MANAGEMENT OF ELECTRONIC WASTE IN THE UNITED STATES: APPROACH TWO

Draft Final Report

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CHAPTER 1 – INTRODUCTION

Although electronics represent less than two percent of the municipal solid waste stream, options have increased for reusing and recycling electronics in recent years. Over 800 communities have instituted electronics collection events to help manage obsolete electronics from households[1]. Many manufacturers of personal computers now offer take back programs on-line, at least seven states ban landfilling of certain electronics, and four states have programs that institute state-wide recovery programs for used electronics. Many other states are looking to pass similar legislation this year, and many are interested in Federal action to harmonize electronics recovery laws.

Recycling end-of-life (EOL) electronics, rather than disposing of them, makes use of valuable components and materials, thereby conserving natural resources and saving energy. EPA has been active in promoting the recycling and reuse of EOL electronics through various programs, including Plug-In To eCycling and the Federal Electronics Challenge.

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[2]. However, since that time, consumption and disposal, as well as reuse and recycling of electronics in the US has 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 looked at this issue from two different points of view. EPA assembled two different data sets and used two different methodologies to estimate the amounts of commonly handled electronics that are stored, reused, recycled and disposed. Our results are detailed in two detailed reports, plus an Overview that summarizes both.

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[1] "817 cities and jurisdictions provide some type of electronics recycling services in the US." Gracestone Inc. and E-Scrap News. "Public Sector Offering of E-Scrap Services: The Why and Why Not." Presentation: *E-Scrap* Oct. 2006.

[2] 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.

Looking at both of the detailed reports together, it is evident that the results are quite similar. We believe that the dual approaches lend credibility to the range of results obtained and enable readers to view the results from several different and helpful angles.

The two detailed reports comprise the entire analysis:

- "Electronics Waste Management in the United States: **Approach One.**" This analysis relies primarily on market research data on sales of electronic products. It then applies these sales data to some of the most comprehensive collection information available to estimate product lifespans and the amounts of particular products that are ready for EOL management. From these EOL estimates, we subtract the estimated quantity recycled 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.

- "Electronics Waste Management in the United States: **Approach Two.**" Approach Two relies primarily on government statistics on sales of electronic products. It then uses the same lifespan data (with some modifications) as Approach One to estimate EOL quantities. From these EOL estimates, we subtract the quantity of selected electronics disposed to yield the quantity recycled. This approach also provides information on the composition of electronic products, as well as the number of select electronic devices entering storage/reuse annually.

The report that follows is Electronics Waste Management in the United States: **Approach Two.**"

Readers should consider that the information presented in both Approach One and Approach Two provides 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.

The scope of this report includes the following electronic products:

- Televisions,
- Personal computers (desktops, laptops, and computer monitors),
- Printers[3]
- Computer mice
- Keyboards
- Cell phones.

[3] Approach One includes hard-copy peripherals, which is comprised of printers, scanners, and fax machines while Approach Two only includes printers.

The purpose of this report is to present EPA's baseline assessment, using the methodology outlined in this report, on e-waste generation and management in the U.S. We present this information in the following chapters:

- **Summary of Methodology.** In this chapter, we describe the methodology that we developed for estimating the amount of e-waste generated in the U.S. each year and for assessing how this waste is managed.
- **Summary of Data Inputs.** Following the discussion of our methodology, we summarize the main data sources and assumptions used to implement this methodology.
- **Baseline E-waste Assessment Results.** In the final chapter of this document, we present and discuss the results of our analysis.

Exhibit 1-1 summarizes the results of our analysis, averaged over the 2003-2005 period. As indicated by the exhibit, CRT televisions and monitors made up nearly two-thirds of the subset of e-waste analyzed in the report in the U.S. between 2003 and 2005. Thus, these electronic products will continue to be an important part of the U.S. e-waste stream for years to come despite the ongoing shift to flat-screen televisions and monitors. The results in Exhibit 1-1 also indicate that the vast majority of U.S. e-waste is deposited in landfills, while approximately 20 percent is recycled. By comparison, EPA estimates that approximately 32 percent of the municipal solid waste generated in the U.S. in 2005 was recycled.[4] We present a more detailed accounting of our results in Chapter 4 below.

[4] Estimate includes composting. U.S. EPA, *Municipal Solid Waste in the United States: 2005 Facts and Figures*, October 2006.

EXHIBIT 1-1 SUMMARY OF ANNUAL E-WASTE GENERATION AND MANAGEMENT: 2003-2005 (THOUSANDS OF TONS)[1]

PRODUCT	MANAGEMENT METHOD			
	RECYCLED[2]	LANDFILLED	INCINERATED	TOTAL
Desktop Computers	65.7	180.9	5.1	251.7
Laptop Computers	7.0	19.3	0.5	26.8
CRT Monitors	97.5	291.6	8.3	397.4
LCD Monitors	0.6	1.8	0.0	2.4
Televisions	112.5	709.1	20.2	841.7
CRT Televisions	98.5	620.7	17.7	736.9
Projection TVs	14.0	88.3	2.5	104.8
Cell Phones	1.9	7.9	0.2	10.0
Printers	62.0	170.6	4.8	237.5
Keyboards	14.1	38.6	1.1	53.8
Computer Mice	0.9	2.4	0.1	3.4
All Products	**362.2**	**1422.1**	**40.4**	**1,824.8**

Notes:
1. The results presented in this exhibit represent average annual tonnages for the 2003-2005 period.
2. As described in the main body of this report, the recycling estimates in this report include amounts exported; however, insufficient data are available to distinguish between recycled and exported waste.

CHAPTER 2 – SUMMARY OF METHODOLOGY

To assess the baseline generation and management of electronic waste in the U.S, we developed a waste flow model that tracks e-waste generation and management over time for the electronic products listed in Chapter 1. Based on several data inputs, the model estimates the number and total mass of electronic products that enter the U.S. waste stream each year and apportions this waste across various management options (e.g., recycling, landfill disposal, and incineration). This chapter provides an overview of the methodology reflected in the model and summarizes the data inputs necessary to implement this methodology.

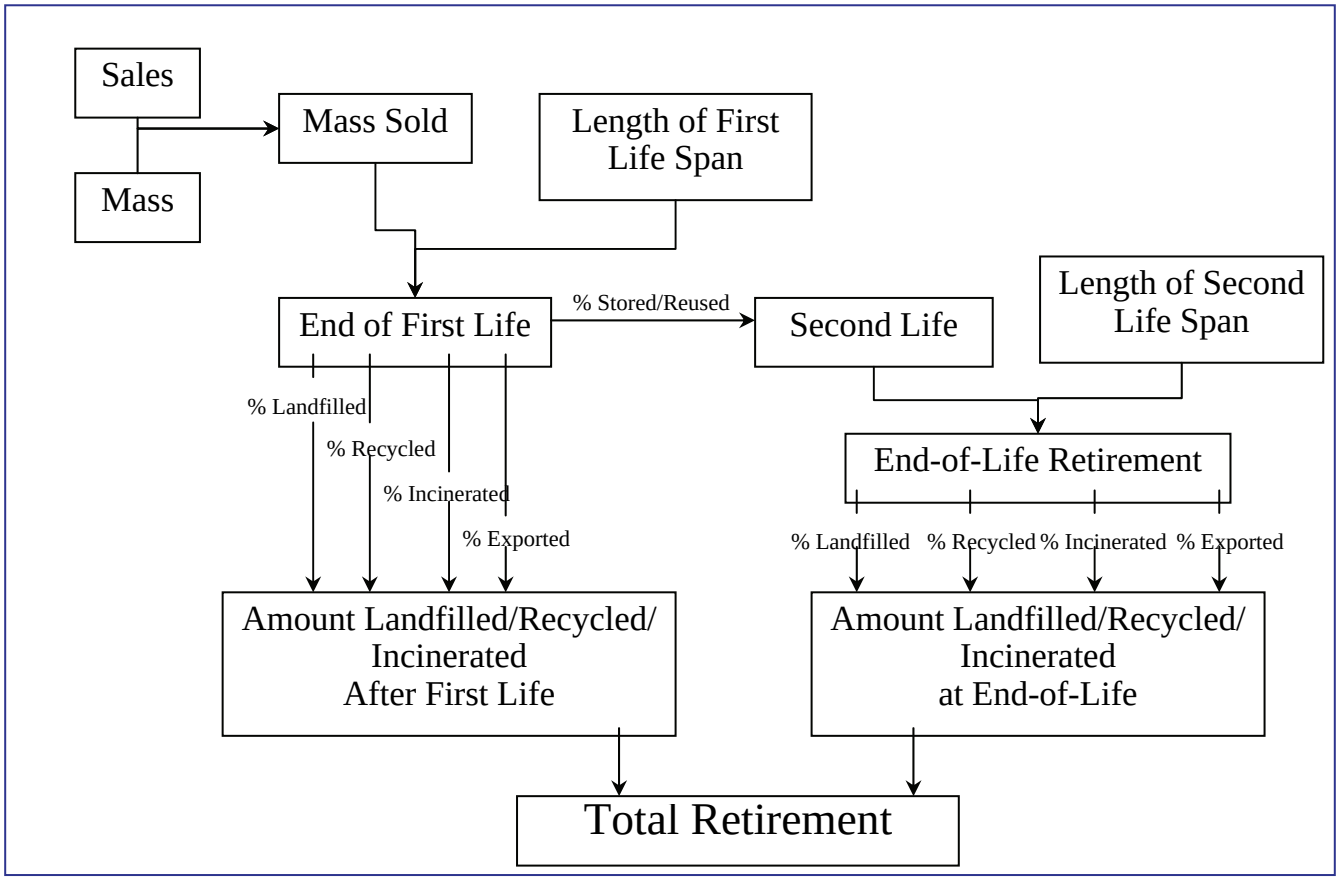
MODEL STRUCTURE

The waste flow model developed for this baseline assessment simulates the generation and management of electronic waste based on a series of sequential calculations, as outlined in Exhibit 2-1. First, based on sales (in units) and per unit mass information, the model calculates

annual tonnages sold for each product. Following each cohort of products (e.g., laptop computers sold in 1995) through time, the model then allocates a portion of each cohort to storage/re-use when it reaches the end of its first life (i.e., when the original owner of a product stops using it), allowing some products to move on to a second life. The model simulates the EOL management of the remainder, allocating the waste to landfills, incinerators, or recycling.

For products moving onto a second life[5] (i.e., products stored or re-used at the end of their first life), the model follows a similar procedure, allocating these items to each management option. For any given year, the waste flow model estimates total retirements (by management method) by summing devices reaching the end of their first life that year and devices reaching the end of their second life.

EXHIBIT 2-1. WASTE FLOW MODEL DESIGN



[5] A product's second life could include multiple users and stages of use.

DATA INPUTS

As suggested by the schematic presented in Exhibit 2-1, the waste flow model requires several data inputs to assess the generation and management of electronic waste in the United States for any given year. These inputs include: sales, product mass, the initial service life of each product, the second service life of each product, probability distributions for any first and second service lives expressed as a range, and EOL management allocation weights.[6] We describe each of these inputs below:

- **Sales:** A key input for the model is the annual sales (in units) for each electronics product.
- **Mass:** To estimate the tonnage of electronic products sold and retired, the model requires per unit mass estimates for each product. Since products produced in more recent years may have a different per unit mass than products sold in earlier years, the model requires product-specific mass estimates by year (e.g., for desktop computers sold in 1998).
- **First Service Life:** The first service life of a device is the length of time the electronic product is used by its original or initial owner. The model uses this information to estimate the volume of electronics reaching the end of their first life each year. To reflect the uncertainty associated with each product's initial service life, the model allows users to enter this input as a range. For example, if desktops sold in 1990 have an average initial service life of two to four years, users can enter two years as the low end of the initial service life range and four years as the high end.
- **First Service Life Probability Distribution:** For first service life estimates expressed as a range, the model requires users to specify a service life probability distribution. For example, if desktops sold in 1990 have an average initial lifespan of two to four years, model users can specify that 25 percent of desktops will be retired by their original users after two years of use, 50 percent in the third year, and the remaining 25 percent in the fourth year.
- **Second Service Life:** Similar to the first service life, the model requires information on the duration of the second service life of each electronics product. We define second service life as the length of time over which a product is reused or kept in storage after its first life.
- **Second Service Life Probability Distribution:** The model requires a probability distribution for each second service life estimate expressed as a range.
- **Management Allocation Weights:** The model requires users to specify how devices at the end of their first life are allocated across the following management options: recycling, landfilling, incineration, and re-use/storage. Similarly, the model requires users to indicate how devices reaching the end of their second life are allocated across the following management options: landfilling, recycling, and incineration.[7]

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[6] For any product, an allocation weight is the percentage of units at the end of their first or second life that the waste flow model apportions to a specific management method (e.g., incineration).

[7] Re-use/storage is not a management option at the end of a product's second service life.

CHAPTER 3 – SUMMARY OF DATA INPUTS

As explained in the previous chapter, the baseline e-waste assessment presented in this document is based on a data-intensive waste flow model that tracks e-waste generation and management over time. This chapter summarizes the various information sources and assumptions supporting the development of the model's inputs, which include product sales, product mass, first service life durations and probability distributions, second service life durations and probability distributions, and management method allocation weights.[8]

SALES DATA

As part of our effort to estimate the total volume of e-waste generated in the U.S., we collected data on electronics sales (in units) from 1975 through 2004 based on publicly available data from sources such as INFORM and the U.S. Census Bureau, and on limited data made publicly available by the market research firms Gartner and DisplaySearch.[9] Exhibit 3-1 summarizes the relevant data available from these sources.

EXHIBIT 3-1. SOURCES OF ELECTRONICS SALES DATA

SOURCE	REPORT(S) AND DATA AVAILABLE
U.S. Census Bureau	• *Current Industrial Report series, "Computers and Office and Accounting Machines"* (annually): Domestic shipments, imports, and exports (units) of desktops, laptops, monitors, keyboards and printers. • *Current Industrial Report series "Consumer Electronics"* (annually): Domestic shipments, imports, and exports (units) of CRT televisions and projection televisions.
INFORM	• *Waste in the Wireless World: The Challenge of Cell Phones*: Presents and cites Gartner data published in 2000 on U.S. cell phone sales (units) from 1995 through 2000, as well as forecasted sales for 2001 through 2004.
Gartner	• *Periodic Press Releases*: Aggregate PC shipments to U.S. retailers (in units) and global cell phone unit sales.
DisplaySearch	• *Periodic Press Releases*: Global (and, in some cases, North American) LCD monitor sales.

[8] As part of EPA's effort to characterize e-waste generated in the U.S., we also collected information on the material composition of electronic products. Appendix D summarizes the composition of televisions, desktops, laptops, monitors, cell phones, and computer peripherals. We were unable to locate information on the composition of printers, mouse devices, and projection televisions. We note that the material composition information available for these products does not in all cases account for 100 percent of the materials contained in these products.

[9] Our sales estimates for some products do not go as far back as 1975. Some of the products included in this analysis were not yet on the market in 1975 (e.g., cell phones), and for other products, the available data do not extend as far back as 1975.

Exhibit 3-2 presents our estimates of electronics sales for the 1975-2004 period. These estimates suggest that sales of personal computers (laptops and desktops) have been growing steadily since 1978, although desktop sales fell by nearly 14 percent during the economic slowdown of 2001. Our sales estimates also suggest that sales of CRT monitors have been declining since hitting a high of 40 million units in 1999, in all likelihood because of consumer substitution to LCD monitors. In contrast, as of 2004, sales of CRT televisions were increasing, which may reflect relatively high prices at the time for substitutes, such as LCD and plasma televisions. Our sales estimates also show that cell phone sales increased dramatically in the late 1990s.

We discuss the available sales data for each product in further detail below.

DESKTOP COMPUTERS

To estimate 1978 through 2004 desktop sales (excluding "white boxes," or computers manufactured by parties other than a branded manufacturer), we used the U.S. Census Bureau's "Computers and Office and Accounting Machines" Current Industrial Report (CIR) series, which contains sales-related data for brand name desktop computers. [10,11] The CIR series includes separate data for domestic shipments (i.e., domestic production), exports, and imports. Therefore, we estimate sales as the sum of domestic shipments and imports minus exports. For those years in which no CIR data were available, we generate sales estimates by interpolating between the years where data were available.

Due to various limitations in the CIR data, we made several assumptions to ensure that our sales estimates are methodologically consistent over the entire 1978-2004 period. For example, between 1978 and 1989, the CIR series includes four categories of computers: general-purpose digital computers, general-purpose analog and hybrid computers, special-purpose digital computers, and special-purpose analog and hybrid computers. We use the CIR data for general-purpose digital computers as a proxy for non-white-box desktop computer data for these years because later CIRs indicate that desktop computers are reflected only in the general-purpose digital computers category.[12] In addition, from 1989 through 2004, the CIR series does not always provide the same level of product detail for imports and exports as it does for domestic shipments. As a result, to estimate sales for these years, we assume that the composition of desktop exports and imports reflects the composition of domestic shipments. For example, although the CIR series reports domestic shipments of desktop and laptop computers separately, it combines the two in the same category for imports and exports. Therefore, we assume that

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[10] The domestic shipment data reported in the CIR for 1977 are drastically lower than subsequent years and appear to be inconsistent with the numbers reported for later years. As a result, we limit our estimates to desktops sold from no earlier than 1978.

[11] White boxes are customized, non-branded computers that retailers assemble themselves from individual computer components.

[12] Laptops may also be reflected in this category. However, because laptops were a relatively new technology in the late 1980s, we assume that a negligible number of laptops are reflected in the CIR general-purpose computers category. In addition, large-scale processing computers may also be reflected in the CIR general-purpose digital computer data between 1978 and 1991. To the extent that such units were sold during this period, we may overestimate non-white-box desktop sales for these years.

desktops' share of the combined desktop and laptop category for imports and exports is the same as its share of domestic shipments.

WHITE BOX DESKTOP COMPUTERS

We used data from the Census CIR series to estimate sales of non-white-box desktop computers and laptops. To estimate white box sales, we employed data on the number of computers in use and the number of non-white box units sold on an annual basis.

To estimate white box sales for 1990 and earlier years, we used publicly available data reported by the market research firm eTForecasts on the number of computers in use in 1980, 1985, and 1990, and our estimates of brand-name (i.e., non-white-box) desktop sales during this period. Assuming that computers sold in the 1980s had a lifespan of four years, we used our estimates of brand name computer sales to estimate the number of brand name desktops in use annually.[13] For example, we estimate brand-name computer use in 1990 as the sum of sales from 1987 through 1990. We then estimate white box computer use for 1990 by calculating the difference between the total number of desktops in use, as reported by eTForecasts, and our estimate of the number of brand-name computers in use. Continuing with our 1990 example, the difference between our estimate for brand-name desktop use in 1990 and eTForecasts' use estimate for all desktops represents the estimated use of white box computers in 1990. To estimate white box computer sales for 1990, we assume that the ratio of white box computer sales to total computer sales in 1990 is the same as the ratio of white box computer use to total computer use. We followed a similar procedure for 1985, using eTForecasts' estimate of computer use in 1985 and our estimates of 1982-1985 brand-name desktop sales. The results of our analysis suggest that a negligible number of white box units were sold in 1985 or earlier. To estimate white box sales for 1986 through 1989, we followed a two-step process. First, we estimated the white box market share for these years by assuming that the white boxes' share of the desktop market grew linearly between the market share we estimated for 1985 (0 percent) and 1990 (28.1 percent). We then applied these values to our estimates of brand-name desktop sales for these years to generate white box sales estimates.[14]

To estimate white box sales between 1997 and 2004, we used publicly available data from Gartner press releases on the size of the overall PC market (non-white-box desktops, laptops, white box systems, and in some cases servers) and the non-white-box desktop and laptop sales estimates were derived from the Census CIR data. Using these data, we estimate white box sales as follows:

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[13] This four-year estimate represents the high end of our estimate of a computer's first life, as indicated in Exhibit 3-5 below. Because computers were not as widely used in the 1970s and 1980s as in the 1990s, we assume that the high end of the lifespan range is more appropriate for use in estimating pre-1990 white box sales.

[14] More specifically, if M equals the white boxes share of the desktop market and B equals the brand-name desktop sales, we estimated white box sales as $M \times B / (1-M)$.

$$W_s = PC_s - S_s - D_s - L_s$$

where, W_s=White box sales

PC_s= Total PC shipments (non-white-box desktop computers, servers, white box desktop computers, and laptops)

S_s= Server shipments

D_s= Non-white-box desktop sales

L_s= Laptop sales

Gartner's press releases provide estimates of annual PC sales from 1997 through 2004 and annual server sales for 2000 through 2002. These data suggest that servers, on average, accounted for approximately 3.8 percent of the PC market between 2000 and 2002. To estimate server sales for other years, we assume that this percentage applies to any year for which the Gartner PC sales data include servers.[15] Using these data in conjunction with our estimates of non-white-box desktop and laptop sales, we estimate that white boxes made up 36.6 percent of the PC market in 1997 and 22.6 percent of the market in 2004.

For 1991 through 1996, we were unable to identify data on white box sales or the white box share of the desktop market. Therefore, to estimate white box sales for this period, we assumed the same interpolation approach outlined above for 1986 through 1989.

LAPTOP COMPUTERS

Similar to our analysis of desktop computer sales, we derive our estimates of domestic laptop sales from the U.S. Census Bureau's "Computers and Office and Accounting Machines" CIR series. Inadequate data are available from the CIR series to estimate laptop sales prior to 1993; therefore, we do not present estimates of laptop sales for those years. For 1997-1998 and 2000-2004, our basic approach for estimating domestic laptop sales is similar to our approach for desktops in that we estimate U.S. laptop sales as domestic shipments plus imports less exports.[16] To estimate laptop sales in 1999, we interpolate between the CIR data for 1998 and 2000.[17] For 1994 though 1996, the CIR series combines domestic laptop shipments with other devices with attached displays in a category called "Portable Computers." Therefore, we do not use the CIR data to estimate laptop sales for these years. Publicly available data from Gartner, however,

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[15] Gartner's PC sales data reflect server sales for every year, except for 1997 and 1998.

[16] To estimate imports and exports of laptops for these years, we assume that the composition of computer exports and imports is the same as the composition of domestic shipments (i.e., if laptops represent 0.17 percent of total domestic computer shipments in 2004, then we assume laptops represent 0.17 percent of computer imports and exports in 2004).

[17] To estimate total laptop sales for 1999, we calculated the laptops' share of the personal computer market in 1999 based on 1998 and 2000 data, and apply the percentage to the 1999 total computer sales.

indicates that global laptop sales increased by 57.7 percent between 1995 and 1998.[18] Based on this estimate and our CIR-derived estimate of U.S. laptop sales in 1998, we were able to estimate U.S. laptop sales in 1995. To estimate 1996 sales, we interpolated between our 1995 sales estimate and our CIR-based estimate for 1997, applying the same methodology used to estimate 1999 sales. To estimate sales in 1994, we assumed that the CIR growth rate for "Portable Computer" sales (i.e., sales of laptops and other devices with attached displays combined) between 1994 and 1995 was the same as the growth rate in laptop sales. Based on this growth rate and our sales estimate for 1995, we projected backwards in time to estimate sales in 1994.

CRT MONITORS

To estimate annual sales of CRT-monitors, we relied on domestic shipment, import, and export data available from the U.S. Census Bureau's CIR "Computer and Office and Accounting Equipment" series, and the information described above for desktop computer sales. More specifically, for 1989-2004, we used the CIR data to estimate CRT sales by estimating total shipments less exports plus imports.[19,20] For 1978 through 1988, insufficient information is available to estimate CRT monitor sales. As a result, we assume that the growth rate in monitor sales for this period is the same as the growth rate in desktop sales.

LCD MONITORS

We estimate U.S. sales of LCD monitors based on data released by the market research firm DisplaySearch. Between 1998 and 2004, DisplaySearch issued quarterly press releases on the global LCD market that in many cases included estimates of North American LCD monitor sales. Based on these data, we developed a time series of North American LCD sales for the entire 1998-2004 period. Although the DisplaySearch press releases do not report North American LCD sales for each quarter of the 1998-2004 period, we generated sales estimates in such cases through interpolation of the DisplaySearch data for other quarters. To estimate U.S. LCD monitor sales from these North American sales estimates, we assume that the ratio of U.S. to North American LCD monitor sales is the same as the ratio of U.S. to North American GDP.[21]

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[18] Gartner, Inc. as cited in cnn.com, "Mobile workforce strains IT staff," January 18, 1999, http://www.cnn.com/TECH/computing/9901/18/roadwarriors.ent.idg/

[19] For 1989 through 1991, the CIR series includes all monitors in a single category, "Monitor-like or graphic displays, excluding graphic terminals." Because other monitor technologies were not highly developed in the early 1990s, we assume that all monitors reflected in the 1989 through 1991 CIRs are CRT monitors.

[20] The CIR series distinguishes between CRT and other monitors from 1992 through 2004, but reports sufficient data to estimate sales only for 1992-93 and 1997-2004. To estimate CRT monitor sales for 1994 through 1996, we interpolated from the 1993 and 1997 estimates we derived from the CIR data. In addition, the CIR series contains CRT monitor import and export data for 2003, but lacks complete information on shipments from domestic manufacturers for this year. To estimate 2003 sales, we used the CIR import and export data for 2003 and the average of the CIR domestic shipment estimates for 2002 and 2004.

[21] Consistent with DisplaySearch, we define North America as the U.S. and Canada for the purposes of this analysis.

EXHIBIT 3-2. VOLUME OF ELECTRONICS SOLD: 1975-2004 (MILLIONS OF UNITS)

YEAR	TOTAL DESKTOPS	NON-WHITE BOXES	WHITE-BOXES	LAPTOPS	CRT MONITORS	LCD MONITORS	TOTAL TVS	CRT TVS	PROJECTION TVS	CELL PHONES	PRINTERS	KEY-BOARDS	COMPUTER MICE
1975	N.E.	N.E.	N.E.	N.E.	N.E.	N.E.	11.5	11.5	N.E.	N.E.	N.E.	N.E.	N.E.
1976	N.E.	N.E.	N.E.	N.E.	N.E.	N.E.	14.4	14.4	N.E.	N.E.	N.E.	N.E.	N.E.
1977	N.E.	N.E.	N.E.	N.E.	N.E.	N.E.	14.7	14.7	N.E.	N.E.	N.E.	N.E.	N.E.
1978	0.7	0.7	N.E.	N.E.	0.6	N.E.	17.4	17.4	N.E.	N.E.	1.2	N.E.	N.E.
1979	1.1	1.1	N.E.	N.E.	0.9	N.E.	16.2	16.2	N.E.	N.E.	1.7	N.E.	N.E.
1980	1.5	1.5	N.E.	N.E.	1.2	N.E.	16.8	16.8	N.E.	N.E.	1.8	N.E.	N.E.
1981	1.9	1.9	N.E.	N.E.	1.5	N.E.	18.2	18.2	N.E.	N.E.	2.8	N.E.	N.E.
1982	3.5	3.5	N.E.	N.E.	2.8	N.E.	17.4	17.4	N.E.	N.E.	3.2	N.E.	N.E.
1983	5.5	5.5	N.E.	N.E.	4.4	N.E.	21.3	21.3	N.E.	N.E.	4.7	N.E.	N.E.
1984	8.2	8.2	N.E.	N.E.	6.5	N.E.	24.2	24.2	N.E.	N.E.	5.8	N.E.	N.E.
1985	7.0	7.0	N.E.	N.E.	5.6	N.E.	28.1	28.1	N.E.	N.E.	4.6	N.E.	N.E.
1986	7.8	7.4	0.4	N.E.	6.2	N.E.	27.7	27.7	N.E.	N.E.	5.5	15.5	1.1
1987	9.8	8.7	1.1	N.E.	7.8	N.E.	27.7	27.7	N.E.	N.E.	6.8	19.4	3.4
1988	10.4	8.7	1.8	N.E.	8.3	N.E.	22.9	22.4	0.6	N.E.	7.8	20.7	5.7
1989	11.8	9.2	2.7	N.E.	9.4	N.E.	25.6	24.9	0.7	N.E.	10.7	23.4	8.0
1990	14.4	10.4	4.1	N.E.	10.3	N.E.	23.2	22.5	0.7	N.E.	9.6	28.6	10.4
1991	16.7	11.8	4.9	N.E.	12.0	N.E.	21.4	20.6	0.7	N.E.	9.8	33.1	11.8
1992	18.0	12.5	5.5	N.E.	13.4	N.E.	28.1	27.3	0.8	N.E.	12.6	35.8	12.5
1993	19.4	13.3	6.2	N.E.	17.3	N.E.	27.9	27.1	0.9	N.E.	16.4	38.6	13.3
1994	20.9	14.0	6.9	1.4	20.3	N.E.	26.6	25.4	1.3	N.E.	22.4	41.4	14.0
1995	23.2	15.3	7.9	1.9	23.3	N.E.	25.3	23.6	1.7	14.5	28.5	47.6	15.3
1996	22.9	14.8	8.1	2.0	26.3	N.E.	31.1	28.7	2.4	16.6	34.5	53.8	14.8
1997	27.7	17.5	10.1	2.7	29.2	N.E.	34.1	31.4	2.7	22.2	26.2	55.6	17.5
1998	33.1	18.0	15.1	2.9	35.1	0.2	35.9	32.9	3.0	30.6	31.9	65.0	18.0
1999	37.8	27.7	10.1	5.3	40.0	0.8	37.6	34.7	2.9	49.3	43.4	63.7	27.7
2000	40.9	30.1	10.8	6.6	37.5	1.4	37.4	33.2	4.2	71.2	46.4	60.6	30.1

YEAR	TOTAL DESKTOPS	NON-WHITE BOXES	WHITE-BOXES	LAPTOPS	CRT MONITORS	LCD MONITORS	TOTAL TVS	CRT TVS	PROJECTION TVS	CELL PHONES	PRINTERS	KEY-BOARDS	COMPUTER MICE
2001	35.2	26.0	9.3	6.9	27.2	4.4	32.1	28.4	3.7	68.9	43.1	57.5	26.0
2002	40.8	29.4	11.4	8.6	24.3	10.6	38.3	33.4	4.9	74.4	43.4	54.4	29.4
2003	44.6	34.4	10.3	10.9	16.4	14.9	36.8	31.1	5.7	89.6	50.9	51.3	34.4
2004	47.5	36.8	10.7	12.4	15.9	21.1	46.9	38.4	8.6	116.2	63.6	47.2	36.8

Notes:

1. N.E. denotes that sales were not estimated.
2. Totals may not match due to rounding.

CRT-BASED AND PROJECTION TELEVISIONS

To estimate annual sales of televisions between 1975 and 2004, we used shipment, import, and export data from the CIR "Consumer Electronics" series. The CIR series reports separate domestic shipment estimates for CRT-based televisions and projection televisions, but combines these categories in its reporting of television exports and imports. To address this issue, we assume that the composition of television exports and imports is the same as the composition of television shipments (e.g., if projection televisions represent 13 percent of shipments in 2002, we assume that projection televisions also represent 13 percent of projection television exports and imports in 2002).

Due to limitations in the CIR television data, we made several assumptions in deriving our television sales estimates from these data. First, for 1975 through 1987, the CIR series reports only "Table and portable models," and "Console and consolette models." We assume that both of these categories represent CRT-based televisions. Second, for 1988 through 1990, the CIR series separates televisions into "Table and portable models," "High definition television (HDTV)," and "Projection televisions." To make our pre-1990 CRT television sales estimates consistent with our estimates for later years (i.e., post-1990), we consider all "Table and portable models" to be CRT-based televisions, all "Projection televisions" to be projection televisions, and we distribute high-definition televisions proportionately across the table and portable models and projection televisions (i.e., if table and portable models represent 97 percent of total table and portable models, and projection televisions in 1990, then we assume 97 percent of high definition televisions in 1990 are table and portable models). Lastly, we estimated 1994 sales by interpolating between our estimates for 1993 and 1995 because the CIR series does not contain sufficient data on 1994 sales.[22]

COMPUTER PERIPHERALS (PRINTERS, KEYBOARDS, AND MICE)

The CIR "Computer and Office and Accounting Equipment" series contains limited sales-related data for a number of peripheral products, including printers, keyboards, and computer mice.[23] For printers, the CIR series presents no import/export data prior to 1978, and no domestic shipment data prior to 1976; therefore, we limit our analysis of printers to units sold no earlier than 1978. Due to limitations in the CIR printer data for the 1978-2004 period, we use several approaches to generate printer sales estimates for these years. For example, because the CIR series contains no import data for printers between 1978 and 1985, we used the ratio of printer imports to total domestic shipments of printers in 1986 and apply this ratio to the 1978-1985 CIR printer shipment data to estimate printer sales for these years. In addition, the CIR import and

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[22] Although the CIR series contains shipment, import, and export figures for televisions in 1994, the import estimate for this year (1.9 million units) is significantly less than the 16.3 million units and 13.2 million units imported in 1993 and 1995 respectively. Because of the magnitude of this discrepancy, we suspect that the 1994 import estimate in the CIR series is incorrect.

[23] The Consumer Electronics Association also has printer sales estimates as far back as 1981. Because the CEA data are proprietary and cannot be released to the public by EPA, we do not use the CEA estimates in this analysis.

export data for 1989 through 1991 combine printers and plotters into a single category. To estimate imports and exports of printers, excluding plotters, we multiply the CIR import and export estimates for printers/plotters by the ratio of domestic printer shipments to total domestic printer and plotter shipments.

The CIR series provides very limited information on keyboard sales. Sufficient data to estimate keyboard sales are available from CIR only for the years 1994, 1996 through 1999, 2003, and 2004. To estimate 1995 sales, we interpolate between our estimates for1994 and 1996. Similarly, we interpolate from 1999 and 2003 sales to estimate sales for 2000-2002. In the absence of better data for keyboard sales, we estimate pre-1994 keyboard sales by assuming that the growth rate for keyboard sales is the same as the growth rate for total desktop sales during this period. We expand our estimates only back to 1986 because estimates for earlier years are not necessary to generate complete keyboard retirement estimates for 2003 through 2005 (i.e., the years for which we assess e-waste generation and management in Chapter 4).

The CIR series contains even less information for computer mice, reporting U.S. shipments only for 1997 and 1998. In the absence of better data for mouse sales, we use non-white-box desktop sales as a lower-bound proxy for mouse sales between 1990 and 2004.[24] For computer mice sales prior to 1990, we do not use non-white-box computer sales as a proxy because many computers sold during this period were not equipped with a mouse. Instead, we assume that mice sales were approximately the same as Apple MacIntosh sales in the mid-1980s and grew steadily through the rest of the decade as other computer makers began releasing computers with graphical user interface (GUI) operating systems (e.g., AMIGA).[25] Although we did not identify estimates of MacIntosh sales during the 1980s, an article published by *Time* magazine indicates that Apple had a 14.6 percent share of the U.S. personal computer market in 1986.[26] Based on this information and our estimate of desktop sales in 1986, we estimate mouse sales of 1.1 million units for 1986. To estimate 1987 to 1989 mouse sales, we interpolated between this estimate and our 1990 estimate.

CELL PHONES

The INFORM report "Waste in the Wireless World: The Challenge of Cell Phones" presents estimates of U.S. cell phone sales for 1995 through 1999 developed by Gartner. Unlike the data available from the Census Bureau's CIR series, these data represent sales, rather than domestic

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[24] The extent to which mouse sales exceed non-white-box sales is uncertain, but we believe non-white-box desktop sales represent a reasonable lower bound estimate because mice are packaged with most brand name computer systems.

[25] Our research suggests that the first commercially viable computer that required a mouse was the Apple MacIntosh released in the mid-1980s. (Sources: "OK, Mac, Make a Wish," Newsweek, February 4, 2004, 143(6): 41; "Apple Turnover," Time, October 2, 1995, 146(14): 56.); Mice did not become necessary on Microsoft-based systems until 1990 when Windows 3.0 was introduced, and companies began to adopt it as their main operating system.

[26] "If you can't beat them…," *Time*, August 18, 1997, 150(7): 35-7.

shipments, exports, or imports. Therefore, we directly use the INFORM data for 1995-1999 cell phone sales.

To estimate cell phone sales for 2000 through 2004, we rely on a series of press releases issued by Gartner between 2001 and 2005. One of these releases issued in March of 2001 indicates that Gartner projected 2001 North American cell phone sales of "90.1 million units, an 18 percent decline over 2000."[27] Based on this information, we estimated North American cell phone sales of 76.4 million units in 2000 (90.1 million/1.18= 76.4 million). To estimate U.S. sales in 2000, we assume that the ratio of U.S. to North American cell phone sales is the same as the ratio of U.S. to North American GDP. For 2001 through 2004, Gartner's press releases report global cell phone sales, but provide no information on North America's share of the global cell phone market. To estimate U.S. cell phone sales for these years, we assume that the growth rate of the U.S. cell phone market between 2000 and 2004 mirrored that of the global cell phone market, applying the global growth rate implied by the Gartner data to our estimate of U.S. cell phone sales in 2000.

MASS DATA

In addition to sales data, we collected information on the average mass of each of the electronic products included in this analysis. Together with the sales estimates presented above, this information allows the waste flow model to estimate the total mass of electronics sold by product. Exhibit 3-3 summarizes the product mass estimates we developed for the analysis. We derived these estimates based on data contained in publications from the Northeast Recycling Council (NERC), the National Safety Council (NSC), the Cascadia Consulting Group, PCWorld, EnviroSIS, RIS International, and ICF Consulting, as well as electronics collection data compiled by the Florida Department of Environmental Protection (FLDEP) as part of its 2004-2005 electronics sorting study.

[27] Gartner, Inc. "Gartner Dataquest Says Worldwide Mobile Phone Sales to Surpass a Half Billion Units in 2001," press release March 20, 2001.

EXHIBIT 3-3. PRODUCT MASS ESTIMATES[*]

PRODUCT	YEAR SOLD	AVERAGE UNIT MASS (LBS.)
Desktop Computers	1975-1989[a]	22.0
	1990-2005[b]	26.8
Laptop Computers	1990-2000[c]	12.1
	2001[d]	10.6
	2002[d]	9.1
	2003-2004[e]	7.7
	2005[f]	6.1
CRT Monitors	1975-1989[a]	29.8
	1990-2005[g]	34.3
LCD Monitors	1990-2005[h]	12.7
Keyboards	1975-1989[a]	3.0
	1990-2005[i]	2.2
Computer Mice	1975-2005[j]	0.3
Desktop Computer Printers	1975-1989[a]	18.0
	1990-2005[k]	18.7
Projection Televisions	1975-2005[l]	149.1
CRT Televisions	1975-1979[a]	55.9
	1980-1989[a]	59.6
	1990-2005[a]	63.4
Cell Phones	1990-1993[m]	0.66
	1994-1996[n]	0.57
	1997-1999[m]	0.49
	2000-2005[o]	0.30

PRODUCT	YEAR SOLD	AVERAGE UNIT MASS (LBS.)

Note:

* Although most of these sources provide estimates of the average mass of specific products, the source we used from the Florida DEP presents the total number and mass of each device collected as part of its 2004-2005 electronics sorting study (e.g., 64 laptops with a total mass of 911 pounds). Therefore, in those cases where we incorporate the Florida data into our average mass calculations, we use the average mass per unit of each collected device (i.e., total mass collected divided by total number collected). Florida DEP, *Florida Electronic Product Brand Distribution Project*, http://www.dep.state.fl.us/waste/categories/electronics/pages/ FloridaElectronicProductBrandDistributionProject.htm.

Sources:

a. Florida Department of Environmental Protection (FLDEP), Florida Electronic Product Brand Distribution Project, 2004-2005. (Data accessed on 19 December 2005.)

b. Average of mass values presented in Minnesota Office of Env. Assistance, "Brand and vintage analysis research project: 2004," Aug 2004; Cascadia Consulting Group, "E-Waste Generation in NW Washington," 11/21/03; Northeast Recycling Council, Inc. (NERC), "Used Electronics Market Study Survey Analysis," August 2003; NSC, "Electronic Product Recovery and Recycling Baseline Report," May 1999; FLDEP data, as of 9/20/2005.

c. Average of mass values presented in National Safety Council (NSC), *op. cit.*; FLDEP data, as of 9/20/2005.

d. Interpolated from 2000 and 2003-2004 estimates.

e. Average of mass values presented in Cascadia Consulting Group, *op. cit.*; Minnesota Office of Env. Assistance, *op. cit.*; NERC, *op. cit.*

f. "A Walk on the Wide Side," *PCWorld*, May 2005.

g. Average of mass values presented in Caplan, Richard A., "Expanding and Developing Markets for Used and End-of-Life Electronics," Spring 2002; Cascadia Consulting Group, *op. cit.*; U.S. EPA, *Desktop Computer Displays: A Life-Cycle Assessment*, EPA-744-R-01-004a, December 2001; Franklin Associates, "Energy and Greenhouse Gas Factors for Personal Computers," 2002; Minnesota Office of Env. Assistance, *op. cit.*; NERC, *op. cit.*; NSC, *op. cit.*; FLDEP data, as of 9/20/2005.

h. Average of mass values presented in Cascadia Consulting Group, *op. cit.;* U.S. EPA, *op. cit.;* RIS International, Ltd., *Information Technology (IT) and Telecommunications (Telecom) Waste in Canada - 2003 Update*, October 16, 2003.

i. Average of mass values presented in Minnesota Office of Env. Assistance, *op. cit.;* NERC, *op. cit.*; FLDEP data, as of 9/20/2005; PHA Consulting Associates, *Electronic Waste Recovery Study*, 1 October 2004.

j. Average mass of the following five mouse devices, as indicated on manufacturer websites: Creative Labs Creative Mouse Classic, Creative Labs Creative Mouse Wireless Optical, Microsoft Wireless Optical Desktop Pro Mouse, Sony PCGAWMS5S VAIO Wireless Optical Mouse, and Sony Optical USB Mousespacer SMU-CL2/L.

k. FLDEP data, as of 9/20/2005.

l. Average mass of 25 projection televisions from electronics retailers and 12 projection televisions collected as part of the Florida Electronic Product Brand Distribution Project.

m. Average of mass values presented in Environment Canada, *IT and Telecom Waste in Canada*, Enviros RIS, October 2000.

n. Average of 1990-93 and 1997-99 estimates.

o. Average of mass values presented in Environment Canada, *op. cit.*; "The Ultimate Wireless Buyers Guide," *PC World*, October 2000.

PRODUCT LIFESPAN

As indicated in Chapter 2, the waste flow model that we developed for this baseline assessment uses information on the lifespan of each product to estimate the volume of electronic products retired each year. This section summarizes our estimates of each product's first life (i.e., the period of time that a product's first owner uses the product) and second life (i.e., the period of time a product is reused or kept in storage after its first life, and prior to its EOL).

INITIAL SERVICE LIFE

To estimate the initial service life for each product included in this analysis, we consulted publications from INFORM, Business Week, PC World, the National Safety Council (NSC), and

EPA. Although the NSC provides relevant information for desktop computers, laptops, CRT monitors, and CRT televisions, we relied on more recent data sources where possible. Exhibit 3-4 presents our estimates of each product's initial service life. We discuss our estimates for each product in further detail below.

EXHIBIT 3-4. INITIAL SERVICE LIFE OF SELECT ELECTRONICS PRODUCTS

PRODUCT	DURATION OF INITIAL SERVICE LIFE (YEARS)
Desktop Computers[a]	1978-1998: 2 to 4
	1999-2004: 3.3 to 4
Laptop Computers[b]	2 to 3
CRT Monitors[c]	4
LCD Monitors[d]	3 to 8
Keyboards	Same as Desktop Computers
Computer Mice[e]	1 to 5
Desktop Computer Printers[f]	3 to 6
Projection Televisions[g]	7 to 13
CRT Televisions[g]	7 to 13
Cell Phones[h]	1.5 to 2.5

Sources:

a. National Safety Council (NSC), *Electronic Product Recovery and Recycling Baseline Report*, May 1999; "Dell, the Conqueror," *BusinessWeek*, 24 September 2001; Gartner Press Release, "Gartner Says Extending the Life Cycle of Desktop PCs Won't Necessarily Save Money on Total Ownership," 15 September 2003.

b. "The PC Replacement Decision," *Information Week*, 20 June 2005; Texas Department of Information Resources, *PC Life Cycles: Guidelines for Establishing Life Cycles for Personal Computers*, January 2003.

c. NSC, *op. cit*.

d. "Shedding Some Light on LCDs," *PCWeek*, 5 October 1998; "LCD Monitors: Light, Slight, and Stylish," *PCWorld*, August 1999; "Is It Time to go LCD?," *Home Office Computing*, November 2000.

e. "Mouse Scurries Toward Future," Dell "Browser" Magazine, Spring 2000, as cited by lightglove.com.

f. U.S. EPA, Municipal Solid Waste in the United States: 2001 Facts and Figures, October 2003; Cardwell, Annette, "The Paperless Office?" Ziff Davis Smart Business, 14 (Dec2001/Jan2002).

g. U.S. EPA, *op. cit.*; Oregon Advisory Committee on Electronic Product Stewardship, *Report to the 2005 Oregon Legislature*, January 2005.

h. U.S. EPA, *op. cit.*; "When Phones Go Bad," *Washington Post*, 10/31/2004; and "Handsets: Catching Customers with Color," *Wireless Week*, 1/1/2003.

Desktop computers

In its 1999 report, the NSC estimates that the initial service life of desktop computers (e.g., 386, 486, Pentium I, and Pentium II) ranged from two to four years,[28] and we used this estimate for all desktop computers sold between 1978 and 1998. However, a different estimate is provided on the initial service life of desktop computers sold between 1999 and 2005 based on three service life estimates generated by Gartner. A 2001 *BusinessWeek* article cites a Gartner study in which the lifespan of a corporate PC in 1999 was estimated to be 3.3 years.[29] In addition, a 2003 Gartner press release recommends a desktop life cycle of four years, while an article published in InformationWeek in 2005 references a Gartner study estimating that businesses replace desktop computers every 43 months (3.6 years).[30,31] Because all three of these sources refer to replacement cycles for desktop computers' original users, they are reasonable data sources to use in estimating the initial service life of a desktop computer. Based on these three studies, we assume that the initial service life of a desktop sold between 1999 and 2005 is between 3.3 and four years.

Laptop Computers

We estimate the duration of a laptop's initial service life based on data from Gartner and the Texas Department of Information Resources.[32] Based on a survey of large businesses conducted by Gartner, *Information Week* reports that mobile PCs are replaced every 36 months. Similarly, the Texas Department of Information Resources indicates that the industry standard for replacing a laptop computer is two to three years, citing a 2001 Gartner Research Note. Based on these data sources, we assume that the duration of a laptop's initial service life is two to three years.

CRT Monitors

In its 1999 report on electronics recycling, the NSC estimated that the duration of a CRT monitor's initial service life is four years.[33] We use this estimate for all CRT monitors sold between 1978 and 2005.

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[28] National Safety Council, Electronic Product Recovery and Recycling Baseline Report, May 1999.

[29] "Dell, the Conqueror," *BusinessWeek*, September 24, 2001.

[30] "The PC Replacement Decision," *Information Week*, June 20, 2005.

[31] Gartner Press Release, "Gartner Says Extending the Life Cycle of Desktop PCs Won't Necessarily Save Money on Total Ownership," September 15, 2003.

[32] *Information Week*, Ibid.; Texas Department of Information Resources, PC Life Cycles: Guidelines for Establishing Life Cycles for Personal Computers, January 2003.

[33] National Safety Council, op. cit.

LCD Monitors

Our survey of the relevant literature revealed three sources containing information on the average service life of an LCD monitor.[34,35] These sources present service life estimates between three and eight years. Two of the three lifespan estimates reflected in this range are based on the expected *useful* life of an LCD display. In the absence of data describing how long the first user of an LCD monitor keeps the display, we assume that the first user of an LCD monitor keeps it for its entire useful life.[36] Therefore, we assume that the initial service life of all LCD monitors sold between 1990 and 2005 is three to eight years.

Keyboards

We located no service life information for keyboards. Absent such information, we assume that the initial service life of a keyboard is the same as that of a desktop computer, with which it is likely sold.

Computer Mice

The only source we identified with information on the service life of a computer mouse was an article published in a 2000 issue of Dell Browser Magazine.[37] This article indicates that the typical computer mouse has a useful life of one to five years, but provided no explanation as to how this estimate was developed. Because we located no additional sources with service life estimates for mice, we use this one-to-five year range as our estimate for the length of a mouse's first life.

Desktop Computer Printers

We identified two sources of information on the service life of a computer printer. EPA's report on municipal solid waste (MSW) generation and management in 2001 states that a printer's total life expectancy (i.e., including both primary and secondary (or reuse) life) is approximately three to five years.[38] We assume that the low end of this range represents the length of a printer's initial service life. In addition, an article published in Ziff Davis Smart Business in 2001 states that the average lifespans of inkjet and laser printers are three years and six years, respectively,

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[34] The LCD monitors that we refer to include stand-alone monitors, but not laptop computer screens.

[35] The three articles that mention LCD monitor lifespan are: "Shedding Some Light on LCDs," PCWeek, 10/5/1998; "LCD Monitors: Light, Slight, and Stylish," PCWorld, August 1999; "Is It Time to go LCD?," Home Office Computing, November 2000. PCWeek (1998) provides a LCD lifespan of 5 to 8 years. PCWorld (1999) and Home Office Computing (2000) report service lives of 3 to 6 years and 6 years, respectively.

[36] Because we assume that the first owner of an LCD monitor keeps it for its entire useful life, we also assume that all LCD monitors not retired after their first life spend their second life in storage.

[37] "Mouse Scurries Toward Future," Dell "Browser" Magazine, Spring 2000, as cited by lightglove.com.

[38] U. S. EPA, Municipal Solid Waste in the United States: 2001 Facts and Figures, October 2003.

according to information released by Gartner and Hewlett-Packard.[39] Based on these data points, we assume that the initial service life of a printer is between three and six years.

Cell Phones

We identified three data sources with information on the service life of a cell phone.[40] EPA's 2001 MSW report states that the life expectancy of a wireless telephone is between two and four years, including primary and secondary use. We assume that the low end of this range reflects the duration of a cell phone's first life. A 2004 Washington Post article cites research from the Yankee Group indicating that the average life cycle of a phone was 25 months in 2001, but that by 2004, this average had fallen to 19.4 months. Although this study suggests that the average first life of a cell phone has fallen in recent years, Nokia has estimated that, on average, cell phones are replaced every 2.5 years.[41] Based on these data sources, we estimate an initial lifespan range between 1.5 and 2.5 years.

Televisions

The research revealed two sources of service life data for televisions.[42] EPA's report on MSW generation and management in 2001 states that a television's life (primary and secondary lives combined) ranges from 13 to 15 years for direct view color TVs, projection TVs, and LCD color TVs. We assume the low end of this range represents the initial service life of a television. In addition, the Oregon Advisory Committee on Electronic Product Stewardship (2005) estimated that the lifespan of a television is seven years. Our own experience suggests that most televisions are functional for much longer than seven years; therefore, we assume that this estimate reflects the length of a television's initial service life. Based on these two sources, we estimate that the duration of a television's initial service life is seven to thirteen years. In the absence of data distinguishing between CRT and projection models, we assume that this represents the initial service life range for both CRT and projection televisions.

INITIAL SERVICE LIFE PROBABILITY DISTRIBUTION

As indicated in Chapter 2, the waste flow model requires information on the distribution of the initial service life expressed as a range. In such cases, we assume a discrete approximation to a triangular distribution (i.e., a bell-shaped distribution) for initial service life ranges spanning more than two years. For an initial service lifespanning two years, we assume a uniform

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[39] Cardwell, Annette, "The Paperless Office?" Ziff Davis Smart Business, 14 (Dec2001/Jan2002).

[40] The three studies are U. S. EPA, op. cit.; "When Phones Go Bad," Washington Post, 10/31/2004; and "Handsets: Catching Customers with Color," *Wireless Week*, 1/1/2003.

[41] *Wireless Week*, op. cit.

[42] U. S. EPA, *op. cit.*; Oregon Advisory Committee on Electronic Product Stewardship, *Report to the 2005 Oregon Legislature*, January 2005.

probability distribution (i.e., 50 percent each year). Exhibit 3-5 summarizes the probability distributions used in the model for this baseline assessment for each product's initial service life.[43]

[43] For products with an initial service life not expressed as integers, we developed service life probability distributions such that the expected value for each product's initial service life equals the average of the high- and low-ends of its service life range. For example, the initial service life for desktops sold in 1999 is 3.3 to 4.0 years. Therefore, we assume that 35 percent of desktop computers will be retired after three years and that the remaining 65 percent will be retired after four years. Based on these probability values, the expected value of the initial service life of a computer sold in 1999 is 3.65 years (0.35 x 3 + 0.65 x 4 = 1.05 + 2.6 = 3.65 years).

EXHIBIT 3-5. INITIAL SERVICE LIFE PROBABILITY DISTRIBUTION

YEARS IN CIRCULATION	DESKTOP COMPUTERS/ KEYBOARDS[b]		LAPTOP COMPUTERS	CRT MONITORS	LCD MONITORS	CRT TVS	PROJECTION TVS	PRINTERS	MICE	CELL PHONES
YEAR SOLD	1978-1998	1999-2004	1990-2004	1990-2004	1990-2004	1975-2004	1975-2004	1978-2004	1989-2004	1990-2004
1	--	--	--	--	--	--	--	--	5%	25%
2	25%	--	50%	--	--	--	--	--	20%	50%
3	50%	35%	50%	--	5%	--	--	10%	50%	25%
4	25%	65%	--	100%	15%	--	--	40%	20%	--
5	--	--	--	--	30%	--	--	40%	5%	--
6	--	--	--	--	30%	--	--	10%	--	--
7	--	--	--	--	15%	5%	5%	--	--	--
8	--	--	--	--	5%	10%	10%	--	--	--
9	--	--	--	--	--	20%	20%	--	--	--
10	--	--	--	--	--	30%	30%	--	--	--
11	--	--	--	--	--	20%	20%	--	--	--
12	--	--	--	--	--	10%	10%	--	--	--
13	--	--	--	--	--	5%	5%	--	--	--
Expected Service Life:a	3.00 years	3.65 years	2.50 years	4.00 years	5.50 years	10.00 years	10.00 years	3.00 years	3.00 years	2.00 years

Notes:

a. For products with an initial service life not expressed as integers, we developed service life probability distributions such that the expected value for each product's initial service life equals the average of the high- and low-ends of its service life range. For example, the initial service life for desktops sold in 1999 is 3.3 to 4.0 years. Therefore, we assume that 35 percent of desktop computers will be retired after three years and that the remaining 65 percent will be retired after four years. Based on these probability values, the expected value of the initial service life of a computer sold in 1999 is 3.65 years (0.35 x 3 + 0.65 x 4 = 1.05 + 2.6 = 3.65 years).

b. We do not present a separate first lifespan distribution for keyboards because we assume that the initial service life of a keyboard is the same as that of a desktop computer. Therefore, the initial service life probability distribution for a keyboard will be the same as that of a desktop computer.

SECOND SERVICE LIFE DURATION AND PROBABILITY DISTRIBUTION

To capture the storage and reuse of electronic products, the waste flow model simulates waste management decisions for such products at two points in time: the end of a product's first life (i.e., the period of time during which its original owner uses it on a regular basis) and the end of its second life (i.e., the period of time between the end of its first life and the end of its total life). Our approach for estimating the probability that a device will reach a second life is presented below. To determine the duration of each product's second life, data was used on the age of electronics collected for recycling as part of the Florida Electronic Product Brand Distribution Project (the Florida Project) during the 12-month period beginning in April 2004. Based on these data, a distribution was developed of the length of time each product remains in circulation before it is disposed of or recycled. Adjusting these distributions based on the procedure outlined in Appendix B, a distribution was developed for the second life of each product included in the analysis, as shown in Exhibit 3-6.

Because the Florida data do not include information for computer mice and cell phones, the second lifespan distributions was used for keyboards as a proxy for computer mice and of laptops as a proxy for cell phones. In addition, as the results in Exhibit 3-6 suggest, we do not estimate a distribution for the second life of projection televisions. The Florida collection data and our estimate of a projection television's first life suggest that almost no projection televisions go into storage or are re-used. Therefore, all projection televisions are assumed to be recycled or disposed of at the end of their first life. Exhibit 3-7 combines the first life information in Exhibit 3-4 and the second lifespan ranges included in Exhibit 3-6.

EXHIBIT 3-6. DISTRIBUTION OF THE SECOND LIFESPAN OF SELECT ELECTRONICS PRODUCTS[1]

YEARS IN CIRCULATION AFTER FIRST LIFE	DESKTOP COMPUTERS	LAPTOP COMPUTERS	CRT MONITORS	LCD MONITORS	CRT TVS	PROJECTION TVS	PRINTERS	KEYBOARDS	COMPUTER MICE[2]	CELL PHONES[3]
1	0.5%	9.8%	3.7%	16.7%	9.2%	0.0%	5.0%	38.9%	38.9%	9.8%
2	1.3%	9.2%	5.4%	16.7%	6.8%	0.0%	6.8%	16.5%	16.5%	9.2%
3	2.0%	22.1%	7.4%	16.7%	9.4%	0.0%	8.0%	4.1%	4.1%	22.1%
4	3.4%	18.4%	9.3%	16.7%	7.3%	0.0%	6.4%	0.0%	0.0%	18.4%
5	4.8%	40.5%	7.1%	16.7%	9.0%	0.0%	8.6%	2.5%	2.5%	40.5%
6	2.2%	0.0%	8.0%	16.7%	6.7%	0.0%	13.3%	2.8%	2.8%	0.0%
7	3.3%	0.0%	10.0%	0.0%	6.8%	0.0%	7.7%	3.2%	3.2%	0.0%
8	6.6%	0.0%	10.0%	0.0%	5.9%	0.0%	10.2%	0.0%	0.0%	0.0%
9	2.8%	0.0%	9.1%	0.0%	3.8%	0.0%	9.3%	11.5%	11.5%	0.0%
10	5.3%	0.0%	4.9%	0.0%	5.7%	0.0%	7.1%	0.0%	0.0%	0.0%
11	4.0%	0.0%	4.7%	0.0%	6.4%	0.0%	4.5%	14.6%	14.6%	0.0%
12	5.8%	0.0%	2.8%	0.0%	4.6%	0.0%	3.8%	6.0%	6.0%	0.0%
13	4.2%	0.0%	4.0%	0.0%	4.7%	0.0%	3.1%	0.0%	0.0%	0.0%
14	7.0%	0.0%	2.3%	0.0%	3.9%	0.0%	2.7%	0.0%	0.0%	0.0%
15	4.4%	0.0%	1.4%	0.0%	2.6%	0.0%	1.3%	0.0%	0.0%	0.0%
16	2.1%	0.0%	2.0%	0.0%	2.3%	0.0%	1.1%	0.0%	0.0%	0.0%
17	4.0%	0.0%	1.1%	0.0%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%
18	6.6%	0.0%	1.5%	0.0%	1.4%	0.0%	1.0%	0.0%	0.0%	0.0%
19	2.9%	0.0%	2.7%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%
20	9.6%	0.0%	0.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
21	9.6%	0.0%	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
22	5.5%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
23	2.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TOTAL	100%	100%	100%	100%	100%	0.0%	100%	100%	100%	100%

Notes:

The distributions presented in this exhibit apply only to products not disposed of after their first life.
We use the distribution of the duration of a keyboard's second life as a proxy for mice.
We use the distribution of the duration of a laptop computer's second life as a proxy for cell phones.

EXHIBIT 3-7. PRODUCT LIFESPANS USED IN WASTE FLOW MODEL

PRODUCT	LENGTH OF FIRST LIFE	LENGTH OF SECOND LIFE	LENGTH OF TOTAL LIFE
Desktop Computers	1978-1998: 2 to 4 years 1999-2005: 3 to 4 years	Up to 23 years	1978-1998: 2 to 27 years 1999-2005: 3 to 27 years
Laptop Computers	2 to 3 years	Up to 5 years	2 to 8 years
CRT Monitors	4 years	Up to 22 years	4 to 26 years
LCD Monitors	3 to 8 years	Up to 6 years	3 to 14 years
CRT Televisions	7 to 13 years	Up to 19 years	7 to 32 years
Projection Televisions	7 to 13 years	0 years*	7 to 13 years
Desktop Computer Printers	3 to 6 years	Up to 18 years	3 to 24 years
Keyboards	1978-1998: 2 to 4 years 1999-2005: 3 to 4 years	Up to 12 years	2 to 16 years
Computer Mice	1 to 5 years	Up to 12 years	1 to 17 years
Cell Phones	1 to 3 years	Up to 5 years	1 to 8 years
Note: * Products disposed of after their first life have a second life of zero years.			

END-OF-LIFE MANAGEMENT

Based on the sales, mass and lifespan data presented above, we estimate the quantity of e-waste generated in the U.S. each year. To inform EPA program and policy development, it is equally important to characterize how this waste is managed at the end of its life. The management options for e-waste include the following:[44]

Landfilling: Electronic waste may be placed in a landfill for final disposal.

Incineration: Electronic waste may be burned at an incineration or waste-to-energy facility.

Recycling: Electronic products may be recovered for the purpose of dismantling, parts and/or materials recovery, and/or resale (resale that occurs by a recycler and not by the user of the product).

[44] Open burning is another potential waste management option for electronic waste, but we Open burning may occur in relatively low population density areas of the United States; open burning of waste is usually banned in high population density areas. We assume that the quantity of electronic waste managed through open burning is minimal. (Outside the United States, open burning of electronic waste may occur.)

Exportation: Transport of electronic products outside U.S. borders for re-use, refurbishing, recycling or disposal.

Re-use/Storage: When a product reaches the end of its first life, it is not necessarily disposed or recycled at that time. The product's original owner may donate or sell the product or keep the product in storage, even though he or she no longer uses it.[45]

All five of these management methods apply to devices at the end of their first life (i.e., after its first owner no longer uses it on a regular basis). When devices reach the end of their second (and final) life, only the first four of these methods apply.

The waste flow model that was developed for this baseline assessment allocates e-waste to the various management options outlined above based on information from several waste characterization studies and e-waste management surveys. In this section, we describe the approach for using these data to distribute the e-waste generation estimates across the various management options outlined above.

END-OF-TOTAL-LIFE E-WASTE MANAGEMENT

In this section, we describe the approach for apportioning electronic products reaching the end of their total life (i.e., electronic products at the end of their second life and devices at the end of their first life that are not re-used or placed in storage) to the various management methods identified above. For each device, we estimate a series of allocation weights--one for each management method--that indicate how the retirement of a given product is distributed across the various management methods. For example, the desktop computer allocation weight for landfilling is 71.8 percent, which indicates that we allocate 71.8 percent of retired desktops to landfilling.

As indicated above, the allocation weights presented in this section correspond to the management of electronic products at the end of their total life. Although it is also important to develop allocation weights for such products at the end of their first service life, we begin with the allocation weights specific to electronic products at the end of their total life because our end-of-first-life allocation weights are based on the allocation weights presented in this section.

To estimate the allocation weights for each electronic product, we rely heavily on the results of five state-specific waste characterization studies that included detailed information on e-waste discards.[46] Based on the per capita e-waste discard rates derived from these studies, the

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[45] A second or third user could store the product as well.

[46] These studies are as follows: Oregon Department of Environmental Quality, *2002 Oregon Solid Waste Characterization and Composition*, April 20, 2004; Cascadia Consulting Group, *Statewide Waste Characterization Study*, prepared for California Integrated Waste Management Board, December 2004; Cascadia Consulting Group, *Wisconsin Statewide Waste Characterization Study*, prepared for the Wisconsin Department of Natural Resources, May 2003; Georgia Department of Community Affairs, *Georgia Statewide Waste Characterization Study*, June 22, 2005; and

electronics retirement estimates generated by the waste flow model, and information from other sources, we estimate device-specific allocation weights for each end-of-life management option. The calculations we performed to generate these estimates are as follows:

1. ***Adjust the waste characterization results to account for interstate import and export of electronic waste.*** The results of most of the waste characterization studies that were identified reflect movement of electronic wastes between states (interstate import and export; as distinguished from import and export to and from abroad). Each state's exports are excluded from its results, but its imports are included. Therefore, per capita e-waste discard rates from these studies may not be representative of the e-waste discard rate for the entire U.S. (i.e., if a state is a major net importer of e-waste, its per capita discard rate would not accurately reflect the volume of e-waste discarded per capita in the U.S.). To address this issue, the results of these studies were adjusted to include each state's exports of e-waste to other states and exclude its e-waste imports from other states.[47]

2. ***Remove electronic products not included in our analysis from the waste characterization results.*** The waste characterization studies that were identified provide discard estimates for a limited number of broad product categories. Many of these categories contain devices not included in our analysis (e.g., the computer-related electronics category in one of these studies includes modems and fax machines). To adjust the waste characterization results to reflect only those computer devices included in our analysis, we assumed that the composition of each state's electronic waste is consistent with the composition of the electronic waste collected for recycling through the Florida Project.[48] Unlike the state waste characterization studies, the Florida Project compiled product-specific data on the mass of the electronic products collected. Therefore, if scanners represent 5 percent of the total mass of computer products collected through the Florida Project, we subtract five percent of the total computer product mass estimated in the state waste characterization studies. Based on these adjustments, the volume of e-waste discards were estimated for three categories of products: computer equipment (i.e., desktop computers, laptop computers, printers, keyboards, and mice), CRT monitors, and CRT televisions.[49,50]

Minnesota Pollution Control Agency and Minnesota Office of Environmental Assistance, *Statewide MSW Composition Study*, March 2000. The California, Oregon, and Minnesota studies are based on a representative sample of disposal facilities in each state, while the Georgia and Wisconsin studies are based on a sample of the largest landfills in each of these two states. Therefore, the results of the California, Oregon, and Minnesota studies may more accurately reflect the composition of waste collected for landfilling or incineration.

[47] We obtained interstate export and import data from James E. McCarthy and Anne L. Hardenbergh, Congressional Research Service, *Interstate Shipment of Municipal Solid Waste: 2002 Update*, November 26, 2002.

[48] Florida Department of Environmental Protection, *Florida Brand Distribution Project,* http://www.dep.state.fl.us/waste/categories/electronics/pages/FloridaElectronicProductBrandDistributionProject.htm.

[49] Some of the waste characterization studies include CRT monitors as a separate category, while others include a category for monitors in general. Because the waste flow model estimates that the mass of LCD monitors retired in recent years has been less than 1.3 percent of the total mass of retired monitors, we assume that all of the monitors reflected in the waste characterization studies are CRT monitors.

[50] Some of the waste characterization studies include a general television category, while others include a category specific to CRT televisions. To estimate CRT discards from the studies that do not distinguish between CRT TVs and non-CRT TVs, we multiplied the general television discard estimates by the ratio of CRT retirements to total TV retirements (by weight), as estimated by the waste flow model.

3. ***Estimate the e-waste discards per capita for each electronic product category.*** Based on the e-waste discard estimates generated in step 2 and the population data from the Census Bureau for the five states that conducted waste characterization studies , state-specific estimates were generated for the e-waste discards per capita for each of the three product categories listed above, as presented in Exhibit 3-8.

EXHIBIT 3-8. ELECTRONIC WASTE DISCARDS PER CAPITA PER YEAR BY STATE

STATE	COMPUTER EQUIPMENT[a] (TONS DISPOSED OF PER CAPITA)	CRT MONITORS (TONS DISPOSED OF PER CAPITA)	CRT TELEVISIONS (TONS DISPOSED OF PER CAPITA)
Minnesota	2.271×10^{-3}	2.839×10^{-4}	2.585×10^{-4}
Wisconsin	4.983×10^{-4}	1.859×10^{-3}	4.028×10^{-3}
Oregon	1.565×10^{-3}	1.187×10^{-3}	2.135×10^{-3}
California	2.765×10^{-3}	2.401×10^{-3}	4.108×10^{-3}
Georgia	4.122×10^{-4}	4.716×10^{-4}	3.417×10^{-4}
Weighted Average[b]	1.396×10^{-3}	1.036×10^{-3}	Low End: 1.820×10^{-3} High End: 3.204×10^{-3}

Notes:
a. Computer equipment includes desktop computers, laptop computers, desktop computer printers, keyboards, and computer mice.
b. Calculations to estimate the weighted averages exclude the highest and lowest values in each column. For CRT televisions, two weighted averages were estimated because of uncertainty in the television disposal data. The lower of the weighted averages for televisions is based on data for Wisconsin, Oregon, and Georgia, while the higher estimate is based on data for California, Oregon, and Georgia.

4. ***Estimate the population-weighted e-waste discards per capita.*** Using the state-specific per capita e-waste discard estimates generated in step 3 and the Census Bureau's population estimates for each state, population-weighted e-waste discards per capita were calculated. Because we do not know whether the five states listed in Exhibit 3-8 are representative of the entire U.S. with respect to e-waste disposal, the states with the highest and lowest discards per capita were excluded from our weighted average calculations.[51] For example, California and Georgia were excluded from our calculations for the weighted average of computer equipment discards per capita. Exhibit 3-8 presents weighted average discards per capita for each of the product categories defined above.

[51] For CRT televisions, discards per capita are slightly higher in Wisconsin than in California. If we exclude Wisconsin from our analysis, our population-weighted estimate of television discards per capita implies that total television discards are greater than the television retirement estimates generated by the waste flow model. However, if we exclude California instead of Wisconsin, the resulting estimate of television discards per capita yields total discard estimates significantly less than the retirements estimated by the model. To address this inconsistency, parallel analyses were conducted of television discards per capita–one excluding the Wisconsin data and one excluding the California data. We combine the results of these two analyses to estimate allocation weights for televisions.

5. ***Estimate the Discard Rate for Retired Electronic Products.*** Multiplying the population-weighted annual discards per capita estimates generated in step 4 by the U.S. population, total discards were estimated for each product category for 2003 and 2004.[52] For example, based on the annual estimate of computer equipment discards per capita presented in Exhibit 3-8, we estimate that 406,100 tons of computer equipment were discarded in 2003 and 410,100 tons in 2004, or 816,200 tons for both years combined as indicated in Exhibit 3-9. After estimating the 2003 and 2004 (combined) discards for each product category, these estimates were divided by the 2003 and 2004 retirement estimates generated by the waste flow model, which yields discard rates for each product category (i.e., the percent of retired electronics that are either landfilled or incinerated), as shown in Exhibit 3-9. Continuing with our example for computer equipment, the waste flow model estimates that approximately 1.1 million tons of computer equipment were retired in 2003 and 2004. Dividing the 816,200 tons in computer equipment discards in 2003 and 2004 by this value, we estimate that approximately 73.9 percent of retired computer equipment is discarded (i.e., deposited in a landfill or incinerated) rather than recycled. Because discards include waste that is either landfilled or incinerated, the discard rates presented in Exhibit 3-9 represent the sum of our end-of-total-life allocation weights for landfilling and incineration.

[52] We chose to estimate discards for these two years because the waste flow model's retirement estimates for these two years are more reliable than for earlier years (i.e., we lack sufficient sales data to generate complete e-waste retirement estimates for earlier years). We obtained this information for Oregon, California, Wisconsin, and Georgia: Georgia Department of Community Affairs, *Georgia Solid Waste Management Report 2004*; Oregon Department of Environmental Quality, "2003/2004 Disposal Status, State of Oregon: Oregon DEQ 2004 Solid Waste Report to the Legislature," 2004; Wisconsin Department of Natural Resources, *A Study of the Future of Solid Waste Management: A Report to the Wisconsin Legislature*, January 2001; Enviros, *Recycling Achievement in North America*, 2000. We were not able to obtain comparable data for Minnesota. U.S. Population data is from: Table 1. Annual Estimates of the Population for the United States and States, and for Puerto Rico: April 1, 2000 to July 1, 2004 (NST-EST2004-01) Source: Population Division, U.S. Census Bureau. Release Date: December 22, 2004. We excluded the data for Puerto Rico from the analysis.

EXHIBIT 3-9. ESTIMATION OF DISCARD RATE FOR RETIRED ELECTRONICS[a]

DEVICE CATEGORY	TOTAL DISCARDS 2003 AND 2004 (THOUSANDS OF TONS)	TOTAL RETIREMENT 2003 AND 2004 (THOUSANDS OF TONS)	ESTIMATED DISCARD RATE
Computer Equipment[b]	816.2	1,104.6	73.9%
CRT Monitors	605.5	802.5	75.5%
CRT Televisions[c]	Low End: 1,063.4 High End: 1,872.4	1,451.4	Low End: 73.3% High End: 100% (assumed discard rate: 86.6%)

Notes:
a. Although this exhibit presents estimated discard rates for 2003 and 2004, these estimates are based on estimates for the years 1999 through 2004.
b. Computer equipment includes desktop computers, laptop computers, printers, keyboards, and mice.
c. For CRT televisions, two estimates were presented for total discards and the discard rate to reflect uncertainty in the television discard data. The lower of total discards and the discount rate is based on data for Wisconsin, Oregon, and Georgia, while the higher estimates are based on data for California, Oregon, and Georgia. For the purposes of our analysis, we use the average of the two discard rates (86.6 percent).
d. The high end CRT television discard estimate exceeds the retirement estimate, and thus subtracting the discards from the retirement would result in a negative number. See the discussion in the text.

6. ***Estimate the End-of-Total-Life Allocation Weights for Landfilling and Incineration.*** To divide discarded e-waste between landfilling and incineration, estimates of the percentage of municipal solid waste landfilled and the percent incinerated for four of the five states with waste characterization data were obtained.[53] Applying these percentages to the e-waste disposal estimates for these states, derived from the states' waste characterization studies, the volume of electronic waste incinerated and landfilled in each state were estimated. Summing these results across all four states, we estimate that approximately 97.2 percent of discarded (i.e., not recycled) electronic waste is landfilled, while the remaining 2.8 percent is incinerated. Multiplying these values by the discard rates in Exhibit 3-9, we estimate the landfilling and incineration allocation weights presented in Exhibit 3-10 for computer equipment, CRT monitors, and CRT televisions.

[53] We obtained this information for Oregon, California, Wisconsin, and Georgia: Georgia Department of Community Affairs, *Georgia Solid Waste Management Report 2004*; Oregon Department of Environmental Quality, "2003/2004 Disposal Status, State of Oregon: Oregon DEQ 2004 Solid Waste Report to the Legislature," 2004; Wisconsin Department of Natural Resources, *A Study of the Future of Solid Waste Management: A Report to the Wisconsin Legislature*, January 2001; Enviros, *Recycling Achievement in North America*, 2000. We were not able to obtain comparable data for Minnesota.

7. ***Estimate the End-of-Total-Life Allocation Weights for Recycling***. Any electronic waste that is not landfilled or incinerated at the end of its total life is likely recycled (either in the US or by export to another country for reuse, refurbishment or recycling, which may include some disposal of residuals). Therefore, the end-of-total-life recycling allocation weights for each device were estimated as follows.

$$R / E_P = 1 - L_P - I_P$$

where, R/E_P = The end-of-total-life recycling/export allocation weight for product P;

L_P = The landfill allocation weight for product P, and

I_P = The incineration allocation weight for product P.

Following this methodology, we estimate the recycling allocation weights presented in Exhibit 3-10. Although estimating the volume of electronic waste recycled in the US separately from the amount exported would be useful for policy planning and program development purposes, we were unable to identify adequate data to estimate the two separately. Therefore, we combine all waste not discarded (i.e., landfilled or incinerated) into a single recycling category (which necessarily includes some export which we have not quantified in this analysis).

EXHIBIT 3-10. END-OF-TOTAL-LIFE ALLOCATION WEIGHTS FOR COMPUTER EQUIPMENT, MONITORS, AND CRT TELEVISIONS

PRODUCT CATEGORY	LANDFILL ALLOCATION WEIGHT	INCINERATION ALLOCATION WEIGHT	RECYCLING ALLOCATION WEIGHT
Computer Equipment	71.8%	2.0%	26.1%
CRT Monitors	73.4%	2.1%	24.5%
CRT Televisions	84.2%	2.4%	13.4%

As indicated above, the computer equipment product category listed in Exhibits 3-8 through 3-10 includes desktop computers, laptop computers, printers, keyboards, and mice. Therefore, the computer equipment allocation weights presented in Exhibit 3-10 were applied to all five of these products. In addition, because the waste characterization studies identified do not contain information on LCD monitors or projection televisions, the allocation weights for CRT monitors were used as a proxy for LCD monitors and the allocation weights of CRT televisions as a proxy for projection televisions. Exhibit 3-11 presents the estimated allocation weights for each product. These results suggest that consumers and businesses are more likely to recycle their computers, monitors, and peripheral equipment than their televisions. Consequently, we

estimate that the landfill and incineration rate for televisions is higher than it is for computers and related products.

The waste characterization studies that were used to estimate allocation weights for computer equipment, monitors, and televisions do not contain detailed data on discards of cell phones. Therefore, to estimate the allocation weights for cell phones presented in Exhibit 3-11, the results of the Consumer Electronics Association's (CEA's) household e-waste management survey and data from INFORM's *Calling All Cell Phones* report published in 2004 were used.[54] The results of these two sources, however, reflect the high level of uncertainty on the percentage of cell phones that are recycled. Based on the INFORM report and our cell phone retirement estimates, the recycling rate for cell phones is relatively low (approximately 2.3 percent in 2002). The results of the CEA survey, on the other hand, indicate that the recycling rate may be much higher (26 percent). As a result, to estimate a recycling rate for inclusion in the waste flow model, we calculated the recycling rate in 2004 inferred by the INFORM- and CEA-derived recycling rates for 2002 and 2005, assuming that the recycling rate grew at a constant rate between these two years.[55]

Based on this approach, a cell phone recycling rate of 19.2 percent was estimated, as indicated in Exhibit 3-11. We assume that the remaining 80.8 percent of cell phones are discarded. As indicated above, we estimate that 97.2 percent of discarded electronic waste is landfilled, while the remaining 2.8 percent is incinerated. Applying these values to our estimate of the percentage of cell phones discarded, 78.5 percent of cell phones are estimated to be landfilled and 2.2 percent are incinerated.

[54] Consumer Electronics Association, *Consumer Electronics Reuse and Recycling*, October 2005, and Eric Most, *Calling All Cell Phones*, INFORM Report, 2004.

[55] We use the recycling rate for 2004 inferred by the INFORM and CEA estimates because this is the second of the three years for which we present model results in Chapter 4.

EXHIBIT 3-11. PRODUCT-SPECIFIC END-OF-TOTAL LIFE ALLOCATION WEIGHTS FOR THE MANAGEMENT OF ELECTRONIC WASTE

PRODUCT	LANDFILL ALLOCATION WEIGHT (% OF DISPOSED PRODUCTS)	INCINERATION ALLOCATION WEIGHT (% OF DISPOSED PRODUCTS)	RECYCLING ALLOCATION WEIGHT (% OF DISPOSED PRODUCTS)
Desktop Computers	71.8%	2.0%	26.1%
Laptop Computers	71.8%	2.0%	26.1%
CRT Monitors	73.4%	2.1%	24.5%
LCD Monitors	73.4%	2.1%	24.5%
CRT Televisions	84.2%	2.4%	13.4%
Projection Televisions	84.2%	2.4%	13.4%
Cell Phones	78.5%	2.2%	19.2%
Printers	71.8%	2.0%	26.1%
Keyboards	71.8%	2.0%	26.1%
Computer Mice	71.8%	2.0%	26.1%

END-OF-FIRST-LIFE E-WASTE MANAGEMENT

The allocation weights presented in Exhibits 3-10 and 3-11 reflect how electronic waste is managed at the end of its second life (i.e., after it will no longer be re-used or held in storage). Therefore, these allocation weights do not apply to products at the end of their first life because such products may be placed in storage or re-used. To generate allocation weights specific to each product's first life, we followed the two-step process outlined below:

1. ***Estimate the percentage of devices that are stored or re-used.*** Based on the results of the e-waste management surveys summarized in Exhibit 3-12, allocation weights that indicate the extent to which devices reaching the end of their first life are re-used or placed in storage were estimated.[56] For example, the allocation weight of 70.1 percent for desktop computers

[56] Although the e-waste management surveys include a great deal information with respect to household and private sector management of electronic waste, we do not use these results to estimate the volume of electronic waste landfilled, incinerated, recycled, or exported. Many households and businesses know whether they send their waste to recycling companies, but they are unlikely to know how much of their electronic waste is actually recycled, as recycling companies do not necessarily recycle every item they receive. The decision of whether to recycle an electronic product is based largely on the potential profit to be earned from recycling it. If a product does not contain enough valuable material for a recycling facility to cover the cost of recycling it, the facility will most likely discard it, in which case it is landfilled, incinerated, or exported. Because of the uncertainty associated with these decisions, we do not use the results of the e-waste management surveys to estimate the volume of electronic waste associated with each end-of-life management option. (End-of-life management options include options for the *final* disposition of a product, including landfilling, incineration, recycling, and exporting. Storage and re-use are not end-of-life management options.)

indicates that 70.1 percent of them are assumed to be placed in storage or re-used at the end of their first life.[57]

EXHIBIT 3-12. E-WASTE MANAGEMENT SURVEY DATA

SURVEY	DESCRIPTION
Consumer Electronics Association Re-use and Recycling Survey[a]	In September 2005, the Consumer Electronics Association (CEA) conducted a nationwide household survey in which respondents were asked to indicate the number of televisions VCRs, cell phones, desktop computers, laptop computers, and monitors they had thrown away, recycled, sold, or given away in the past 12 months.
MetaFacts, Inc. Technology User Profile Survey[b]	For its 2004 Technology User Profile, MetaFacts surveyed 7,527 households and 2,500 workplaces, asking respondents to specify how they managed computers they had replaced during the previous year.
IBM Survey of Senior IT Executives at U.S. Companies[c]	IBM surveyed 176 senior-level IT executives at companies with more than 5,000 computers to determine which e-waste management methods were most prevalent among larger businesses
Massachusetts Department of Environmental Protection (DEP) Household Survey[d]	In 1999, the Massachusetts DEP surveyed 450 Massachusetts residents asking them to indicate how they managed televisions that stopped working and computers that they no longer used.
California Integrated Waste Management Board E-waste Diversion Study[e]	In 2001, the California Integrated Waste Management Board surveyed 1,003 California households asking them to specify how they managed the televisions and computer monitors they had most recently stopped using.

Sources:

a. Consumer Electronics Association, *Consumer Electronics Reuse and Recycling*, October 2005.
b. Metafacts Inc., *Technology User Profile 2004* as cited in Karl Schoenberger, "Many Old Computers Put to Use Again, Study Finds," *San Jose Mercury News*, April 27, 2005.
c. IBM Global Financing, survey of senior IT executives, cited in John G. Spooner, "Weighing the results of PC recycling," CNET News.com, April 16, 2004.
d. Massachusetts Department of Environmental Protection, *Massachusetts DEP Electronic Equipment and Household Chemicals Disposal Research*, July 1999.
e. California Integrated Waste Management Board, *Selected E-waste Diversion in California: A Baseline Study*, November 2001.

2. ***Estimate the proportion of devices that are not stored/re-used at the end of their first life.*** The proportion of devices that are not stored/re-used at the end of their first life is represented by the expression (1 - $R_{EFL,P}$) below. The proportion not stored/re-used is the proportion of devices to which we need to apply an allocation weight for incineration, landfilling, and recycling.

[57] Appendix C provides a more detailed description of our approach for estimating the storage/re-use allocation weight for devices reaching the end of their first life.

3. ***Estimate the allocation weights for incineration, landfilling, and recycling.*** To estimate end-of-first-life allocation weights for incineration, landfilling, and recycling, the allocation weights presented in Exhibit 3-11 were multiplied by the percentage of products that are not stored or re-used following the end of their first life (i.e., for those products for which the end of their first life is also the end of their total life—the estimate obtained in step 2). The following equation illustrates this approach for incineration:

$$I_{EFL,P} = (1 - R_{EFL,P}) \times I_{EOL,P}$$

where $I_{EFL,P}$ = The end-of-first-life allocation weight for the incineration of product *P*;

$R_{EFL,P}$ = The end-of-first-life allocation weight for the storage/re-use of product P.

$I_{EOL,P}$ = The end-of-total-life allocation weight for the incineration of product *P*.

Based on this approach, we estimate the end-of-first-life allocation weights presented in Exhibit 3-13.

As indicated by the allocation weights presented in Exhibit 3-13, at least half of all products, except for projection televisions, were estimated to be stored or re-used after they reach the end of their first life. In addition, the results in Exhibit 3-13 suggest that CRT televisions are less likely to be recycled at the end of their first life as compared to CRT monitors.

EXHIBIT 3-13. END-OF-FIRST-LIFE MANAGEMENT ALLOCATION WEIGHTS

PRODUCT	STORAGE/RE-USE ALLOCATION WEIGHT (% OF PRODUCTS AT THE END OF THEIR FIRST LIFE)	LANDFILL ALLOCATION WEIGHT (% OF PRODUCTS AT THE END OF THEIR FIRST LIFE)	INCINERATION ALLOCATION WEIGHT (% OF PRODUCTS AT THE END OF THEIR FIRST LIFE)	RECYCLING ALLOCATION WEIGHT (% OF PRODUCTS AT THE END OF THEIR FIRST LIFE)	TOTAL
Desktop Computers	70.1%	21.5%	0.6%	7.8%	100%
Laptop Computers	70.1%	21.5%	0.6%	7.8%	100%
CRT Monitors	64.7%	25.9%	0.7%	8.7%	100%
LCD Monitors	64.7%	25.9%	0.7%	8.7%	100%
CRT Televisions	65.1%	29.4%	0.8%	4.7%	100%
Projection Televisions	0.0%	84.2%	2.4%	13.4%	100%
Cell Phones	52.9%	37.0%	1.1%	9.1%	100%
Printers	70.1%	21.5%	0.6%	7.8%	100%
Keyboards	70.1%	21.5%	0.6%	7.8%	100%
Computer Mice	70.1%	21.5%	0.6%	7.8%	100%

Note:
The allocation weights presented in this exhibit reflect the portion of each product that the waste flow model allocates to each management method at the end of the product's first life (i.e., when its original owner stops using it on a regular basis).

CHAPTER 4 – BASELINE E-WASTE ASSESSMENT RESULTS

This chapter presents the results of our baseline e-waste assessment, based on the data and methods described in the previous chapters. We first present retirement estimates that reflect electronic products reaching the end of their total life (i.e., devices at the end of their second life and products disposed of at the end of their first life). We then present product-specific estimates of the volume of electronic waste landfilled, incinerated, or recycled.[58]

RETIREMENT ESTIMATES

Exhibit 4-1 summarizes the product retirement estimates for 2003 through 2005. As retirement estimates, these results reflect electronic products that are disposed of, but not products that are put into storage or re-use, since stored and re-used products have not yet reached their retirement. The results in Exhibit 4-1 suggest that retired tonnages are highest for CRT televisions and CRT monitors, with the tonnage of CRT televisions retired each year higher than the tonnage retired for any other product. Exhibit 4-1 also suggests that retirement volumes (in tons and units) for CRT monitors are declining, while retirement volumes (by tons and units) for LCD monitors appear to be increasing. This shift reflects the decline in CRT monitor sales in recent years as more consumers switch from CRT to LCD monitors. In addition, Exhibit 4-1 reveals that the most significant electronic products in terms of the number of units retired are keyboards and cell phones. However, the tonnages retired for these devices are fairly low due to their low per unit mass relative to other such devices.

MANAGEMENT OF RETIRED ELECTRONICS

Based on the management allocation weights discussed in the previous chapter, we estimate retirement by management method for each product included in the analysis. Exhibits 4-2 through 4-4 summarize our estimates. Key results included in these exhibits are as follows:

- Exhibit 4-2 and 4-4 suggests that, on average, 75 percent of all electronic products retired (by number of units) are landfilled each year, while approximately 23 percent are recycled and the remaining 2 percent incinerated.

- Exhibit 4-3 and 4-4 suggests that, on average, 78 percent of all electronic products retired (by number of tons) are landfilled each year, while approximately 20 percent are recycled and the remaining 2 percent incinerated.

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[58] As indicated in the previous chapter, adequate data were not available to estimate e-waste exports. However, because our estimates of the landfill and incineration rates are based on product discard data, we assume that electronic waste exported is reflected in our estimates of total e-waste recycled.

EXHIBIT 4-1. AGGREGATE E-WASTE RETIREMENT ESTIMATES BY YEAR[A,B]

PRODUCT	2003		2004[c]		2005[c]		TOTAL[d]	
	UNITS	TONS	UNITS	TONS	UNITS	TONS	UNITS	TONS
Desktop Computers	18.5	242.1	19.4	253.6	19.8	259.5	57.6	755.2
Laptop Computers	4.0	23.3	4.8	26.4	6.1	30.8	15.0	80.5
CRT Monitors	24.5	418.6	22.5	383.9	22.8	389.8	69.8	1,192.3
LCD Monitors	0.1	0.6	0.3	1.8	0.8	4.9	1.1	7.3
Televisions	24.4	795.4	25.2	837.8	26.3	891.9	75.9	2,525.1
CRT Televisions[c]	23.3	716.1	23.8	735.4	24.5	759.1	71.6	2,210.6
Projection Televisions	1.1	79.3	1.4	102.4	1.8	132.8	4.2	314.5
Cell Phones	49.0	8.6	57.0	9.8	70.6	11.7	176.6	30.1
Printers	22.3	207.7	25.8	241.0	28.2	263.8	76.3	712.5
Keyboards[c]	43.6	48.5	50.0	55.5	52.2	57.5	145.7	161.5
Computer Mice[c]	20.8	3.1	22.7	3.4	24.2	3.6	67.7	10.1
All Products	207.1	1,747.8	227.8	1,813.1	251.0	1,913.6	685.9	5,474.5

Notes:
a. Units are in millions and tons are in thousands. Totals may not match due to rounding.
b. Because products in storage or re-use have not yet reached their final retirement, units put into storage or retirement are not reflected in this exhibit.
c. Due to the long total service lives of desktop computers, CRT monitors, and CRT televisions, the amounts shown here provide incomplete estimates of aggregate e-waste volumes for these products. Based on the sales information used in the model, the earliest years for which complete estimates could be generated for desktop computers, CRT monitors, and CRT televisions are 2005, 2004, and 2007, respectively.
d. Totals may not be the sum of the individual years shown due to rounding.

- At least 60 percent of the total tonnage landfilled each year represents the disposal of CRT televisions and monitors.
- Although keyboards and cell phones account for more than 40 percent of the total units landfilled each year, they make up only 3 to 4 percent of the total tonnage landfilled.
- More than 60 percent of the total tonnage incinerated is CRT television and monitor waste.
  - Desktops and CRT monitors account for more than 40 percent of the tonnage of e-waste recycled each year.

EXHIBIT 4-2. AGGREGATE E-WASTE RETIREMENT ESTIMATES BY MANAGEMENT METHOD (IN MILLIONS OF UNITS)**

PRODUCT	RECYCLED			LANDFILLED			INCINERATED			TOTAL		
	2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005
Desktop Computers	4.8	5.1	5.2	13.3	13.9	14.2	0.4	0.4	0.4	18.5	19.4	19.8
Laptop Computers	1.0	1.3	1.6	2.9	3.5	4.4	0.1	0.1	0.1	4.0	4.8	6.1
CRT Monitors	6.0	5.5	5.6	18.0	16.5	16.7	0.5	0.5	0.5	24.5	22.5	22.8
LCD Monitors	0.0	0.1	0.2	0.1	0.2	0.6	0.0	0.0	0.0	0.1	0.3	0.8
Televisions	3.3	3.4	3.5	20.5	21.2	22.2	0.6	0.6	0.6	24.4	25.2	26.3
CRT Televisions*	3.1	3.2	3.3	19.6	20.1	20.6	0.6	0.6	0.6	23.3	23.8	24.5
Projection TVs	0.1	0.2	0.2	0.9	1.2	1.5	0.0	0.0	0.0	1.1	1.4	1.8
Cell Phones	9.4	11.0	13.6	38.5	44.8	55.4	1.1	1.3	1.6	49.0	57.0	70.6
Printers	5.8	6.7	7.4	16.0	18.5	20.3	0.5	0.5	0.6	22.3	25.8	28.2
Keyboards*	11.4	13.1	13.6	31.3	35.9	37.5	0.9	1.0	1.1	43.6	50.0	52.2
Computer Mice*	5.4	5.9	6.3	14.9	16.3	17.4	0.4	0.5	0.5	20.8	22.7	24.2
All Products	47.2	52.0	57.0	155.5	170.9	188.7	4.4	4.9	5.4	207.1	227.8	251.0

Note:
* Due to the long total service lives of CRT televisions, keyboards, and mice, the amounts shown here provide incomplete estimates of aggregate e-waste volumes for these products. Based on the sales information used in the model, the earliest years for which complete estimates could be generated for CRT televisions, keyboards, and mice are 2004, 2005, and 2004, respectively.
** Total may not sum due to rounding.

EXHIBIT 4-3. AGGREGATE E-WASTE RETIREMENT ESTIMATES BY MANAGEMENT METHOD (IN THOUSANDS OF TONS)

PRODUCT	RECYCLED			LANDFILLED			INCINERATED			TOTAL		
	2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005
Desktop Computers	63.2	66.2	67.8	173.9	182.2	186.5	4.9	5.2	5.3	242.1	253.6	259.5
Laptop Computers	6.1	6.9	8.0	16.8	19.0	22.1	0.5	0.5	0.6	23.3	26.4	30.8
CRT Monitors	102.7	94.2	95.7	307.1	281.7	286.0	8.7	8.0	8.1	418.6	383.9	389.8
LCD Monitors	0.1	0.4	1.2	0.4	1.3	3.6	0.0	0.0	0.1	0.6	1.8	4.9
Televisions	106.3	112.0	119.3	670.0	705.8	751.4	19.1	20.1	21.4	795.4	837.8	891.9
CRT Televisions*	95.7	98.3	101.5	603.2	619.5	639.5	17.2	17.6	18.2	716.1	735.4	759.1
Projection TVs	10.6	13.7	17.8	66.8	86.3	111.9	1.9	2.5	3.2	79.3	102.4	132.8
Cell Phones	1.7	1.9	2.2	6.8	7.7	9.2	0.2	0.2	0.3	8.6	9.8	11.7
Printers	54.2	62.9	68.9	149.2	173.1	189.5	4.2	4.9	5.4	207.7	241.0	263.8
Keyboards*	12.7	14.5	15.0	34.8	39.8	41.3	1.0	1.1	1.2	48.5	55.5	57.5
Computer Mice*	0.8	0.9	0.9	2.2	2.5	2.6	0.1	0.1	0.1	3.1	3.4	3.6
All Products	347.8	359.9	379.0	1,361.2	1,413.0	1,492.2	38.7	40.2	42.4	1,747.8	1,813.1	1,913.6

Note:
* Due to the long total service lives of CRT televisions, keyboards, and mice, the amounts shown here provide incomplete estimates of aggregate e-waste volumes for these products. Based on the sales information used in the model, the earliest years for which complete estimates could be generated for CRT televisions, keyboards, and mice are 2004, 2005, and 2004, respectively.
** Total may not sum due to rounding.

EXHIBIT 4-4. RETIREMENT MANAGEMENT METHOD FOR SELECT ELECTRONIC PRODUCTS: 2003-2005*

PRODUCT	RECYCLED	LANDFILLED	INCINERATED	TOTAL
Desktop Computers	26%	72%	2%	100%
Laptop Computers	26%	72%	2%	100%
CRT Monitors	25%	73%	2%	100%
LCD Monitors	25%	73%	2%	100%
CRT Televisions	13%	84%	2%	100%
Projection Televisions	13%	84%	2%	100%
Cell Phones	19%	79%	2%	100%
Printers	26%	72%	2%	100%
Keyboards	26%	72%	2%	100%
Computer Mice	26%	72%	2%	100%
All Products (units):	23%	75%	2%	100%
All Products (tons):	20%	78%	2%	100%

Note:
* The percentages are the same for total volumes based on units or tons, except for All Products, which are shown separately for units and tons.

ELECTRONICS PUT INTO RE-USE OR STORAGE

As indicated above, the retirement estimates presented in Exhibits 4-2 through 4-4 do not include products put into storage or re-use. Nevertheless, the waste flow model tracks the storage and re-use of electronics to estimate the volume (in units) and tonnage of electronics retired each year, as retired electronics include units that leave storage or re-use. Exhibit 4-5 presents the waste flow model's estimates for the quantity of electronics put into storage or re-use for the years 2003 through 2005. The results in this exhibit reflect a number of trends in the electronics industry. First, consistent with the retirement estimates presented above, the results in Exhibit 4-5 suggest that the number of CRT monitors put into storage or re-use each year is declining, while the number of LCD monitors put into storage or re-use is increasing. This trend is consistent with the ongoing shift in sales from CRT to LCD monitor technology.[59] Similarly, the storage and re-use of desktop computers appears to be leveling off or falling, while laptop computers in storage/re-use is on the rise, which reflects laptops' growing share of the personal computer market. The waste flow model estimates that no projection televisions are put into storage or re-use because the data identified on the lifespan of projection televisions suggests that they are disposed of at the end of their first (and only) life.

[59] Because of this shift, the tonnage of electronic products in re-use or storage between 2003 and 2005 fell, while the number of products (units) in re-use or storage increased.

EXHIBIT 4-5. ELECTRONICS PUT INTO STORAGE OR RE-USE: 2003-2005 (MILLIONS OF UNITS AND THOUSANDS OF TONS)

PRODUCT	2003		2004		2005	
	UNITS	TONS	UNITS	TONS	UNITS	TONS
Desktop Computers	27.2	365.0	27.2	365.1	26.0	349.0
Laptop Computers	4.7	26.9	5.5	26.6	6.8	28.4
CRT Monitors	24.3	416.5	17.6	302.3	15.7	269.4
LCD Monitors	0.2	1.0	0.5	2.9	1.2	7.7
Televisions	16.7	529.0	16.9	535.4	17.4	552.1
CRT Televisions	16.7	529.0	16.9	535.4	17.4	552.1
Projection TVs	0.0	0.0	0.0	0.0	0.0	0.0
Cell Phones	37.5	5.6	40.6	6.1	48.9	7.3
Printers	26.2	244.7	30.4	284.4	31.2	291.5
Keyboards	43.8	48.2	41.7	45.8	39.5	43.4
Computer Mice	19.7	3.0	19.6	2.9	21.1	3.2
All Products	200.3	1,639.8	200.0	1,571.7	207.9	1,552.0

MANAGEMENT OF ELECTRONICS REACHING THE END OF ITS FIRST OR SECOND LIFE

The retirement estimates presented in Exhibits 4-2 through 4-4 combined with the storage/re-use estimates in Exhibit 4-5 represent the universe of electronics products reaching the end of either their first or second lives between 2003 and 2005. Exhibits 4-6 through 4-9 summarize the management of these products. The results in Exhibits 4-6 through 4-9 suggest that most electronics reaching the end of their first or second life are either put into storage/re-use or are deposited in a landfill. This is consistent with the allocation weights in Exhibits 3-11 and 3-13, which indicate that most electronic products are put into storage or re-use at the end of their first life and landfilled at the end of their second life.[60]

[60] The allocation weights in Exhibits 3-11 and 3-13 are different than the percentages in Exhibits 4-9 because Exhibits 3-11 and 3-13 apply exclusively to electronic products at the end of their second life and first life, respectively, while Exhibit 4-9 combines these two classes of products.

EXHIBIT 4-6. SUMMARY OF ELECTRONIC PRODUCTS REACHING THE END OF THEIR FIRST OR SECOND LIVES - 2003 (MILLIONS OF UNITS ANDTHOUSANDS OF TONS)

PRODUCT	PUT INTO STORAGE/RE-USE		RECYCLED		LANDFILLED		INCINERATED		TOTAL DISPOSED OR PUT INTO STORAGE/RE-USE	
	UNITS	TONS	UNITS	TONS	UNITS	TONS	UNITS	TONS	UNITS	TONS
Desktop Computers	27.2	365.0	4.8	63.2	13.3	173.9	0.4	4.9	45.7	607.1
Laptop Computers	4.7	26.9	1.0	6.1	2.9	16.8	0.1	0.5	8.7	50.2
CRT Monitors	24.3	416.5	6.0	102.7	18.0	307.1	0.5	8.7	48.8	835.1
LCD Monitors	0.2	1.0	0.0	0.1	0.1	0.4	0.0	0.0	0.2	1.6
CRT Televisions*	16.7	529.0	3.1	95.7	19.6	603.2	0.6	17.2	40.0	1,245.1
Projection Televisions	0.0	0.0	0.1	10.6	0.9	66.8	0.0	1.9	1.1	79.3
Cell Phones	37.5	5.6	9.4	1.7	38.5	6.8	1.1	0.2	86.5	14.2
Printers	26.2	244.7	5.8	54.2	16.0	149.2	0.5	4.2	48.4	452.3
Keyboards*	43.8	48.2	11.4	12.7	31.3	34.8	0.9	1.0	87.4	96.7
Computer Mice*	19.7	3.0	5.4	0.8	14.9	2.2	0.4	0.1	40.5	6.1
All Products	200.3	1,639.8	47.2	347.8	155.5	1,361.2	4.4	38.7	407.4	3,387.6

Note:
* Due to the long total service lives of CRT televisions, keyboards, and mice, the amounts shown here provide incomplete estimates of aggregate e-waste volumes for these products. Based on the sales information used in the model, the earliest years for which complete estimates could be generated for CRT televisions, keyboards, and mice are 2004, 2005, and 2004, respectively.

EXHIBIT 4-7. SUMMARY OF ELECTRONIC PRODUCTS REACHING THE END OF THEIR FIRST OR SECOND LIVES - 2004 (MILLIONS OF UNITS ANDTHOUSANDS OF TONS)

PRODUCT	PUT INTO STORAGE/RE-USE		RECYCLED		LANDFILLED		INCINERATED		TOTAL DISPOSED OR PUT INTO STORAGE/RE-USE	
	UNITS	TONS	UNITS	TONS	UNITS	TONS	UNITS	TONS	UNITS	TONS
Desktop Computers	27.2	365.1	5.1	66.2	13.9	182.2	0.4	5.2	46.6	618.8
Laptop Computers	5.5	26.6	1.3	6.9	3.5	19.0	0.1	0.5	10.3	53.0
CRT Monitors	17.6	302.3	5.5	94.2	16.5	281.7	0.5	8.0	40.1	686.2
LCD Monitors	0.5	2.9	0.1	0.4	0.2	1.3	0.0	0.0	0.7	4.8
CRT Televisions*	16.9	535.4	3.2	98.3	20.1	619.5	0.6	17.6	40.7	1,270.8
Projection Televisions	0.0	0.0	0.2	13.7	1.2	86.3	0.0	2.5	1.4	102.4
Cell Phones	40.6	6.1	11.0	1.9	44.8	7.7	1.3	0.2	97.7	15.9
Printers	30.4	284.4	6.7	62.9	18.5	173.1	0.5	4.9	56.2	525.3
Keyboards*	41.7	45.8	13.1	14.5	35.9	39.8	1.0	1.1	91.7	101.3
Computer Mice*	19.6	2.9	5.9	0.9	16.3	2.5	0.5	0.1	42.3	6.3
All Products	200.0	1,571.7	52.0	359.9	170.9	1,413.0	4.9	40.2	427.8	3,384.9

Note:
* Due to the long total service lives of CRT televisions, keyboards, and mice, the amounts shown here provide incomplete estimates of aggregate e-waste volumes for these products. Based on the sales information used in the model, the earliest years for which complete estimates could be generated for CRT televisions, keyboards, and mice are 2004, 2005, and 2004, respectively.

EXHIBIT 4-8. SUMMARY OF ELECTRONIC PRODUCTS REACHING THE END OF THEIR FIRST OR SECOND LIVES - 2005 (MILLIONS OF UNITS AND THOUSANDS OF TONS)

PRODUCT	PUT INTO STORAGE/RE-USE		RECYCLED		LANDFILLED		INCINERATED		TOTAL DISPOSED OR PUT INTO STORAGE/RE-USE	
	UNITS	TONS	UNITS	TONS	UNITS	TONS	UNITS	TONS	UNITS	TONS
Desktop Computers	26.0	349.0	5.2	67.8	14.2	186.5	0.4	5.3	45.8	608.5
Laptop Computers	6.8	28.4	1.6	8.0	4.4	22.1	0.1	0.6	13.0	59.3
CRT Monitors	15.7	269.4	5.6	95.7	16.7	286.0	0.5	8.1	38.5	659.2
LCD Monitors	1.2	7.7	0.2	1.2	0.6	3.6	0.0	0.1	2.0	12.6
CRT Televisions*	17.4	552.1	3.3	101.5	20.6	639.5	0.6	18.2	41.9	1,311.2
Projection Televisions	0.0	0.0	0.2	17.8	1.5	111.9	0.0	3.2	1.8	132.8
Cell Phones	48.9	7.3	13.6	2.2	55.4	9.2	1.6	0.3	119.5	19.0
Printers	31.2	291.5	7.4	68.9	20.3	189.5	0.6	5.4	59.4	555.3
Keyboards*	39.5	43.4	13.6	15.0	37.5	41.3	1.1	1.2	91.7	100.9
Computer Mice*	21.1	3.2	6.3	0.9	17.4	2.6	0.5	0.1	45.3	6.8
All Products	207.9	1,552.0	57.0	379.0	188.7	1,492.2	5.4	42.4	458.9	3,465.6

Note:
* Due to the long total service lives of CRT televisions, keyboards, and mice, the amounts shown here provide incomplete estimates of aggregate e-waste volumes for these products. Based on the sales information used in the model, the earliest years for which complete estimates could be generated for CRT televisions, keyboards, and mice are 2004, 2005, and 2004, respectively.

EXHIBIT 4-9. MANAGEMENT OF ELECTRONIC PRODUCTS REACHING THE END OF THEIR FIRST OR SECOND LIVES 2003 - 2005*

PRODUCT	PUT INTO STORAGE/RE-USE			RECYCLED			LANDFILLED			INCINERATED			TOTAL DISPOSED OR PUT INTO STORAGE/RE-USE
	2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005	2003, 2004, AND 2005
Desktop Computers	60.1%	59.0%	57.3%	10.4%	10.7%	11.1%	28.6%	29.5%	30.6%	0.8%	0.8%	0.9%	100.0%
Laptop Computers	53.5%	50.2%	48.0%	12.1%	13.0%	13.6%	33.4%	35.8%	37.4%	1.0%	1.0%	1.1%	100.0%
CRT Monitors	49.9%	44.1%	40.9%	12.3%	13.7%	14.5%	36.8%	41.0%	43.4%	1.0%	1.2%	1.2%	100.0%
LCD Monitors	62.7%	61.8%	61.1%	9.2%	9.4%	9.5%	27.4%	28.0%	28.5%	0.8%	0.8%	0.8%	100.0%
CRT Televisions	42.5%	42.1%	42.1%	7.7%	7.7%	7.7%	48.4%	48.7%	48.8%	1.4%	1.4%	1.4%	100.0%
Projection Televisions	0.0%	0.0%	0.0%	13.4%	13.4%	13.4%	84.2%	84.2%	84.2%	2.4%	2.4%	2.4%	100.0%
Cell Phones	39.5%	38.4%	38.6%	11.6%	11.8%	11.8%	47.5%	48.4%	48.3%	1.4%	1.4%	1.4%	100.0%
Printers	54.1%	54.1%	52.5%	12.0%	12.0%	12.4%	33.0%	33.0%	34.1%	0.9%	0.9%	1.0%	100.0%
Keyboards	49.9%	45.3%	43.1%	13.1%	14.3%	14.9%	36.0%	39.3%	40.9%	1.0%	1.1%	1.2%	100.0%
Computer Mice	48.7%	46.3%	46.5%	13.4%	14.0%	14.0%	36.9%	38.6%	38.4%	1.0%	1.1%	1.1%	100.0%
All Products	48.4%	46.4%	44.8%	10.3%	10.6%	10.9%	40.2%	41.7%	43.1%	1.1%	1.2%	1.2%	100.0%

Note:
* Percent of e-waste tonnage associated with each method.

CONCLUSION AND NEXT STEPS

The purpose of this report is to establish a set of baseline data, using the methodology outlined in this report, 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 electronic products.

The results should provide interested parties with useful information for developing choices on how to manage electronic products at the end of their useful lives. For example, Exhibit 4-1 indicates that, of the products studied, CRT monitors and televisions make up more than half of the electronic waste generated in recent years. Although sales of these products are falling as consumers convert to newer technologies, the results of our analysis suggest that they will continue to make up a significant portion of the electronic waste stream for years to come, particularly if households continue to keep their televisions for as long as they have in the past. Even as new technologies, such as plasma televisions and LCD monitors increase in sales, there will still be millions of CRTs that will be disposed of during the next several years.

The existing information indicates that, generally speaking, U.S. landfills are the primary repository of discarded electronic products, with recycling facilities playing a secondary role. This finding raises important questions about resource conservation, since such electronics deposited in landfills represent lost energy and material resources.

Material composition of electronic devices is important to examine. Information on material composition is important to identify products with recycling potential. For example, although cell phones make up a small fraction of the e-waste deposited in landfills each year, the information in Appendix E suggests that they may contribute a larger proportion of silver to U.S. landfills than other devices included in this study.[61] Silver and other valuable materials found in electronic products represent important resources to recover from electronic waste.

[61] Exhibit E presents the material composition of retired electronic products by management method and by product for the following devices: desktop computers, laptop computers, CRT monitors, LCD monitors, CRT televisions, cell phones, and keyboards. Material composition data were not available for projection televisions, printers, and mouse devices.

APPENDIX A: GLOSSARY OF TERMS

Allocation Weight: For a given quantity of devices, the percentage of those devices at the end of their first or second life that the waste flow model allocates to a specific management method (e.g., incineration).

Age Distribution: A distribution describing the various ages at which a particular product is made available for end-of -life management and the frequency at which products are made available for such management at a given age. The age of a product is based on the number of years between its original sale and the end of its life.

Cohort: A group of products that are sold by the original manufacturer or retailer in the same year.

Discard: Disposal of waste through landfilling or incineration.

Discard Rate: The rate at which waste is landfilled or incinerated (i.e., the percent of waste incinerated or landfilled).

Disposal: Management of a product at the end of its useful life through landfilling or incineration.

End-of-First-Life Management: The method used to manage a product when it reaches the end of its first life. Management options for the end of a product's first life include landfilling, incineration, recycling (including export), reuse, and storage.

End-of-Total-Life Management: The method used to manage a product when it reaches the end of its total life. Management options for the end of a product's total life include landfilling, incineration, recycling (including export) (end-of-total-life is the sum of products reaching end-of-first-life and the end-of-second-life).

Export/exportation: Transport of devices outside U.S. borders for re-use, refurbishing, recycling or disposal.

First Life: The length of time a product is used by its original or initial owner.

Gross State Product (GSP): The value of goods and services produced by the labor and property located in a state.

Incineration: Electronic waste may be burned at an incineration or waste-to-energy facility.

Initial Retirement: The point in time at which the original or initial owner of a product stops using it.

Initial Service Life: *See* **First Life**.

Landfilling*:* Electronic waste may be deposited in a landfill for final disposal.

Lifespan Distribution: Probabilities assigned across a range of years indicating the likelihood of a product reaching the end of its lifespan in any given year.

Recycling: Electronic products may be recovered for the purpose of dismantling, parts and/or materials recovery, and/or resale (resale that occurs by a recycler and not by the user of the product).

Retirement: Retirement is when a product reaches the end of its life.

Reuse: Occurs when the first user gives up a product by informal sale or donation (other than making it available for end of life management) and a subsequent user uses the product for its intended purpose.

Second Life: The length of time over which a product is reused or kept in storage after its first life. *See* **First Life** and **Initial Retirement**.

Storage: Holding or storing a product for a temporary period by the first owner of the product or any other owner, at the end of which it is reused, resold, recycled, or disposed.

Total Life or **Total Lifespan**: The period of time between when a product is initially purchased and when it reaches the end of its life. The length of time for a product's total lifespan is the sum of its first life and its second life. *See* **End-of-Life Management**, **First Life**, and **Second Life**.

Total Service Life: *See* **Total Life**.

White boxes: computers that are distributed without a well-recognized brand name.

APPENDIX B: ESTIMATING THE TOTAL LIFESPAN AND SECOND LIFE OF ELECTRONIC PRODUCTS

As described in the main body of this report, the amount of electronic waste generated in the U.S. each year was estimated based on the annual sales of individual electronic products and the typical lifespan of them (i.e., the amount of time that elapses from their initial purchase to final disposition/recycling). To estimate the total lifespan of each product included in our baseline assessment, data was used on the age of the electronic products collected for recycling as part of the Florida Electronic Product Brand Distribution Project (the Florida Project) during the 12-month period beginning in April 2004. Based on these data, a distribution was developed of the length of time each product remains in circulation before it is recycled or disposed. Exhibit B-1 summarizes these data for several of the electronic products collected as part of the Florida Project. Although the data presented in this exhibit represent the age distribution of electronic products collected through the Florida Project, they do not represent the distribution of each product's lifespan. For example, although 7.1 percent of the CRT televisions collected were 15 years old, this does not imply that 7.1 percent of televisions remain in circulation for 15 years after they are sold. The number of 15-year-old televisions included in the Florida data reflects the amount of time that a television remains in circulation *and* the number of televisions sold 15 years ago. Therefore, if no televisions had been sold 15 years prior to the Florida collection, the Florida data would include no 15-year-old televisions, even though a certain (non-zero) percentage of televisions are retired when they reach this age.

As the example above illustrates, the age data presented in Exhibit B-1 reflects both the amount of time a product remains in use (or in storage) and the product's annual sales prior to the Florida collection. Therefore, because sales of each product vary from year to year, the age distributions in Exhibit B-1 do not accurately represent the distribution of each product's lifespan. To address this issue, we standardized the Florida collection data to account for differences in electronic product sales from year to year based on the following procedure:

EXHIBIT B-1: AGE DISTRIBUTION OF PRODUCTS COLLECTED FOR RECYCLING IN FLORIDA

AGE (YEARS)	DESKTOP COMPUTERS	LAPTOP COMPUTERS	CRT MONITORS	LCD MONITORS	CRT TVS	PROJECTION TVS	PRINTERS	COMPUTER KEYBOARDS
0	0.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.4%	0.0%
1	0.1%	0.0%	0.1%	0.0%	0.6%	0.0%	1.7%	0.0%
2	0.4%	0.0%	1.2%	0.0%	1.2%	0.0%	2.6%	0.0%
3	1.0%	0.0%	2.3%	0.0%	1.6%	0.0%	2.4%	4.9%
4	1.7%	20.0%	4.4%	0.0%	2.4%	0.0%	12.2%	43.9%
5	4.6%	15.0%	8.1%	0.0%	2.9%	0.0%	7.5%	19.5%
6	6.0%	20.0%	10.3%	33.3%	3.8%	14.3%	7.2%	4.9%
7	8.5%	15.0%	11.6%	0.0%	3.8%	14.3%	7.9%	0.0%
8	10.0%	25.0%	13.0%	0.0%	4.0%	42.9%	12.3%	2.4%
9	4.6%	0.0%	8.8%	0.0%	4.1%	14.3%	8.1%	2.4%
10	6.1%	0.0%	8.6%	33.3%	5.7%	14.3%	8.5%	2.4%
11	11.3%	0.0%	9.1%	0.0%	8.2%	0.0%	9.5%	0.0%
12	4.4%	0.0%	6.9%	33.3%	6.0%	0.0%	4.2%	7.3%
13	7.7%	0.0%	5.6%	0.0%	6.3%	0.0%	4.3%	0.0%
14	4.9%	5.0%	2.6%	0.0%	5.2%	0.0%	3.8%	7.3%
15	5.9%	0.0%	2.3%	0.0%	7.1%	0.0%	3.2%	2.4%
16	3.7%	0.0%	1.2%	0.0%	4.7%	0.0%	1.5%	0.0%
17	5.8%	0.0%	1.6%	0.0%	5.9%	0.0%	1.1%	0.0%
18	2.8%	0.0%	0.7%	0.0%	5.0%	0.0%	0.7%	0.0%
19	1.2%	0.0%	0.4%	0.0%	3.2%	0.0%	0.5%	0.0%
20	2.5%	0.0%	0.6%	0.0%	4.0%	0.0%	0.3%	2.4%
21	2.8%	0.0%	0.2%	0.0%	3.9%	0.0%	0.2%	0.0%
22	0.7%	0.0%	0.2%	0.0%	2.2%	0.0%	0.0%	0.0%
23	1.3%	0.0%	0.2%	0.0%	2.3%	0.0%	0.1%	0.0%
24	1.0%	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%
25	0.4%	0.0%	0.0%	0.0%	1.1%	0.0%	0.0%	0.0%
26	0.1%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%
27	0.2%	0.0%	0.0%	0.0%	0.9%	0.0%	0.0%	0.0%
28	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%
29	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%	0.1%	0.0%
30	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
31	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%
32	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
33	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
34	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Source: Florida Department of Environmental Protection, *Florida Brand Distribution Project*, http://www.dep.state.fl.us/waste/categories/electronics/pages/FloridaElectronicProductBrandDistributionProject.htm.

1. First, Florida sales of each product were estimated based on the assumption that Florida's share of the national electronics sales is proportional to its share of U.S. economic output, as indicated by its gross state product.[62] Equation B-1 summarizes this calculation.

(B-1)
$$F_{P,Y} = N_{P,Y}\left(\frac{GSP_{F,Y}}{\sum_{S=1}^{50} GSP_{S,Y}}\right)$$

where, $F_{P,Y}$ = Florida sales of product P in year Y;
$N_{P,Y}$ = National sales of product P in year Y;
$GSP_{F,Y}$ = Florida's gross state product in year Y, and
$GSP_{S,Y}$ = The gross state product of State S in year Y.

For example, as shown in Exhibit B-2, Florida generated 4.8 percent of the U.S. economic output in 2000, and U.S. sales of computer keyboards were approximately 60.6 million units that year. Therefore, based on Equation B-1, 2.9 million computer keyboards were estimated to be sold in Florida in 2000.

2. Based on the Florida sales estimates generated in step 1 and the 2004 collection data from the Florida Project, the percentage of each cohort (e.g., electronics sold in 1992) collected in 2004 was estimated. For example, as indicated in Exhibit B-2, 18 keyboards sold in 2000 were collected through the Florida Project in 2004; these keyboards represent 0.0006 percent of the keyboards sold in Florida in 2000.[63]

3. Using the percentage values calculated in step 2, the number of electronic units was estimated for each cohort that would have been collected through the Florida Project if annual electronic sales had been constant over time. For example, if annual keyboard sales had been constant at 1,000,000 units per year between 1989 and 2004, approximately 6 keyboards sold in 2000 would have been collected in 2004 as part of the Florida Project, as shown in Exhibit B-2.

4. After performing the calculations outlined in step 3, it is possible to estimate an age distribution for electronic products that would have been collected if sales were constant over time. For example, as indicated in Exhibit B-2, keyboards sold in 2000 would represent the keyboards collected in 2004 if keyboard sales were the same each year. As indicated above, the age

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[62] Gross state product (GSP) as defined by the Bureau of Economic Analysis is "the value added in production by the labor and property located in a state." U.S. Bureau of Economic Analysis, http://www.bea.gov/bea/regional/definitions/nextpage.cfm?key=Gross%20state%20product%20(GSP).

[63] This step in our calculations relies on the availability of sales data for the cohorts of each product reflected in the Florida collection data. In most cases, we were able to obtain these sales data. In the few cases where we were unable to obtain sales estimates, we exclude the corresponding collection data from our analysis. For example, the Florida data indicate that one of the 20 laptops collected through the Florida Project was sold in 1990. Because we lack laptop sales data for 1990, we do not include the collection data for 1990 vintage laptops in our analysis. Overall, such exclusions do not significantly affect our lifespan estimates because we exclude very few collected items from our analysis (i.e., one of 20 laptops included in the Florida data, four of 1,912 desktops, one of 4,517 CRT monitors, and one of 1,028 printers).

approximately 37 percent of the keyboards collected in 2004 if keyboard sales were the same each year. As indicated above, the age distribution of products collected for recycling reflects the lifespan of the collected products only if sales do not vary over time. Because we held annual sales constant to generate the keyboard age distribution presented in Exhibit B-2, this distribution represents the lifespan distribution of keyboards collected for recycling through the Florida Project.

Exhibit B-3 presents the lifespan distributions developed, applying the method outlined above to each product included in our analysis. The results presented in Exhibit B-3 suggest that televisions have the longest lifespan of the products included in our analysis, while laptop computers have the shortest.

EXHIBIT B-2: ESTIMATION OF KEYBOARD LIFESPAN DISTRIBUTION

VINATAGE	AGE	U.S. KEYBOARD SALES (1000S OF UNITS)[1]	FLORIDA SHARE OF U.S. ECONOMIC ACTIVITY[2]	FLORIDA KEYBOARD SALES (1000S OF UNITS)	KEYBOARDS COLLECTED IN 2004 FLORIDA STUDY[3]	PERCENT OF COHORT COLLECTED BY FLORIDA PROJECT IN 2004	SIMULATED NUMBER OF KEYBOARDS COLLECTED IN 2004, BY COHORT, ASSUMING 1 MILLION KEYBOARDS SOLD PER YEAR	AGE AND LIFESPAN DISTRIBUTION
1989	15	23,434	4.5%	1,058.7	1	0.00009%	0.9	5.7%
1990	14	28,603	4.5%	1,296.8	3	0.00023%	2.3	14.0%
1991	13	33,099	4.6%	1,513.6	0	0.0%	0.0	0.0%
1992	12	35,784	4.6%	1,644.8	3	0.00018%	1.8	11.0%
1993	11	38,563	4.7%	1,805.0	0	0.0%	0.0	0.0%
1994	10	41,442	4.7%	1,944.1	1	0.00005%	0.5	3.1%
1995	9	47,599	4.7%	2,240.9	1	0.00004%	0.4	2.7%
1996	8	53,756	4.7%	2,547.2	1	0.00004%	0.4	2.4%
1997	7	55,605	4.8%	2,642.2	0	0.00000%	0.0	0.0%
1998	6	64,957	4.8%	3,115.0	2	0.00006%	0.6	3.9%
1999	5	63,675	4.8%	3,062.1	8	0.00026%	2.6	15.8%
2000	4	60,571	4.8%	2,920.9	18	0.00062%	6.2	37.2%
2001	3	57,468	4.9%	2,838.8	2	0.00007%	0.7	4.3%
2002	2	54,364	5.0%	2,727.2	0	0.0%	0.0	0.0%
2003	1	51,260	5.1%	2,598.3	0	0.0%	0.0	0.0%
2004	0	47,209	5.1%	2,409.2	0	0.0%	0.0	0.0%
TOTAL	**-**	757,388	-	36,364.7	41[4]	-	16.6	100.0%

Notes:

Derived from U.S. Census Bureau, *Current Industrial Report series, "Computers and Office and Accounting Machines,"* 1989 through 2004.

Based on gross state product data from the Bureau of Economic Analysis, www.bea.gov.

Florida Department of Environmental Protection, *Florida Electronic Product Brand Distribution Project*, Collection data for 2004-2005.

The annual values do not sum to 41 because the Florida collection data include one keyboard sold in 1984 that is not included in our calculations. We exclude this keyboard from our analysis because we were unable to obtain keyboard sales values for 1984.

EXHIBIT B-3: LIFESPAN DISTRIBUTION OF SELECT ELECTRONIC PRODUCTS

LIFESPAN (YEARS)	DESKTOP COMPUTERS	LAPTOP COMPUTERS	CRT MONITORS	LCD MONITORS	CRT TVS	PROJECTION TVS	PRINTERS	KEYBOARDS	MICE[1]	CELL PHONES[2]
0	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%
1	0.0%	0.0%	0.1%	0.0%	0.4%	0.0%	0.6%	0.0%	0.0%	0.0%
2	0.1%	0.0%	0.8%	0.0%	0.8%	0.0%	1.1%	0.0%	0.0%	0.0%
3	0.3%	0.0%	1.5%	0.0%	1.2%	0.0%	1.1%	4.3%	4.3%	0.0%
4	0.5%	9.8%	2.1%	0.0%	1.6%	0.0%	5.1%	37.2%	37.2%	9.8%
5	1.3%	9.2%	3.6%	0.0%	1.9%	0.0%	3.4%	15.8%	15.8%	9.2%
6	2.0%	22.1%	5.2%	14.3%	2.6%	9.7%	4.5%	3.9%	3.9%	22.1%
7	3.4%	18.4%	7.1%	14.3%	2.8%	10.8%	6.0%	0.0%	0.0%	18.4%
8	4.8%	40.5%	8.9%	14.3%	3.2%	37.2%	7.1%	2.4%	2.4%	40.5%
9	2.2%	0.0%	6.8%	14.3%	4.0%	18.2%	5.7%	2.7%	2.7%	0.0%
10	3.3%	0.0%	7.7%	14.3%	5.2%	24.1%	7.6%	3.1%	3.1%	0.0%
11	6.5%	0.0%	9.5%	14.3%	7.0%	0.0%	11.8%	0.0%	0.0%	0.0%
12	2.8%	0.0%	9.5%	14.3%	5.2%	0.0%	6.8%	11.0%	11.0%	0.0%
13	5.3%	0.0%	8.7%	0.0%	7.2%	0.0%	9.1%	0.0%	0.0%	0.0%
14	3.9%	0.0%	4.7%	0.0%	5.6%	0.0%	8.3%	14.0%	14.0%	0.0%
15	5.8%	0.0%	4.5%	0.0%	6.9%	0.0%	6.3%	5.7%	5.7%	0.0%
16	4.2%	0.0%	2.7%	0.0%	5.1%	0.0%	3.9%	0.0%	0.0%	0.0%
17	7.0%	0.0%	3.9%	0.0%	5.2%	0.0%	3.3%	0.0%	0.0%	0.0%
18	4.4%	0.0%	2.2%	0.0%	4.5%	0.0%	2.7%	0.0%	0.0%	0.0%
19	2.1%	0.0%	1.4%	0.0%	2.9%	0.0%	2.4%	0.0%	0.0%	0.0%
20	3.9%	0.0%	1.9%	0.0%	4.4%	0.0%	1.2%	0.0%	0.0%	0.0%
21	6.5%	0.0%	1.1%	0.0%	4.9%	0.0%	1.0%	0.0%	0.0%	0.0%
22	2.8%	0.0%	1.4%	0.0%	3.5%	0.0%	0.0%	0.0%	0.0%	0.0%
23	9.5%	0.0%	2.6%	0.0%	3.6%	0.0%	0.9%	0.0%	0.0%	0.0%
24	9.6%	0.0%	0.9%	0.0%	3.0%	0.0%	0.0%	0.0%	0.0%	0.0%
25	5.5%	0.0%	0.6%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%
26	2.1%	0.0%	0.9%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%
27	0.0%	0.0%	0.0%	0.0%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%
28	0.0%	0.0%	0.0%	0.0%	1.1%	0.0%	0.0%	0.0%	0.0%	0.0%
29	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%
TOTAL	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Notes:

We use the lifespan distribution for keyboards as a proxy for mice.

We use the lifespan distribution for laptop computers as a proxy for cell phones.

Although Exhibit B-3 presents lifespan information for mice and cell phones, the Florida data do not include these two products. Therefore, the keyboard lifespan distribution was used as a proxy for mice and the laptop distribution was used for cell phones. We believe that keyboards are a reasonable proxy for mice because both are relatively inexpensive input devices necessary to use a computer. Although laptops differ from cell phones in several important ways, we

believe they represent the best proxy for cell phones among the various products included in our analysis because both are portable technologies that have advanced significantly during the past ten years. In addition, because only three LCD monitors are reflected in the Florida data, the methodology outlined above is not applied to estimate their lifespan. Instead, LCD monitors were assumed to have a uniform lifespan distribution, with the low end of the distribution representing the age of the youngest LCD monitor included in the Florida data and the high end reflecting the oldest.

DURATION OF SECOND LIFE

The distributions in Exhibit B-3 represent the *total* lifespan of each product. As outlined in the methodology chapter in the main body of this report, however, the management decisions for individual products were simulated at two points in time: the end of their first life (i.e., the point in time when the original owner of a product stops using it) and the end of their second life (i.e., the period of time over which a product is reused or in storage after its first life). To develop a distribution of the second life of each product included in Exhibit B-3, the steps outlined above were followed for each product's total life, but we limited the analysis to that data collected that corresponded to the second life of each product. For example, the main body of this report indicates that a keyboard's first life lasts for approximately three years. Therefore, to estimate a lifespan distribution for the second life of a computer keyboard, the steps outlined above were followed, but we did not use the data collected for keyboards three years old and younger at the time of their collection.

Applying this approach to each product, lifespan distributions were generated for the second lives of the products included in our analysis, as presented in Exhibit B-4. The distributions presented in this exhibit suggest that desktop computers have the longest second life among the products included in our analysis, while keyboards and mice have the shortest.

Similar to the total lifespan distributions presented in Exhibit B-3, the second lifespan distributions of keyboards was used as a proxy for mice and laptops was used as a proxy for cell phones. In addition, as the results in Exhibit B-4 suggest, a distribution for the second life of projection televisions was not estimated. The Florida collection data and our estimate of a projection television's first life suggest that almost no projection televisions go into storage or are re-used. Therefore, all projection televisions were assumed to be disposed of or recycled at the end of their first life.

EXHIBIT B-4: DISTRIBUTION OF THE SECOND LIFESPAN OF SELECT ELECTRONIC PRODUCTS

YEARS IN CIRCULATION AFTER FIRST LIFE	DESKTOP COMPUTERS	LAPTOP COMPUTERS	CRT MONITORS	LCD MONITORS	CRT TVS	PROJECTION TVS	PRINTERS	KEYBOARDS	MICE[1]	CELL PHONES[2]
1	0.5%	9.8%	3.7%	16.7%	9.2%	0.0%	5.0%	38.9%	38.9%	9.8%
2	1.3%	9.2%	5.4%	16.7%	6.8%	0.0%	6.8%	16.5%	16.5%	9.2%
3	2.0%	22.1%	7.4%	16.7%	9.4%	0.0%	8.0%	4.1%	4.1%	22.1%
4	3.4%	18.4%	9.3%	16.7%	7.3%	0.0%	6.4%	0.0%	0.0%	18.4%
5	4.8%	40.5%	7.1%	16.7%	9.0%	0.0%	8.6%	2.5%	2.5%	40.5%
6	2.2%	0.0%	8.0%	16.7%	6.7%	0.0%	13.3%	2.8%	2.8%	0.0%
7	3.3%	0.0%	10.0%	0.0%	6.8%	0.0%	7.7%	3.2%	3.2%	0.0%
8	6.6%	0.0%	10.0%	0.0%	5.9%	0.0%	10.2%	0.0%	0.0%	0.0%
9	2.8%	0.0%	9.1%	0.0%	3.8%	0.0%	9.3%	11.5%	11.5%	0.0%
10	5.3%	0.0%	4.9%	0.0%	5.7%	0.0%	7.1%	0.0%	0.0%	0.0%
11	4.0%	0.0%	4.7%	0.0%	6.4%	0.0%	4.5%	14.6%	14.6%	0.0%
12	5.8%	0.0%	2.8%	0.0%	4.6%	0.0%	3.8%	6.0%	6.0%	0.0%
13	4.2%	0.0%	4.0%	0.0%	4.7%	0.0%	3.1%	0.0%	0.0%	0.0%
14	7.0%	0.0%	2.3%	0.0%	3.9%	0.0%	2.7%	0.0%	0.0%	0.0%
15	4.4%	0.0%	1.4%	0.0%	2.6%	0.0%	1.3%	0.0%	0.0%	0.0%
16	2.1%	0.0%	2.0%	0.0%	2.3%	0.0%	1.1%	0.0%	0.0%	0.0%
17	4.0%	0.0%	1.1%	0.0%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%
18	6.6%	0.0%	1.5%	0.0%	1.4%	0.0%	1.0%	0.0%	0.0%	0.0%
19	2.9%	0.0%	2.7%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%
20	9.6%	0.0%	0.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
21	9.6%	0.0%	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
22	5.5%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
23	2.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TOTAL	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%

Notes:

We use the distribution of the duration of a keyboard's second life as a proxy for mice.

We use the distribution of the duration of a laptop computer's second life as a proxy for cell phones.

APPENDIX C: ESTIMATING THE REUSE AND STORAGE OF ELECTRONIC PRODUCTS

As part of our assessment of the baseline generation and management of electronic waste, the number of products that are reused or placed in storage was estimated after their first life (i.e., the number of products that move on to a second life after their original owners stop using them). To estimate the percentage of electronic products (by product) that are reused or stored, data was used from surveys conducted by the Consumer Electronics Association, MetaFacts, IBM, the Massachusetts Department of Environmental Protection, and the California Integrated Waste Management Board.[64] In the following sections, we summarize how we used these data for each product included in our baseline assessment.

STORAGE AND RE-USE OF COMPUTERS AND COMPUTER PERIPHERALS

To estimate the storage/re-use rate for computers (desktops and laptops), separate storage/re-use rates were estimated for computers used by households and computers used by businesses. The weighted average of these two values was then estimated and combined to a single storage/re-use rate for all computers. This rate was applied to both desktop and laptop computers, as well as to the peripheral devices included in the baseline assessment (i.e., printers, keyboards, and mouse devices).

Based on data from surveys conducted by MetaFacts and the Massachusetts Department of Environmental Protection, a household storage/re-use rate of 82.7 percent was estimated.[65] This value represents the mean of the storage/re-use rates implied by these two studies, both of which asked respondents about their management of computers that they replaced or that they no longer used.

To estimate the storage/re-use rate for workplace computers, publicly available results were used from an IBM survey of 176 IT executives. This survey asked executives to list the various ways in which their companies disposed of their computers, but it did not ask about the extent to which companies relied on each method or whether companies stored old computers before disposing of them. Therefore, the results of this survey at best provide a rough approximation of the storage/re-use rate for workplace computers. The results of the survey are presented in Exhibit C-1.

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[64] Consumer Electronics Association, *Consumer Electronics Reuse and Recycling*, October 2005; Metafacts Inc., *Technology User Profile 2004* as cited in Karl Schoenberger, "Many Old Computers Put to Use Again, Study Finds," *San Jose Mercury News*. April 27, 2005; IBM Global Financing, survey of senior IT executives, cited in John G. Spooner, "Weighing the results of PC recycling," CNET News.com, April 16, 2004; Massachusetts Department of Environmental Protection, *Massachusetts DEP Electronic Equipment and Household Chemicals Disposal Research*, July 1999; and California Integrated Waste Management Board, *Selected E-waste Diversion in California: A Baseline Study*, November 2001.

[65] In developing this estimate, we assume that computers repaired or sold by households are re-used.

EXHIBIT C-1: IBM IT EXECUTIVE SURVEY RESULTS

MANAGEMENT OPTION	PERCENT OF COMPANIES THAT USE MANAGEMENT PRACTICE FOR AT LEAST SOME OF THEIR UNWANTED COMPUTERS[1]	SURVEY RESULTS SCALED TO 100 PERCENT TOTAL[2]
Use Outside Disposal Company	50.0%	44.2%
Donate	40.0%	35.4%
Discard On Site	23.0%	20.4%
TOTAL	**113%**	**100%**

Notes:

[1] Column does not total to 100 percent because the survey asked respondents to list all of the management practices they use. Therefore, respondents were able to list multiple management methods.

[2] This column represents the previous column scaled to add up to 100 percent.

Source: IBM Global Financing, survey of senior IT executives, cited in John G. Spooner, "Weighing the results of PC recycling," CNET News.com, April 16, 2004.

To estimate the storage/re-use rate for workplace computers based on the IBM data, the IBM survey results were assumed to represent the proportional relationship between the number of workplace computers managed by disposal companies, donated to charity, and discarded on site (e.g., depositing them in on-site trash containers).[66] Based on this assumption, approximately 44 percent of workplace computers were estimated to be managed by an outside disposal company, while 35 percent were donated to charity. Due to resource constraints, we were unable to identify any studies of the electronics disposal industry indicating how many computers are re-sold by disposal companies on an annual basis. An article published by the Kansas City Star in May of 2000, however, suggests that these companies re-sell approximately 50 percent of the electronic products they collect.[67] Based on this percentage, approximately 22 percent of workplace computers (i.e., half of 44 percent) were estimated to be managed by disposal companies and subsequently re-sold. Adding this to the 35 percent of workplace computers donated to charity, a storage/re-use rate of 58 percent was estimated for workplace computers.[68]

To estimate the storage/re-use rate for all computers, the weighted average of the household and workplace storage/re-use rates presented above was estimated, using the number of computers in

[66] Mathematically, this entails scaling the survey results to sum to 100 percent.

[67] Bergstrom, Bill. "New breed of recyclers handles castoff computers," *Kansas City Star*, May 9, 2000. In this article, Neil Peters-Michaud, chief executive of Cascade Asset Management, is quoted as saying that the company re-sells 50 percent of the electronics it collects by weight.

[68] This estimate is rounded from 57.5 percent.

residential and commercial buildings in 1999 as weights.[69] According to the Energy Information Administration (EIA), approximately 58 million computers were in commercial buildings in 1999.[70] Based on EIA and Census data for 1997 and 2001 respectively, approximately 57.6 million computers were estimated to be in U.S. households as of 1999.[71] Therefore, calculating the weighted average of the household and workplace storage/re-use rates presented above, the overall storage/re-use rate for computers (desktops and laptops) was estimated to be 70.1 percent, as indicated in Exhibit C-2. Because we identified no survey data specific to the storage or re-use of computer peripherals, the computer storage/re-use rate was applied to printers, keyboards, and mice, as well.

EXHIBIT C-2: STORAGE/RE-USE RATE OF SELECT ELECTRONICS PRODUCTS

PRODUCT	STORAGE/RE-USE RATE
Desktop Computers	70.1%
Laptop (Portable) Computers	70.1%
CRT Monitors	64.7%
LCD Monitors	64.7%
CRT Televisions	65.1%
Projection Televisions	0.0%
Desktop Computer Printers	52.9%
Keyboards	70.1%
Computer Mice	70.1%
Cell Phones	70.1%
Note: We apply these percentages only to products at the end of their first life. By definition, products at the end of their total life are disposed of rather than stored or re-used.	

[69] We use estimates for 1999 because this is the most recent year for which data were available for both households and commercial buildings.

[70] U.S. DOE, EIA, "Computers and Photocopiers in Commercial Buildings,"

http://www.eia.doe.gov/emeu/cbecs/pc_copier/pccopier99.html, accessed November 10, 2005.

[71] EIA estimates that approximately 43 million computers were in U.S. households in 1997 (U.S. DOE, EIA, "U.S. Households Usage of Appliances in 1997" http://eia.doe.gov/emeu/recs/recs97/appusage.html, accessed November 10, 2005). In addition, the U.S. Census Bureau estimates that approximately 45.8 million U.S. households had one computer in 2001 and that approximately 15.7 million households had more than one computer (U.S. Census Bureau, Current Population Survey, September 2001). Assuming that all households with more than one computer had two computers, we estimate that approximately 77.1 million computers were in U.S. households in 2001. Assuming a constant growth rate between 1997 and 2001, we estimate that approximately 57.6 million computers were in U.S. households in 1999.

STORAGE AND RE-USE OF COMPUTER MONITORS

The estimate of the storage/re-use rate for household computer monitors is based on the results of the California Integrated Waste Management Board's e-waste diversion survey.[72] Based on the results of the California survey, a household storage/re-use rate of 72 percent was estimated.

None of the information sources identified contained data specific to the storage or re-use of computer monitors in workplaces. Therefore, the storage/re-use rate estimated for workplace computers (57.6 percent) was used as a proxy for the storage and re-use of monitors in the workplace. Similarly, the proportional relationship between the number of monitors in households and the number of monitors in commercial buildings was assumed to be the same as the corresponding relationship for computers. Calculating the weighted average of the household and workplace storage/re-use rates, the overall storage/re-use rate for monitors was estimated to be 64.7 percent

STORAGE AND RE-USE OF TELEVISIONS

To estimate the storage/re-use rate for CRT televisions, household storage/re-use was assumed to be representative of all storage and re-use of televisions. Several of the surveys identified contain questions about televisions, but only the California Integrated Waste Management Board e-waste diversion survey included questions that capture both the storage and re-use of televisions.[73] According to the results of this survey, 65.1 percent of respondents gave away, stored, sold, or traded in televisions that they stopped using. Therefore, the storage/re-use rate for CRT televisions was assumed to be 65.1 percent, as indicated in Exhibit C-2.

Although projection televisions and CRT televisions are similar in several ways, the results of the California survey were not used to estimate the storage/re-use rate for projection televisions. As indicated in the main body of this report, no projection televisions were assumed to be re-used or put into storage at the end of their first life.

STORAGE AND RE-USE OF CELL PHONES

The only data source identified with information related to the storage and re-use of cell phones is the Consumer Electronics Association's (CEA's) re-use and recycling survey. Based on the results of this survey, consumers donate or sell approximately 52.9 percent of their unwanted cell phones. Because the CEA survey asks respondents about cell phones they removed from their homes rather than cell phones they no longer use, the results of the survey do not reflect the

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[72] The California Integrated Waste Management Board's survey asks respondents about monitors in general with no specific mention of CRT or LCD monitors. Therefore, we assume that the results of the survey apply to both technologies.

[73] The Massachusetts DEP survey asked individuals what they did with their broken televisions; however, because several of the respondents had their televisions repaired, the survey includes several televisions that are not at the end of their total life. Therefore, we do not use the results of the survey in our analysis.

storage of cell phones. Absent data from other sources, the CEA results were used as a proxy for cell phone storage and re-use.

APPENDIX D: MATERIAL COMPOSITION OF SELECT ELECTRONIC PRODUCTS

As indicated in the main body of this report, information on the material composition of several electronic products was collected to inform our baseline assessment of the generation and management of electronic waste in the U.S.[74] Exhibits D-1 through D-7 summarize this information. As these exhibits indicate, we were able to obtain detailed constituent data for desktop and laptop computers, CRT monitors, flat-panel LCD monitors, CRT televisions, and cell phones. We also obtained composition data for keyboards, although these data are not as detailed as the information we have compiled for other products.[75] We were unable to locate information on the composition of printers, mice, and projection televisions.

The constituent estimates presented in Exhibits D-1 through D-7 indicate that most of the electronic products included in our analysis include lead. Lead is most highly concentrated in CRT products, but it is also found in desktop and laptop computers, LCD monitors, and cell phones. The constituent data included in Exhibits D-1 through D-7 also show that a number of valuable metals are included in most electronic products. For example, CRT monitors, desktops, and cell phones all contain silver, while desktops and CRT monitors both contain gold.

[74] The data sources from which we obtained these data include Bhuie, A. K., *et al.*, "Environmental and Economic Trade-Offs in Consumer Electronic Products Recycling," Proceedings of IEEE 2004 conference on electronic waste; California Department of Toxic Substances Control, Hazardous Materials Laboratory, *Determination of regulated elements in discarded laptop computers, LCD monitors, Plasma TVs and LCD TVs,* SB20 Report, December 2004; Five Winds International, *Toxic and Hazardous Materials in Electronics*, October 2001; Microelectronics and Computer Technology Corporation, *Electronic Industry Environmental Roadmap*, 1996, as cited in Silicon Valley Toxic Coalition (SVTC), *Poison PCs and Toxic TVs*, February 2004; Matsuto, T, *et al.*, "Material and heavy metal balance in a recycling facility for home electrical appliances," *Waste Management,* 24, (2004); RIS International, Ltd., *Baseline Study of End-of-Life Electrical and Electronic Equipment in Canada*, June 2003; U.S. EPA, *Desktop Computer Displays: A Life-Cycle Assessment*, December 2001; and Williams, Eric. "Environmental Impacts in the Production of Personal Computers," *Computers and the Environment*, edited by Ruediger Kuehr and Eric Williams, Kluwer Academic Publishers, 2003.

[75] Lee, C. H., et al., "An overview of recycling and treatment of scrap computers," *Journal of Hazardous Materials* B114 (2004) 93-100.

EXHIBIT D-1: MATERIAL COMPOSITION OF A DESKTOP COMPUTER

MATERIAL	AMOUNT CONTAINED IN A DESKTOP (GRAMS)
Metals	7,254 - 7,524
Steel[1]	6,050
Copper[1]	670
Aluminum[1]	440
Tin[1]	47
Lead[1]	27
Silver[1]	1.4
Gold[1]	0.36
Nickel[1]	18
Germanium[2]	< 45
Gallium[2]	< 45
Indium[2]	< 45
Europium[2]	< 45
Ruthenium[2]	< 45
Bismuth[2]	< 45
Non-metallic Elements	0.44 - 45.44
Selenium[2]	0.44
Arsenic[2]	< 45
Plastics[1]	650
Epoxy Resin[1]	1,040

Sources:
1. Williams, Eric. "Environmental Impacts in the Production of Personal Computers," Computers and the Environment, edited by Ruediger Kuehr and Eric Williams, Kluwer Academic Publishers, 2003.
2. Microelectronics and Computer Technology Corporation, Electronic Industry Environmental Roadmap, 1996, as cited in Silicon Valley Toxic Coalition (SVTC), Poison PCs and Toxic TVs, February 2004. This study combines desktops and CRT monitors into one product category but provides some composition information specific to desktops.

EXHIBIT D-2: MATERIAL COMPOSITION OF A CRT MONITOR

PRODUCT	AVERAGE AMOUNT CONTAINED IN A CRT MONITOR		RANGE OF MASS VALUES IDENTIFIED IN THE LITERATURE	
	GRAMS*	PERCENT OF TOTAL MASS	GRAMS*	PERCENT OF TOTAL MASS
Metals	5,683-5,818	36.5%-37.4%	4,788-7,145	30.8%-45.9%
Steel[1]	3,322	21.4%	2,850-3,794	18.3%-24.4%
Copper[2]	952	6.1%	705-1,198	4.5%-7.7%
Aluminum[3]	242	1.6%	199-717	1.3%-4.6%
Lead[1]	464	3.0%	331-597	2.1%-3.8%
Ferrite[4]	483	3.1%	Only one value identified.	
Tin[4]	20	0.13%		
Silver[4]	1.25	0.01%		
Gold[4]	0.31	0.002%		
Nickel[5]	199	1.28%		
Barium[6]	< 45	<0.29%		
Vanadium[6]	< 45	<0.29%		
Yttrium[6]	< 45	<0.29%		
Glass[7]	6,845	44.0%	5,982-6,865	38.5%-44.1%
Plastics[8]	2,481	16.0%	2,235-3,555	14.4%-22.9%
Epoxy Resin[4]	141	0.91%	Only one value identified.	

Note:

* The composition estimates presented in grams are scaled from the sources we consulted to be consistent with an average CRT monitor mass of 34.3 pounds, which is consistent with the estimate for the 1990-2005 period presented in Exhibit 3-3.

Sources:

1. Based on average of percent of total mass from Williams, Eric. "Environmental Impacts in the Production of Personal Computers," Computers and the Environment, edited by Ruediger Kuehr and Eric Williams, Kluwer Academic Publishers, 2003 and U.S. EPA, Desktop Computer Displays: A Life-Cycle Assessment, December 2001.
2. Based on average of percent of total mass from Williams (2003) and Menad, N. "Cathode ray tube recycling," Resources, Conservation, and Recycling, Vol. 26, 1999.
3. Average value based on percent of total mass as derived from Williams (2003). Low-end and high-end estimates based on U.S. EPA (2001) and Menad (1999), respectively.
4. Based on percent of total mass as derived from Williams (2003).
5. Based on percent of total mass as presented in U.S. EPA (2001).
6. Microelectronics and Computer Technology Corporation, Electronic Industry Environmental Roadmap, 1996, as cited in Silicon Valley Toxic Coalition (SVTC), Poison PCs and Toxic TVs, February 2004. This study combines desktops and CRT monitors into one product category but provides some composition information specific to CRT monitors.
7. Average value based on percent of total mass as presented in U.S. EPA (2001). Low-end and high-end estimates based on Menad (1999) and Williams (2003), respectively.
8. Average value based on percent of total mass as derived from Menad (1999). Low -end and high-end estimates based on U.S. EPA (2001) and Williams (2003), respectively.

EXHIBIT D-3: PRIMARY MATERIAL INPUTS FOR A 15-INCH LCD MONITOR

MATERIAL	AMOUNT CONTAINED (GRAMS)	PERCENT OF TOTAL MASS
Metals	2,702	47.15%
Steel	2,530	44.12%
Aluminum (heat sink)	130	2.34%
Solder (60% tin, 40% lead)	40	0.66%
Transition metals, other (Mo, Ti, W)	1.9	0.03%
Mercury	0.00399	0.0001%
Plastics	1,780	30.98%
Glass	590	10.31%
Miscellaneous Compounds	11	0.17%
Polyvinyl alcohol	10	0.15%
Indium tin oxide (ITO) (electrode)	0.5	0.01%
Polyimide alignment layer	0.5	0.01%
Other	44.2	0.72%
Color filter pigment	40	0.65%
Liquid crystals	2.3	0.04%
Backlight lamp (CCFL)	1.9	0.03%

Source:
EPA, "Desktop Computer Displays: A Life-Cycle Assessment," EPA-744-R-01-004a, December 2001.

EXHIBIT D-4: MATERIAL COMPOSITION OF A CELL PHONE

MATERIAL	AMOUNT CONTAINED (GRAMS)*	PERCENT OF TOTAL MASS
Metals	58	43.8%
Lead	1	0.9%
Aluminum	12	9%
Iron	11	8%
Tin	1	1%
Copper	26	19%
Nickel	1	1%
Zinc	4	3%
Silver	1	0.9%
Mercury	1	1%
Plastics	63	46%
Silica	5	4%

Note:
* Assuming a cell phone average weight of 136 g, consistent with the average mass of a cell phone during the 2000-2005 period, as presented in Exhibit 3-3.
Source:
Bhuie, A. K., et al., "Environmental and Economic Trade-Offs in Consumer Electronic Products Recycling: A case study of cell phones and computers," IEEE, 2004, 75.

EXHIBIT D-5: COMPONENTS IN A TYPICAL PC KEYBOARD

COMPONENT	MATERIAL	AMOUNT CONTAINED (GRAMS)	PERCENT OF TOTAL MASS
Shell	Plastic	348	37.91%
Top plate	Plastic	118	12.85%
Bottom plate	Plastic	230	25.06%
IC Board	IC, resin, copper, iron	384	41.83%
Button	Plastic	116	12.63%
Wire	Copper, plastic	70	7.63%
Total		918	100.00%

Source:
Lee, C. H., et al., "An overview of recycling and treatment of scrap computers," *Journal of Hazardous Materials* B114 (2004) 93-100.

EXHIBIT D-6: MATERIALS IN A CRT TELEVISION

MATERIAL	AMOUNT CONTAINED (GRAMS)*	PERCENT OF TOTAL MASS
Metals	4,107-4,262	14.3%-14.8%
Steel/Iron[1]	2,088	7.3%
Lead[1,2]	1,291-1,347	4.5%-4.7%
Copper[1,2]	606-705	2.1%-2.5%
Aluminum[1]	67	0.23%
Zinc[2]	8.6	0.03%
Tin[2]	31.6	0.11%
Cadmium[2]	0.2	0.001%
Chromium[2]	0.03	0.0001%
Antimony[2]	14.4	0.05%
Glass[1]	15,760	54.8%
Plastic[1]	8,755	30.4%

Note:
* We scale the mass values presented in the sources listed below to be consistent with our estimate of the average mass of a CRT TV during the 1990-2005 period as reported in Exhibit 3-3 (28.8 kg or 63.4 pounds).
Sources:
1. RIS International, Ltd., *Baseline Study of End-of-Life Electrical and Electronic Equipment in Canada*, June 2003, Table 4.2. This table presents the composition of a 42.7-kg 28-inch CRT TV.
2. Matsuto, T., et al., "Material and heavy metal balance in a recycling facility for home electrical appliances," Waste Management 24 (2004), 434. This study presents grams of material (e.g., cadmium) per kg of CRT TV mass.

EXHIBIT D-7: MATERIALS IN A LAPTOP LCD PANEL AND PC BOARD

MATERIAL	GRAMS PER KG OF PRODUCT[1]	GRAMS PER LAPTOP, ASSUMING A LAPTOP MASS OF 3.5 KG
Antimony	0.22	0.77
Arsenic	0.003	0.01
Barium	0.70	2.45
Chromium	0.02	0.07
Copper	38.7	135.45
Lead	1.5	5.25
Mercury[2]	-	0.00012 - 0.0005
Molybdenum	0.01	0.04
Nickel	1.03	3.61
Silver	0.07	0.25
Zinc	0.001	0.004

Notes:
1. Except for mercury, these values represent the average composition of four laptops analyzed in California Department of Toxic Substances Control, Hazardous Materials Laboratory, Determination of regulated elements in discarded laptop computers, LCD monitors, Plasma TVs and LCD TVs, SB20 Report, December 2004.
2. Based on various sources cited in Five Winds International, Toxic and Hazardous Materials in Electronics, October 2001.

APPENDIX E: MATERIAL COMPOSITION OF RETIRED ELECTRONIC PRODUCTS

This appendix presents estimates of the total quantity (i.e., mass) of individual constituents included in the electronic waste stream in 2003, 2004, and 2005, by management method. These estimates were developed by multiplying the product retirement estimates generated by the waste flow model described in the main body of this report by the per unit constituent information presented in Appendix D. The results are presented both in aggregate and for individual products. It is important to note, however, that the aggregate estimates only reflect constituents included in those products for which we were able to identify material composition information (i.e., desktops, laptops, CRT monitors, LCD monitors, CRT televisions, cell phones, and keyboards). Constituents included in other products (e.g., mice) are not reflected in the results presented in this appendix.

EXHIBIT E-1: MATERIAL COMPOSITION OF AGGREGATE E-WASTE VOLUME FOR ELECTRONIC PRODUCTS BY MANAGEMENT METHOD (IN POUNDS)*

	LANDFILLED			RECYCLED			INCINERATED		
MATERIAL	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**
Aluminum	26,431,609	26,498,975	27,413,819	8,608,041	8,620,096	8,894,458	751,906	753,822	779,847
Antimony	610,576	627,803	649,233	98,382	101,312	104,998	17,369	17,859	18,469
Arsenic	1,287,810	1,349,293	1,380,765	467,980	490,322	501,759	36,635	38,384	39,279
Backlight lamp (CCFL)	256	800	2,152	86	268	720	7	23	61
Barium	1,804,774	1,660,163	1,689,663	604,378	556,094	566,090	51,341	47,227	48,066
Bismuth	1,287,709	1,349,179	1,380,633	467,943	490,281	501,711	36,632	38,380	39,275
Cadmium	12,064	12,389	12,790	1,914	1,966	2,029	343	352	364
Chromium	1,877	1,997	2,164	435	472	525	53	57	62
Color filter pigment	5,543	17,331	46,630	1,854	5,797	15,598	158	493	1,326
Copper	88,258,064	87,330,456	90,066,155	25,004,088	24,562,575	25,284,892	2,510,697	2,484,310	2,562,133
Epoxy Resin	35,349,969	36,307,212	37,112,743	12,684,407	13,045,649	13,336,101	1,005,609	1,032,840	1,055,755
Europium	1,287,709	1,349,179	1,380,633	467,943	490,281	501,711	36,632	38,380	39,275
Ferrite	19,041,421	17,462,811	17,730,607	6,369,382	5,841,335	5,930,913	541,676	496,769	504,387
Gallium	1,287,709	1,349,179	1,380,633	467,943	490,281	501,711	36,632	38,380	39,275
Germanium	1,287,709	1,349,179	1,380,633	467,943	490,281	501,711	36,632	38,380	39,275
Glass	931,457,141	927,062,970	953,283,703	195,320,967	190,716,659	195,626,819	26,497,375	26,372,373	27,118,281
Gold	22,586	22,060	22,484	7,853	7,691	7,840	643	628	640
Indium	1,287,709	1,349,179	1,380,633	467,943	490,281	501,711	36,632	38,380	39,275
Indium tin oxide (ITO)	85	267	717	29	89	240	2	8	20
Iron	1,082,829	1,228,467	1,469,765	265,136	300,796	359,879	30,803	34,946	41,811
Lead	74,866,062	74,894,463	77,052,109	15,297,215	15,043,390	15,439,439	2,129,732	2,130,540	2,191,919
Liquid crystals	341	1,067	2,870	114	357	960	10	30	82
Mercury	135,357	153,564	183,732	33,143	37,602	44,989	3,851	4,368	5,227
Molybdenum	335	379	443	122	138	161	10	11	13
Nickel	8,547,251	7,942,740	8,102,602	2,862,813	2,659,812	2,711,134	243,146	225,949	230,497
Plastics	525,330,685	534,412,179	552,676,242	112,229,943	113,625,481	117,524,174	14,944,203	15,202,546	15,722,108
Polyimide alignment layer	85	267	717	29	89	240	2	8	20

	LANDFILLED			RECYCLED			INCINERATED		
MATERIAL	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**
Polyvinyl alcohol	1,279	4,000	10,761	428	1,338	3,599	36	114	306
Ruthenium	1,287,709	1,349,179	1,380,633	467,943	490,281	501,711	36,632	38,380	39,275
Selenium	12,591	13,192	13,500	4,575	4,794	4,906	358	375	384
Silica	541,414	614,233	734,882	132,568	150,398	179,940	15,402	17,473	20,905
Silver	225,652	239,163	268,596	65,786	68,900	76,353	6,419	6,804	7,641
Solder (60% tin; 40% lead)	5,629	17,598	47,347	1,883	5,886	15,838	160	501	1,347
Steel	304,948,841	303,115,768	311,181,864	107,007,493	106,633,087	109,453,378	8,674,950	8,622,804	8,852,262
Steel/Iron	88,066,758	90,441,248	93,365,913	13,972,230	14,348,954	14,812,967	2,505,255	2,572,803	2,656,002
Tin	3,605,839	3,657,826	3,776,140	999,526	1,010,847	1,040,919	102,576	104,055	107,421
Transition Metals, other (Mo, Ti, W)	256	800	2,152	86	268	720	7	23	61
Vanadium	1,781,294	1,633,618	1,658,670	595,845	546,447	554,827	50,673	46,472	47,185
Yttrium	1,781,294	1,633,618	1,658,670	595,845	546,447	554,827	50,673	46,472	47,185
Zinc	768,013	832,389	934,902	156,858	171,781	195,846	21,848	23,679	26,595
Total	2,123,711,840	2,127,286,180	2,190,839,299	506,199,091	502,048,822	516,258,342	60,413,719	60,515,399	62,323,309
* Based on available material composition information for desktops, laptops, CRT monitors, LCD monitors, CRT televisions, cell phones, and keyboards.									

EXHIBIT E-2: MATERIAL COMPOSITION OF AGGREGATE E-WASTE VOLUME FOR DESKTOPS BY MANAGEMENT METHOD (IN POUNDS)

	LANDFILLED			RECYCLED			INCINERATED		
MATERIAL	2003	2004	2005	2003	2004	2005	2003	2004	2005
Aluminum	12,590,934	13,191,975	13,499,518	4,575,444	4,793,857	4,905,616	358,177	375,275	384,024
Arsenic	1,287,709	1,349,179	1,380,633	467,943	490,281	501,711	36,632	38,380	39,275
Bismuth	1,287,709	1,349,179	1,380,633	467,943	490,281	501,711	36,632	38,380	39,275
Copper	19,172,559	20,087,780	20,556,084	6,967,153	7,299,737	7,469,915	545,406	571,442	584,764
Epoxy Resin	29,760,390	31,181,032	31,907,952	10,814,685	11,330,934	11,595,091	846,601	887,014	907,693
Europium	1,287,709	1,349,179	1,380,633	467,943	490,281	501,711	36,632	38,380	39,275
Gallium	1,287,709	1,349,179	1,380,633	467,943	490,281	501,711	36,632	38,380	39,275
Germanium	1,287,709	1,349,179	1,380,633	467,943	490,281	501,711	36,632	38,380	39,275
Gold	10,302	10,793	11,045	3,744	3,922	4,014	293	307	314
Indium	1,287,709	1,349,179	1,380,633	467,943	490,281	501,711	36,632	38,380	39,275
Lead	772,626	809,508	828,380	280,766	294,168	301,026	21,979	23,028	23,565
Nickel	515,084	539,672	552,253	187,177	196,112	200,684	14,653	15,352	15,710
Plastics	18,600,244	19,488,145	19,942,470	6,759,178	7,081,834	7,246,932	529,125	554,384	567,308
Ruthenium	1,287,709	1,349,179	1,380,633	467,943	490,281	501,711	36,632	38,380	39,275
Selenium	12,591	13,192	13,500	4,575	4,794	4,906	358	375	384
Silver	40,062	41,974	42,953	14,558	15,253	15,609	1,140	1,194	1,222
Steel	173,125,347	181,389,655	185,618,374	62,912,349	65,915,531	67,452,214	4,924,937	5,160,033	5,280,329
Tin	1,344,941	1,409,143	1,441,994	488,741	512,071	524,009	38,260	40,086	41,021
Total	264,959,044	277,607,123	284,078,950	96,283,970	100,880,180	103,231,989	7,537,351	7,897,154	8,081,259

EXHIBIT E-3: MATERIAL COMPOSITION OF AGGREGATE E-WASTE VOLUME FOR LAPTOPS BY MANAGEMENT METHOD (IN POUNDS)

	LANDFILLED			RECYCLED			INCINERATED		
MATERIAL	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**
Antimony	7,380	8,343	9,741	2,682	3,032	3,540	210	237	277
Arsenic	101	114	133	37	41	48	3	3	4
Barium	23,480	26,545	30,993	8,533	9,646	11,263	668	755	882
Chromium	671	758	886	244	276	322	19	22	25
Copper	1,298,123	1,467,575	1,713,462	471,728	533,305	622,658	36,928	41,748	48,743
Lead	50,315	56,883	66,413	18,284	20,671	24,134	1,431	1,618	1,889
Mercury	3	3	4	1	1	1	0	0	0
Molybdenum	335	379	443	122	138	161	10	11	13
Nickel	34,550	39,059	45,604	12,555	14,194	16,572	983	1,111	1,297
Silver	2,348	2,655	3,099	853	965	1,126	67	76	88
Zinc	34	38	44	12	14	16	1	1	1
Total	1,417,339	1,602,352	1,870,821	515,050	582,282	679,841	40,319	45,582	53,220

EXHIBIT E-4: MATERIAL COMPOSITION OF AGGREGATE E-WASTE VOLUME FOR CRT MONITORS BY MANAGEMENT METHOD (IN POUNDS)

	LANDFILLED			RECYCLED			INCINERATED		
MATERIAL	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**
Aluminum	9,827,830	9,013,064	9,151,281	3,287,423	3,014,882	3,061,116	279,575	256,397	260,329
Barium	1,781,294	1,633,618	1,658,670	595,845	546,447	554,827	50,673	46,472	47,185
Copper	37,468,603	34,362,305	34,889,260	12,533,300	11,494,239	11,670,507	1,065,878	977,512	992,503
Epoxy Resin	5,589,578	5,126,180	5,204,791	1,869,722	1,714,714	1,741,010	159,008	145,826	148,062
Ferrite	19,041,421	17,462,811	17,730,607	6,369,382	5,841,335	5,930,913	541,676	496,769	504,387
Glass	270,265,331	247,859,250	251,660,235	90,404,133	82,909,268	84,180,703	7,688,300	7,050,909	7,159,037
Gold	12,285	11,266	11,439	4,109	3,769	3,826	349	320	325
Lead	18,427,182	16,899,494	17,158,652	6,163,918	5,652,905	5,739,593	524,202	480,744	488,116
Nickel	7,862,264	7,210,451	7,321,025	2,629,938	2,411,906	2,448,893	223,660	205,117	208,263
Plastics	98,278,302	90,130,636	91,512,813	32,874,230	30,148,825	30,611,165	2,795,745	2,563,967	2,603,286
Silver	61,424	56,332	57,196	20,546	18,843	19,132	1,747	1,602	1,627
Steel	131,447,229	120,549,726	122,398,387	43,969,283	40,324,053	40,942,433	3,739,310	3,429,306	3,481,895
Tin	798,511	732,311	743,542	267,103	244,959	248,716	22,715	20,832	21,152
Vanadium	1,781,294	1,633,618	1,658,670	595,845	546,447	554,827	50,673	46,472	47,185
Yttrium	1,781,294	1,633,618	1,658,670	595,845	546,447	554,827	50,673	46,472	47,185
Total	604,423,843	554,314,680	562,815,237	202,180,626	185,419,040	188,262,489	17,194,184	15,768,717	16,010,534

EXHIBIT E-5: MATERIAL COMPOSITION OF AGGREGATE E-WASTE VOLUME FOR LCD MONITORS BY MANAGEMENT METHOD (IN POUNDS)

	LANDFILLED			RECYCLED			INCINERATED		
MATERIAL	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**
Aluminum	19,956	62,392	167,868	6,675	20,870	56,152	568	1,775	4,775
Backlight lamp (CCFL)	256	800	2,152	86	268	720	7	23	61
Color filter pigment	5,543	17,331	46,630	1,854	5,797	15,598	158	493	1,326
Glass	87,926	274,899	739,624	29,411	91,954	247,405	2,501	7,820	21,040
Indium tin oxide (ITO)	85	267	717	29	89	240	2	8	20
Liquid crystals	341	1,067	2,870	114	357	960	10	30	82
Mercury	1	3	7	0	1	2	0	0	0
Plastics	264,204	826,031	2,222,459	88,377	276,308	743,416	7,516	23,498	63,223
Polyimide alignment layer	85	267	717	29	89	240	2	8	20
Polyvinyl alcohol	1,279	4,000	10,761	428	1,338	3,599	36	114	306
Solder (60% tin; 40% lead)	5,629	17,598	47,347	1,883	5,886	15,838	160	501	1,347
Steel	376,265	1,176,387	3,165,103	125,861	393,503	1,058,731	10,704	33,465	90,038
Transition Metals, other (Mo, Ti, W)	256	800	2,152	86	268	720	7	23	61
Total	761,826	2,381,840	6,408,409	254,832	796,729	2,143,622	21,672	67,757	182,301

EXHIBIT E-6: MATERIAL COMPOSITION OF AGGREGATE E-WASTE VOLUME FOR CRT TELEVISIONS BY MANAGEMENT METHOD (IN POUNDS)

	LANDFILLED			RECYCLED			INCINERATED		
MATERIAL	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**
Aluminum	2,774,706	2,849,519	2,941,666	440,221	452,090	466,710	78,933	81,061	83,682
Antimony	603,197	619,461	639,493	95,700	98,281	101,459	17,159	17,622	18,192
Cadmium	12,064	12,389	12,790	1,914	1,966	2,029	343	352	364
Chromium	1,206	1,239	1,279	191	197	203	34	35	36
Copper	27,747,061	28,495,188	29,416,658	4,402,209	4,520,903	4,667,099	789,327	810,609	836,822
Glass	661,103,884	678,928,821	700,883,844	104,887,422	107,715,437	111,198,711	18,806,574	19,313,644	19,938,204
Lead	55,494,122	56,990,375	58,833,315	8,804,419	9,041,807	9,334,198	1,578,654	1,621,218	1,673,645
Plastic	366,743,761	376,632,047	388,811,475	58,185,723	59,754,549	61,686,876	10,432,844	10,714,138	11,060,609
Steel/Iron	88,066,758	90,441,248	93,365,913	13,972,230	14,348,954	14,812,967	2,505,255	2,572,803	2,656,002
Tin	1,327,033	1,362,813	1,406,884	210,540	216,217	223,209	37,750	38,768	40,022
Zinc	361,918	371,676	383,696	57,420	58,968	60,875	10,296	10,573	10,915
Total	1,204,235,711	1,236,704,776	1,276,697,012	191,057,990	196,209,369	202,554,337	34,257,170	35,180,825	36,318,493

EXHIBIT E-7: MATERIAL COMPOSITION OF AGGREGATE E-WASTE VOLUME FOR CELL PHONES BY MANAGEMENT METHOD (IN POUNDS)

	LANDFILLED			RECYCLED			INCINERATED		
MATERIAL	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**
Aluminum	1,218,182	1,382,025	1,653,485	298,278	338,396	404,864	34,654	39,315	47,037
Copper	2,571,718	2,917,609	3,490,691	629,698	714,391	854,713	73,158	82,998	99,300
Iron	1,082,829	1,228,467	1,469,765	265,136	300,796	359,879	30,803	34,946	41,811
Lead	121,818	138,203	165,349	29,828	33,840	40,486	3,465	3,931	4,704
Mercury	135,354	153,558	183,721	33,142	37,600	44,985	3,850	4,368	5,226
Nickel	135,354	153,558	183,721	33,142	37,600	44,985	3,850	4,368	5,226
Plastics	6,226,266	7,063,684	8,451,147	1,524,532	1,729,578	2,069,305	177,120	200,942	240,412
Silica	541,414	614,233	734,882	132,568	150,398	179,940	15,402	17,473	20,905
Silver	121,818	138,203	165,349	29,828	33,840	40,486	3,465	3,931	4,704
Tin	135,354	153,558	183,721	33,142	37,600	44,985	3,850	4,368	5,226
Zinc	406,061	460,675	551,162	99,426	112,799	134,955	11,551	13,105	15,679
Total	12,696,168	14,403,773	17,232,991	3,108,720	3,526,836	4,219,584	361,171	409,747	490,231

EXHIBIT E-8: MATERIAL COMPOSITION OF AGGREGATE E-WASTE VOLUME FOR KEYBOARDS BY MANAGEMENT METHOD (IN POUNDS)

	LANDFILLED			RECYCLED			INCINERATED		
MATERIAL	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**
Copper/plastic (Wire)	5,316,831	6,079,790	6,300,846	1,932,093	2,209,346	2,289,676	151,249	172,953	179,242
IC/resin/copper/iron (IC Board)	29,148,499	33,331,273	34,543,170	10,592,328	12,112,315	12,552,708	829,194	948,182	982,657
Plastic (Button)	8,800,993	10,063,925	10,429,841	3,198,210	3,657,149	3,790,120	250,364	286,291	296,700
Plastic (Shell)	26,416,916	30,207,711	31,306,038	9,599,693	10,977,238	11,376,361	751,488	859,326	890,570
Total	69,683,239	79,682,699	82,579,894	25,322,325	28,956,047	30,008,864	1,982,295	2,266,752	2,349,169