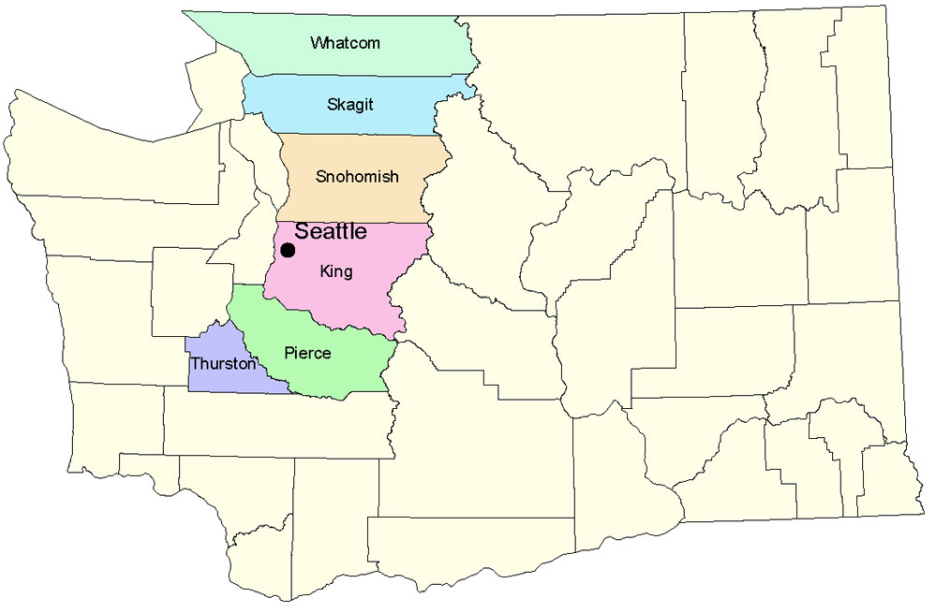
E-Waste Generation in Northwest Washington



Final Report

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Prepared by Cascadia Consulting Group, Inc. and Sound Resolutions

For Seattle Public Utilities

CASCADIA CONSULTING GROUP

SOUND RESOLUTIONS

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Executive Summary

This report presents estimates of obsolete computers, monitors, televisions, and cell phones expected to be generated now and in the future in Seattle and Northwest Washington.[1] These electronic items, collectively referred to as "e-waste", are a growing solid waste management concern as they often contain toxic materials such as lead, cadmium, and mercury that can pose threats to human or environmental health if not managed properly. Although national negotiations with manufacturers and retailers are underway concerning a national recovery program for these items, it is unclear whether a viable agreement for a collection and financing system can be enacted in the next several years.

As these and other developments unfold, it is useful for the City of Seattle and other local governments to better understand how much e-waste is likely to be generated and how much a minimum level of e-waste collection service might cost. Accordingly, Seattle Public Utilities (SPU) contracted with Cascadia Consulting Group and Sound Resolutions to research and estimate potential e-waste generation and the costs of establishing two fixed e-waste facilities in Seattle.

Key findings of this research include the following:

- **An estimated 251,000 computers, computer monitors, and televisions will become obsolete in Seattle households in 2003**, a quantity of material that weighs approximately 4,800 tons. A product is considered to be obsolete and therefore "generated" when its original owner no longer uses it. Survey data indicate that currently these obsolete items are donated, given to friends or family, re-sold, stored, recycled, or in some cases illegally disposed.
- **Northwest Washington residents will generate an estimated 1,286,000 computers, computer monitors, televisions, and cell phones in 2003**, a quantity of material that weighs approximately 25,000 tons.
- **Seattle residents are already storing an estimated 223,000 obsolete computers, computer monitors, and televisions, and Northwest Washington residents are storing an estimated 1,220,000 of these items.** These items are estimated to weigh 3,530 tons and 19,200 tons, respectively. These materials are not included in the above generation or cost estimates because it is uncertain when they would come out of storage.
- **Small-quantity generators (SQGs) will generate an estimated 100,000 units in Seattle (1,260 tons) and 361,000 units in Northwest Washington (4,500 tons) in 2003**.
- **Residents and businesses will generate an estimated 157,000 cell phones in Seattle and 995,000 cell phones in Northwest Washington in 2003.** These cell phones are estimated to weigh 79 and 497 tons, respectively.
- **The City of Seattle would incur an estimated cost of $300,000 - $400,000 annually to lease and staff two fixed e-waste collection facilities in Seattle, and to transport material collected at those facilities to a recycler.** This

[1] For the purposes of this report, Northwest Washington includes Whatcom, Skagit, Snohomish, King, Pierce, and Thurston Counties.

figure does not include promotion of the program, costs paid to the recycler for processing, or equipment costs, which are likely to add significantly to the overall cost of the program.

- **These two fixed e-waste facilities in Seattle are projected to collect a total of 500 – 700 tons annually, which amounts to 7-11% of the estimated annual residential and SQG e-waste generation in Seattle.** These estimates suggest that two fixed e-waste facilities would collect only a portion of the e-waste generated in Seattle. Therefore, to prevent improper disposal or continued stockpiling of these items, a much more extensive collection system – possibly including manufacturer take-back, fully-developed reuse infrastructure, or other programs or options – would need to be available for Seattle residents and businesses.

Introduction and Purpose

This report presents estimates of obsolete computers, monitors, televisions, and cell phones expected to be generated now and in the future in Seattle and Northwest Washington – an area which for this study extends from Whatcom County in the north down the I-5 corridor through Thurston County in the south. The purpose of these estimates is to quantify the expected flow of electronic scrap, or "e-waste", that will need effective management to ensure that it does not become a threat to human or environmental health. A further purpose of this report is to estimate the facility costs – and potential impacts – of establishing a base level of e-waste collection in Seattle.

Background

Electronic equipment often contains toxic materials such as lead, cadmium, and mercury that can pose health and environmental threats. Although items such as computer monitors, central processing units (CPUs), televisions, and cell phones are considered safe during use, the potential for release of their toxic ingredients can increase during storage or disposal. For this reason, manufacturers, environmental organizations, and government officials alike generally believe that an effective system to collect and appropriately manage end-of-life electronic equipment is necessary.

To this end, the National Electronics Product Stewardship Initiative (NEPSI) was convened to negotiate a national recovery program and financing system for obsolete electronics. Participants in this joint initiative are promoting product stewardship as a method to address waste electronics. A fundamental tenet of product stewardship is that all parties who have a role in producing, selling or using a product also have a role in managing it at the end of its useful life.

After 2.5 years of negotiations, however, it is not clear that a viable agreement will be reached. If an agreement is reached, national legislation will be required to implement the agreement – a process that could take several years. Because of this uncertainty and potentially lengthy process, many states are proceeding on their own with the introduction of state legislation. Bills were introduced in 23 states in 2003 with legislation passing in 4 states.

In February 2003, Representative Mike Cooper introduced HB 1942 to the Washington State House of Representatives. This bill would require manufacturers of all computers, televisions, and cell phones sold in Washington to design, establish, and finance a collection system for obsolete products. The bill was not enacted into law in the 2003 session, but is expected to be reintroduced in the 2004 session. Locally, disposal of cathode ray tubes (televisions and computer monitors) has been banned from business generators in King County and from all generators in Snohomish County and the City of Seattle.

In addition, alternate models and voluntary options for end-of-life management continue to emerge. Several manufacturers and retailers have organized collection events and mail-order return programs, and at least one major electronics manufacturer has indicated a willingness to finance the transport and recycling of their own brand of equipment if that equipment is delivered to regional "consolidation" points.

Regardless of the approach and model that is ultimately adopted, it is useful for the City of Seattle and other local governments to understand the potential quantities of e-waste that will be generated and the cost to collect and transport these obsolete electronics. Seattle Public Utilities (SPU) contracted with Cascadia Consulting Group and Sound Resolutions to estimate the quantity of e-waste in Seattle and Northwest Washington. Although no plans are underway to collect e-waste, SPU also asked the consultants to estimate the potential cost of establishing two basic e-waste collection facilities in Seattle.

Methodology

Research for this project consisted of four basic elements:

- Estimate e-waste generation by the residential sector (i.e., households);
- Estimate e-waste generation by "small quantity generators" (SQG), which are businesses that are exempt from Washington Department of Ecology's hazardous waste threshold;[2]
- Estimate cell phone generation; and
- Develop facility cost estimates for establishing a base level of e-waste collection service in Seattle.

The general methodology for the generation estimates was to estimate how many such products are purchased and/or in use each year, investigate how long these products are typically used, and then calculate the resulting annual generation of obsolete electronic equipment. Note that for the purposes of this study, a product is considered to be obsolete and therefore "generated" when it is no longer used by its original owner.

The consultant developed cost estimates for e-waste collection service in Seattle by projecting the e-waste quantities and rate of facility use, and by researching the appropriate staffing, lease, and other operating costs of the potential facilities. Note that costs presented are not intended to be representative of all possible program costs, which would also include promotion, recycling expenses, and other program elements.

Following are the results of this research. Please note the appendix contains a detailed discussion of methodology and assumptions.

[2] State standards currently permit up to 220 pounds per month for some substances, and 2.2 pounds per month for others (Ecology 2003).

Results

RESIDENTIAL E-WASTE GENERATION

E-waste generation estimates for the residential sector were conducted following the methodology of the Department of Ecology's *Assessment of Electronic Waste Generation, Collection, and Processing in Eastern Washington* (Cascadia Consulting Group 2002).[3]

Basic assumptions used in these calculations include the following:

- **About 76% of Seattle households and 74% of Northwest Washington households have computers at home.** These households have an average of about 1.5 computers. This information was obtained from the City of Seattle's Residential Technology Survey (City of Seattle, 2002) as well as by processing raw data from the U.S. Census Bureau's Current Population Survey Computer Use Supplement (U.S. Census Bureau, 2002).
- **About 95% of Seattle households and 96% of Northwest Washington households have televisions.** According to the City of Seattle's Residential Technology Survey (City of Seattle, 2002), 95% of Seattle households have televisions. Although no survey data were available particular to the broader Northwest Washington region, a recent survey of King County outside Seattle found that 96% of households have televisions (King County Solid Waste Division, 2003); this 96% figure will be used for Northwest Washington. According to a similar survey in Massachusetts, television-owning households average 2.55 televisions per household (Massachusetts DEP, 2000). Although no local survey data were available, this figure is assumed to be applicable in our region.
- **Computer sales growth will taper off in the next decade, but will still reach many new households.** Market research presented by eT Forecasts indicates growth of 6% in 2001-2003 (eT Forecasts 2002). These rates are expected to gradually taper off as the decade progresses (eT Forecasts 2002 and Computer Industry Almanac 2002). Census survey data indicate that 1998 and 1999 were big years for computer purchases in our region (U.S. Census Bureau 2002).
- **Computer equipment is generally used for four or fewer years.** Research by the National Safety Council and others indicate that the average lifespan of computer monitors is 4 years, and the lifespan of CPUs and laptops is 3 years (National Safety Council 1999).
- **Televisions are assumed to be used for five years.** The National Safety Council found the average life of televisions to be 5 years (National Safety Council 1999).
- **Once an item reaches the end of its estimated lifespan, it is assumed to be "obsolete" and generated as e-waste.** The user must then decide how to manage this material. Some unknown fraction of this material certainly goes on to a second life, through gift to relatives, re-sale, or legitimate donation. However,

[3] Please note, however, than some of the input assumptions were updated to reflect more current information. As a result, the generation estimates are not directly comparable on a per-capita basis.

much of it does not, as the user either stockpiles the material, disposes it (perhaps illegally), or recycles it. For the purposes of this report, all of these dispositions (whether re-use for a second life, stockpiling, disposal, or recycling) are considered "generation," because there is not sufficient information available to determine the relative prevalence of each method.

Based on these assumptions and household growth estimates published by the Puget Sound Regional Council (2003) and the Washington Office of Financial Management (2003), Cascadia estimated the annual generation of obsolete electronic equipment. These figures are presented in Table 1, below. Please note that all Northwest Washington figures include estimates for the City of Seattle.

Table 1: Projected Annual Generation of Obsolete Electronics by Northwest Washington Households, in number of units

	Seattle			Northwest Washington		
	2003	**2005**	**2010**	**2003**	**2005**	**2010**
TVs	129,000	132,000	138,000	710,000	733,000	795,000
Laptop/Mobile computers	15,000	17,000	25,000	81,000	92,000	132,000
Flat-panel monitors	0	400	14,000	0	2,000	76,000
CRT computer monitors	60,000	43,000	38,000	243,000	225,000	203,000
CPUs	47,000	49,000	58,000	251,000	258,000	307,000
Total	**251,000**	**241,000**	**274,000**	**1,286,000**	**1,311,000**	**1,513,000**

Note: Individual figures may not add to total due to rounding.

Cascadia further estimated the weight of these items by using the following assumptions, which are based on other e-waste studies (California Integrated Waste Management Board, 2002 and Massachusetts DEP, 2000) and review of computer manufacturer web sites.

- The average weight of a computer CPU is 26 pounds.
- The average weight of a cathode ray tube (CRT) monitor is 30 pounds.
- The average weight of a flat-panel monitor is 10 pounds.
- The average weight of a laptop computer is 7 pounds.
- The average weight of a television is 50 pounds.

Applying these weights to the generation estimates above yields the following estimates of annual generation of electronics, by weight.

Table 2: Projected Annual Generation of Obsolete Electronics by Northwest Washington Households, by weight (tons)

	Seattle			Northwest Washington		
	2003	**2005**	**2010**	**2003**	**2005**	**2010**
TVs	3,200	3,300	3,500	17,800	18,300	19,900
Laptop/Mobile computers	50	60	90	280	320	460
Flat-panel monitors	0	2	70	0	10	380
CRT computer monitors	900	600	600	3,700	3,400	3,000
CPUs	600	600	800	3,300	3,400	4,000
Total	**4,800**	**4,600**	**4,900**	**25,000**	**25,400**	**27,800**

Note: Individual figures may not add to total due to rounding.

STOCKPILING

The quantities presented in Table 1 and Table 2 represent the number of electronic items that become obsolete each year. As such, they do not include generation of any items already stored in residents' homes. Survey data indicate that residents often do store their old equipment – likely because of the perceived value of these items, and presumably influenced by the lack of options for reselling or reusing them. In a recent survey in King County, 25% of households reported storing at least one computer that they no longer use, and 16% reported storing a television (King County Solid Waste Division 2003). Furthermore, research in California has found that residents who store computers and televisions store an average of 1.4 of each item (California Integrated Waste Management Board, 2001). Applying these figures to the estimated number of households in Seattle and Northwest Washington yields the estimates in Table 3.

Table 3: Estimated Current (2003) Stockpiling of E-Waste by Northwest Washington Households

	Seattle		Northwest Washington	
	Number of Units	**Weight, in tons**	**Number of Units**	**Weight, in tons**
TVs	**58,000**	**1,450**	**320,000**	**8,000**
Computers	**94,000**	**1,010**	**510,000**	**5,400**
Laptop/Mobile (estimated)	*23,000*	*80*	*120,000*	*400*
CPUs (estimated)	*71,000*	*930*	*390,000*	*5,000*
Monitors (estimated)	***71,000***	***1,070***	***390,000***	***5,800***
Flat-panel monitors (estimated)	*0*	*0*	*0*	*0*
CRT computer monitors (estimated)	*71,000*	*1,070*	*390,000*	*5,800*
Total	**223,000**	**3,530**	**1,220,000**	**19,200**

As the numbers in the above table indicate, households in Seattle and Northwest Washington are estimated to be storing 223,000 and 1,220,000 units of e-waste, respectively. Please note that stockpiling of cell phones was not estimated due to lack of available survey data.

SMALL QUANTITY GENERATOR E-WASTE GENERATION

Like the residential projections, e-waste generation estimates for small quantity generators rely on estimating computer usage and lifespan. However, unlike the residential sector, the SQG sector is difficult to define and therefore is more difficult to estimate. Assumptions regarding which businesses are SQGs are undoubtedly over-generalized, but much more detailed analysis was beyond the scope of this study. Nevertheless, some relevant data exist, and the consultant developed a procedure to estimate SQG generation. Estimates rely on current and future employment by industry group, average ratio of employees to computers by industry group, and average useful lifespan of equipment. These calculations are detailed in the appendix.

Specific assumptions include the following:

- Businesses in the wholesale and retail trades; food service; finance, insurance, and real estate; hotels and lodging; and business, legal, social, engineering, and other services are considered to be small quantity generators. Operation of these types of businesses generally does not produce large enough quantities of hazardous waste to render them regulated generators by state standards.[4]
- The following business types were not considered as SQGs: manufacturing, mining, construction, transportation, utilities, hospitals and health services, schools, and government generators.
- Offices have nearly one computer per employee (0.954), whereas retail and wholesale trades use significantly fewer computers. For example, the U.S. Energy Information Administration estimated that the average retailer has approximately 0.31 computers per employee and the average restaurant has approximately 0.14 computers per employee (USEIA 1999).
- The consultant assumed that computers have been commonplace in the workplace for the last decade, such that their prevalence in the workplace is not increasing at a significant rate. Data on actual computer use trends in different types of businesses were not available.
- The consultant further assumed that the average lifespan of computers in the business environment is similar to that in the residential environment. This assumption was necessary as no information was readily available to quantify the difference in lifespan between residential and commercial uses.
- Televisions are not as widespread in the business environment, and so will not be included in the projections. Furthermore, little information was readily available on television use by businesses.

The following table displays the estimated number of e-waste units generated annually by SQGs in Seattle and Northwest Washington.

[4] State standards currently permit up to 220 pounds per month for some substances, and 2.2 pounds per month for others (Ecology 2003).

Table 4: Projected Annual Generation of Obsolete Electronics by Small Quantity Generators, in number of units

	Seattle			Northwest Washington		
	2003	**2005**	**2010**	**2003**	**2005**	**2010**
TVs	N/A	N/A	N/A	N/A	N/A	N/A
Laptop/Mobile computers	12,000	13,000	14,000	45,000	47,000	51,000
Flat-panel monitors	0	400	12,000	0	1,400	42,000
CRT computer monitors	37,000	38,000	32,000	135,000	138,000	113,000
CPUs	50,000	51,000	58,000	180,000	186,000	206,000
Total	**100,000**	**103,000**	**115,000**	**361,000**	**373,000**	**412,000**

Note: Individual figures may not add to total due to rounding.

Table 5 displays the estimated e-waste generation in terms of annual tons. The same per-item weights were used for these calculations as for the residential estimates.

Table 5: Projected Annual Generation of Obsolete Electronics by Small Quantity Generators, by weight (tons)

	Seattle			Northwest Washington		
	2003	**2005**	**2010**	**2003**	**2005**	**2010**
TVs	N/A	N/A	N/A	N/A	N/A	N/A
Laptop/Mobile computers	40	40	50	200	200	200
Flat-panel monitors	0	2	60	0	10	210
CRT computer monitors	560	570	470	2,000	2,100	1,700
CPUs	650	670	750	2,300	2,400	2,700
Total	**1,260**	**1,280**	**1,330**	**4,500**	**4,700**	**4,800**

Note: Individual figures may not add to total due to rounding.

It is important to reiterate that SQG estimates are less certain than the residential estimates. Furthermore, many businesses – even if officially small quantity generators – may participate in asset recovery or other e-waste management services and therefore would not utilize publicly-provided services.

Information on stockpiling or storing of e-waste by businesses was not readily available, so no estimates of stockpiling were conducted.

CELL PHONE GENERATION

In 2002, the research group INFORM completed a study on the number of cell phones becoming obsolete each year in the United States (Fishbein 2002).[5] Because no

[5] The INFORM study used the term "retired", but we have used the term "became obsolete" to keep terminology consistent throughout this report.

detailed region-specific information was readily available, Cascadia applied INFORM's national estimates to Seattle and Northwest Washington on a per-capita basis. Basic assumptions include the following:

- **Current cell phone penetration is estimated at 41%.** INFORM's study of cell phone penetration found that the total number of cell phones in use in the U.S. was equivalent to 41% of the population (Fishbein 2002). In other words, the study estimated that there are 0.41 phones for every person in the population. The INFORM study did not distinguish between residential and business uses.
- **2005 cell phone penetration is estimated at 50%.** INFORM used 50% as a conservative estimate for 2005 (Fishbein 2002).
- **Penetration in 2010 is estimated at 62%.** This is the current penetration in Western Europe, where cell phone use is much higher than in the United States (Fishbein 2002). Cascadia assumed that by 2010 Seattle-area cell phone usage would reach the levels currently seen in Western Europe.
- **Cell phone life is estimated to average 1.5 years.** This is the mid-range average figure used by INFORM (Fishbein 2002).
- **The INFORM study estimated the amount of waste associated with each cell phone at 1 pound**, including handset, battery, and case.

Based on these assumptions and population growth estimates published by the Washington Office of Financial Management, we estimated annual generation and weight of obsolete cell phones. Table 6, below, presents these results. Please note that these phones may be generated by either personal or business uses.

Table 6: Projected Annual Generation of Obsolete Cell Phones

	Seattle			Northwest Washington		
	2003	**2005**	**2010**	**2003**	**2005**	**2010**
Cell Phones, number of units	157,000	194,000	249,000	995,000	1,241,000	1,635,000
Cell Phones, in tons	79	97	124	497	620	818

TOTAL E-WASTE GENERATION

The following tables display the total estimated e-waste generation by residents and small quantity generators in Seattle and Northwest Washington, considering all computers, computer monitors, televisions, and cell phones.

Table 7: Total E-Waste Generation, in number of units

	Seattle			Northwest Washington		
	2003	**2005**	**2010**	**2003**	**2005**	**2010**
Residential	251,000	241,000	274,000	1,286,000	1,311,000	1,513,000
Small Quantity Generator	100,000	103,000	115,000	361,000	373,000	412,000
Cell Phones	157,000	194,000	249,000	995,000	1,241,000	1,635,000
Total	**508,000**	**538,000**	**638,000**	**2,642,000**	**2,925,000**	**3,560,000**

Note: Individual figures may not add to total due to rounding.

Table 8: Total E-Waste Generation, in total tons

	Seattle			Northwest Washington		
	2003	**2005**	**2010**	**2003**	**2005**	**2010**
Residential	4,800	4,600	4,900	25,000	25,400	27,800
Small Quantity Generator	1,260	1,280	1,330	4,500	4,700	4,800
Cell Phone	79	97	124	497	620	818
Total	**6,140**	**5,980**	**6,350**	**30,000**	**30,700**	**33,400**

Note: Individual figures may not add to total due to rounding.

As the tables indicate, Seattle residents and small quantity generators will generate about 6,000 tons of e-waste annually throughout this decade, and Northwest Washington residents and small quantity generators will generate about 33,000 tons.

Cost Estimate – City of Seattle

Although no specific plans are underway, the City of Seattle is interested in understanding the potential cost of establishing an e-waste collection service analogous to its other current self-haul facilities. Existing services are currently offered at two fixed facilities: one in north Seattle and one in south Seattle.

The consultant, in consultation with Seattle Public Utilities, developed a cost estimate based on this type of service. Although program parameters are in no way fixed, the assumptions listed below are believed to be reasonable, and allow for an estimation of the range of costs the City could expect to incur.

Facilities would be:

- **Operated by City staff.** Staff will be responsible for collecting the material from the public, sorting it by type (but not brand) into collection containers, and storing the material on-site in gaylord boxes until pick-up by a recycler.
- **Open to residents and small quantity generators.**
- **In rented space, located in the north and in the south.** Neither the current transfer stations nor the household hazardous waste facilities have enough space to accommodate new services.
- **Open five days per week, 7 – 8 hours per day.** This schedule was assumed to be a reasonable level of service, and would facilitate staffing using normal, 8-hour shifts.
- **Staffed by two employees at all times.** This requirement helps maintain staff safety and uninterrupted service to the public.

In addition, please note the following about the cost estimates.

- **Cost estimates were developed assuming no fee is charged to drop off electronic material.** This assumption was made to simplify staffing calculations, as staff would not need to be responsible for handling money. Actual funding of the collection services could occur through a variety of mechanisms.
- **Promotion costs were not included in the estimate.**
- **Equipment, signage, and materials costs were not included on the estimate.**
- **Processing costs were not included in the estimate.**

Based on these assumptions, the consultant researched real-estate lease rates, staffing rates, and transportation costs to recycling providers. Combining these estimates with projected facility use and collection quantities yielded the following cost estimates. Table 9 displays the cost estimates, with separate line item estimates for labor, benefits, and other aspects of the cost of operating the possible facilities. Please see the appendix for further detail on the assumptions and calculations.

Table 9: Estimated Annual Facility Operating Costs for Two Fixed E-waste Facilities in Seattle

Item	Cost
Labor	~$186,000
Benefits	~$101,000
Facility Lease	~$46,000
Utilities	~$5,000
Transportation to recycler	~$15,000
Total of above	~$353,000
Expected Range	**$300,000 - $400,000**

The above table indicates that the cost of renting and staffing two fixed e-waste collection sites in Seattle, and transporting materials to a recycler, is likely to be in the range of $300,000 to $400,000. As mentioned above, this range assumes two fixed facilities, one in north Seattle and one in south Seattle, that would be open 5 days per week, 7-8 hours per day. Residents and interested small quantity generators would be able to bring their e-waste to the facilities. Please note that the estimate excludes promotion costs, fees paid to the recycler for processing, equipment, and materials.

Finally, please note that the expected cost range presented here is not highly dependent on the quantity of e-waste collected since most of the costs are fixed. Cost *per ton*, on the other hand, is highly dependent on the quantities collected.

The expected annual attendance would be at least 9,000 customers at each site. Each site is expected to collect about 250-350 tons of e-waste per year, for a total of 500 – 700 tons annually.[6] **Note that this total represents about 7-11% of Seattle's total expected e-waste generation for 2003 of 6,140 tons** (as displayed in Table 8). Other re-use and recycling options would clearly need to be in place to effectively manage Seattle's e-waste generation.

[6] For a discussion of how collection quantities were estimated, please see the appendix.

Conclusions

Large quantities of obsolete computers, televisions, and cell phones are generated annually by residents of Whatcom, Skagit, Snohomish, King, Pierce, and Thurston Counties – an area that in this report has been called Northwest Washington. In particular,

- **Seattle residents will generate an estimated 251,000 computers, computer monitors, and televisions in 2003**, a quantity of material that weighs approximately 4,800 tons. The number of items generated is expected to increase about 9% by 2010.
- **Northwest Washington residents will generate an estimated 1,286,000 computers, computer monitors, and televisions in 2003**, a quantity of material that weighs approximately 25,000 tons. The number of items generated is expected to increase about 18% by 2010.
- **Seattle residents are already storing an estimated 223,000 obsolete computers, computer monitors, and televisions, and Northwest Washington residents are storing an estimated 1,220,000 of these items.** These items are estimated to weigh 3,530 tons and 19,200 tons, respectively. These materials are not included in the above generation or cost estimates because it is uncertain when they would come out of storage.
- **Small-quantity generators will generate an estimated 100,000 units in Seattle (1,260 tons) and 361,000 units in Northwest Washington (4,500 tons) in 2003.** The number of items generated is expected to increase about 15% by 2010.
- **Residents and businesses will generate an estimated 157,000 cell phones in Seattle and 995,000 cell phones in Northwest Washington in 2003.** These cell phones are estimated to weigh 79 and 497 tons, respectively. The number of cell phones generated is expected to increase about 60% by 2010.
- **The City of Seattle would incur an estimated cost of $300,000 - $400,000 annually to lease and staff two fixed e-waste collection facilities in Seattle, and to transport material collected to a recycler.** This figure does not include promotion of the program, costs paid to the recycler for processing, or equipment costs, which are likely to add significantly to the overall cost of the program.
- **Two fixed e-waste facilities in Seattle are projected to collect a total of 500-700 tons annually**, **which amounts to 7-11% of Seattle's estimated residential and SQG generation.** Therefore, other collection systems such as manufacturer take-back programs or reuse programs would be necessary to prevent improper disposal or continued stockpiling of e-waste.

Appendix — Detailed Methodology

RESIDENTIAL GENERATION

E-waste generation estimates for the residential sector were conducted following the methodology of the Department of Ecology's *Assessment of Electronic Waste Generation, Collection, and Processing in Eastern Washington* (Cascadia Consulting Group 2002). In short, these calculations involved estimating how many computers and televisions are in use, how sales or use patterns are expected to change in the next several years, and how long each item is expected to last. Information on computer use patterns in Seattle and Northwest Washington was derived from the U.S. Census Bureau's 2001 Current Population Survey Computer Use Supplement as well as from the City of Seattle's Residential Technology Survey. By obtaining data and projections from other studies on annual sales growth and technology trends, and making simple assumptions about the average useful lifespan of computers, the consultant was able to construct present and future estimates of the quantities of electronic waste generated by residents in the region. Similar calculations were conducted for televisions.

THE U.S. CENSUS BUREAU'S COMPUTER USE SUPPLEMENT

Each month, the U.S. Census Bureau conducts the Current Population Survey (CPS), a survey of about 50,000 households across the U.S. The survey has been conducted for more than 50 years, and is the primary source of information on the labor force characteristics of the U.S. population.

In September 2001, the CPS included the Computer and Internet Use Supplement. This survey supplement queried households about their computer and internet use and purchasing patterns. Please note that the Computer and Internet Use Supplement has not been conducted again since 2001. The Census Bureau has reported results only on a national level. However, they have made available the raw survey data on a web site, http://www.bls.census.gov/cps/computer/2001/suppovrw.htm.

Cascadia Consulting Group obtained this data to estimate computer ownership patterns in Seattle and Northwest Washington. This process involved setting up a Microsoft Access Database to interpret and query the data. Although the specific location of each survey respondent was not detailed, Cascadia was able to select respondents from Northwest Washington based on metropolitan statistical area (MSA) and county. The result was a dataset of 181 Seattle respondents and 1,663 Northwest Washington respondents. Please note that not all respondents were coded by city. Therefore, there were certainly more respondents from within the City of Seattle limits than could be identified as such, even though they could be identified as residing in King County or the Seattle metropolitan region.

The data set was used to estimate computer ownership patterns, such as the following:

- What percentage of households in Seattle and Northwest Washington own computers;
- How many computers, on average, each household owns; and
- When households purchased their newest computer.

These statistics formed the foundation for projections of future e-waste generation from households. Table 10, below, shows the fraction of households in the region that have at least one computer at home. These figures were calculated from unweighted tallies of the Census Bureau's raw survey data. All error rates are shown at a 90% confidence interval.

Table 10: Computer Ownership Rates

	Fraction of households with at least one computer
Seattle	65% (± 6%)
Northwest Washington	74% (± 2%)

For comparison, 67% of Washington State households and 57% of U.S. households have at least one computer.

Please note that the Seattle results are based on only 181 respondents that could be identified in the database as residing in Seattle. Therefore, Cascadia substituted data collected by the City of Seattle Department of Information Technology, which conducted a survey of 1,011 people in 2001. This study found that 76% (± 3%) of Seattle residents have a computer in their home (City of Seattle 2001).

Table 11: Number of Computers Owned, of Households that Own at Least One

# of computers	Seattle (2001)	Northwest Washington (2001)
1	61%	64%
2	27%	23%
3+	12%	14%

Note that at the time of the Census Bureau's survey (September 2001), approximately three-quarters of households had purchased their newest computer since 1998. In Seattle, 1999 was the most popular year to buy a computer (35% of respondents cited it) whereas in Northwest Washington respondents were more evenly split between 1999 and 2000 (26% and 28% of households, respectively).

RESIDENTIAL E-WASTE GENERATION CALCULATIONS

Projections for **computer e-waste** generated by residents were calculated using the following approach:

1. **Project the number of households in Seattle and Northwest Washington through 2010.** This was accomplished using Census data (U.S. Census Bureau, 2001), projections by the Puget Sound Regional Council (Puget Sound Regional Council, 2003), and projections by Washington State Office of Financial Management (Washington OFM, 2002). These projections are summarized in the following table.

	Seattle	Northwest Washington
Households, 2000 (U.S. Census, 2001)	258,482	1,381,491
*Estimated Households, 2010 (PSRC, 2003)	285,702	1,623,232
Estimated Households, 2003 – Interpolated, assuming exponential growth	266,374	1,449,646
Estimated Households, 2005 – Interpolated, assuming exponential growth	271,751	1,497,101

** PSRC published household estimates for King, Pierce, and Snohomish Counties only. Household estimates for the other counties were estimated by considering their population growth (Washington OFM, 2003), the number of households in 2000 (U.S Census, 2001), and a rate of household size reduction comparable to that for either Pierce or Snohomish County, whichever was closer geographically.*

2. **Gather, process, and analyze survey information from Seattle and Northwest Washington to determine computer ownership and purchase patterns.** The U.S. Census Bureau's Current Population Survey Supplement conducted in September 2001 (U.S. Census Bureau, 2002) and the City of Seattle's Residential Technology Survey (City of Seattle, 2002) provided the data for this analysis.
3. **Use the survey information to estimate computer purchases by year between 1991 and 2001.** We then assumed sales growth rates to estimate the sales through 2010. Sales growth rates were obtained from electronics industry web sites (eT Forecasts, 2002 and Computer Industry Almanac, 2002).
4. **Gather information about the relative proportion of different types of computers and monitors.** This information was obtained from studies by Stanford Resources, the leading market research firm focusing on the computer display market (Stanford Resources 2001-1 and 2001-2).
5. **Make assumptions about the average useful life of computer equipment.** These assumptions were based in data published in other e-waste studies (National Safety Council 1999 and Socolof et al. 2001).
6. **Use the above calculations to estimate the annual generation of obsolete computer equipment.** This step of the analysis was patterned after a model developed by Carnegie Mellon University in Pennsylvania (Mathews et al, 1997).

Calculations for **television e-waste** were calculated using a slightly simplified approach:

1. **Estimate how many televisions will be in use in each year between 2001 and 2010.** This involved combining household projections (discussed above) with television ownership data compiled from the Massachusetts e-waste study, which found that 99% of households have at least one TV, with the average household having an estimated 2.55 televisions (Massachusetts Department of Environmental Protection, 2000). Since televisions are ubiquitous, the findings in the Massachusetts study are assumed to be reasonably accurate in Seattle and Northwest Washington.
2. **Assume an average lifespan for televisions**. The National Safety Council estimated a lifespan of 5 years (National Safety Council, 1999).
3. **Calculate the number of obsolete televisions generated each year** by assuming that in any given year, the number of televisions that become obsolete is the total number divided by their average lifespan. In other words, if the average lifespan of a TV is 5 years, then each year 1/5 of all televisions in use will become obsolete.

The following weights were assumed in converting unit-based e-waste projections to weight.

Item	Avg weight, in pounds	Source
Central Processing Unit (CPU)	26	California Integrated Waste Management Board, 2001
Cathode Ray Tube (CRT) Monitor	30	California Integrated Waste Management Board, 2001
Television	50	California Integrated Waste Management Board, 2001 and Massachusetts Department of Environmental Protection, 2000.
Laptop computer	7	Approximate average weight of standard Dell and Gateway laptop computers listed on www.dell.com and www.gateway.com. The standard laptop from both manufacturers weighs between 6.8 and 7.5 pounds. Lightweight models range from 3 – 6 pounds, while fully loaded models intended to replace a desktop computer weigh 8 – 9 pounds.
Flat-panel monitor	10	Approximate average weight of several models detailed on Gateway website, www.gateway.com. Gateway lists product specifications for a wide variety of models made by Gateway, ViewSonic, NEC, Sony, and others. In general, 15" flat-panel monitors weigh 7 – 10 lbs; 17" flat-panel monitors weigh 10 – 15 lbs; and 18" and larger monitors weigh 15 – 25 lbs. We assume an average weight of 10 pounds for this study.

Finally, please note the following assumptions or limitations.

- It is assumed that the average lifespan of computers, monitors, and televisions remains relatively constant. Note in particular that the National Safety Council predicts that the useful life of new PCs will decline from about 3 years in 2000 to 2 years in 2006, when it will level off (National Safety Council, 1999). In this study, we make the conservative assumption that the average useful life of a CPU is 3 years.
- It is assumed that households with more than one computer purchased their computers in the same interval as computers become "obsolete." In other words, every 3 years.
- The generation estimates themselves do not attempt to estimate current or future stockpiling of e-waste, only annual generation. Generated obsolete items may be stored, donated or sold, recycled, or illegally disposed.
- The generation estimates do not track computers that became obsolete before 2003. This means that computers that were stockpiled before 2003, and are still stockpiled, are not included in the annual generation estimates. The generation estimates track only the annual generation of electronics that become obsolete in each year.

Residential Stockpiling Calculations

As mentioned above, the estimates of annual e-waste generation do not include items that were stored or stockpiled before 2003. Present stockpiling of items was estimated using the following approach.

1. **Estimate how many households are storing computers and televisions.** In a recent survey in King County, 25% of households reported storing at least one computer that they no longer use, and 16% reported storing a television (King County Solid Waste Division 2003). Applying these figures to the estimated 266,000 Seattle and 1,450,000 Northwest Washington households yielded estimates of the number of households storing e-waste. Please note that stockpiling of cell phones was not estimated due to lack of available survey data.
2. **Estimate how many items each household is storing.** Survey data from California indicates that households that are storing computers or televisions are storing an average of 1.4 of each item (California Integrated Waste Management Board, 2001).
3. **Calculate the estimated number of items currently stockpiled.** Multiplying the number of households storing each item by the number of each items estimated to be stored (1.4) yielded the estimated number of televisions and computers currently stored by Seattle and Northwest Washington households.
4. **Allocate the computer estimates into more-specific items.** Although the process above only produces estimates of televisions and computers, the figures for computers was allocated into the same subtypes used for the e-waste generation calculations (i.e., CRT monitors, CPUs, and so on). This was accomplished by using the same relative ratios of equipment estimated by the generation calculations.

SMALL QUANTITY GENERATOR GENERATION

The first task in estimating e-waste generation by small quantity generators is deciding what types of businesses should be considered small quantity generators. This involved making simplified assumptions about which industry groups are SQGs and which are regulated generators. Although there are many different types of business in each industry group (and therefore hazardous waste generation varies), the consultant made the simple assumption that the following industry groups were likely to generate only minimal quantities of hazardous waste, and therefore be considered "small quantity generators":

- Wholesale and retail trades;
- Food service;
- Finance, insurance, and real estate;
- Hotels and lodging; and
- Business, legal, social, engineering, and other services.

Businesses that we have excluded from these calculations are manufacturing, mining, construction, transportation, utilities, hospitals and health services, schools, and government generators. These assumptions are undoubtedly limiting, but much more detailed analysis was beyond the scope of this study.

Projections for e-waste generation from small quantity generators involved a somewhat different methodology than for the residential sector. Because extensive survey or sales information was not available, the consultant took the following approach, once the SQG sector was defined:

1. **Project employment in each industry in Seattle and Northwest Washington through 2010.** The State government projects employment figures by County (Washington Employment Security Department 2003). Projections for Seattle were accomplished by applying King County industry-specific growth rates (Washington Employment Security Department 2003) to 2001 Seattle data (PSRC, 2002). The number of farms present in Northwest Washington was acquired on a county level from the Washington Agricultural Statistics Service (USDA 2003).
2. **Gather data on computer use by industry group.** The next step was to acquire data on the number of computers per employee for each industry group (or per farm, for the agriculture sector), assuming *that this ratio is virtually constant over the time period* (United States Energy Information Administration, 1999). Although this last assumption is somewhat limiting, sufficient information was not available to document changing use of computers within each industry. Following are the industry groups used, their corresponding EIA categories, and the average number of computers per employee. Note that the figure for Agriculture was taken from the United States Department of Agriculture (USDA 2003).

Industry Group	EIA categories	Avg. Computers per employee
Communications	Office	0.954
Wholesale trade	Warehouse	0.419
Food stores	Food sales	0.252
Food service	Food service	0.138
Retail trade	Mercantile	0.313
Finance, Insurance, Real Estate	Office	0.954
Hotels, lodging	Lodging	0.800
Services (business, legal, social, etc.)	Office	0.954
Agriculture	N/A	0.5 *per farm*

3. **Estimate how many computers are *in use* by SQGs in each year between 2000 and 2010.** The numbers of computers per employee from step 2 were multiplied by the number of employees in each industry group from step 1.
4. **Assume average lifespans for computer monitors and CPUs, as well as laptops.** These assumptions were based in data published in other e-waste studies (National Safety Council 1999 and Socolof et al. 2001). The same figures were used for the SQG and residential calculations.
5. **Assume that the relative proportion of flat-panel monitors, laptops, and CRT monitors is the same as it is for residential computers.**
6. **Calculate the number of obsolete computers generated each year** by assuming that in any given year, the number of computers that become obsolete is the total number of computers divided by the average lifespan of those computers. In other words, if the average lifespan of a computer monitor is 4 years, then each year 1/4 of all computer monitors in use will become obsolete.

CELL PHONE GENERATION

Cell phone generation was calculated by applying national figures published by INFORM to Seattle and Northwest Washington. This process involved the following:

1. **Estimate how many cell phones are in use each year in 2003, 2005, and 2010.** This involved multiplying the estimated population in each year by the expected cell phone penetration in that year. Cell phone penetration as assumed to be 41% in 2003, 50% in 2005, and 62% in 2010. See the main body of the report for more detail on these assumptions.
2. **Assume an average lifespan for cell phones.** The INFORM study assumed 1.5 years as a mid-range, average estimate. This figure was assumed to remain relatively constant over the decade.

3. **Calculate the number of obsolete phones generated in each year.** Simply divide the number of phones in use by the expected lifespan to arrive at an estimate of annual generation.

COST ESTIMATES – CITY OF SEATTLE

Cascadia estimated costs for operating an e-waste drop off program in Seattle by researching staffing, leasing, and other costs needed to operate the facilities, and by developing program parameters and assumptions in coordination with Seattle Public Utilities staff. Together, Cascadia and SPU decided to estimate the costs for a program using the following assumptions. Note that these assumptions were also listed in the main body of this report.

- **City staff would operate the facilities.** Staff would be responsible for collecting the material from the public, sorting it by type (but not brand) into collection containers, and storing the material on-site in gaylord boxes until pick-up by a recycler.
- **The facilities would be open to residents and small quantity generators.**
- **There would be two facilities – one in the north and one in the south. Both the north and south facilities would be in rented space.** Neither the current transfer stations nor the household hazardous waste facilities have enough space to accommodate new services.
- **The facilities would be open five days per week.**
- **The facilities would be open 7 – 8 hours per day.** This schedule was assumed to be a reasonable level of service, and would facilitate staffing using normal, 8-hour shifts.
- **Two staff would need to be present at each site at all times.** This requirement helps maintain staff safety, uninterrupted service to the public, and ability to meet peak flow demands.
- **Cost estimates were developed assuming no fee is charged to drop off electronic material.** This assumption was made to simplify staffing calculations, as staff would not need to be responsible for handling money. Actual funding of the collection services could occur through a variety of mechanisms.
- **Promotion costs were not included in the estimate.**
- **Equipment, signage, and materials costs were not included on the estimate.**
- **Processing costs were not included in the estimate.**

The basic steps in estimating the costs were as follows.

1. **Determine labor needs.** Given the schedule of 7-8 hours per day, 5 days per week, a total of two staff would be needed at each site, for a total of 160 hours per week. In addition, SPU recommended the addition of a part time supervisor (20 hours per week) to coordinate these staff and fill in when necessary.
2. **Determine labor costs.** SPU staff provided expected hourly base costs for the staff described in step 1. These costs are $16.33 per hour for the basic laborers and $25.00 per hour for the supervisor. In addition, the laborers require a 1.18 multiplier to account for vacation, training, and sick time (Bagby 2003).

3. **Determine benefit costs.** SPU provided the benefits multiplier of 1.54 to be provided to all hourly staff costs (Bagby 2003).
4. **Estimate expected leasing costs per square foot.** Cascadia researched published leasing rates for warehouse/industrial space and communicated with two local real estate professionals (Jacobsen 2003 and Hester 2003). Based on this research, Cascadia estimated a reasonable expected monthly lease rate in the North to be $0.80 per square foot and an expected rate in the South to be $0.70 per square foot. These rates apply to interior square feet only but include the use of parking space for customer access. These rates would then be subject to an additional estimated $0.20 per square foot for "triple nets" which include property insurance, property taxes, and building maintenance (Jacobsen 2003).
5. **Determine facility throughput.** Facility throughput was estimated by two different methods, both of which are described in the next section. The expected facility throughput is needed to size the facility and determine transportation costs.
6. **Determine needed facility size and cost.** The needed size of the collection facility was estimated by considering the space required to handle two weeks of throughput at each site and to give workers enough space to comfortably operate. These calculations assumed that material would be stored in gaylord boxes, each of which requires 36 square feet of floor space and can hold an estimated 556 pounds of e-waste. Furthermore, it was assumed that an additional 336 square feet of interior space would be needed to facilitate e-waste handling and 144 square feet would be needed for dedicated staff space (Caudill et al. 2003). The resulting figure (1,970 feet of interior space) was rounded up to 2,000 square feet (per site), and the estimated cost was calculated based on the expected rates determined in step 4.
7. **Estimate utility costs.** Utility costs for commercial space averages about $0.10 per square foot per month (Building Owners and Management Association, 2003).
8. **Determine transportation needs and costs.** Although the facility is sized to handle two week's worth of collected e-waste, the number of collections required is determined by the capacity of the truck. According to one local e-waste recycler, a typical 28-foot trailer can hold 14 gaylords of material (Lorch, 2003). Cascadia therefore calculated the number of pick-ups required by dividing the number of gaylords expected to be filled by 14. The cost of each pick-up was assumed to average $100, based on rates of various Washington e-waste recyclers.

These steps, in total, provided reasonable estimates of the expected costs of operating two fixed e-waste facilities in Seattle. As described in the main body of this report, the expected total cost is $300,000 - $400,000 per year. Note that this estimate assumes that the facilities would handle 500 – 700 tons (combined) of e-waste annually from residents and small quantity generators, as described below. This figure translates into roughly 5 customers per hour at each site.

FACILITY THROUGHPUT

Step #5 in the above process called for estimating the expected throughput of the two facilities. Because dedicated, fixed facilities for e-waste collection would be a new type of service for the region, there is little precedent from which to estimate expected customer demand and use of such facilities. Therefore, the consultant relied on two different methods to estimate a reasonable range of demand and throughput. In one method, the consultant looked at e-waste facilities in another part of the country, and in the other method the consultant looked at data from a different type of facility in Seattle. Below is a description of these methods to estimate how much material could expected to be collected by the facilities. Please note that although much of this report has been devoted to how much e-waste is expected to be generated, any collection program would capture only some fraction of that material.

METHOD 1: ESTIMATE COLLECTION BASED ON SIMILAR PROGRAMS IN MASSACHUSETTS

Massachusetts has a relatively extensive network of e-waste collection options, including numerous fixed facilities. Based on a study of these 41 permanent, on-going drop-off facilities (Northbridge Environmental, 2002), the average quantity of e-waste collected was

1.2 pounds per resident living in the service area.

But in general, this included only televisions and CRT monitors. If we add in the proportional number of computer CPUs, laptops, and cell phones, we would add

0.20 pounds per resident of CPUs and laptops, and

0.03 pounds per resident of cell phones, for a total of

1.43 pounds per person of all targeted e-waste.

Applying these rates to the population of Seattle yields:

411 tons of material collected annually.

METHOD 2: ESTIMATE COLLECTION BASED ON ACTUAL USE OF HHW FACILITIES

The potential Seattle e-waste facilities have no direct local analog from which to estimate expected attendance. However, the City does operate drop-off sites in north and south Seattle for other waste materials, including garbage and household hazardous waste (HHW). Attendance at the household hazardous waste sites is used here as a coarse predictor of attendance at the potential e-waste facilities. The consultant chose the HHW sites over the garbage drop-off sites because the HHW sites – like the potential e-waste sites – collect a type of material that is banned from disposal. Please note that by making this comparison, the consultant makes no assumptions about the adequacy or effectiveness of the level of service offered either by the HHW sites or the potential e-waste sites.

Therefore, please note that there are about

575,000 people in Seattle in 2003, and

266,000 households.

According to Jim Talbot of the City of Seattle, the Household Hazardous Waste Collection facilities recorded 15,867 customers in 2002 and expect to serve a similar number this year (Talbot, 2003). This number of customers represents about

6.0% of Seattle's 264,000 households each year.

Due to the consultant's assumption that HHW facility attendance is a reasonable predictor of e-waste facility attendance, it is assumed that the two e-waste facilities could also serve about

16,000 customers per year.

This figure should be considered a minimum since the HHW sites are open only three days per week, and the proposed e-waste sites would be open five days per week.

If we assume that each customer brings either one television or one CPU and monitor, then each customer would be bringing an average of

50 pounds of material per visit.

This would amount to

400 tons of material annually, minimum.

But suppose 1 out of every 2 customers also brought an item from their attic, or an item from a neighbor. Then the total could be

600 tons of material annually.

CONSIDERATION OF SMALL BUSINESS/SQG E-WASTE

This report estimated how much e-waste was expected to be generated by SQGs in Seattle and Northwest Washington. However, because SQGs were defined as they were in the Eastern Washington Study, businesses included in these projections could be very large, such as Amazon.com or Safeco.

Large businesses, even if officially classified as small quantity generators, are much more likely to use a private collection service than to self-haul loads of computers to a public facility. Therefore, for the purposes of estimating the quantities collected and costs of fixed facility e-waste collection in Seattle, Cascadia assumed that only businesses with less than 50 employees would be small enough to consider self-hauling their computer waste.

Therefore, refining the SQG estimates to include only businesses with less than 50 employees yields a total of

39,000 units, or

490 tons.

For lack of better information, it seems reasonable to assume that as with the households, only

6.0% of these businesses would use the service.

However, it seems reasonable to assume that a business would be bringing e-waste accumulated over several years. Assuming that each business would need to use the service approximately every 3 years (the lifespan of a CPU), then we could assume that each business brings:

3 years worth of stockpiled e-waste.

Therefore, we could assume that the facilities would collect 490 x 4.5% x 3 =

88 tons, or

7,020 units of e-waste from small quantity generators.

CONCLUSION ABOUT QUANTITIES GENERATED

The above residential e-waste collection estimates ranged from 411 to 600 tons, and the small quantity generator estimate was 88 tons. Adding these two estimates together yields a rounded estimate of 500-700 tons of e-waste and cell phones collected annually. Please note that all cost calculations were conducted using 600 tons, the midpoint of this range, or 300 tons per site.

Works Cited

Bagby, Jenny, 2003. Principal Economist at Seattle Public Utilities. Personal Communication September 5, 2003.

Building Owners and Management Association, 2003. *U.S. Office Market Highlights.* http://www.boma.org/research/BOMA_US_Office.pdf. Accessed September 8, 2003.

California Integrated Waste Management Board, 2001. "Selected E-Waste Diversion in California: A Baseline Study."

Cascadia Consulting Group, 2002. *Assessment of Electronic Waste Generation, Collection, and Processing in Eastern Washington.* Prepared for the Washington State Department of Ecology.

Caudill, Reggie et al., 2003. *A Final Report to the NEPSI Infrastructure Subgroup: Assessment of Base Level of Service in the Seattle-Tacoma Area*. Unpublished discussion draft. March.

City of Seattle, 2001. *Residential Technology Survey: Summary of Results.* City of Seattle Information Technology Indicators Project. http://www.cityofseattle.net/tech.

Computer Industry Almanac, Inc. "PCs-In-Use Surpassed 600M. Over 45% of Worldwide PCs Are in Homes." Press Release Issued March 11, 2002.

eT Forecasts, 2002. *Worldwide PC Forecast 1990-2007. http://www.etforecasts.com/products/1.1*

Fishbein, Bette, 2002. *Waste in the Wireless World: The Challenge of Cell Phones*. New York, New York: INFORM, Inc.

Hester, Brian, 2003. Commercial Realtor with CB Richard Ellis. Personal Communication October 28, 2003.

Jacobsen, Barbara, 2003. Commercial Realtor with the Jacobsen Group. Personal Communication September 4, 2003.

King County Solid Waste Division, 2003. *Residential Waste Reduction and Recycling Survey 2003: Final Report.* King County, Washington: July.

Local Hazardous Waste Management Program, 1998. *Household Hazardous Waste Collection Service Level Study: Draft Report*. King County, Washington. July.

Lorch, Craig, 2003. Owner, Total Reclaim. Personal Communication September 4, 2003.

Puget Sound Regional Council, 2002. *2001 Covered Employment Estimates.* http://www.psrc.org/datapubs/data/employment_est.htm. Accessed September 2, 2003.

Puget Sound Regional Council, 2003. *2002 Small Area Forecasts of Population and Employment, Central Puget Sound Region.* http://www.psrc.org/datapubs/pubs/forecasts_2002.htm. Accessed October 29, 2003.

Massachusetts Department of Environmental Protection, 2000. *Electronics re-use and recycling infrastructure development in Massachusetts.* September.

Mathews, H. Scott et al, 1997. *Disposition and End-of-Life for Personal Computers.* Carnegie Mellon University Green Design Initiative Technical Report #97-10.

National Safety Council, 1999. *Electronic Product Recovery and Recycling Baseline Report: Recycling of Select Electronic Products in the United States.* Washington, DC. May.

Northbridge Environmental Management Consultants, 2002. *Characteristics of Massachusetts' CRT Recycling Program.* Prepared for Electronic Industries Alliance. October.

Scolof, Maria et al. *Desktop Computer Displays: A Life-Cycle Assessment.* Environmental Protection Agency. Publication 744-R-01-004a. December 2001, p. 2-37.

Stanford Resources, 2001-1. "Stanford Resources Expert Forecasts Major Shifts in CRT Monitor Marketplace." Press Release issued October 2, 2001. www.stanfordresources.com/press/011002.html.

Stanford Resources, 2001-2. "Stanford Resources Forecasts LCD Demand to be Driven by Desktop Monitor Application." Press Release issued June 4, 2001. www.stanfordresources.com/press/010604.html.

Talbot, Jim, 2003. City of Seattle HHW Program Supervisor. Personal communication October 30, 2003.

United States Census Bureau, 2001. Census 2000 results. http://factfinder.census.gov.

United States Census Bureau, 2002. Data from the Current Population Survey Computer Use Supplement. http://www.bls.census.gov/cps/computer/2001/suppovrw.htm.

United States Department of Agriculture, 2003. Washington Agricultural Statistics Service. http://www.nass.usda.gov/wa/. Accessed September 2, 2003.

United States Energy Information Administration, 1999. "Commercial Buildings Energy Consumption Survey." http://www.eia.doe.gov/emeu/cbecs/contents.html. Accessed September 4, 2003.

Washington State Department of Ecology, 2002. "Dangerous Waste Generator Status and Requirements Summary" http://www.ecy.wa.gov/programs/hwtr/demodebris/pages2/genstatus.html. Accessed September 18, 2003.

Washington State Employment Security Department, 2003. *Nonagricultural Wage And Salary Employment Projections.* http://www.wa.gov/esd/lmea/labrmrkt/nonagest/naehome.htm. Accessed September 3, 2003

Washington State Office of Financial Management, 2002. *Projections Of The Total Resident Population For The Growth Management Act.* http://www.ofm.wa.gov/pop/gma/index.htm. Accessed September 3, 2003.