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North Carolina stocks large quantities of computers and computer waste as a result of increasing advancement in technology in the electronic industry. Households in the state are constantly changing over to more powerful and cheaper versions of computers. The result is the creation of huge stock of computer waste in households. Only small portions of these waste computers are collected for recycling due to lack of comprehensive state legislations on electronic waste. The objective of the thesis is to estimate the quantities of computer waste in North Carolina for which appropriate legislations and infrastructures are needed to properly collect and compare it to the actual waste computers recycled in 2000 and 2005. The estimation of the amount of computer waste is very important. US Census Bureau, USEPA, and Sales and Marketing Management's reports for 2000 and 2005 were used to generate the estimate of computer waste in those two years. The results indicate that only 7.6% of the projected 669,862 computer waste in 2000 was recycled. In 2005 the waste stock increased by 113.3%, but recycling rose by only 6.7% to 54,019.

THE GEOGRAPHY OF HOUSEHOLD COMPUTER WASTE MANAGEMENT:

THE CASE OF NORTH CAROLINA

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Solid waste management is critical for all states in the United States. New kinds of waste are always being introduced into the solid waste stream due to changing consumption patterns and rapid population increase. Consumer electronic equipments have become a very important part of human life because of advances in the electronic industry and lifestyles over the last three decades as well as the increasing importance of information technology. This has lead to an increase in the use of computers and other electronic products which have now become important part of human lives (Mundada et al., 2004). This growth is significant because it has made life in homes and offices easy, simple, and better. For example there are cell phones with computer capabilities which have made life on the road better. The result is a dramatic increase in the demand for electronic products such as computers (Karen and Jhih-Shyang, 2003). This increased use of computers brings with it the issue of their waste which has been building up since they were first introduced (Schoenung and Kang, 2006).

Computers contain hazardous materials and heavy metals and therefore need to be managed well at the end of their lives. In 2001, the Department of Toxic Substances Control (DTSC), California affirmed that cathode ray tube monitors are hazardous waste because it contains high level of lead and therefore they need careful attention (Santa Clara County Department of Environmental Health, 2004). It was estimated that over 364 million personal computers were in use around the world in 1998. This figure was 222 million in 1995 and 98 million in 1990 (Computer Industry Almanac, 1999; Karen and Jhih-Shyang, 2003).

Product inventors continue to produce high speed computer processors and larger memory sizes which are making the useful lifespan of computers shorter and shorter. Mundada et al., report that the average lifespan of a computer has reduced to two years and that each new invention has the potential of doubling the obsolescence rate. This is due to the fact that consumers find it cheaper and convenient to buy new computer than to upgrade an old one (Mundada et al., 2004). Lack of proper management of this toxic-laden computer waste often enables it to find their way into the municipal solid waste stream. Jim et al., report that over three hundred and fifteen million computers will become obsolete by 2004 and by 2005 there will be one obsolete computer for every new one put on the market (Jim et al., 2002). The United States Environmental Protection Agency (USEPA) estimated that about two hundred and fifty million computers were obsolete in 2005, (USEPA, 1999).

There is a high environmental price to pay for the rapid changes in technology because a significant portion of the waste stock of computers ends up in developing countries and landfills (Schoenung and Kang, 2006). Computers are made of components which are harmful to the environment and life and therefore must not be released into the environment untreated. Although, the problem of computer waste management is of national nature, it is state legislators who are pressing for ways to handle the problem. For instance twenty five bills, aimed at managing electronic waste, were introduced during the 2005 – 2006 legislative season (Spielvogel, 2006). Local governments have been collecting computer and other electronic wastes that are considered harmful and therefore pose a risk to human health and the environment if they end up in landfills and incinerators. Computer waste is considered a universal waste, and therefore needs to be managed well to meet standard requirements for those types of waste (Santa Clara County Department of Environmental Health, 2004). The collection of domestic computer waste should be controlled by household hazardous waste management programs so that the responsibility of bad treatment will fall on collector in accordance with the 1999 Superfund Recycling Equity Act (Santa Clara County Department of Environmental Health, 2004). Electronic waste contains both valuable and harmful materials and therefore it needs better management to reduce the potential harmful effects they can pose to the environment and at the same time maximize their benefits.

Computers fall under the big umbrella of electronic-waste (e-waste). Electronic waste is the term used to describe electronic gadgets which have reached the end of their life. These gadgets include computers, entertainment electronics, and mobile phones that have been disposed of by their users (Mundada et al., 2004). There is no generally accepted definition of e-waste but in most cases these are expensive and durable electronic products that are easily stored, reused or trashed by their users (Schoenung and Kang, 2006). In 2001 only 11% of personal computers were recycled (USEPA, 1999). Sizeable portion of waste computers are stored by users and they need to be collected and managed (Schoenung and Kang, 2006). This will prevent the possibility of many of those waste computers finding their way into landfills and incinerators. The USEPA estimates that more than 2.05 million tons of e-waste ends up in incinerators and landfills every year (USEPA 1999). Electronic waste contains many toxic materials such as lead, mercury, and cadmium. There is an increasing concern about the effect these materials will have on the environment if waste computers are disposed of in incinerators and landfills.

Electronic waste is now the fastest growing component of the municipal solid wastes and its management has become a major challenge. It is expected that the amount of e-waste will increase 16% – 28% yearly. This indicates a growth rate three times as fast as the average for municipal waste (European Environmental Agency (EEA), 2003). It is also estimated that consumer electronics accounts for seventy percent of heavy metals and forty percent of lead found in landfills (Silicon Valley Toxics Coalition, 2004; USGS, 2001). Experts believe that we are in the initial stages of the environmental impact of improper treatment of electronic waste. The fate of most of the electronic waste produced in the US remains a mystery, but it is believed that most ends up in landfills (Focus, 2002).

The problem of electronic waste disposal is not unique to developed countries such as the United States, but it persists in developing countries as well. The problem in the United States is an indication of the pattern of technology and material changes in the contemporary world. Consumption and production systems move resources and energy around the world and it takes with it environmental pollution. For example, computers are designed in the United States, Europe, and Japan, manufactured in Taiwan and Singapore, with materials extracted from Africa and Australia. They are used and dumped everywhere in the world (Iles, 2004). This trans-national flow of resources brings out the issue of who bears the responsibility for the impact these products have on the environment, and human health, world wide when they reach the end of their life. The US-based Electronics Industry Alliance argues that production should determine responsibility (IT Matters, 2002). However, activists and policy makers argue that consumption should rather determine responsibility. That is, consumers should be required to pay an extra charge when purchasing a new computer, which will be used to finance better disposal programs. Others like Silicon Valley Toxics Coalition, Greenpeace, and the Basel Action Networks, call on manufacturers to bear the full responsibility for proper disposal because they have control over their products (Iles, 2004). In this respect, producers can use recyclable materials, design environmentally friendly computers and label material contents of components. They can set up take-back programs to effectively collect end-of-life computers from consumers (Schoenung and Kang, 2006). Without effective collection programs many computers will not be recycled but rather stored, landfilled or incinerated.

Problem Statement

The situation in North Carolina in terms of electronic waste follows that of the national trend. The states' problem is worsened by the absence of a comprehensive electronic waste legislation and it is becoming a cause for concern for solid waste administrators. The USEPA estimated the quantity of information product waste such as computers, telephones, fax machines etc., in North Carolina's solid waste system to be about twenty one thousand tones in 1999 (USEPA, 1999). The task of solid waste administrators is, therefore, not only to deal with the high volumes of waste but also to well manage the hazardous chemicals they contain. This is important because the potential exists for these toxic chemicals to be released into the environment causing water, and air contamination (NCDPPEA, 2003).

A successful computer waste treatment in the state requires strict laws and legislations such as a complete ban on landfilling and incineration as well as imposing a heavy fine on violators. This will help increase the recycling rate and save the environment. However, there will be the need for an increase in infrastructures for recycling. This calls for an accurate estimation of the domestic computer waste generation. Previous studies were only centered on the totality of electronic waste which includes appliances and electronic gadgets in all the sectors (NCDPPEA, 2003). Although the methods are still valid, the results do not provide any idea on domestic computer waste and they are no longer realistic in North Carolina now. This study focuses on domestic computer waste because it is the largest contributor to electronic waste.

Households, businesses, schools and colleges dispose of large quantities of computers every year because these computers are either technologically or economically obsolete as a result of rapid technological advancements in the computer industry. For instance Microsoft released a new windows operating system (Vista) in January, 2007 which requires one gigabyte of RAM, and one gigahertz processor speed for optimum performance. This will increase the computer obsolesce because many computers do not meet this optimum requirement. Though there are a number of private recyclers in the state of North Carolina, they are inadequate and their demand for electronic waste falls short of the waste supply. Also there are inadequate collection programs to ensure that most of the states computer wastes are recycled. Finally, there are not enough legislation to properly regulate the handling and processing of these wastes. All these explain why much of the computer waste in the state may end up in landfills and incinerators.

Objectives

This thesis studies the geography of computer waste management in the state of North Carolina. It discusses the need for more programs to better manage domestic computers waste because existing programs are not being fully utilized. There are inadequate state legislations to handle domestic sources of computer waste and this has left this source of computer waste unregulated. Federal legislations such as the Resource Conservation and Recovery Act of 1979, rather seek to regulate waste from institutions and large businesses leaving the household and small businesses sectors. The specific objectives or this thesis are to;

(a) estimate the total number of computers in households and the portion which were considered obsolete in the years 2000 and 2005 based on data from US Environmental Protection Agency, and US Census Bureau or those years,

(b) analyze the quantity of computer waste that were recycled in 2000 and 2005 compared to the projected total waste,

(c) determine the relationship between computers recycled and some selected socio-economic indicators such as education, urban / rural status of counties, and age group,

(d) discuss the various recycling programs that are common in the state,

(e) evaluate the gap between computer waste generation and recycling, and

(f) suggest ways to better manage computer waste to reduce the dangers it can present if they are not managed well.

CHAPTER II

REVIEW OF THE LITERATURE

Waste mattered little until a century ago but situations are different today. During those periods humans were not producing much waste and nature was able to process anthropogenic waste naturally. Rapid increase in population and technology has increased the production of solid waste, which far exceeded the earth's treatment ability (Smith, 2004). The US population crossed the three hundred million mark in 2006 (US Census Bureau's population Clock, 2006). Given the recent rate of waste production in the US, the earth's processing capacity will have to increase three fold before it can naturally process it (Smith, 2004).

The problem of solid waste disposal is one of a global concern. Though it persists in all regions, it is much intense in urban settings. Several studies which examined this problem suggested ways to reduce the intensity of the problem (Carboo et all, 2002). However, the rates of waste production has grown so much that those suggestions have been rendered ineffective. It is therefore clear that the regenerative capacity of the earth will not allow waste production expansion forever. Waste cannot accumulate in the environment without seriously impinging on the health and growth of humanity (Smith, 2004).

Nations with high standards of living and productivity tend to produce more municipal solid waste per capita than less developed ones. For instance, the United States and Canada are the world's leaders in waste production (Carboo et all, 2002). There is therefore the need for these nations to take steps to stem the tide.

Smith (2004) notes that the resources of the world are finite and therefore, everything we do impacts the system. He indicates that every time we drive our automobiles there is more oxides of nitrates (NO_x) released into the atmosphere and an increased depletion of our oil resources. Carbon Dioxide concentration in the atmosphere has been increasing since the industrial revolution but their effect in terms of global temperature increase is now being felt. The rates of pollutants production and resource depletion have far exceeded the natural rate of purification and replenishment.

The earth is a spaceship which receives its energy from the external environment. It works with whatever resources it has and therefore when a resource is depleted it is gone for good. Commoner (1971) used four laws of ecology based on scientific norms to explain how the system functions. The first law states that everything is connected to everything else and therefore impacting one affects the other. For example, when new bridges are constructed on rivers, the rivers' water flow is altered which affects aquatic life along a good portion of the stream. Also, settlements along these rivers that depend on it for their water source are affected. The second law states that everything must go somewhere. This shows that nothing is ever lost and therefore anything disposed of or moved from one location will eventually go to affect other systems. Most people work on the principle that once something is out of sight it means it is lost but that is not the case. For instance when a computer is incinerated, toxic metals such as mercury is evaporated into the air. This evaporated mercury is brought back to the earth's surface through precipitation and deposited in water beds. Bacteria action converts it to methyl mercury which is then taken by fish. Humans eat these fish and the mercury gets into them. Neither humans nor fish metabolizes mercury and therefore it has a cumulative effect in their organs and causes medical complications. The third law states that nature knows best. The assumption was long held that man can conquer nature and dictate how it works but that has been proven to be rather untrue. Nature is able to balance any imbalances better than man and therefore the best man can do is to assist nature to perform its duties. The fourth and final law sates that there is no such thing as free lunch. Any action of man has some environmental cost and therefore activities such as extraction, and construction should be carefully evaluated.

Consumers consume only a small portion of the products they supposedly consume (Smith, 2004). Almost everything these days has been designed to be wasted because they have a built in obsolescent and therefore lasts for only a short period. Ninety percent of resources extracted for the production of commodities in the US become waste almost immediately (McDonough and Braungart, 2002). Products are designed to make them attractive, meet regulations, affordable, work well and long enough to meet consumer expectations. They are therefore designed to satisfy only manufacturers and consumers but not humanity and ecological health. It is cheaper to buy new products than to get a faulty one repaired and this is a big contributing factor to the large quantity of waste generation (McDonough and Braungart, 2002). In 1992, it was estimated that the US could run out of landfill space by 2004 if the then solid waste treatment methods continue (Glen, 1992). An increased focus on more sustainable methods such as recycling and composting resulted in the extension of the period.

There are basically three methods of treating solid waste. These are landfilling, recycling and incineration. Land filling is the oldest method which dates back to the early periods of human existence. Recycling is the most recent of the three.

Landfills are disposal facilities at which solid waste is placed on or in the land. (Columbia Encyclopedia, Sixth Edition). They are filled with all kinds of waste products such as food residues, metals, electronic products, plastic packages, dippers papers, and furniture. These waste that ends up in landfills took much energy and resources in production which are wasted in these facilities. Furniture, paper and food residue are biodegradable which means they decompose and return their biological nutrient to the soil naturally. The problem with landfilling is that these biodegradable wastes are lumped together with non-biodegradable ones such as plastics and metals. This leads to the loss of valuable resources and materials (Smith, 2004).

Modern landfills are not just "dumps", but are carefully engineered facilities equipped with liners, leachate collection and monitoring systems, and methane gas controls. These are called sanitary landfills and they play a critical role in the handling of municipal solid waste. Landfills will always be needed for the disposal of non-recyclable waste. The importance of protecting the environment has been realized and therefore modern landfill sites are chosen carefully to reduce their environmental damage. Modern sanitary landfills are difficult and expensive to develop because of the various permitting requirements. It takes about five or more years and costs millions of dollars (Chahine et al., 2003).

Incineration is a disposal means that reduces the volume of waste as well as toxicity (Klein et al., 2001). This is a widely used means to handle non-recyclable combustible municipal solid waste (Eighmy et al., 1995; Ferreira et al., 2003; Feng et al., 2007). In 1990 incineration was the fastest growing method of municipal solid waste disposal In the US in conjunction with landfills. Incineration is the preferred method of waste disposal in European countries because of is advantage of producing electricity as a by-product (Miller, 1994). The USEPA estimates that about fifteen percent of municipal solid waste in the United States was incinerated in 1999 (USEPA, 1999).

The problem with incineration is that it produces about 17 mega tons of ash residue annually world-wide (Klein et al., 2001). Heavy metals from raw materials are condensed into incinerated residues which may present a problem for the environment (Gau and Jeng, 1998; Feng et al,, 2007). During incineration, metals such as iron, cupper, chromium and aluminum remain in the ash. For example, about two thirds of lead and zinc are found in incinerated ash despite their high volatility (Jung et al., 2004; Feng et al., 2007). Also Polychlorinated Biabenzo-p-dioxins and dibenzofurans are among the most hazardous substances and they have been found in vegetation, human, and marine lives. Incineration is the major means by which these chemicals get into the environment (Behinsch et al., 2001)

Recycling is a method of disposal which ensures that the product is not just wasted at the end if their life but rather it gets back into the production stream. This holds the most promise for long term reduction of solid waste. Much of the waste produced in the US can be recycled. Paper, yard trimmings, and packaging containers form the bulk of municipal solid waste and they are recyclable (Smith, 2004). In 1998, two-thirds of US states recycled at least twenty two percent of their solid waste. Only Alaska, Montana, and Wyoming recycled under ten percent capacity (Glenn, 1998).

Computers

According to the USEPA, a computer is an electronic device designed to accept data (input), perform mathematical and logical operations at high speed (processing), and supply the results of these operations (output) (EPA, 2002).

The origin of computers dates back many centuries. This was triggered by advancements in mathematics, which led to the development of tools to help in computations. Blaise Pascal, has been credited with building the first calculating machine in the 17th century France (Rojas and Hashagn, 2000). The first electronic numerical integrator and computer were developed in 1946 for the United Sates Army. The idea was then advanced by Von Newman which enabled computers to store programs. The first computer was made of vacuum tubes and therefore they were very huge and expensive. Small transistors replaced the vacuum tubes and reduced the computers size drastically. Integrated circuits (IC) have now replaced the transistors and they are the major components of modern computers. The ICs are very small and therefore have made it possible to produce much smaller and cheaper computers, and other electronic devices. For example, in 1960, the typical transistor based computer was one and a half million dollars. They were very huge and needed a large air-conditioned room to prevent over-heating. It also required an onsite engineer to monitor the heat. Presently, the same computer costs only a few hundred dollars and is very small. These IC based computers are hundred times powerful than those made of transistors. Producers keep making computers that are more powerful, smaller and cheaper every year. (Burks, R. A, and Burks, W. A., 1997)

The reduction in size and the increase in the power of computers have made them very important gadget that is need for everyday use. Consumers are always on the move to upgrade to newer versions of computers since they are more powerful and cheaper compared to older ones. This situation has greatly reduced their lifespan of computers and at the same time increased the rate of their retirement. The result is that more computer wastes are now being created which are not disposed of in an environmentally friendly manner (Mundada et al., 2004). The National Safety Council projected that nearly 250 million computers will become obsolete by the year 2005 (National Safety Council, 1999).

A New Category of Solid Waste, Electronic Waste

Consumer electronics was the fourth source of lead in the municipal solid waste in 1970. By 1975 it had moved to second position, contributing twenty seven percent of lead. It was then projected that by 2000 it will account for thirty percent of the municipal solid waste lead (EPA, 1989). USEPA data shows that four million monitors are disposed of in landfills annually (USEPA 2001). This forms only a fraction of the estimated fifty million computers which become obsolete each year (USEPA, 2001). The National Safety Council forecasted in 1999 that nineteen million computers and monitors will be recycled in 2005 (National Safety Council, 1999). In 2003 the International Association of

Electronic Recyclers (IAER) reported that about hundred million computers and monitors will become obsolete that year (IAER, 2003). Computer world further projected the estimate to three hundred million by 2004 (Computer World, 2004). Clearly there is a big gab between quantities of computers recycled and obsolete which suggests that larger quantity is stored and this has a greater chance of ending up in the landfills and incinerators.

Most discarded desktop computers in the solid waste stream have cathode ray tube monitors. These cause high concentration of metals in landfills, which may leach. This is a serious problem because CRT is a major source of lead in landfills. Townsend et al., 2000 reports that color CRT's leached out 18.5 milligrams of lead per liter when subjected to regulatory tests for hazardous waste (Townsend et al., 2000). Lead accounted for 213,652 tons of municipal solid waste in 1986 and was projected to rise to over 281,000 tons by 2000 (USEPA 1989). This lead is found in both combustible and non-combustible portions of municipal solid waste (Townsend et al 2000).

Cathode ray tube (CRT) computer monitors and TV picture tubes contain an average of four pounds of lead which makes them to require careful handling at the end of their lives. Other chemicals that are found in computers are chromium, lead, plastic, cadmium, mercury, beryllium, nickel, zinc, and brominated-flame-retardant. When electronics are not disposed of properly, these toxins can present problems to the environment. (The National Safety Council, 2000)

Chemical pollutants which get into water bodies have great effect on human life when these water bodies are source drinking water. The frightening effects are cancers, nerve system damage, genetic mutations, sterility, fetal damage and infant deaths. Only a small fraction of the bad chemicals found in drinking water are constantly tested for federal water quality standards. The bulk of these chemicals are left untested and therefore their exact bad effects are not known. Quality standards for the known chemicals are even not certain because of the problem of risk analysis and uncertainties in the scientific field which creates incremental policies (Smith, 2004).

Lead is used to solder printed circuit boards and other electronic components. It is also found in glass panels in CRT computer monitors. It is soluble in acid water and can cause serious health effects, such as damage to the central and peripheral nervous systems, as well as the blood system and kidneys in humans (Nordic Council of Ministers, 1995). It also has a significant effect on fetuses, endocrine system and children's brain development. Lead has an accumulation effect and causes acute chronic toxic effects on plants, animals, microorganisms and the environment (OECD Paris, 1993).

Cadmium is found in chip resistors, infrared detectors, semiconductors and older types of cathode ray tubes. It is also used as a plastic stabilizer and is a toxin with a possible risk of irreversible effects on human health. It accumulates particularly in kidneys. It enters the body through respiration and food ingestion. It has a half-life of 30 years, and can accumulate enough to causes poisoning symptoms. Cadmium shows cumulative effects in the environment due to its acute and chronic toxicity. (Jarup et. al. 1998)

Computers contain 13.8 pounds of plastics on the average. Microelectronics and Computer Technology Corporation (MCC) estimates the total electronics plastic scrap to be more than 1 billion pounds per annum of which Polyvinyl Chloride (PVC) constitutes the largest volume. PVC type of plastic has more environmental and health hazards than most plastic (SVTC, 2004). They never decompose because they are non-biodegradable.

Mercury will leach when electronic devices, such as circuit breakers are destroyed and dumped in landfills (Nordic Council of Ministers, 1995). Inorganic mercury is transformed into methylated mercury within the bottom sediments when it spreads out in water. This methylated mercury easily accumulates in living organisms and causes chronic damage to the brain. The problem with mercury is not only limited to leaching but also it evaporates (Riss, Hagenmaier, 1990). It is estimated that 22% of the yearly world consumption of mercury is from electronic equipments (EU, 1999 sited in SVTC, 2004). Currently there is no technology to destroy mercury and therefore the only solution now is to reuse it so that more mining of it will not be required (More, 2006)

Brominated flame-retardants are used to reduce the flammability of computers. It is found in printed circuit boards, connectors, plastic covers, and cables. Studies have shown that it reduces the level of thyroxin and can potentially harm developing fetus (Swedish EPA, sited in SVTC, 2004).

Phosphor is applied as a coat to the interior of CRTs face plate. It is not well known how harmful it is but the US Navy has warned that it is highly toxic (Puckett et al, (2002), Barium is used in the front panel of CRT to prevent radiation. Short term exposure to it can cause brain swelling, muscle weakness and damage to the heart and spleen (Puckett et al, (2002),

The major role of Hexavalent Chromium is to protect corrosion of untreated and galvanized steel plates as well as serve as a hardener for steel housing. It can cause DNA damage and asthmatic bronchitis (Puckett et al, (2002), Beryllium is commonly found on motherboards and connecters. It has recently been classified as a human caseinogens (Puckett et al, (2002). Table 2.1 summarizes the above discussed toxins and where they are found in a computer.

Computer Waste Management

The cheapest means to dispose off unwanted computers is landfilling; however, it is known that landfills are not completely leak proof. Even the best "state of the art" landfills are not completely leak free throughout their lifetimes. Frequent fires that break out at landfills cause metals and other chemical substances to evaporate (Riss, Hagenmaier, 1990). When computers are crushed before incineration, hazardous substances, such as polychlorinated biphenyls dissipates into the waste. Computers should therefore be seen as chemical products whose wastes is dangerous and needs careful handling (SVTC, 2004).

Table 2.1: Chemicals and their Location

Chemical	**Location,**
Lead	computer circuit boards and CRT
Cadmium	computer circuit boards and batteries
Barium	cathode ray tubes
Brominated Flame-Retardants	circuit boards, cables, plastic casing
Polyvinyl Chloride	copper cables and computer casings
Mercury	switches and flat screens
Hexavalent Chromium	Steel plats
Beryllium	Motherboards and connectors
Phosphor	CRT

Landfilling end-of-life computers creates two scenarios: (a) there is a potential loss of valuable resources such as gold, copper, rubber, aluminum, silver, and platinum; and (b) toxic substances such as lead, cadmium, and PBDEs, which has serious health and environmental implications, are allowed to find heir way into the environment (Stephenson, 2005). USGS reports that one metric ton of computer circuit board contain between forty and eight hundred times the concentration of gold contained in gold ore and between thirty to forty times the concentration of copper (Bleiwas and Kelly, 2001). Another dimension of the problem is that most of these computers are shipped to developing countries where there is not enough environmental regulations to protect the environment and people from the harm these toxins can cause (Stephenson, 2005). This problem does not directly affect the US environment and its people but it is known that climate has no political boundaries. Also in this era of increased financial aid to developing countries to help fight diseases, the impact on the US economy cannot be overlooked.

Recycling is being perceived as the sure means to solve the problem of computer waste management. This is because it is a more environmentally friendly compared to landfilling. However, participation by consumers has not increased as expected. This is because of lack of collection programs and facilities. For instance, consumers are either charged high fees to drop-off their waste computers, or the locations of drop-offs sites are too far that it inconveniences them. According to Stephenson (2005), people in Snohomish County, Washington may travel over an hour to find a drop-off point and pay between ten dollars ($10) and twenty seven dollars ($27) per unit depending on size and type. In Portland, Oregon residents pay fifty cents (50c) per pound which sums up to about twenty eight dollars ($28) for an average sized desk top computer (Stephenson, 2005). This serves as a motivating factor for consumers to send their computer waste to the landfills. This appeals to them because they neither have to drive for long distances nor pay any fee. Recyclers on the other hand justify these charges with the fact that recycled computers do not generate enough revenue to defray their operation cost and there is no state or federal programs to subsidize their business. The International Association of Electronic Recyclers (IAER) quotes the value of recycled commodities from computers between one dollar and fifty cents ($1.50) and two dollars ($2.00) per unit (IAER, 2003).

Many consumers do not have enough information about recycling as a means of product recovery. This lack of knowledge therefore, prevents many consumers from participating in recycling programs. It is projected that about seventy percent of end-of–life electronic waste are stored (USEPA, 2000). This is a waste because electronic products lose value drastically over time. For instance a 486 computer is now worth nothing if it was kept because will now be more difficult to recycle using the current technology.

Effective recycling depends on consumers being well informed about the process. Also technology developers should come out with better recycling technology which will ensure very high recovery rate both in terms of quantity and quality. For instance the glass-to-glass method of recycling cathode ray tubes yields 100% recovery (Julie and Hai-Yong, 2005). Current methods of computer recycling are glass to glass, glass to lead, mechanical, chemical, and thermal (Julie and Hai-Yong, 2005).

The glass-to-glass method is a closed process because all the recovered glass is used in the production of a new cathode ray tube. It involves crushing the whole unit without separating the funnel from the panel. With glass-to-lead recycling, the CRT is shredded to recover metallic lead and cupper through smelting (Julie and Hai-Yong, 2005). Mechanical, chemical, and thermal recycling methods apply to plastic and metallic parts. In mechanical recycling machines are used to ground (size reduction) the units and the metals are separated out through the process of magnetism. Thermal recycling involves using high temperature clay kilns to melt down the units and the various components extracted. Paint and coatings on painted parts are also removed by this method. Chemical recycling uses chemicals for separation in the same way as refineries do. For instance the solvent stripping method involves lowering coated parts into solvents to remove the paints (Julie and Hai-Yong, 2005). Figure 2.1 shows the methods in a chart.

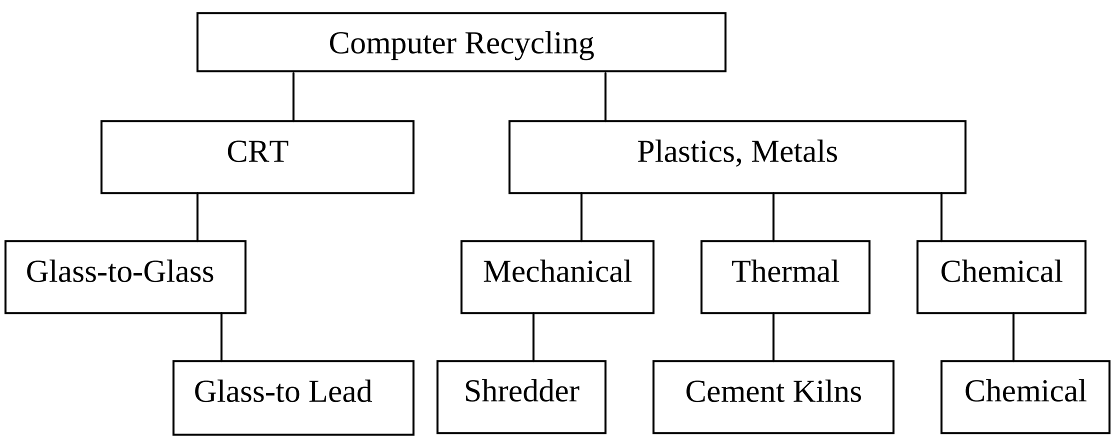

Figure 2.1 Recycling Types

The recycling process begins with deconstruction and grouping of the computer into their various parts. These parts are then tested and the good ones are sold in whole. The bad ones which cannot be used any more are taken through the recycling process to recover constituent parts (Fig 2.2). Current methods of recycling do not yield much recovery rate. This is because available technology is not efficient enough. Table 2.2 shows the various constituent of a computer and their corresponding recovery percentages.

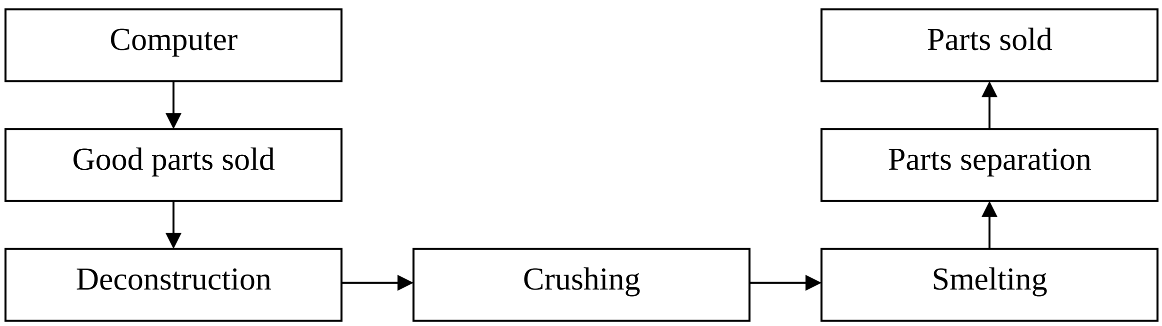

Figure 2.2: Recycling Processes

Federal Policy Regulations

Federal regulation which seeks to regulate toxic waste handling and processing such as Resource Conservation and Recovery Act of 1976 (RCRA) and Pollution Prevention Act of 1990 have all failed to properly regulate domestic electronic waste. RCRA promotes resource recovery either by converting waste to energy or recycling, but it regulates only large quantities of hazardous waste. RCRA puts a barn on the disposal of two hundred and twenty pounds (220lb) or more of electronic waste in landfills per month (RCRA, 1976). This does not apply to households because no single household dispose of this much of electronic waste a month. Therefore by implication households are allowed to dump their computer waste into landfills. Also the Pollution Prevention Act of 1990 (PPA) require the safe treatment or recycling of unpreventable pollutants. These toxins should only be disposed of or release into the environment as a last resort (PPA, 1990).

Recycling is a highly labor intensive business and has a high operational cost making cost recovery difficult. The components such as plastics, copper wires, metals, and circuit boards have to be disassembled, grouped and processed. Computers are not designed with recycling as a major consideration and therefore unpacking them is very tedious. For instance, thirty different screws have to be removed from an HP computer to take out a lithium battery (Stephenson, 2005). Added to the labor cost is the machinery needed to process the materials as well as handling the toxic waste to meet the standards in the RCRA and PPA.

USEPA has not defined data requirements and collection mechanisms for household computer waste. This is the main reason for the lack of federal legislation for this sector. Lack of available data is hampering the USEPA‘s effort to address the problem. The agency does not even keep records of its own waste computers. For instance, both Regions three and nine do not have records of the excess computers they have disposed off or stored (Office of Inspector General’s Evaluation Report, 2004).

Table 2.2: Components and Percent Recycled

Name	Recycling Efficiency (%)	Name	Recycling Efficiency (%)
Plastics	20	Aluminum	80
Lead	5	Iron	80
Gallium	0	Copper	90
Tin	70	Nickel	80
Barium	0	Tantalum	0
Zinc	60	vanadium	0
Indium	60	beryllium	0
Terbium	0	europium	0
Gold	99	ruthenium	80
Titanium	0	palladium	95
Cobalt	85	silver	98
manganese	0	bismuth	0
Antinomy	0	cadmium	0
Chromium	0	niobium	0
Selenium	70	rhodium	50
Platinum	95	mercury	0
Arsenic	0	silica	0

Source: Handy and Harman Electronic Materials Corp. 1999

State Legislations

Lack of Federal control over household electronic waste disposal in landfills has some states taking the initiative to tackle the problem (Figure 2.3). For instance, California, Maine, Minnesota and Massachusetts have banned e-waste disposal in landfills. This regulation is in response to concerns raised about the potential health and environmental effects of toxic substances they contain (Stephenson, 2005). The ban has increased recycling of end-of-Life computers in these states as compared to states that have no such legislation. For instance, in San Ramon, California, a day's collection event yielded two thousand four hundred (2,400) units whereas in Richmond, Virginia, an area four times the size of San Ramon a similar collection event produced only six thousand (6,000) units because there is no such ban (Stephenson, 2005).

Thirty one (31) of the fifty (50) states in the US have introduced or passed some legislation to control or barn e-waste disposal in landfills and incinerators. Some states advocate Cathode Ray Tube (CRT) waste storage by consumers for as long as it takes. This ensures larger collection volumes and reduces the cost of tracking. States in this category are Colorado, Florida, Kentucky, Michigan, New Jersey, North Carolina, Ohio, Texas, Washington and Wisconsin (Office of Inspector General's Evaluation Report, 2004)

Other states have a taskforce program which empowers a commission within the waste divisions to recommend options for legislation. These states include Georgia, Maine, New Jersey, New Mexico, Oregon, Rhoda Island and

Virginia (Office of Inspector General's Evaluation Report, 2004). There is a complete ban on landfilling or incinerating cathode ray tubes in California, Maine, Massachusetts and Minnesota (Office of Inspector General's Evaluation Report, 2004). Some states provide funding for recycling and collection infrastructure. This has helped the establishment of small recycling facilities through state grants. Such grants have been given in Arkansas, Colorado, Florida and Massachusetts (Office of Inspector General's Evaluation Report, 2004).

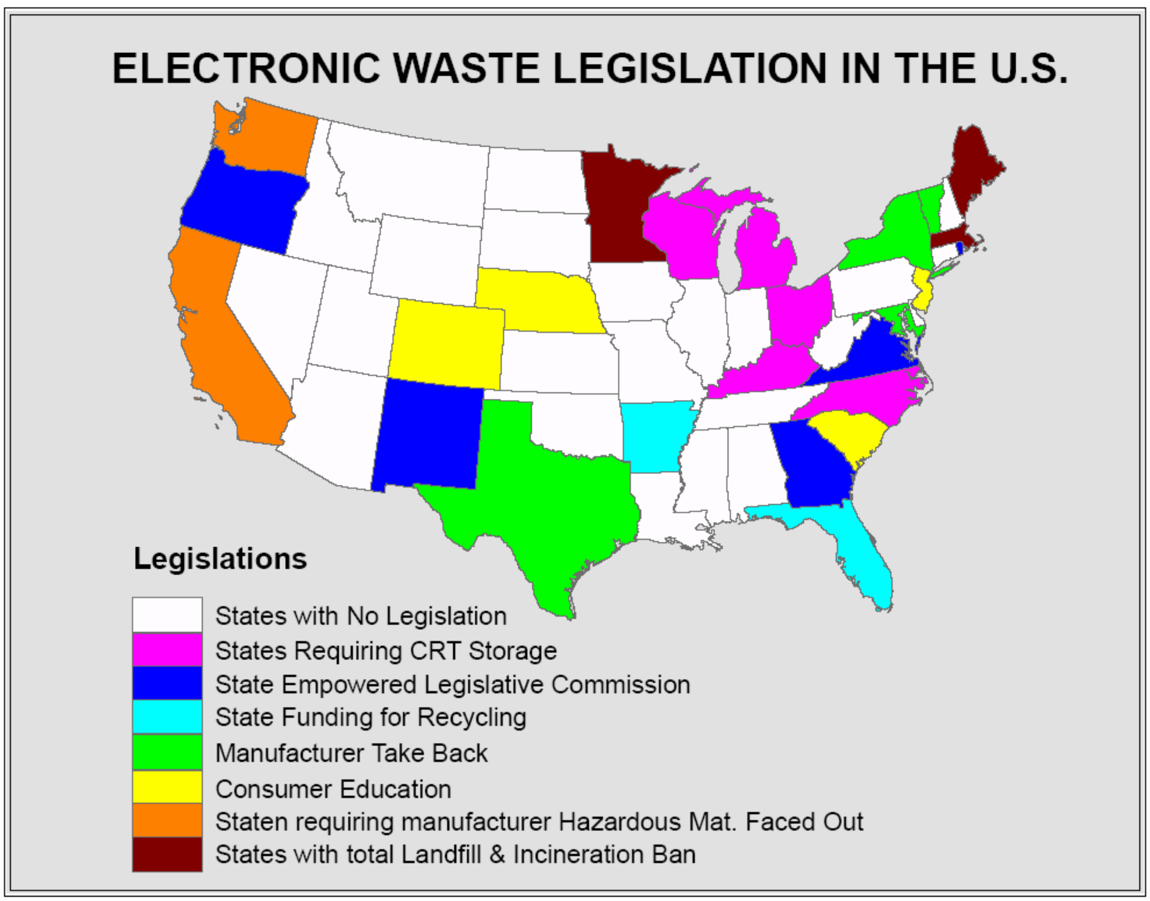

Figure 2.3: States with Legislation on Electronic Waste

Manufacturers are required to develop programs in some states to ensure that their old computers are returned back to them for recycling at the end of their life. These states put manufacturers in charge of developing, financing and implementing recycling programs. This legislation is pending in Maine, Maryland, New York, Vermont, Rhode Island, Texas and Washington (Spielvogl, 2006). North Carolina will soon be added to this group since the recycling act of 2005 requires a manufacturer to come out with a recycling program or pay a fee. New Jersey and Colorado have been carrying out consumer education campaign to promote reuse and recycling among schools and businesses. This legislation, however, is pending in Nebraska and South Carolina (Office of Inspector General's Evaluation Report, 2004). Last but not the least; California is pushing for hazardous materials faced-out. This legislation will restrict manufacturers from producing computers with large hazardous substances after 2007. Washington may follow this path (Office of Inspector General's Evaluation Report, 2004).

European Union (EU) and Other Countries

The US is far behind when it comes to legislations in electronic waste. European countries are far ahead just as in privacy legislation. The Basel Convention adopted the Control of Trans-Boundary Movements of Hazardous Waste in 1989. This came into force in 1992 after it was ratified by over twenty countries. This requires an exporter of hazardous waste to notify the importer before shipment. This does not apply in the US (Basel Convention, 1992).

The EU took this notification system a step further and passed the Waste Electrical and Electronic Equipment and Reduction of Hazardous Substances Directives in 2003. This covered all consumer electronic and required manufacturers to take full financial responsibility to recover their end-of-life products using the best available technology. It required EU members to use manufacturer financing for collection programs. This directive also banned six toxic chemicals (lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE)) in electronics. However, the legislation allows some lead and mercury containing parts in computers (Barnand, 2002).

Japan, Australia, Canada, Denmark and Taiwan are promoting recycling and product stewardship. Australia and Canada are developing product voluntary stewardship strategies. This is through public and private working groups that include government representatives and industry associations. Japan’s Specific Home Appliance Recycling Law of 2001 requires take-back for manufacturers of electronic goods (Office of Inspector General’s Evaluation Report, 2004).

CHAPTER III

METHODOLOGY

The determination of the quantity of domestic computer waste generated in North Carolina is critical for the establishment of appropriate infrastructures to better manage it. The study estimates computers and computer waste at county level for year 2000 and 2005 and compares it to the quantity recycled. The lifecycle of a computer is simple and short. Figure 3.1 illustrates a possible life cycle of a household computer.

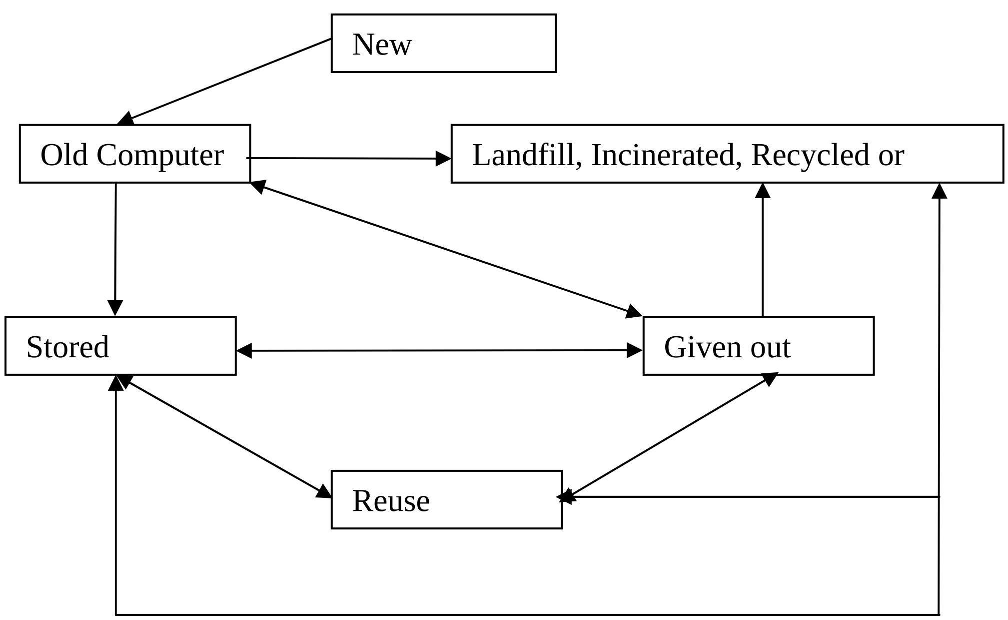

Figure 3.1: Life Cycle of a Computer.

When a new computer is bought, the old one is stored, given out as a gift, sold or trashed. A user resorts to a stored computer if the new one stops working or fails to perform functions the owner is conversant with. An old computer is reused when it is given out as a gift or sold to a new owner. The new owner also resorts to any of the three scenarios above when he/she acquires a new computer. If the second owner hands over the old computer to a third person, it is again reused. At each location, the computer faces one of the three options. All computers at the end of their life are either landfilled, incinerated, or recycled (manufacturers). Of these, landfilling appears to be the most preferred option for final disposal of end-of-life computers.

The total number of computers in North Carolina is estimated by county using the state's household computer ownership rate, county and state households, and state and county median incomes. Projected life expectancy for computers for 2000 and 2005 was used to determine the portion of the total computers which were considered as waste in those years. In other to better compute the quantity of computers and the associated waste, the following assumptions have been made: (a) when a consumer buys a computer he/she gets a Central Processing Unit (CPU) and a Cathode Ray Tube Monitor (CRT). This is because an average weight of seventy pounds for a computer was used for the computation; (b) all users of a computer are first users and therefore they will keep the computer for the maximum projected life expectancy. This ensures that all computers last for their projected lifespan; and (c) the lifetime of a computer is fixed though in reality some individual products will have shorter or longer life span than the average. Household computer wastes are complex to manage because the rate of domestic computer retirement is increasing (Schoenung and Kang, 2005). Spatial distribution and changes of computers and computer waste for 2000 and 2005 are examined. Computer waste recycled is correlated with some socio-economic and demographic indicators to determine their association.

Data Description

Population and Household

Population and household data for 2000 was derived from the 2000 Population Census Report (US Census Bureau, 2000). However the 2005 household and population data are an estimate since there is not a complete census data available. This estimate was acquired from a 2005 survey report by Sales and Marketing Management, a consumer reporting agency, which specializes in consumer statistics (Sale and Marketing Management, 2005). Their data covered all counties in North Carolina which made it a better data to use than the 2005 US Census Bureau's survey data which covered only thirty seven counties. The US Census Bureau's survey data was not useful for the study because it was too small a sample for one hundred counties.

Number of Computers

There are no data on the number of computers at the county level in the state and therefore the total number of household computers is estimated from two sources. The first one was from a US Census Survey of household computer ownership. The 2000 and 2005 reports showed that computer ownership rates for North Carolina were 45.7 and 58.3 respectively (US Census Bureau, 2000; US Census Bureau, 2005).

Income is a major determinant of individual's ability to own a computer and therefore the median household incomes for 2000 and 2005 were used as a variant to compute the number of computers per county. Computer ownership is and has always been high for high incomes households. According to the Benton Foundation, 80% of households with annual income of $75,000 or more owned computer(s) in 2001, whereas only 25% of poor American families owned a computer in the same year (NTIA, 2000). The USEPA in 2000 identified that households with; (a) high income, (b) two to four persons, (c) married couples, (d) school-aged children, and (e) metropolitan origin are more likely to own a computer. Purchasing power, however, is the most important.

A study by the Massachusetts Department of Environmental Protection in 2000 estimated that 36% of households with computers had more than one computer (Massachusetts Department of Environmental Protection, 2000). This was useful because, though the median household income for Massachusetts was about $10,000 more than that of North Carolina; the other characteristics such as education, income, presence of students, and age; which determine whether a household owns a computer or not will not differ much between the two states.

Computer Waste

The USEPA estimated the life expectancy of a computer to be 5 years in 2000 (USEPA, 2001). This life expectancy was used to compute the total number of computers that was expected to be considered as waste in 2000. To effectively determine the computer waste, the assumption is made that no computer will be in use after their expected life span. The 5 years life expectancy indicates that a fifth of the total number of computers in 2000 was considered obsolete. In 2005, the life expectancy of computers dropped about two years according to all estimates (USEPA, 2001; US Census Bureau 2005; Massachusetts Department of Environmental Protection, 2000). Three years life expectancy was therefore used to calculate the computer waste in 2005. This drop in lifespan is mainly explained by the fact that there is frequent release of more powerful programs and computer due to advancement of technology in the computer industry.

Computers Recycled and Non- Recycled

All counties in North Carolina have a recycling section under the department of solid waste. These departments have programs to collect various wastes for recycling including computer waste. These sections were contacted via e-mails or phone and requested for data on the number of computers they collected for recycling in 2000 and 2005. The data were in tons but they were converted using the 70lb as the average weight of a desk-top computer into number of computers. Though the standard is tons, the unit of computers gives a clear picture of the problem. The weight of computers range from 20 pounds to 140 pounds but most desk top computers weigh 70 pounds. Some counties such as Mecklenburg had their records not separated by years.

To determine the portion of computers which were not recycled and may have ended up in unwanted places, the total number of recycled computers was deducted from the projected waste for 2000 and 2005. The non-recycled computers could be in storages, artic, dumped at places where they cannot be recovered or are resting in landfills. The final place for most of the computer waste is the landfills.

Urban / Rural Counties

Counties were classified into percent urban and rural based on the percentage of its population which lived in rural or urban areas. This variable was only available for 2000 and not 2005. The 2000 population census recorded the number of people who live in rural and urban areas per county. The percentages that those people constitute with respect to the total population were computed. For instance, an urban county will have 100% which means that the county is fully urban. On the contrary, a county is rural if it has 100% for rural. A county has both rural and urban class if it has population living in both areas.

Level of Education

The educational attainment of the population was also computed for the research. This variable sums up the population with high school diploma, some college education, college degree, graduate degree, and doctorate degrees. This was computed for 2000 from the census report but it was not available in the 2005 Sales and Marketing Management survey data. This was therefore used for the 2000 only. However the relationship between education and recycling in 2000 will not be very different in 2005. If anything the magnitude will be increased but not decreased.

Age

The age distribution of the population is put into two major groups for 2000 and 2005. This group consists of people within the ages 18 to 34 and 35 to 79. Peoples' perception on recycling is influenced by age and residential type. Most of the population within the age group of 18 to 34 lives in rented apartment buildings and therefore space is very expensive. Unlike those who own their homes and therefore space is cheaper and can afford to store their waste computer as long as they like.

Data Analysis

The study is confined to the geographical boundary of North Carolina and its counties. It focuses on household computer ownership, projected household computer waste, and computers recycled in 2000 and 2005. The major variables for the study are the number of domestic computers, the corresponding projected computer waste, and the portion of computer waste recycled. Because of the lack of available data on the total computers in North Carolina, the number of computer stock in the state and counties for the years 2000 and 2005 were computed using equation 3.1 below. The equation gives the rates (in percentages) for computer ownership for the year 2000 and 2005. It is simply the product of the state's household computer ownership rate and the quotient of counties and the state median incomes. These county percentages are then multiplied by their respective number of county households (EQ. 3.2) to arrive at the number of computers per county. The portion of the total number of computers which were considered obsolete was computed using equation 3.3.

$$\hat{C}Hc = (HYc / HYs) * R_Y \qquad (3.1)$$

Where; $\hat{C}Hc$ *= percent of household with computers in a county*

HYc = county median household income

HHc = state median household income

R_Y *= State computer ownership rate*

$$CT = \hat{C}Hc * H_n \qquad (3.2)$$

Where; *CT = total number of household computers per county*

$\hat{C}Hc$ *= percent of household with computers in a county*

H_n *= number of county households*

$$CW = CT / L \qquad (3.3)$$

Where; *CW = computer waste*

CT = county computer total

Le = Life expectancy of computers

The data analysis is divided into four major groups. These are computer ownership, waste computers, and computer waste recycled. The other is the relationship between computer recycling and some selected socio-economic indicators such as age, education and rural or urban nature of a county. The counties were ranked according to the total number of computers in 2000 from the highest to the lowest. Descriptive statistics was employed to discuss the number of domestic computers owned by the top seven counties as well as the lowest seven counties in 2000 and 2005. It must be noted that the magic number, seven, was chosen because there was a big drop of (2000 computers) between the sixth County (Durham) and the seventh County (Buncombe) in

2000. The top six counties should have been used for the analysis but to show the break, the seventh county was added. For the purpose of consistency, the lower seven counties were also selected for discussion. The counties were again ranked by the percentage of computers gained between 2000 and 2005 and analyzed descriptively in terms of statistics. Here too the top and bottom seven counties were the focus. They were not selected as a result of any observation but to show consistency in presentation. The computer ownership and the number of households for the state and counties were also analyzed statistically. This analysis focused on the magnitude of the increase for these two variables between 2000 and 2005 and their implications. The second and the third categories (computer waste and computers recycled) were analyzed along the same lines as the computer ownership for 2000 and 2005. The projected computer waste and computers recycled for 2000 were used to rank the counties in an ascending order. The top and bottom seven counties were chosen as the focus of the analysis. Here again the selections were to show consistency. The seven counties at the extreme ends of the data table with respect to net computer waste gain and net increase in computers recycled were analyzed. Tables, line graphs and bar graphs were used to portray the data for the descriptive statistics.

The spatial distribution of computer ownership, projected computer waste, and computers recycled for 2000 and 2005 were represented by choropleth maps with seven classes. The spatial patterns for 2000 and 2005 were then examined. The net gain in all three variables (computer ownership, computer waste, and computers recycled) were spatially analyzed and also represented in maps. The projected computer waste was analyzed by county and state.

The relationship between education level, age, urban / rural nature of counties and computers recycled were analyzed using correlation. The results from the analysis were presented in a table. This is to find out which of these variables has the strongest relationship with computers recycled.

The state and private computer waste recyclers engage in various computer waste collection and recycling programs. These various collection programs are examined to determine their efficiency in harnessing the computer waste build-up in the state. Also the recycling methods such as glass-to-glass and lead-to-glass are discussed to determine the most effective method of recycling computer waste.

CHAPTER IV

RESULTS

Computer Ownership

The number of domestic computers in North Carolina increased dramatically between 2000 and 2005 according to the estimated data. This increase was in keeping with the state's population, households and internet use increases (US Census Bureau, 2001). In 2000 there were 3,349,312 estimated household computers in the state but this number increased dramatically to 4,287,248 in 2005 as estimated (Fig 4.1a). The average number of computers per county in the state was 33,960 in 2000 and 42,829 in 2005 (Table 4.1a). According to the 2000 US Census report, there were 3,132,000 households in North Carolina. This increased to 3,356,000 in 2005 (US Census Bureau, 2000; Sales and Marketing Management, 2005)

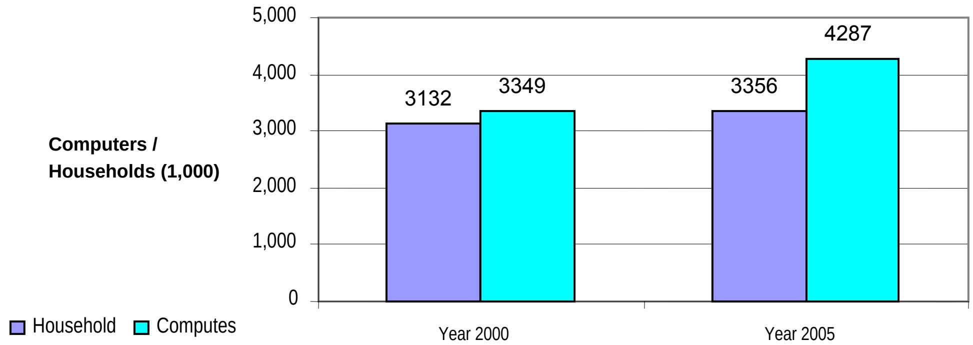

Figure 4.1a: Number of Computers and Households (2000 and 2005)

Table 4.1a: Descriptive Statistics on Computers (2000 and 2005)

North Carolina	Computers		
	Total	Mean	Std. Deviation
2000	3,349,312	33,960	57,137
2005	4,287,240	42,829	72,900

Domestic computers therefore increased about 28% between 2000 and 2005. However the total number of households in the state increased by only about 7.1% within the same period (Table 4.1b). That means the number of domestic computers rose by about 20.9% more than households. The average number of computers per household in 2000 was 1.0 but this increased to 1.3 in 2005 (Table 4.1b). This increase can be attributed to the growing importance of computers in human life. The internet has become a very powerful toll for home based research and business. A computer is the major means by which these groups are able to connect to the internet and do business (US Census Bureau, 2001).

Mecklenburg County had 377,413 computers in 2000 but this number increased to 484,429 in 2005. It had the highest number of computer ownership in the state for both 2000 and 2005. Tyrrell county had the lowest number of computers for the same years 2000 and 2005 with only about 1,077 and 1,490 respectively (Table 4.1c; Table 4.1f). Wake County was the second in terms of computer ownership in the state. Its ownership was very close to that of Mecklenburg County. Wake had about 363,227 computers in 2000 but this increased to 471,704 in 2005. This reflects an increase of about 29.9%.

Table 4.1b: Change in Households and Computers between 2000 and 2005

	Households	Computers	Computer/Household
2000	3132013	3349312	1.1
2005	3355600	4287240	1.3
Change	7.1%	28.0%	3.9

Though Mecklenburg County had the highest computer ownership, the number of computers it gained over the five year period was less than that of Wake County. Guilford County was the third in terms of computer ownership for 2000 and 2005 but it gained only 20.7%. Cumberland and Durham Counties followed in that order in computer ownership but they gained more computers than Guilford County. Computer ownership increased by 26.5% in Durham County's followed by Cumberland County with 22.5% (Table 4.1c).

The county with the second lowest number of computers was Hyde County. It had only 1,696 computers in 2000 which increased to 2,048 in 2005. Graham County was third from the bottom but it was not the third in terms of computers gained over the period. Though Jones County was the forth lowest in ownership it gained as much as 46.7% between 2000 and 2007. It had the highest computers gain among the lowest 7 counties followed by Tyrrell County (Table 4.1e). Alleghany County had the highest number of computers among the last 7 but it was the 4th in computer gain among the group.

Table 4.1c: Top 7 Counties with regard to Number of Computers

County	**Computers 2000**	**Computers 2005**	**Change (%)**
Mecklenburg	377413	484429	28.4
Wake	363227	471704	29.9
Guilford	196176	236769	20.7
Forsyth	142289	172874	21.5
Cumberland	109772	134467	22.5
Durham	105279	133135	26.5
Buncombe	85832	105949	23.5

Table 4.1d: Change in Counties in terms of Computers (2000 - 2005)

Range	0 < computers ≤ 80,000		80,000 > Computers ≤ 640,000	
Year	2000	2005	2000	2005
Counties	93	89	7	11

Ninety-three counties had computers within the range of 10,000 and 80,000 in 2000. In 2005, this decreased to 89 counties. However, counties having more than 80,000 computers increased from 7 to 11 (Fig 4.1b; Table 4.1d).

Table 4.1e: Low 7 Counties with Regard to Number of Computers

County	**Computers 2000**	**Computers 2005**	**Gain (%)**
Tyrrell	1077	1490	38.4
Hyde	1696	2048	20.8
Graham	2438	2995	22.9
Jones	2869	4208	46.7
Camden	3296	4364	32.4
Clay	3422	4423	29.3
Alleghany	3665	4590	25.3

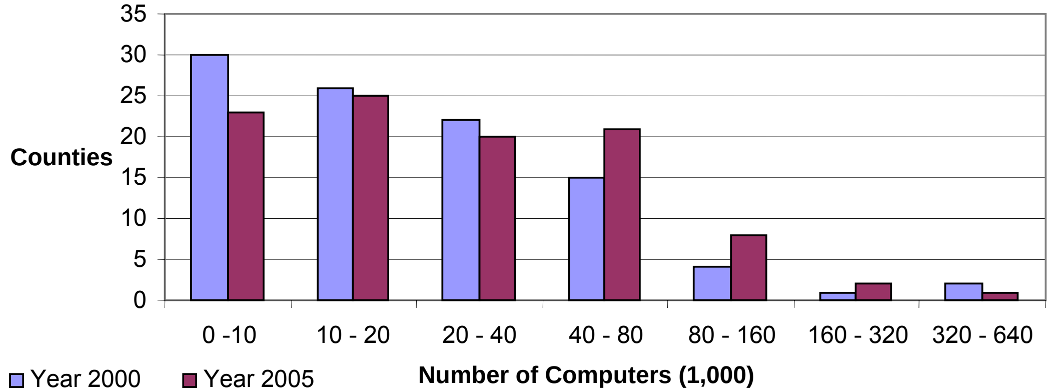

Figure 4.1b: Distribution of Counties in Computer Ownership (2000 – 2005)

The spatial distribution of household computer ownership in North Carolina in 2000 is depicted in Figure 4.1c. It can be seen from the map that the highest concentrations of computers were in the mid-west and north-eastern pockets of the eastern and the mid-south. The mid-western section has a cluster situation from Davidson to Madison counties. However some counties in this region such as Iredell, Burk, Caldwell and Avery has low rates. There is also a high household compute ownership rate at the central section of the state. This follows a linear pattern from Johnston through Durham to Guilford counties. There are some isolated cases, for instance, Jackson County, located at the west had a rate of between 1.10-1.20 computer ownership per household. Cherokee County located at the eastern tip of the county and Brunswick at the southern tip had 0.94-1.00 computers. Dare County, located at the coast, had household ownership of 1.10 - 1.20 computers. Craven and Onslow counties had the highest ownership at the coastal counties whilst Carteret had the least of 0.69-

0.79. Onslow, Rutherford and Person counties had the highest computer ownership in the state. These three counties are in a triangle, Person is at the north, Rutherford is at the west and Onslow is at the east. Counties with the lowest computer ownership are distributed all over the state. For instance Warren and Stokes are at the north, Randolph, Lee and Moore are at the central section and Roberson, Sampson and Duplin counties are at the south

The spatial situation in 2005 was not very different form that of 2000 except that some counties increased their household computer ownership greatly. The north-eastern section of the state was still the high zone. However, two counties Dare, and Pasquotank, increased their total computer ownership from 14,688 and 10,723 to 20,953 and 13,620. The mid-western portion of the state was still in the high computer ownership range. Within the central portion, Orange County was the only place where the household ownership increased greatly. Onslow, Craven and Dare were the coastal counties with the highest ownership. Anson, Richmond and Hoke counties had the highest computer ownership in the south. The highest concentration of computer ownership was at the mid-western section of the state (Figure 4.1d).

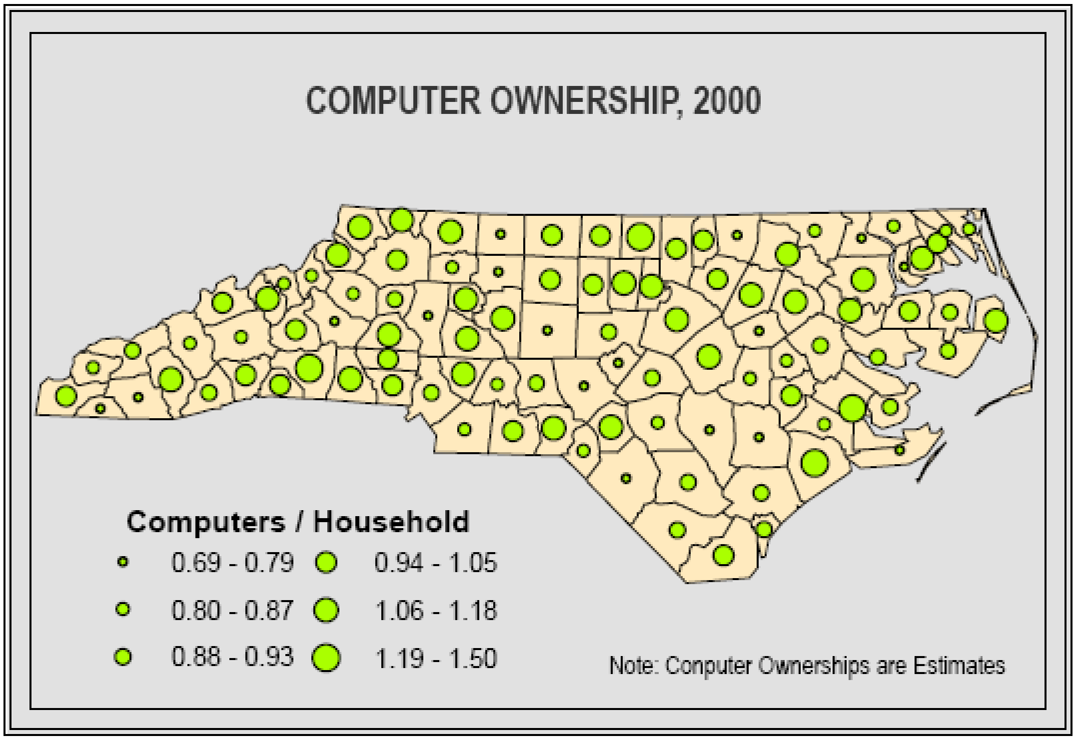

Figure 4.1c: Total Household Computers in 2000

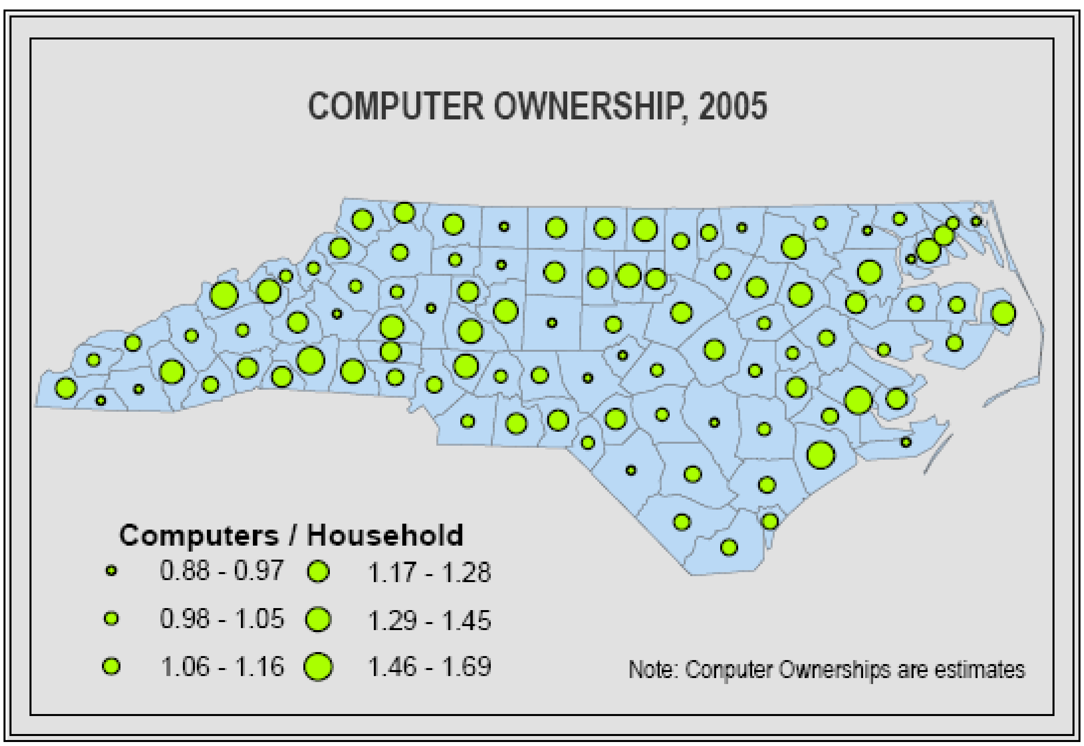

Figure 4.1d: Total Household Computers in 2005

Percent Change in Computer Ownership

As alluded to in the previous discussion, the percentage of computers gained in the state does not follow that of the trend in the actual number of computers owned per county. The three counties that gained the most computers were all rural counties. These are Gates County with 66.1%, followed by Camden County with 52.1% and Currituck County having 47.0%. The other four counties are Union with 45.7%, Brunswick 44.7%, Hoke 42.7%, and Dare 42.7% (Table 4.1f)

Table 4.1f: The 7 Counties with Most Gain of Computers (2000 – 2005)

County	**Computer 2000**	**Computer 2005**	**Change**	**Rural**	**Urban**
Gates	3795	6303	66.1%	100%	0%
Camden	2869	4364	52.1%	100%	0%
Currituck	7689	11306	47.0%	100%	0%
Union	59963	87381	45.7%	50%	50%
Brunswick	29811	43134	44.7%	66%	34%
Hoke	10314	14721	42.7%	57%	43%
Dare	14688	20953	42.7%	31%	69%

Table 4.1g: The 7 Counties which gained the least Computers (2000 – 2005)

County	Computer 2000	Computer 2005	Change	Rural	Urban
Transylvania	12974	15186	17.0	62%	38%
Lee	19604	23012	17.4	49%	51%
Stokes	18618	21899	17.6	80%	20%
Burke	33573	39615	18.0	46%	54%
Onslow	44332	52332	18.0	29%	71%
Washington	4227	5007	18.5	66%	34%
Cleveland	35672	42379	18.8	55%	45%

Transylvania County, which had the lowest gain between 2000 and 2005 among the bottom seven, was 62% rural and gained only 17%. This was followed by Lee and Stokes counties which had 17.4% and 17.6% growth respectively. The other four counties were Burke, Onslow, Washington and Cleveland. Table 4.1g portrays their respective computer totals and the percent gain.

The spatial distribution of the percentage of computers gained per household between 2000 and 2005 is depicted in Figure 4.1e. The counties with the least number of computers owned rather added more household computers to their stock. Gates County which was among the lowest group in terms of ownership rather tops all the counties in the number of computers it took in. Other low to moderate counties who added more computers were Union in the south, Forsyth in the central portion and Stakes and Warren in the north. The North eastern portion of the state is ranked the highest followed by the south and the western sections. Among the counties which added fewer computers than households, Wilson and Mecklenburg counties were the least followed by Haywood and Buncombe counties. Northampton added the least computers per household.

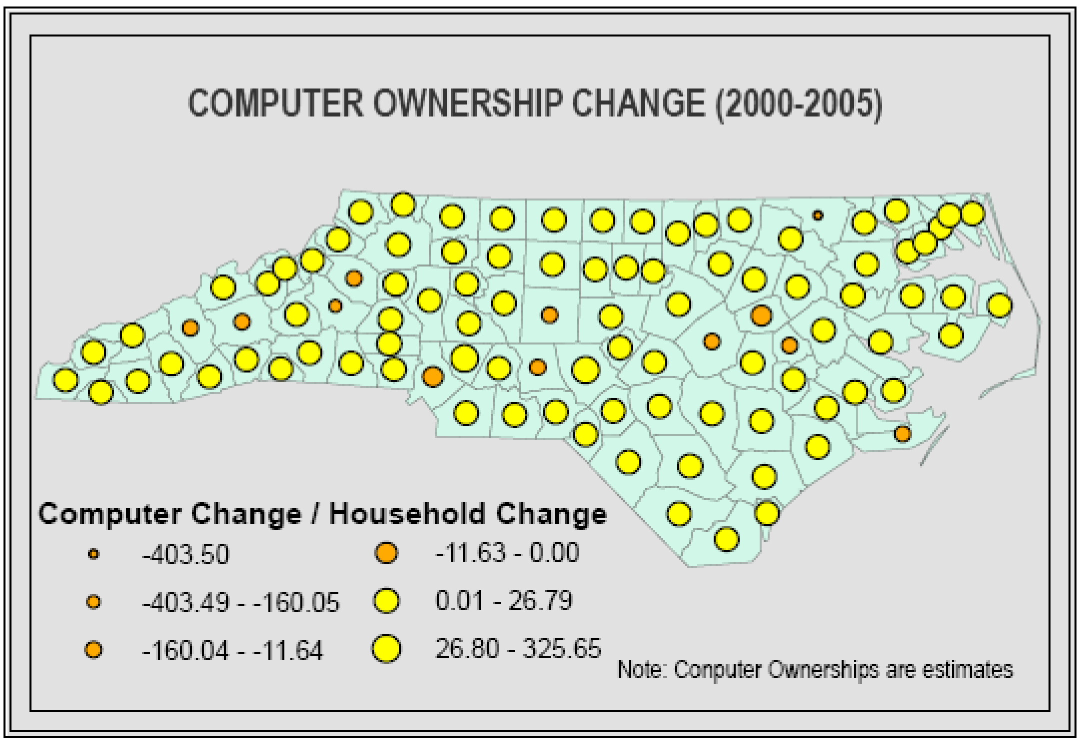

Figure 4.1e: Percent Change of Computers between 2000 and 2005

Waste Computer

The life expectancy of computers has been decreasing due to rapid advancement in technology. This has caused a dramatic price reduction whilst functionality and design have been increasing. Computer waste refers to those computers which have reached their end of life or are no more in use by their owners. Some of these computers are kept in storages waiting for the day they will be trashed. The quantity of waste computers increase is parallel with computer ownership. There were about 669,862 waste computers in North Carolina in 2000. The average waste per county was 6792 with a standard deviation of 11,427. This waste increased to 1,429,082 in 2005 with a mean of 14,271 (Table 4.2a).

Table 4.2a: Computer Waste

	Waste 2000	Mean	Standard Deviation
2000	669,862	6,792	11,427
2005	1,429,082	14,271	24,303
Change	113.3%	110.1%	

This jump represents a huge increase of 113.3%. This presents a major challenge to solid waste administrators because computer wastes are increasingly becoming a major part of the municipal solid waste (NCDPPEA, 2003). These wastes need to be managed well since they are classified as a universal waste and needs to be treated with care (Santa Clara County Department of Environmental Health, 2004).

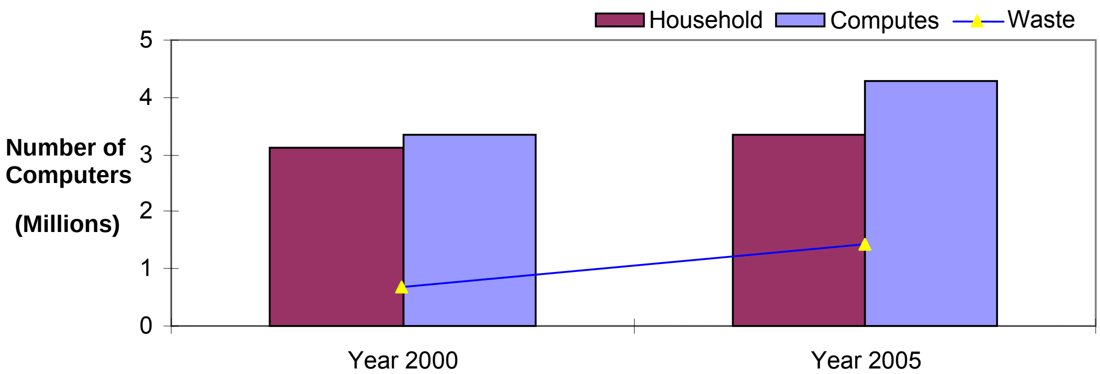

Figure 4.2a: Households, Computers and Waste in 2000 and 2005

Percent Change in Computer Waste

The three counties which produced the most waste were Mecklenburg, wake and Guilford counties. Mecklenburg County had an estimated waste of 75,482 in 2000 which reached 161,476 in 2005 an increase of 113.9% which is equivalent to the state rate. Though Wake County was the second in estimated computer waste after Mecklenburg, it generated more waste than the latter. Wake County's computer waste increased form 72,645 in 2000 to 157,234 in 2005 (Table 4.2b). Guilford County's waste was just about doubled within the same period.

The bottom 7 counties in 2000 and 2005 in the ascending order were Tyrrell, Hyde, Graham, Jones Camden Clay, and Alleghany (Table 4.2c). Tyrrell had 215 computers which were considered as waste. In 2005 this number increased to 496 an increase of 130.7%. All the last 7 counties more than doubled their waste between 2000 and 2005.

Table 4.2b: The 7 Counties with the Most Waste Gain (2000 – 2005)

County	Waste 2000	Waste 2005	Change (%)
Mecklenburg	75482	161476	113.9
Wake	72645	157234	116.4
Guilford	39235	78923	101.2
Forsyth	28457	57624	102.5
Cumberland	21954	44822	104.1
Durham	21055	44378	110.8
Buncombe	17166	35316	105.8

Table 4.2c: The 7 Counties with the Least Computer Waste (2000 – 2005)

County	Waste 2000	Waste 2005	Change (%)
Tyrrell	215	496	130.7
Hyde	339	682	101.2
Graham	487	998	104.9
Jones	573	1402	144.7
Camden	659	1454	120.6
Clay	684	1474	115.5
Alleghany	733	1530	108.7

Ninety four counties had less than 20,000 waste computers in 2000. Cumberland, Durham, Forsyth, Guilford, Mecklenburg, and Wake counties had more than 20,000 computer wastes. Counties which had waste computers between 1000 and 20,000 decreased from 94 to 79 in 2005 (Table 4.2d; Fig. 4.2b).

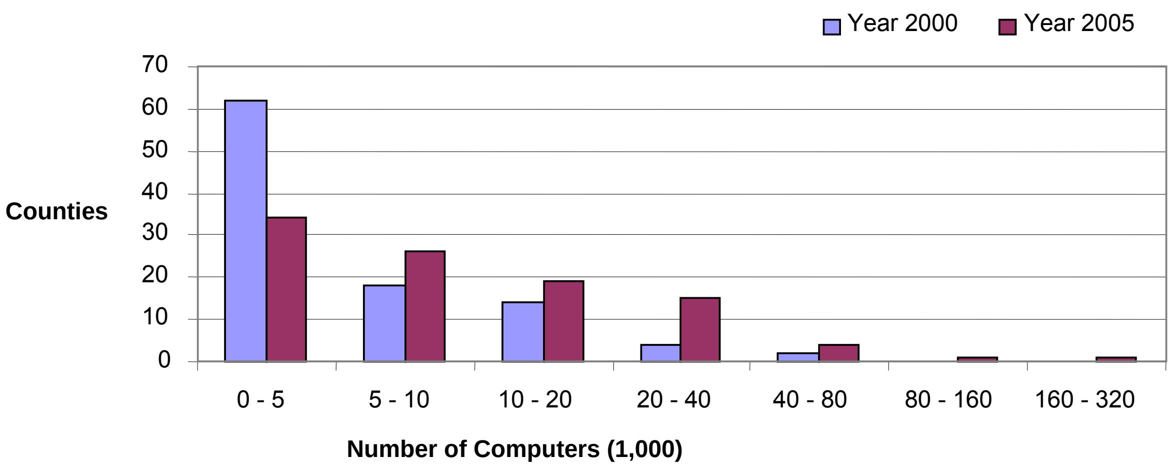

Figure 4.2b: Distribution of Counties in terms of Computer Waste (2000 – 2005)

Figure 4.2c shows the spatial distribution of the projected household computer waste in 2000. Counties with the most waste were concentrated at the mid-west and north-eastern portions of the state. Person, Craven, and Onslow counties dominated in household computer waste in the state. Onslow and Craven counties are at the coast whilst Person County is at the north. Counties at the Central section of the state had the lowest computer waste. The southern portion has moderately high household computer waste.

Table 4.2d: Change in Counties in terms of Computer Waste (2000 – 2005)

Range	0 < waste ≤ 20,000		20,000 > waste ≤ 320,000	
Year	2000	2005	2000	2005
Counties	94	79	6	21

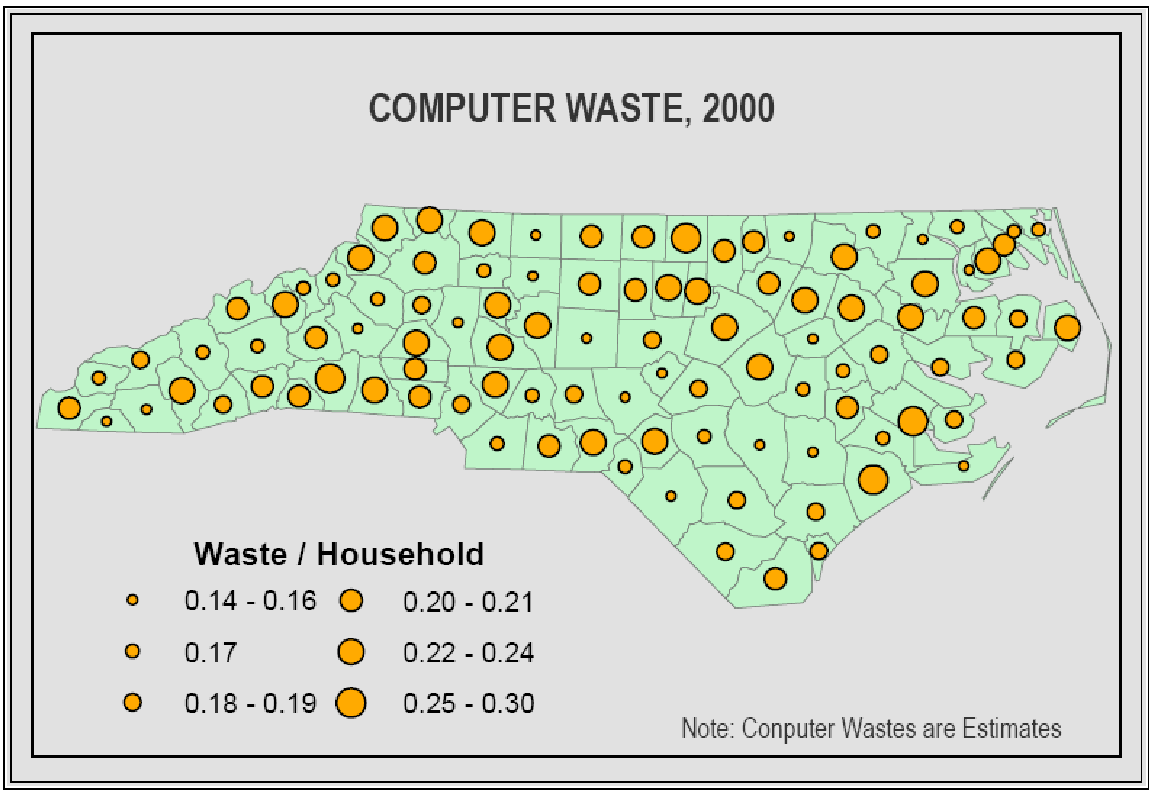

Figure 4.2c: Total Household Computer Waste in 2000

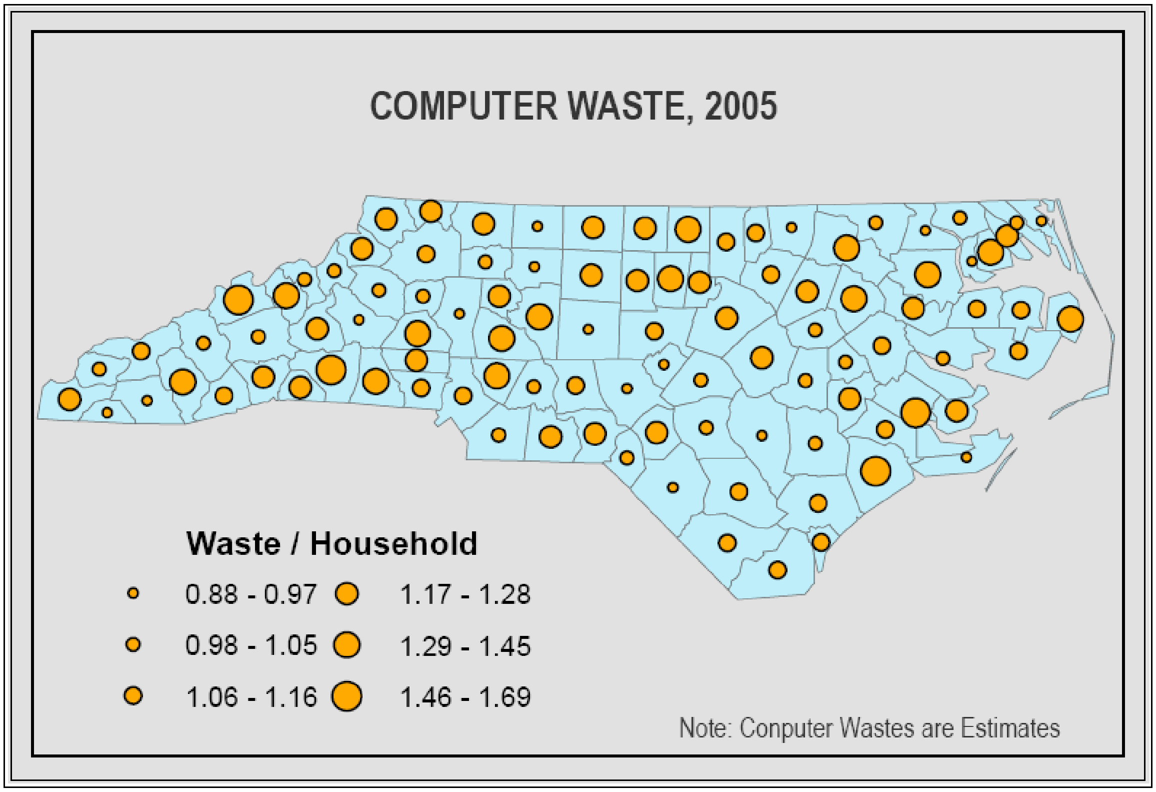

Figure 4.2d: Total Household Computer Waste in 2005

The situation in 2005 followed the same trend as in 2000. Counties with the highest number of computer waste were concentrated at the mid-west portion of the state. The top counties were Craven, Onslow, Madison and Rutherford with household waste of between 1.45 and 1.70. Orange, Cleveland, Catawba, and Davidson counties followed closely with 1.28-1.45. The western and eastern section of the state had the highest projected household computer waste (Figure 4.2d).

The number of computers considered waste in 2000 was not as high as in 2005. The data shows that there was no county with more than 80,000 estimated computer wastes in 2000. By 2005, two counties, Wake and Mecklenburg, had crossed this mark and were having and 157,232 and 161,476 respectively.

Table 4.2e: Distribution of Counties in Waste Change (2000 and 2005)

Range	1 < waste ≤ 5,000		10,000> waste > 5,000	
Year	2000	2005	2000	2005
Counties	63	18	35	26

Counties which had between one and five thousand (1-5,000) computer waste decreased from 63 to 35. However, counties having more than five thousand but less than ten thousand computer waste (5,000<c<10,000) rose from 18 to 26. Counties having between twenty thousand and forty thousand (20,000<c<40,000) computer waste rose to 15 from 4. It is therefore clear from the results that more counties took produced more waste in 2005. The net increase of computer waste is illustrated in Figure 4.2e Table 4.2e.

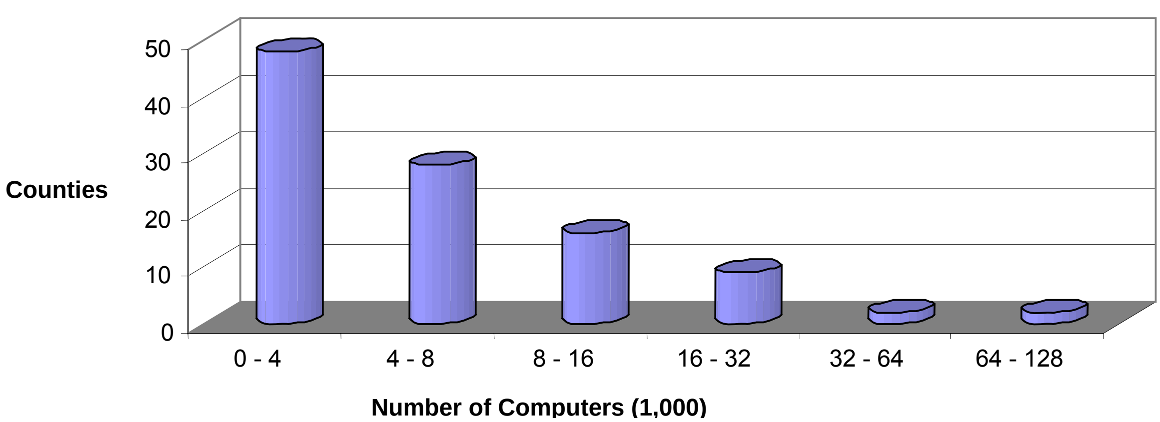

Figure 4.2e: Change in Computer Waste between 2000 and 2005

Computer waste gained by counties did not follow the trend of the counties with the highest waste in 2000 and 2005 Table 4.2f. Camden had the most projected waste increase followed by Currituck and Union counties. The other four counties were Brunswick, Hoke, Dare, and Chatham counties. Table 4.2f shows their respective percentage increase as well as their percent urban and rural.

Table 4.2f: The 7 Counties with the Most Computer Waste Change (2000 –2005)

County	**Waste 2000**	**Waste 2005**	**Gain (%)**	**Rural**	**Urban**
Camden	573	1454	153.8	100%	0%
Currituck	1537	3768	145.2	100%	0%
Union	11992	29127	142.9	50%	50%
Brunswick	5962	14378	141.2	66%	34%
Hoke	2062	4907	138.0	57%	43%
Dare	2937	6984	137.8	31%	69%
Chatham	4617	10876	135.6	80%	20%

Computers Recycled

According to the North Carolina Department of Pollution Prevention and Environmental Assistance's (DPPEA) website, there are about 52 registered private recyclers in the state (Table 4.3a). Not every county has a recycler to process their waste computers and therefore some counties ship their waste to other counties for processing. For instance, Synergy Recycling L.L.C, which handles most of the waste computers from Guilford County, is located in Rockingham County (NCDPPEA, 2003). It must however be noted that the registration of recyclers at the site is voluntary and therefore this list may not contain all the recyclers in the state.

Table 4.3a: Registered Recyclers in North Carolina as of December 2006

Recycler	**City, County**
Alternative Waste Mgt. Solutions	Asheville, Buncombe
Asset Recovery Corporation	Durham, Durham
C & H Metals and Salvage	Haw River, Alamance
Capital Trade Services LLC	Charlotte, Mecklenburg
Carolina Environmental Associates Inc.	Burlington, Alamance
Cohen & Green Salvage Co., Inc.	Fayetteville, Cumberland
Compu Tel IG	Charlotte, Mecklenburg
ECOFLO, Inc.	Greensboro, Guilford
ESC Refining	Greensboro, Guilford
Environmental Recycling Alternative, Inc.	High Point, Guilford
ExplorNet	Raleigh, Wake
Franklin’s Recycling, Inc.	Greenville, Pitt

Table 4.3a continued

Recycler	**City, County**
Friendship Helping Ministries	Charlotte, Mecklenburg
G & L Industries	Winston Salem, Forsyth
GEEP, Inc	Durham, Durham
H & H Technologies	Hickory, Catawba
Habitat for Humanity ReStore,	Burlington, Alamance
Holmes Iron & Metals, Inc.	East Spencer, Rowan
Hometown Computers	Hillsborough, Orange
IBS Environmental Services, Inc.	Lenoir, Caldwell
JLA Enterprises	Raleigh, Wake
Kemp Services Inc.	Indian Trail, Union
LDS Inc.	Greensboro, Guilford
LodeStar Recovery, Inc.	Jamestown, Guilford
Millennium Metals	Concord, Cabarrus
Morrison’s Recycling	Elkin, Surry
NetCorp	Durham, Durham
OC Stafford Electronic Services & Development	Greensboro, Guilford
Raeford Salvage Company, Inc.	Raeford, Hoke
Regal Asset Recovery	Matthews, Mecklenburg
Safety-Kleen	Archdale, Randolph

Table 4.3a continued

Recycler	City, County
Safety-Kleen	Charlotte, Mecklenburg
Safety-Kleen	Raleigh, Wake
Safety-Kleen Systems	St. Pauls, Robeson
Simputer (USA)	Charlotte, Mecklenburg
Southern Resources, Inc.	Charlotte, Mecklenburg
Synergy Recycling, LLC	Mayodan, Rockingham
Teaming for Technology	Morrisville, Wake
Triangle Recycling Services	Wendell, Wake
TWC Inc.	Charlotte, Mecklenburg
Warehouse PC	Benson, Johnston
Waste Management, Inc.	Morrisville, Wake
Wesbell Asset Recovery Center, Inc.	Durham, Durham

North Carolina generates an enormous amount of computer waste but the rate of computer waste recycling is no where near the quantity of waste generated. Out of the 669,862 computer waste in 2000, only 50,641 were recycled. This constituted just about 7.6% of the waste. The situation was even worse in 2005 because whereas the waste computers rose by 113.3% to

1,429,082, recycling increased by just 6.7% to 54,019 (Fig 4.3a). The average number of computers recycled per county for 2000 and 2005 were 513 and 539. Table 4.3b represents the descriptive statistics for computers recycled.

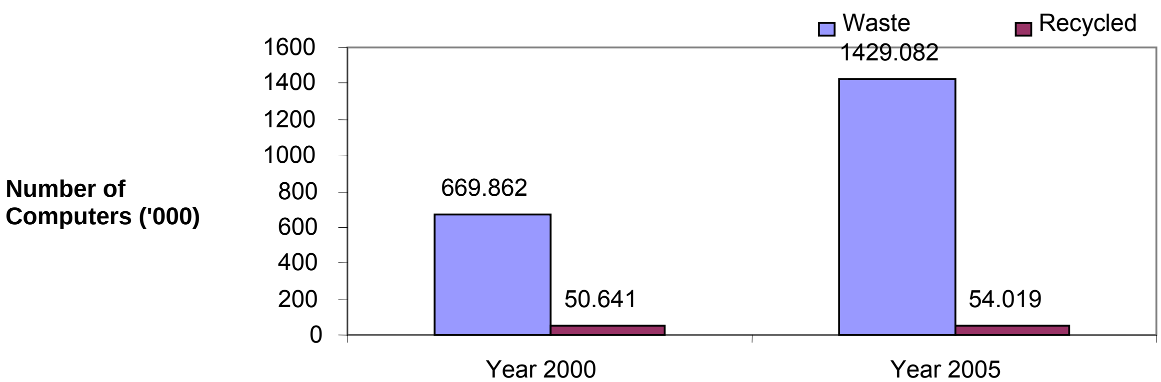

Figure 4.3a: Computers and the Portion Recycled (2000 and 2005)

Table 4.3b: Descriptive Statistics for Computers Recycled (2000 – 2005)

Computers	Recycled	Mean	Std. Deviation
2000	50641	513	863
2005	54015	539	920

The quantities of computer waste recycled by individual counties did not change much between 2000 and 2005. 37 and 36 counties recycled up to 200 computers in 2000 and 2005 respectively. 17 and 20 counties recycled between 401 and 800 computers. Figure 4.3b illustrates the distribution of computer waste recycled for the two periods. This confirms the fact that recycling is rarely selected by households as a means of disposal (Karen and Jhih-Shyang, 2003).

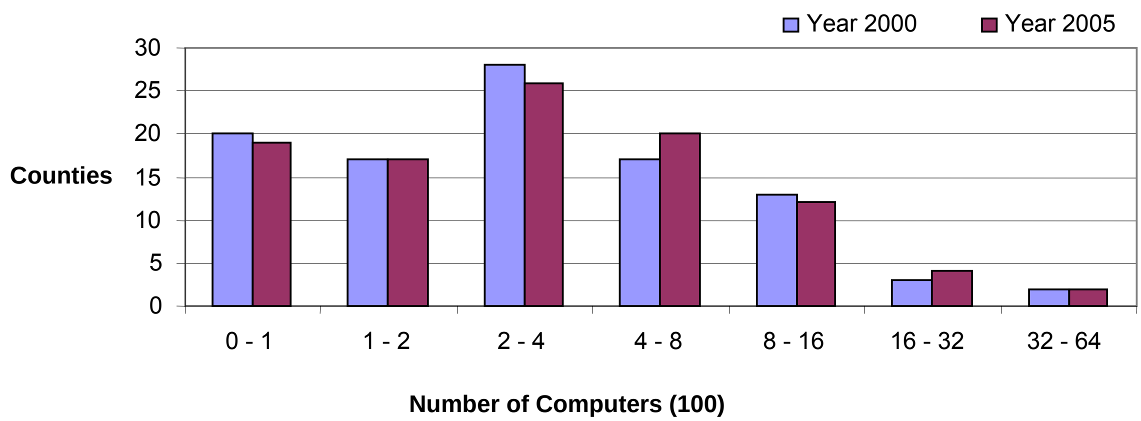

Figure 4.3b: Distribution of Counties in Computers Recycled (2000 – 2005)

Also there are not many comprehensive county recycling programs to well manage the large number of computers which reach the end of their life yearly in the state (Hickman, 2002). Storage is always expensive for apartment dwellers and therefore they will always resort to the cheapest means of disposing of their waste computer. However, for house dwellers storage is the cheapest and therefore even if there is no price for disposal, they will resort to storage (Shoenung and Kang, 2005).

The house bill (H1765), which will ban e-waste landfilling will go into effect in 2009. This will reduce the health effects associated with landfilling computer waste and increase the rate of recycling. This bill requires the state to advance its recycling capacity and collection programs. However, there is the potential for an increase in the cost of disposal to consumers and county budgets because more infrastructures will be required to handle the increase.

The spatial distribution of computer waste recycled in the state for 2000 and 2005 are represented by Figures 4.3c and 4.3d. Durham, Craven, Onslow and Nash counties stands out in the quantity of household computer waste recycled. The north east and south western portions of the state dominate in recycling both in 2000 and 2005. The coastal areas have moderately high computer waste recycling rate followed by the mid-south. Davidson, Rowan and Davie counties are neighbors and they fall in the same category in terns of quantity of household computer waste recycled for both years but they did not have the same waste recycled for the two years. Durham County recycled more household computers than the rest of the counties in the RTP area. Wake and Chatham counties falls within the range of 0.01.The counties at the central portion of the state have a relatively less computers recycled for both years.

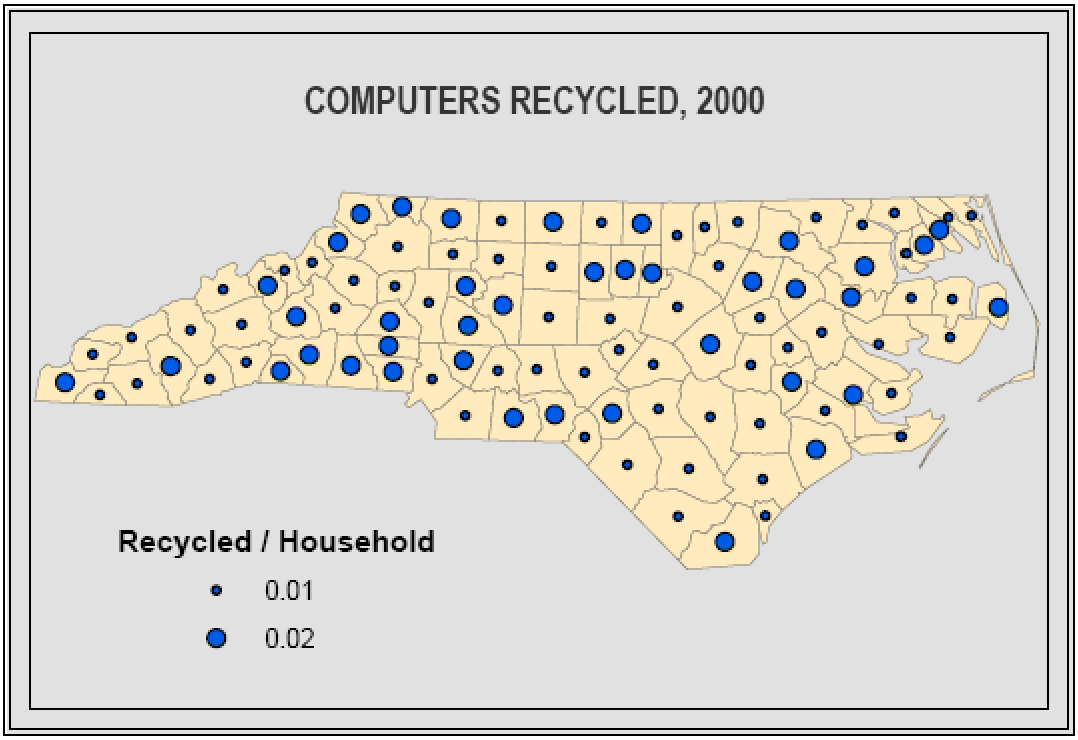

Figure 4.3c: Total Household Computers Recycled in 2000

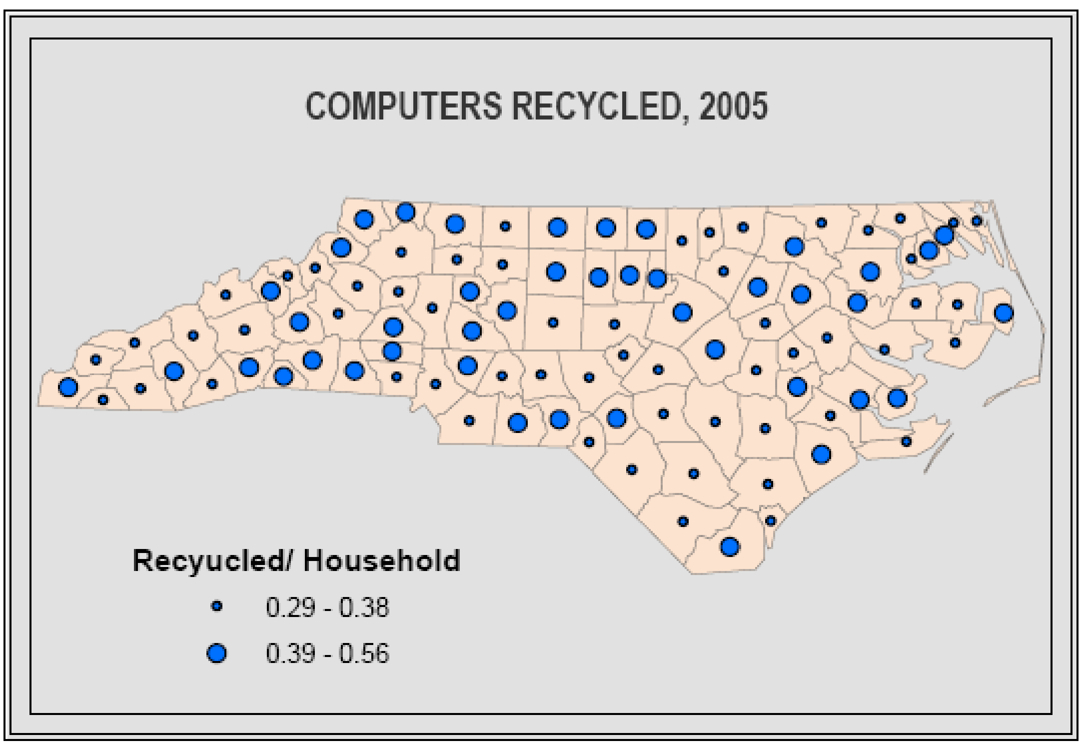

Figure 4.3d: Total Household Computers Recycled in 2005

The average number of computers recycled per household in North Carolina did not change between 2000 and 2005. It was 0.061 in 2000 and 0.062 in 2005 (Table 4.3c). There was therefore no significant difference in the quantity of computers recycled between those years. Recycling behavior of consumers is controlled by having appropriate opportunities and knowledge to recycle (SVTC, 2004). Some researches have indicated that consumers' recycling attitudes depends on age, gender, income, education, and ideology (Darby and Obara, 2005). USEPA reports that about 80% of consumers are willing to pay a fee less than $5 to recycle their electronics (USEPA, 2000). Any charge beyond the $5 will force people to resort to other means of disposal.

Table 4.3c: Computer Waste per Household

State	**Households**		**Number of Waste**		**Waste/Household**	
	2000	2005	2000	2005	2000	2005
N. C.	3132013	3355600	669862	1429082	0.061	0.062

Percent Change in Computers Recycled

Eighteen counties recycled fewer computers than they did in 2000, 74 counties recycled a little over 60 more computers, and 4 recycled under 200 more. This is a clear indication that the state did not increase its recycling in computers. Only three states increased the computers they recycled to between

300 and 500. If this increase is compared with the projected waste then it can be said that the state is under recycling. Figure 4.3e illustrates the difference between 2000 and 2005.

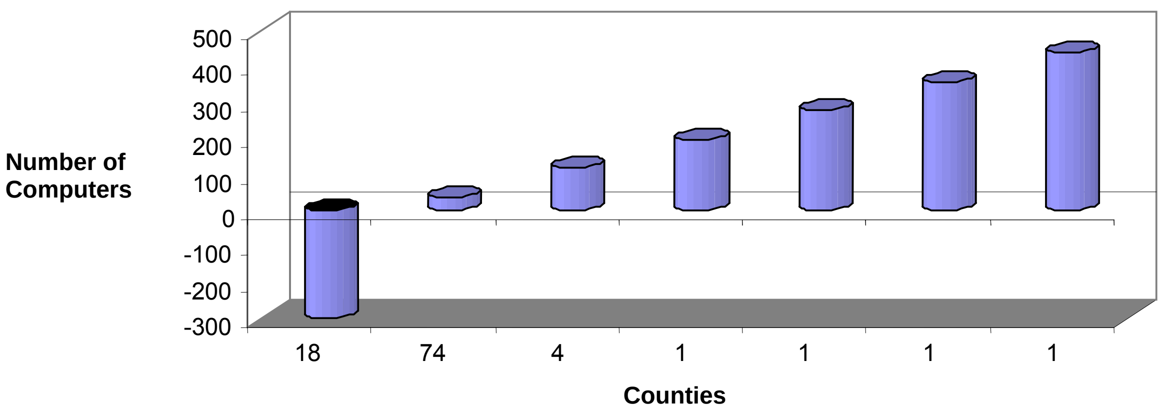

Figure 4.3e: Change in Computers Recycled between 2000 and 2005

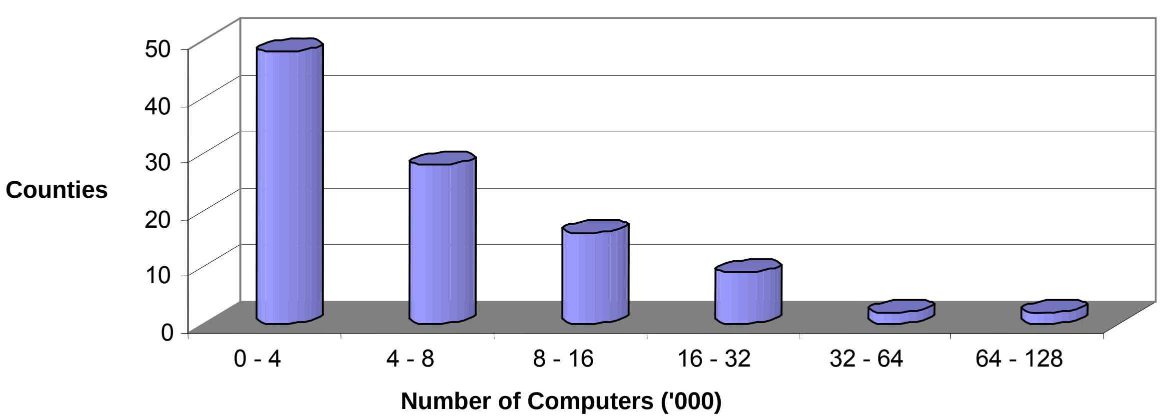

Figure 4.3f: Change in Computers from 2000 to 2005

Within those same years, the quantity of computers and the estimated waste increased drastically (Table 3a). Forty-eight counties gained up to 4,000 more computers. Twenty-eight counties increased their computer stock by up to 8,000. Four counties gained as many as between 64,000 to 128,000 (Fig. 4.3f).

The waste increase over this same period followed the same trend as the total computers. This makes sense because consumers tend to retire their old computer when a new one is acquired (Figure 4.3g). Fifty four counties increased their waste to about 4,000 whilst 20 gained between 4,000 and 8,000 waste computers. Three counties gained as many as between 64,000 to 128,000. This is very close to the number of counties which increased their total computers by the same margin (Figure 4.1b).

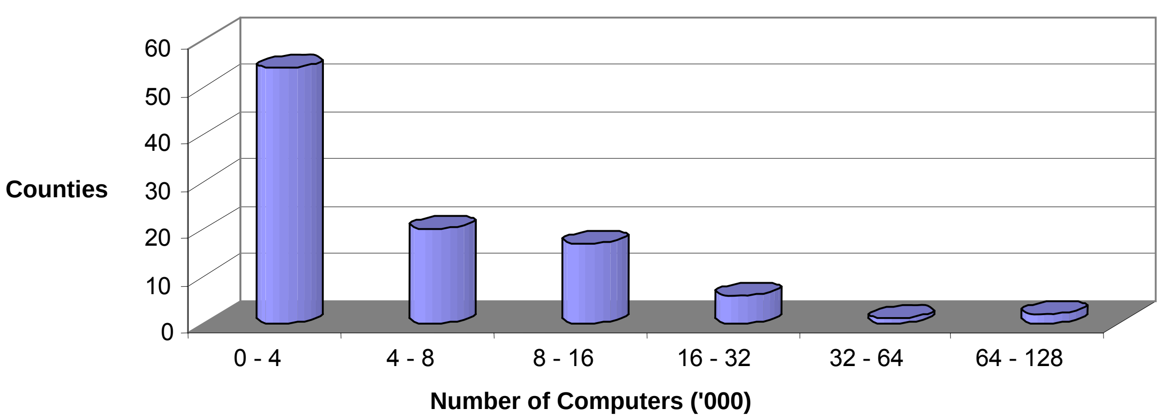

Fig. 4.3g: Computer Waste Change between 2000 and 2005

Relationship between Recycling and Some Selected Socio-Economic Indicators

There is a direct relationship between a counties percent urban / rural, population within the age groups 18 – 34, People with high school education and recycling (Table 4.3d). The relationship between the old age (35 – 75) and recycling for both years were rather negative. This indicates that whilst the likelihood of recycling waste computers increases with increasing age within the young age group, that of the older population decreases with increasing age within their group. However, the likelihood of computer waste recycling decreased in 2005 for both age groups. Also urban populations are more likely than their rural counterparts to choose recycling to dispose off their waste computers. This direct relationship between the population living in urban centers and recycling can be explained by the fact that there are more recycling programs in the urban areas and therefore more waste computers are collected. The correlation coefficient for recycling and a county's percent urban was not reported because it is the direct opposite of the urban coefficient with a p-value of 0.0001. People with high school diploma or higher education have a medium probability of disposing of their unwanted computers through recycling.

Table 4.3d: Correlation of Computers Recycled and Some Selected Socio-Economic Indicators

Recycled / Socio-Economic Indicators	Correlation	p-value
Recycled and % of people Aged 18 – 34, 2000	0.40916	0.0001
Recycled and % of people Aged 35 – 75, 2000	-0.38117	0.0001
Recycled and % of people Aged 18 – 34, 2005	0.26638	0.0074
Recycled and % of people Aged 35 – 75, 2005	-0.34736	0.0004
Recycled and % of higher education, 2000	0.29727	0.0027
Recycled and County's population percent urban, 2000	0.62336	0.0001

State Legislation and Collection Programs

The first county in NC to offer curbside pickup of discarded computers for recycling was Cary (www.townofcary.org). Other local governments in the state later realized the seriousness of the problem of waste computers and subsequently came out with various programs to tackle the problem. Legislations were proposed to handle the issue at the state level. However, the house bill (H1765) which seeks to tackle this problem has a long way to go. The bill imposes a ban on incinerating and landfilling of electronic products by 2009 (Electronic Recycling Act of 2005). It must be said that North Carolina is far behind in this respect because California, Minnesota, Maine, and Massachusetts have advanced legislations.

The bill requires manufacturers who sell their products in North Carolina to develop product management plans approved by the state department. Notice prohibiting the disposal of electronic products in landfills and incinerators shall accompany electronic product sold in the state. It also requires manufacturers to provide a 1-800 number and a website to educate customers about disposal options. Manufacturers who fail to prepare a plan will be required to pay a privilege tax, which will be equal to one percent of the retail cost to state coffers. The proceeds from the tax will be held in an electronic recycling account for onward disbursement through local governments for recycling programs. Recyclers who qualify for the fund shall be paid ten dollars per device recycled and cannot charge customers any additional fee (Electronic Recycling Act of 2005). The ten dollars is believed to be enough to make for the cost of processing (“*Recycling Fee”*, 2002).

Computer recycling is quite young in the state of North Carolina and there is the need for it to be expanded. Many people have little knowledge about computer recycling and as a result there is a high rate of waste computer storage among residents because they do not know what to do with them. Others prefer to get rid of them in dumpsters (Darby and Obara, 2005).

To effectively recycle all the waste computers in the state, there should be adequate recyclers and collection programs to enable the waste to move from consumers to recyclers. Market should also be created for the redeemed materials and there should be the establishment of funding programs for recyclers to make recycling an attractive business. Several collection programs exist in the sate to harness the computer waste but they are either not well known to consumers or under utilized (USEPA, 2000).

The well known collection programs for computer waste are consumer-drop-off and manufacturer-pick-up. Consumer-drop-off requires a permanent or temporal site where consumers can send their waste. Wake County has a permanent drop-off site where residents send their waste anytime at no charge. However businesses are charged a token of five dollars per monitor (Hickman, 2002). Pick-up on the other hand does not require a permanent site. The collector sends all waste to a transfer post and then to the final point. Collection programs can either be organized by city governments, recyclers, manufacturers, or nonprofit organizations. The most effective collection approach is special drop of events which are usually organized at the weekends, where consumers are encouraged to bring their computer waste. Such programs bring together experts from the repair and recycling industries to ensure proper sorting of good reusable ones from the bad. These events are held at anywhere provided it is well advertised and organized (USEPA, 2000). Special collection events yields more waste than permanent drop-offs because it attracts high participation. For instance, the Office of Waste Reduction and Recycling (OWRR) at UNCG collaborated with businesses and the local governments to hold a one day e-waste collection event in 2005. The program was a success they collected more than ninety thousand (90,000) pounds of materials (Campus Ecology year book, 2005). Cabarrus County, after successfully holding a no charge collection event, also tried a fee of between five dollars per monitor to twenty three cents per pound for large monitors which was a success (Hickman, 2002). This charge was within the range of USEPA's reported amount that consumers are willing to sacrifice for recycling. Free collection event needs to be frequent to collect all stored computer waste. One advantage of special event is that everything happens in a day or two and more than enough waste is collected for recycling rather than recyclers having to wait for a certain quantity of waste to be gathered before recycling. Recyclers' individual programs, charity parties and solid waste howlers also organize collection programs (Northeast Recycling Council Inc., 2002). The computer maker HP in conjunction with Recycling Industry in Greensboro carried out a one day collection in February 2007.

The cost of collection and shipment of computer wastes to the right place for recycling is the most expensive part of the whole operation. This explains why special collection events are not organized very frequently as they should (Loun and Stuart, 2002). It accounts for almost eighty percent (80%) of the total cost of recycling (Smith and Hainault, 2000). This is made up of payments to drivers, advertisers and packagers. The cost drops drastically if there are more volunteers to handle the shipment during special events. There is also less cost if customers drop-off their waste at the recyclers' site.

Other collection approaches are curbside collection, and point of purchase collection. The curb side approach works like the municipal solid waste collection system. Consumers bring their junk computer to curb side for a truck to pick it up. The city of Raleigh provides curbside collection by appointment for residents (Hickman, 2002). There is also the point of purchase collection. Retailers of computers serve as collection agencies where consumers bring in their old unwanted computer when they purchase a new one. This option can either be permanent or temporal. It works well when manufacturers fund the program through discounts to retailers if they collect certain amount of waste. This will ensure that managers encourage their sales representatives to convince customers to bring their old junk computer. Consumers will also participate fully if they also receive a discount on the new computer.

Some manufacturers have empowered some recyclers to collect their brand of computers for recycling. These manufacturers include IBM, Dell, Compaq, and HP (Environmental and Plastics Industry Council, 2003). For instance Compaq has authorized United Recycling in Western Chicago, IL to collect and recycle their brands of computer waste (United Recycling, 2006)

Of all the above collection options, the most cost effective in terms of percent per participant is the retailer special drop-off event (Smith and Hainault, 2000). Curbside collection is the most convenient to customers but the operational cost is high. When the various collection methods are arranged according to their frequency of use, permanent drop-of point is first followed by special drop-of events and curbside pick-up. This has a direct relationship with the cost of the method. That is the higher the cost the less it is used (IAER, 2003)

CHAPTER V

CONCLUSIONS

Computer waste is an emerging issue which is driven by the increasing technological changes. Levels of production, consumption, and recycling have resulted in large flow of toxic and valuable resources into parts of the environment where they are not needed. North Carolina had about 3,349,312 projected computers in 2000 which increased by about 28% to 4,287,248 in 2005. All counties increased their computer stock. The average number of computers per county in 2000 was 33,960. This increased to 42,829 in 2000 indicating an increase of 26%. Households on the other hand increased by just 7% from 3,132,000 in 2000 to 3,356,000 in 2005. The average number of computers per household did not change within those two years. It was 1.0 in 2000 and 1.3 in 2005.

The two counties which occupied the topmost position in terms of computer ownership in both 2000 and 2005 were Mecklenburg and wake counties. Mecklenburg County's computer stock was 377,413 in 2000 and 484,429 in 2005. Wake County had 363,227 and 471,704 computers in 2000 and 2005 respectively. Tyrrell County had the lowest number of computers in the state. It had 1,077 computers in 2000 and 1,490 in 2005. Although all counties gained computers, the maximum gains were at the rural counties. Gates, Camden, and Currituck counties, which are mainly rural, gained 66.1%, 52.1%, and 47.0% respectively. Dare County was the only county among the top seven gainers which is 69% urban. Transylvania county gained only 17% computers which happened to be the states lowest. Rural counties tool in more computers than their urban counterparts. The North eastern and western portions of the state had low computer ownership. The central portion was high in computer ownership. The northern and southern sections fell within the medium category. The trend in 2000 changed in 2005 to low at the north-east and the west. With the exception of some few scattered counties at the northern and southern portions which were medium, all the others had high computer ownership.

The projected computer waste in the state increased from 669,862 in 2000 to 1,429,082 in 2005. This is an increase of 113.3%. All counties doubled their stock of computer waste between 2000 and 2005. The average computer waste per county was 6,792 in 2000 and 14,271 in 2005. Wake, Mecklenburg, and Guilford counties stocked the most computer waste. Guilford County's projected waste was 39,235 in 2000 but went to 78,923. Mecklenburg County increased its computer waste from 75,482 in 2000 to 161,476 in 2005. The two counties which gained most computer waste were Camden and Currituck. Their respective percentage gains were 153.8 and 145.2. The western tip and north-eastern sections of the state had less computer waste in 2000. Greater portion of the central part had medium waste. This trend continued in 2005 though some few counties in the south changed their category.

The state recycled only a small portion of the projected computer waste. Only 50,641 computers were recycled in 2000 which is about 7.6% of the projected waste that year. In 2005, computers recycled did not increase much, only 54,019 computers were recycled. Rural counties recycled much less computers compared to the urban areas. The mean computers recycled per county for the two years were 513 and 539. Eighteen counties recycled 300 waste computers less in 2005 than in 2000. Apart from the middle portion of the state and the counties at the Mecklenburg area, all the counties fell under the medium to low levels of recycling category in 2000 and 2005.

There was no difference between older people (age 35 – 75) younger people (age 18 – 34) in their computer recycling habits in 2000 and 2005. However, both age groups increased their recycling habits in 2005. This was due to awareness programs that are being organized by counties. Urban folks are more likely to recycle their waste computers than the rural folks. In the same vein, higher education (high school diploma or higher) is a significant indicator as to whether a person will decide to choose recycling for their waste computers or not.

Toxins such as lead, mercury, cadmium and PVCs are common in landfills in North Carolina as a result of lack of appropriate control of domestic computer waste. Regulations developed by the state which aims at reducing the environmental impact of computer waste, is not yet in full implementation. However, the introduction of education and collection programs by various counties is advancing an elaborate management system. This is transforming perceptions about how computers should be handled. Also there are campaigns for developers to rethink their design to facilitate recycling so that computers do not end up in the landfill or incinerated. Although the awareness is being created, there are many obstacles which make tackling the problem of end-of-life computers very slow and challenging.

Lack of reliable data is a challenge to policy makers in their quest to design a management strategy to handle the issue. The computer ownership and projected waste increased very much between 2000 and 2005 but the number of computers recycled in those two years was very low. Infrastructures are also lacking in the formal and informal sector to effectively recycle all computer waste in the state. This is the major reason why the state performed poorly in computer waste recycling in 2000 and 2005. Lack of state standards for domestic computer waste regulation has resulted in the counties embarking on their own programs to stem the situation. North Carolina needs to develop expertise in the collection and recycling sectors to better manage the increasing computer waste problem. This can be done by taping from other states which have advanced in this field. Partnership with other states and manufacturers will help in the development of a comprehensive computer waste management program that will benefit all parties. It is important that the house bill (H1765) carries with it a very stern punishment for violators when it comes into full force. Apartment managers can play a key role in the collection of the computer waste at their premises. This they can do by ensuring that tenants treat computer waste as a hazardous waste which needs careful handling. Facilities can be provided in apartment complexes by apartment managers to collect computer waste from residents for recycling. Recyclers can then be assigned to these facilities to recycle the waste computers. This will ensure a high collection and recycling rate in the state. Assigned recyclers will bill the apartment managers for the recycling which will then be passed on to tenants. This will go a long way to reduce the problem and also ensure that the house bill is effective.

Recommendations for Further Study

The greater portion of the data for the study was based on estimates due to the unavailability of collected data. It is therefore important for a proper survey to be conducted to acquire data on the stock of computers in the state and also the number of waste computers sitting in people's storages. In addition, data should be established for the preferred means of residents to dispose of their waste computers. This research can therefore be repeated using the true acquired data. The cell phones waste is another category of the electronic waste which needs to be studied to determine its contribution to the environmental damage.

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