonetheless, has tried to set a benchmark in safety and environmental awareness. They are committed to adhering not only to all Costa Rican regulations, but those of the US as well. If there are two conflicting laws or regulations, Intel Costa Rica will obey the one which would be considered stricter. In addition, we have personally observed that Intel Costa Rica operates with very strict safety regulations in general. All proper safety equipment must be worn at all times, and all proper procedures must be followed in it's plant. These standards are enforced by safety officers that patrol the grounds looking for problems. By doing this, Intel Costa Rica hopes to create a paradigm that other local companies would strive to match.

The arrival of Intel in 1998 signified a new economic and industrial era in Costa Rican history. Since the existence of high tech corporations was relatively new to Costa Rica, the country had never established laws and regulations governing the environmental impact of such industries (Carl, 2000, p. 2). In the past decade, however, environmental conservation has become a hot topic for many countries, including Costa Rica.

Solid waste pollution became so much of a problem that, in 1989, the Costa Rican government declared it a national emergency. They enacted two regulations governing the processes of waste management and sanitary landfill usage. Furthermore, in 1995, the government enacted more regulations in order to protect the Costa Rican environment. Generally, these new laws require any company producing wastes to install a treatment plant for that waste in their own facility (Araya, 1999, p. 2).

Costa Rica's national turn towards greater environmental conservation is being reflected in the agendas of local businesses as well as the ideals of individual citizens. Businesses are beginning to purchase pollution control equipment at an increasing rate. The market for pollution control equipment, for both public and private sectors, has seen a leap in growth during the last decade. One of the primary reasons for this is that the industrial sectors of Costa Rica are slowly starting to adopt ISO 14000 standards (Kinsella 1994, p.1).

The Intel Costa Rica facilities were put in place after the advent of the laws governing solid waste, thus making them responsible for implementing solutions to the excess waste produced by the assembly plant. Because the facilities to treat the given waste produced by the new plant do not exist in Costa Rica, Intel Costa Rica has arranged to have its waste exported to the U.S. where there are facilities to properly dispose of it (Araya, 1999, p. 3). Currently, the prime motivation is not economic gain from a through waste management, but rather the preservation of the environment. In addition is goes along with their goal to operate to the standards set by the Costa Rican and United States governments. However, as with any business initiative, if it could be done in a way which would lower costs, it would be a big incentive for Intel Costa Rica.

2.7.2 The Basel Conferences

One of the options to consider for a solution to E-waste buildup is its exportation to other countries that are better equipped to process the material. There is, however, an important cosideration in the discussion of this option. The Basel Agreement, created March 22, 1989, and put into effect May 5, 1992, is an agreement among 130 nations issued to reduce the effects of hazardous material on the environment and people (Basel Conference, 1989). The motivation behind this agreement was that developed countries, looking for a more economically feasible solution to their scrap management issues, would export their hazardous waste to undeveloped nations that were ill-equipped to process this material safely.

Realizing that this was an issue, the nations involved in the Basel Convention began to establish an outline for an agreement intended to reduce the amount of toxic materials used in manufacturing. The prime method by which they attempted to do this was by agreeing to disallow transboundary movement of hazardous waste, specifically from a developed nation to a non-developed nation. The list of materials this covers includes volatile, radioactive, and any materials that could cause harm to humans or the environment. As computer scrap includes some materials from the list, including lead, zinc, and several others, it is deemed hazardous waste, and thus restricted by the Basel Agreement. And since Costa Rica signed the Basel agreement on July 3, 1995, any exportation might seem to go against the agreement.

There is, however, a clause in Article 4, Paragraph 9, that states, "Parties shall take the appropriate measures to ensure that the transboundary movement of hazardous wastes and other wastes only be allowed if: (a) The State of export does not have the technical capacity and the necessary facilities, capacity or suitable disposal sites in order to dispose of the wastes in question in an environmentally sound and efficient manner; or (b) The wastes in question are required as a raw material for recycling or recovery industries in the State of import…." (Basel Conference, 1989) Since Costa Rica does not have the technical capacity, necessary facilities or suitable disposal sites and in addition, the scrap would be exported to a country as a raw material for a recovery and recycling process, the restriction would not apply.

There was, in 1995, an amendment to the Basel Convention, which Costa Rica supported, entitled Basel Ban Decision III/1 (Basel Conference 3, 1995). This decision only banned the export of computer scrap from Organization of Economic Cooperation and Development (OECD) countries, the United States of America, and Liechtenstein. OECD countries are defined by the Basel Convention as 30 more highly developed industrialized countries that have the facilities to properly dispose of the materials listed in the Basel Convention. Since Costa Rica is not on the list of OECD countries, this does not present an a problem for exporting waste from Costa Rica.

2.7.3 Intel Costa Rica's Relationship with Costa Rica

Intel Costa Rica has a history of positive community involvement within the Costa Rica. According to Intel (2002), they recycle 50 percent of their solid wastes generated by the plant and donate the revenue created to local public schools. They have also established the Belen Environmental Industrial Committee, which addresses such topics as the environment, health, safety, waste handling and odor abatement. In addition, they have arranged an Environmental, Health and Safety conference for the last three years in order to address the concerns of community members, non-governmental organizations, industry, and government personnel alike (Intel, 2002). Intel Costa Rica has done much to please the Costa Rican government and population through its activism.

The Costa Rican government and Intel Costa Rica have both shown their respect and admiration for each other. For Intel Costa Rica's involvement in the community and for fostering positive environmental programs, the government has presented them several awards and recognitions including the Premio Global Preventico Award for the past 3 years in a row. This is the most prestigious safety and health award presented by any government institution in Costa Rica (Intel, 2002).

2.8 A Complex Decision

In conclusion, there are several key issues at hand regarding the complexity of Intel Costa Rica decision to consider a waste management system for computer scrap generated by Costa Rica:

- The original controversy over the construction of the plant and the continued pressure exerted on all industries by certain environmental groups and individuals.
- The close economic ties between Intel and the Costa Rican economy. Although there is low risk in setting up a scrap management system, there is still concern due to the complexity of economic connections. There is a possibility for economic gain or loss to either or both Intel and Costa Rica, depending on each party's level of involvement. In theory, it is possible for both to gain profits in addition to helping to preserve the environment.
- The desire to maintain the positive relationship between the Costa Rican government and Intel Costa Rica.

The decision to take action to more effectively manage computer scrap is not without risk, but the potential gains outweigh the risks.

Chapter 3. Methodology

3.1.1 Introduction

The methodology section of this report includes the methods of analysis to complete each objective defined in the introduction. Each methodology is explained and justified based on the particular objective being accomplished.

3.1.2 Corporate, Institute, and Individual Disposal Methods

To determine the level of the computer scrap management problem in Costa Rica, we evaluated the current disposal methods being used by the Costa Rican population. This provided information concerning the computer scrap disposal practice of the public. To carry out this methodology, we conducted several interviews among respected persons who are knowledgeable about the most feasible and common disposal methods used among Costa Rican businesses, organizations, and the general public. The people who contributed include: Dr. Rosendo Pujol, director of the Programa de Investigación en Desarrollo Urbano Sostenible (PRODUS) at the University of Costa Rica (UCR), Anibal Alterno of Intel Costa Rica, Don Fernando, chief of several technical high schools in San José, Patricio Solis from Centro de Investigaciones en Contaminación Ambiental (CICA), and Henry Salazar from the Omar Dengo Foundation. Among other things, these interviews reconfirmed that the majority of Costa Rican computer scrap exists in the Central Valley, where the majority of the population resides. Since this is one hypothesis and since individual municipalities are responsible for the disposal of their own waste, the majority of Costa Rica's computers will probably end up in the Central Valley landfills.

To further develop the study of disposal methods, archival research was conducted to discover facts about general waste disposal in several cities in the Central Valley. Archival research revealed a CICA survey investigating the extent to which the Costa Rican population was interested in recycling. The survey includes information as to whether or not the public thought waste disposal services were expensive, along with information about recycling habits (such as separation of waste materials for easy pickup). These ideas all influence active participation in a recycling program.

Since the majority of the Costa Rican population is known to use one particular and easy disposal method, interviews and a small amount of archival research was sufficient to obtain the different perspectives of corporation, organizations, and individuals disposal methods.

3.1.3 Computer Scrap Distribution in Costa Rica

In order to determine where Costa Ricans distribute computer scrap, we evaluated the final resting places of local computer scrap and performed archival research to determine the quantity and distribution of computer scrap in Costa Rica. This task included locating landfills and performing direct observation to estimate visible computer scrap. In addition, two managers from major landfills in the Central Valley area were interviewed regarding three key aspects: to determine an estimated volume of computer scrap, to obtain records for the environmental damage caused by heavy metals and other elements found in computer scrap as discussed in chapter two, and to evaluate the managers' awareness of environmental damage caused by computer scrap. The volume of computer scrap in each landfill also confirmed the geographical distribution indicated in archival research.

We used census data as a source to examine the quantity and distribution of computers in Costa Rica. The studies provided a breakdown of how many computers exist in households throughout the country. Dr. Rosendo Pujol of PRODUS provided information on the number of computers per household in each municipality, derived directly from the 2000 census data. Additionally, archival research was conducted to uncover additional sources of interest, including the rate of growth of Internet usage. Also, import records were evaluated to determine the weight of computers being imported into the country on a yearly basis from the Ministerio de Hacienda. This weight was used to estimate the number of computers that entered the country.

To determine the rate of replacement, several individuals were interviewed at various organizations to see how often they replace their computers. Estimates and comments on this issue were obtained from Don Fernando, chief of several technical high schools in San José, Henry Salazar from the Omar Dengo Foundation, and Federico Castro from Intel Costa Rica. This information was used to roughly estimate and speculate on the weight of each element that may end up in the landfills in the future (discussed in Determining Computer Scrap Volume in the Central Valley Landfills, section 4.3).

3.1.4 Analyzing The Extent to which Computer Scrap is Hazardous

An important dimension and objective discussed in the introduction is an analysis depicting the point at which computer scrap becomes hazardous to the environment. This analysis includes calculating both the amount of time generally required for computer scrap to become a chemical hazard in a landfill and possibly more importantly, the quantity of chemicals needed to cause harm to the surrounding community.

An explanation of how much computer scrap is needed to cause a significant environmental damage can be important evidence to support an initiative to implement a computer-recycling center.

Proof of the extent to which computer scrap is hazardous in Costa Rica could pressure the creation of a governmental or corporate computer-recycling center. The initial focus of research in this area was archival. We uncovered documents detailing the exact content of lead and various other hazardous elements and compounds commonly found in computer scrap. Documentation was uncovered revealing the contribution E-waste in a landfill adds to the leakage of hazardous elements as well as the exposure dosages of many elements found in computer scrap (this information has all been included in Chapter 2. Background Information, starting with section 2.2).

Once the hazardous elements and the effects of their exposure on humans had been identified (detailed in Appendix G), we pursued research and speculated on the extent of the E-waste problem in Costa Rica. These investigations included an evaluation of disposal methods, an analysis of the landfills and the distribution of computers in the Central Valley, and the turn-around rate of computers in Costa Rica.

3.1.5 Development of Recycling Model

We researched the best possible model for Costa Rica to dispose of their computer scrap. Under the assumption that disposing of computer scrap is hazardous, we began research on what possible solutions existed for Costa Rica to recycle their computer scrap. The methodology was based mostly on unstructured interviews, as most of the people we talked to gave us more leads to follow. Eventually, we gained enough information to develop models which we analyzed based on feasibility, cost, and efficiency in the amount of scrap that would be recycled or reused.

Our initial discussions with Anibal Alterno, an Environmental Engineer working for Intel Costa Rica, gave us some preliminary information on who to contact both at Intel Costa Rica and throughout Costa Rica. Anibal also gave us some information regarding the legalities of moving computer scrap internationally, which we further researched on the Internet.

We had several teleconferences with both Todd Brady and Scott O'connell, both Product Ecology Managers at the Intel plant in Arizona. They gave us much insight into the StRUT program and more importantly, their yearly recycling day which has been operating for the past three years successfully. They provided much information on how it was run, as well as providing statistical data.

We visited two landfills, Río Azul and Los Mangos, to determine what role, if any, they would play in the solution. We talked to Arturo López at the Los Mangos landfill and Adolfo Cordoba at the Río Azul landfill.

As part of the model, we wanted to include s refurbishing and recirculation function. The methodology on how we determined the possibility of this is discussed in

Investigation of Existing Student Refurbishing Operations, section 3.1.6. In addition, we determined that there were no local processing faculties, so that it would have to be done internationally. The details of how we discovered and analyzed these companies are located in the North American Computer Mining Corporation Survey, section 3.1.8.

We also needed to determine how we would ship the scrap to the US if there were to be an international processing model. We knew that Intel Costa Rica was shipping its High Value Inventory (HVI), or defective chips that were shredded, to California in order to be recycled. We talked to Luis, who is in charge of the shredding, packing and part of the logistics of the HVI. In addition, while visiting Henry Salizar at the Omar Dengo Foundation, he expressed his enthusiasm about the project and wanted to help. We discussed with him what role the foundation would play in the model.

We also wanted to determine what the model needed in order to be successful. Taking note of what was given to us about the StRUT initiative in Arizona and taking a look at past recycling events, we realized that there needed to be a more public awareness about the benefits of recycling, as well as knowledge of the existence of a recycling program. We then asked Emilia Mora and her co-worker, both employees of La Nación, how they might help.

After compiling the information, we developed several models with multiple options. Results and analyses can be found in detail in Chapter 4. Findings and Analysis.

3.1.6 Investigation of Existing Student Refurbishing Operations

The most desired recycling technique with companies such as Hewlett Packard and IBM is to reuse as much computer scrap as possible. Here reuse comes in the form of dismantling components to salvage as much of the original system as possible. Therefore, one of the main portions of a computer-recycling center would be to extract as much working components as possible. Just as students reuse computer scrap in the United States through the StRUT program, students in Costa Rica in technical high schools might be able to play a similar role. They could possibly be involved in the preprocessing segment by separating working components from non-working components.

Intel Costa Rica has specified that the technical high schools are not interested in participating until a solution is implemented to recycle the computer scrap that cannot be refurbished and which they would have otherwise had to store or get rid of. They were not able to provide information about the extent of the technical high school's desired participation nor what facilities currently exist at the schools.

In order to determine the role that the students from the technical high schools could play in a refurbishment system, we needed information to determine what resources and operations currently exist and the extent of interest for expansion. Intel Costa Rica provided a list of a few technical high schools indicating that they have a type of computer refurbishment operation. The list of schools included the Don Bosco and the San Sebastian Technical High School. From the list, we choose the San Sebastian Technical High School as a possible school to interview to obtain more information on their program. Our visit to this particular technical high school was on the advice of Don Fernando who is the director of technical education.

Upon our visit we were able to interview two individuals who are directly involved with the computer refurbishment curriculum. The first set of questions posed revolved around their existing facilities. We asked questions to obtain a feel for what type of activities their students engaged in. We also wanted to determine the exact focus of their work, how much is on teaching through demonstration and how much self teaching occurs through refurbishment. Additionally, we sought to obtain a feel for the resources that they have in place. Asking about their resources and facility limits provided us with ideas about the ease at which their operations could be incorporated into refurbishing computer scrap from a recycling center. We asked various questions pertaining to where they obtain their computer scrap, how many students currently are involved in the program, and other questions design ed to depict the limits of their operations.

One we gathered enough information to grasp a sense of their current activities and what resources they have at their disposal, our line of questioning changed to ask about their desire for possible involvement in the refurbishment portion of our proposed recycling center. We designed questions to assess their willingness to expand and what might limit possible expansion. Our questions evolved around determining their interest in having more working computer scrap to use to create computers for their current facilities. We wanted to know what they would need to separate working components from non-working components, including space needs. In addition, we asked if they could carry out the refurbishing at a central warehouse or whether they need equipment that cannot be moved from the school.

The interview provided necessary information depicting their possible involvement in a refurbishment center. In addition, more information resulted in a better understanding of current student refurbishing in Costa Rica.

3.1.7 Discussion of the Sociological and Economic Impacts

As practical as it seems to just recommend a solution by considering only factors such as costs and processing capabilities, it's not that simple. With every innovation, change or initiative there are consequences associated, some good and some bad. It would be irresponsible of us to recommend a solution without considering what sort of side effects might result from its implementation.

In this section, we will talk about our hypotheses, considering these side effects. We will then discuss how we analyzed whether these hypotheses were valid.

We brainstormed possible effects that might happen as a result of the implementation of a recycling system. One of the most obvious possibilities was either the loss or creation of jobs and revenues. We initially decided that the best way to research this would be to interview the managers of the landfills to determine their opinion. We also asked them to estimate how much of their waste received was computer scrap, in order to determine a worst-case scenario, if they lost all revenue from this scrap.

Along the same lines, we realized that there was a great potential for creation of jobs, as well as a new industry, that might help the economy. If a profitable recycling industry were to develop, which is part of our long term goals, then it is logical that it would result in more jobs, as well as a small boost for the local economy. In addition, we talked to San Sebastian Technical High School, which we hope to involve in the model, to determine their interest and how it would affect them. Finally, we talked to Juan Carlos Salas Jiménez, who runs a product recycling/materials exchange program to determine whether it would affect his business in any way.

We also considered what sort of social conditions would have to exist in order for the program to succeed. We knew that people would have to be aware of the hazards and waste associated with the improper disposal of computer scrap, as well as knowledge of the alternatives in order to participate in the program. As part of our interviews with the landfill managers, any potential players in the model and other organizations such as La Nación, we attempted to determine whether or not these people were aware of the hazards of improper disposal. Of course, we could not determine their knowledge of the alternatives, however, because at this point, none exists.

3.1.8 North American Computer Mining Corporation Survey

A major segment of one of the computer scrap management systems is to ship computer scrap outside Costa Rica for recycling. Although recycling the scrap in Costa Rica would be ideal, before Intel Costa Rica can create or have someone create a recycling center, Costa Rica must export the scrap for recycling. For example, computer scrap collected from a computer recycling day or from over a period of time would have to be shipped internationally.

Determining where to export the scrap was not such a complex issue as having to choose a recycling company that can adequately recycle the material. In choosing a location for computer recycling, shipping costs played a major factor in our calculations. Therefore, the only suitable place to ship material would be North America because of its proximity to Costa Rica. Using Internet searches, we first examined Central America because of close proximity to Costa Rica. However, this was unsuccessful, so we further investigated if these companies knew of any computer-recycling program in Central

America. MBA Polymers had indicated they were interested in expanding their operations to Central America, but they did not know of any recycling facilities. We also contacted IBM to determine if they have any facilities in Mexico or in the rest of Central America. Unfortunately their facilities in Mexico did not meet our needs for a computer-recycling center.

We eliminated Central America as a possible search location because not enough information lead to even the possibility of a computer scrap company there. As a result, the remaining option was the United States. We performed Internet searches to identify computer scrap companies located in the United States. The prime search engine used was google.com, searching for phrases such as "computer recycling company". When a Google search provided a possible hit, we briefly examined the website to determine if the company appeared to recycle computer scrap. If the website indicated that they recycle computer scrap, we saved their contact information and website address for future contact. We obtained as many names and contact information for computer recycling companies as possible. The logic was the greater amount of companies discovered, the greater chance some of them would prove to be capable of handling Costa Rica's computer scrap. In the process of Google and other Internet searches, we obtained a website with e-mail addresses of computer recycling and or refurbishing companies located in the San Francisco Bay Area. The Silicon Valley Toxics Collation produced this list. We browsed it for all companies listed as recycling computer scrap. Also recorded was all of the companies' contact information. Additionally before we used the Google searches, we were aware of many companies that recycle computer scrap in the United States. For all the companies that we could think of such as IBM, Hewlett

Packard, Dell Computer Corporation, Envirocycle, and others we obtained contact information from their websites. From previous research, we were already aware of their websites. In addition, we sent Metech an e-mail since Intel Costa Rica mentioned them as being a possible player as they were already involved with recycling high value inventory from Intel Costa Rica.

We created and sent a questionnaire to all the discovered computer recycling companies. The questionnaire appears in Appendix E. Through the development of the questionnaire, we created questions that carefully asked about their business or regulations in the steps of sending computer scrap to a recycling company, the actual recycling, and the final distribution of the recovered material. Questions were then incorporated that provided information on the financial aspects of sending computer scrap to a recycling center. The purpose of the questionnaire was to be able to eliminate companies based upon undesirable aspects of their business. For example, questions were included that looked at the costs involved in sending computer scrap to a recycling company. In addition, we posed questions that determined the value returned from the material sent. All of the questions were direct questions, because we needed specific information from each stage in the recycling process. Although they were direct questions, they still provided the opportunity for a lengthy response even though a yes or no answer might suffice.

After the completion of the questionnaire, we made a revision to improve its clarity and re-grouped the questions. As can be seen in the survey we grouped some questions together because they form a single point, which needed addressing. We then sent the revised questionnaire out to the companies obtained from the Internet search, previously known computer recycling companies, and the ones found in the SVTC directory. In total, we sent the questionnaire to 28 companies and one division of IBM in Mexico. Most of the questionnaires we sent by e-mail to the e-mail addresses of the companies previously obtained. However, not all of the companies provided e-mail addresses. On some of the company's websites are contact forms. The contact forms request information such as name and e-mail address and provide a space to leave questions or comments. When submitted, the information provided and questions are sent by the contact form to the company electronically. We used these forms and pasted the questionnaire into the appropriate section when the company did not list an e-mail address. Sometimes when the company provided an e-mail address and a contact form, we used both for a greater chance of response. From the collected contact information, we sent the questionnaire to 28 companies located in the United States and one division of IBM in Mexico. The purpose of sending the questionnaire to IBM Mexico was to determine whether there was a computer recycling facility operated by IBM in Mexico.

If an e-mail sent out bounced back, meaning that the company we sent the e-mail to could not be reached because the e-mail address was invalid, we searched for other e-mail addresses. If multiple e-mail addresses failed then we tried no more e-mail addresses regardless of the quantity on the website. In addition, if an e-mail address failed and we had not yet used a contact form from the company's website, then we also tried the contact form. We were unable to make telephone calls because of the expensive cost of calling the United States from Costa Rica. However, using e-mail was sufficient.

From the 28 companies which received the questionnaire 14 companies provided responses, giving a 50% rate of response. Three companies including IBM Mexico had e-mails that bounced back because of invalid e-mail addresses.

Information provided by the companies that responded to the questionnaire and information gathered from all of the company's websites, was analyzed to eliminate companies that did not meet the desired qualifications for one of our computer recycling management models.

The first criteria was eliminating companies which either did not respond to the survey and or do not provide sufficient information on their websites to make a decision about whether they were appropriate for our purpose. Given the large number of companies contacted and the need for only one in the end, simply eliminating a few companies because they do not provide enough information was an acceptable tactic.

The second criteria used to eliminate companies was incompatibility with our desired need for a recycling company. Companies that it turns out do not recycle computers or only accept computers from a limited area would be an insufficient partner in a management system, which would involve shipping computer scrap to the United States.

The third set of criteria used to eliminate companies as possible choices as players in our management system was location. Since the computer scrap will be originating from Costa Rica, large transportation costs will be a major factor in shipping the scrap to the United States for recycling. Therefore, we also eliminated companies based on their distance from Costa Rica. The only companies that remained based upon location were those located in the South West region of the United States or California.

After the elimination of undesired companies, the remaining ones could be suitable candidates for shipping computer scrap to the United States for recycling. The analysis and results of the companies to which we sent the survey appears in, section 4.10. Additionally summaries of the results received appear in Appendices C and D.

Chapter 4. Findings and Analysis

4.1.1 Introduction

The Results and Analysis chapter describes the findings and analysis on the original objectives presented in the introduction. This includes detailing the problem further, commenting on the effects of computer waste, and discussing several possible management models that present solutions to the problem in Costa Rica.

4.2 Disposal Methods of Computer Scrap in Costa Rica

Research has revealed four common End of Life (EOL) options for computer scrap in Costa Rica: donating obsolete computer(s) to a family friend or needy organization, refurbishing the computer for reuse, storing it in a basement or other facility, or throwing it into a local landfill.

Donating computers to others is popular among all businesses, organizations, and individuals. In many cases, a lot of products are “fix it” as labeled by Dr. Rosendo Pujol, director of the Programa de Investigaciòn en Desarrollo Urbano Sostenible (PRODUS) at the University of Costa Rica. People fix old electronic products to get as much use out of them as possible, he explains, so it is very common to use small parts to repair a broken electronic device. This philosophy of “fix it” products not only creates a market for small parts but also is the basis for refurbishment programs and donation disposal. Nonetheless, he pointed out that the current software in computers is too advanced for most old computers to handle, inevitably creating some unusable computer waste. Aware of this situation, Intel Costa Rica actively donates relatively new computers to needy primary and secondary schools and other educational institutes to help boost higher educational standards and provide much needed technology for the students to use. Don Fernando, chief of several technical high schools in San José, explains that many donated computers come from a variety of corporations or institutions into his student-run computer refurbishing centers at the technical high schools. Usually, not more than 20 computers are donated at a time.

The refurbishment option is also possible among the educated population. The computer can either be donated to the technical high schools as described above, or the owner of the computer can do the refurbishment. Refurbishment will generally put the computer back into use for several years before it will have to be disposed of once again, at which time another EOL option has to be chosen.

Of course, many individuals and institutions have been known to use the storage method to temporarily solve the problem of what to do with an old computer. Some individuals place the old computer in some sort of storage room in their house, or as Dr. Rosendo Pujol, the director of PRODUS said, PRODUS has a few old, unused computers sitting in temporary storage only because they do not know what to do with them. This seems to be the case in many places; people are either not willing to part with the old machine, seeing potential future use, or they may not want to be a part of the population disposing of computers into landfills. Increasingly, the Costa Rican population is becoming aware of the adverse environmental impacts of computer scrap if it is improperly disposed of. For more information, see section 4.4, Social and Economic Impacts of a Management System. Patricio Solis from Centro de Investigaciones en

Contaminación Ambiental (CICA) explained that even the University of Costa Rica (UCR) has this problem. UCR has reportedly kept a large warehouse full of obsolete computers, waiting for a better disposal method than sending them to landfills. Likewise, Henry Salazar from the Omar Dengo Foundation expresses concern over what to do with his computers, especially monitors, some of which could be fixed. He has temporarily stored them in two rooms, where the computers are waiting to be fixed or disposed of. This seems to be a recurring theme among many people we have spoken with throughout this research project; many simply don't know what to do with their old computers.

The fourth disposal method common in Costa Rica is to throw computers into a landfill. Since there are reportedly a limited number of enforced laws on the disposal of computer scrap in landfills, this is an easy method for all individual users of computers. Since there is already a municipal trash service taking waste to landfills, people simply throw their computer away with their general waste. For corporations, the disposal of computer scrap in landfills is prohibited, assuming it fails the Toxic Characteristic Leaching Procedure (TCLP) marking it a hazardous waste item. Many experts, including Anibal Alterno of Intel Costa Rica and Patricio Solis from CICA, agree that sending computer scrap to a landfill is the most common disposal method in Costa Rica. Since storage is only a temporary solution to the problem in any case, eventually the scrap will exceed the storage capacity of the facility. This will prompt the use of another disposal method, usually disposal into a landfill. Several rumors about improper disposal by large institutions were also uncovered, but not confirmed. These rumors raise questions about the proper, and environmentally friendly disposal method big corporations and institutions should use when they have large amounts of computer scrap to dispose of. It also reinforces a belief that there is a problem with computer scrap in the country.

4.3 Determining Computer Scrap Volume in the Central Valley Landfills

Computer scrap volume and distribution is difficult to determine from the records available in Costa Rica. The Instituto Nacional de Estadística y Censos conducts a census every 10 years. The year 2000 was the first survey that included questions about computer ownership. From these data, it was calculated that 81.6% of households with computers are in the Central Valley of Costa Rica. Also, since it is assumed that the majority of the countries large businesses are in the Central Valley, most corporate computers are assumed to be in the Central Valley as well. It is also interesting to point out that about 63.4% of Costa Rica's population resides in the Central Valley (Céspedes, & Calvo, 2001, p. 23-35), indicating that the majority of the computers will be in the Central Valley since that is where the business, Internet, and other electronic transactions are more likely to exist. Since all municipalities are required to dispose of their own waste, and the most popular disposal method is throwing computers into a landfill, it is pretty clear that the majority of all Costa Rica's computers will eventually end up in a landfill in the Central Valley, unless an alternative is developed. There are a number of potential problems with disposal in landfills, as Arturo Lopez, an engineer at Los Mangos landfill in the Central Valley, explained. Computer scrap contains elements that may have adverse impacts on human health and it is taking up valuable space in the landfills.

Arturo Lopez estimates that from a daily intake of 550 tons of trash at Los Mangos landfill, less than 2% is computer waste. But even this amount of waste takes up valuable space in the landfill that could be used for other waste. Moreover, this problem will obviously grow if this disposal method is used in the years to come, rather than creating a recycling solution. At the Río Azul landfill, Adolfo Cordoba, in charge of managing a new recycling program at Río Azul, explained that they too are receiving computer waste. Of the 79 tons of industrial or commercial waste Río Azul receives per day, Cordoba estimates that about 2.2% is computer scrap, much of which could be recycled. This number is believed to be much more accurate than the estimate at the Los Mangos landfill since an analysis was done on the types of waste received. However, unlike Arturo Lopez, Cordoba does not think computer waste in landfills is that big a problem. There are more serious problems than computer waste, explained Cordoba. He may have said this because he was thinking of the serious amounts of plastics and other large volume wastes from households that are buried every day at Río Azul.

Based on the fact that 2.2% of the 79 tons of industrial waste received per day last year at Río Azul, we estimate that about 17,000 computers were disposed of in the landfill last year. Assuming an average computer, with all possible peripherals, weighs about 70 pounds, we were able to produce an estimate. Since there was about 27 thousand metric tons of industrial and commercial waste received last year, 594 tons was computer scrap (2.2%). This translates to 1.188 million pounds, which is about 17 thousand 70-pound computers. No information is available on the amount of computer scrap in the 180 thousand metric tons of domestic waste.

An indicator that may be used to estimate the growth rate of computer usage in Costa Rica and indirectly the volume of computer scrap ending up in landfills is the import records of computers and computer related material. The import records listed under the tax code 8471, obtained from Ministerio de Hacienda, for the year 2001 to May of 2002 shows the accumulated weight of computers (and computer peripherals) and its corresponding dollar value for each country of origin.

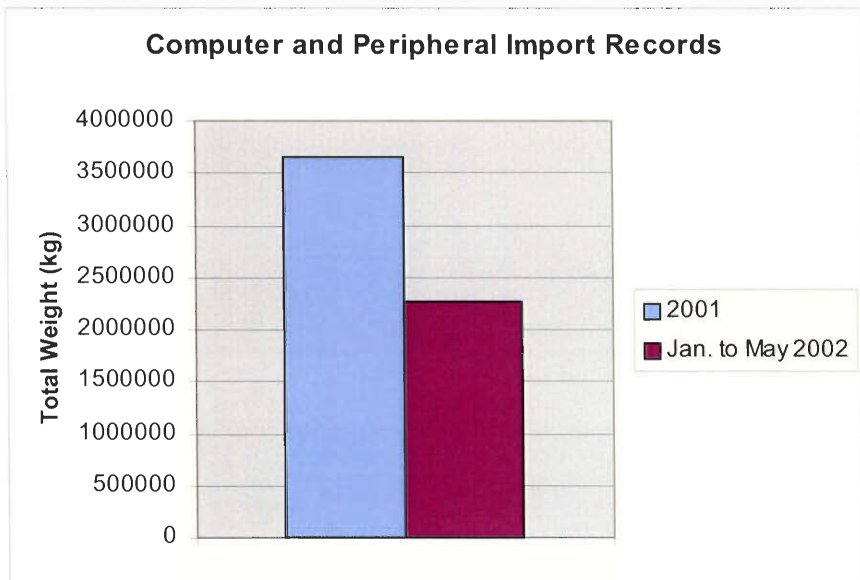

Figure 3: Weight of computers and peripherals in 2001 thru May 2002 in Costa Rica.

Figure 3 summarizes the important aspects of the import records evaluation; a total of 3,665,895.98 kilos of computers and computer related items were imported in the year 2001 and a total of 2,260,589.72 kilos of computers and computer peripherals were imported from January to May 2002. These numbers possibly suggest a rise in computer ownership as well, since about 61% of the imported weight in computers and computer peripherals of the previous year has been reached already in just 5 months time in the year 2002. Also, since there was about three and a half million kilos of computers and computer related products imported in the year 2001, no matter where their final destination in Costa Rica, it can be safely assumed that there are large quantities of hazardous elements imported each year as mentioned in section 2.2, Overview of Computer Scrap.

For the purpose of clarity, the number of kilos imported has also been converted to an estimated number of computers. In 2001, about 3.6 million kilos of computers and computer related equipment were imported. Based on a 70 pound computer, this translates into about 113 thousand computers. To derive the number of computers, we first converted 3.6 million kilos to 7.92 million pounds, and then divided by 70 to arrive at about 113 thousand computers. Similarly, the 2.3 million kilos of computers and computer related material imported from January to May 2002 could be converted to roughly 72 thousand computers. If this trend continues, clearly this indicates a rise in computer ownership.

Another indication that computer usage is rising in Costa Rica is the increase in Internet usage. There are 3,126 new Internet clients every month (Alvarado, 2001) in Costa Rica. Although no data were discovered about the total number of computer users, it is safe to assume that as the trend towards greater Internet access continues, more new computer users and owners will be added each year, adding to the problem of what to do with old computers.

It is also interesting to note that the growing use of computers in Costa Rica may soon produce more computer waste. The need to replace computers is driven by the inability to efficiently run new software on old computers. An important number that needs to be estimated, but is difficult to determine, is the turn-around rate of computers in

Costa Rica. Don Fernando, director of several technical high schools in San José who is knowledgeable about the student run computer refurbishment programs, indicated that the schools would soon have a problem with computer waste. In the next three years, he explained, half of the computers they use will need to be replaced. Based on Don Fernando's current estimate of 2,000 computers in the schools, this is about a thousand computers that will need to be disposed of. This cycle is expected to continue every three years in the technical high schools. Likewise, Federico Castro, in charge of systems administration at Intel Costa Rica, explains that Intel Costa Rica replaces computers every four years or as is necessary when software requirements overcome the capabilities of the computer. The three-to-four-year replacement policy seems to be common in Costa Rican industry, as software demands higher processing capabilities, all producing a constant flow of computer waste, thus adding to the computer waste disposal problem.

Based on the fact that there is an increase in computer usage in the country, and the most common disposal method for computer scrap is throwing it in a landfill, a severe problem will surely be seen in the near future. It is difficult to determine exactly when the country will feel the effects of this problem, but in five years when thousands of computers need to be disposed of, there will undoubtedly be a major problem. Based on a conservative five-year turn around rate for a computer and the 2000 census data, there will be more than 130 thousand computers in the year 2005, just from households, that will need disposing of. Section 4.6, Recycling Model discusses some potential solutions to the growing E-waste problem in Costa Rica.

4.4 Social and Economic Impacts of a Management System

As mentioned in our methodology, our recommendations would undoubtedly produce unintended consequences. Some might be positive, and some might be negative, but we attempted to predict the possibilities, and determine whether they were valid concerns.

The first hypothesis we had was that people might gain or lose jobs or business as a result of a recycling system. We talked to landfill managers from both the Los Mangos and Río Azul landfill in order to determine how it would affect them, their employees, or as we later discovered, scavengers. Arturo López of the Los Mangos landfill in Alajuela informed us that there would be little consequence to him or his landfill if computer scrap no longer was brought there. In fact, computer scrap accounted for less than 2% of their scrap according to his estimate. Upon taking a visual look at some of the trash that had yet to be covered, we saw no computer scrap. Thus, we believe that if our system were 100% efficient and no computer scrap was sent to the landfill, they would not lose any noticeable business.

The Río Azul landfill in Desamparados, San José gave us different findings. Jorge Cardoza, an administrator at the Río Azul landfill did an analysis that showed 2.2% of the non-municipal trash (where a majority of computer scrap comes in from industries and companies) was electronics waste. This non-municipal trash accounts for about 15% of the total trash (27,381 metric tons in 2001), putting the total estimate around .3%, plus the small amount that comes in with municipal trash. We did not see any computer waste in the unburied section of the landfill, but we did see several cases and CRTs dumped illegally in front of the gate. Jorge Cardoza did not believe that the elimination of computer waste would affect the landfill noticeably from an intake point of view. It accounted for so little of the trash that it would go virtually unnoticed by the workers.

There is another facet to this issue, however. The landfill came under new management approximately two years ago. At this point, there were over one hundred scavengers at the landfill that would sort through the trash looking for valuable items. Not wanting unknown people searching through the landfill, but not wanting to deny the scavengers their only source of income, the new management took a roster of the scavengers, created a scavenger association and closed membership. The scavengers would still be allowed to be there, but no new ones were admitted. Of the 84 scavengers there today, three of them have enough technical knowledge to search for computer scrap, build working computers, and sell them for money. Jorge Cardoza speculated that unfortunately, most of the scavengers just need the money for some sort of drug addiction, but admitted that it was probably their only source of income.

This presents a problem, as if we were to eliminate the computer scrap from the landfill, then this would affect them greatly. Jorge Cardoza believes that it would make little difference, however, as they have many other scavengers making money without the collection of computer scrap, and they could do the same. In addition, there is a way that this could benefit them. Jorge Cardoza had though about implementing a collection system previously, where the scavenger would help to locate and retrieve computer scrap from the landfill. He never got to pursue it, however, since he did not know what to do with the scrap after it was collected. If a recycling system were in place in Costa Rica, perhaps they could be paid a small amount to help collect the computer scrap that will inevitably still make it into the landfill. Nevertheless, the standard is not the ideal, it is the alternative. It would be unfortunate if these three scavengers suffer negative consequences based on the implementation of an E-waste management system, but the cost to the environment in the long run is much greater.

Since we determined that only the scavengers would have negative social or economic consequences, we wanted to determine what sort of positive things would result. We talked to David R. Portilla, who helps run the computer refurbishment program at San Sebastian Technical High School. They take used computer donations and use them in the curriculum to teach PC repair. Currently, there are more students who would like to get into the program than they can accept. They are limited by the amount of decent computers they receive and space. If more space could be allocated to them and more used computers could be sent to them, as suggested in our models, then they could expand their curriculum and educate more students.

Juan Carlos Salas Jiménez works for the Technical Institute of Costa Rica (ITCR) and helps administrate the incubation program. This program is set up to help jump-start new business initiatives, such as a material exchange program that has been successful in recycling plastics and metals that would otherwise be in a landfill. They negotiate with local industries and companies to take their bulk recyclable trash, which may include defect plastic parts, paper or cardboard boxes and resell this material to an interested buyer. There is a large amount of manual labor that goes into some of the items, such as the sorting of paper by type. Upon hearing about the project, Juan Carlos Salas Jiménez became very enthusiastic. Being in the materials exchange industry, he was aware of what a waste it is to just throw electronics in a landfill. He recognized that there are no facilities in Costa Rica to process these machines but is hopeful about developing a solution. Since his facility resells many different types of plastics and metals, the program will likely play a vital role in the process if the plastics can be of use to him. If this is the case, surely it will benefit his operation economically.

To tally this information up, the only negative consequence that we could predict would be the negative effects on the three scavengers that depend upon the computer scrap, which can hopefully be averted by including them in the process. Positive economic effects are numerous, assuming that this is a successful venture. If it fails, however, the only ones to be disadvantaged would be the sponsors, which will most likely be larger companies. In addition, it has the potential to create a large number of new jobs, depending on how it develops. It also has the possibility of increasing business to other local companies, such as the materials exchange program, and the possibility of expansion at San Sebastian Technical High School.

One last issue we addressed as part of our methodology is what sort of socio-cultural conditions must exist in order for the program to work. At many of the interviews we performed we attempted to determine the interviewees' level of knowledge as to the harm of computer scrap. An overwhelming number were aware of the problem, and most people were more than willing to help because they felt that the issue was very pressing. The following is a list of some of the people who were aware of the issue of computer scrap and displayed direct interest in our project:

1. Walter Araya – Hacianda
2. Jorge Cardoza – Río Azul Landfill
3. Don Fernando – Technology director for San José technical schools
4. Juan Carlos Salas Jiménez – ITCR
5. Arturo Lopez – Los Mangos Landfill
6. Emilia Mora – Journalist for La Nación
7. Sergio Musmanni – CNP+L
8. Ana Gabriel Perez – CICA

9. David R. Portilla – San Sebastian Technical High School
10. Patricia Soliz - CICA

4.5 Potential Expansion of Costa Rican High School Refurbishing Programs

The need exists during the preprocessing stage of a computer scrap management system to separate usable components from non-usable components. Since working systems or individual components provide the most value, successful analysis and evaluation of received computer systems is the first step in a management model after collection.

The StRUT program in the United States, as described in section 2.4.6, Students Recycling Used Technology, already shows the promise of obtaining workable parts from computer scrap. However, such student-run refurbishing programs are not limited to the United States. In Costa Rica, students are already refurbishing computers and constructing new systems by reassembling the working parts of computer systems donated to the school. Just like StRUT, but on a smaller scale, high school students in Costa Rica are primarily examining broken computer systems for educational purposes, and as a byproduct they are producing working computer systems to be used in their schools.

4.5.1 Current Operations and Facilities of San Sebastian High School

Upon our visit to the San Sebastian Technical High School we meet with David Portilla and his associate who introduced us to the computer repair field. They were able to provide information about the computer repair program that they run.

Part of the training in computer repair involves examining broken components of computer systems, including motherboards and CD-ROM drives. The students investigate and discover through analysis faults and possibly the causes of problems in the computer parts. Additionally, students construct computer systems from working components. Distribution of the built systems through the school provides a partial solution for needed computing power. Unlike the StRUT program in the United States, where sometimes designated organizations receive computer systems, no computers built out of the computer repair program in the San Sebastian Technical High School actually leave the school.

Currently the students who participate in computer repair are either in one of two classes, with approximately 15 to 20 students in each class. Each class has the primary focus of teaching diagnostic and repair techniques for computer systems that are directly applicable to refurbishing. Corporations in Costa Rica donate used computer systems to the schools. There are no exact numbers on the quantity and the frequency of computers received. However, the maximum number of computers ever received in one load was between 20 and 30 systems.

4.5.2 Receiving and Analyzing Used Systems

Originally, corporations would drop off their systems at the school for the students to use in their training. Since the donations primarily consist of used and old systems, the school received too much equipment that had no working value. Therefore, when companies inform the school of a desired donation, the school examines the computer scrap at the donating company. The purpose of examining the scrap is to determine how much scrap is actually usable. If considered acceptable, upon arrival at the school the computer scrap is stored in a room on campus with other reusable goods including automotive repair parts. The students then analyze the material to separate working components from non-working components. On average about 20% of the computers received by the school, provide working parts, while the other 80% are not working or are too old. The students use functioning components to compose working systems, while instructors teach diagnostic techniques on the non-working parts.

4.5.3 Current Limitations on Resources and Space

The main limitation on the current program is not the lack of student interest, but instead the physical limits of working computers, classroom space and storage space on campus. The major limiting factor is space. One main room exists where instruction and repair occurs. The room is of moderate size. Donated computers are stored in a storage facility. However, the storage facility is not limited to computer scrap, but also contains other donated materials used in different fields of study. The second limiting factor is resources. The amount of working computers available for the computer repair classes limits the size of the classes. In addition, there are limits on the amount of computer scrap that the school can accept. Although the school does not have a set maximum amount, their limits are determined by storage constraints and on the quality of the equipment. If they had more space and more equipment was available, then the school would definitely be interested in expanding its operations.

4.5.4 Expansion of the Computer Repair Program

The current facilities found in the school are not sufficient for expansion. When we proposed possible expansion and working with computer scrap brought by the public to a central warehouse, David Portilla was immediately very interested. Obtaining a central warehouse would resolve space constraints imposed by the current storage limitations on campus. David Portilla would definitely like to expand the school's operation by acquiring more working parts to create functioning computers for their school. Regardless of whether computer scrap would gradually arrive at the warehouse or if computer scrap would arrive from an annual computer-recycling day, they indicated the warehouse as a prime location to store and search through computer scrap. However, they would prefer having the computer scrap arrive gradually at the central warehouse over the course of a year to provide an easier method to sort working from non-working components. Another instructor from the computer repair program indicated a great interest exists in having more students be part of the computer repair program, especially if they produce more working computer systems. David Portilla stressed the point that it will be important for instructors to be able to go to the location and sort through the material to obtain necessary equipment. Just as they currently examine material to be donated, they indicated the same practice would be necessary at a central warehouse to avoid taking to their facilities too many unusable parts.

4.5.5 Reusing Computer Casing for non-Computer Applications

After the removal of all usable working components, the remaining components must be shredded or melted down to obtain metals in their basic form. This method is common practice in recycling centers found throughout the world. Although mining computer systems would be the final step in a management system after the retrieval of all working parts, the San Sebastian Technical High School explained that their students use parts of the donated computers for non-computer based applications.

In addition to retrieving working computer boards, the school is currently using the casing in other specialties taught at the school. Welding classes use the metal structural support of the case and the surrounding shell. Therefore, in addition to retrieving materials such as working parts for new computer systems and non-working boards for instruction in the computer repair specialty, students remove other parts having use in other disciplines. An important part of preprocessing could be removing non-working parts that have uses other than in computer applications before mining occurs.

David Portilla's and the other instructor's eagerness to embark on such a refurbishing program could constantly be seen through their disappointment in our explanation that we are only proposing a recycling system to Intel Costa Rica and do not already have vast amounts of computer scrap for them to refurbish.

4.6 Recycling Model

4.6.1 Introduction

Reviewing our findings, we brainstormed possible recycling models and developed several different methods of collecting and recycling E-waste. We categorized these methods into three different models, detailed below in terms of the capabilities and shortcomings of each particular model. Each model serves as an outline of the procedure that could be used to process E-waste, from collection to recirculation into the industry and community. This can be accomplished either through direct refurbishment and recirculation or complete remanufacturing and recycling of individual elements. All three models involve several options, including choice of companies to be involved, collection methods, and so forth. Several of these details will be further analyzed in section 4.8, Options within each Recycling Model. We present the rest below.

In order to fully understand what is involved in each of these models, an explanation of each node of the recycling models is given *after* the models presentation in section 4.7, Explanation of nodes. But first, we begin by taking a look at each model.

Model 1

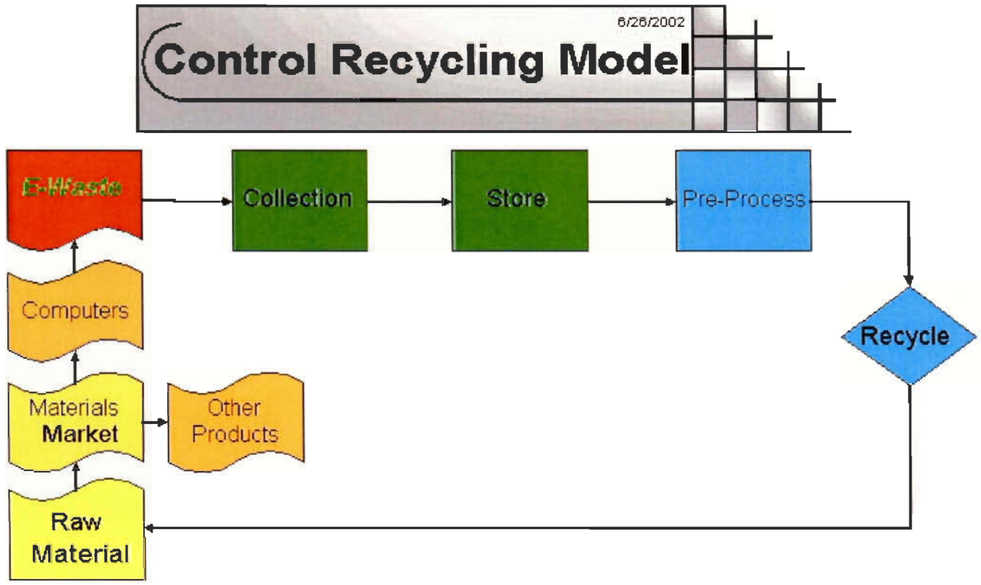

Figure 4: Model 1 -- Control Recycling Model

This is the simplest of the three models, used solely as a control for comparison. It is a "bare-bones" system, depicting nothing more than the bare essentials necessary to recycle E-waste in any situation. It is not as efficient as the other models, nor does it include a recirculation system. As stated before, it serves as a basis for comparison only.

In this model, the material is collected and stored in a local facility. At this point, depending on the requirements of the recycler, it may or may not be processed before it is sent to the recycler. The recycler then processes the material, converting it into usable raw materials that are sold on the materials exchange market, sometimes returning a percentage of the profit to the sender. In most cases, these recyclers accept corporate lots of computer scrap, so the collection process is much simpler. In addition, the money returned to the sender usually offsets any costs (such as transportation) that the company incurred during the whole process. In this manner, companies can reduce their disposal cost as well as create value out of what was considered waste and gain extra revenue. This is often referred to as "Asset Management" or "Asset Recovery."

The problems with this model are that first, as mentioned before, relative to the other models, it is inefficient. It has no refurbishment and recirculation system, therefore sending potentially useful hardware to be processed and recycled. There is often more value to be gained by recirculation of hardware than by sending it to be recycled. Second, Costa Rica does not currently have the necessary facilities, machinery, or personnel to implement this system. Currently, there is no E-waste recycling industry in Costa Rica, as this has never been formally presented as a problem before.

Model 2

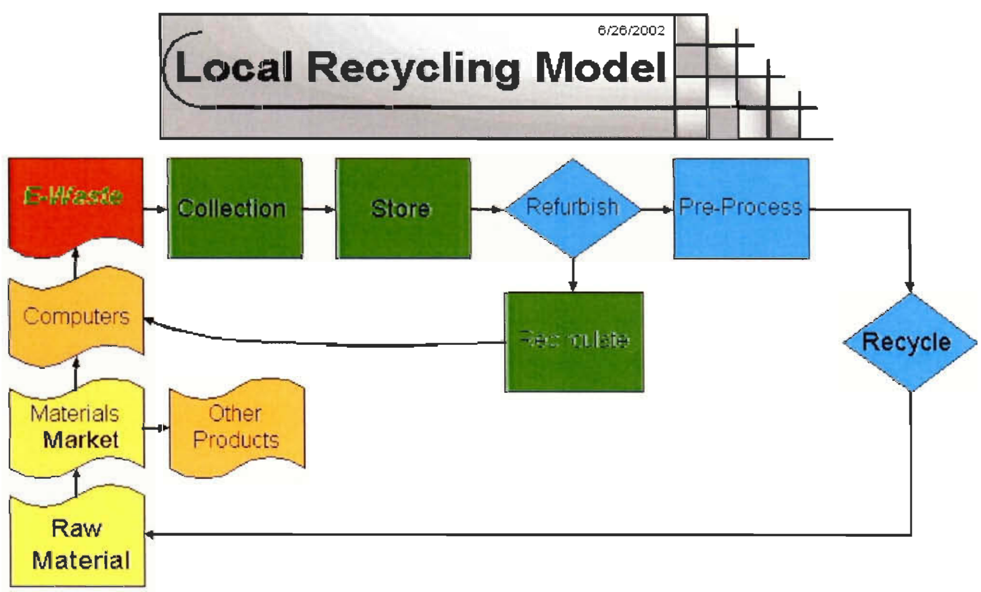

Figure 5: Model 2 -- Local Recycling Model

This second model differs from the first mainly in the addition of a refurbishing and recycling system. After E-waste is collected and stored, a refurbishing company, school, or organization can sort through the material and pull out any potentially useful parts. The material that is pulled out will then be used in a new computer, or used in some other useful manner, such as welding material, as in the case of San Sebastian Technical High School. This creates a much more efficient model, since more material is returned directly without any cost in shipping. In addition, the material or part would be given away or sold much cheaper than if the purchaser were to get it new.

Other than the addition of refurbishment, the model functions very similarly to the first, which means it shares the remaining restriction-- there are currently no facilities in Costa Rica to process E-waste. Even though it would be cheaper to process the material locally (in addition to contributing to the local economy), this option is *currently* not available.

<u>Model 3</u>

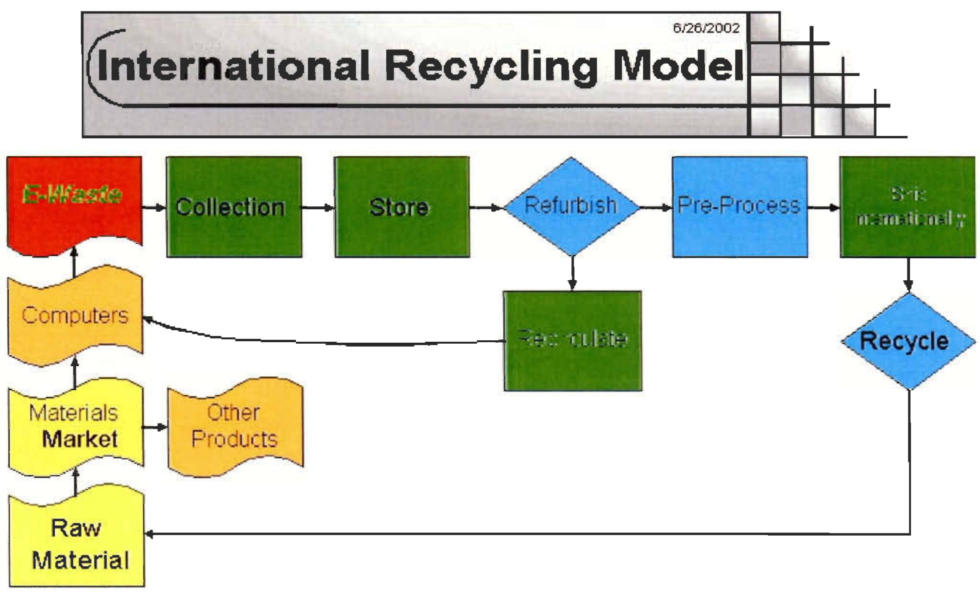

Figure 6: Model 3 -- International Recycling Model

Our third model operates in the same way as the second model, including the refurbishment and recycling dimension. The primary difference between these two models is that the scrap is shipped internationally in this model, rather than processed locally. This implies that the pre-processing includes, at the very least, a packing function as it is going to be shipped, and most companies require that the material be packed on a pallet or gaylord package.

A more complex picture of these models can be obtained by filling in details about their sub-parts, which is what will be discussed in this next section.

4.7 Explanation of nodes

- **E-waste** – This is the physical E-waste itself, generated by either individual consumers or businesses. It represents a resource which has potential to be reused, although it may be considered waste by the owner.
- **Collection** – The means by which the E-waste is found and consolidated. It actually represents two processes. First, it includes the method by which the E-waste owners become aware of the potential for recycling their scrap, and second, it includes the process of collecting the scrap and transferring ownership from the "donor" to the "collector." These options will be discussed in greater detail after the introduction of the models.
- **Store** – The consolidated waste needs to be accumulated in a specific place. This storage facility may be one of several options.
- **Refurbish** – Much of what will be collected will have great potential to:

1. Be working equipment, which may be **Recirculated** elsewhere.
2. Have working parts, which may be collected as part of the refurbishment program, and used for repairs and renovations to other computers which would be **Recirculated.**
3. Have parts that may be usable for non-computer application. The San Sebastian Technical High School, for example, reduces their need for buying metals by using old computer cases as raw material for their welding classes. Other such innovations in reuse are to be encouraged.

- **Pre-Process** – All the scrap which cannot be either **Refurbished** or **Recirculated** flows to this next step. This is a dynamic node, depending on the step that follows, as the recyclers often prefer doing some of these operations themselves (such as sorting), whereas others encourage that it is done before they receive it. Realistically, it may not be a part of the model if the recycler does not have any prerequisites. The node may include:
    1. Sorting of materials by type (plastics, PCBs, CRTs, wires, etc.), if the recycling center requires it.
    2. Packaging for shipping, either locally or internationally.
    3. Taking inventory of all collected material, either for statistical use, or shipping requirements.
- **Ship Internationally** – This node only exists in the third model, as it includes the treatment of E-waste in another country. The **Pre-Process** node is, thus, mandatory as it will include packing for shipping.

- **Recycle** – This is the completing link in all the models. Wherever the final waste ends up, locally or internationally, it will be processed by a mining company that will convert it into **Raw Materials**.
- **Raw Materials** that will be returned into the **Materials Market** possibly to be used to create new **Computers** or **Other Products**.

4.8 Options within each Recycling Model

Each model has several possibilities as to how each node functions. These options are presented here:

<u>Collection Method</u>

Continuous Collection

The first possibility for a collection method would be continuous collection, whereby computer scrap could be dropped off at any point during the year at a central location or satellite locations, which would then transport it to the central processing facility. One such location would be at landfills. Our interview with Adolfo Cordoba, an administrator at the Río Azul landfill outside San José, revealed that he has already been considering a similar system. He recognizes that computer scrap being dumped into that landfill is a problem, as mentioned in section 4.3, Determining Computer Scrap Volume in the Central Valley Landfills. He talked about the possibility of separating this trash from the rest and collecting it in a local building. He has not yet determined what would be done with the scrap after that, since there are no recycling facilities for it in Costa Rica.

One option would be to work with Río Azul and other landfills to request the separation of computer scrap from general trash so that it could be collected and then transported to a storage facility. This is beneficial since it doesn't imply much cost beyond transport from the landfill to the storage facility. Its principal shortcoming, as discussed above (section 4.4, Social and Economic Impacts of a Management System), is that people need to be made aware of such a system to use it and publicity for such a system might prove hard to implement in comparison to the next option. In addition, environmentally conscious people might be wary about sending computers to a *landfill* to be *recycled*. Nevertheless, at landfills it would be helpful to have a year-round system in place for disposal of old computer technology.

National Computer Recycling Day

A national recycling day, similar to those that have proven successful in the US, would seem to be an effective approach. Todd Brady, a Product Ecology Manager at the Intel Arizona plant, gave us information on a recycling day program they have run in the Phoenix, AZ, Metro area for the past 3 years and will continue to hold in the future. The program has been highly successful and has brought in over 114,000 lbs. of computer scrap in just the 2001 recycling day alone (Brady, 2001). The advantages of holding a recycling day versus a process of constant collection are numerous.

First, storage facilities would only be needed temporarily, rather than year round. Depending on the amount of computer scrap and the number of people working, sorting might take a month to several months to pre-process the scrap for shipment and recycling. It would be much cheaper to rent a facility for a shorter period of time rather than year-round. However, a storage facility like this might be harder to find.

Second, there are obviously costs attached to any system that is implemented. It is much more likely that a company might be willing to sponsor an event such as a "Recycling Day" than a year-round collection service. Since these costs are inevitable, and there is little return on computer scrap, the funding for such an event would need to come from organizations willing to sponsor it in order to attach their name to an environmentally friendly event. It would be a mutually beneficial arrangement since the event would receive sponsorship, and the company would receive positive publicity.

Third, publicity would be limited to a shorter period of time and could be more aggressive. In addition, individual sponsors of the event could create additional publicity within their own organizations. A company that is actively involved would most likely make most of its employees aware.

The downsides are that first, you can only estimate what volume of computer scrap will be received the first year. The recycling event could be overwhelming, or disappointing. You can estimate how many computers are in the country, as well as when they will reach their EOL, but you can never be certain when people are ready to dispose of their old technology. Nor do you know if they will even bother to participate in the event rather than throwing it in a landfill. Second, computer scrap owners might not be able to wait several months in order to dispose of used technology, which may force them to send it to a landfill.

Hybrid

Perhaps the most promising model is one that encompasses both strategies. A yearly recycling day would surely raise awareness of computer scrap problems. In addition, having a continuous, if less intense, collection program would allow companies and individuals to dispose of their E-waste at any given time. Furthermore, both initiatives would be great sources of publicity for the other. People could become aware of the computer recycling system through the recycling day and vice versa.

Incentives

Advertisement

Todd Brady also showed us survey data on their Arizona-based recycling day that confirmed that newspaper advertisements were more effective than any other form of publicity. It seems like this would hold true of Costa Rica as well. In addition, Emily Mora, a journalist for La Nación who recently published two articles having to do with computer scrap being disposed of in landfills expressed concern over what was being done with E-waste and said La Nación would be willing to help with publicity for a recycling initiative.

Internet-based advertising is another feasible method for a computer scrap collection event. The actual cost to Intel would be negligible. They already have a reliable web server in place and employees to create and publish the information on the web. The information about computer scrap and the recycling event could be online year-round for people to access. In addition, you are likely to hit your target audience (computer owners), since someone accessing the web (unless they are using an Internet café) probably owns his or her own PC and thus will have to dispose of it eventually. The downside is that people will not see such Internet publicity unless they are searching for it, or if they stumble across it by mistake. Nevertheless, it's practically free.

Rebates

One of the ideas incorporated into several recycling day projects, including the Arizona program, is offering a rebate on the purchase of a new computer to anyone who donates computer scrap. It was in collaboration with Staples, an American office supply chain, that Intel gave a $100 rebate towards the purchase of any Pentium-based PC for any scrap donation.

Tax Receipts

Another incentive common to many donation services is giving tax receipts so that a person can write the donation off as a tax deduction. This system has also been implemented in the Arizona initiative, which may account partially for its success. This sort of system would depend upon the local tax laws and might not be applicable to this type of donation.

Collection Surcharge

A collection surcharge might also be a good idea. There is a lot of cost associated with the disposal of computer scrap, especially CRTs. The question, however, is how much would people be willing to pay (if anything) to dispose of their electronics properly? According to survey statistics taken in the 2001 computer recycling day in Arizona, 63% of people said they would be willing to pay for disposal, leaving 37% saying they wouldn't. Twenty-nine percent said they wouldn't pay more than $5, fifty-eight percent said they would pay $5-10, and thirteen said they would pay greater than $10. These statistics may not be accurate for Costa Rica, however, it does suggest that most people wouldn't mind paying a small fee.

So as not to discourage people from donating, and to get an accurate count of how many people are disposing of their computers every year, it might be best to keep it free or at very low cost. However, it would be very beneficial to charge for the disposal of CRTs since recyclers give no money back in return (in fact, many companies charge to take them), and they take up a lot of space and weight in shipping. A small fee of ¢2000-3000 per unit would help to reduce costs without discouraging people from the program.

Tax on Purchase

A small tax on the purchase of a new computer may serve as a long term solution to the issue of recovering disposal costs. Such systems, as discussed in section 2.4, International E-waste Management Systems, are currently being considered, but have yet to be implemented. It would be most beneficial to wait and see how the systems work in other regions before something like this was to be attempted. A program of this type would require participation by the distributors and manufacturers of the product. It may, however, prove to be a worthwhile initiative in the future, depending on its success elsewhere.

Refurbishment/Recirculation

School

In place already, as discussed in section 4.5, Potential Expansion of Costa Rican High School Refurbishing Programs, is a group of students capable to sorting through, refurbishing and recirculating computers into the school system. In addition, they have use for some of the scrap beyond just making computers. They are the first option for the refurbishment node. They claim they are capable of processing much more computer scrap but are limited by space. If storage space were available, they believe they have the capabilities to process computer scrap in bulk.

Private

Another option, especially if the amount of computer scrap proves to be too much for the student refurbishing centers, would be to encourage some sort of business venture. Private companies could purchase useful parts and materials in order for it to be refurbished and recirculated. The issue with this, however, is that there is no guarantee that the purchaser will reuse all or any of the material. Some of the material may just end up in the landfill again.

Storage

Intel Costa Rica can accurately determine the location of storage facilities at the appropriate time. Nevertheless, it is an important part of the entire process. The E-waste will need to be collected and sorted in a central location until it is ready for shipment.

The size of the warehouse needed will depend upon the amount of computer scrap received, as well as efficiency in design of the sorting/packing process. For the necessities of sorting and packing, a materials handling company would be able to assist.

Preprocessing

Students

The first option for preprocessing would be to integrate it with the student refurbishment program. Motivated by the StRUT initiative in the United States, it would become the first step after collection and storage in the operation.

Private or volunteer

The second option would be to hire trained people or volunteers to sort through the scrap. This would be best used as a supplement for the student workers after the computer recycling day, when the amount of computer scrap will peak. For the most part, the amount of computer scrap received will be manageable, but a single day in which many people donate computers might prove to be an overload. Bringing in extra people trained to sort through the material would help to process the material faster and keep things running smoothly.

Logistics

Piggyback with Intel

Intel Costa Rica currently ships their defective computer chips to California to be mined. One possibility for saving on the cost of shipping would be to combine the shipments of computer scrap and defective computer chips. Shipping in bulk costs less per unit than sending smaller amounts, therefore, combining the two into one shipment would reduce the overall cost. In addition, the bulk rate would also translate into cost reduction for Intel Costa Rica, since they too would also receive a better deal. A mutual gain such as this is ideal, since both parties benefit.

Individual Shipments

Of course there is always the option of keeping the shipment of computer scrap separate. It would cost more per unit to ship, but it would require less coordination among organizations, but that is not prone to be an issue.

Omar Dengo Foundation

The Omar Dengo Foundation, a non-profit organization that helps to get technology into local Costa Rican schools, is also aware of the problem of E-waste. In an interview with Henry Salazar, a representative of the organization, he explained to us that the foundation had two rooms full of computer scrap (mostly CRTs) that they did not know what to do with. He had searched for a disposal plan, but had not found one. They were very happy to hear about our project and expressed an interest in helping out. The

Omar Dengo Foundation deals with logistical issues, since they are an international organization and many of their computers are imported. In addition, since they are a non-profit organization, they do not have to pay the taxes associated with international shipments. Upon being asked whether the foundation would be interested in playing a part in an E-waste recycling plan, Henry Salazar stated that they would be very interested. The Omar Dengo Foundation felt that they could help with the shipping, not only in terms of organization and allowing it to be tax free by making it their shipment, but also in funding. He will recommend that the Omar Dengo Foundation get involved, and if a proposal were presented to the foundation, they might be willing to help out financially.

Recycling

Processor

There are many choices for the processor of the material. Therefore, we have devoted an entire section to it. See section 4.10, Analysis of North American Computer Mining Companies for more details.

4.9 Analysis of Models

The issue with the control and local models is that currently, they cannot be implemented because there are no local facilities in Costa Rica to process this material. Therefore, the only option is to ship the material internationally. The issue with that is the associated cost. It may not be profitable to send the computer scrap that far. Therefore, efforts should be made to change the situation that exists by developing a computer scrap recycling industry in Costa Rica.

Before any company is willing to invest in a recycling industry in Costa Rica, they would need to know that it would be profitable, and therefore would need to know the amount of computer scrap being generated over a given period of time. As stated in section 4.3, Determining Computer Scrap Volume in the Central Valley Landfills, it is not feasible at this time to try to get an accurate estimate on the amount of computer scrap being generated due to several unpredictable variables and inadequate information.

For these reasons, it would be beneficial to implement the international model temporarily. If a recycling day/E-waste collection program were initiated, one could not only take care of the computer scrap issue, but would also learn the exact number of computers that people would be willing to dispose of, as well as other useful statistical data.

If the international recycling model were implemented for 5 years, it would allow adequate time for Costa Rica to dispose of the buildup of computer scrap and get an accurate estimate of how much scrap is generated annually. After trends have been shown to be consistent, the statistical data collected on how much and what kind of computer scrap is being disposed of can be used to attract companies that would be interested in investing in an E-waste recycling initiative.

Initially, for simplicity, it might be best to just implement a recycling day. After time progresses, however, a continuous collection service would be worth considering in conjunction with the yearly recycling day. As discussed above, this sort of hybrid model would come with several advantages.

4.10 Analysis of North American Computer Mining Companies

One part of the proposed international computer recycling management systems is the possibility of shipping the computer scrap to the United States for recycling. Varieties of computer mining companies exist throughout the United States. Each has its own focus in recycling and rules concerning the acceptance of computer scrap. Privately owned computer mining companies form the majority, while a few publicly traded companies exist. Some only accept computer scrap while others recycle all kinds of metals and plastics. Appendix C and D, respectively contain spreadsheets with contact records and a compilation of our survey responses. We eliminated some of the companies because their recycling operations were incompatible with our proposed computer recycling management system.

4.10.1 Elimination of Undesired Computer Recycling Companies

From the 33 questionnaires sent out to 29 corporations, four of the e-mails bounced back. The e-mails, which bounced back, came from IBM Mexico, Supreme

Computer Recycling, Inc., and The Computer Recycling Center at CMU. Since we could not establish contact with these companies, we eliminated them as possibilities except for IBM Mexico. However, we later eliminated IBM Mexico because further information about their operations in Mexico indicated do not fall under our requirements for a computer recycler. We also eliminated South Bay Metals as a possibility because we did not receive a response and could not locate a website.

After eliminating companies because of lack of information, we eliminated those companies whose business focus is not a suitable match for a partner in a computer management system. These companies ranged from those that only sort material and did not recycle, to those that accept computer scrap only from a limited local area. The companies we eliminated were Back Thru the Future Micro Computers, Inc., Ecological Technologies, Inc., Metals Reclamation Services, and Montgomery Country, MD's Solid Waste Services. We eliminated Back Thru the Future Micro Computers, Inc., because they only collect and sort material. Ecological Technologies, Inc. only recycles plastic IC trays, so therefore we eliminated them as a possibility. We eliminated Metals Reclamation Services or MRS because they only offer consulting services and not recycling. In addition, we eliminated InterConnection because we determined they are not in the computer scrap recycling business. Finally, we eliminated Montgomery Country, MD's, Solid Waste Services because they only offer recycling to their local area.

The final set of eliminations occurred based upon company location. Although not nearly as important as a company being able to accept desired scrap, location creates a huge obstacle when factoring in transportation costs. Shipping computer scrap out of the country to the United States or Central America for processing will need to occur in some of the management models. The ideal location will be a country in Central America such as Mexico. However, since we were not able to retrieve definite information on a possible computer recycling company located anywhere in Central America, we had to focus on the South West United States and California. We eliminated DMC, Envirocycle, Intercon Solutions, and United Recycling because they are all located in the North East United States. Also eliminated because of distance was Asset Recovery Corporation located in Minnesota and Environmental Computer Recycling Company located in Canada on the border of New York.

All of the 15 remaining companies have locations in California except for Hewlett Packard, IBM, and Dell for which we are unsure. Because of the limited information provided by HP and IBM in their responses to the questionnaire and also due to the lack of detailed information provided on their website, the best location where to ship computer scrap cannot be determined at this time. Therefore, they remain possible options. Upon the actual implementation of an E-waste recycling system, it will be vital to choose a preferred company to ship Costa Rica's computer scrap.

4.10.2 Final Analysis and Categorizing of Companies

After we eliminated companies by location, 15 companies remained. From the 15 remaining companies, only six of the companies provided responses to the questionnaire.

To provide a final analysis and make a determination of which companies could play a possible role in a recycling center, we obtained further information. For the companies that did not respond to the questionnaire, we analyzed information provided on their websites. Appendix D contains a listing of the websites. However, the majority of the websites did not provide enough information to make a concrete determination of which companies could be possible players in recycling Costa Rica's computer scrap.

The only analysis that we could do was to categorize the companies by type, based upon their current business practices. When Intel Costa Rica actually needs their participation in a recycling program, Intel Costa Rica should contact the companies for more detailed information, such as costs.

However, from the companies that remain, we directly eliminated one. The Tung Tai Group, according to their website, has a location in Asia in addition to their facility in California. Unless they can provide assurance that no material from their California site leaves the country to their location in Asia, they would not be a suitable candidate. Having computer scrap leave the country would be devastating for proper recycling of the material as well as defeating the purpose of an efficient recycling management system. Therefore, until we can obtain more information, their elimination as a possible candidate is the only option. Below we categorized the remaining 14 possible recyclers.

4.10.3 Category 1: Computer Manufactures with Recycling Operations

From the 14 companies who recycle computer scrap, we formed one category with those companies whose primary focus is computer manufacturing but who have extensive and or environmentally focused recycling programs. These companies are IBM, Hewlett Packard, and Dell Computer Corporation. Although each company provides limited information about their recycling programs, they could all be possible players in a Costa Rican computer recycling management system. Intel Costa Rica can obtain further information to determine their willingness to expand operations to Latin America.

4.10.4 Category 2: Recycling Computer Scrap & Selling Recovered ICs

The second category is not made up of companies whose primary business is computer sales, but instead contains companies whose focus is the recycling of computer scrap and refurbishing of integrated circuits and electrical components. Depending on the company, recycling may or may not be the prime focus in regards to reselling integrated circuits and other components. However, each of these companies maintain large facilities in California and their operations include recycling.

These companies are: Hackett Electronics, which recycles computer scrap and retrieves integrated circuits with a 20,000 square foot facility, according to their website; Fox Electronics whose business includes recycling computer scrap and selling refurbished integrated circuits has a 65,000 square foot facility and according to their website can refurbish over 100,000 integrated circuits per day. Just like Fox Electronics and Hackett, Allied Electronic Recovery also recycles computer scrap and resells electrical components including integrated circuits. According to their website, Allied Electronic Recovery presently has over 35 million components. Additionally the HMR group provides computer recycling and sells electronic equipment from a 100,000 square foot complex in San Francisco according to their website. Just like Allied Electronic Recovery, Fox and Hackett both recycle computer scrap and sell refurbished products. VPElectronic.com also recycles computer scrap and resells components including integrated circuits.

Although among the companies that pursue recycling and sell recovered integrated circuits and electrical components, United Datatech and ECS Refining fall under a slightly different category. United Datatech and ECS Refining are sister companies, which, according to their websites, through a combination of efforts by both companies can fully refurbish and recycle computer scrap. Apparently, United Datatech's focus is on the recovery of usable components, including working boards and individual chips and electronic components found on circuit boards. From the information provided on their website, ECS Refining is more of a second stage recycler, melting down components to retrieve metals. Therefore, since they are sister companies, as a pair they meet our qualifications for the previous category of companies.

4.10.5 Category 3: Publicly Traded & World Wide Metal Corporations

As with the second category previously mentioned, which has a significant focus on computer scrap recycling, two major companies, SimsMetal America and Noranda, with a subdivision called Micro Metallics Corp. heading their computer scrap recycling division, form the third category of publicly traded, worldwide corporations with a larger focus than mainly recycling electronic scrap. Noranda, which has worldwide metal mining operations and recycling of metals, owns Micro Metallics Corp's whose primary focus is recovering precious metals from computer scrap. Just like Noranda, SimsMetal America also has a large interest in recycling a variety of metals including copper, steel, and iron, according to their website. However, they both have a computer recycling division located in California dealing with the extraction of metals.

4.10.6 Categories 4 & 5: Other Specialized Companies

The remaining two companies we discovered, Metech and MBA Polymers, fall into two separate categories. Although Metech can be compared to the second category of computer recyclers, on their website they do not make a significant point of recovering individual components on circuit boards and instead focus more on recycling computer scrap. Additionally Intel Costa Rica already sends them their HVI or high value inventory for shredding and destruction. Since Intel Costa Rica has established business relations with Metech, arranging to ship them computer scrap will take a different approach than with a new company. Therefore, we placed them in a category of their own, located in Table 3 under category four.

MBA Polymers' focus is different from all of the previously mentioned companies. Their recycling focuses around accepting types of plastics including the plastics found in computers, such as monitor casings. According to the response to our questionnaire, they accept anything with an electrical cord; however, their website indicates they can only receive plastics that contain no metals or a limited amount. Therefore, it appears as if they can only recycle plastics and not computer scrap, such as circuit boards. However, they still could be a major player in a recycling management system where they would receive separated plastics from preprocessing, and another recycling company would receive the rest of the computer scrap. Since according to their response from the questionnaire they might pay for the plastics, sending them plastics separately could be a viable option, whereas other recyclers have a hard time processing plastics. As a result, MBA Polymers falls under their own category of plastics recyclers, listed in Table 3 under category four.

Table 3 shows a summary of all the different companies organized into the previously determined categories.

Table 3: Compilation of US Computer Recycling Companies

Possible players in a computer recycling management system categorized by business type or focus				
Category 1	Category 2	Category 3	Category 4	Category 5
Computer manufactures with recycling operations	Recycling computer scrap and selling recovered ICs.	Publicly traded; world wide	Currently recycling Intel Costa Rica's HVI	Mainly plastic recycling
IBM	Hackett Electronics	Noranda with Micro Metallics Corp.	Metech	MBA Polymers
Hewlett Packard	Fox Electronics	SimsMetal America		
Dell Computer Corporation	Allied Electronic Recovery			
	HMR Group			
	VPElectronic.com			
	United Datatech + ECS Refining			

4.10.7 Recommendations for Choosing Categories

Ideally, in choosing a recycling company to collaborate with or to expand their operations to Costa Rica it would be preferable to select a company that has had experience with operations outside the United States.

From Table 3 two possible groups of companies are categories one and three. In category one, the companies are computer manufactures who have computer-recycling programs. These companies would be ideal because of their business in computer manufacturing combined with recycling. The prime choices from category one are IBM and Hewlett Packard, since we lack information on whether Dell is currently running computer-recycling operations. The advantage of choosing a company from this category is that the companies are both computer manufactures, and they also recycle computers. Their familiarity with the manufacturing process of computer systems can aid a great deal in a recycling center.

Similar to category one is category three, containing worldwide companies with a division or segment focused on computer recycling. Just like category one, these companies have the resources and the knowledge to assist in setting up a recycling operation in Central America. Since they are not computer manufactures, their possible assistance will not reflect back on the computer industry as a whole, however, their size and global scope as being worldwide metal companies can be as important in solving possible barriers. Therefore, there is not a significant difference between choosing a company from categories one or three.

Choosing a company to accept computer scrap gathered through a computer-recycling day in Costa Rica does not have to be limited to the same companies who might participate in a part of the recycling operation in Costa Rica or Central America. The companies listed in categories one and three are possible options as well as those in category two. The main difference between the companies listed in categories one and three and those in category two is that those in category two most likely do not have the resources for much expansion. However, all of them could be the receivers of computer scrap from a recycling day in Costa Rica. One advantage of the companies listed in category two is that they are smaller companies than those in categories one and three. Therefore they could possibly play a more supportive role because of the large amount of computer scrap received should provide a significant increase in their operations.

However, at the same time, because of their smaller size, they might not have the resources at their disposal as would a larger company. Therefore, they might not be as willing to provide aid that could result in a loss to their company.

Just like those in categories one through three, Metech listed in category four is also a possible recycler for material from a recycling day. Choosing Metech as a partner might be easier to accomplish than a company from categories one through three. Since Metech already recycles material from Intel Costa Rica, it might be easier to obtain an extended partnership for a computer-recycling day than to create a completely new partnership with an unfamiliar company.

The final category, category five containing MBA Polymers, could participate in any operation where plastic needs to be recycled. In fact, according to their response to our questionnaire, they are already looking at a possible expansion of their operations into Central America. If a computer scrap recycling center is created either in Costa Rica or somewhere else in Central America, then the separated plastic could be sent to MBA Polymers after preprocessing. This could save the hassle of possibly having to implement a plastics recycling operation as part of a computer-recycling company in Costa Rica.

Another possibility is to send plastics to MBA Polymers and the rest of the material to another computer recycling company. By doing so, there could possibly be an increased return value because of the success of MBA Polymers recycling plastics. Also, the trouble of choosing a company which both recycles computer scrap and also accepts plastic without much cost could be avoided.

Regardless of which company Intel Costa Rica might select, the ideal situation would be to have the material shipped to a recycler in Central America to avoid hassles with extended shipping. Moreover, if the company were to be located in Costa Rica, the shipper could avoid complex international laws.

4.11 Summary

We have learned that there is an overall concern for the issue of computer scrap disposal in Costa Rica. Many people and organizations have expressed great interest in our project and are willing to help in creating a solution to E-waste disposal. In order to create a solution that is most beneficial, thereby recycling the most material for the smallest amount of money, there needs to be local recyclers within Costa Rica. In order for this to happen, statistical data must be generated. This can be accomplished through the implementation of an international recycling. Afterwards, the collected data can be presented to recycling organizations to entice them to form a local computer scrap recycling operation in Costa Rica. A detailed explanation of the steps needed to accomplish this are presented in the following chapter.

Chapter 5. Conclusions and Recommendations

5.1.1 Introduction

This section presents conclusions drawn from our research and recommends specific actions to ensure successful implementation of a computer scrap management system in Costa Rica. The first section 5.1.2, Long Term Goals and Objectives, describes the long term goals of the management system as foreseen in the next few years. The second section, section 5.1.3, Overview of the Process, explains the process required to achieve the final management system recommendation. Section 5.1.4, Initial Actions, details the actions required in the near future to get implementation on the right track and start the first steps of the recommended process.

5.1.2 Long Term Goals and Objectives

Ideally, Costa Rica would ultimately be able to implement the second management model as detailed in section 4.6, Recycling Model, where computer scrap is processed locally. For now, it is currently infeasible to implement this model due to Costa Rica's lack of recycling facilities. Therefore, in the long run, Costa Rica would benefit by acquiring the capability to process this material locally rather than internationally, thereby reducing shipping costs and gaining a new industry. Not only would Intel Costa Rica benefit from gaining such an industry since currently they have to ship shredded defective computer chips to the United States to be mined, but the whole country would be better served as well by a national industry. If the facilities were local, Intel Costa Rica could cut costs, and the total savings would increase yearly. For these reasons, it is logical to establish the long term goal of encouraging the development of such an industry in Costa Rica.

Broadening public awareness about the effects of E-waste on the environment should be a key step in the entire process. The system will only be effective if people are made aware of the hazards and waste of resources associated with improper disposal of computer scrap. Through publicity and education, the public should be informed of the benefits of recycling. In time, broadening public awareness of the hazards of improper computer scrap disposal, individuals and companies will become reluctant to throw their old computers into a landfill, especially if there is an alternative recycling solution.

Also, a key objective should be the overall reduction of computer scrap. This is already being done by means of product ecology and design for recyclablity. A broad and on-going focus should be placed upon innovations and development towards more recyclable products. Furthermore, Intel should encourage Original Equipment Manufacturers (OEMs) to follow suit and create more products that are recyclable.

In addition, we recommend that the proposal and pressure towards the creation of stricter laws that encourage the recycling of E-waste in the country be implemented, once the recycling industry has developed. For example, Costa Rica must make it illegal to dispose of computer scrap improperly, particularly if better solutions are established. If the recycling option were available for E-waste, and if it were illegal to dispose of it in landfills, people would be more likely to recycle their used computers.

Lastly, it is also possible that by the time the recycling industry develops, surrounding Latin American countries will begin to experience the same disposal issues that Costa Rica is currently facing. If this is the case, attempts should be made to import computer scrap for processing from these countries. This will not only show that Costa Rica is a leader in environmental responsibility but will create more business for the recycling industry.

The most difficult aspect of reaching these goals lies beyond these initial recommendations: the implementation of a successful national recycling business. The next section will outline the recommended process to achieve these final goals.

5.1.3 Overview of the Process

Since the local processing of computer scrap, as depicted in the second model of section 4.6, Recycling Model, is currently infeasible, there is little choice but to implement the local model, where scrap is sent internationally to be recycled. There are some benefits associated with this solution. The international model will help to achieve the long term goal of developing a recycling industry in Costa Rica, by gathering crucial data concerning E-waste. It could be that the primary reason that companies have not already started a recycling industry in Costa Rica is lack of knowledge about the actual amount of Costa Rican computer scrap. By implementing the international model, in conjunction with collecting statistics about what amounts of computer scrap are available, one can then get a proper estimate of exactly how much computer scrap is being produced per year in Costa Rica. These data can then be used to encourage the development of a recycling industry, either by expansion of a company from another country, or via local venture capitalists and entrepreneurs.

As explained in section 4.6, Recycling Model, the international model includes E-waste generation, collection, refurbishment, recirculation, storage, pre-processing, and recycling. The options chosen for each phase of the management system should be based on a known working system and may be subject to change as the years of recycling proceed and as new statistical data become available. For now, the most logical approach for the collection phase would be the hybrid collection method as described in section 4.8, Options within each Recycling Model (also see section 4.6, Recycling Model). This would utilize both an annual recycling day as well as a continuous collection method. The collection of computer scrap would constantly stock a warehouse and maintain an active business, while once a year the recycling day would maintain awareness of recycling E-waste and prevent more obsolete computers from ending up in landfills.

The refurbishment method recommended for the final management model should include elements from both the school and private sector refurbishment methods described in section 4.6, Recycling Model. By making use of the current student-run computer refurbishing center and expanding it to include more students and more schools, both students and the organization running the recycling facility would benefit. The private sector should be included to provide funds for the recycling program and to lower operating costs. The exact details of each involvement would have to be analyzed more closely to determine the best ratio once the business is fully operational. The management of the new recycling facility should maintain an active agreement with the school systems to allow the students to learn computer skills through refurbishment, to allow students to gain interests in engineering and sciences, and allow the refurbished computers back into the local educational institutions.

The exact method of storage is impractical for us to determine. Someone knowledgeable about the San José area and existing storage facilities or available land could easily locate a storage facility. The criteria for a storage system in this management model would simply be a facility that could hold the volume of estimated computers based on previous recycling days, and the facility must be in a reasonable and strategic location where people could drop off their E-waste during a continual collection as well as on the annual recycling day.

The pre-processing phase of the recommended final management system should include students, volunteers, and possibly employees, if necessary. The students could separate components while claiming refurbishable items, and trained employees with proper equipment could separate the remainder of the unseparated items. The use of volunteers could also speed up the task of separation and reclamation during the annual recycling day event. Once the separation has taken place, the material could be recycled locally with the various recyclers, which take specific items that exist in computer scrap.

Since the goal is to have a local recycling facility for E-waste in the future, the majority of the unused waste could be smelted and mined, providing the owner of the recycling industry with revenue to maintain a business. Some of the waste could be separated into metals and plastics, which could be processed by a different local facility, if necessary. However, a strict “no landfill” policy should be implemented by the recycling industry to promote environmentally safe processing.

5.1.4 Initial Actions

In order to initiate the plan of action outlined above, several key procedures must take place:

- Begin negotiations with potential sponsors to fund the initial recycling day events. We have included a list of key contacts in Appendix B.

- Take a closer look at the potential recyclers listed in Table 3: Compilation of US Computer Recycling Companies in section 4.10 to determine the one(s) that will work best with the international processing model. Section 4.10 also presents a thorough analysis of potential recyclers.

- Search and select a warehouse to hold all the collected computer scrap from the recycling day event and make plans to use the facility on the day of the recycling event (and perhaps beyond for several months to process all received computer scrap).

- Determine what pre-processing requirements are most cost effective and necessary by the chosen recycler. This also includes plans to obtain shipping material for the recycling day.

- Locate a possible storage and processing facility within Costa Rica (if it is different from the selected warehouse) to pre-process the material after it is received and set up a handling layout and protocol for how to pre-process the scrap efficiently.

- Locate interested parties in the collection industry to determine how the collection process will go on the recycling day (possibly sponsored by the collection company involved).

- Contact local businesses and organizations (UCR, The Omar Dengo Foundation, Firestone, OTS, etc.) that might have computer scrap in order to inform them of upcoming event(s) so that they might store their computer scrap rather than disposing of it.

- Contact Luis Picado and Omar Dengo Foundation to work out shipping or to propose an alliance to ship the computer scrap to the selected recycler. This may involve writing a proposal to the Omar Dengo Foundation, as detailed in section 4.8.

- Contact David Portilla at San Sebastian Technical High School to determine the exact involvement the school and its students will have in the model. Additionally, other technical high schools should be contacted offering the chance to participate.

- Begin creating public awareness. Contact Emilia Mora of La Nación, who is willing to help in the publication of information regarding the harms of computer scrap and help to announce the recycling initiative.

5.1.5 Conclusion

Intel Costa Rica has impressed us with their dedication to environmentally friendly operations and their excellent community and educational involvement. Their presence in Costa Rica is unique, as it sets an example for other companies to follow in regards to safety, environmental concern, educational programs, and community activities. Therefore, their interest in the issue of E-waste disposal is not surprising. The implementation of an E-waste management system will be of great benefit to Costa Rica, and an inspiration to other developing countries. We are confident that Intel Costa Rica will be a leader in the development of Costa Rica, and their involvement in the creation an E-waste management system will serve to exemplify this.

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Appendix A – Mission and Organization of Intel Costa Rica

Founded in 1968, Intel is now a multinational producer of microprocessors, chipsets and other microprocessor related electronics (Intel, 2002e). Making only 41% of their revenues in the Americas, Intel does a quarter of its business in Europe, quarter in the Asia-Pacific area and 9 percent in Japan. In total, Intel brought in $26.5 billion dollars in revenue by the fourth quarter of last year.

While Intel employs over 85,000 people across 45 nations, the Intel facility in Costa Rica is the main area of focus in this project (2002b). Ten kilometers outside of San José lies Intel's $420 million dollar assembly and testing plant employing 1,900 people. The facility began operation in 1998 assembling the latest in Intel technology. Currently, it assembles and test Pentium IV and Xeon processors.

Intel Costa Rica's Mission Statement, Values, and Objectives

- **Our Mission**

  Do a great job for our customers, employees and stockholders by being the preeminent building block supplier to the worldwide Internet economy.

- **Our Values**

  Customer Orientation

  Results Orientation

  Risk Taking

  Great Place to Work

  Quality

  Discipline

- **Our Objectives**

  Make Intel the number one computing platform everywhere on the Internet.

  Aggressively grow new businesses by building on our capabilities.

  Achieve operational excellence" (Intel, 2002b).

Of the many sites Intel operates, most have a department devoted to educational and community involvement. The Costa Rican site, in particular, has one of these divisions, with a sub-division specifically devoted to education called the Innovation in Education program.

Objetivos de Intel Costa Rica en la educación

- Apoyar a las instituciones educativas estratégicas a desarrollar la fuerza laboral futura del país, enfocándose no sólo en la cantidad, sino además en la calidad de los graduados en los campos de ingeniería, tecnología y técnicos medios en electrónica y computación.

- Mejorar la educación primaria y secundaria en los campos de ciencia, ingeniería y educación informática, y promover el interés de los estudiantes en estos campos" (Intel 2002c).

Intel attempts to be good citizens in whatever nation they operate, and to make good in the communities in which they are a part. These sections of the company are specifically devoted to maintaining that good reputation.

Intel Costa Rica Public Affairs

Each Intel facility employs personal in the public affairs division. One aspect of this division is to promote education throughout the world by following these objectives:

- Improving science and math in primary and secondary education.
- Increasing the effective use of technology in classroom teaching.
- Broadening access to technology.
- Increasing the number of people, especially women and minorities, pursuing technical careers (Intel, 2002c).

The Public Affairs division at Intel Costa Rica was interested in ensuring the continued support for these objectives throughout this project. The important role of education in the community was fully understood while considering these recommendations for Intel Costa Rica. The involvement of students and organizations that promote education fulfills this important aspect of the project.

Intel Costa Rica Environmental Division

The environmental division at Intel Costa Rica employs individuals dedicated to upholding the strict environmental and safety rules set by Intel Costa Rica. Several programs exist that are geared towards a better environment. The first program, entitled “We save our planet”, consists of several environmental sessions carried out by volunteers at Intel Costa Rica in the primary and secondary school to promote environmental awareness. Another environmental initiative carried out by Intel Costa Rica is the treatment of water and testing the local supply for contaminants introduced by the local facility. The results prove to exceed the local requirements and those requirements set by the United States for companies in the United States. The third initiative Intel Costa Rica takes is the recycling and exportation of waste. Community groups collect the extra plastic waste, which is separated and sent for recycling. Also, the bad production products or circuit boards are exported to the United States for materials mining. Another important program Intel Costa Rica does is the program of coolant handling. The rules set in this program comply with the strict rules set by the United States EPA for proper recycling and reuse of coolants. These examples are just a few initiated by Intel Costa Rica to show the community the importance of environmental preservation.

The organization of the Environmental department is shown in Figure 7.

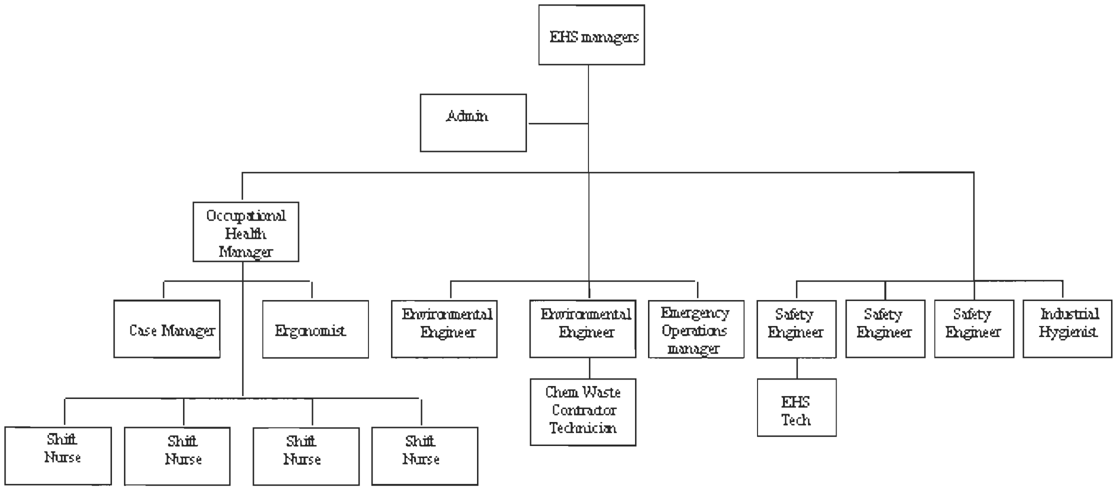


Figure 7: EHS Organizational Chart of Intel Costa Rica

Intel's Original Objective for this Project

"This project will wrap itself around the issues of disposal of computers. INTEL wishes to know what are the alternatives and barriers to putting into place a project that deals with computer scrap. Students will discover what is being done on the international scene regarding scrapped computers and uncover the resources that exist in Costa Rica to manage computer scrap."

In our project, the environmental division was interested in ensuring the protection of the environment and the health of the people. While performing this project, it was understood that the effects of computer scrap can be harmful to the environment if improperly disposed. The technical aspects of environmentally sound computer scrap recycling model recommended must conform to the strict regulations and restrictions set by Intel Costa Rica, which follow the stricter of either United States laws or local laws.

Appendix B – Key Individual Possible Players in an E-waste Management System

Table 4: Key Individuals to Contact

Key Individuals to Whom We Have Spoken				
Name of individual	Company or organization	Contact information	What they do	His or her desired participation is
Adolfo Cordoba	Río Azul landfill	Contact thru Jorge Cardoza at (506) 276-9800	They are a landfill serving 11 municipalities in San José	He is interested in starting a computer scrap collection at the landfill
Juan Carlos Salas	ITCR	(506) 550-2229 jcsalas@itcr.ac.cr	He is in charge of a waste collection and separation center. There waste is collected and separate to become raw materials for companies.	Would be interested in setting up a small computer disassembly operation.
David R. Portilla	San Sebastian Technical High School	(506) 252-3903 davidrob@costarricensc.cr	He runs the computer repair specialty part of which includes refurbishing computer systems	He is highly interested in participating at a central warehouse to refurbish computer scrap
Henry Salazar	Omar Dengo Foundation	(506) 258-5060 ex. 153 henry.salazar@fod.ac.cr	It is an international foundation that works towards getting technology into education systems of smaller and poorer communities.	He is highly interested in participating in a computer recycling program. One possibility is that they could provide shipping for computer scrap, because of they already ship material internationally.
Emilia Mora	La Nación	(506) 247-4277 emora@nacion.com	She has written two articles for La Nación regarding the E-waste problem in Costa Rica	She is interested in providing publicity or writing articles about E-waste to keep the Costa Rican population informed

We recommend contacting the individuals listed in Table 4. We directly spoke to each one during the course of our project. They all provided interest in participating in a computer scrap recycling model.

Additionally Justo Colon, whose contact information we listed in Table 5, received word about our project from the distributed survey. He is part of IBM's division in Miami, Florida that directly deals with IBM issues in Latin America. Although IBM does not service IBM computers in Latin America, a separate company does called GBM, which used to be part of IBM. GBM is in charge of servicing all IBM computers in 7 Latin American countries and has relations with Justo Colon in Miami. Justo Colon recommended contacting two individuals, Edwardo Blanco and Manual Sanbria whose contact information also appears in Table 5. They both work for GBM in Costa Rica and could provide information about IBM in relation to a possible computer scrap management system. We tried contacting them, but were unsuccessful. However, we strongly recommend to try to get in touch with them directly or either through Justo Colon, because they might provide valuable resources to a computer scrap management system.

Table 5: Key Individuals from GBM and IBM

Suggested contacts from GBM and IBM				
Name of individual	Company or organization	Contact information	Where they work	How we discovered them
Justo Colon	IBM, Miami	011 (305) 442-3696 colonj@us.ibm.com	Miami, Florida	Through our survey
Edwardo Blanco	GBM, Costa Rica	(506) 223-6222, ex. 280	Costa Rica	Through Justo Colon
Manual Sanbria	GBM, Costa Rica	(506) 223-6222	Costa Rica	Through Justo Colon

Appendix C – Compiled Data from Survey to Computer Mining Companies

Table 6: Data obtained from company responses to computer mining survey

Company Information			Feasibility of Company	
Company	Contact	Contact information from reply	Recycle computers sent by a corporation	Outsourcing
Back Thru The Future Micro Computers, Inc.	Daniel F. Bayha	nj@backthruthefuture.com	no	n/a
DMC, The Electronics Recycling Company	Lisa Collins	lcollins@dmcrecycling.com; (703) 264-0042	yes	no
Ecological Technologies, Inc.	John M. Eames	info@eco-tech.com; (408) 524-7100	no	n/a
Envirocycle, Inc.	Tina Haley	thaley@matcogroup.com	yes	no
Environmental Computer Recycling Company	Michael Whitaker	mikew@iaw.on.ca	yes	breakdown the material; then outsourced
Fox Electronics	Brad Fox	BRAF@foxelectronics.com	yes	yes
HP Recycling	Chris Altobell	chris_altobell@hp.com; (916) 785-7415	yes	no; not directly specified
IBM Asset Recovery	Edward Grenchus Jr	grenchus@us.ibm.com; (607) 755-4755	yes	initial sorting of usable parts and separation then outsourcing
Intercon Solutions: Recycling Division	Monica Marsicek	monica@interconrecycling.com; (773) 521-5642	yes	they demanufacuture the products; recycling is outsourced
InterConnection	Charles Brennick	brennick@interconnection.org	no	n/a
MBA Polymers	Dr. Darren Arola	darola@mbapolymers.com	yes	sell plastic and metal byproducts
Metals Reclamation Services	Grant J. Hill	mrsgjhill@aol.com; (408) 723-8528	no	n/a
Montgomery County, MD, Solid Waste Services	Susanne Brunhart Wiggins	susanne.Wiggins@co.mo.md.us	no	n/a
United Datatech	Thomas Q. Hogye	tomh@uniteddatatech.com	yes	not specified

Company Information	Recycling Process		Limits	Preprocessing	
Company	Shredding	Manual separation	Limits to types of computer scrap	Preprocessing requirement	Preprocessing encouraged
Back Thru The Future Micro Computers, Inc.	n/a	n/a	n/a	n/a	n/a
DMC, The Electronics Recycling Company	yes	yes	no	normally receive whole units	n/a
Ecological Technologies, Inc.	n/a	n/a	n/a	n/a	n/a
Envirocycle, Inc.	not specified	Not specified	less than 4 years old?	not specified	not specified
Environmental Computer Recycling Company	no	yes	no	not required	preprocessing can be done
Fox Electronics	yes	yes	no	no	Discouraged
HP Recycling	yes	no	no loose batteries, loose toner and ink; no broken monitors	prefer whole units	no
IBM Asset Recovery	yes	yes	no hazardous materials	no	not specified
Intercon Solutions: Recycling Division	no	yes	no	no	doesn't matter
InterConnection	n/a	n/a	n/a	n/a	n/a
MBA Polymers	yes	no	no	no	yes
Metals Reclamation Services	n/a	n/a	n/a	n/a	n/a
Montgomery County, MD, Solid Waste Services	n/a	n/a	n/a	n/a	n/a
United Datatech	yes	Not specified	not specified	not specified	not specified

Company Information	Facility Limits		Shipping Requirements		
Company	Max tons per month	Minimum or maximum shipment requirement	Restrictions on shipping	Packing requirements	Limits on frequency of shipments
Back Thru The Future Micro Computers, Inc.	n/a	n/a	n/a	n/a	n/a
DMC, The Electronics Recycling Company	2 million pounds	smallest load 4,000 pounds	prior to shipping, need paperwork done	pallets with shrink wrap or gaylord boxes	Monday thru Friday
Ecological Technologies, Inc.	n/a	n/a	n/a	n/a	n/a
Envirocycle, Inc.	not specified	not specified	not specified	not specified	not specified
Environmental Computer Recycling Company	40 to 80 tons	no	no	trailer/container loads preferred	prefer container loads of 20 tons per week
Fox Electronics	666,000 pounds in 2001	no	preferred full trailer loads	pallets with shrink wrap or gaylord boxes	no
HP Recycling	800 tons in each of two facilities	no	safe manner	pallets with shrink wrap	Monday thru Friday, 6am to 9pm Pacific time
IBM Asset Recovery	facility in Endicott, New York can process 3 million pounds	no	no	no	no
Intercon Solutions: Recycling Division	1400 tons	no	no	either in boxes or pallets with shrink wrap	no
InterConnection	n/a	n/a	n/a	n/a	n/a
MBA Polymers	6.6 metric tons per month	no	no	either in bags, gaylord boxes or pallets	no
Metals Reclamation Services	n/a	n/a	n/a	n/a	n/a
Montgomery County, MD, Solid Waste Services	n/a	n/a	n/a	n/a	n/a
United Datatech	not specified	not specified	not specified	not specified	not specified

Company Information	Returned Value and Fees			Destination of Materials	
Company	Recycling fees	Percentage of value returned to sender	Variation of fee	Recycled material sent to sender	Final distribution of materials
Back Thru The Future Micro Computers, Inc.	n/a	n/a	n/a	n/a	n/a
DMC, The Electronics Recycling Company	depends on type and value of materials	based upon value of equipment	yes	no	sold in various markets
Ecological Technologies, Inc.	n/a	n/a	n/a	n/a	n/a
Envirocycle, Inc.	$6 monitors; $3 CRTs; $0.15 per pound for other equipment	not specified	not specified	not specified	not specified
Environmental Computer Recycling Company	damaged monitors, monitors under 14" SVGA, $5 fee; $4 broken dot matrix or bubble jet printers	no	no	no	not specified
Fox Electronics	$0.21/lb heavy plastics; $0.75/lb CRTs; $0.21/lb faxes & printers	50% of all revenues back on ICs and boards	no	no	primary recyclers
HP Recycling	depends on equipment; most items have a recycling fee	no; however special considerations are possible	yes	no	companies receive the material to be used in manufacturing or further recycling
IBM Asset Recovery	negotiated upfront depending on quality of material	no	no	no	approved recycling vendor process the material for recovery or use
Intercon Solutions: Recycling Division	$10 for CRTs and UPCs; $5 CPUs, printers, scanners; $1 mice, keyboards, modems; others depend on weight	no	no	no	used to make other products
InterConnection	n/a	n/a	n/a	n/a	n/a
MBA Polymers	for mainly plastic, there is usually no fee	if decent plastics, then they might pay for the material	not specified	no	sold for new applications
Metals Reclamation Services	n/a	n/a	n/a	n/a	n/a
Montgomery County, MD, Solid Waste Services	n/a	n/a	n/a	n/a	n/a
United Datatech	not specified	not specified	not specified	not specified	not specified

Company Information	Definition of Materials		Other Considerations
Company	Materials recycled	Materials considered waste	Unique aspects of company
Back Thru The Future Micro Computers, Inc.	n/a	n/a	They only collect and sort the product into usable and non usable parts; resell the usable parts and send non usable parts to an EPA approved recycler; Also they are themselves and EPA approved computer recycling company
DMC, The Electronics Recycling Company	all	none	ISO 14001 certified; audited twice a year by an outside firm; excellent reputation with the EPA; around August 2002 will include a foreign trade zone
Ecological Technologies, Inc.	n/a	n/a	They only recycle used plastic IC trays
Envirocycle, Inc.	not specified	not specified	
Environmental Computer Recycling Company	all, including shrink wrap	none	They are very interested in our proposal
Fox Electronics	all	packaging and foam	
HP Recycling	all	none	
IBM Asset Recovery	depends on country; in New York no material is sent to landfills except packaging	see previous comment	GBM not IBM is responsible for all IBM products in 7 Central American countries
Intercon Solutions: Recycling Division	all	none	
InterConnection	n/a	n/a	Help developing countries with their technology needs; they do not recycle computers
MBA Polymers	not specified	not specified	They are looking to expand their operations possibly to Central America
Metals Reclamation Services	n/a	n/a	They are a monitoring service for computer recycling; however, they do have a list of references that they are more than happy to provide
Montgomery County, MD, Solid Waste Services	n/a	n/a	They only handle material for their local area
United Datatech	not specified	none	Also donate computer equipment to non profit causes

Explanation of Table 6 – Company Information

Unlike Appendix D, Appendix C contains summaries of the information sent by the companies in response to the questionnaire. Although we researched most of the reaming companies on the Internet, they were not included in the table because of lack of information. The first column contains the name of the company that responded to the questionnaire with the individual representative listed in the second column. His or her e-mail address we list in the column entitled "Contact information from Reply". It is important to distinguish that this is not the initial e-mail address used to contact the company. We recommend using this e-mail address should Intel Costa Rica require further information.

Under the title of "Feasibility of Company", the subheading of "Recycle computers sent by a corporation" indicates if the company is willing to accept computers sent by a corporation. The subheading of "Outsourcing" depicts whether the contacted company performs all recycling and refurbishing on their own premises or whether outsourcing of material or work occurs.

The title of "Recycling Processes" provides information concerning how the company actually recycles computer scrap through either shredding and or manual separation. It is important to note that companies can use either or both of the processes in a recycling program as is shown in the survey responses.

"Limits to types of computer scrap" reveals whether there are any limitations to types of computer scrap that the recycling facility can receive. This could include cathode ray tubes and toner cartridges.

The preprocessing heading specifies whether there are any preprocessing requirements such as the separation of components and if preprocessing is encouraged as a means to reduce costs.

"Facility Limits" specify limits to the capacity of the recycling facility. The "maximum tons per month" are the maximum amount of material, which the facility can process in one month. However, the "Minimum or maximum shipment requirement" specify limits for individual shipments sent and not the limits to the facility as a whole. "Shipping Requirements" specify limits on shipping to the recycling company. "Restrictions on shipping" indicates possible unacceptable forms of transportation. "Packing requirements" indicate if the scrap must arrive shrink-wrapped on palettes or in gaylord boxes. "Limits on frequency of shipments" indicates if there is a limit to the frequency of possible delivers to the recycling facility.

Under the heading of "Returned Value and Fees", the subheading of "Recycling fees" refers to any mandatory fees with "Variation of fee" indicating if the fees are set rates or based upon material received. "Percentage of value returned to sender" specifies if any value from the shipments sent to the recycler is returned to the sender.

Under "Destination of Materials", the subheading of "Recycled material sent to sender" specifies whether the sender receives any processed materials such as shredded copper or plastic. "Final distribution of materials" specifies what happens to the separated materials after completion of the recycling.

"Definition of Materials" specifies how much of the recycled materials are used and how much waste ends up in landfills assessing the success of a given recycling company. Any special or useful information retrieved through the survey appears under "Other Considerations".

Appendix D – Contact Information for Contacted Companies through a Questionnaire

Table 7: Contact Information for Surveyed Computer Mining Companies

Records of Contact				
Company	Location	Contacted	Responded	E-mail
Allied Electronic Recovery	California & New Hampshire	yes	no	mathew@aerxchange.com
Asset Recovery Corporation	Minnesota	yes	no	info@assetrecoverycorp.com
Back Thru The Future Micro Computers, Inc.	New Jersey	yes	yes	nj@backthruthefuture.com
Dell Asset Recovery Services	not specified	yes	no	US_DFS_AssetRecovery@Dell.com
DMC, The Electronics Reycling Company	Maryland	yes	yes	info@DMCrecycling.com
Ecological Technologies, Inc.	California	yes	yes	info@eco-tech.com
ECS Refining	California & Texas	yes	no	contact form
Envirocycle, Inc.	Pennsylvania	yes	yes	envirosales@matcogroup.com
Environmental Computer Recycling Company	Niagara Region, Canada	yes	yes	info@ecrco.com
Fox Electronics	San Jose, California	yes	yes	contact form
HACKETT ELECTRONICS	California	yes	no	Sales@hackettelec.com
HMR Group	California	yes	no	jb@hmrusa.com
HP Recycling	not specified	yes	yes	contact form
IBM Asset Recovery	not specified	yes	yes	ICCUSED@us.ibm.com
IBM Asset Recovery	not specified	yes	yes	contact form
IBM Mexico	Mexico	yes	bounced back	dgomez@mxl.ibm.com
Intercon Solutions: Recycling Division	Chicago, IL	yes	yes	info@interconrecycling.com
InterConnection	Oregon	yes	yes	info@interconnection.org
MBA Polymers	Richmond, California	yes	yes	info@mbapolymers.com
Metals Reclamation Services	San Jose, California	yes	yes	mrsgjhill@aol.com
Metech	California & Rhode Island	yes	no	recycleapc@metech-arm.com
Micro Metallics Corp., a Noranda company	California	yes	no	beckmanc@micrometallicscorp.com
Montgomery County, MD, Solid Waste Services	Maryland	yes	yes	info@mcrecycles.org
SimsMetal America	California, Virginia & Illinois	yes	no	custserv@simsusa.com
South Bay Metals, Inc.	not available	yes	no	southbaymetals@gilroy.com
Supreme Computer Recycling, Inc.	New Jersey	yes	bounced back	info@supremerecycling.com
Supreme Computer Recycling, Inc.	New Jersey	yes	bounced back	ABoufarah@supremerecycling.com
Supreme Computer Recycling, Inc.	New Jersey	yes	no	contact form

The Computer Recycling Center at CMU	Pennsylvania	yes	bounced back	computer.recycling@andrew.cmu.edu
Tung Tai Group	California	yes	no	sales@tungtai.com
United Datatech	California & Texas	yes	yes	contact form
United Recycling Industries	Illinois	yes	no	contact form
VPElectronic.com "Electronic Recycler"	California	yes	no	billvp@vpelectronic.com

Records of Contact			
Company	Discovered from[i]	Suggested as a possible client	Website
Allied Electronic Recovery	SVTC listing	yes	http://www.aerxchange.com/
Asset Recovery Corporation	Internet search	no	http://www.assetrecoverycorp.com/
Back Thru The Future Micro Computers, Inc.	Internet search	no	http://www.thegreenpc.com/
Dell Asset Recovery Services	Internet search	yes	http://www.dell.com/us/en/biz/services/asset_005_assetrecovery.htm
DMC, The Electronics Reycling Company	Internet search	no	http://www.dmcrecycling.com
Ecological Technologies, Inc.	SVTC listing	no	http://www.eco-tech.com/
ECS Refining	SVTC listing	yes	http://www.ecsrefining.com
Envirocycle, Inc.	Internet search	no	http://www.enviroinc.com
Environmental Computer Recycling Company	Internet search	no	http://www.ecrco.com/
Fox Electronics	SVTC listing	yes	http://www.foxelectronics.com
HACKETT ELECTRONICS	SVTC listing	yes	http://www.hackettelec.com/
HMR Group	SVTC listing	yes	http://www.hmrusa.com/
HP Recycling	Internet search	yes	https://warp1.external.hp.com/recycle/custom_quotes.asp
IBM Asset Recovery	Internet search	yes	http://www-1.ibm.com/financing/contact/us.html
IBM Asset Recovery	Internet search	yes	http://www-1.ibm.com/financing/gars/services/adss/#adss1
IBM Mexico	Internet search	no	http://www-1.ibm.com/financing/contact/mx.html
Intercon Solutions: Recycling Division	Internet search	no	http://www.interconrecycling.com/
InterConnection	Internet search	no	http://www.interconnection.org/
MBA Polymers	SVTC listing	yes	http://www.mbapolymers.com
Metals Reclamation Services	Internet search	no	http://www.mrsscrap.com/
Metech	Intel CR	yes	http://www.recycleapc.com/
Micro Metallics Corp., a Noranda company	SVTC listing	yes	http://www.micrometallics.com
Montgomery County, MD, Solid Waste Services	Internet search	no	http://solidwaste.dpwt.com/recycling/how_to/computers.htm
SimsMetal America	SVTC listing	yes	http://www.simsmetal.com/
South Bay Metals, Inc.	SVTC listing	no	non existent

Supreme Computer Recycling, Inc.	Internet search	no	http://www.supremerecycling.com
Supreme Computer Recycling, Inc.	Internet search	no	http://www.supremerecycling.com
Supreme Computer Recycling, Inc.	Internet search	no	http://www.supremerecycling.com
The Computer Recycling Center at CMU	Internet search	no	http://www.cmu.edu/acs/hardweb/Recycling.html
Tung Tai Group	SVTC listing	no	http://www.tungtai.com/
United Datatech	SVTC listing	yes	http://www.uniteddatatech.com/
United Recycling Industries	SVTC listing	no	http://www.unitedrecyclingind.com/uri/uri.html
VPElectronic.com "Electronic Recycler"	SVTC listing	yes	http://www.vpelectronic.com

[i] SVTC listing is the San Francisco Bay Area Computer Recycling Directory -- http://www.svtc.org/cleancc/recycle/recycletable.html

Explanation of Table 7 – Contact Information

In Appendix D, under the column "Company" each company is listed once, however some companies are listed twice or more. Either a double or triple listing is the result of more than one contact attempt by two different e-mail addresses or by an e-mail address and a website contact form. For example, the double listing of IBM Asset Recovery exists, because contact occurred once through e-mail and a second time through a website contact form. The reason for sending out the survey twice through each method was for a greater chance of response from the company.

Following the company name column is the column "Location". The location column provides the facility's location. The purpose of the column is to be able to analyze the feasibility of transporting scrap to a recycling company based upon their location. The third column indicates whether contact occurred with each of the companies. Each discovery of a company resulted in contact.

Under the responded column, there are three possibilities, either the company responded indicated by "yes", the company did not respond indicated by "no" and the e-mail was an invalid e-mail with a resulting error message received indicated by "bounced back".

The "e-mail" column lists the e-mail address used for contact or whether we used a website contact form. It is important to note that the e-mail addresses listed are those used to contact the company, while the e-mail addresses listed in Appendix C are those of the individual who responded.

The purpose for the separate listings is to show the initial contact method, but still to be able to respond directly to the individual who answered the questionnaire.

The column "Discovered from" indicates the means by which the company was located. "Internet search" means that the company was located from an Internet search by searching for "computer recycling company". "SVTC listing" indicates that companies were located through the Silicon Valley Toxics Coalition's San Francisco Bay Area Computer Recycling Directory. The directory provides a list of all computer mining and/or refurbishing companies, and stores that sell refurbished computers located in the San Francisco Bay Area. "Intel CR" indicates the third option in which Intel Costa Rica initially mentioned the company as a possibility.

The "possible client" column indicates whether the company was determined to be a possibility through the analysis presented in Recycling Model, section 4.6. The "website" column provides the main website for each company that also contains contact information.

Appendix E – Questionnaire to Computer Mining Companies

Information request regarding computer scrap recycling

We are a group of WPI students examining the possibility of sending computer scrap produced in Costa Rica to your recycling facility or organization. Our project is sponsored by Intel Costa Rica who is interested in the ability to recycle E-waste or computer scrap produced by the Costa Rican population. We would greatly appreciate your answers to the following questions and any additional relevant information you might include. You may send your responses either by replying to this e-mail or to intelcr@wpi.edu or by fax to (425) 940-0903. We would appreciate it greatly if you could reply by Thursday June 13th.

Thank you for your time and effort in completing this questionnaire.

Daniel Wallance
Antti Koski
Joe Havelick

intelcr@wpi.edu
Phone: 011 (506) 234-0146 ex. 129 (Costa Rica)
Fax: (425) 940-0903 (US)

----------Questions follow below---------

Do you recycle computer scrap sent by corporations?

Does your organization actually recycle the material or is it outsourced to a second party who recycles the scrap?

What recycling process is used at your facility? For example, is the material shredded or is manual separation the prime recycling technique?

Are there limits or restrictions to what type of computer scrap you accept, such as printers or computer monitors?

Can computer scrap be sent to your facility as whole computers, monitors, or devices? Or is there a preprocessing requirement to separate components?

How many tons of computer scrap can you handle per month?

Is there a minimum requirement or maximum limit of computer scrap for a given shipment?

Are there any restrictions on the methods by which computer scrap can be shipped to your facility? Are there any packaging restrictions such as the items must arrive on a pallet?

How often can shipments be sent to your facility?

Is there a recycling fee which must be paid to your organization for the recycling?

What percentage of the value recovered from the material is returned to the sender, if any? Does the fee or return vary depending on the size of the shipment?

Does the sender receive any material back in the form of separated metals or plastics? If not, then what happens to the recycled material?

What particular elements or materials are recycled and which particular elements or materials are considered wastes?

Appendix F – Intel AZ, Computer Recycle Day Project Packet

This packet was given to us by Todd Brady. The packet details the recycling initiative that was created by StRUT Arizona and Intel Arizona specifically in reference to a recycling day that has been in commission for the past three years.

This section has been removed due to confidentiality

Appendix G – Detailed Human Risk Assessment of Computer Scrap

The risk assessment of human exposure to chemicals found in computer scrap is difficult to determine in many cases. The U.S. EPA has encouraged and/or sponsored a multitude of studies on the exposure to many different elements, including those found in computer scrap. This Appendix will summarize the foreseen risk of each element as dictated by the U.S. EPA.

Exposure to polychlorinated biphenyls (PCBs), a common element of capacitors, is known to cause cancer. The U.S. EPA (1997) lists the human carcinogenicity data as inadequate. However, several studies were discovered that evaluated cancer mortality among workers exposed to PCBs in capacitor manufacturing plants in New York and Massachusetts. The study looked at 2588 workers who worked at the facilities for 3 months or longer. All were considered to have a high risk for exposure to PCBs. At the end of the study in 1982, there had been 295 deaths, 62 from cancer. Compared with national rates, a statistically significant increase in death from cancer was reported in the area of the study: 5 observed, 1.9 expected (U.S. EPA, 1997). Several similar studies have been performed at manufacturing plants at various areas around the world, each of which shows an increased cancer mortality rate among workers exposed to PCBs. No trend was identified after a proportional hazards analysis had been conducted on the small amount of data collected. Norback and Weltman (1985) examined the effect of exposure to PCBs in lab rats. In males and females fed Aroclor 1260, liver foci appeared at 3 months, area lesions at 6 months, neoplastic nodules at 12 months, trabecular carcinomas at 15 months, and adenocarcinomas at 24 months, demonstrating progression of liver lesions to carcinomas. By 29 months, 91% of females had liver carcinomas and 95% had carcinomas or neoplastic nodules; incidences in males were smaller, 4% had liver carcinomas and 15% had carcinomas or neoplastic nodules (U.S. EPA, 1997). Table 8 shows the summary of PCB exposure as determined by the collection of studies.

Table 8: Cancerous tumors in lab rats after exposure to types of PCBs (Brunner et al., 1996; Norback and Weltman, 1985)

	Administered Dose (ppm)	Human Equivalent (mg/kg)/day	Tumor Incidence
Aroclor 1260	0	0	1/85
	25	0.35	10/49
	50	0.72	11/45
	100	1.52	24/50
Aroclor 1254	0	0	1/85
	25	0.35	19/45
	50	0.76	28/49
	100	1.59	28/49
Aroclor 1242	0	0	1/85
	50	0.75	11/49
	100	1.53	15/45
Aroclor 1016	0	0	1/85
	50	0.72	1/48
	100	1.43	7/45
	200	2.99	6/50
Aroclor 1260	0	0.75	1/45
	100/50/0	1.3	41/46

Humans exposed to PCBs are considered at high risk for developing symptoms when exposed to the following concentrations of PCBs: 2.0 per (mg/kg)/day to about 1.0 per (mg/kg)/day. Exposure to 0.4 per (mg/kg)/day to about 0.3 per (mg/kg)/day is considered low risk. The lowest risk factor is 0.07 per (mg/kg)/day to about 0.04 per (mg/kg)/day (U.S. EPA, 1997). For further information on exposure limits refer to U.S. EPA, 1997.

The most well known element found in computer scrap is lead. As stated before, exposure to inorganic lead and lead compounds causes damage to central and the peripheral nervous system, blood systems, kidney, and the reproductive system in humans. U.S. EPA (1993) describes the human carcinogenicity data as inadequate. Four studies were examined of occupational exposure to lead and lead compounds. Two of the studies did not find any connection between exposure and cancer mortality, one study found a slight decrease in total cancer mortality, and the last found a statistically significant increase in cancer mortality among exposed workers. The researchers of the last study felt that it was possible that the subjects monitored were selected on the basis of obvious signs of lead exposure while the other studies also monitored others who showed no symptoms of lead poisoning at all (U.S. EPA, 1993). In laboratory rats, lead has been shown to produce renal tumors. Azar et al. (1973) performed a study on rats that lasted two years. Male rats fed 500, 1000, and 2000 ppm lead acetate had an increased renal tumor incidence of 5/50, 10/20, and 16/20, while 7/20 females in the 2000-ppm group developed renal tumors. No renal tumors were reported in the control groups or in treated animals of either sex receiving 10 to 100 ppm. U.S. EPA reports that this study is limited by the lack of experimental detail. There is no mention of possible environmental contamination from lead in the air or the drinking water of the tested rats. Another study, conducted by Kasprzak et al. (1985) investigated the effects of diatary calcium on lead carcinogenicity. The research group fed 1% (8500 ppm) lead subacetate to male rats in their diet for 79 weeks. After 58 weeks one rat had died, 44.8% had renal tumors, 4 had adenocarcinomas, and the remaining 9 had adenomas. No renal tumors were noted among the controlled rat group (U.S. EPA, 1993). Other more specific data on human exposure to lead were not available or has not been discovered.

A large percentage of aluminum is found in computer scrap. Data were discovered only on the aluminum phosphide form of aluminum. The effect of aluminum on humans has not been discovered. Aluminum phosphide has been know to cause weight loss and other clinical problems to rats when exposed to the compound. Even though, Hackenburg (1972) investigated the effects of feeding aluminum phosphide in food fed to 30 rats of different sex groups. The average concentration was 0.51 mg phosphine/kg food for a 2-year period. At the end of the treatment period, there were no differences between treated and control rats in blood or urine chemistry, or histologic parameters (U.S. EPA, 1988).

Copper is another element found in large percentages in computer scrap. No human carcinogenicity data were available for exposure to copper. In lab rats, the U.S. EPA describes the results as inadequate. Nonetheless, an increased incidence of reticulum cell sarcomas was observed in a 28-day study. No tumors were noticed in the treated mice (U.S. EPA, 1991). For more information regarding supporting data for carcinogenicity refer to U.S. EPA, 1991.

Two point two pounds of a 70 pound computer is made of Zinc (Byster et al., 2002, p. 44). The U.S. EPA (1992) lists that a 47% decrease in erythrocyte superoxide dismutase (ESOD) concentration in adult females was reported after 10 weeks of exposure to zinc (1.0 (mg/kg)/day exposure). There was also a significant decline in serum ferritin and hematocrit values at 10 weeks. Despite this and other similar studies, the U.S. EPA still lists the human carcinogenicity data as inadequate (U.S. EPA, 1992). However, case studies have been conducted on workers exposed to zinc. In one case, a 59 year old female and a 26 year old male received 100-150 mg/day of zinc sulfate (female) and zinc acetate (male). The study concluded saying that a profound anemia is associated with hypoceruloplasminemia and hypocupremia. The conditions were corrected by copper supplementation and, in one case, withdrawal of zinc (U.S. EPA, 1992). In lab rats, several effects of copper were noted. "An apparent increase in the incidence of hepatomas was observed in treated mice surviving for 45 weeks or longer relative to controls…The hepatoma incidence in the control, low-dose drinking water, high-dose drinking water, and test-diet group was 3/24 (12.5%), 3/28 (10.7%), 3/22 (13.6%), and 7/23 (30.4%), respectively. Incidence of malignant lymphoma in the control, low-dose drinking water, high- dose drinking water, and test-diet groups was 3/24 (12.5%), 4/28 (14.3%), 2/22 (9%), and 2/23 (8.7%), respectively. Incidence of lung adenoma in the control, low-dose drinking water, high-dose drinking water, and test-diet groups was 10/24 (41.7%), 9/28 (32.1%), 5/22 (22.7%), and 9/23 (39.1%), respectively. None of these were significantly elevated in a statistical analysis of [these] data performed by the EPA. In a 14-month study conducted with 150 C3H mice (sex not reported), administration of 500 mg/L zinc sulfate (approximately 100 mg/kg/day) in the drinking water resulted in hypertrophy of the adrenal cortex and pancreatic islets (Aughey et al., 1977). No tumors were noted; however, only the adrenal, pancreas and adenohypohysis were examined. Accurate consumption data could not be obtained due to spillage during drinking" (U.S. EPA, 1992).

Barium is another element found in computer scrap as seen in Table 2. Byster et al. (2002, p. 9) describe that short term exposure to barium can cause brain swelling muscle weakness, and damage to some vital organs. The U.S. EPA reports on many studies done to evaluate human exposure to barium in the workplace. In one such finding by Doig (1976), 5 workers in 1947 were examined who were employed for more than 3.5 years in an environment where they could have been exposed to barium. There was no evidence of baritosis in any of the workers. Years later in 1961, 8 more workers were evaluated who were employed for 3.5 to 18 years. Other than one worker who reported a slight occasional cough, no abnormal findings were observed. Pneumoconiosis was detected in the radiographs of 7 workers. In the 1961 study, dust concentrations ranged from 2,7834 to 11,365 particles/ml^3 were measured using a thermal precipitator. Of this dust measurement, barium concentration was not measured. Also, 10 workers examined in 1961 were reexamined 18 months later. Two new cases of pneumoconiosis were diagnosed that were not previously detected. The most recent tests now indicated that 9 of the 10 workers exposed to barium sulfate for 1.5 to 19.5 years had well-marked baritosis. Of the 9 workers 3 did not smoke, 4 smoked less than a pack a day, and 2 smoked more than a pack a day (U.S. EPA, 1999). The National Toxicology Program (1994) studied the effect of barium in lab mice. Groups of male and female mice received 0, 125, 500, 1,000, 2,000, or 4,000 ppm (13-week duration) or 0, 500, 1,250, or 2,500 ppm (2 years) barium chloride dihydrate in drinking water. "The nephropathy was characterized as tubule dilatation, renal tubule atrophy, tubule cell regeneration, and the presence of crystals primarily in the lumen of the renal tubules" (U.S. EPA, 1999) among the high dose animals. Other adverse effects observed were attributed to related debilitation of the animals. In a short term study on lab rats (4, 8, 13 weeks) with doses of 0, 10, 50, or 250 ppm barium cloride, there were no significant alterations in survival, organ weights, hematologic and serum clinical chemistry parameters, and gross or histopathologic appearance of major tissues (liver, kidney, spleen, heart, brain, muscle, femur, and adrenal glands) (U.S. EPA, 1999).

The presence of nickel in computer scrap has also lead to many wondering how this element impacts humans. The U.S. EPA (1991a) considers the human carcinogenicity data on nickel refinery dust sufficient to classify it as a human carcinogen. The evidence discovered throughout the years from pyrometallurgical sulfide nickel refineries around the world all show similar results. All studies have reported a high risk of lung and nasal cancer among all men exposed to the dustier areas of the refinery. In lab rats, it was found that when exposed to a combination of nickel and iron dust at concentrations of 2.1 +/- 0.2 mg/m^3 and 1.9 +/- 0.2 mg/m^3, one of the 60 surviving rats developed lung cancer (U.S. EPA, 1991a). Also, an intermediate of nickel refinery dust that contains nickel subsulfide, nickel oxide, and metallic nickel was tested in lab rats at 70 mg $dust/m^3$, 5 hours a day for 6 months. Two of the five surviving rats had squamous-cell carcinomas. In a second similar study, the dust was injected at 90 to 150 mg/rat. Six of the 39 rats that survived developed injection-site sarcomas (U.S. EPA, 1991a). Other types of nickel, such as nickel carbonyl, have been classified as a probably human carcinogen with inadequate human carcinogenicity data (U.S. EPA, 1987). Nickel in the form of soluble salts has been shown to significantly decrease organ and body weight in lab rats in a two year study. Even at 6 weeks females rats showed a reduction of weight and after 52 weeks the male rats showed a reduction (U.S. EPA, 1996).

Vanadium, another element found in computer scrap may have adverse effects in humans. No documents on vanadium were discovered pertaining to humans. However, the U.S. EPA (1996a) explains that a study done on rats exposed to about 17.9 and 179 ppm vanadium pentoxide for two and a half years showed significant decrease in the cystine in the hair of animals exposed. A second study where Wistar rats were fed vanadium pentoxide for 68 days also showed similar results. In addition, the second study concluded that a decreased level of erythrocyte and hemoglobin were detected in the exposed rats. Also, in an inhalation study on rats and mice exposed to 1 to 3 mg/m^3 of vanadium pentoxide for three months, six hours a day developed histopathologic changes in their lungs and had a decreased growth rate. Adverse effects were not detected in rats exposed to 0.1 to 0.4 mg/m^3 (U.S. EPA, 1996a).

Small amounts of beryllium can be found in computer scrap. Beryllium is know to promote cancer but is used since it is a good conductor (Byster et al, 2002, p. 9). The U.S. EPA (1998) classifies the human carcinogenicity data of the effects of beryllium and beryllium compounds as limited. Wagoner et al. (1980) initiated a study of over three thousand white males employed between 1942 and 1967 at a beryllium extraction, processing, and fabrication plant in Pennsylvania. The researchers concluded that the total number of deaths was not significantly different from the number expected on the basis of age and calendar time period for the general white U.S. male population. However, significant cases of malignant neoplasm of trachea, bronchus, lung and heart disease, and nonneoplastic respiratory disease were observed in the study participants (U.S. EPA, 1998). In lab rats and other animals, conflicting research has documented both little and many adverse effects have been documented. In one study conducted by Morgareidge et al. (1975, 1977), groups of rats were fed diets containing 5, 50, or 500 ppm beryllium as beryllium sulfate tetrahydate. In this study, no overt signs of toxicity were observed and mortality appeared to be similar to controls. A slight loss in weight was observed through the later part of the study. U.S. EPA speculates that these data suggest that the maximum tolerated dose was not reached in this study. Morgareidge et al. (1976) also conducted a long term study in which 5 male and 5 female beagle dogs were fed diets of beryllium (0, 5, 50, or 500 ppm) for 172 weeks. After 33 weeks the 500 ppm group had been terminated due to overt signs of toxicity (two at week 26, the remainder at week 33). Symptoms included lassitude, weight loss, anorexia, and visibly bloody feces. Also, one male and one female dog died in the 50 ppm group. Interestingly, the appearance, behavior, food intake, and body weight gain of the animals in the other beryllium groups did not differ from the controls (U.S. EPA, 1998). For more information on these studies, see U.S. EPA, 1998.

Antimony, another element in computer scrap, can affect longevity, blood glucose, and cholesterol levels (U.S. EPA, 1991a). The effects of antimony on humans are not available. However, the U.S. EPA (1991a) refers to an incident where 70 people became slightly ill after drinking lemonade containing a small percentage (0.013%) of antimony. Most of the people affected were taken to the hospital with burning stomach pains, colic, nausea, and vomiting. Most recovered in about three hours, but it was noted that some didn't recover for several days (U.S. EPA, 1991a). In lab rats, the effect of antimony is still inadequately known. In one experiment, a group of 50 males and 50 female rats were fed 5ppm potassium antimony tartrate in water. The growth rate of the treated animals was not different than the control group. Each group survived about 106 days less than the controls at median life spans. Cholesterol levels were affected in both sexes and nonfasting blood glucose levels were decreased in the treated males. No tumors were observed, but a decrease in mean heart weight was detected in the treated group (U.S. EPA, 1991a).

Another element found in computer scrap is Arsenic. Arsenic has been classified as a human carcinogen by the U.S. EPA (1998a) based on sufficient evidence from human data. The studies reviewed by the U.S. EPA (1998a) indicate that the critical effect of exposure to arsenic includes hyperpigmentation, keratosis, and possibly vascular complications. Several studies listed included skin cancer and blackfoot disease associated with prolonged exposure to arsenic. One researcher concluded that the dosage level and age group both effect the contraction of blackfoot disease. In the 20-39 age group, 4.6 per 1000 were affected, in the 40-59 age group, 10.5 per 1000 were affected, and in the greater than 60 group, 20.3 per 1000 were affected (U.S. EPA, 1998a). Workers exposed to arsenic have been identified as a group more likely to contract lung cancer and skin cancer. In one incident in Taiwan, drinking water was found to be slightly contaminated with arsenic. Researchers found that the residents exposed to the water had more skin cancer per capita than in other noncontaminated areas. This study did not consider several crucial topics such as the nutritional status of the exposed population, their genetic susceptibility, and their exposure to arsenic other than the contaminated drinking water (U.S. EPA, 1998a). No studies have been discovered that labeled inorganic arsenic as a carcinogenic substance in animals according to the U.S. EPA (1998a).

Documents explain that exposure to cadmium, another element found in computer scrap, can cause significant proteinuria (U.S. EPA, 1987a). The U.S. EPA (1987a) classifies the human carcinogenicity data as limited for cadmium and labels it as a probable human carcinogen. In one documented case there was twice the risk of lung cancer among smelter workers who were exposed to cadmium. Six hundred and two workers who worked at least 6 months in a potentially exposed environment between 1940 and 1969 were studied. Urine samples indicated the workers were indeed exposed to cadmium. The researchers were able to ascertain that the increased risk of lung cancer was probably not due to the presence of arsenic or to smoking. Several other small numbered studies have also associated cadmium exposure to lung cancer and prostate cancer. Studies of human ingestion of cadmium are too insignificant to assess carcinogenicity (U.S. EPA, 1987a). In lab rats, exposure to cadmium has shown an increased number of lung tumors. One study exposed rats to a gaseous form of cadmium chloride at concentrations of 12.5, 25, and 50 ug/m^3 for 18 months with an additional 13 month observation period. In the exposed animals, there was a significant increase in lung tumors observed. A different study used cadmium oxide, which did not produce lung tumors, but rather mammary tumors in females and tumors in multiple sites in males. Numerous authors involved in cadmium exposure studies also report injection site tumors (U.S. EPA, 1987a).

Computer scrap also contains small amounts of chromium. The U.S. EPA (1998b, 1998c) has documented the effects on humans and animals of chromium III (as insoluble salts) and of chromium VI. The effect of exposure to chromium III and VI in the workplace includes upper respiratory irritation and atrophy, changes in lung functions, and renal toxicity. Data for exposure to chromium III alone is not available (U.S. EPA, 1998b). A study involving chromium VI recorded the adverse effects of exposure in drinking water. In 1965, one hundred and fifty-five subjects were examined after being exposed to about 20 mg/L for an unspecified period of time. Nonetheless, the subjects presented sores in the mouth, diarrhea, stomachache, indigestion, vomiting, elevated white blood cell count (in comparison to controls), and a higher per capita cancer rate (including lung and stomach cancer). This study concludes that exposure to 20 ppm of chromium VI in drinking water could lead to gastrointestinal effects. Chromium VI in lab rats had different results. Groups of 8 male and 8 female rats were given 0.45 to 11.2 ppm (mg/L) hexavalent chromium as K_2CrO_4 for one year. Another test group of different size was given 25 ppm of the same chromium and the final group was given 25 ppm chromium in the form of chromic chloride. No significant adverse effects were seen in appearance, weight gain, or food consumption. The researchers indicate that tissues apparently can accumulate some chromium before pathological changes result (U.S. EPA, 1998c). The U.S. EPA (1998c) also states that several reports uncovered showed possible fetal damage caused by chromium compounds.

A collection of 100 computers that weigh 70 pounds each contains 3.15 pounds of manganese (Byster et al., 2002, p. 44). In humans, several disease states have been associated with both deficiencies and excess intakes of manganese according to the U.S. EPA (1988b). Most studies of manganese have concentrated on inhalation of manganese and therefore much less is known about manganese ingestion. The U.S. EPA (1998b) document focuses on the safe human intake of manganese. The Food and Nutrition Board of National Research Council estimates that a safe and adequate daily intake of manganese is about 2 to 5 mg/day (and an occasional 10 mg/day is safe). One study conducted in Greece showed that exposure to manganese in drinking water (as high as 2.3 mg/L) may have contributed to minor weakness/fatigue, gait disturbances, tremors, and dystonia. The only other reported chemical in the water above the economic community standards, which defines the maximum allowable chemicals in the public water supply, was calcium carbonate (120-130 mg/L) (U.S. EPA, 1988b). A second report described the effects of dry cell batteries buried near a drinking water well. The batteries caused an increase in both manganese and zinc in the water consumed by the subjects. Twenty-five cases of manganese poisoning were reported with symptoms including lethargy, increased muscle tonus, tremors, and mental disturbances. Most severe symptoms were noticed in elderly people. Reportedly, three people died; one from suicide, two from unknown causes. The autopsies showed the manganese concentration in the liver to be two to three times higher than in control autopsies. The well was analyzed one month after the outbreak and was found to contain approximately 14 mg/L. It was then estimated that the exposure level at the time of the epidemic might have been as high as 28 mg/L (U.S. EPA, 1988b).

Another commonly known element in computer scrap is mercury. The U.S. EPA (1988c) lists the critical effects of mercury: hand tremors, increase in memory disturbance, and slightly subjective and objective evidence of autonomic dysfunction. In one study, 26 male workers (mean age of 44) were exposed to low level of mercury vapor (estimated average exposure about 0.026 mg/m^3) in various occupations. The average exposure duration was 15.3 years. The measure of tremor was significantly increased in the subjects compared to the controls, which were shown to be an effect of exposure and not age (U.S. EPA, 1988c). A second study concluded that workers exposed to mercury vapor also had slower and attenuated brain activity (15.6 +/- 8.9 years exposure, mean blood mercury level of 12 ug/L, urine mercury level of 20 ug/L). Other similar studies have also found that exposed workers' performance on motor speed measurements (finger tapping), visual scanning, visuomotor coordination and concentration, visual memory, and visuomotor coordination speed were significantly lower than equally aged (and sex) control group. These particular workers were exposed to approximately 5.5 years to a concentration of about 0.023 mg/m^3 (U.S. EPA, 1988c). Due to inadequate human and animal data, the U.S. EPA (1988c) has classified the evidence for human carcinogenicy of mercury as 'not classifiable'. One study done on exposed workers showed no significant increases in mortality from exposed workers compared to the general population in the same area (U.S. EPA, 1988c).

Another element in computer scrap is silver. The U.S. EPA (1987b) explains that the critical effect in humans of ingesting silver is argyria, a medical term for permanent blue-gray skin coloration. Even though the sunlight increases the pigmentation of the exposed areas of the skin, it is not associated with any adverse health effects. One study discusses the exposure of a 33-year-old female to silver nitrate over a period of one year. The subject reportedly ingested 16mg of sliver nitrate three times a day (or about 30 mg/day) for alternate periods of 2 weeks. A blood analysis revealed a blood silver level of 0.5 mg/L one week after ingestion of silver nitrate ceased and there was only a small decrease in this level after 3 months. In this patient, no obvious dark pigmentation marks were observed other than gingival lines, which are characteristic of the beginning of argyria (U.S. EPA, 1987b). U.S. EPA (1987b) explains that this study is not suitable to serve as the basis for a quantitative risk assessment for silver since it only evaluated one patient and the actual amount of silver ingested based on the patient's memory cannot be accurately determined. A typical diet contains only about 27 to 88 ug of silver every day

(U.S. EPA, 1987b). Toxic effects of silver have been observed in lab rats. One study reports administering 0.1% silver nitrate (about 89 mg/kg/day) to rats in drinking water for 218 days. It appeared to statistically show a significant increase in the incidence of ventricular hypertrophy. Upon autopsy, advanced pigmentation was observed in body organs, but the ventricular hypertrophy was not attributed to silver (U.S. EPA, 1987b). The U.S. EPA (1987b) also reports that there is no evidence of cancer in humans due to silver exposure even when therapeutic use of silver compounds has been taking place for years.

Printed Wire Boards (PWBs) contain small a amount of selenium. The U.S. EPA (1991c) uncovered studies that revealed that exposure to selenium can cause liver dysfunction and selenosis, where the subject observes hair or nail loss, morphological changes of the nails, etc. One study revealed that approximately 400 people in China were in an environment considered abnormally high for selenium levels. The subjects were evaluated for selenium intoxication in low, medium, and high exposure populations (estimated at 70, 195, and 1438 ug Se/day for adult males and 62, 198, and 1238 ug Se/day for adult females). The evaluation revealed possible selenium induced liver dysfunction and clinical signs of selenosis among the exposed population. In a similar manner, a marginal safe level of daily selenium intake was estimated at 0.853 mg selenium per day to produce no clinical signs of selenosis (U.S. EPA, 1991c). Selenium toxicology is clinically classified into three types: acute selenosis, subacute selenosis, and chronic selenosis. Consuming relatively high amounts of selenium in a short period of time causes the acute selenosis condition. After this consumption and diagnosis of the acute condition, walking becomes unsteady, cyanosis of the mucous membranes occurs and labored breathing is usually seen, sometimes resulting in death. Subacute selenosis occurs from exposure to large amounts of selenium over a longer period of time. This diagnosis generally results in impaired vision, ataxia, disorientation, and respiratory distress. This has been seen on lifestock feeding on selenium exposed plants. Chronic selenosis is the result of prolonged exposure to more moderate to high levels of selenium. Skin lesions involving alopecia, hoof necrosis and loss, emaciation, and increased serum transaminases and alkaline phosphatase have been documented in animals when diagnosed with chronic selenosis. In humans, this condition is characterized by chronic dermatitis, fatigue, anorexia, gastroenteritis, hepatic degeneration, enlarged spleen, and increased concentrations of selenium in the nails and hair (U.S. EPA, 1991c). Due to inadequate evidence, the carcinogenic classification of selenium compounds in humans indicates that selenium may or may not be cancerous (U.S. EPA, 1991c). Selenium sulfide, on the other hand, is classified as a probable human carcinogen. Although this is based on inadequate human studies, the sufficient evidence in animals has promoted this classification (U.S. EPA, 1991d). Little other information of interest has been discovered specifically about selenium sulfide.

Very little or no information is available about the human risk assessment of exposure to many other elements found in computer scrap. This list includes tin, iron, tantalum, indium, terbium, gold, europium, titanium, ruthenium, cobalt, palladium, bismuth, niobium, yttrium, rhodium, and platinum. No other additional information on the effects of these elements on humans was discovered.

Appendix H – What is an IQP? Why is this an IQP?

Science, technology and society are dependent upon each other for change. Society helps to induce changes in science, which helps to evolve technology. This is obvious to most people, but the final step is not always as apparent. Technology and science in turn affect society, in several facets. Individuals, communities, economies, ecologies, social values and attitudes all represent things that have and can be changed by the advancement of science and technology. The Interactive Qualifying Project at Worcester Polytechnic Institute is a project designed to help students realize this interaction between science, technology and society.

Intel has a very good reputation as far as environmental awareness goes. Their dedication to being an environmentally friendly company goes beyond what is expected of them by law. Currently, their facility in Costa Rica is looking ahead in order to head off future problems. They recognize the growing numbers of PC's and the country's lack of ability to dispose of them once they become outdated. They hope to discover a solution to the problem before it grows out of hand.

Our project group attempted to create this solution. In order to do this, we needed to analyze how computer scrap is affecting people, communities and the environment. Furthermore, we took into account how society and the economy could be affected by the solution(s) that we recommend. In the end, we took all these aspects into consideration when analyzing and developing a solution.

We cannot expect to make a technical recommendation without social consequences. Science, technology and society are interlinked with each other to create a complex system. Our project was not only an attempt at discovering a solution, but an attempt at understanding the social aspects of the problem, and incorporating those into our recommendations.

Appendix I – Handout Distributed at the Final Presentation

The following is the handout given to the attendees of our final presentation. It gives specifics about the project, presentation, and a visual reference for the recycling model.

Efficient E-waste Management in Costa Rica

A presentation given June 28, 2002 by Joseph Havelick, Antti Koski and Daniel Wallance

-Presentation Outline-

- What is an IQP?
- Background
    - Product Ecology
    - Discussion of E-waste
    - International Management Systems
- Methodology
- Results and Analysis
    - Social and Economic Effects
    - E-waste in Costa Rica
    - Management Models
- Conclusions
- Recommendations
    - Long Term Goals
    - Overview of the Process
    - Initial Actions
- Acknowledgements
- Questions

-Project Goal-

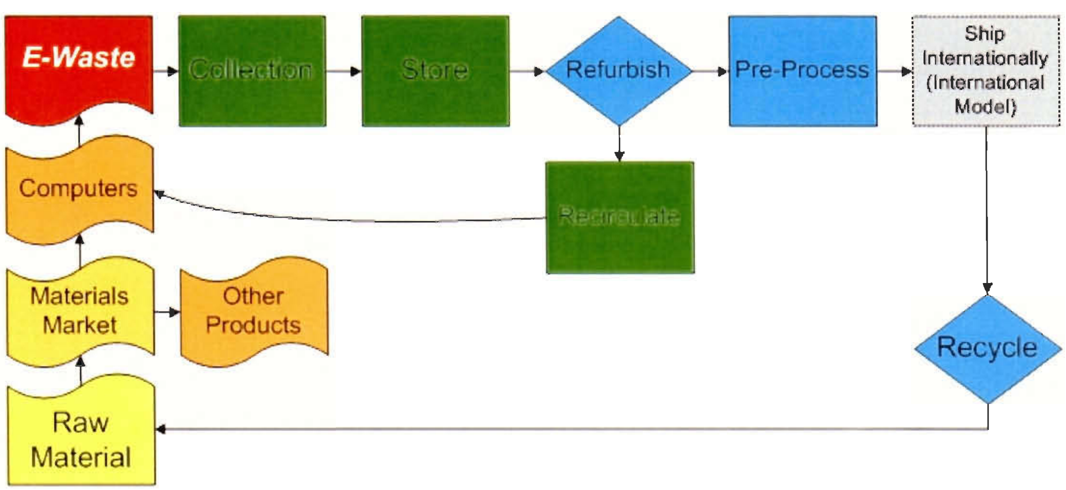
- To recommend a system to efficiently manage E-waste generated by Costa Rica

-Objectives-

- Determine the extent to which computer scrap is a problem to Costa Rica
- Research and develop possible management models for E-waste in Costa Rica
- Determine the best model and give recommendations for implementation
- Determine key players and alliances in the model

6/26/2002

Recommended Recycling Model



Appendix J – Glossary of Terms and Acronyms

Asset Management – "The process whereby a large organization collects and maintains a comprehensive list of the items it owns such as hardware and software. This data is used in connection with the financial aspects of ownership such as calculating the total cost of ownership, depreciation, licensing, maintenance, and insurance" (Dictionary.com, 2002a).

Basal Agreement – An international agreement to restrict movement of hazardous waste to countries not capable of processing it in an environmentally safe manner. Costa Rica has signed the Basel Agreement, but is allowed to export hazardous waste if it is to be used as a raw material for a recycling or reclamation process.

BFR – Brominated Flame Retardant. A group of chemicals added to computer monitor cases to reduce the risk of fire. When incinerated, BFRs can release dioxins that are harmful to the environment (Brominated Flame Retardants, 1999).

CRT – Cathode Ray Tube. "An electrical device for displaying images by exciting phosphor dots with a scanned electron beam" (Dictionary.com, 2002b).

Computer Scrap – See E-waste.

Controls / Control Group – The group of experimental animals (in our case) that are not administered a test dosage when performing an experiment.

Design for Recyclability – The process of enhancing a design of a product to make it easier to recycle.

EOL – End of Life. The point that a computer or electronic product is no longer used and needs to be disposed of or recycled.

EMC – Electro Magnetic Compliance. The attempt to reduce the interference based on electromagnetism between units of electronics, for example the case of a PC.

EPA – Environmental Protection Agency. A United States government agency that is "dedicated to protect human health and to safeguard the natural environment" (U.S. EPA, 2002).

EPR – Extended Producer Responsibility. "The extension of the responsibility of producers for the environmental impacts of their products to the entire product life cycle -- and especially for their take-back, recycling, and disposal" (Inform, Inc., 2002).

E-waste – "E-waste is a popular, informal name for electronic products nearing the end of their 'useful life'. Computers, televisions, VCRs, stereos, copiers, and fax machines are common electronic products. Many of these products can be reused, refurbished, or recycled (Cronin, 2002).

Gaylord Box – A one or two layered cardboard box, usually on top of a pallet, that is required by many companies while shipping products for recycling.

HVI – High Value Inventory. Inventory with precious metals that Intel Costa Rica sends to Metech in California to be mined, in most cases the inventory consists of crushed defective chips from the assembly floor.

Intel –Intel Corporation, a world wide chip making corporation.

Intel Costa Rica – Intel Corporation's specific facility in Costa Rica.

Motherboard – Central component of a computer that contains the CPU, memory, card slots, and more.

OEM – Original Equipment Manufacturer. "A company that purchases computers or other complex components from manufacturers, adds other hardware or software, and sells the systems, often for specific applications" (Dictionary.com, 2002c).

Outsourcing – "The procuring of services or products, such as the parts used in manufacturing a motor vehicle, from an outside supplier or manufacturer in order to cut costs" (Dictionary.com, 2002d).

PC – Personal Computer. A computer built around a microprocessor for use by an individual.

PCB - Polychlorinated biphenyls. A common toxic element found in older electronic equipment. PCBs are resistant to biodegradation, they are fat soluble, and tend to accumulate in organisms, with those highest in the food chain being most affected (Brominated Flame Retardants, 1999).

PPM – Parts Per Million. Some toxic chemical exposures/doses are measured in ppm.

Preprocessing – The process of preparing E-waste in an organized manner prior to sending the material to its final destination. This would include salvaging and separation.

Product Ecology – The effort to create a more environmentally friendly device. This includes four key areas: energy conservation, material content, packaging, and EOL impact.

Product Stewardship – See Product Ecology.

PVC – Polyvinyl Chloride. A common plastic used for insulating and jacketing many wire and cable products and in some cases, polyvinyl chloride is used instead of rubber in electric cables (Dictionary.com, 2002e).

PWB – Printed Wire Board. A circuit etched onto a board that is placed into the computer. The motherboard is an example of a PWB.

Recirculate – The process of re-using an older, possibly refurbished computer for a new function. For example, when a computer is donated to the student run computer refurbishment program, it is refurbished and put back into the school system.

Recyclability – A word that implies the product is recyclable. For example, designing for the ease of recyclability implies that the design will change to make the product more recyclable.

Recycle – The process of using waste and used materials in an effective manner to conserve resources.

Refurbish – The process of reusing computer parts from used computers to create a working computer.

Reuse – The process of re-using material from unwanted waste and/or used materials to conserve resources.

RoHS – Directive on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment; A European environmental directive designed to phase-out the use of heavy metals and other toxic substances found in electronic waste such as flame retardants (Fishbein, 2002, p. 54).

SVTC – Silicon Valley Toxics Coalition. A environmental coalition that is "engaged in research, advocacy, and organizing associated with environmental and human health problems caused by the rapid growth of the high-tech electronics industry" (Silicon Valley Toxics Coalition, 2002d).

WEEE – Directive on Waste and Electronic Equipment; A European environmental directive designed to decrease the amount of electronic waste produced in nations under control of the European Union, thereby decreasing the amount of electronic waste entering landfills. Including the RoHS directive, the WEEE forms the set of European directives on electronic waste and the environment (Fishbein, 2002, p. 54).