# ELECTRONICS WASTE MANAGEMENT IN THE UNITED STATES

## *APPROACH 1*

Final

July, 2008

EPA530-R-08-009

Office of Solid Waste
U.S. Environmental Protection Agency
Washington, DC

## ACKNOWLEDGEMENTS

This Report is based on analyses prepared under contract for the Office of Solid Waste by Eastern Research Group, Inc of Lexington, MA. The Office of Solid Waste would like to thank especially Lynn Knight and Shelly Schneider for their assistance in developing the model upon which this report is based. This Office would also like to thank Robin Ingenthron of American Retroworks Inc., Good Point Recycling and the World Reuse, Repair and Recycling Association for his assistance on the end markets discussion.

# TABLE OF CONTENTS

## 1.0 Introduction

EPA has been helping to improve the management of used and end-of-life (EOL) electronics for over a decade. EPA promotes the reuse and recycling of used and EOL electronics through various programs, including Plug-In To eCycling and the Federal Electronics Challenge. Although electronics currently represent less than two percent of the municipal solid waste stream, EPA's interest in used and EOL electronics stems from three primary concerns:

1) rapid growth and change in this product sector, leading to a constant stream of new product offerings and a wide array of obsolete products needing appropriate management;
2) the presence of toxic substances in many products which can cause problematic exposures during recycling or disposal, if these products are not properly managed; and
3) the need for widespread, convenient and affordable opportunities to reuse/recycle electronics (with initial emphasis on TVs, PCs and cell phones). Reuse and recovery of electronics conserves energy and materials embodied in used electronics and reduces the environmental impact of these products.

Policymakers at the Federal, state and local levels, as well as manufacturers, retailers, recyclers, non-governmental organizations (NGOs) and many others are interested in updated national estimates of how many TVs, PCs, cell phones and other common electronic products are in storage, recycled, or disposed. In 1999, the National Safety Council issued the first large-scale survey and analysis of electronic product recycling and reuse in the United States[1]. However, since that time, consumption and disposal, as well as reuse and recycling of electronics in the US have continued to mount along with the need for updated data.

The International Association of Electronics Recyclers publishes a comprehensive triennial report on the state of the electronics recycling industry in the US. This report surveys "all electronics" that are recycled by the electronics recycling industry. Its estimates of recycling include consumer electronics and electronic equipment from industry and manufacturers (including medical equipment, robotics systems, movie production equipment), and therefore do not highlight information specific to the products that are the subject of our analysis.

In response to stakeholder requests for detailed examination of the sales and management of the electronics most commonly addressed by community collection programs and state recycling legislation, EPA took a closer look at this issue. The results are detailed in two reports: *"Electronics Waste Management in the United States: **Approach One**"* [2] and

[1] The NSC survey covered the years 1997 and 1998 and included the following electronic products: desktop computers, mainframe computers, workstation computers, portable computers, CRT monitors, computer peripherals, telecommunications equipment, and CRT TVs.

[2] US EPA. *"Electronics Waste Management in the United States: **Approach One**."* Final July 2008. EPA530-R-08-009. (The report was originally released as draft final in April 2007.)

"*Management of Electronic Waste in the United States: **Approach Two.***"[3] Some newer information has been included in this final version of Approach One. The document, "*Fact Sheet: Management of Electronic Waste in the United States,"* summarizes the methodologies used in each approach and highlights the major findings.[4] Both reports contribute to the information base on electronics generation and management in the US and, hopefully, will aid strategic and policy considerations aimed at providing national, regional, or local solutions to this prominent issue.

Readers should consider the information presented in this report a "snapshot" of electronics waste generation and management in the United States in recent years. As products, usage patterns and EOL management options change over time, purchase, storage, and end-of-life disposition patterns will also change.

### *1.1 Objectives and Scope*

In pursuing activities related to EOL electronics, information regarding the amount of material potentially in need of EOL management needs to be up-dated periodically. This report presents a compilation and assessment of data to establish a baseline of knowledge that can be built upon as the nation moves forward in managing electronics. The scope of products covered in this report includes:

- Personal computers (PCs), including desktops, portables, and computer monitors
- Televisions
- Hard copy computer peripherals, including printers, scanners, and fax machines
- Computer mice and keyboards
- Cell phones

These products were chosen because they make up the majority of the electronic products collected and have been the focus of electronics recycling initiatives at the federal, state, and local level. This analysis includes products from all sectors of the economy (i.e., residential, commercial, and institutional).

The objectives of this study are to:

- Estimate the number and weight of products that will become obsolete and need EOL management annually.
- Estimate what portion of EOL electronic products are recycled versus disposed.
- Estimate how much material that is ready for EOL management may be in storage.

[3] US EPA. "*Management of Electronic Waste in the United States: **Approach Two**.*" Draft Final April 2007. EPA530-R-07-004b.
[4] US EPA. "*Fact Sheet: Management of Electronic Waste in the United States.*" November 2007. EPA530-D-07-002.

- Examine the collection rates experienced by existing electronics recycling programs as an indicator of the amount of material that is, on a practical basis, available for recycling.
- Examine the current situation regarding the end markets for TV and CRT monitors collected for recycling.

### *1.2 Overview of Methodology*

This study relies primarily on market research data regarding sales of electronic products. It then applies these sales data to some of the most comprehensive collection information available to estimate product life spans and the amounts of particular products that are ready for EOL management. From these EOL estimates, the estimated quantity recycled was subtracted to yield the quantity disposed. This approach also provides information on the export of CRT monitors and TVs, as well as the amount of selected electronics cumulatively in storage. The original Approach One report, published in April 2007 as a draft final, included EOL management estimates through 2006. This updated report provides EOL management estimates through 2007. Revisions were made to historical industry sales and recycling data. However, the underlying model calculations remain unchanged from the original version. Specific changes are highlighted within the body of this report.

The estimates developed in this report are based on several sources of data. Sales data are based primarily on industry data on product sales. In addition, this report relies on data from the Florida Department of Environmental Protection and other state data, as well as data bases developed by EPA for the publication of the report *Municipal Solid Waste in the United States: 2006 Facts and Figures.*

The pattern of product use forms the methodological framework used in this study. This pattern begins at the point the product is purchased and ends with its final disposition. Figure 1.1 depicts the framework used in this analysis. As shown in the figure, the first phase of a product's life begins with the purchaser or "first user" of the product. After the first use is Phase 2, in which the product may be given or sold to someone else for reuse, be stored (e.g., in a closet or basement) for a period of time, or undergo some combination of reuse and storage. Phase 2 may include the transfer of the product from one person to another, either as a gift or a sale, but only if this transfer is from individual to individual as opposed to involving a third party, such as an electronics recycler, broker, or donation organization. Phase 3 is the point at which the last user is ready to remove the product from a private home or business. This change can result from the desire to replace or otherwise stop using the product or the desire to remove the product from storage. It is at this point that we state that the product is ready for EOL management and it is transferred to a third party, such as a recycler or donation organization, or it is disposed. Once the product is in the hands of a recycler, the product may be sold for reuse "as is" or after some refurbishment. The resale may occur domestically or by firms outside the United States. Electronic devices that are not candidates for resale are dismantled or shredded, and the resulting material is separated into secondary material streams and recovered. Recovered materials from the recycling

process are used to make new products, and the residuals of the processing stage are disposed of in a landfill or incinerator. Material recovery may occur domestically or abroad.

This report quantifies the number and weight of products that correspond to each phase of the products lifecycle as illustrated in Figure 1.1. For Phase 1, we assembled product sales data, as well as data on the average weight of products by year. We then developed assumptions regarding how long Phases 1 and 2 would last. Since the life spans of different types of products vary, unique life span assumptions were made for each type of product. For example, televisions are typically kept longer than computers. Combining the product sales and weight data, and applying the life span assumptions, we used a spreadsheet model to predict the number and corresponding weight of material that would become ready for EOL management each year. The model considered product sales from 1980 through 2007, and predicted the annual quantity needing EOL management through 2007.

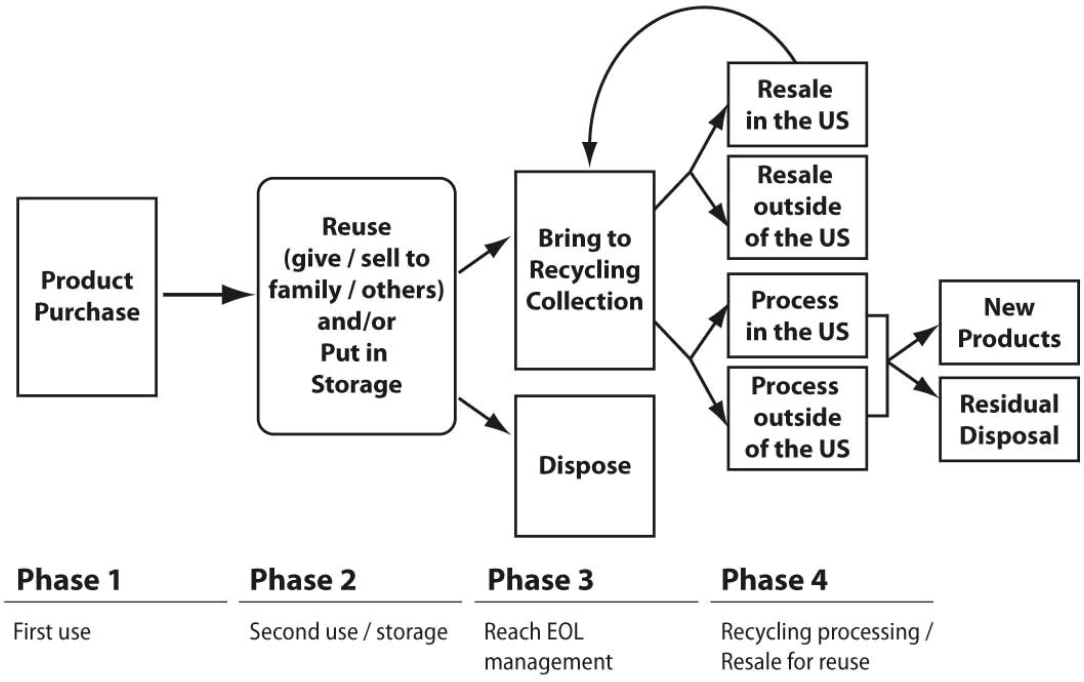



Figure 1.1 Framework for Modeling the Product Lifecycle

Having estimated the annual quantities of EOL products needing management, we examined how much material has been recycled in recent years by the electronics recycling industry. We then calculated the amount potentially being disposed of by finding the difference between what is generated for management and what is collected for recycling on an annual basis. More detail on data and the assumptions used is provided in Section 2.0. The organization of the report is described below.

### *1.3 Organization of the Report*

Section 2.0 provides a description of the data and assumptions used to develop estimates of the number of products ready for EOL management annually. We quantified the number of products sold historically by collecting data on product sales. (See Section 2.1 for more detail.) We then developed assumptions regarding the time for which the product is used before it reaches EOL management. (Section 2.2 describes this methodology.) The methodology used to estimate average product weights is described in Section 2.3.

Section 3.1 presents the results of the modeling conducted and estimates when and what volume of products are ready for EOL management on an annual basis (estimates for 1999 through 2007 are presented). The estimates regarding the portion that is collected for recycling and disposal are described in Section 3.2. Estimates of the number and weight of products that might be in storage at a given point in time are presented in Section 3.3.

In theory, all of the material that is in storage is ready for EOL management. In practice, however, product users are ready for EOL management at different times. Some may choose to hold onto products that have some perceived value to them. The distinction between theoretical and practical EOL management is discussed in Section 4.0. Section 5.0 presents an analysis of the EOL management of CRTs to assess what portion collected in the United States is managed domestically versus abroad. Finally, Section 6.0 summarizes the results and conclusions reached.

## 2.0 Data and Assumptions in the Model

### *2.1 Historic Sales Data: Televisions, Cell Phones, and Personal Computer Products*

The sales of televisions, cell phones, and personal computer products form the basis for estimating the number and weight of products within the scope of this report requiring EOL management at some point in the future. Historic sales data from industry sources was the primary source (supplemented where necessary by government statistics from the U.S. Census Bureau and the U.S. International Trade Commission). The following is a discussion of data sources for each product type.

The market research firm, IDC, provided sales data on desktop and portable computers, CRT and flat panel computer monitors, as well as hard copy peripherals.[5] Hard copy peripherals include printers, multi-function printers, faxes, and other devices. The availability of industry data was important, especially for computer product sales. The sales estimates of personal computers based solely on the Census and Trade Commission data would not have accounted for the sale of "white box" products—generic computers with no brand names, manufactured by vendors that purchase components. It is widely accepted that white box sales account for a substantial portion of total U.S. consumption. In a 2004 press release, IDC stated that the white box market share in the personal computer sector is about 28 to 30 percent in the United States.[6] In addition, Census and trade data were not available for faxes and some other hard copy peripheral devices.

Sales of personal computer monitors (prior to 2005), mouse devices, and keyboards were derived by analyzing Federal government statistics. In this latter case, we developed sales estimates by calculating what is referred to in this study as "apparent consumption," which represents products sold in the United States for use in the United States. Apparent consumption was estimated using the following formula:

Apparent consumption = U.S. shipments - domestic exports + imports for consumption

The U.S. Census Bureau's Current Industrial Reports (CIRs) show U.S. shipments, as well as domestic exports and imports for consumption. However, the export and import data are shown as combined categories, which would not allow us to develop totals by product type. Therefore, to better account for the export and imports we used the U.S. International Trade Commission (USITC) interactive database.[7]

[5] The original baseline report published in April 2007, used U.S. Census data to represent personal computer monitors. This updated version replaced 2004 - 2007 Census data for personal computer CRTs and 2005 - 2007 flat panel monitors with IDC market data. Census data for personal computer flat panel monitor used in the original report were revised downward from 1997 through 2004 after discussions with IDC staff to eliminate non-computer related monitors, for example, those used in cash register applications.
[6] Halperin, David, Mac News World. *The Secret Market Contender: White-Box PCs.* Technology Special Report. May 1, 2004. www.TechNewsWorld.com.
[7] The source cited by the Census Bureau for exports was the Harmonized Systembased Schedule B; for imports the Harmonized Tariff Schedule (HTS) was cited. The USITC data are also based on the HTS.

Television sales data were supplied by the Consumer Electronics Association. Cell phone sales data were based on a combination of Consumer Electronics Association data on consumer sales (1984 through 1994), total cell phone sales as reported by Inform (1995 through 2003)[8] and IDC market data on cell phone sales (2004 through 2007).

TV and cell phone sales are shown in Table 2.1. Table 2.2 shows the U.S. sales data for computer-related equipment by product type and year.

[8] Inform, Inc., *Waste in a Wireless World: The Challenge of Cell Phones*, 2001. In this report, Inform published total cell phone sales figures for 1995 through 2003. Sales prior to 1995 were interpolated based on the annual growth rate in prior years as exhibited by the CEA data. Sales after 2003 were supplied by IDC.

## Table 2.1

**Historic Sales Data - Television and Cell Phone Products**
**(Million units)**

| Year | Color CRT <19" | Color CRT >19" | Flat Panel TVs | Color Projection | Monochrome | Total TVs | Cell Phones |
|---|---|---|---|---|---|---|---|
| 1980 | 5.4 | 5.4 | | | 6.7 | 17.6 | |
| 1981 | 5.6 | 5.6 | | | 5.7 | 16.8 | |
| 1982 | 5.7 | 5.7 | | | 5.7 | 17.1 | |
| 1983 | 7.0 | 7.0 | | | 5.7 | 19.7 | |
| 1984 | 8.0 | 8.0 | | 0.2 | 5.1 | 21.3 | 0.04 |
| 1985 | 8.4 | 8.4 | | 0.3 | 3.7 | 20.8 | 0.11 |
| 1986 | 9.1 | 9.1 | | 0.3 | 4.0 | 22.5 | 0.40 |
| 1987 | 9.7 | 9.7 | | 0.3 | 3.5 | 23.2 | 0.80 |
| 1988 | 10.1 | 10.1 | | 0.3 | 2.6 | 23.1 | 1.3 |
| 1989 | 10.9 | 10.9 | | 0.3 | 1.7 | 23.6 | 2.1 |
| 1990 | 10.4 | 10.4 | | 0.4 | 1.4 | 22.6 | 2.6 |
| 1991 | 9.4 | 10.7 | | 0.4 | 0.8 | 21.3 | 3.4 |
| 1992 | 9.7 | 12.3 | | 0.4 | 0.6 | 23.0 | 5.4 |
| 1993 | 10.6 | 14.0 | | 0.5 | 0.6 | 25.6 | 7.9 |
| 1994 | 11.7 | 15.0 | | 0.6 | 0.5 | 27.9 | 12.4 |
| 1995 | 10.8 | 14.6 | | 0.8 | 0.5 | 26.7 | 14.5 |
| 1996 | 10.1 | 14.5 | | 0.9 | 0.4 | 25.9 | 16.6 |
| 1997 | 9.6 | 14.0 | | 0.9 | 0.4 | 24.9 | 22.2 |
| 1998 | 10.3 | 15.1 | | 1.1 | 0.3 | 26.8 | 30.6 |
| 1999 | 11.2 | 16.4 | 0.002 | 1.3 | 0.3 | 29.3 | 49.3 |
| 2000 | 12.2 | 17.1 | 0.008 | 1.7 | 0.3 | 31.3 | 72.9 |
| 2001 | 9.8 | 16.4 | 0.1 | 2.0 | 0.3 | 28.4 | 100.1 |
| 2002 | 11.7 | 17.0 | 0.2 | 2.5 | 0.2 | 31.6 | 122.3 |
| 2003 | 8.3 | 17.6 | 1.0 | 2.7 | 0.2 | 29.7 | 140.0 |
| 2004 | 6.9 | 17.8 | 2.7 | 3.5 | 0.2 | 31.2 | 142.7 |
| 2005 | 5.4 | 16.7 | 5.7 | 3.0 | 0.1 | 31.0 | 150.0 |
| 2006 | 3.4 | 13.4 | 13.4 | 3.1 | 0.1 | 33.4 | 165.1 |
| 2007 | 2.1 | 4.2 | 20.3 | 2.0 | 0.0 | 28.6 | 181.9 |

Source: Data for TVs were obtained from Consumer Electronics Association Market Research. Data for cell phones were based on CEA data and sales data reported by Inform, Inc., *Waste in a Wireless World: The Challenge of Cell Phones, 2001* . Cell phone data from the Inform report for 1995 through 2003 were used. Sales prior to 1995 were interpolated based on the annual growth rate in prior years as exhibited by the CEA data. After 2003, cell phone data were provided by IDC.

## Table 2.2
### Historic Sales Data - Computer-Related Products
### (Million units)

| Year | Desktops | Portables | Hard Copy Peripherals | Mice | Keyboards | PC CRTs | PC Flat Panel |
|---|---|---|---|---|---|---|---|
| 1980 | 1.0 | | 0.5 | 1.0 | 1.0 | 1.0 | |
| 1981 | 2.0 | | 1.0 | 2.0 | 2.0 | 2.0 | |
| 1982 | 3.0 | | 1.6 | 3.0 | 3.0 | 3.0 | |
| 1983 | 5.5 | | 2.9 | 5.5 | 5.5 | 5.5 | |
| 1984 | 6.7 | | 3.5 | 6.7 | 6.7 | 6.7 | |
| 1985 | 5.8 | | 3.0 | 5.8 | 5.8 | 5.8 | |
| 1986 | 6.9 | | 3.6 | 6.9 | 6.9 | 6.9 | |
| 1987 | 8.2 | | 4.3 | 8.2 | 8.2 | 8.2 | |
| 1988 | 8.7 | | 4.6 | 8.7 | 8.7 | 8.7 | |
| 1989 | 8.9 | | 4.7 | 8.9 | 17.5 | 8.4 | 1.1 |
| 1990 | 9.5 | | 5.0 | 9.5 | 21.7 | 9.4 | 0.9 |
| 1991 | 9.5 | | 5.0 | 14.3 | 27.0 | 10.5 | 1.5 |
| 1992 | 9.9 | 1.9 | 6.2 | 20.9 | 37.6 | 13.4 | 1.7 |
| 1993 | 13.0 | 2.5 | 8.2 | 31.3 | 36.1 | 17.3 | 1.8 |
| 1994 | 15.3 | 3.2 | 9.7 | 39.7 | 41.4 | 18.1 | 2.8 |
| 1995 | 19.1 | 3.6 | 11.9 | 19.1 | 47.6 | 22.2 | 3.0 |
| 1996 | 22.4 | 4.9 | 14.9 | 22.4 | 53.8 | 23.1 | 2.3 |
| 1997 | 26.8 | 6.0 | 16.2 | 24.9 | 55.6 | 26.6 | 0.9 |
| 1998 | 32.5 | 6.4 | 22.5 | 27.9 | 65.0 | 32.6 | 1.5 |
| 1999 | 39.5 | 7.9 | 27.5 | 39.5 | 63.7 | 36.9 | 2.8 |
| 2000 | 40.8 | 9.6 | 28.7 | 56.2 | 51.7 | 37.5 | 4.8 |
| 2001 | 35.1 | 9.6 | 26.8 | 53.0 | 43.8 | 27.2 | 6.6 |
| 2002 | 35.1 | 10.9 | 28.7 | 57.5 | 48.6 | 23.3 | 11.7 |
| 2003 | 37.0 | 13.8 | 30.7 | 37.0 | 51.3 | 15.8 | 18.0 |
| 2004 | 39.4 | 16.6 | 32.2 | 39.4 | 47.2 | 13.9 | 22.7 |
| 2005 | 38.0 | 19.6 | 33.1 | 38.0 | 44.1 | 7.8 | 33.0 |
| 2006 | 35.4 | 24.3 | 34.3 | 35.4 | 44.6 | 3.5 | 38.6 |
| 2007 | 34.2 | 30.0 | 36.9 | 34.2 | 43.1 | 1.0 | 37.0 |

Note: Hard copy peripherals (HCPs) include printers, multifunction printers, digital copiers, and faxes.

Source: Data for 1980 - 2004 desktops and portable PCs, as well as 1997 - 2004 hard copy peripherals (HCPs) were obtained from IDC WW Quarterly PC Tracker in October 2005. Data for HCPs were estimated for 1980 - 1996 and 2005 - 2007 based on the ratio of HCPs to PCs. Data for 2005 - 2007 desktops and portable PCs were provided by IDC Data for flat panel PC monitors prior to 2005, CRT PC monitors prior to 2004, and all keyboards, were based on ERG analysis of US Census data on shipments and Trade Commission data on imports and exports. Data for flat panel PC monitors 2005 - 2007 and CRT PC monitors 2004 - 2007 were provided by IDC. Data for mice were based on ERG analysis of US Census data on shipments and Trade Commission data on imports and exports compared to desktop PC sales. Data prior to 1990 for mice and 1988 for CRT monitors and keyboards were estimated assuming one mouse, keyboard, or monitor per desktop PC.

## *2.2 Assumptions Regarding the Life Span of Electronic Products*

The life span—the time between the initial purchase of a product and the time it is ready for EOL management—is one of the most critical assumptions in this type of methodology. The total life span of any particular product will encompass several stages of use. The "first use" is the time period that the product was considered functional to the first purchaser. When the product ceases to be functional to the first user, the product may be put in storage, discarded or recycled. If it is in working order, however, it will most likely be reused by someone else. This is referred to as the "second use" stage. There are many combinations of use, reuse, and storage underlying the second use stage before the last user is ready for EOL management of the product.

### *Life Span of Televisions and Computer Products*

In the past, researchers have modeled the flow of products from purchase to EOL management by assuming a time period for each use stage (i.e., number of years for first use, second use, etc.). However, if the ultimate goal is to model when products are ready for EOL management, the pattern of use prior to EOL management is somewhat immaterial. For example, one product could be used initially for 3 years, reused for 2, and then put in a closet for 5, while a second product might be used initially for 5 years and reused for another 5 years. However, both products enter the EOL management stream after 10 years. Because our objective was to model when products will enter the EOL management stream, we examined the age distribution of the products being collected by electronics collection programs and used that as a proxy for both the first and second use stage that occurs prior to the EOL management stage. By using this approach, we assumed that the time and effort for any type of EOL management, either recycling or disposal, are roughly the same—that is, a comparable action is required to remove an unwanted product from a home or office whether it is recycled or disposed. We acknowledge that this may not be true in all cases, but in the absence of better data, we considered this a reasonable assumption.

The State of Florida has been providing grants to its counties for electronic collection programs since 2002. In 2004, the Florida DEP conducted a study in which the individual units in the loads from electronics collection programs were sorted and the product type, brand, weight, and age were recorded. These loads represent collections from residential and small business sources that are generally served by county recycling or thrift store donation services. The Florida counties did not charge a fee for recycling services, so fees were not an influence in people's decisions to participate in the collection program.

At the time of our original analysis, the data set from this project had information on 20,619 units collected in a 12-month period beginning April 2004. It contained the date of manufacture of each product if those data were easily identified. We analyzed these data to investigate the age distribution of each type of product collected. Out of 20,619 products collected, the vintage of 12,801 (62 percent) units was recorded. We calculated the age of the products by subtracting the date of collection from the date of manufacture.

Although we cannot represent with certainty that the Florida results are representative of the nation as a whole, it is the largest available data set that accounts for the age of the electronic products collected. The State of Minnesota also conducted a study of age, brand, and weight of about 1,000 electronic products collected at one 3-day collection event in September 2004. Statistical tests that were conducted (the Kolmogrov-Smirnov two-sample test) showed that the age distribution of the laptops and desktop computers collected in these two locations were not significantly different. This result does not allow us to conclude that the Florida data are representative of the nation, but at least we know that two states in different parts of the country did not exhibit significant differences in this regard.

Table 2.3 presents the general statistics for each product type from the Florida brand/vintage sort project at the time of the data analysis. The age distribution of selected product types is depicted graphically in Appendix A. These data give us insight into how long consumers and small businesses hold on to products before they bring them to available collection sites for EOL management. As already stated, this is a multiple-phase life span, which could include first use, second use, and storage. The Florida data show that the large majority of computer products that enter EOL management are over 5 years old and the average first use of computers is often cited as about 4 years.[9] Noting that the oldest TVs, desktop computers, and CRT monitors are around 30 years old, it is obvious that reuse/storage periods range widely from what might be considered short to very long term.

To develop the assumptions on the life span of products to use in the modeling effort, we examined the distributions and decided on an approach that would best represent the data for each individual product type. For most products, the life span assumptions are based on the medians of each of the quartiles. (For example, the "youngest" 25 percent of desktop computers are used for the length of time represented by the median of the 1st quartile; the next-youngest 25 percent are assumed to be used for the length of time represented by the median of the 2nd quartile; etc.) Thus, for most electronic products, there are four life span assumptions, one for each 25 percent of products sold in any given year.

For hard copy peripherals, we conducted statistical tests to determine whether or not the individual age distributions for printers, fax machines, multifunction devices, and scanners were similar. Using the Kruskal-Wallis Test, we found that there was no statistically significant difference in the age distribution among the four product types. Therefore, we combined the data for all hard copy peripherals and used the median of the four quartiles to represent the life spans of all these products.

For some products, such as laptop computers, keyboards, and LCD monitors, we took a different approach to best represent the data because there were relatively few observations in these data sets. In these cases, we used the mean or mode, or chose

[9] Matthew, H. Scott, Deanna H. Matthews. 2003. "Information Technology Products and the Environment." In: Kuehr, R. and Williams, E., Eds. 2003. *Computers and the Environment*. Dordrecht, The Netherlands: Kluwer Academic Publishers, pp. 41–72.

specific quartiles to represent the distribution. Table 2.4 lists the life span assumptions and basis for each product type.

We recognize that the Florida data represent product usage patterns of 2004, and that 5 or 10 years prior, people may have used products for longer or shorter periods of time. Usage patterns could have varied in the past based on changes in purchasing behaviors or changes in technology that may have influenced purchasing behavior. Due to data limitations, we assumed that usage patterns were not significantly different in the past and that they have not changed dramatically since 2004.

*Differences in Life Span Between the Residential and Commercial Sectors*

The Florida electronics collections data represents computer and TV products mainly from the residential sector. We assumed that the life spans exhibited for TVs in this data set were also appropriate for the commercial and institutional sectors. In other words, for each type of television technology (e.g., flat panel, projection, etc.), we assumed there is not a significant difference in patterns of use or upgrade cycles between residential and commercial TV users.[10]

For computers, however, we do believe there is a difference in usage patterns between sectors. We, therefore, developed separate lifespan assumptions for products used in the commercial/institutional sector. Due to data limitations on usage patterns in the non-residential sector, we relied on industry expert opinion. We assumed that 40 percent of businesses remove and manage their computers after 3 years (the midpoint between a 2 to 4 year replacement cycle), while 60 percent are on a 5-year cycle (the midpoint between a 3 to 7 year replacement cycle).[11,12] The 40 percent assumption is based on IAER reporting that about a third of the output of recycling operations is equipment for reuse.[13] In other words, 33 percent is suitable for resale "as is" or with some refurbishment. One would expect computer products to meet the criteria for resale "as is" only if they are relatively new, such as under 3 years old. A small portion of equipment collected by recyclers is from the residential sector, which tends to be older and unsuitable for reuse. To account for this, using professional judgment, we adjusted the 33 percent to 40 percent to account for the fact that the percentage suitable for reuse for just commercial equipment would likely be higher than the percentage for all sectors.

The share of computer product sales that are residential versus commercial is based on an analysis of IDC PC sales data for both sectors. An average of 48 percent residential and 52 percent commercial based on data from 1992 to 2004 was assumed. This assumption most likely overestimates the residential share of computer products in the early years of PC use. However, due to data limitations, we assumed a constant rate.

[10] Based on a phone conversation with Shawn DuBravac of the Consumer Electronics Association, 9/11/06.
[11] Lynch, Jim. 2004. "Islands in the Wastestream: Baseline Study of Noncommercial Computer Reuse in the United States," CompuMentor, Fall 2004.
[12] Based on a phone conversation with John Powers of the International Association of Electronics Recyclers, June 2, 2006.
[13] International Association of Electronics Recyclers, *IAER Electronics Recycling Industry Report, 2006.*

**Table 2.3. Florida Electronics Sort Project: Age Distribution By Product Type**

| Product Type | Observations With Data (Number) | Observations Missing Data (Number) | Percentile (%) | | | | Mean | Mode | Min. | Max. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 25th | 50th | 75th | 100th | | | | |
| Desktop | 1,912 | 2,222 | 8 | 12 | 16 | 27 | 12.2 | 8 | 1 | 27 |
| Laptop | 20 | 44 | 5 | 6 | 8 | 14 | 6.5 | 8 | 4 | 14 |
| Keyboard | 41 | 1,844 | 4 | 5 | 8 | 20 | 6.7 | 4 | 3 | 20 |
| Monitor (CRT) | 4,515 | 897 | 7 | 9 | 12 | 30 | 9.3 | 8 | 1 | 30 |
| Monitor (LCD) | 3 | 1 | 6 | 10 | 12 | 12 | 9.3 | N/A | 6 | 12 |
| Multifunction device | 30 | 46 | 7 | 9 | 11 | 17 | 9.5 | 11 | 5 | 17 |
| Printer | 1,032 | 1,286 | 6 | 9 | 11 | 29 | 8.8 | 4 | 0 | 29 |
| Fax | 52 | 168 | 7 | 9 | 12.5 | 18 | 9.8 | 9 | 4 | 18 |
| Scanner | 23 | 204 | 5 | 7 | 12 | 14 | 8.3 | 7 | 4 | 14 |
| TV <19' | 1,914 | 355 | 11 | 15 | 20 | 34 | 15.1 | 12 | 1 | 34 |
| TV >19' | 3,196 | 691 | 10 | 13 | 18 | 33 | 13.5 | 12 | 0 | 33 |
| TV - console | 56 | 55 | 9 | 11.5 | 17 | 27 | 12.7 | 8 | 2 | 27 |
| TV - projection | 7 | 5 | 7 | 8 | 9 | 10 | 8.0 | 8 | 6 | 10 |
| Total | 12,801 | 7,818 | | | | | | | | |

Source: Florida Department of Environmental Protection. Database accessed 8/22/05.
www.dep.state.fl.us/waste/categories/electronics/pages/FloridaElectronicProductBrandDistributionProject.htm

**Table 2.4**
**Life Span Assumptions By Product Type-Residential Sector**
**(Number of Years Before Collection)**

| Product Type | Assumption | Basis |
|---|---|---|
| PCs—desktop | 25%—7 years<br>25%—10 years<br>25%—14 years<br>25%—18 years | Median of each quartile |
| PCs—portable | 20%—4 years<br>15%—5 years<br>20%—6 years<br>45%—7 years | 1st through 4th quartiles |
| PC Monitors—CRT | 25%—5 years<br>25%—8 years<br>25%—10 years<br>25%—13 years | Median of each quartile |
| PC Monitors—flat panel | 100%—9 years | Mean of all observations |
| PC Hard copy peripherals | 25%—4 years<br>25%—7 years<br>25%—10 years<br>25%—14 years | Median of each quartile |
| PC Keyboards | 100%—5 years | Median of all observations |
| TVs—CRT <19” | 25%—8 years<br>25%—13 years<br>25%—17 years<br>25%—23 years | Median of each quartile |
| TVs—CRT >19” | 25%—7 years<br>25%—12 years<br>25%—15 years<br>25%—20 years | Median of each quartile |
| TVs—Projection | 100%—8 years | Mean of all observations |
| TVs—Flat Panel | 100%—9 years | No data-Assumed the same as PC flat panel monitors |

Note: Assumptions were based on statistical analyses of data from the Florida DEP.

*Life Span of Cell Phones*

Unfortunately, we do not have access to any data on the age distribution of cell phones when they are collected for recycling. Here again, we relied on industry expert opinion. We assumed that 65 percent of cell phones were 2 years old based on industry reports that about that percentage of cell phones collected were suitable for resale “as is” or after

refurbishment.[14] We also assumed that the remaining 35 percent of phones collected were 5 years old and were only suitable for materials recovery.[15] Due to lack of data, we did not assume any difference in cell phone use patterns between the residential and commercial sectors.

### *2.3 Average Weight Data: Televisions and Computer Equipment*

The average weight of products is an important input to this methodology for modeling the use stages of electronic products. We developed product weight estimates for each product type, for each year covered in the analysis. Within some product types, such as TVs, weights vary depending on the size and type of screen. Product weights also can vary over time as technology, style, and features change.

To develop estimates of average product weights, we reviewed two data sets. The first data set was developed from electronics collection data obtained from the Florida DEP (described in Section 2.2 above). At the time of this analysis, the Florida data set had weight and year of manufacture data for 12,801 units. The average weights were calculated for each product and each year of manufacture. Again, we cannot represent with certainty that the Florida results are representative of the nation as a whole, but it is a large, available data set with product weight and age information.

In addition, we used the data set on product weights developed over past years for the EPA municipal solid waste (MSW) characterization report series.[16] These data were gathered from Consumer Reports Annual and Monthly Buying Guides from 1984 through 1999. For the most recent years studied (2000 to 2007), data on product weights were collected from product specification listed by large consumer electronic retailers. Table 2.5 identifies which data set was used for each product type in this analysis.

[14] Based on a phone conversation between Jennifer Chambers, Recellular, Inc. and Lynn Knight, ERG July, 2006.
[15] International Association of Electronics Recyclers, *IAER Electronics Recycling Industry Report, 2006.*
[16] U.S. EPA. *Municipal Solid Waste in The United States: 2006 Facts and Figures* and previous years' editions of the same report. www.epa.gov/epaoswer/non-hw/muncpl/msw99.htm.

**Table 2.5**
**Data Source, by Product Type**

| Product | Source of Product Weight Data |
|---|---|
| TVs | |
| <19 inch | Florida DEP collection study |
| >19 inch | Florida DEP collection study |
| Projection | Consumer product publications and retailer product specifications |
| Flat screen | Consumer product publications and retailer product specifications |
| Computers | |
| Desktop | Florida DEP collection study |
| Laptop | Consumer product publications and retailer product specifications |
| Monitors | |
| CRT | Consumer product publications and retailer product specifications |
| Flat panel | Florida DEP collection study and ERG in-house data |
| Keyboards | Florida DEP collection study |
| Mouse devices | Consumer product publications and retailer product specifications |
| Printers and other hard copy devices | Florida DEP collection study and consumer product publications and retailer product specifications |
| Cell Phones | Retailer product specifications |

The average weights for televisions and cell phones, and computer products are shown in Tables 2.6 and 2.7, respectively.

## Table 2.6
### Average Weight of Television and Cell Phone Units (pounds)

| Year | Color CRT (<19 inches) | Color CRT (>19 inches) | Flat Panel | Projection | Monochrome | Cell Phones |
|---|---|---|---|---|---|---|
| 1980 | 42.0 | 73.0 | | | 42.0 | |
| 1981 | 42.0 | 73.0 | | | 42.0 | |
| 1982 | 42.0 | 73.0 | | | 42.0 | |
| 1983 | 42.0 | 73.0 | | | 42.0 | |
| 1984 | 42.0 | 73.0 | | 219.0 | 42.0 | 3.5 |
| 1985 | 40.6 | 72.6 | | 221.0 | 40.6 | 3.5 |
| 1986 | 41.1 | 73.0 | | 223.0 | 41.1 | 3.5 |
| 1987 | 40.8 | 73.0 | | 225.0 | 40.8 | 3.5 |
| 1988 | 41.2 | 72.9 | | 227.0 | 41.2 | 3.5 |
| 1989 | 41.0 | 71.7 | | 229.0 | 41.0 | 3.5 |
| 1990 | 40.5 | 74.8 | | 231.0 | 40.5 | 3.5 |
| 1991 | 41.1 | 73.9 | | 233.0 | 41.1 | 3.5 |
| 1992 | 40.9 | 73.5 | | 235.0 | 40.9 | 0.5 |
| 1993 | 40.7 | 75.4 | | 237.0 | 40.7 | 0.5 |
| 1994 | 41.1 | 73.3 | | 239.0 | 41.1 | 0.5 |
| 1995 | 40.9 | 73.5 | | 241.0 | 40.9 | 0.5 |
| 1996 | 41.3 | 72.8 | | 243.0 | 41.3 | 0.5 |
| 1997 | 40.7 | 73.8 | | 245.0 | 40.7 | 0.5 |
| 1998 | 41.6 | 74.1 | | 247.0 | 41.6 | 0.5 |
| 1999 | 41.2 | 73.0 | 29.0 | 249.0 | 41.2 | 0.5 |
| 2000 | 39.8 | 74.5 | 29.0 | 251.0 | 39.8 | 0.4 |
| 2001 | 41.1 | 72.2 | 29.0 | 251.0 | 41.1 | 0.4 |
| 2002 | 40.4 | 72.8 | 29.0 | 223.3 | 40.4 | 0.3 |
| 2003 | 41.0 | 73.0 | 29.0 | 195.7 | 41.0 | 0.3 |
| 2004 | 41.0 | 73.0 | 29.0 | 168.0 | 41.0 | 0.3 |
| 2005 | 41.0 | 73.0 | 29.0 | 140.0 | 41.0 | 0.3 |
| 2006 | 41.0 | 73.0 | 29.0 | 140.0 | 41.0 | 0.2 |
| 2007 | 41.0 | 73.0 | 29.0 | 140.0 | 41.0 | 0.2 |

## Table 2.7
**Average Weight of Personal Computer-Related Units (pounds)**

| Year | Desktop Computers | Portable Computers | CRT Monitors | Flat Panel Monitors | Keyboards | Mouse Devices | Hard Copy Peripherals |
|---|---|---|---|---|---|---|---|
| 1980 | 22.0 | | 24.50 | | 2.9 | 0.2 | 18.00 |
| 1981 | 22.0 | | 24.50 | | 2.9 | 0.2 | 18.00 |
| 1982 | 22.0 | | 24.50 | | 2.9 | 0.2 | 18.00 |
| 1983 | 22.0 | | 24.50 | | 2.9 | 0.2 | 18.00 |
| 1984 | 22.0 | | 24.50 | | 2.9 | 0.2 | 18.00 |
| 1985 | 22.0 | | 24.50 | | 2.9 | 0.2 | 18.00 |
| 1986 | 22.0 | | 24.50 | | 2.9 | 0.2 | 18.00 |
| 1987 | 22.0 | | 24.50 | | 2.9 | 0.2 | 18.00 |
| 1988 | 22.0 | | 24.50 | | 2.9 | 0.2 | 18.00 |
| 1989 | 21.9 | | 24.50 | 24.6 | 2.9 | 0.2 | 17.86 |
| 1990 | 21.8 | | 24.63 | 24.6 | 2.9 | 0.2 | 19.62 |
| 1991 | 21.8 | | 24.75 | 24.6 | 2.9 | 0.2 | 18.36 |
| 1992 | 22.2 | 9.0 | 24.88 | 24.6 | 2.9 | 0.2 | 17.43 |
| 1993 | 21.9 | 8.7 | 25.00 | 24.6 | 2.9 | 0.2 | 17.76 |
| 1994 | 21.7 | 8.5 | 28.86 | 24.6 | 2.9 | 0.2 | 17.81 |
| 1995 | 23.0 | 8.2 | 32.71 | 24.6 | 2.9 | 0.2 | 16.83 |
| 1996 | 22.1 | 7.9 | 36.57 | 24.6 | 2.9 | 0.2 | 15.37 |
| 1997 | 22.6 | 7.7 | 40.43 | 24.6 | 2.9 | 0.2 | 16.74 |
| 1998 | 22.7 | 7.4 | 44.29 | 24.6 | 2.9 | 0.2 | 16.27 |
| 1999 | 22.0 | 7.1 | 48.14 | 24.6 | 2.9 | 0.2 | 16.40 |
| 2000 | 22.1 | 7.1 | 52.00 | 24.6 | 2.9 | 0.2 | 18.46 |
| 2001 | 22.0 | 7.0 | 51.62 | 24.6 | 2.9 | 0.2 | 16.93 |
| 2002 | 24.1 | 6.8 | 51.25 | 24.6 | 2.9 | 0.2 | 16.42 |
| 2003 | 22.0 | 6.6 | 50.87 | 24.6 | 2.9 | 0.2 | 16.59 |
| 2004 | 22.0 | 6.4 | 50.50 | 24.6 | 2.9 | 0.2 | 17.40 |
| 2005 | 22.0 | 6.4 | 50.50 | 24.6 | 2.9 | 0.2 | 17.40 |
| 2006 | 22.0 | 6.4 | 50.50 | 24.6 | 2.9 | 0.2 | 17.40 |
| 2007 | 22.0 | 6.4 | 50.50 | 24.6 | 2.9 | 0.2 | 17.40 |

Note: Average weights for hard copy peripherals 1989 - 2004 are based on a weighted average of printers and scanners each year. From 2005 - 2007, average weight for 2004 was assumed.

## 3.0 Model Results

### *3.1 The Quantity of EOL Electronics Generated for Management Each Year*

This section presents estimates of the quantity of EOL electronic products generated for management each year. As described earlier, we developed the estimates by starting with product sales data and assuming specific life spans for each product type to represent the time between product purchase and the need for EOL management. These estimates would correspond to Phase 3 in Figure 1.1. As explained earlier, ready for EOL management means that the product has gone through a first use and possibly a second use stage (which could include reuse and storage) and the last user is ready to give the product to a recycler or dispose of it. The quantities of products generated for EOL management each year are presented for personal computer products, televisions, and cell phones in Tables 3.1 and 3.2.

According to the estimates presented in Table 3.1, 29.9 million desktop computers, 25.7 million hard copy peripherals, and 12.0 million portable computers were ready for EOL management in 2007. About 40 percent (by weight) of computer-related equipment generated in 2007 was from CRT computer monitors. About 26 percent of the weight was attributed to desktops and 17 percent was from hard copy devices. Flat panel monitors accounted for about 8 percent and portable computers accounted for 3 percent of the weight of EOL products generated that year.

As shown in Table 3.2, in 2007, 26.9 million TVs were ready for EOL management. TVs with CRTs accounted for the majority of the TV units as many of the newer projection and flat panel units had not yet reached EOL. Over time, the proportion of computer-related products reaching the EOL stage has increased relative to TVs. For example, in 1999, the weight of EOL TVs was very close to the weight of all EOL computer equipment generated that year. In 2007, however, TVs account for 69 percent of the weight of computer equipment. It is estimated that 140 million cell phones will be ready for EOL management in 2007 as well.

## Table 3.1

**Estimated Annual Personal Computer Products Ready for EOL Management, By Year**

| Year | Desktops | | Portables | | Hard Copy Devices | | Mice/Keyboards | | CRT Monitors | | Flat Panel Monitors | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Units(mill) | Tons(000) | Units(mill) | Tons(000) | Units(mill) | Tons(000) | Units(mill) | Tons(000) | Units(mill) | Tons(000) | Units(mill) | Tons(000) | Units(mill) | Tons(000) |
| 1999 | 12.6 | 138.3 | 3.2 | 13.5 | 9.2 | 77.6 | 81.2 | 64.1 | 15.7 | 238.3 | 1.8 | 21.7 | 123.7 | 553.5 |
| 2000 | 15.4 | 174.3 | 3.9 | 16.0 | 10.9 | 91.8 | 66.7 | 70.9 | 18.9 | 314.8 | 1.8 | 22.7 | 117.7 | 690.4 |
| 2001 | 18.4 | 204.4 | 4.8 | 19.0 | 13.6 | 110.7 | 76.2 | 80.2 | 21.1 | 386.6 | 1.8 | 22.6 | 135.9 | 823.5 |
| 2002 | 21.9 | 244.8 | 5.8 | 22.0 | 16.2 | 134.7 | 80.5 | 83.1 | 23.9 | 480.7 | 1.8 | 21.7 | 150.1 | 987.0 |
| 2003 | 24.7 | 275.0 | 6.9 | 25.4 | 19.6 | 166.7 | 92.8 | 97.0 | 27.7 | 597.8 | 2.8 | 34.3 | 174.5 | 1,196.2 |
| 2004 | 26.6 | 293.6 | 7.8 | 28.2 | 21.3 | 181.7 | 103.2 | 96.3 | 27.8 | 627.8 | 3.7 | 45.3 | 190.4 | 1,272.9 |
| 2005 | 28.4 | 322.6 | 9.0 | 31.8 | 22.9 | 198.3 | 107.9 | 80.6 | 28.5 | 673.1 | 5.0 | 61.5 | 201.6 | 1,368.0 |
| 2006 | 28.3 | 311.6 | 10.2 | 35.2 | 24.0 | 199.1 | 96.8 | 68.8 | 23.8 | 550.3 | 6.3 | 77.1 | 189.4 | 1,242.1 |
| 2007 | 29.9 | 341.3 | 12.0 | 40.3 | 25.7 | 219.2 | 106.1 | 76.2 | 22.8 | 533.6 | 9.1 | 111.4 | 205.5 | 1,321.9 |

Source: ERG estimates based on modeling results.

## Table 3.2

**Estimated Annual Television and Cell Phone Products Ready for EOL Management**

| Year | Color CRT <19" | | Color CRT >19" | | Flat Panel | | Projection | | Monochrome | | Total TVs | | Cell Phones | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Units(mill) | Tons(000) | Units(mill) | Tons(000) | Units(mill) | Tons(000) | Units(mill) | Tons(000) | Units(mill) | Tons(000) | Units(mill) | Tons(000) | Units(mill) | Tons(000) |
| 1999 | 6.1 | 125.0 | 7.5 | 274.2 | 0.0 | 0.0 | 0.4 | 44.3 | 2.6 | 54.2 | 16.5 | 497.7 | 18.8 | 5.0 |
| 2000 | 6.6 | 135.8 | 9.5 | 350.3 | 0.0 | 0.0 | 0.4 | 47.5 | 2.5 | 51.4 | 19.0 | 585.0 | 25.0 | 6.7 |
| 2001 | 7.2 | 148.3 | 10.1 | 369.2 | 0.0 | 0.0 | 0.5 | 55.1 | 2.0 | 42.5 | 19.8 | 615.1 | 37.9 | 8.9 |
| 2002 | 7.7 | 158.4 | 10.1 | 371.4 | 0.0 | 0.0 | 0.6 | 76.0 | 1.5 | 30.0 | 19.9 | 635.8 | 55.2 | 11.2 |
| 2003 | 9.0 | 183.6 | 10.6 | 386.6 | 0.0 | 0.0 | 0.8 | 98.8 | 3.1 | 65.0 | 23.5 | 734.1 | 75.8 | 14.5 |
| 2004 | 8.7 | 179.1 | 11.3 | 412.8 | 0.0 | 0.0 | 0.9 | 107.8 | 2.6 | 54.0 | 23.5 | 753.6 | 96.8 | 17.0 |
| 2005 | 8.8 | 180.3 | 12.0 | 445.0 | 0.0 | 0.0 | 0.9 | 112.3 | 2.3 | 48.4 | 24.0 | 786.0 | 116.5 | 18.6 |
| 2006 | 9.7 | 200.0 | 12.8 | 470.0 | 0.0 | 0.0 | 1.1 | 133.6 | 2.1 | 43.2 | 25.7 | 846.8 | 127.8 | 19.0 |
| 2007 | 10.3 | 212.8 | 13.4 | 493.9 | 0.0 | 0.0 | 1.3 | 165.8 | 1.8 | 38.1 | 26.9 | 910.6 | 140.3 | 19.2 |

Source: ERG estimates based on modeling results.

The share of computer products sold to the commercial versus the residential sector is based on recent sales data and is assumed constant for all the study years. This assumption could have the effect of overestimating the residential computer share in earlier years when household penetration of personal computers was lower than it is today. Therefore, the life spans could be too long for the portion of residential products in the 1980's that may have actually been in the commercial sector.

To test the sensitivity of this assumption, we ran a scenario in which we assumed that 25 percent of desktop computer sales were attributable to the residential sector from 1980 thru 1985, 40 percent from 1986 thru 1990, and 48 percent (the constant rate assumed in the original analysis) from 1991 thru 2004. Testing this scenario, the resulting estimates of units ready for EOL management in 2005 were less than 1 percent lower than the original estimates. In 2000, the sensitivity test resulted in about a 3 percent lower estimate. Therefore, we do not believe our lack of data regarding the split between computer product sales in the residential versus the commercial sector in previous years has a significant effect on the estimates of EOL products ready for management in recent years.

## *3.2 Estimating the Quantity of EOL Products Generated That Are Recycled Versus Disposed*

The modeling effort resulted in estimates of the quantity of products that are generated annually for EOL management. EOL management consists of recycling or disposal. This corresponds to the two options in Phase 3 of Figure 1.1: "Dispose" or "Bring to Recycling Collection." We estimated the amount of EOL electronics recycled by gathering data from the recycling industry. Disposal was estimated as the difference between what was generated for EOL management and what was recycled. The following sections discuss the details of this part of the analysis.

### *Estimating the Portion of EOL Electronics Recycled*

Recycling of consumer electronics includes the recovery of products by municipal and other collection programs for materials separation and recovery, as well as reuse in both domestic and foreign end markets. It also includes businesses and institutions contracting directly with electronic recyclers for recycling services of their EOL equipment. Donation organizations also collect EOL electronic equipment for reuse or recycling. In this report, we do not distinguish between a for-profit electronics recycler and a donation organization that collects EOL equipment. The term "reuse" in the EOL management stage refers to products entering the recycling materials management system that are in working order and can be resold "as is" or refurbished for resale by electronics recyclers and dismantlers. The reuse of consumer electronics before they enter the management system (i.e., products that pass between individual users) is assumed to occur prior to EOL management.

The recycling estimates for 1999 through 2004 were developed previously for EPA.[17] They were based on extrapolations of recovery and market share data from a few electronics recyclers. The amount recycled in 2005 was projected based on the same recovery rate exhibited in 2004. Recycled quantities of electronics in 2006 and 2007 were developed from state program recycling gains as reported by the National Center for Electronics Recycling (NCER) Estimated quantities of EOL consumer electronics recycled from 1999 through 2007 are shown in Table 3.3 below.

As a check on the recycling estimate, we turned to industry data. In its 2006 Industry Report, the IAER estimated that the electronics recycling industry processed an annual total volume of 1.4 million tons of electronic equipment in 2005.[18] This estimate was based on a survey of over 500 electronics recyclers, OEMs and non-profit organizations. However, it included a much broader scope of products, as well as several source sectors that were not included in this analysis. For example, the IAER estimate would include servers, main frames, copiers, DVDs, VCRs, etc. It also includes equipment collected from industrial, medical, and other sectors that are not addressed in this study. To compare the IAER estimates with our estimate, we did the following analysis. The IAER reported that 74 percent of the equipment processed was computer and consumer equipment. Further, they reported that 39 percent of equipment was from the residential, commercial, manufacturing, industrial, or institutional sectors. If we assume that the proportion of equipment types collected is equal in each of the source sectors, we could estimate that roughly 404,000 tons of EOL consumer and computer equipment from the residential and commercial/institutional sectors was processed by recyclers in 2005. Our adjusted IAER estimate of 404,000 is higher than our estimate of 345,000 tons for 2005. However, given that the IAER data reflects certain types of consumer and computer equipment that we were not addressed in this report (e.g., VCRs, DVDs, servers, main frames, copiers), and further, we cannot relate the product types within each source/sector category, our estimate does not appear to be significantly different. In any case, we conducted a sensitivity analysis to test the effect of a possible underestimate of the amount recycled in Section 6 below.

*Estimating the Portion of EOL Electronics Disposed*

To estimate the portion of the estimated EOL electronics generated every year that is disposed, we subtracted the amount estimated to be recycled from the estimated amount generated for EOL management. Table 3.3 includes the disposal estimates for 1999 through 2007.

[17] U.S. EPA. *Municipal Solid Waste In The United States: 2005 Facts and Figures* and previous years' editions and updates of the same report.
[18] International Association of Electronics Recyclers, *IAER Electronics Recycling Industry Report, 2006.*

**Table 3.3**
**Distribution of EOL Products By Management Method**

| | Total EOL Products | | Total Recycled | | | Total Disposed | | |
|---|---|---|---|---|---|---|---|---|
| Year | Units(mill) | Tons(000) | Units(mill)* | Tons(000) | Tons (%) | Units(mill)* | Tons(000) | Tons (%) |
| 1999 | 159.0 | 1,056.2 | 23.6 | 157.0 | 14.9% | 135.4 | 899.2 | 85% |
| 2000 | 161.6 | 1,282.0 | 24.0 | 190.0 | 14.8% | 137.7 | 1,092.0 | 85% |
| 2001 | 193.6 | 1,447.6 | 28.1 | 210.0 | 14.5% | 165.5 | 1,237.6 | 85% |
| 2002 | 225.2 | 1,634.0 | 34.5 | 250.0 | 15.3% | 190.7 | 1,384.0 | 85% |
| 2003 | 273.8 | 1,944.7 | 40.8 | 290.0 | 14.9% | 232.9 | 1,654.7 | 85% |
| 2004 | 310.7 | 2,043.5 | 48.6 | 320.0 | 15.7% | 262.0 | 1,723.5 | 84% |
| 2005 | 342.1 | 2,172.6 | 54.3 | 345.0 | 15.9% | 287.8 | 1,827.6 | 84% |
| 2006 | 342.9 | 2,107.8 | 61.3 | 377.0 | 17.9% | 281.5 | 1,730.8 | 82% |
| 2007 | 372.7 | 2,251.7 | 68.5 | 414.0 | 18.4% | 304.2 | 1,837.7 | 82% |

*Number of units estimated based on the units/ton factor exhibited by EOL products.

According to this analysis, 18.4 percent, by weight, of the EOL electronics generated in 2007 were collected for recycling. During the time period 1999 through 2005, even though the amount of material being recycled increased, the amount of EOL products generated kept pace such that the percentage of material being recycled remained relatively constant. A larger gain in the recycling rate has been estimated for 2006 and 2007. Implementation of state electronics recovery and disposal regulations has provided a boost to the electronics recycling industry.

The majority of EOL material that is not being recycled is probably mostly going into landfills. According to EPA data, about 19 percent of all MSW discards goes to the waste-to-energy process.[19] Within that 19 percent, furthermore, it is possible that computer monitors or televisions with CRTs are not being combusted, but rather are being removed on the tipping floor and sent to landfills (unless there is a ban on CRT disposal in landfills). Waste-to-energy operators would be inclined to remove these items because the glass is not combustible and because of concerns about the resulting lead in the ash from the CRT glass. Non-CRT computer equipment may not be removed because it contains plastic, which is combustible. Without further research, we cannot predict how EOL electronic products disposed of in communities with waste-to-energy are actually managed, but based on national averages, we can say that no more than 19 percent that is discarded is combusted, which we believe is a very conservative scenario, and at least 81 percent goes to a landfill

In order to check the accuracy of the disposal estimate, we explored a second way to estimate the quantity of EOL electronics disposed. We reviewed and analyzed seven waste sort/sampling studies, all of which delineated consumer electronics as a separate category. This methodology resulted in an average number of pounds of consumer electronics disposed per person. By applying the pounds per person result to the U.S. population we estimated that 1.4 million tons of waste electronics was disposed of in 2003. This is within a reasonable range of the estimate of 1.7 million tons we derived from the model results. The details of this methodology (based on the waste sort analysis) are described in Appendix B.

[19] U.S. EPA. *Municipal Solid Waste in the United States: 2006 Facts and Figures*. 2007.

*Limitations of the Analysis*

Our estimates of the amount of EOL material generated annually and the proportion that is subsequently managed through recycling versus disposal rely heavily on many assumptions and analyses as discussed in Section 2. Some assumptions regarding the estimates of the amount of material generated annually for EOL management have the following limitations:

- The age distribution of the electronic products collected for recycling in Florida is assumed to be representative of the age distribution of products collected for EOL management nationally. This assumption may misrepresent product usage patterns, which could have the effect of over- or under-estimating the volume of products ready for EOL management in any given year.
- The age distribution of electronic products exhibited in Florida collections in recent years represents a product usage pattern that is held constant in all years of the analysis. This assumption could have overestimated product life span in specific years past when, for example, significant changes in product technologies, such as computer processor improvements, temporarily spurred a faster product replacement rate. This limitation would have the most effect on computer products.
- The share of computer products sold to the commercial versus the residential sector is based on recent sales data and is assumed constant for all the study years. This limitation could have overestimated the residential computer share in earlier years, which might have increased the product life spans assumed for a portion of the products.

As already discussed in Section 3.1, we conducted a sensitivity analysis to explore the potential effect of the last limitation and concluded that the lack of data regarding the split between computer product sales in the residential versus the commercial sector in previous years did not have a significant effect on the estimates of EOL products ready for management in recent years.

### *3.3 Estimating the Quantity in Storage*

We have presented estimates of the number of products ready for EOL management on an annual basis. During the time period prior to EOL management, however, they may have been used, reused and/or stored for a period of time. Therefore, in 2007 for example, our model predicts that 29.9 million desktop computers will be ready for EOL management; however, there are units that are not being actively used anymore and are being stored because their owners are not ready to bring them for EOL management. To try to gain an understanding of the possible number of units being stored in this manner, we calculated the total number of units sold from 1980 through 2007, and then removed those units that we estimate have already been brought for EOL management. Further, we

removed those products that are likely to still be in their first or second use stage.[20] The remaining amount is what might be in storage.

Table 3.4 presents estimates of the number of units in each use stage in 2007. We estimate that, of the products considered in this study that were sold between 1980 and 2007, approximately 235 million units could be in storage as of 2007. Televisions account for the largest portion of units being stored, while desktop PCs account for the next largest portion. Overall, 9.7 percent of the products sold in this time period are in storage, while 41 percent are still in use and about half have already been collected for EOL management (i.e., have already been recycled or disposed). At the time of this study, we did not have enough information to make similar estimates for cell phones.

**Table 3.4**
**Estimated Number of Units in Various Stages of Use as of 2007 (million units)**

| | Collected for EOL Management | | In Storage | | Still in Use | | Total Sold 1980-2007 | |
|---|---|---|---|---|---|---|---|---|
| Product Type | Number | % of Total | Number | % of Total | Number | % of Total | Number | % of Total |
| Desktop PCs | 277.6 | 50.6% | 65.7 | 12.0% | 205.8 | 37.5% | 549 | 100.0% |
| PC monitors | 339.0 | 57.6% | 42.4 | 7.2% | 207.2 | 35.2% | 588.7 | 100.0% |
| Portable PCs | 67.1 | 39.3% | 2.1 | 1.2% | 101.7 | 59.5% | 170.8 | 100.0% |
| Hard copy peripherals | 209.3 | 51.3% | 25.2 | 6.2% | 173.7 | 42.6% | 408.2 | 100.0% |
| Televisions | 306.6 | 43.5% | 99.1 | 14.1% | 299.1 | 42.4% | 704.9 | 100.0% |
| Total | 1199.6 | 49.5% | 234.6 | 9.7% | 987.6 | 40.8% | 2421.7 | 100.0% |

Source: ERG estimates based on model results.

For the residential sector, we examined the use stages in a little more detail by trying to separate the first use from the reuse stage for computer equipment. Estimates of the number of units in the first use and reuse stage in 2007 were based on the assumption that computer equipment is used for 4 years initially and reused for an additional 3 years.[21, 22] Figures 3.1 through 3.4 illustrate the results for 2007 based on these assumptions. Collectively, of the residential sector computer-related products sold between 1980 and 2007, 31 percent were in their first-use stage and 16 percent were in the reuse stage in 2007.

When considering the amount of material possibly being stored, one has to keep in mind that different product owners will choose to keep items for different periods of time. Therefore, even if there were a convenient, free outlet for EOL management of this material, many people would not necessarily change their pattern and the products lifecycle. The next section examines the question of how residential product owners are likely to make use of electronics recycling opportunities.

[20] Assumptions regarding the number of years products are probably still in their first or second use was based on Consumer Electronics Association survey data on perceived life expectancy of electronic products: 11 years for a color TV; 6 years for a notebook PC; seven years for a desktop PC and PC monitor. Assumed the same 7 years as desktop PC for hard copy devices. *Presentation at 2005 E-Scrap North American Electronics Recycling Conference: "From Here to There: Facts on Product Life Cycles and Recycling." By Shawn G. DuBravac, Consumer Electronics Association.*

[21] Matthews, H. Scott and Deanna H. Matthews. 2003. "Information Technology Products and the Environment." In: Kuehr, R. and Williams, E., Eds. 2003. *Computers and the Environment.* Dordrecht, The Netherlands: Kluwer Academic Publishers, pp. 17-39.

[22] International Association of Electronics Recyclers, *IAER Electronics Recycling Industry Report, 2006.*

**Figure 3.1**

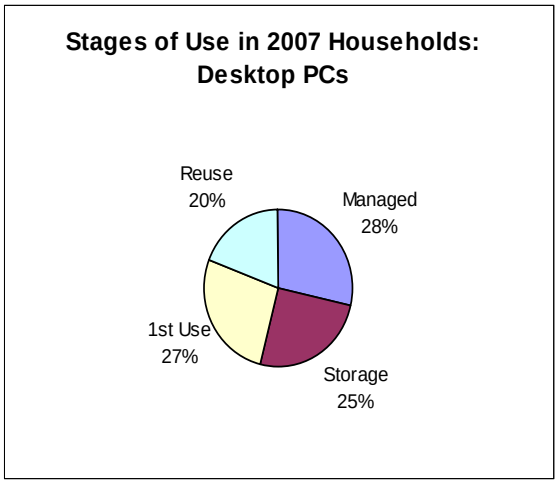



**Figure 3.2**

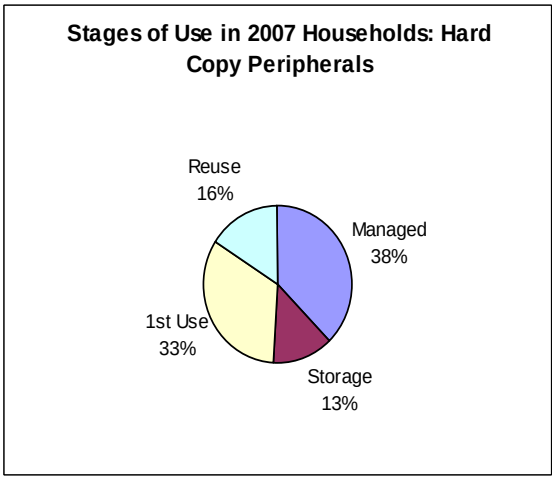



**Figure 3.3**

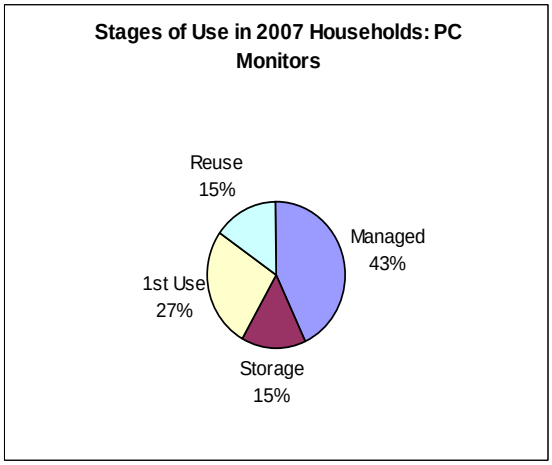
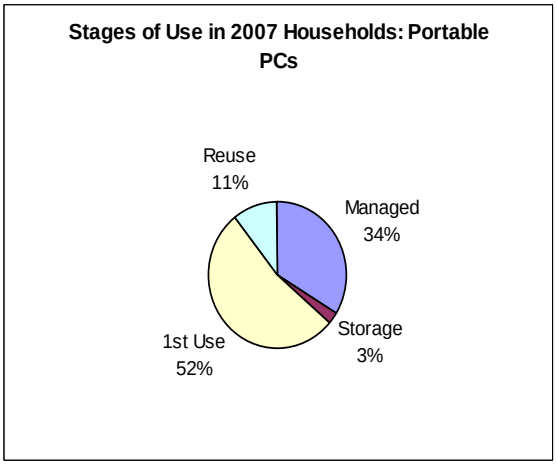



**Figure 3.4**



## 4.0 Quantity Available for Recycling Based on Observed Collection Rates

Recovery rates experienced by existing state and local electronics collection programs allow us to begin to understand how residents respond to available recycling opportunities. This is important when municipalities or other entities are planning to establish electronics recycling opportunities to a given population. We examined recovery rate information on a per capita basis from a handful of programs to get a sense of the quantities of material that might be anticipated.

Each of the recycling programs selected for this analysis met the following criteria:

- The program served a discrete and quantifiable population. Examples include state programs available to all state residents, collections run out of county or municipal waste management facilities, and curbside collections within a specific city or county.
- The program involved regular daily, weekly, or monthly collection—not a one-time or annual collection event.

We obtained 2004 data from:

- Hennepin County, Minnesota
- Waukesha County, Wisconsin
- Alberta, Canada
- State of Massachusetts
- Citrus County, Florida
- Broward County, Florida
- Charlotte County, Florida
- Lee County, Florida
- Miami-Dade County, Florida
- Polk County, Florida
- Sarasota County, Florida

We found that overall results can vary widely from one program to the next. The variance in recovery rates experienced by these programs can reflect a number of factors, such as the program type (drop-off, special event, curbside pickup, etc.), accessibility and frequency of collection, whether or not there is a recycling fee, extent and effectiveness of public outreach and education, availability of alternative disposal options, and characteristics of the target population (e.g., attitudes toward recycling). The programs in this analysis represent somewhat of a cross-section of electronics recycling programs not only in terms of scale (state, county, and municipal programs), but also in terms of program type and maturity.

Also, the results from Massachusetts should be viewed with the perspective that there is a statewide ban on the disposal of CRTs.

The per capita recovery rates exhibited by the specific programs we examined varied widely. Table 4.1 summarizes the range of results for 2004, broken down by product type. Without further analysis, it is difficult to say what one might expect as far as a per capita recovery rate from residential programs on a national basis. Combining the product types shown in the table, a range of about 1 to 3 pounds per capita has been experienced. The midpoint of that range is 2 pounds per capita. Using this recovery rate as a basis and extrapolating to the entire U.S. population, we could estimate that if all residents had access to electronics recycling programs, 294,000 tons of material could have been collected in 2004 from the residential population.

The recovery rates in both Hennepin County, as well as Massachusetts were on the high end of the range. The recovery rate of 3 pounds per capita experienced in Hennepin County is a good indicator of the quantity of material available from a residential population when there is a well-established, well-publicized program. In Massachusetts, there is a state-wide ban on CRT disposal and the recovery rates for just CRTs was about 3 pounds per person as compared to 2.6 pounds per person for just CRTs in Hennepin County in 2004. From this limited analysis, it may be that jurisdictions with disposal bans on some or all EOL electronic products can experience a somewhat higher recovery rate.

**Table 4.1**
**Range of Per Capita Per Year Recovery Rates Among Selected Programs, 2004**

| Product Type | Recovery Range (Pounds per Capita per Year) | |
|---|---|---|
| | **Minimum** | **Maximum** |
| Monitors | 0.23 | 0.60 |
| CPUs | 0.13 | 0.35 |
| TVs | 0.4 | 1.99 |
| Printers | 0.07 | 0.17 |
| Laptops[23] | 0.002 | 0.007 |
| Total | 0.83 | 3.12 |

[23] Only Waukesha County, Alberta, and Hennepin County reported laptops as a distinct category in 2004.

## 5.0 Examining the End Markets in 2005 of Products Collected Through Electronics Collection Programs in the United States

The purpose of this section is to examine the end markets, both domestic and abroad, of EOL electronic products that are collected for recycling in the U.S. in 2005 by electronics recyclers or donation organizations. This is a difficult task since data on the end markets of these materials is not publicly available. In order to arrive at a rough estimate, we relied on an industry expert to develop a best estimate for CRT-containing devices.[24] These estimates were derived based on industry data and specific knowledge of the domestic and export end markets for EOL electronics. Only CRT-containing devices—televisions and computer monitors—were considered because there are reasonably feasible means of tracing these material flows. This section presents estimates of the quantity of collected CRT-containing devices that are sent to domestic and foreign end markets.

Table 5.1 presents estimates of the quantity of CRT-containing products collected by U.S. recyclers going to the various end markets. These estimates were developed by an industry expert who researched the U.S. resale outlets typically used by recyclers, as well as interviewed individuals from firms conducting CRT refurbishing, glass processing, and lead smelting. Data on glass-to-glass recycling were obtained via EPA's Office of Solid Waste research. [25]

**Table 5.1**
**End Markets for EOL TVs and CRT Monitors Collected for Recycling in the U.S. in 2005**

| End Market | Tons/Year | % of Total |
|---|---|---|
| Resale "as is" or after some repair/upgrade in the U.S. | 3,000 | 2% |
| Resale "as is" or after some repair/upgrade abroad | 3,500 | 2% |
| Refurbishing or remanufacturing into specialty monitors in the U.S. | 2,500 | 1% |
| Refurbishing or remanufacturing into new TVs or specialty monitors abroad* | 107,500 | 61% |
| CRT glass-to-glass factories in the U.S. | 4,000 | 2% |
| CRT glass-to-glass factories abroad | 24,000 | 14% |
| CRT glass to smelters in North America for lead recovery ** | 10,000 | 6% |
| Plastic, metal, and other material recovery from demanufacturing*** | 20,500 | 12% |
| **Total** | **175,000** | 100% |

Source: World Reuse, Repair and Recycling Association, 2005. Figures for CRT glass-to-glass factories are based on EPA research.

*Industry experts interviewed by Robin Ingenthron report that about 30% of material destined for remanufacturing abroad is not technically suitable for remanufacturing and has to be recycled or disposed. The recycling or disposal of unsuitable units occurs abroad.

**Includes units shipped to one smelter in each of the U.S. and Canada.

***End markets for these materials are both domestic and abroad.

[24] Robin Ingenthron of the World Reuse, Repair and Recycling Association developed these estimates after gathering knowledge from Association members, industry contacts, and published data sources.
[25] Research conducted by Bob Tonetti, U.S. EPA, Office of Solid Waste, 2006.

In total, about 175 thousand tons of CRT-containing products coming from U.S. electronics recyclers in 2005 was accounted for in this analysis. The estimates presented in Table 5.1 show that the largest portion of this material (about 61 percent) was sent to markets abroad for the purpose of refurbishing or remanufacturing CRTs into new televisions or specialty monitors. The next largest portion (about 14 percent) was CRT glass sold to markets abroad for glass-to-glass processing, while lead recovery in North America accounts for about 6 percent of the material. Resale for reuse in the U.S. and abroad, as well as remanufacturing in the U.S. are other relatively small end markets.

There may be additional end markets that were not identified or quantified in these estimates, however, it is believed that the major end markets were covered and therefore these estimates should assist us in understanding where used and EOL CRT devices and components are going after they are collected and processed by U.S. electronics recyclers. The estimates in the table were not intended to be comprehensive estimates of the actual tonnage of EOL CRT-containing products collected and managed. They were developed to explore the distribution of these EOL products among the major end markets.

Further, these estimates reflect the state of the recycling industry in 2005. Changing industry trends have had a significant impact on these estimates since then and will continue to alter the distribution in the near future. For example, the domestic market for CRT glass has changed since U.S. CRT glass-to-glass factories have closed. Further into the future, as more flat panel monitors and TVs replace CRT-containing products, end markets will shift again when these products are ready for EOL management.

## 6.0 Summary and Conclusion

The purpose of this report is to establish a baseline regarding the management of EOL electronic products. These data can be referenced in the future to characterize changes and trends with respect to the generation and handling of EOL electronic products.

The baseline data addresses televisions, cell phones, personal computers (including desktops, laptops, monitors, keyboards, and mice), and hard copy devices (e.g., printers, scanners, faxes) sold between 1980 and 2007. This timeframe is probably adequate to account for all but a very small portion of the quantity of computer products used in the United States. It does not, however, account for televisions sold before 1980 that might still be in storage, which is probably a relatively small quantity at this point.

### *Annual Quantity of Obsolete Electronic Products Generated for EOL Management*

As described in Section 3.1, the analysis presents the quantity of EOL electronic products generated for management annually. Table 6.1 presents these estimates for the period of 1999 through 2007. The table also puts the totals in terms of pounds per capita based on U.S. Census population estimates.[26] According to the modeling results, 2.3 million tons of EOL TVs, cell phones, and personal computer products were ready for EOL management in 2007. This is equivalent to about 15 pounds per capita.

**Table 6.1**

**Estimated Annual Products Ready for EOL Management**

| Year | TVs | | Computer Products | | Cell Phones | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | Units(mill) | Tons(000) | Units(mill) | Tons(000) | Units(mill) | Tons(000) | Units(mill) | Tons(000) | Lbs/Cap |
| 1999 | 16.5 | 497.7 | 123.7 | 553.5 | 18.8 | 5.0 | 159.0 | 1,056.2 | 7.7 |
| 2000 | 19.0 | 585.0 | 117.7 | 690.4 | 25.0 | 6.7 | 161.6 | 1,282.0 | 9.1 |
| 2001 | 19.8 | 615.1 | 135.9 | 823.5 | 37.9 | 8.9 | 193.6 | 1,447.6 | 10.2 |
| 2002 | 19.9 | 635.8 | 150.1 | 987.0 | 55.2 | 11.2 | 225.2 | 1,634.0 | 11.4 |
| 2003 | 23.5 | 734.1 | 174.5 | 1,196.2 | 75.8 | 14.5 | 273.8 | 1,944.7 | 13.4 |
| 2004 | 23.5 | 753.6 | 190.4 | 1,272.9 | 96.8 | 17.0 | 310.7 | 2,043.5 | 13.9 |
| 2005 | 24.0 | 786.0 | 201.6 | 1,368.0 | 116.5 | 18.6 | 342.1 | 2,172.6 | 14.7 |
| 2006 | 25.7 | 846.8 | 189.4 | 1,242.1 | 127.8 | 19.0 | 342.9 | 2,107.8 | 14.1 |
| 2007 | 26.9 | 910.6 | 205.5 | 1,321.9 | 140.3 | 19.2 | 372.7 | 2,251.7 | 14.9 |

Source: ERG estimates based on modeling results.

### *Annual Quantity of Electronic Products Ready for EOL Management That Is Recycled*

Section 3.2 presents estimates of the quantity of EOL electronic products collected that is recycled in the United States. These estimates are duplicated in Table 6.2. As shown in the table, an estimated 414,000 tons of EOL TVs, cell phones, and personal computer products were collected for recycling in 2007. This is equivalent to about 2.7 pounds per

[26] U.S. Census figures for beyond 2006 and 2007 were interpolated based on Census projections for 2005 and 2010.

capita, which accounts for 18 percent of the 15 pounds per capita estimated to be ready for EOL management in 2007.

## Table 6.2

**Estimated Annual Products Collected for Recycling**

| Year | TVs | | Computer Products | | Cell Phones | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | Units(mill) | Tons(000) | Units(mill) | Tons(000) | Units(mill) | Tons(000) | Units(mill) | Tons(000) | Lbs/Cap |
| 1999 | 2.6 | 74.1 | 19.2 | 82.4 | 1.9 | 0.5 | 23.6 | 157.0 | 1.2 |
| 2000 | 3.0 | 86.8 | 18.5 | 102.5 | 2.5 | 0.7 | 24.0 | 190.0 | 1.3 |
| 2001 | 3.1 | 89.4 | 21.2 | 119.7 | 3.8 | 0.9 | 28.1 | 210.0 | 1.5 |
| 2002 | 3.4 | 97.5 | 25.5 | 151.4 | 5.5 | 1.1 | 34.5 | 250.0 | 1.7 |
| 2003 | 3.9 | 109.7 | 29.3 | 178.8 | 7.6 | 1.4 | 40.8 | 290.0 | 2.0 |
| 2004 | 4.3 | 118.4 | 34.7 | 199.9 | 9.7 | 1.7 | 48.6 | 320.0 | 2.2 |
| 2005 | 4.5 | 125.2 | 38.1 | 217.9 | 11.7 | 1.9 | 54.3 | 345.0 | 2.3 |
| 2006 | 5.8 | 152.1 | 42.8 | 223.0 | 12.8 | 1.9 | 61.3 | 377.0 | 2.5 |
| 2007 | 6.3 | 168.1 | 48.2 | 244.0 | 14.0 | 1.9 | 68.5 | 414.0 | 2.7 |

Source: ERG estimates based on modeling results and industry input from cell phone recyclers.

According to our estimates, 18 percent of the electronic products ready for EOL management are recycled and the remainder is disposed in 2007. In 1999, 157,000 tons of EOL electronic products within the scope of this study were recycled as compared to 414,000 tons in 2007. As shown in Table 6.2, the per capita recovery rates have exhibited steady increases, from an estimated 1.2 to 2.7 pounds per capita in 1999 to 2007, respectively.

An important factor in this analysis is the estimate of the quantity of EOL electronic products recycled annually. The scope of this study did not allow for an in-depth analysis of this factor. However, given that this estimate directly affects the proportion of EOL products that are recycled versus disposed, we conducted a sensitivity analysis to test the effect on the results by assuming that our estimate of the amount recycled was underestimated by 20 percent. When assuming that 497,000 tons of EOL electronic products were recycled in 2007 (a 20 percent increase over 414,000 tons), the estimated portion of the total EOL products generated for management that are recycled increases from 18 to 22 percent and the portion that is disposed of decreases from 82 to 78 percent. Based on our analysis and industry estimates of electronic products recycled, we believe that this is a reasonable range to represent the portion of electronic products generated for EOL management that are recycled.

### *Electronic Products in Storage and Other Stages of the Lifecycle*

In Section 3.3 (Table 3.4), we estimated that in 2007, about 235 million units of EOL electronic products could be in storage. This represents the quantity of material that may be in home closets, attics, or basements. Televisions comprise about 42 percent and desktop computers about 28 percent of the stored products in that timeframe.

According to our modeling results, of all the electronic products sold[27] (excluding cell phones) from 1980 to 2007, 41 percent are still in use either by the first or subsequent users. (See Figure 6.1.) Of the remainder, about 49 percent would have already been managed via recycling or disposal, and about 10 percent are likely to be ready for management, but still are in storage.

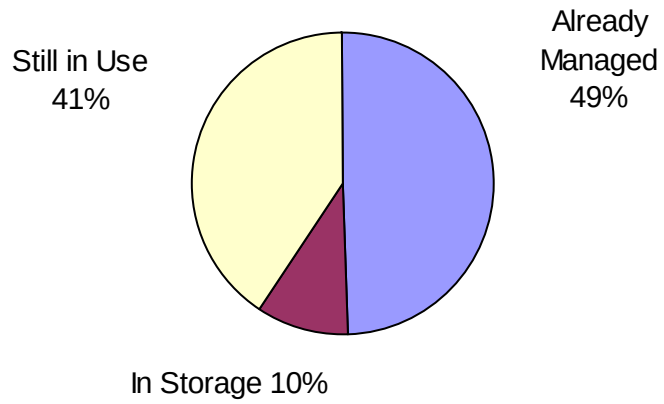



**Figure 6.1 Stages of Life Cycle: Electronic Products 2007**

For residential sector computer products, we estimated the number of products that might be in their "first use" and "second use" or reuse stage. According to our modeling results, in 2007, of the residential sector computer-related products sold from 1980 through 2007, 31 percent are in their "first use" stage (i.e., the first owner is still using) and 16 percent are being reused (second owner is using). Intuitively, we believe that the reuse of electronic products is high, since these products are relatively expensive, and even though product turnover rates may be short compared to other products, there is still substantial intrinsic value to the product. In fact, according to Consumer Electronics Association survey data, consumer-to-consumer reuse of electronic products through donations, give-away, or sales ranges from 65 percent of consumers for televisions to 83 percent of consumers for laptops.[28]

*Quantity of EOL Electronic Products Collected by Existing Collection Programs*

In Section 4.0, we examined a number of mostly residential electronics collection programs. The programs studied were not a statistical sample; rather, they were selected based on the suitability and availability of the data (when we conducted our analysis in 2006). In this review of program data, we found that, for municipal electronics collection

[27] Electronic products from residential, commercial, and institutional sources.
[28] DuBravac, Shawn G., *From Here to There: Facts on Product Life Cycles and Recycling*, Consumer Electronics Association. 2005.

programs the mid-range of 2 pounds per capita (based on a range of 0.8 to 3.1 pounds per capita) of EOL TVs and personal computer equipment was recovered for recycling. (See Table 4.1.) This wide range is indicative of the maturity and type of program, as well as the extent of outreach and the characteristics of the population; they all play an important role in determining the recovery rates. When there is a disposal ban, higher recovery rates may be experienced.

*Electronic Products Collected for Recycling, Managed Domestically Versus Abroad*

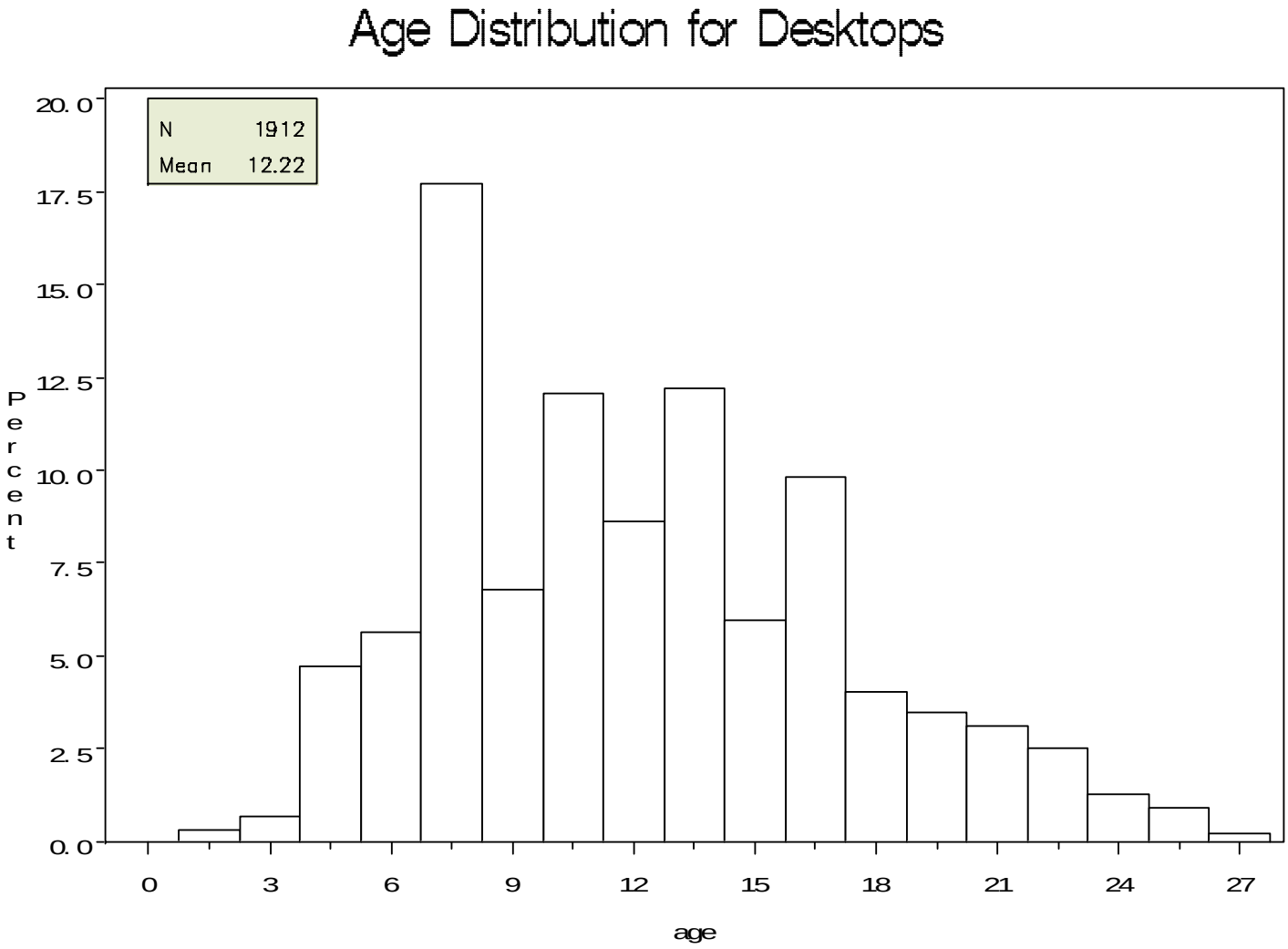
In Section 5, we developed estimates regarding where and how CRTs from computer monitors and TVs were being handled after collection by electronics recyclers in the U.S. Of the CRT devices collected in the U.S. in 2005 by recyclers, more than 80 percent[29] is sent to end markets abroad for resale, refurbishment, remanufacturing, or materials recovery. In 2005, most of the used and EOL electronic products containing CRTs (about 60 percent) were sent to end markets in Asia, South America, and elsewhere, where CRTs that were in working order were refurbished or remanufactured into new TVs or specialty equipment (e.g., monitors for medical or other technical applications). However, the end market distribution is changing rapidly as glass factories close and the increasing popularity of flat panel displays changes the nature of the EOL stream from TVs and computer monitors.

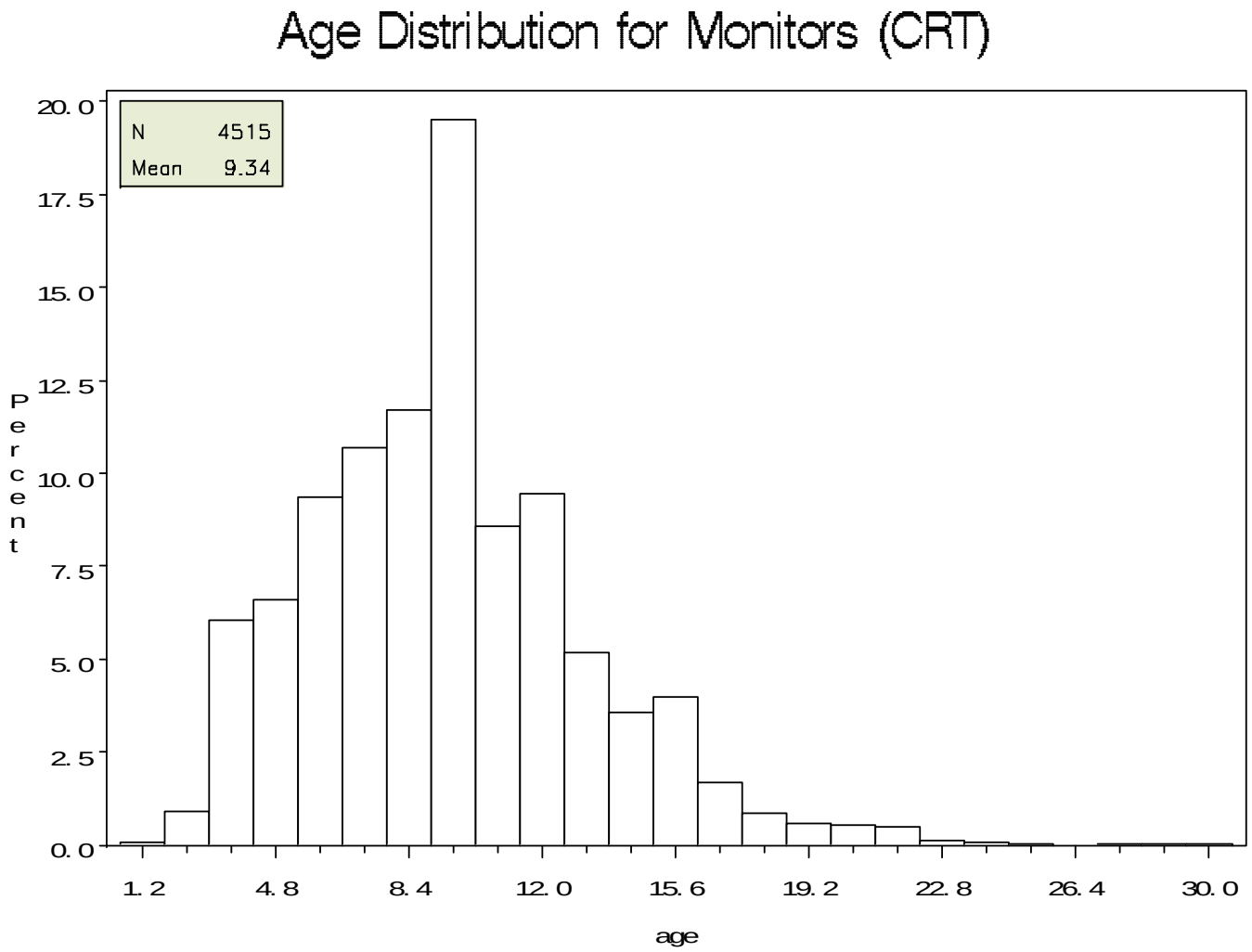
The handling of CPUs, laptops, and hard copy peripherals in the U.S. versus abroad was not examined in this analysis. These products at EOL have different technical and economic characteristics and therefore, the resale and recycling end markets are not at all similar. Non-CRT-containing products may be addressed in a subsequent analysis.

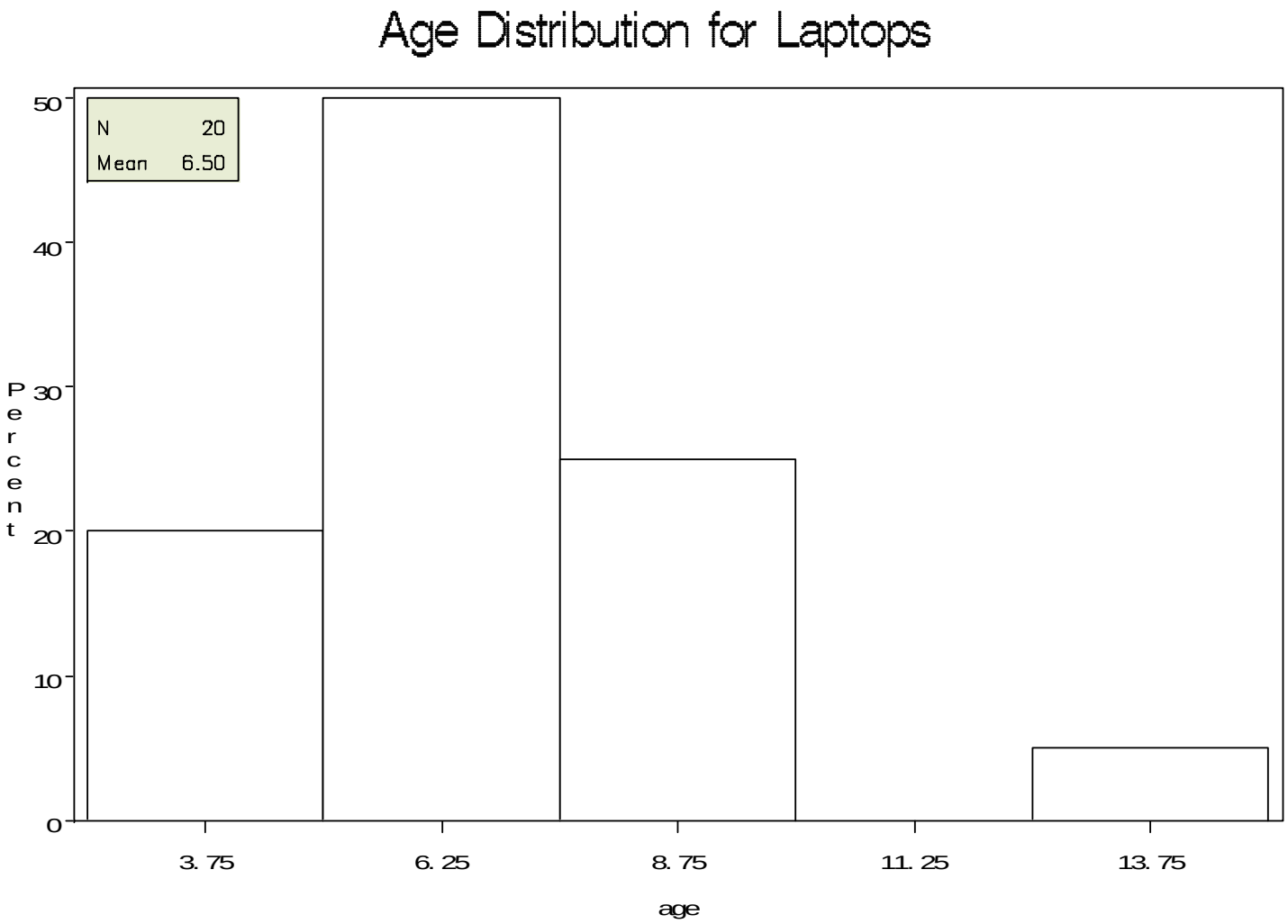
[29] The "more than 80%" estimate is derived by adding the following categories from Table 5.1: 1) Resale "as is" or repair abroad; 2) Remanufacturing abroad; and 3) CRT glass abroad. These three categories yield about 77%. We also assume that a portion of two other categories in Table 5.1 should also be included, bringing the total up to at least 80%: 1) CRT glass to lead smelters in North America; and 2) Plastic, metal, etc. from demanufacturing.

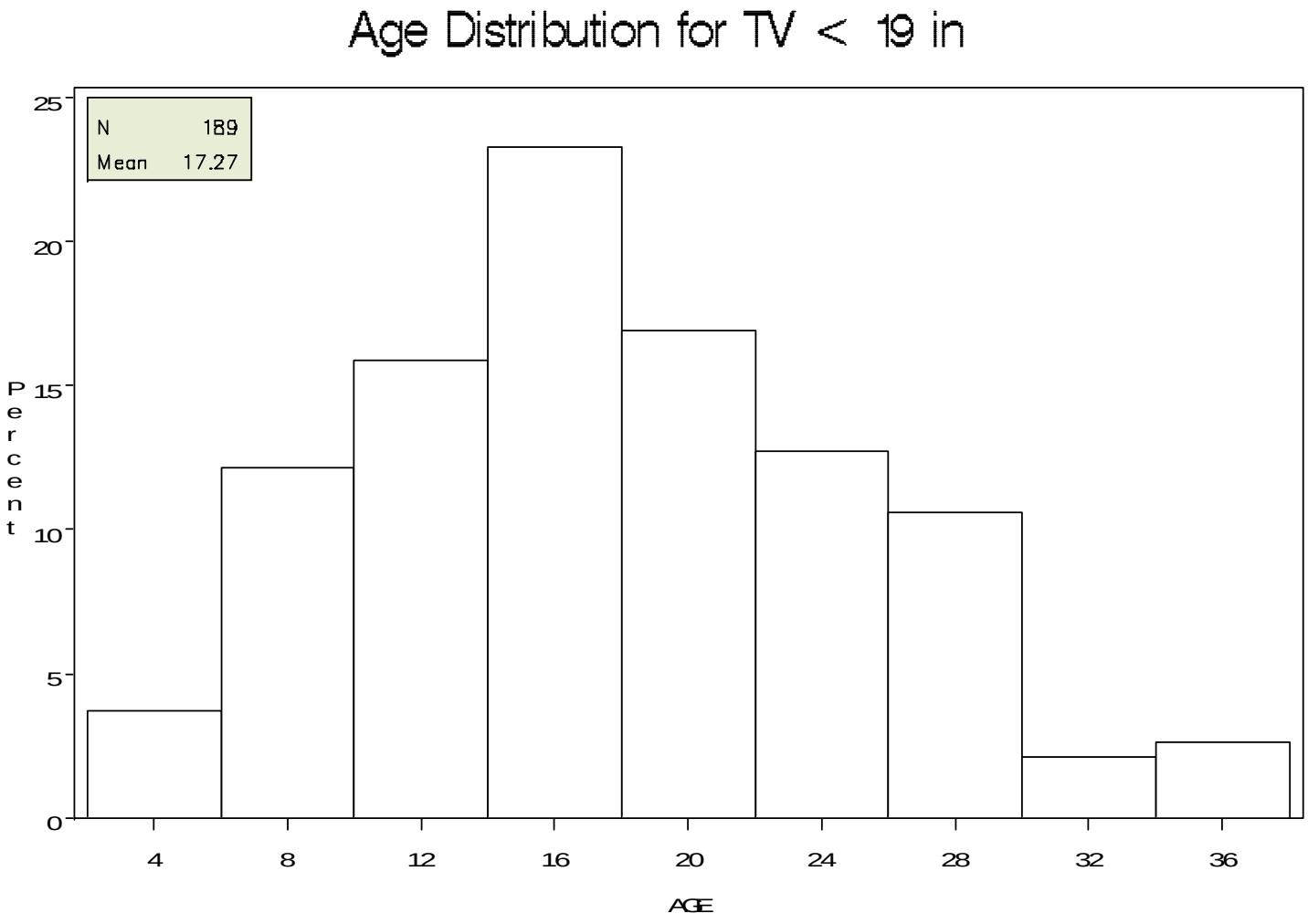
# APPENDIX A

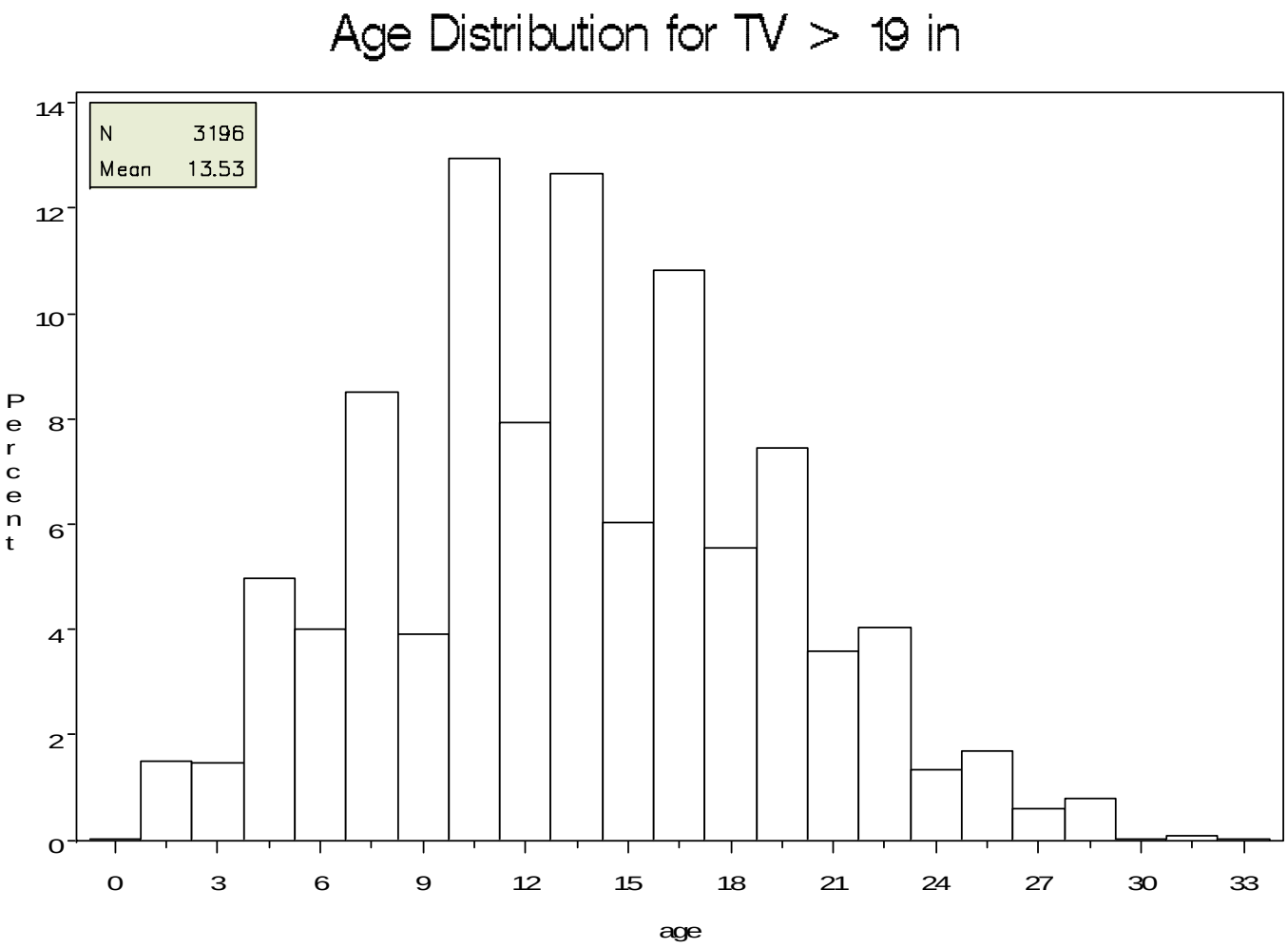
## AGE DISTRIBUTION OF ELECTRONIC PRODUCTS
## BASED ON ANALYSES OF 2004 DATA FROM
## THE FLORIDA STATE DEPARTMENT OF ENVIRONMENTAL PROTECTION


Age Distribution for Desktops
N 1912
Mean 12.22
Percent
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
3
6
9
12
15
18
21
24
27
age


Age Distribution for Monitors (CRT)
N 4515
Mean 9.34
Percent
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
1.2
4.8
8.4
12.0
15.6
19.2
22.8
26.4
30.0
age


Age Distribution for Laptops
N 20
Mean 6.50
Percent
50
40
30
20
10
0
3.75
6.25
8.75
11.25
13.75
age


Age Distribution for TV < 19 in
N 189
Mean 17.27
Percent
0
5
10
15
20
25
4
8
12
16
20
24
28
32
36
AGE


Age Distribution for TV > 19 in
N 3196
Mean 13.53
Percent
0
2
4
6
8
10
12
14
0
3
6
9
12
15
18
21
24
27
30
33
age

# APPENDIX B

# ESTIMATING THE QUANTITY OF EOL ELECTRONIC PRODUCTS DISPOSED: ANALYSIS OF WASTE SORT STUDIES

Waste sort studies characterize the waste streams sampled from both residential and commercial disposal loads. These characterizations describe the volume of different categories of materials disposed as a percentage of the solid waste disposed. These figures can be used to estimate the pounds per person per year for each category. The major material categories examined in the waste sorts are paper, plastic, metal, and glass, etc.; each major category is further divided into specific products.

Although all the waste sort studies included a category for consumer electronics, the contents of this category—i.e., its subdivision into individual product types, such as televisions, monitors, and computers—varied from study to study. The annual data from the waste sorts also varied, by the year the data were collected, but each sort presented numbers that represented a full 1-year period. Six of the studies were statewide (covering California, Georgia, Minnesota, Oregon, Pennsylvania, and Wisconsin) and one was local (covering Seattle).[30]

Data from each study were analyzed in detail to make sure that the waste categories matched each other as closely as possible. For example, major categories such as construction and demolition debris, ash, sewage sludge, and other special wastes that were included in some, but not all of the waste sort studies were removed. The yard waste category was also removed, due to regional differences associated with this type of waste. The percentages of the remaining categories were then adjusted to reflect the adjusted composition.

A second series of adjustments were made to the broad waste categories to make the studies more comparable. For example, if there were insufficient data in the waste sort studies to match the specific items included in these broad categories between studies, these categories were removed and replaced with national average data to fill in the data gaps. An example of when such adjustment might be made is in the category of "durable goods." Durable goods include such items as appliances, tires, carpet, and furniture and furnishings. In some of the studies, these items were specifically cited, while in others, they were included in other broad categories, such as "other metals," "other plastics," and "wood and wood products." Another example is that some broad categories may also have included non-MSW products such as lumber, windows, doors, fixtures, tubing, and

[30] California Integrated Waste Management Board. *Contractor's Report to the Board: Statewide Waste Characterization Study*. Publication Number 340-04-005. December 2004.
Department of Community Affairs. *Georgia Statewide Waste Characterization Study*. June 22, 2005.
Solid Waste Management Coordinating Board et al. *Statewide MSW Composition Study: A Study of Discards in the State of Minnesota*. March 2000.
Oregon Department of Environmental Quality et al. *2002 Oregon Solid Waste Characterization and Composition*. 2004.
Pennsylvania Department of Environmental Protection et al. *Final Report: Statewide Waste Composition Study*. 2003.
Cascadia Consulting Group, Inc., et al. *Wisconsin Statewide Waste Characterization Study: Final Report*. May 2003.
Seattle Public Utilities. *2002 Residential Waste Stream Composition Study*. August 2003. *2004 Commercial and Self-Haul Waste Streams Composition Study.* September 2005.

wiring from home or commercial renovation projects; also, automobile parts are commonly included. Adjustments were made to correct inconsistencies between studies.

Table B.1 shows the results of the waste sort analysis on a pounds per person per year basis. Detailed data from the waste sorts were segregated to the extent possible to reflect the consumer electronics that are the focus of this study. There is some uncertainty due to the lack of information in the individual studies as to whether scanners and facsimile machines are included in all of the factors shown.

The average of the waste sort studies, on a per person per year basis, is shown in the following table. Although seven waste sort studies were analyzed, only six were judged to have sufficient information to allow for the separation of the specific consumer electronic product categories.

**Table B.1**
**Discards of Electronic Products, in Average Pounds per Capita**

| Consumer Electronic Discards | Average of Waste Sorts (lbs/cap/yr) | California (lbs/cap/yr) | Georgia (lbs/cap/yr) | Minnesota (lbs/cap/yr) | Wisconsin (lbs/cap/yr) | Oregon (lbs/cap/yr) | Seattle (lbs/cap/yr) |
|---|---|---|---|---|---|---|---|
| Computer-related electronics | 3.6 | 6.9 | 2.0 | 2.5 | 1.0 | 4.9 | 4.2 |
| CRTs (monitors and televisions) | 5.8 | 13.0 | 0.9 | 1.2 | 12.6 | 6.6 | 0.7 |
| Total | 9.4 | 19.8 | 2.9 | 3.7 | 13.6 | 11.6 | 4.8 |
| Data year | | 2002 | 2003/2004 | 1998 | 2001 | 2002 | 2002 |

Source: ERG estimates based on analysis of six waste sort studies. See footnote #26.

Applying the resulting average factor of 9.4 pounds per person per year to the U.S. resident population, results in the discard estimates for the EOL electronic products presented in Table B.2.

**Table B.2**
**Estimated Discards of EOL Electronics Based on Waste Sort Averages**

| Year | U.S. Population (millions) | Estimated Discards (Million Tons per Year) |
|---|---|---|
| 1999 | 272.7 | 1.28 |
| 2000 | 281.4 | 1.32 |
| 2001 | 284.8 | 1.34 |
| 2002 | 288.0 | 1.35 |
| 2003 | 290.8 | 1.37 |

Comparing the results for 2003, both methods of estimating the amount disposed are reasonably close. The estimate in Table 3.3, which was based on the modeling results of EOL electronic products ready for EOL management less the amount recycled, yielded

1.7 million tons, whereas the estimate developed based on the average results from six waste sort studies estimated 1.4 million tons.

# APPENDIX C

## AVERAGE COLLECTION RATES FROM EXISTING ELECTRONICS COLLECTION PROGRAMS BASED ON DATA ANALYSIS CONDUCTED IN 2006

Recovery rates experienced by existing state and local electronics collection programs allow us to begin to understand how residents respond to recycling opportunities when they are available. This is important when municipalities or other entities are planning to establish electronics recycling opportunities to a given population. We examined recovery rate information on a per capita basis from a number of programs to get a sense of the quantities of material that might be anticipated.

Each of the recycling programs selected for this analysis met the following criteria:

- The program served a discrete and quantifiable population. Examples include state programs available to all state residents, collections run out of county or municipal waste management facilities, and curbside collections within a specific city or county.
- The program involved regular daily, weekly, or monthly collection—not a one-time or annual collection event.

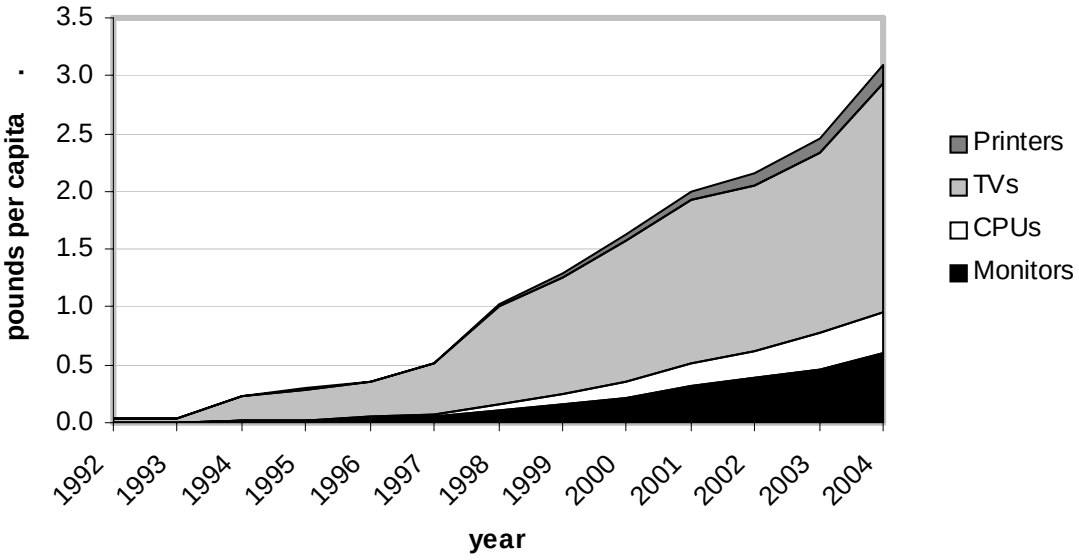
Hennepin County, Minnesota, which includes Minneapolis and several surrounding communities, has one of the longest-running electronic waste recovery programs in the nation. As of 2004, the county collected 54 percent of its e-waste at two drop-off centers, 29 percent through curbside pickup in the city of Minneapolis, and the remainder through various hazardous waste collection events.[31] Figure C.1 shows annual per capita recovery by product type from 1992 to 2004, based on data provided by the Minnesota Office of Environmental Assistance. (These data were originally collected in units; they were converted to pounds based on a standard set of mass factors that were used for all program data presented in this section.)[32] Per capita recovery was calculated using county-wide population figures from the U.S. Census. Annual population figures between 1990 and 2000 were estimated by linear regression between the 1990 and 2000 Census totals. Post-2000 population estimates were based on a linear regression between the 2000 Census total and the 2003 Census estimate.

Waukesha County, Wisconsin, is located just west of Milwaukee. The county collects EOL computer products, but not TVs, at several drop-off locations, each open at least one day per week to all county residents. Businesses recycle computers through a separate program, although some businesses could have dropped electronics off at the residential collection sites. Recovery data were provided by the Waukesha County Recycling and Solid Waste Office, with units converted to pounds using our standard conversion factors. Figure C.2 shows the per capita recovery data, which were calculated using the county-wide population from the 2000 Census.

[31] www.electronicsrecycling.com/NCER/UserDocuments/121541970Hennepin_Brand_Tally.pdf

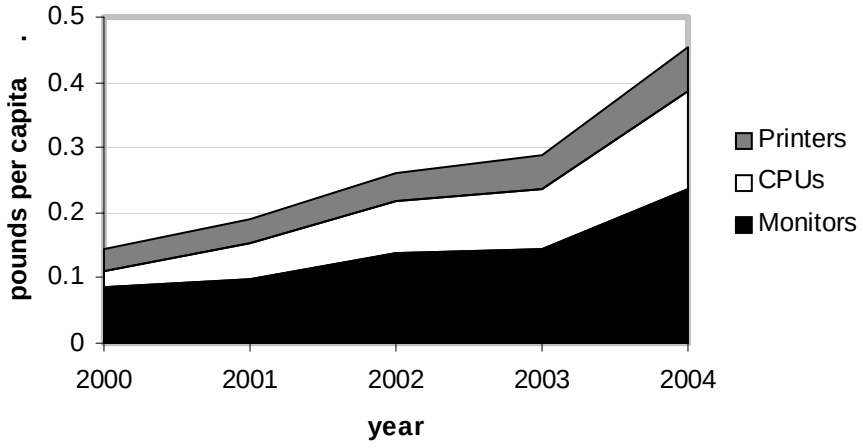
[32] Standard factors assumed for all per capita calculations were: CPUs, 23 pounds; monitors, 30 pounds; Printers/peripherals, 21 pounds; laptops, 9 pounds; and TVs, 63 pounds.

**Figure C.1. Per Capita Electronics Recovery in Hennepin County, MN, 1992–2004**




Notes: The program began in fall 1992. Minneapolis curbside electronics recycling began in 1997. The program began tracking laptops as a separate category in 2003. Per capita laptop recovery in 2003 and 2004 was 0.002 pounds and 0.005 pounds, respectively.
Source: Minnesota Office of Environmental Assistance, September 2005.

**Figure C.2. Per Capita Recovery of Computer Products Only in Waukesha County, WI, 2000–2004**




Notes: The program began in 2000 with two drop-off locations. A third drop-off location was added in 2001; unlike the other two, it was open daily. A fourth drop-off site was added in May 2002.
Source: Waukesha County Recycling and Solid Waste Office, September 2005.

The Canadian province of Alberta started an e-waste collection program in October 2004, with collection locations throughout the province. Recycling is free to all residents, and is funded by an Advance Recovery Fee (ARF) levied on certain electronic goods at the point of sale. The Alberta Recycling Management Authority provided unit recovery data through May 2005 by product type. Table C.1 presents the recovery data in annual pounds per capita, with the original 8 months of data multiplied by 1.5 (for an annual estimate). Pounds per capita were calculated using the standard set of product mass factors and the provincial population figure from Canada's 2001 Census. Note that, in other programs that have been in operation several years, the recovery rate is usually low in the first year and increases substantially in subsequent years.

**Table C.1**
**Per Capita Electronics Recovery in Alberta**

| Product | Pounds per Capita |
|---|---|
| Monitors | 0.43 |
| CPUs | 0.29 |
| TVs | 0.40 |
| Printers | 0.17 |
| Laptops | 0.004 |
| TOTAL | 1.30 |

Notes: Annual recovery rate is based on prorated data from October 2004 through May 2005. The province-wide program began in October 2004. As of May 2005, more than 100 collection sites and e-roundups had been established.
Source: Alberta Recycling Management Authority, September 2005.

Citrus County, Florida, is a rural county located north of Tampa along the Gulf Coast. The county operates an e-waste drop-off site at the county landfill. Businesses must pay a per-item fee, while recycling for residents is free.[33] Product recovery data for 2002 were available from the National Electronics Product Stewardship Initiative (NEPSI), which maintained a database of e-waste recovery data for a short period of time. The 2002 figures represent a 9-month pilot, but were extrapolated to annual rates for comparison. Data for 2003 and fiscal year 2005 for Citrus County were obtained from the Florida DEP. Table C.2 shows Citrus County's e-waste recovery in pounds per capita, calculated using standard mass factors and the county's 2004 population estimate (U.S. Census).

**Table C.2**
**Per Capita Electronics Recovery in Citrus County, FL, 2002–2005**

| Product | Pounds per Capita (Annual Rate) | | |
|---|---|---|---|
| | 2002 | 2003 | Oct 2004–Sep 2005 |
| Monitors | 0.43 | 0.20 | 0.32 |
| CPUs | 0.19 | 0.06 | 0.13 |
| TVs | 0.72 | 1.65 | 1.93 |
| Printers[34] | | 0.08 | 0.10 |
| TOTAL | 1.33 | 1.99 | 2.48 |

Notes: The program began as a pilot in 2002 with a monthly drop-off. After the pilot stage, the program was expanded to a daily drop-off.
Source: NEPSI On-Line Data Base, 2003. Florida Department of Environmental Protection. September 2005.

[33] www.bocc.citrus.fl.us/swm/electronics_recycling_tipping.htm
[34] In 2002, Citrus County reported printers as part of "peripheral devices," not as a separate category.

Several other counties in Florida have operated pilot or permanent e-waste collection programs. Product recovery data from these counties were available from the NEPSI database. Programs with regular collection and at least 8 months of data (mostly from 2002) include:

- Broward County (1 weekly drop-off location; pilot program)
- Charlotte County (1 daily drop-off location; pilot program)
- Lee County (1 weekly drop-off location; permanent)
- Miami-Dade County (1 daily drop-off location; permanent)
- Polk County (1 daily drop-off location; permanent)
- Sarasota County (daily curbside pickup and 1 daily drop-off location; pilot program)

Table C.3 shows the per capita recovery from these counties, by product type. Unit totals from the NEPSI database were converted to pounds using the standard conversion factors and compared with county populations from the 2000 Census.

**Table C.3**
**Per Capita Electronics Recovery in Several Florida Counties**

| Product | Pounds per Capita, by County | | | | | |
|---|---|---|---|---|---|---|
| | **Broward** | **Charlotte** | **Lee** | **Miami-Dade** | **Polk** | **Sarasota** |
| Monitors | 0.07 | 0.08 | 0.09 | 0.03 | 0.03 | 0.13 |
| CPUs | 0.04 | 0.07 | 0.05 | 0.01 | 0.01 | 0.05 |
| TVs | 0.05 | 0.07 | 0.05 | 0.13 | 0.27 | 0.24 |
| Printers[35] | 0.02 | | 0.03 | 0.01 | 0.01 | 0.03 |
| Laptops[36] | | | 0.0002 | | | 0.0006 |
| TOTAL | 0.18 | 0.22 | 0.21 | 0.19 | 0.32 | 0.45 |

Source: NEPSI On-Line Data Base, 2003. Florida Department of Environmental Protection. September 2005.

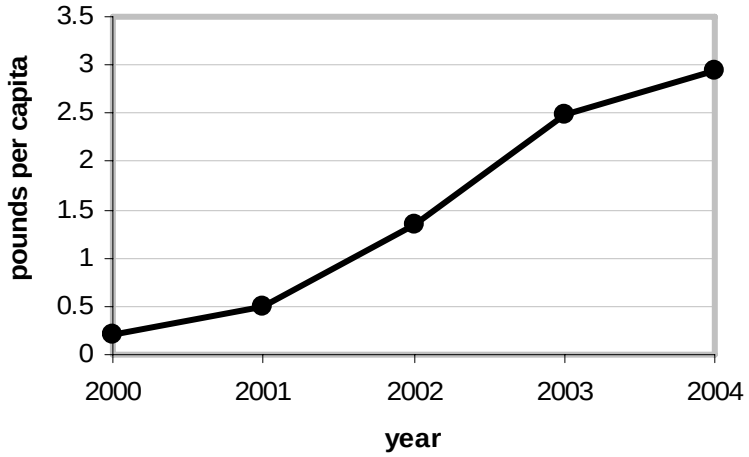
Another state with extensive e-recycling infrastructure is Massachusetts. Since the early 1990s, the state Department of Environmental Protection (MA DEP) has provided grants to help municipalities establish CRT collection programs.[37] In April 2000, the state banned CRTs from all solid waste disposal facilities, and since then, CRT collection programs have gradually expanded to cover a large percentage of the state's 6.4 million residents. Programs are operated by individual municipalities, and range from curbside pickups to daily drop-off locations, special collection events, collaborations with charities, or a combination of methods. Some programs charge a per-unit fee.

Each municipality reports annual collection totals to MA DEP. Reporting methods vary, with some programs reporting recovery in pounds as measured by their vendor, others reporting pounds calculated from the number of units recovered, and the rest reporting

[35] Charlotte County reported totals for peripheral devices, but did not break these down by type of device.
[36] Many programs did not report laptops as a separate category.
[37] www.mass.gov/dep/recycle/reduce/crtqanda.htm

unit totals, which MA DEP converts to pounds using a set of mass factors. These data only include products with CRTs and are generally not broken down by product type, so we were unable to determine what portion was monitors as opposed to TVs. Figure C.3 shows the per capita recovery of total CRTs from 2000 to 2004, based on data provided by MA DEP. Each year's per capita figure reflects the population served by the CRT recycling programs reporting data to MA DEP for that year (municipal population figures provided by MA DEP). This denominator increased overall from 2000 to 2004, as more and more communities established recycling programs.

**Figure C.3. Per Capita CRT Recovery in Massachusetts, 2000–2004**




Notes: Data covers only computer monitors and televisions with a CRT.
Source: Massachusetts Department of Environmental Protection, September 2005.

Table C.4 summarizes the results from the individual programs examined.

**Table C.4**
**Range of Per Capita Recovery Rates Among Selected Programs, 2004**

| Product Type | Recovery Range (Pounds per Capita) | |
|---|---|---|
| | Minimum | Maximum |
| Monitors | 0.23 | 0.60 |
| CPUs | 0.13 | 0.35 |
| TVs | 0.4 | 1.99 |
| Printers | 0.07 | 0.17 |
| Laptops[38] | 0.002 | 0.007 |
| Total | 0.83 | 3.12 |

It was not in the scope of this study to delve more deeply into what factors most affect collection rates. We did, however, briefly analyze the data from Massachusetts to see if there was a statistically significant difference in the per capita recovery rates of different types of programs (e.g., drop-off, curbside pickup, special event).

[38] Only Waukesha County, Alberta, and Hennepin County reported laptops as a distinct category in 2004.

As stated earlier, Massachusetts has had a ban on CRT disposal since 2000. Each town chooses what type, if any, of collection program it will offer residents. The state maintains a database of what is collected by the towns that access the statewide recycling contracts to support their programs. We analyzed the effect of program type on the pounds product per capita recovered. We used a nonparametric one-way anova procedure for a simple standard analysis of variance test on the raw data. The multiple sample Kruskal-Wallis test was used to detect a significant difference in the distributions of the program type variable. The analysis showed that program type is, in fact, statistically significant in determining the pounds per capita recovery rate.

Table C.5 presents the analysis of the variance for the recovery rate variable. As shown in the table, drop-off programs in Massachusetts collected the most material on a pounds per capita basis. Massachusetts state recycling officials informed us that many of the curbside pickup programs require residents to make an appointment for a pickup and in some cases there is a monthly limit constraining the number of pickups that can be scheduled. This factor could partially explain why the curbside programs had a lower recovery rate than the drop-off programs. Of the three main types of programs (curbside, drop-off, and special event), special events had the lowest recovery rates. The data for the combination programs are difficult to interpret because we have no information regarding the predominant method of collection in these communities.

**Table C.5**
**Analysis of Variance for the Pounds per Capita Variable**
**Classified by Program Type**

| Program Type | Number in Sample | Mean Pounds per Capita |
|---|---|---|
| Drop-off | 524 | 2.82 |
| Curbside pickup | 71 | 1.95 |
| Special event | 67 | 1.18 |
| Drop-off/special event | 25 | 1.36 |
| Drop-off/curbside | 60 | 1.30 |
| Curbside/special event | 7 | 1.15 |
| Charity/curbside | 5 | 0.55 |
| Drop-off/curbside/special event | 9 | 0.61 |