



## MANAGEMENT OF ELECTRONIC WASTE IN THE UNITED STATES

Electronic equipment has become a mainstay of our American way of life. In one way or another, it is an integral part of everything we do and own: TVs in our homes, GPS's in our cars, cell phones and MP3 players in our ears, blackberries and video games in our hands, and computers in our laps and on our desks. The electronic industry generates nearly \$2 billion a year, and it's no small wonder. Americans own nearly 3 billion electronic products.

For each new product that comes along, one or more becomes outdated or obsolete. Consequently, we're storing or discarding older electronic products faster than ever. In 1998, studies estimate about 20 million computers became obsolete in one year. In 2005, some estimate that 130,000 computers were discarded in a single day. Along with computers, TVs, VCRs, cell phones, and monitors—an estimated 304 million electronics—were removed from US households in 2005, with about two-thirds of those still in working order, according to Consumer Electronics Association (CEA) estimates.

Although used electronics represent less than two percent of the municipal solid waste stream, if we continue to replace old or outdated electronic equipment at our current rate, that percentage will continue to grow.

In 2005, used or unwanted electronics amounted to approximately 1.9 to 2.2 million tons. Of that, about 1.5 to 1.9 million tons were primarily discarded in landfills, and only 345,000 to 379,000 tons were recycled.

**In 2005 . . .**

1.9 – 2.2 million tons obsolete  
1.5 – 1.9 million tons discarded  
345,000 – 379,000 recycled

Recognizing the need to find better end-of-life (EOL) management for these products, the Environmental Protection Agency (EPA or the Agency) has been working with stakeholders to help improve awareness of the need for recovery of electronics and access to safe reuse and recycling options. State and local governments, manufacturers, and retailers, who are already aware of the pressing need to better manage these materials, are providing more opportunities to recycle and reuse this equipment. At least seven states ban some electronics from landfills, and four have instituted recovery programs. Many other states are considering some sort of legislation to manage used electronics. Over 800 communities have instituted electronics collection events to help manage obsolete electronics from households. Many computer manufacturers, TV manufacturers, and electronics retailers offer some kind of take back program or sponsor recycling events.

In an effort to get a better understanding of the scope of the issue, the Agency is providing a snapshot of electronics management and waste generation in the United States in recent years. As products, usage patterns, and management options change, purchase, storage, and EOL disposition patterns also are likely to change. Details on the data sources, assumptions, and calculations underlying the information are available in two complementary reports:

- *Management of Electronic Waste in the United States: Approach One and*

- *Management of Electronic Waste in the United States: Approach Two.*

For more information and copies of the reports, please visit our website at [www.epa.gov/ecycling/manage.htm](http://www.epa.gov/ecycling/manage.htm).

## **Analyses of Electronics in the U.S.**

In describing the amount of electronic products sold, stored, recycled, disposed of, and exported in the United States, we made a series of assumptions and estimates because information was not always complete or current, and it was sometimes developed for purposes other than deriving national estimates. The products covered in this analysis are:

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

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. The analyses:

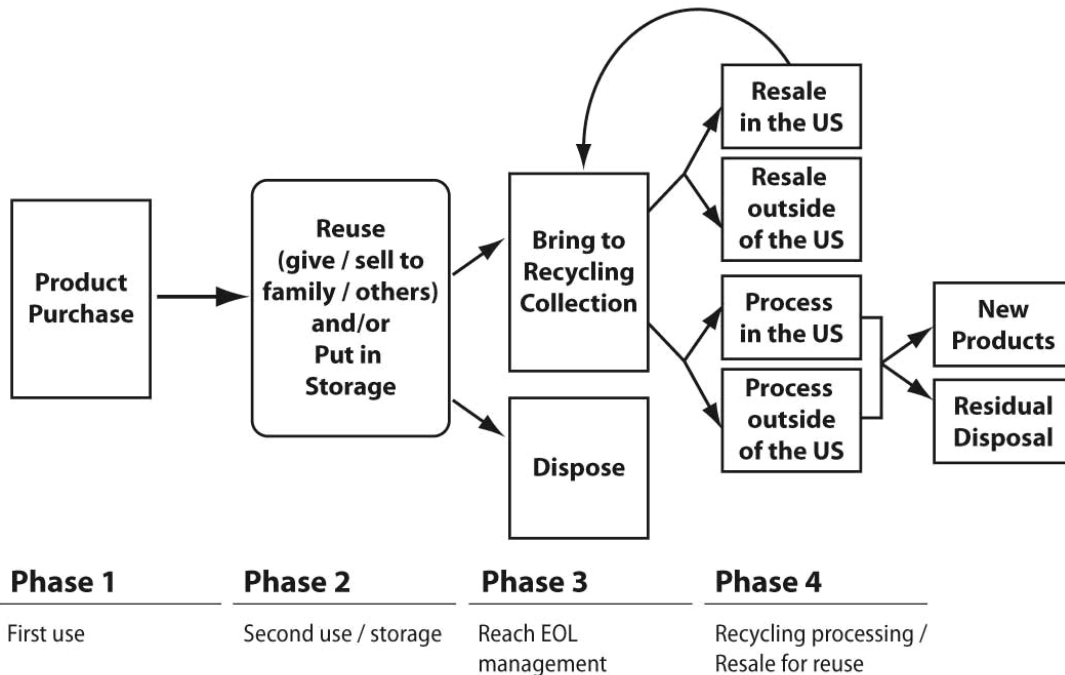
- Estimate the number and weight of products that become obsolete and need EOL management annually.
- Estimate the amount of electronic products that are recycled or disposed of.
- Estimate the amount of EOL electronic equipment that is stock-piled.
- Examine the collection rates of current electronics recycling programs to indicate the amount of material that is available for recycling.
- Examine the export of EOL electronic material that is collected for recycling.

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. We used different data sets to estimate primary outcomes, including recycling, and disposal rates, which we present as ranges. The two approaches used in arriving at these estimates are:

- *Approach One* relied primarily on market research data for sales, and then used data from electronics collection programs to estimate EOL quantities. From the EOL estimates, we subtracted the quantity recycled/exported to yield the quantity disposed of.

- *Approach Two* relied primarily on government statistics for sales, and then used the same lifespan data (with some modifications) to estimate EOL quantities. From these end-of-life estimates, we subtracted the quantity disposed of to yield the amount recycled/exported.

As a general matter, both approaches quantified the number and weight of products that correspond to each phase of the products lifecycle, as illustrated below.



**Framework for Modeling the Product Lifecycle**

## Key Findings as of 2005

### Electronic Products Lifecycle

- Almost half, or 976 million units, of all the products sold between 1980-2004 are still in use or reuse.
- About 42 percent, or 842 million units, of the products sold between 1980-2004 have been recycled or disposed of.
- Nine percent, or 180 million units, of products sold between 1980-2004 are still in storage.

### Storage

- Between 1980-2005, 180 million electronic products had accumulated in storage.

- In 2005 alone, approximately 460 million products were put into storage and/or reuse.
- TVs account for approximately 34-52 percent (by weight) of the units in storage.
- Desktop PCs account for approximately 24 percent (by weight) of stored units.

### **Recycling vs Disposal**

- Between 2003-2005, electronic products available for EOL management were recycled or disposed of in the following approximate percentages (for more specific numbers, please see Table 3):
  - About 15-20 percent were collected for recycling. The recycled/disposed split remained fairly constant between 1999-2005. Although recycling continues to increase, the percentage recycled remains constant because of the ever-increasing number of electronics available for EOL management.
  - About 80-85 percent were disposed of (largely to landfills).
- Between 2003 – 2005, when we include products put into storage or reuse,
  - Approximately 44 percent of products were disposed of, and 11 percent recycled.

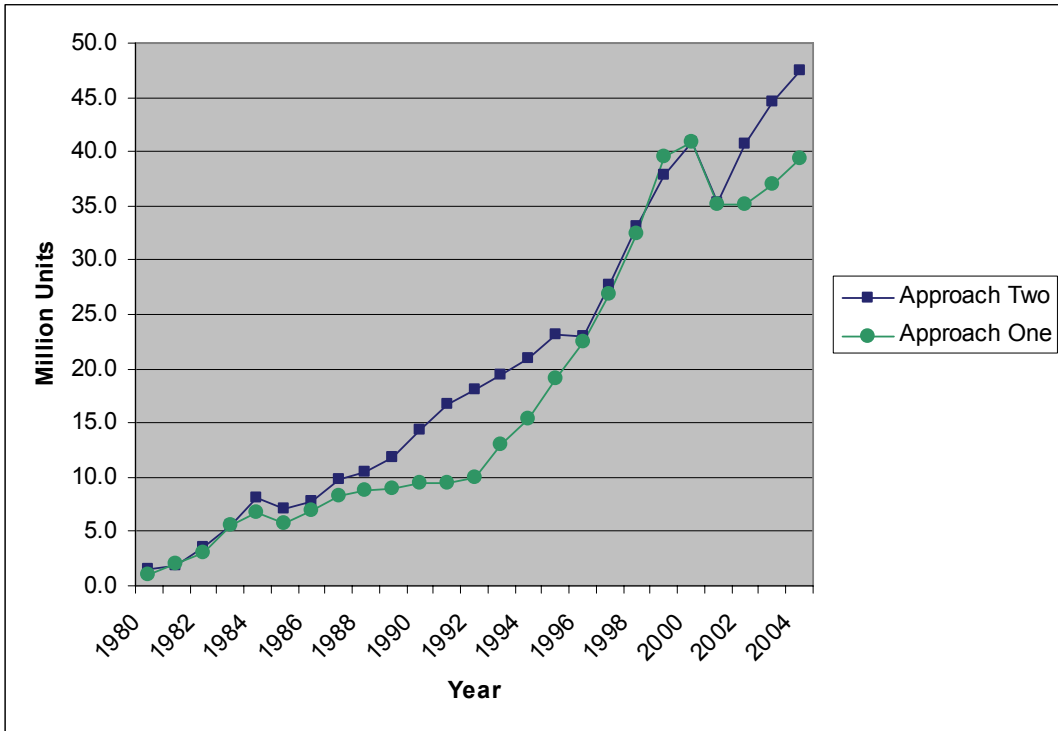
### **End Markets**

- In 2005, approximately 61 percent, or 107,500 tons, of CRT monitors and TVs collected for recycling were exported for remanufacture or refurbishment.
- The next largest portion (about 14 percent or 24,000 tons) was CRT glass sold to markets abroad for glass-to-glass processing, while lead recovery in North America accounts for about 6 percent (10,000 tons) of the material.

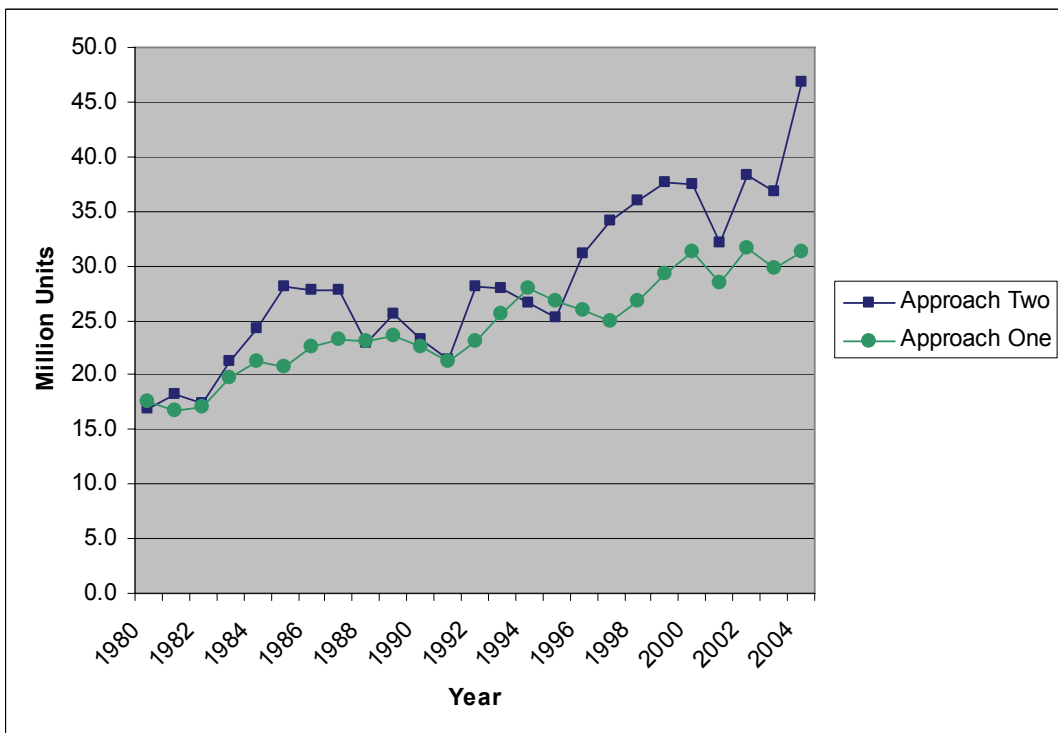
### **Sales Data**

We collected sales data for each type of product. *Approach One* relied primarily on industry-generated sales data to measure the sales of electronic products. *Approach Two* relied solely on publicly available data, such as the U.S. Census Bureau's Current Industrial Reports and press releases from market research firms. The sales numbers for desktops and TVs are presented in Figures 1 and 2. Sales numbers for additional products are included in the full reports.

**Figure 1: Desktop Sales 1980 – 2004**



**Figure 2: TV Sales 1980 – 2004**



## Product Lifespans

A key part of the analysis involves determining the lifespan of the various products from point-of-sale to EOL management (such as recycling, export, or disposal). Since the lifespans of different types of products vary, product-specific lifespan assumptions had to be derived. By combining sales and weight data, and applying the lifespan assumptions for each particular product, we were able to predict the number and corresponding weight of products that were ready for EOL management each year. Both approaches looked at product sales from 1980-2004, and predicted the annual quantity ready for EOL management through 2006. The results from 2003 - 2005 are presented in the tables below.

Two options were used to track the flow of products from their purchase, through use, storage and/or reuse to disposition for EOL management. *Approach One* relied on the age distribution of the products collected by electronic collection programs and used that as a proxy for the lifespan of the products before they reached the EOL stage. *Approach Two* also used the same collection program information, but aimed to account for variations in product flow that may be due to fluctuations in yearly product sales. It also estimated, by year, the number of products being stored and/or reused.

**Table 1.**  
**Estimated Products Ready for EOL Management**  
**(Million Units)**

<b>Year</b>	<b>Desktops</b>	<b>Laptops</b>	<b>CRT Monitors</b>	<b>LCD Monitors</b>	<b>Mice/Keyboards</b>	<b>Total TVs</b>	<b>Cell Phones</b>	<b>Hard Copy Peripherals</b>	<b>Total</b>
2003	18.5 - 24.7	4.0 - 6.9	24.5 - 27.7	0.1 - 4.6	64.3 - 92.8	23.5 - 24.4	49.0 - 75.8	19.6	207.1 - 275.6
2004	19.4 - 26.6	4.8 - 7.8	22.5 - 27.8	0.3 - 7.8	72.8 - 103.2	23.5 - 25.2	57.0 - 96.8	21.3	227.8 - 314.8
2005	19.8 - 28.4	6.1 - 9.0	22.8 - 28.5	0.8 - 10.0	76.4 - 107.9	24.0 - 26.3	70.6 - 116.5	22.9	251.0 - 347.2

\*Hard copy peripherals (HCP) include printers, multifunction printers, digital copiers, and fax machines. The total category includes printers (not shown) for *Approach Two* and HCPs for *Approach One*.

**Table 2.**  
**Estimated Products Ready for EOL Management**  
**(Thousand Tons)**

<b>Year</b>	<b>Desktops</b>	<b>Laptops</b>	<b>CRT Monitors</b>	<b>LCD Monitors</b>	<b>Mice/Keyboards</b>	<b>Total TVs</b>	<b>Cell Phones</b>	<b>Hard Copy Peripherals</b>	<b>Total</b>
2003	242.1 - 275.0	23.3 - 25.4	418.6 - 597.8	0.6 - 56.4	51.6 - 97.0	734.1 - 795.4	7.5 - 8.6	166.7	1,747.9 - 1,959.9
2004	253.6 - 293.6	26.4 - 28.2	383.9 - 627.8	1.8 - 96.2	58.9 - 96.3	753.6 - 837.8	7.5 - 9.8	181.7	1,813.2 - 2,084.9
2005	259.5 - 322.6	30.8 - 31.8	389.8 - 673.1	4.9 - 122.6	61.1 - 80.6	786.0 - 891.9	8.2 - 11.7	198.3	1,918.5 - 2,223.2

\*Hard copy peripherals (HCP) include printers, multifunction printers, digital copiers, and fax machines. The total category includes printers (not shown) for *Approach Two* and HCPs for *Approach One*.

## Recycling and Disposal Estimates

Having estimated the annual quantities of products ready for EOL management, we estimated how much material had been recycled and disposed of in recent years. *Approach One* determined the amount recycled based on industry sources, and estimated the disposal amounts by calculating the difference between what is generated for EOL management and what is collected for recycling on an annual basis: disposal amount equals quantity generated for EOL management minus the amount recycled. *Approach Two* calculated the amount disposed of based on five states' waste sorting studies extrapolated to the national rate, and estimated the amount recycled by calculating the difference between what is generated for EOL management and what is disposed of: recycled amount equals quantity generated for EOL management minus amount disposed.

Together, these approaches suggest that about 15 to 20 percent of the products (by weight) were recycled<sup>1</sup>, while between 80 to 85 percent of the products (by weight) were disposed of (which includes landfilling and incineration)<sup>2</sup>. Although we have seen a substantial increase in the tonnage recycled each year, the percentage of recycled products has stayed about the same because of the ever-increasing quantity of electronics becoming available for EOL management. Estimates of the amount of electronics recycled are presented in Table 3 below and Figures 3 through 5 provide data for three of the products included in the analysis: Desktops, TVs, and cell phones. The unit recycling rate developed for *Approach One* results from multiplying an overall 15% weight recycling rate, across all device types, to the individual device types shown in each figure (percent recycled by weight multiplied by the number of units reaching EOL equals the number of units recycled).

---

<sup>1</sup> *Approach Two* also determined the recycling rate based on number of devices rather than based on weight, which is 23% recycled and 77% disposed.

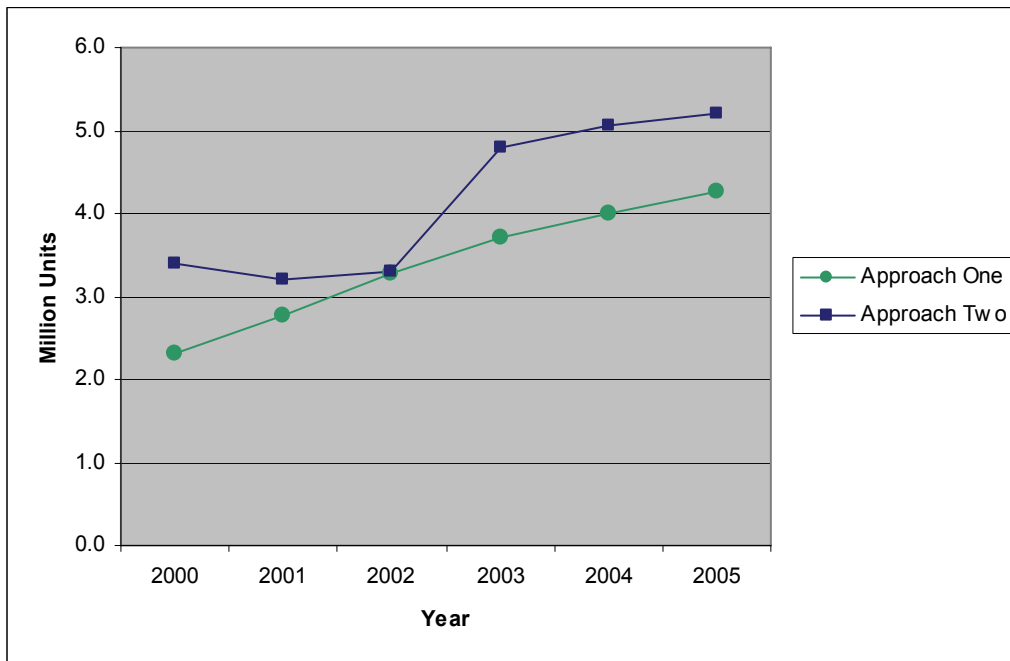
<sup>2</sup> According to the 2005 MSW Characterization Report, approximately 12.5 percent of selected consumer electronics were recycled. This recycling rate is lower than the range presented here for two reasons: 1) it includes a broader scope of electronic products, including VCRs, stereos, and video cameras, which are recycled at lower rates than the narrower scope of products studied in the two reports and 2) a different methodology was used to derive estimates in *Approach One*. These estimates include all products from both approaches. *Approach One* includes all hard-copy peripherals while *Approach Two* only includes printers.

**Table 3.**  
**Estimated Devices Collected for Recycling 2003 - 2005**

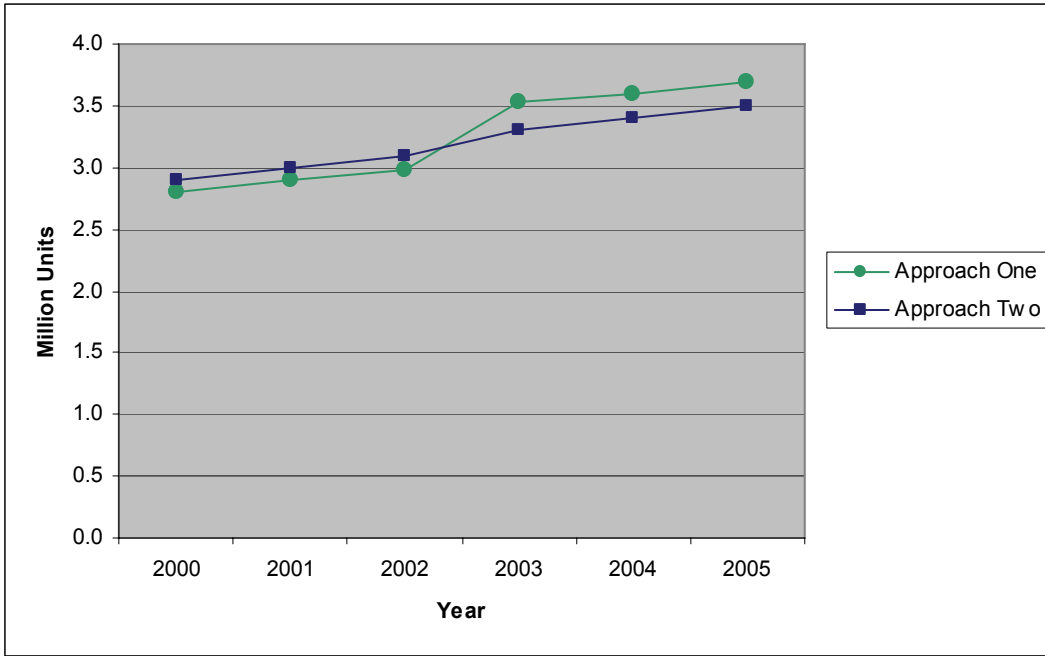
<b>Year</b>	<b>Units (million)</b>	<b>Tons (thousand)</b>
2003	40.8 - 47.2	290.0 - 347.8
2004	48.3 - 52.0	320.0 - 359.9
2005	53.9 - 57.0	345.0 - 379.0

\*These ranges are derived from both *Approach One* and *Approach Two*.

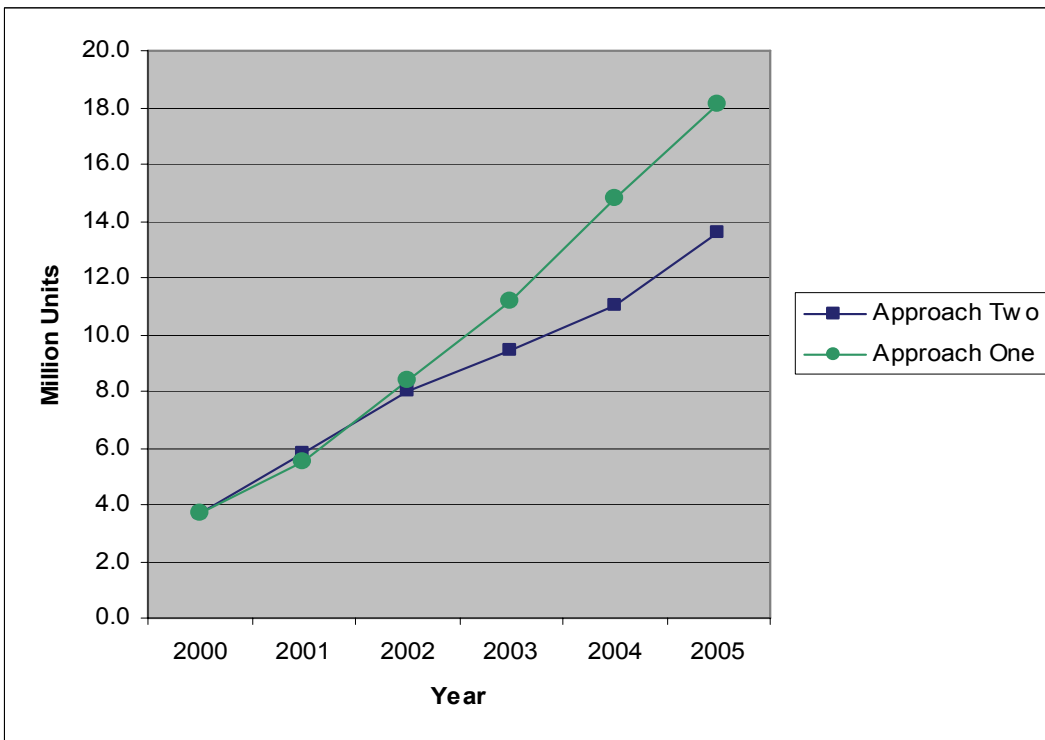
**Figure 3: Amount of Desktops Recycled 2000 – 2005**



**Figure 4: Amount of TVs Recycled 2000 – 2005**



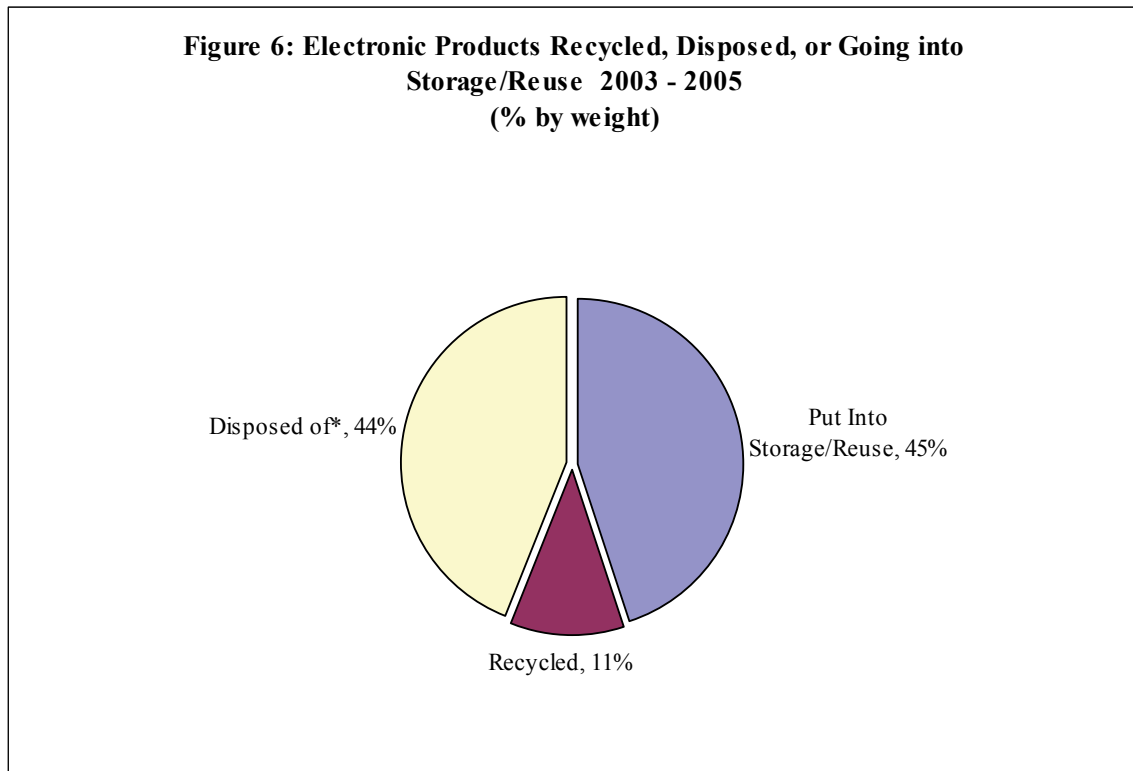
**Figure 5: Amount of Cell Phones Recycled 2000 – 2005**



## Storage and Reuse

Quite a bit of unwanted or obsolete electronic equipment remains in storage for varying reasons. We used two approaches to estimate the quantity of electronics in storage (but does not include reuse). *Approach One* estimated the number of units cumulatively stored as of 2005 to be 180 million products

*Approach Two* estimated the annual number of products going into storage and/or reuse. Figure 6 presents the average amount of electronics recycled, disposed of, or put into storage or reuse between 2003 - 2005. In 2005 alone, approximately 460 million units were put into storage and/or reuse. Once we accounted for storage/reuse, the percentages of products disposed of or recycled decreases due to the increase in the amount of total products. However, the numbers of products disposed of and recycled remains the same.



\*Includes landfilling and incineration.

## End Markets for TVs and CRT Monitors

The purpose of this section is to examine the end markets, both domestic and abroad, of EOL electronic products that are collected for recycling in the U.S. by electronics recyclers or donation organizations. This is a difficult task since data on the end markets of these materials is not publicly available. In order to arrive at a rough estimate, we

relied on an industry expert to develop a best estimate for CRT-containing devices,<sup>3</sup> as well as EPA data on glass sent to glass-to-glass markets.

Estimates regarding where and how CRTs from computer monitors and TVs were handled after collection by electronics recyclers in the U.S are presented in Table 4. Differences in handling of desktops, laptops, hard copy peripherals, and cell phones in the U.S. and abroad were not examined in this analysis. These products at EOL have different technical and economic characteristics and therefore, the resale and recycling end markets are not at all similar. Non-CRT-containing products may be addressed in a subsequent analysis. Data indicates that a large majority of CRT monitors and TVs (61 percent) that were collected for recycling are exported for the purpose of producing remanufactured or refurbished TVs and CRT monitors.

**Table 4:**

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

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

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

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

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

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

<sup>3</sup> Robin Ingenthron of the World Reuse, Repair and Recycling Association developed these estimates after gathering knowledge from Association members, industry contacts, and published data sources.

## Glossary of Terms

**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 device is based on the number of years between its original sale and the end of its life.

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

**End-of-life (EOL) Management:** When a product is no longer used, stored, or reused, it has reached its end-of-life. The management options for a product at end-of-life include recycling or disposal.

**Lifespan:** The period of time between when a product is initially purchased and when it reaches the end of its life. *See* definition of age distribution above.

**Recycling:** Electronic devices 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).

**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.

**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.

April 2007  
EPA530-D-07-002